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Installation and equipment for liquefied natural gas — Design of floating LNG installations —

Part 1: General requirements

Installations et équipements de gaz naturel liquéfié — Conception des installations flottantes de GNL —

Partie 1: Exigences générales

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

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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 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 9, *Liquefied natural gas installations and equipment*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 282, *Installation and equipment for LNG*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all parts in the ISO 20257 series can be found on the ISO website.

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.

This corrected version of ISO 20257-1:2020 incorporates the following corrections:

- the broken links in References [50] and [51] were updated;

- the missing content in 5.1.2, 5.4.3.2.3, and 5.5.10.2 was added;

- editorial corrections in 12.2.2.2, G.1.2.1, G.2.1 and in the bibliography.

Introduction

This document provides a non-exhaustive list of potential concepts. When a novel concept is proposed, the general principles in this document can be applied as far as applicable. Such design will result in a concept with equivalent level of safety and environmental friendliness to those currently considered as standard solutions. Guidance on the assessment of novel technology is provided in Annex F.

In case a part of the installation, such as hull, vessel or structure, is already covered by another International Standard, including IMO, this document will only complement that applicable standard where necessary in order to ensure global safety, stability and integrity of the overall floating LNG installation.

This document assumes that a floating LNG installation is also designed to meet IMO and classification society requirements. It is not intended to preclude the use of a 'barge' solution. This document neither specifies the shape of the installation nor specifies the need for propulsion or an installation to fall within a particular regulatory regime. A barge can either be subject to exactly the same considerations as a unit designed as a non-propelled ship or not. This will depend on aspects such as whether a barge is located offshore or at shore, how it is transported, whether it stores LNG or not, the level of manning, the regulatory regime imposed on it. In this respect, the user of this document is expected to take hull structure design, means of external communications, and evacuation, escape and rescue arrangements, etc. into consideration.

Additional requirements by the Flag process, Shelf or Coastal Regulations can be applicable, that will vary depending on the type of floating LNG installation.

LNG as fuel bunkering applications is covered in ISO 20519 and in publications by the Society for Gas as a Marine Fuel.

Installation and equipment for liquefied natural gas — Design of floating LNG installations —

Part 1: General requirements

1 Scope

This document provides requirements and guidance for the design and operation of floating liquefied natural gas (LNG) installations, including installations for the liquefaction, storage, vaporisation, transfer and handling of LNG, in order to have a safe and environmentally acceptable design and operation of floating LNG installations.

This document is applicable to:

— floating LNG liquefaction installations (plant) — FLNG;

— floating LNG regasification installations (plant) — FSRU;

— floating storage units — FSU.

This document is applicable to offshore, near-shore or docked floating LNG installations.

This document includes any jetty in the scope in case of docked floating LNG installations with regards to the mooring. This document briefly describes floating LNG mooring concepts.

This document is applicable to both newbuilt and converted floating LNG installations, and addresses specific requirements.

This document is not applicable to:

— onshore LNG storage, liquefaction and/or regasification installations/plants, except for docked FSRU and/or FLNG installations;

— offshore LNG plants based on non-floating structure (such as gravity based structure [GBS] principle); and

— support onshore based facilities (such as support vessels, tugs, etc.).

This document is not intended for design floating power generation facilities though relevant parts of this document can be used.

This document is not intended to cover LNG as fuel bunkering applications.

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 834 (all parts), *Fire resistance tests — Elements of building construction*

ISO 1460, *Metallic coatings — Hot dip galvanized coatings on ferrous materials — Gravimetric determination of the mass per unit area*

ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods*

ISO 4126 (all parts), *Safety devices for protection against excessive pressure*

ISO 9606 (all parts), *Qualification testing of welders — Fusion welding*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

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

ISO 12944 (all parts), *Paints and varnishes — Corrosion protection of steel structures by protective paint systems*

ISO 15614-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys*

ISO 16903, *Petroleum and natural gas industries — Characteristics of LNG, influencing the design, and material selection*

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

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

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

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

ISO 19904-1, *Petroleum and natural gas industries — Floating offshore structures — Part 1: Ship-shaped, semi-submersible, spar and shallow-draught cylindrical structures*

ISO 20088 (all parts), *Determination of the resistance to cryogenic spill of insulation materials*

ISO 22899 (all parts), *Determination of the resistance to jet fires of passive fire protection*

ISO 23251, *Petroleum, petrochemical and natural gas industries — Pressure-relieving and depressuring systems*

ISO 24409-1, *Ships and marine technology — Design, location and use of shipboard safety signs, fire control plan signs, safety notices and safety markings — Part 1: Design principles*

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

IEC 60079 (all parts), *Explosive atmospheres*

IEC 60092-502, *Electrical installations in ships — Part 502: Tankers — Special features*

IEC 60331 (all parts), *Tests for electric cables under fire conditions — Circuit integrity*

IEC 61511 (all parts), *Functional safety — Safety instrumented systems for the process industry sector*

IEC 61892 (all parts), *Mobile and fixed offshore units — Electrical installations*

IEC 62305 (all parts), *Protection against lightning*

ISO/IEC 80079 (all parts), *Explosive atmospheres*

API RP 17B, *Recommended Practice for Flexible Pipe*

CAA CAP 437, Standards for Offshore Helicopter Landing Areas

EN 1127-1, *Explosive atmospheres — Explosion prevention and protection — Part 1: Basic concepts and methodology*

EN 1474-2, *Installation and equipment for liquefied natural gas — Design and testing of marine transfer systems — Part 2: Design and testing of transfer hoses*

EN 1474-3, *Installation and equipment for liquefied natural gas — Design and testing of marine transfer systems — Part 3: Offshore transfer systems*

IMO/IGC Code, International code for the construction and equipment for ships carrying liquefied gases in bulk (IGC Code)

International Ship and Port Facility Security Code, IMO

IMO/SOLAS, International convention for the safety of life at sea

IMO/MODU, Code for the Construction and Equipment of Mobile Offshore Drilling Units

MARPOL, International Convention for the Prevention of Pollution from Ships

Ship to ship transfer guide for petroleum chemicals and liquefied gases, OCIMF

WHO Guidelines for Drinking Water Quality, World Health Organization

MOORING EQUIPMENT GUIDELINES OCIMF

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
floating LNG installation
installation typically comprising of hull structure, gas processing, vaporization and liquefaction, LNG storage, hydrocarbon *transfer* (3.1.53), mooring systems, and other systems

Note 1 to entry: The hull structure is also known as hull.

Note 2 to entry: The gas processing, vaporization and liquefaction, including flare, are also known as topsides. Topsides are not relevant for floating storage units applications.

Note 3 to entry: The LNG storage is also known cargo containment systems and cargo handling systems.

Note 4 to entry: The hydrocarbon transfer is also known as cargo transfer systems, including offloading equipment and systems (if applicable).

Note 5 to entry: Mooring systems include jetties and fendering (if applicable).

Note 6 to entry: Examples of other systems are utilities and accommodation.

3.1.2
floating storage and regasification unit
FSRU
floating unit for storage and regasification of *LNG* (3.1.31) for sending out to natural gas grid

Note 1 to entry: An FSRU is intended to be permanently or temporarily moored or anchored as part of an LNG installation located in a protected harbour, in a near-shore location (protected or unprotected) or offshore.

3.1.3
floating liquefied natural gas unit
FLNG
floating unit for production, liquefaction, storage and *transfer* (3.1.53) of *LNG* (3.1.31)

Note 1 to entry: An FLNG unit can receive gas either from offshore fields, onshore fields, onshore pipeline or other facilities (other platforms, associated gas, etc.). An FLNG units has the ability to process and export gas-field related hydrocarbon products, such as liquefied petroleum gas and condensate.

3.1.4
floating storage unit
FSU
floating unit for storage of *LNG* (3.1.31) and permanently or temporarily moored as part of an LNG installation

Note 1 to entry: Non-modified LNG carriers might be considered as suitable, provided that the following aspects are appraised and resulting safety level is found acceptable:

— mooring arrangement;

— transfer system;

— sloshing aspects;

— effects from/on other part of LNG installation;

— long term use inspectability.

3.1.5
accident
mean uncontrolled event that can entail the loss of human life, personal injuries, environmental damage or the loss of assets and financial interests

3.1.6
barge
box shaped non-propelled floating structure

3.1.7
boiling liquid expanding vapour explosion
violent explosive vaporization following the rupture of a pressurized tank containing liquid well above its boiling point at atmospheric pressure, which can be followed by a ball fire if the vapour cloud is ignited

3.1.8
boil-off gas
gas generated during the storage or handling of volatile liquefied gases

3.1.9
boundary
property line on land or water inside over which the *operator* (3.1.38)/*owner* (3.1.39) has full control and authority, or exclusive use

3.1.10
braid
layer, or layers, of cylindrically woven wires covering the *hose* (3.1.25) and attached to the flexible *hose assembly* (3.1.26) end fittings, serving the function of restraining the flexible hose against elongation

3.1.11
classification society
non-governmental organization, which establishes and maintains technical standards for the construction and operation of ships and offshore structures, validates that the construction conforms to these standards, and carries out regular surveys in service to ensure continued conformance with the standards

3.1.12
condensate
hydrocarbon liquids (liquid state at standard conditions) produced from primary separation of *natural gas* (3.1.35) from a reservoir

3.1.13
drip tray
spill containment for minor leakage

3.1.14
emergency release system
ERS
system that provides a positive means of quick release of the *transfer system* (3.1.54) and safe isolation of receiving source from the supply source

3.1.15
emergency shutdown
ESD
system that safely and effectively stops the whole plant or individual units to minimize incident escalation

3.1.16
enclosed area
enclosed space
space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally

3.1.1.17
explosion
deflagration event of uncontrolled combustion

3.1.18
flammable gas
gas or vapour which, when mixed with air in certain proportions, forms a combustible gas mixture

3.1.19
flag administration
maritime authority of a country in which a vessel is registered

3.1.20
green water
sea water reaching the deck of the vessel in harsh conditions

3.1.21
harm
physical injury or damage to the health of people, or damage to assets or the environment

3.1.22
hazard
potential source of *harm* (3.1.21)

3.1.23
hazardous area
area in which an explosive atmosphere is present, or can be expected to be present, in quantities such that special precautions for the construction, installation and use of electrical apparatus are taken

3.1.24
hazard identification
HAZID
brainstorming exercise using checklists where the potential *hazards* (3.1.22) in a project are identified and gathered in a risk register for follow up in the project

3.1.25
hose
flexible leak tight inner tube either corrugated metal, elastomer or plastic

3.1.26
hose assembly
hose (3.1.25) with end fittings attached, complete with *braid* (3.1.10) and/or other covering, ready for service

3.1.27
high pressure natural gas
gas under high pressure produced from either gas field or from regasification of *LNG* (3.1.31) to be dispatched in grid

3.1.28
impact assessment
assessment of how consequences (e.g. fires, explosions) affect people, structures, the environment, etc.

3.1.29
individual risk
risk to which an individual is exposed during a defined period of time

3.1.30
jetty
facility consisting of a trestle or similar structure, berthing facilities including fendering and topside equipment to enable primarily the *transfer* (3.1.53) of hydrocarbons

3.1.31
liquefied natural gas
LNG
colourless and odourless cryogenic fluid in the liquid state at normal pressure composed predominantly of methane which can contain minor quantities of ethane, propane, butane, nitrogen, or other components normally found in *natural gas* (3.1.35)

3.1.32
major accident
hazardous event that results in multiple fatalities or severe injuries; or extensive damage to structure, installation or plant; or large-scale impact on the environment

Note 1 to entry: In this document, a major accident is the realization of a major accident hazard.

Note 2 to entry: Large-scale impact on the environment is, for example, persistent and severe environmental damage that can lead to loss of commercial or recreational use, loss of natural resources over a wide area or severe environmental damage that will require extensive measures to restore beneficial uses of the environment.

Note 3 to entry: This definition is intended to incorporate terms such as “major accident” as defined by UK HSE.

3.1.33
major hazard
hazard (3.1.22) with the potential, if realized, to result in a *major accident* (3.1.32)

3.1.34
management system
set of interrelated or interacting elements of an organization to establish policies and objectives and processes to achieve those objectives

3.1.35
natural gas
gas without condensation at common operating pressures and temperatures where the predominant component is methane with some ethane and small amounts of heavier hydrocarbons (mainly propane and butane)

3.1.36
non-hazardous area
area in which an explosive atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus

3.1.37
normal operation
routine operation and also including intermittent operation such as ship loading or unloading, start-up, maintenance, planned shutdown and commissioning

3.1.38
operator
organization responsible for the operation of the installation

3.1.39
owner
organization responsible for the safe design and construction of the installation

3.1.40
probability
number in a scale from 0 to 1, which expresses the likelihood of an event occurrence

3.1.41
response amplitude operator
ratio of a vessel's motion to the wave amplitude causing that motion and presented over a range of wave periods

3.1.42
recognized standard
international or national standard acceptable to the relevant regulator or authorities, industry and project stakeholders

3.1.43
risk
combination of *probability* (3.1.40) of occurrence of harm and the severity of that harm

3.1.44
risk analysis
systematic use of information to identify sources and to estimate the risk

3.1.45
risk assessment
overall process of *risk analysis* (3.1.44) and *risk evaluation* (3.1.46)

3.1.46
risk evaluation
procedure based on the *risk analysis* (3.1.44) to determine whether the tolerable risk has been achieved

3.1.47
rapid phase transition
shock wave forces generated by instantaneous vaporization of *LNG* (3.1.31) upon coming in contact with water

3.1.48
safety
freedom from unacceptable risk

Note 1 to entry: This definition is according to ISO/IEC Guide 51.

3.1.49
safety critical system
system whose failure or malfunction can result in one or more of the following outcomes: death or serious injury to people, loss or severe damage to equipment/property, environmental harm

3.1.50
safety management system
management process which defines and monitors the organizational structure, responsibilities, procedures, processes and resources for determining and implementing the *major accident* (3.1.32) prevention policy

3.1.51
safety integrity level
integrity level of a safety related system in accordance with specific conditions

Note 1 to entry: to entry. The conditions are in specified in the IEC 61508 series.

3.1.52
topsides
gas processing, vaporization and liquefaction equipment installed on a supporting structure on top of the main or upper deck, or on a *jetty* (3.1.29)

3.1.53
transfer
operation consisting of moving liquid product from one container to another

Note 1 to entry: LNG transfer can be either loading or unloading.

3.1.54
transfer system
means of conveying liquid or gas between installations including couplings and associated safety systems

3.1.55
water curtain
sprinkler arrangement to protect steel surfaces from direct contact with *LNG* (3.1.31) or a system to mitigate gas releases and protect against radiant heat

3.2 Abbreviated terms

ALE	abnormal level earthquake
ALS	accidental limit state
ANSI	American National Standard Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers

BOD	biochemical oxygen demand
BOG	boil-off gas
BTEX	benzene toluene ethylbenzene xylene
CCR	central control room
CCTV	closed circuit television camera
CFD	computed flow dynamics
COD	chemical oxygen demand
CSRA	cryogenic spill risk analysis
CSU	commissioning and start-up
DCS	distributed control system
DEC	design extreme conditions
DOC	design operating conditions
DSC	design survival conditions
EER	emergency escape response
EERA	emergency escape response analysis
EHS	environmental, health and safety
EIA	environmental impact assessment
ELE	extreme level earthquake
ENVID	environmental impact identification
ERA	explosion risk assessment
ESSA	emergency systems survivability analysis
ESD-1	emergency shutdown stage 1
ESD-2	emergency shutdown stage 2
F&G	fire and gas
FE	finite element
FLS	fatigue limit state
FRA	fire risk assessment
HSE	health, safety and the environment
HVAC	heating ventilation air conditioning
IALA	International Association of Marine Aids and Lighthouse Authority
ICAO	International Civil Association Organization

IEC	International Electrotechnical Commission
IGC Code	International Code of the construction and equipment of ships carrying liquefied gases in bulk
IMO	International Maritime Organization
IR	infrared
kW	kilowatt
LDAR	leak detection and repair
LQ	living quarters
LNGC	liquefied natural gas carrier
LPG	liquefied petroleum gas
LRFD	load resistance factor design
MAE	major accident event
MODU	mobile offshore drilling unit
MSC	Maritime Safety Committee
MWth	Megawatt thermal
NOx	nitrogen oxides
OBE	operating basis earthquake
OCIMF	Oil Companies International Marine Forum
OESD-1	offloading emergency shutdown stage 1
OESD-2	offloading emergency shutdown stage 2
OGI	optical gas imaging
OGP	International Association of Oil and Gas Producers (now IOGP)
PAGA	public address general alarm
PAH	polycyclic aromatic hydrocarbon
PIANC	Permanent International Association of Navigation Congresses
PM	particulate matter
POB	personnel on board
ppm	parts per million
PSD	process shutdown
QRA	quantitative risk assessment
RCS	recognized classification societies
SAT	site acceptance test

SECE	safety environmental critical element
SIGTTO	Society of International Gas Tanker and Terminal Operators
SIM	structural integrity management
SLS	serviceability limit state
SOx	sulfur oxides
SOLAS	Safety of Life at Sea
SPM	single point mooring
SRLA	semi rigid loading arm
SSE	safe shutdown earthquake
STS	ship-to-ship
TCTS	temporary connectable transfer system
THC	total hydrocarbon
TLV	threshold limit values
TM	thickness measurement
TSC	transit survival conditions
TSS	total suspended solid
ULS	ultimate limit state
UPS	uninterruptible power supply
VOC	volatile organic component
WHO	World Health Organization

4 Basis of design

4.1 Site and meteocean conditions

4.1.1 Site study

4.1.1.1 Depending on the location of the LNG installations (i.e. docked, near-shore or offshore), the site study shall include, where appropriate:

a) A seabed and soil survey, which shall include:

   1) a geotechnical survey that will enable the geo-mechanical characteristics of the subsoil to be defined;

   2) a geological and tectonic investigation;

3) a study of bathymetry.

b) A metocean data study, which shall be in accordance with ISO 19901-1 and shall include at least the following:

1) a study of water level including tidal variations;

2) wave study including at least wave heights, periods and directions;

3) wind study including wind speed and directions covering incidence of tropical storms and local squalls;

4) currents study including at least current speed and direction throughout the water column;

5) a study of shock waves and flooding (e.g. tsunami, failure of dams);

6) a study of sea water quality, turbidity and temperature;

7) a study of marine growth

8) a study of possible sea ice, icebergs, snow and ice accretion impact;

9) visibility;

10) other relevant site conditions parameters, such as air temperatures, rainfall, atmospheric pressure variations, frequency of lightning strikes, and corrosive characteristic of the air.

c) A study of underkeel clearance, in which particular attention shall be given to shallow water and dockside operating floating LNG installations.

NOTE 1 PIANC Report N° 153[39] provides further guidance.

d) A study of terrain to assess the dispersion of liquid and gas clouds to be assessed.

NOTE 2 This study mostly applies to docked installations.

e) A study of vegetation to assess, in particular the vegetation fire risks to be identified.

NOTE 3 This study mostly applies to docked installations.

f) A study to identify sources of stray electrical currents (e.g. those emanating from high voltage power lines, railways).

NOTE 4 This study mostly applies to docked installations.

g) A study of the marine aquatic environment and marine access.

NOTE 5 This study mostly applies to docked installations.

h) A survey of the surrounding infrastructure (e.g. industrial sites, built up areas, communications).

NOTE 6 This study mostly applies to docked installations (see also 4.1.3).

i) Navigational studies for LNG carrier access to floating LNG installation including simulation of manoeuvring areas, access channel, safety distances whilst an LNG carrier is in transit within the port and at berth.

NOTE 7 This study mostly applies to docked installations.

4.1.1.2 The studies listed in 4.1.1.1 under a) and b) shall:

a) focus on periodic events for design purposes and events with associated frequencies, so as to evaluate possible risks related sloshing effects, availability of transfer, and possibilities of connections;

b) focus on critical equipment to remain operational and to keep integrity, for which items to be designed for which conditions shall be listed;

c) consider conditions for towing, mooring, travel, partial completion stage conditions for offshore structures to be addressed.

If project conditions requires the installation of breakwater, the site studies shall properly take the impact of the breakwater into consideration.

4.1.2 Earthquake

Earthquake action is relevant for LNG installations anchoring, mooring and jetties, trestle and their topsides facilities. Earthquake levels definitions shall be carried out in accordance with relevant standards (e.g. ISO 19901-2, EN 1997, EN 1998).

A site-specific earthquake analysis shall be performed. This analysis shall include assessments of the risks, such as earthquake, soil liquefaction, fault movement, tsunamis, landslides, shock waves and volcanic activities. These investigations involve thorough research, review and evaluation of all historically reported earthquakes that have affected, or that could reasonably be expected to have affected, the site.

In case of seismic faults in the immediate vicinity of the site, further investigations shall be conducted to estimate their possible activity. Faults for which inactivity cannot be confirmed are not allowed inside the site or within a distance to be determined from the soil morphology.

The definitions of seismic level shall be consistent with the design code used. Typically, two levels of earthquake are defined:

a) OBE, being an earthquake under the action of which the structure should not sustain major damage (also known as ELE);

b) SSE, being an abnormal intense earthquake under the action of which the structure should not suffer complete loss of integrity (also known as ALE).

NOTE The rationale behind these two levels is that during OBE/ELE, the structure will retain its full capacity for all subsequent conditions, which can mean that design is for linear (or elastic) response, and that during SSE/ALE, the structure will maintain structural integrity for a sufficient period of time to enable evacuation to take place, which can mean that design is for non-linear (or plastic) response.

4.1.3 Location

During the feasibility study phase of the project site location, assessments shall be carried out to ensure the suitability of the location options with regards to adjacent development if existing. The assessment shall as a minimum take into account:

a) public area in the vicinity (e.g. residential development, retail and leisure developments, schools, hospitals, retirement homes, sports stadium);

b) industrial development;

c) transportation infrastructure.

When the site has been selected, a detailed site location assessment shall be carried out. The location assessment methodology and scope shall have regard for the proposed inventory of hazardous material contained on the plant and the presence and scale of adjacent existing and identified future developments.

It is recommended to:

— update the assessment on a regular basis and when major modifications or changes take place;

— monitor the development around the plant to minimize the subsequent incompatible development.

4.1.4 Other studies

Other studies can be necessary, if certain topics are not adequately covered by the studies described in 4.1.1 to 4.1.3. These studies can include:

— a marine traffic assessment when an LNG installation is located in sensitive area such as a port, a high marine traffic density area, or a sensitive environmental area;

— manoeuvring studies, for example in relation to emergency departure from a shoreside location, and

— water dispersion and/or water recirculation studies, for example in relation to possible scour and/or effects on marine life, from cooling water inlets and outlets.

Other studies related to marine operations can be found in ISO 19901-6.

4.2 Design criteria

4.2.1 General

4.2.1.1 Design life and project nature

The overall design life of the floating LNG installation shall be defined. The selected design life will determine docking plans (dry dock), for example the floating LNG installation might need to remain on station throughout the project life, hence no interim dockings anticipated. Further, the design lifes of components of the floating LNG installation shall be defined, as they can have a lower design life, due to the inspection and maintenance strategy. Both the overall and the components design lifes will have an effect on the fatigue design, inspection and maintenance approaches.

The floating LNG installation may be designed for a longer lifetime than the project duration to enable future use. The project for which the floating LNG installation is originally planned can change during its life, for example an FLNG or FSRU can be redeployed to a different location or converted into a trading ship.

4.2.1.2 Limit states definitions

The design verification for a system and its components shall be performed with reference to a specified set of limit states beyond which the structure or the system no longer satisfies the design requirements given in Clauses 6 to 13. In addition, for each limit state, water-tightness and hydrostatic stability shall be ensured in accordance with 7.2.

For each limit state, design criteria shall be established, appropriate design situations shall be defined, calculation models shall be established, and adequate procedures shall be followed to verify conformity with the design requirements. These requirements cover all phases of the structure's life cycle, including construction, transportation, installation, operation and removal.

The following limit state categories shall be used in the structural design of a floating platform:

a) ULS, which generally involves verifying the floating structure's strength to resist extreme actions and action effects;

b) SLS, which generally addresses the structure's performance during its normal intended use, and involve verifying the floating structure's strength to resist operational actions and action effects;

c) FLS, which covers the structure's strength to resist cumulative effects of repeated actions;

d) ALS, which investigates the structure's ability to resist accidental and abnormal events, and the structure's resistance to the effects of specified metocean actions after damage has occurred as a consequence of an accidental or abnormal event.

The design criteria to be applied for the various components of the floating LNG installation, for the respective limit state verification are provided in 4.2.2 to 4.2.7.

Design situations to be considered are provided in Clause 6 to Clause 13.

4.2.1.3 Design philosophy

For structural and mechanical safety, it is important that loads (L) do not exceed capacity (C), and that there is a margin of safety between these (f). To ensure clarity in design, it is important to note three different possible design approaches, each of which ensures L < C, where C is expressed in terms of stress:

— an "allowable stress" (or permissible stress or working stress) approach, whereby L = C/f, in other words a factor of safety, typically in the range 1,3–1,7 is applied to the capacity of the element under consideration;

— a "load factor" approach, whereby f·L = C, in other words the factor of safety is applied to the loading side of the equation;

— a "limit state" (or partial factor or LRFD) approach, whereby f1·L = C/f2, where f1 is a partial factor applied to the loading, and f2 a partial factor applied to the capacity (usually to materials).

Different elements of an FSRU/FLNG can be designed using different philosophies, for example the hull might be designed following an allowable stress approach, the topsides following a load factor approach, and the cargo containment system following a limit state approach. Whichever approach is adopted, a consistent set of safety factors (f) shall be chosen.

NOTE It will be dangerous and potentially unsafe to pick and choose seemingly favourable factors from different design codes in order to effect some economy, at the possible expense of eroding the margin of safety.

4.2.1.4 Weight control

Weight control during engineering and construction is provided in ISO 19901-5.

4.2.2 Topsides

Taking into account all the environmental and operational conditions, the analysis of the design shall take into account safety factors with the mechanical and functional limits of the material and equipment. The safety factors are considered with definition of maximum allowable stresses to be applied in the analysis in relation with the equipment and conditions to be studied.

The following design conditions in accordance with ISO 19900 shall be considered:

a) DOC or SLS: Under this condition, systems and processes on the facilities can be operated normally, which means that they can be started or kept running without tripping alarms or safety shutdown devices or endangering equipment and personnel involved. This condition is applicable for mechanical and structural designs of facilities.

   Corresponding motion/metocean data: if not specified, 1 year non-cyclonic return period conditions can be considered.

b) DEC or ULS: Under this condition, processes and nonessential systems on the floating LNG installation will be stopped, but have to withstand all effects without any damages. Safety systems/barriers as identified in 5.2.3 and determined for the specific project risk assessment shall remain in operation. Systems and processes can be restarted without any repairs or replacements (inspection and/or adjustment can be required) after the condition goes back to operating condition. This condition is applicable for mechanical and structural designs of the facilities.

   Corresponding motion/metocean data: if not specified, 100-year return period conditions can be considered.

c) TSC: Under this condition, the floating LNG installation is towed from shipyard to the site, and systems and processes on the facilities will not be in operation. After this condition, systems and processes should be able to start their commissioning and/or operation without any damages, repairs or replacement (inspection and/or adjustment may be required).

   Corresponding motion/metocean data: if not specified, 10-year return period conditions applicable to the routing of the transit can be considered.

d) DSC or ALS: Under this condition, a certain deformation of equipment or structure is allowed, but no collapse. This condition is applicable for mechanical and structural designs of floating LNG installation. The structural configuration and equipment arrangements shall be such that any deformation or damage resulting from a DSC shall not lead to an escalation of undesirable events or impair safety-critical functions.

   Corresponding motion/metocean data: if not specified, 10 000-year return period conditions can be considered.

4.2.3 Transfer systems

4.2.3.1 Environmental installation classification

4.2.3.1.1 General

Due to the different potential locations of the floating LNG installation, the exposure to the environmental conditions and the response in term of amplitude of the supplying and receiving units will be significantly different. The exposure to these different conditions is a major criterion for the transfer solution to be implemented. For this reason, and to cover the different locations with limited number of cases, this document adopted the terminology of dynamic sensitive areas and non-dynamic sensitive areas.

This notion of dynamic and non-dynamic sensitive areas is applied to transfer systems design and can be different for the rest of the installation.

The key parameters to select either dynamic sensitive area or non-dynamic sensitive area are the metocean conditions (wind, wave), response amplitude operator of the vessel (FSRU/FLNG and LNGC), and the natural frequency of the transfer systems. Dynamic sensitive areas include non-protected areas and the protected areas when the installation might be dynamically sensitive whereas non-dynamic sensitive areas include protected areas.

4.2.3.1.2 Non-dynamic sensitive area

An area is considered as a non-dynamic sensitive area for transfer systems if the environmental conditions applied to the facilities will generate neither large relative motions between the units nor excessive motion of the unit where the transfer systems is installed.

The dynamic motions will not affect significantly the transfer systems and can be neglected in most of the cases. Therefore, no fatigue analysis is required and standard equipment can be used to achieve the connections.

To classify the facilities in non-dynamic sensitive area, an analysis of the expected motion amplitudes, frequencies and accelerations of the floating units in regards with the impact to the transfer system shall be performed. If the facility is located in a port equipped with a natural or artificial breakwater protected area, requirements shall be considered for the transfer system design without a specific motions analysis. If the facility is located in near-shore location without natural or artificial breakwater, the analysis of the motions shall be performed to decide classification of the area.

Smaller facilities with smaller LNGCs and smaller LNG installations can lead to apply a design methodology linked to dynamic sensitive area where such facilities are impacted by high frequency waves.

NOTE Smaller LNGC and smaller LNG installations are considered to be understood.

4.2.3.1.3 Dynamic sensitive areas

An area is considered as dynamic sensitive if the installation is exposed to motions of the floating facilities equipped with transfer systems and/or relative motions between the supplying and receiving units, which are significant for the design of the transfer systems.

In dynamic sensitive areas, the effective motions of the facilities shall be considered in the transfer system design for:

a) operating envelope;

b) connection solution;

c) dynamic and fatigue analysis;

d) operating procedures;

e) maintenance purpose.

4.2.3.2 Design conditions and maximum allowable stresses

4.2.3.2.1 General

Design conditions corresponding to the following project phases shall be considered:

a) construction;

b) integration;

c) installation: transit from the shipyard to site;

d) operations: normal (stored, connection/disconnection connected, maintenance) and emergency;

e) accidents: dropped object, blast, etc., if specified.

The allowable stresses are defined as follows:

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

  — (yield strength/1,5) or

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

— S = allowable design stress = K × Sd.

NOTE Allowable stresses are adopted from ISO 16904.

4.2.3.2.2 Transfer system in non-dynamic sensitive area

In non-dynamic sensitive area, the dynamic motions are neglected and only a quasistatic analysis is performed. The design criteria to be consider are defined in Table 1, which lists the project phases and design conditions associated with the allowable stresses to be considered.

Table 1 — Design basis of transfer system in non-dynamic sensitive areas

Project phase/ design condition	Return period	Allowable stress (S) K × Sd	Comment
Construction/load out	NA	K = 0,9	
Integration/lift	NA	K = 0,9	

Table 1 *(continued)*

Project phase/ design condition	Return period	Allowable stress (S) K × Sd	Comment
Transit to site for installation (TSC)	If not specified 10-year return period can be considered	K = 1,2	Stored in transit Transit locking devices
In place/operating (DOC) or SLS	If not specified, 1-year return period can be considered	Manoeuvring: K = 0,9	See case 3 in Table 3
		Connected: K = 0,8 to 1,5 (in function of the case studied)	See cases 4 to 6 in Table 3
		Emergency release: K = 1,1	See cases 7 and 8 in Table 3
In place/extreme operating (DEC) or ULS	If not specified, 100-year return period can be considered	K = 1,2	Stored in extreme condition Standard locking device see case 1 in Table 3
In place/accidental: maximum allowable heel by damaged stability and black-out	If not specified, 1-year return period can be considered	Plastic deformation: no collapse	Other scenarios with occurrence probability above 10^{-4} should also be considered on top of metocean induced scenarios
In place/blast or ALS	If not specified, 10 000-year return period can be considered	Plastic deformation: no collapse	Refer to Clause 5 for scenario to be considered

The allowable stresses to be considered in quasistatic analysis for the various operating mode shall be in accordance with ISO 16904. For flexible or hybrid solution, the flexible part of the transfer system shall at least conform to EN 1474-2. The design, manufacturing and assembly technologies shall conform to API RP 17B.

4.2.3.2.3 Transfer system in dynamic sensitive area

In dynamic sensitive area, the dynamic motions cannot be neglected and different analyses shall be performed as a function of the operating conditions, including:

a) quasistatic analysis in transit and stored conditions;

b) spectral analysis and/or time domain analysis in offloading conditions (manoeuvring, connected and emergency).

For spectral analysis, the following inputs are required:

— Response amplitude operator of each coupled vessel for the 6/12 degrees of freedom associated with the environmental conditions according to different heading. The roll motion shall properly be addressed due to its non-linear characteristics.

— Wave spectra according to different heading.

For time domain analysis, the time series of the degrees of freedom are required.

Time domain analysis is more accurate than spectral analysis, but is time consuming and requires particular attention to the worst seeds selected. When performing time domain analyses, spike load/stress can occur. The determination of the extreme value can be addressed by the methods given in API RP 2SK. Moreover, due to dynamic motions in dynamic sensitive area, a fatigue analysis shall be performed.

Table 2 lists the project phases and design conditions associated with the allowable stresses to be considered.

Table 2 — Design basis of transfer system in dynamic sensitive areas

Project phase/ design condition	Return period	Allowable stress (S) K × Sd	Comment
Construction/load out	N/A	K = 0,9	
Integration/lift	N/A	K = 0,9	
Transit to site for installation (TSC)	If not specified, 10-year return period can be considered	K = 1,2	Stored in transit Transit locking devices
In place/operating (DOC) or SLS	If not specified, 1-year return period can be considered	Manoeuvring: K = 1	See case 5 in Table 3
		Connected: K = 1 to 1,5 (in function of the case studied)	See cases 6 to 8 in Table 3
		Emergency release: K = 1,2	See cases 9 and 10 in Table 3
In place/extreme operating (DEC) or ALS	If not specified, 100-year return period can be considered	K = 1,2	Stored in extreme condition Standard locking device See case 3 in Table 3
In place/survival condition (DSC)[a] or (ALS)	If not specified, 10 000-year return period can be considered	K = 1,5	Stored in survival condition Standard locking device — Additional locking devices/ fastening can be defined See case No.4 in Table 3
In place/accidental: max allowable heel by damaged stability and blackout or ALS	If not specified, 1-year return period can be considered	Plastic deformation: no collapse	
In place/blast or ALS	N/A	Plastic deformation: no collapse	
In place/fatigue or FLS	Fatigue sea states [b]	Design life	

[a] The survival condition are corresponding to abnormal environmental actions due to wind, wave, current.

[b] Typical environment corresponding to average operational conditions shall be provided by customer to perform fatigue calculations. Fatigue analysis to be performed using S-N curve.

The allowable stresses to be considered for the various operating mode are defined in Table 3.

Table 3 — Allowable stresses according operating modes

Case N°	Mode	Loading combination	Allowable stress (S) K × Sd
1	Stored extreme	$DL + WL_{S2} + WIIL_e$	1,2 Sd
2	Stored survival	$DL + WL_{S3} + WIIL_s$	1,5 Sd
3	Manoeuvring	$DL + WL_O + WIIL$	1 Sd
4	Connected	$DL + WL_O + WIIL$	1 Sd
5	Connected	$DL + FL + PL + WL_O + WIIL$	1 Sd
6	Connected	$DL + FL + PL + WL_O + TL + WIIL$	1,5 Sd
7	Emergency release	$DL + WL_O + WIIL$	1,2 Sd
8	Emergency release	$DL + FL + PL + WL_O + WIIL$	1,2 Sd
9	Maintenance	$DL + WL_M + WIIL$	1 Sd
10	Hydrostatic test	$DL + FL + PL_T\text{-} + WL_O + WIIL$	1,3 Sd

Key

DL: dead load

FL: fluid load

PL: design pressure load

PL_T: test pressure loads

TL : thermal load

WL_{S2}: wind load in stored extreme mode

WL_{S3}: wind load in stored survival mode

WL_O: wind load in operating mode

WL_M: wind load in maintenance mode

WIIL: wave induced inertia load

$WIIL_e$: wind load in stored extreme mode

$WILL_s$: wind load in stored survival mode

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

NOTE 1 In cases 1, 2, 3, 9 and 10, ice build-up is excluded from DL.

NOTE 2 The yield and ultimate tensile stresses involve the values specified in ASME B31.3 or ASME III for ASTM materials at design temperature. Alternatively, these values can be derived according to BS 5500 or equivalent national material specification with owner's approval.

For flexible or hybrid solution, the flexible part of the transfer system shall conform to EN 1474-2 and EN 1474-3. The design, manufacturing and assembly technologies shall conform to API RP 17B.

4.2.4 Hull

4.2.4.1 Design conditions

All relevant design conditions shall be considered including, but not limited to:

a) transit and non-operational conditions;

b) operating conditions;

c) survival conditions;

d) accidental conditions;

e) temporary phases.

4.2.4.2 Wave analysis design basis

Table 4 provides typical design basis of wave load analysis for ultimate strength calculations. Table 5 provides typical design basis of wave load analysis for hull fatigue strength calculations.

Table 4 — Typical design basis of wave load analysis for ultimate strength calculations

Wave parameters	Design condition		
	Transit	**Operation**[a]	***Survival***
Wave environment	Specific for transit route[b]	Relevant significant wave height (H_s) and corresponding period (Tp or Tz)	Site specific[f]
Wave spectrum	Pierson-Moskowitz spectrum	Specified spectrum[c]	Specified spectrum[c]
Wave heading profile	All headings included (0 to 360)	Head sea: 0°[d] Oblique sea: 15° Oblique sea: 30°[e]	Head sea 60 %[d,g] +/−15: 30 % +/−30: 10 %
Wave spreading	Cos^2	Cos^2	None[h]

a Operation is mainly based on ability to process gas/LNG.

b North Atlantic conditions can be considered if unrestricted transit routes are desired.

c Jonswap spectrum is normally used.

d Relevant for weathervaning units. Other heading profiles for survival and operation condition may be used, if documented. For units with spread mooring, all headings with same probability should be considered.

e The direction (0, 15, 30) giving the highest short-term response shall be used.

f For units intended for unrestricted service (worldwide operation), North Atlantic scatter diagram shall be used. The scatter diagram used shall represent a period of 100 years when used for ultimate strength. For units operating at one particular location, the 100 years return period at that location may be used.

g If the operation and survival limits are based on a site-specific scatter diagram using long term approach, the heading profile similar as for the survival condition may be considered.

h Accelerations for topside interface analysis shall be based on Cos^2 wave spreading.

Table 5 — Typical design basis of wave load analysis for hull fatigue strength calculations

Wave parameters	Design condition	
	Transit	*Operation (at site)*
Wave environment	Specific for transit route[b]	Site specific[c]
Wave spectrum	Pierson-Moskowitz spectrum	PM spectrum
Wave heading profile	All headings included (0 to 360)	Head sea 60 %[d, e] +/−15: 30 % +/−30: 10 %

a Cos2 to be used unless otherwise specified.

b North Atlantic conditions can be considered if unrestricted transit routes are desired.

c For units intended for unrestricted service (worldwide operation), the worldwide scatter diagram shall be used. For units operating at one particular location, the fatigue assessment should be based on the scatter diagram for the given location.

d Relevant for weathervaning units. Other heading profiles for operation condition may be used, if documented. For units with spread mooring, all headings with same probability should be considered.

e If the fatigue limit is based on a site-specific scatter diagram using long term approach, a specific heading profile may be considered.

Table 5 *(continued)*

Wave parameters	**Design condition**	
	Transit	*Operation (at site)*
Wave spreading[a]	Cos^2	Cos^2

[a] Cos2 to be used unless otherwise specified.

[b] North Atlantic conditions can be considered if unrestricted transit routes are desired.

[c] For units intended for unrestricted service (worldwide operation), the worldwide scatter diagram shall be used. For units operating at one particular location, the fatigue assessment should be based on the scatter diagram for the given location.

[d] Relevant for weathervaning units. Other heading profiles for operation condition may be used, if documented. For units with spread mooring, all headings with same probability should be considered.

[e] If the fatigue limit is based on a site-specific scatter diagram using long term approach, a specific heading profile may be considered.

Accidental conditions should consider loadings defined by risk assessment. For environmental loading, this typically will be conditions with a frequency of occurrence of 1 per 10 000 years. Environmental events, such as hurricane and typhoon, are considered within the survival design conditions of Table 3.

4.2.4.3 Temporary phases

During temporary phases, structural strength is generally limited as a result of partial levels of completion of the structure and/or application of action combinations that differ from those applicable to normal operation. The effects of design situations applicable to temporary phases shall be addressed during design to avoid exceedance of either ULS or SLS, and to assess contributions to FLS.

Detailed planning of erection sequences and construction methods is essential to ensure all critical conditions are identified.

Transportation and installation assessments should comply with the requirements of a qualified marine surveyor accustomed to advising on transportation of these types of structures (e.g. an insurance marine warranty surveyor) or equivalent.

4.2.5 LNG storage

The loads applicable to the LNG storage can be derived from various scenarios, including:

— construction, installation and tests;

— onsite operations (e.g. floating unit operations, LNG transfer operations, inspection and maintenance operations, and accidental situations);

— transit conditions (i.e. LNG storage not in operation).

The most stringent conditions with associated loads combination shall be taken into account.

The assessment criteria associated with LNG storage testing depend on the cargo containment system type and are defined in the IMO/IGC Code chapter 4, part E (section 4.21 to 4.26).

The environmental loads for the design of the LNG storage shall be the site(s)-specific environmental loads of the floating LNG installation and also for all transit conditions (e.g. delivery voyage and disconnected sail conditions for potential relocations, if any).

The topsides facilities (e.g. process plant, crane, flare, transfer station) transfer mechanical loads to the hull structure may be taken into account in the design of the LNG storage and associated structure for strength, fatigue and vibration assessments.

As per 7.1.4 for hull design, there are four categories of limit states and associated design conditions to be considered for the LNG storage and associated structure:

a) Design conditions for ULS

On site(s), the LNG installation motions/metocean data for ULS design conditions of the LNG storage and associated structure (liquid/gas domes/pump tower/tank supports, if any) is the DEC (100-year return period conditions for instance) as described in 4.2.1.

This return period should be used for the determination of the LNG tanks internal and external pressures, dynamic loads due to the floating unit accelerations, the external ambient temperatures for thermal loads, the sloshing loads, the hull elongations, the tank supports reactions (if any) and tank associated structure load to be combined for relevant design loading cases.

DEC condition is applied with the LNG storage in normal/intact condition (i.e. not accidental situation).

The assessment criteria associated with ULS depend on the cargo containment system type and are defined in the IMO/IGC Code chapter 4 part E (section 4.21 to 4.26).

b) Design conditions for FLS

A fatigue analysis of critical area of containment system and associated structure (liquid/gas domes/pump tower/tank supports, if any) shall be carried out with respect to at least the design life of the floating unit and intended number of loading/unloading operations.

The design life should not be less than 108 wave encounters and 1 000 thermal cycles (i.e. number of loading and unloading operations) as per IMO/IGC Code chapter 4.18.1 and 4.18.2.

The LNG installation motions/metocean data should be in accordance with the expected life time of the floating unit at its various site locations.

The fatigue assessment (cumulative damage or fracture mechanics) depends on the cargo containment system type and are defined in the IMO/IGC Code chapter 4 part E (section 4.21 to 4.26).

c) Design conditions for ALS

On site(s), with the LNG storage in normal operating/intact condition, the LNG installation motions/metocean data for ALS design conditions of the LNG storage and associated structure (liquid/gas domes/pump tower/tank supports, if any) is the DSC (10 000-year return period conditions for instance) as described in 4.2.1.

The DOC condition may also be applied with LNG storage in accidental situation, such as tank overpressure, overfilling, blast or flooded.

The assessment criteria associated with ALS depend on the cargo containment system type and are defined in the IMO/IGC Code chapter 4 part E (section 4.21 to 4.26).

4.2.6 Mooring

4.2.6.1 General

A floating LNG installation, whether an FSRU, an FLNG or an FSU, will generally be kept on station permanently for the full project life (permanent or long-term mooring). This can be in docked (in-shore and/or sheltered waters), near-shore or offshore location.

Depending on the function of the stationkeeping system in a specific situation, a suitable design can be selected. The various types of design are discussed in Clause 6.

Apart from the permanent stationkeeping systems applied for floating LNG installations, there are mooring arrangements needed for the short-duration mooring of a visiting LNG carrier for the loading or unloading of LNG.

The broad range of possible stationkeeping/mooring concepts implies that a variety of design criteria are applicable to the mooring design. This document distinguishes four categories of criteria:

— permanent stationkeeping in open waters;

— permanent stationkeeping in near-shore or docked locations;

— moorings with special project design conditions, comprising of moorings for a project life substantially lower than 20 years and/or disconnectable mooring systems;

— short-duration mooring of a visiting LNG carrier for loading/unloading LNG cargoes.

4.2.6.2 Permanent stationkeeping in open waters

The design criteria for the permanent mooring system for the full project duration, that ensures the stationkeeping of a floating LNG installation offshore in open waters, shall be in accordance with ISO 19901-7.

The term offshore in open waters is used here to describe that the mooring is situated at a location where metocean conditions can approach from various directions and are not affected by a nearby coastline, breakwaters or otherwise.

Limit states and associated environmental conditions (return periods) to be considered are provided in ISO 19901-7.

The project specific maximum operational criteria for the short-duration mooring of an LNGC alongside or in tandem to the floating LNG installation shall be defined, to allow a design verification of the stationkeeping system of the floating LNG installation for the loads on the combination of the two vessels in those operating conditions.

4.2.6.3 Permanent stationkeeping in near shore or docked conditions

If a floating LNG installation is to be moored in near-shore or docked conditions, generally a quayside mooring or jetty mooring will be selected.

The design criteria to be applied in this situation shall be considered for the moored floating LNG installation in combination with the jetty or dockside to which it is moored, as both will be affected by the applicable loads.

In general the same design criteria shall be considered as provided in ISO 19901-7. However, ISO 19901-7 is intended for moorings in open waters. If the installation is moored in docked conditions or to a jetty, it can be assumed that the location will be in-shore or near shore. That implies that the environmental conditions will be affected by the local geometry and bathymetry and the local circumstances. Breakwaters may be used to reduce the effect of metocean conditions. Consequently, additional loads typical for such near shore or confined water locations shall be considered, such as seiches (wind induced wave effects near shore), infra-gravity waves, solitons, hydrodynamic effects of passing ships, and tsunamis.

Apart from direct wave, wind and current actions, and the specific near-shore hydrodynamic effects mentioned above, temperature effects, seismic loading and potential collision loads shall be considered for the moored LNG installations as well as the jetty or quayside structures that form part of the mooring system. Where applicable, reference shall be made to ISO 19901-2 for seismic design criteria.

Although different types of loads can play a role in the design of a near-shore or docked mooring situation, when compared to a stationkeeping design in open waters, the design criteria (return periods of loads for specific limit states) shall still be in accordance with the relevant parts of ISO 19901-7.

The floating LNG installation may permanently comprise of two vessels (for example an FSU moored alongside an FSRU or FLNG, which FSRU or FLNG itself is moored along a quayside or to a jetty). In that case, the design criteria for both mooring systems shall be in accordance with the relevant parts of ISO 19901-7. Consequently, in that case one of the mooring systems will be subjected to loads on the combination of two vessels, which shall be taken properly into account.

A more common situation that two vessels in side-by-side arrangement are moored to a quayside or jetty occurs when a quayside/jetty moored floating LNG installation receives an LNGC for short-duration loading/unloading. The project specific maximum operational criteria for the short-duration LNGC mooring shall be defined, to allow a design verification of the permanent stationkeeping system of the floating LNG installation for the loads on the combination of the two vessels in those operating conditions.

4.2.6.4 Permanent moorings with special project design conditions

Projects may adopt special design conditions for the permanent stationkeeping of the floating LNG installation. In ISO 19901-7, the following cases are addressed:

a) the project location is subject to certain adverse environmental events, e.g. iceberg impact or hurricanes, which would permit a stationkeeping system design based on the principle that the floating LNG installation leaves the site in advance of the adverse event (disconnectable mooring);

b) the project duration is substantially lower than 20 years.

ISO 19901-7 contains a definition of the consequences of such special design conditions for the design criteria.

4.2.6.5 Short-duration mooring of a visiting LNG carrier for loading/unloading

A visiting LNGC can moor for a relatively short duration alongside another vessel, to a jetty or to a specific loading/unloading terminal facility for the loading/unloading of LNG cargo.

Project specific design criteria shall govern the boundaries of the environmental conditions in which a mooring/berthing operation may take place and until which conditions a moored situation can be maintained. Moreover, project operational criteria shall describe the type and size range of LNGC that can be accepted for loading or unloading LNG cargo.

For the specification of project specific design criteria, guidance can be found in the latest issue of SIGTTO Ship to Ship Transfer Guide for Petroleum, Chemicals and Liquified Gases.

4.2.7 Pipe-work

Piping shall be designed in accordance with recognized industrial piping codes and standards.

Design conditions for each fluid shall be clearly defined upfront. Typically, pipes having similar design conditions are standardized into a piping class.

Piping shall be designed by taking into account the following criteria:

a) operating conditions:

- — normal operating conditions, in which normal operating conditions of pressure and temperature shall be the most severe conditions expected to coexist under usual long-time operating conditions;
- — transient operating conditions, in which usual operating conditions shall include more severe transient conditions, such as those incidentals to start-up, shutdown, commissioning or abnormal operation;

b) design conditions:

— design temperature;

— design pressure.

c) wind;

d) earthquake loads, if applicable;

e) snow and ice accumulation;

f) vibrations;

g) differential displacement of structures;

h) vessels accelerations;

i) hogging/sagging induced by hull deformation;

j) green water loads;

k) process surge loads, for which piping systems shall be designed to withstand surge loads, including water hammer (e.g. unloading lines, fire water lines, seawater lines);

l) fatigue;

m) reaction forces (anchoring/supporting);

n) corrosion allowances;

o) accidental loads (such as blast, drop object).

Piping systems shall be designed with sufficient flexibility to avoid any excessive stresses coming from permanent or occasional loads.

All piping shall be adequately supported and restrained so as to prevent undue vibration, deflection, stresses or loads on equipment.

5 Health, safety and the environment

5.1 General

5.1.1 Main objectives

The HSE main objectives shall at least focus on:

a) minimizing the potential of hazardous occurrences;

b) minimizing the risks and consequences of an accidental event;

c) ensuring a safe working environment for personnel and local communities;

d) minimizing the potential for pollution and damages of the environment.

The ultimate goal shall contribute to protecting people and the environment against long-term effects (health and environmental aspects) and short-term effects (safety aspects).

5.1.2 Main principles

The ultimate goal shall be achieved through four main steps:

Step 1 - Hazard identification

Hazard identification, frequently done through reviews, shall be carried out at an early project stage to determine any aspect of the facility that can generate short-term or long-term exposure if not adequately considered. This step shall cover all aspects related to the floating LNG installation itself or to the surroundings as well as human and natural related aspects.

Step 2 - Assessment

Once all hazardous aspects are identified, qualitative or quantitative assessments (occurrence frequency as well as consequences) shall be performed to anticipate potential effects on people (inside and outside the floating LNG installation) and the environment. This step shall be carefully carried out, as it will be necessary to select HSE measures to be implemented.

Step 3 - Control

Controls are HSE measures implemented to manage the development of a hazardous situation. Control encompasses the elimination/prevention of the hazardous situation and the limitation/mitigation of its occurrence frequency and consequences. These measures shall be thoroughly identified. Even if procedural measures can be part of control, they are typically part of the design. It shall be ensured that their performance requirements are in line with the events for which they are designed.

Step 4 - Recover

Recover engulfs all the HSE measures, including the procedural ones, which are meant to recover from the hazardous situation. These measures can be internal or external to the floating LNG installation, depending on the situation that occurred. Non-procedural HSE measures are often called safety and environmental barriers or critical elements.

5.2 Identification of safety and environmental barriers and design requirements

5.2.1 General

The nature of the main products (flammability, toxicity, anoxia) handled on the floating LNG facilities, operating conditions (pressure, temperature) associated with occupational hazards and external hazards imply that the risk of having severe accidents, such as fire, explosion, cryogenic, toxic events (also called MAE) cannot be discarded.

In order to limit the occurrence of MAE, it is normal practice to implement prevention and protection measures in the design whose main purpose is to protect people (internally and externally) as well as the environment. These elements are generally called barriers (see ISO 17776) or SECEs.

NOTE Although the terminology refers to the UK Safety Case, when not required by authorities, alternative terminology can be used.

This subclause describes the process to be followed to identify barriers and to associate design requirements to them. The typical work frame for this activity is as follows:

— identification of main hazards/accidents through HAZID (see 5.4.3.2);

— identification of MAE based on HAZID outcomes;

— identification of SECEs through bowtie or generic list;

— development of performances standards of the SECEs.

Additional details are provided in ISO 17776.

This subclause focuses on the barriers that are meant to protect people against short-term effects. The same principles can be applied to barriers meant to protect people against long-term effects as well as to protect the environment.

5.2.2 Purpose

In order to achieve the safety objectives in case of an MAE, at least the following main safety functions shall be maintained (by order):

a) Preventing escalation of accident situations, so that personnel outside the immediate escalation zone are not injured.

b) The capacity of main load-bearing structures until the facility has been evacuated. Local collapses are acceptable, if it occurs and stays inside the same escalation zone.

c) Protecting rooms of significance to combatting accidents, so that they remain operative until they have ensured their functional requirements.

d) Protecting the facility's safe areas, so that they remain intact until the facility has been evacuated.

e) Maintaining at least one escape route from every area where personnel are found, except in the escalation zone where initial event occurs, until escape to the facility's safe areas. At least one evacuation route until evacuation has been completed.

Other safety functions can be useful to investigate, depending on project specificities, constraints and context.

Implementation of the goals mentioned in 5.1 into the design of the facility (whether onshore, near shore or offshore) requires the definition of functional requirements to be ensured by safety systems. These safety systems are then split into safety and environmental barriers, each of them being provided with performance criteria that shall be guaranteed to prevent MAE from occurring.

MAE can be linked to (non-exhaustive list):

— internal process events (e.g. fires, explosion, cryogenic release);

— internal non-process events (e.g. dropped objects);

— external non-environmental events (e.g. ship collision);

— external environmental events (e.g. seismic [see also Annex E], green water, storms).

5.2.3 Safety and environmental barriers

A safety and environmental barrier can be defined as any hardware barrier (e.g. structure, equipment, system, including computer software or component part) or human barrier (e.g. maintenance procedure and activities, repair activities, emergency response plans) whose failure can cause or substantially contribute to a major accident is safety-critical, and which is intended to prevent or limit the effect of a major accident.

Because the failure of these barriers can have adverse effects on the personnel safety, the environment and facility assets (whose failure can have consequences on escalation potential or other safety systems), it is necessary that:

a) hardware barriers shall be designed to withstand fire, explosion, cryogenic loads and/or any other identified accidental loads;

b) human barriers are developed, amended and maintained to ensure correct actions of people to prevent major events and limit the potential consequences.

5.2.4 Generic barriers

The following barriers shall be used at early project phases:

a) critical equipment (i.e. equipment whose collapse can have severe consequences from an escalation point of view) and associated supports;

b) shutdown valves and piping associated to critical equipment;

c) ESD valves;

d) blowdown/depressurization system including BDVs, BD piping, supporting structures;

e) all structural members and module stools, if their collapse can give rise to an escalation event which can impair the safe escape and evacuation of personnel or can impair the operability of emergency response systems;

f) hull deck and main deck (near-shore and offshore environment);

g) hull side (near-shore and offshore environment);

h) buildings containing safety systems;

i) LQs (offshore environment)/control rooms (onshore and near-shore environment)/administrative building (onshore and near-shore environment);

j) EER facilities including temporary refuges/muster areas/rescue means (mainly near-shore and offshore environment);

k) fire water and foam systems and associated supports;

l) fire and blast walls;

m) ballast systems.

The list of barriers shall be developed in agreement with all parties concerned. ISO 17776 and ISO/TR 12489:2013, Annex A provide a list of safety barriers.

5.2.5 Safety and environmental barriers identification process

5.2.5.1 The definition of the safety and environmental barriers shall allow to register the following information:

a) name of the barrier (e.g. tag number);

b) its type (e.g. process equipment, structure, piping);

c) its functionality;

d) its location;

e) its performance criteria, e.g. operability, integrity, stability [this involves the minimum functional requirements of the barrier to be maintained to ensure it can fulfil its purpose (e.g. the performance criterion of a structure is related to its stability, survivability against various weather conditions). For some barriers, a combination of several criteria can be required (e.g. permanently manned buildings for which integrity and stability shall be typically ensured)];

f) its criticality.

NOTE 1 This involves its importance in terms of MAE/escalation prevention. For example, a barrier whose failure can generate local escalation effects might be considered as less critical than a barrier whose failure can have adverse effects on the whole facility.

In order to ensure the barriers identification's thoroughness, the project equipment list coupled with the various safety philosophies may be used. This will allow to review all the items one by one and to categorize them as barriers or not. The use of bowtie is a possible approach to identify the barriers, in which causes of accidents, consequences of accidents as well as barriers preventing, controlling or mitigating them will be indicated.

NOTE 2 See ISO/TS 16901 for details on the bowtie approach.

5.2.5.2 Items shall be considered safety and environmental barriers if they meet the following definitions:

a) those necessary for the safe shut down of the installation;

b) those necessary for personnel protection and escape;

c) those necessary for fire detection, suppression and control;

d) those necessary for communications;

e) those necessary for hydrocarbon processing, transport and storage.

ISO 17776 provides guidance to help project teams and operators to assess whether an item is to be considered a barrier or not and to assess its criticality level.

The level of details of the barriers identification shall be adapted to the project phase (early project phase vs. detailed project phase), to the installation complexity, and to the context (e.g. environment vulnerability, project replication). The level of details is important for offshore areas and for facilities located in a vulnerable environment (e.g. high manning level, presence of neighbours).

The exhaustive list of retained barriers shall be presented along with the proper justifications as part of the typical engineering work process.

The list of barriers shall be updated throughout the various project phases.

5.2.6 Safety and environmental barriers design requirements

5.2.6.1 The safety and environmental barriers design requirements shall be based on:

a) class requirements, operator's requirements, and good engineering practice;

NOTE 1 Relevant regulations might also apply.

b) the identification of the MAE against which these barriers are meant to be implemented;

c) the requirements in terms of performance criteria;

d) the barriers' criticality rating;

NOTE 2 The design of a critical barrier can be made more stringent than the design of a barrier considered less critical. Therefore, the risk acceptance criteria can be adapted on a case-by-case basis.

e) the results of hazard assessments whatever the MAE (the use of a risk-based approach is recommended);

f) the required functionality duration.

The design requirements shall depend on barriers' criticality and location with respect to the hazardous events and their occurrence frequency. Besides, the protection duration shall be at least equal to the minimum between the considered hazardous events durations and the necessary duration during which the items shall keep its functionality (in most cases, the time needed for workers/neighbours to safely escape from a potential hazardous situation shall form the basis for setting the functionality duration).

5.2.6.2 The safety and environmental design requirements can be achieved by:

a) intrinsic resistance (e.g. by using suitable material unaffected by embrittlement in case of cryogenic exposure);

b) external protection (e.g. protection of equipment against fire events by adding fire wall or by coating it with passive fire protection).

Residual damage following an accidental event may be tolerated, provided it is demonstrated that the barrier can still fulfil its functional requirement (e.g. permanent deformation of a process item with no leakage generation).

5.2.7 Safety and environmental barriers design requirements certification

During construction and operation phases, it shall be demonstrated that the safety and environmental design requirements of the different barriers have been properly implemented when under construction and that they will be able to fulfil their functional requirement.

For this purpose, at all project phases it shall be agreed between engineering companies, facility owner, vendors and authorities having jurisdiction:

a) How the validation of the barriers design (adequacy of design requirements with constructed items) shall be done, i.e. whether:

  — tests shall be consistently done;

  — certificates shall be produced;

  — calculations shall be performed;

b) Which entity shall be in charge of final documentation approval (e.g. state, flag state, classification society, accredited third-party organism).

5.3 Environmental considerations

5.3.1 General

This subclause provides an overview of environmental aspects associated with floating LNG installation commissioning and operation.

This subclause is neither intended to be exhaustive nor to replace the EIA, but aims at providing environmental aspects to be addressed when developing a floating LNG installation and giving additional recommendations.

5.3.2 Floating LNG installations specificities

Compared to onshore LNG facilities, the floating LNG facilities distinctive feature is its dual status, i.e.:

— ship, whose characteristics are similar to an LNG carrier or ship/barge design specific to local site and transit conditions;

— LNG/regasification facility at the same time, whose characteristics are similar to the ones that can be found in onshore plants.

As such, each environmental aspect can be linked to:

— ship operation;

— oil and gas operation; or

— both operations.

By consequence, these aspects shall be managed taking into consideration the best practice of each activity type.

NOTE As an example, hazardous waste management is specific to LNG installations whereas underwater noise generated by the thrusters is specific to ships.

Due to its dual status, the floating LNG installation can be simultaneously subject to the relevant international shipping rules and regulations (IMO) as well as the national laws and regulations for LNG activities. If the country does not have any specific rules, HS guidelines should be used as a minimum reference.

In case of conflicts or ambiguities regarding the part of the floating LNG installation generating the environmental aspect, the most stringent requirements in relevant codes and standards shall prevail (if the requirements in applicable regulations are less stringent).

5.3.3 Environmental aspects identification

Whatever the installation configuration, the design considerations shall take into account the following potential environmental aspects associated with floating LNG installation when developing such an LNG installations:

a) gaseous emissions;

b) wastewater discharges (part of the wastewater that cannot meet regulatory limits into the water body even after treatment will be considered as solid and liquid wastes);

c) solid and liquid waste;

d) energy efficiency and greenhouse gas;

e) chemicals;

f) impact on shoreline and on seabed profile;

g) cooling and/or heating of seawater;

h) other aspects (e.g. lighting, underwater and abovewater noises and vibrations).

5.3.4 Environmental design review

In the early phase of the floating LNG installation project, it is recommended to perform an environmental impact identification (ENVID).

Like the HAZID review, an ENVID review is a structured multidisciplinary, checklist assisted, aspect identification methodology that enables for a quick, yet accurate, identification of environmental protection and regulatory compliance measures and for a qualitative assessment of their effectiveness. The ENVID review focuses on environmental issues associated to normal operation and not associated with hazardous/accidental events (which is included in HAZID).

The ENVID ensures the identification of all controls already made to reduce adverse environmental impacts from the project in the context of the preparation of an EIA and to provide some guidance to engineers on potential improvement opportunities.

Depending on project complexity, this review may be combined with the HAZID review. See also 5.4.3.2.

5.3.5 Environmental design requirements

5.3.5.1 General

This subclause aims at presenting the different type of environmental aspects to be considered. Aspects that are well covered by other international guidelines and practices are briefly mentioned in 5.3.5.2 to

5.3.5.7 and explained in more detail in Annex B. Aspects that are not specifically addressed in other international guidelines and practices are described in detail in 5.3.5.2 to 5.3.5.7.

5.3.5.2 Gaseous emissions

5.3.5.2.1 Gaseous emissions categories

Whatever the installation configuration, gaseous emissions can be divided in three categories of sources:

1) large point source emissions, mainly due to power and heat generation;

2) flare and vent emissions;

3) fugitive emissions.

For these three categories of sources, the regulatory requirements applicable to the facility will influence the design requirements, the monitoring and the validation requirements. The three categories of sources are further detailed in Annex B.

5.3.5.2.2 Regulatory requirements

Regarding air quality, two types of limit values apply:

a) in ambient air at the facilities border or in the facilities vicinities;

b) at point source that will depend on the nature and source of the streams as mentioned in Table 6 (see also Annex B).

Table 6 — Emission sources and corresponding monitoring parameters

Source of emission	Applicable regulation	Main parameters to be monitored
Turbines and engines (main power generation)	Local regulation[a,b]	NOx, SOx, PM, CO and in some cases for H_2S and heavy metals[c]
Boilers	Local regulation[a,b]	NOx, SOx, PM, CO and in some cases for H_2S and heavy metals[c]
Emergency generators	Most stringent between local regulation and MARPOL[a,b]	NOx, SOx, PM, CO and in some cases for H_2S and heavy metals[c]
Essential generators	Most stringent between local regulation and MARPOL[a,b]	NOx, SOx, CO and in some cases for H_2S and heavy metals[c]
Gas incinerators	Local regulation[a]	Parameters associated to gaseous waste incineration
Flare and vents	Local regulation[a]	N/A — Emergency only

[a] In absence of local legislation regarding the management of combustion sources, World Bank guidelines shall be followed.

[b] World Bank guidelines split the air emissions standard into two categories: small combustion with a thermal power lower or equal to 50 MWth and large combustion with a thermal power greater than 50 MWth. In order to decide the set of air emissions standards to be applied, the thermal power calculation shall take into account all the combustion sources operating in parallel. Combustion sources independency shall not be applicable due to project footprint congestion.

[c] Emissions limit values given for combustion sources depend on the fuel type used (e.g. natural gas, fuel gas, diesel).

The number of limit values to be applied depends on the floating LNG installation location:

a) For offshore facilities (remote installation): From a regulatory point of view, due to general absence of community and terrestrial ecosystem in the vicinity, only limit values at point source different for each type of streams shall be applied.

b) For onshore/nearshore facilities: Due to potential presence of community and terrestrial ecosystem in the vicinity, both set of value at point source and in ambient air shall be applied.

5.3.5.2.3 Design requirements

5.3.5.2.3.1 Stack height

Presence of stack is directly linked with LNG activities (e.g. power generation, waste gas incineration). The height of the stack shall be determined taking into account the surrounding to avoid workers' and public exposure to potentially hazardous pollutants with significant concentration and duration. This principle shall be adapted to the characteristics of the facility vicinity as well as to the applicable requirements (see G.1.1.2 for details).

5.3.5.2.3.2 Vents

Vents are addressed in Annex B.

5.3.5.2.3.3 Fugitive emissions

Fugitive emissions from equipment (e.g. pumps, compressors, flanged joints) shall be minimized by state-of-art technologies.

Fugitive emissions from storage and handling shall be, as far as feasible, captured and ducted via destruction mechanism (e.g. flaring, incineration or captured by a vapour recovery system.

5.3.5.2.4 Monitoring requirements

The environmental monitoring is generally prescribed by the environmental ministry of the facility hosting country.

Monitoring is generally split into three main activities:

a) Point source emissions monitoring:

   — CEMS and annual testing (sampling) shall be implemented on the main exhaust sources and for the main pollutants NOx, SOx, PM, COx and/or methane, heavy metals, aromatics (BTX) to be defined on a day-to-day basis);

   — PEMS, if accepted by local environmental authority, is recognized by World Bank Standard for offshore oil and gas development. This system may be considered as a good option to reduce the requirement of the stack height fourth criterion (see Annex G).

b) Ambient air monitoring (optional, pending on community/ecosystem presence in the vicinity and ambient air concentration to be respected):

   — Continuous monitoring and/or passive samplers shall be implemented on the main pollutants NOx, SO_2, PM, CO and/or O_3, mercury, benzene (to be defined on a day-to-day basis).

   — In absence of meteorological station in the floating LNG installation vicinity, the implementation of such a station is strongly recommended in order to measure in real time as minimum: rainfall, nebulosity, temperature and wind (at + 1m above ground level and at stack level, if possible).

c) Fugitive emissions follow-up:

   Each project shall adopt a structure approach commonly known as LDAR program to reduce fugitive methane and VOC emissions. Two methods are recommended for leak detection:

   — The sniffing method and correlation curves for small individual equipment (e.g. pumps, flanges, valves);

   — The OGI method for leaking point difficult to access with hand-held detectors as well as for condensate storage area and for loading/unloading area.

5.3.5.2.5 Ambient air quality validation

Ambient air quality final compliance shall be demonstrated by a worldwide recognized model, that is able to:

a) model single-port/multi-port diffuser emissions as well as surface emission sources;

b) take into account different type of emissions (e.g. turbines, vents, fugitive emissions).

5.3.5.3 Wastewater discharges

5.3.5.3.1 Effluent types

In operation, a floating LNG installation generates four types of effluents:

a) sewages: wastewater from domestic areas (e.g. galley, laundry, accommodation);

b) wastewaters:

- wastewater from LNG process areas (e.g. produced water, brine from potable water unit);
- storm water (e.g. rainfall, deck washing water, accidentally released hydrocarbons);
- fire water;
- ballast water;
- bilge water;

c) sea water systems:

- cooling water systems;
- regasification systems;
- sea water scrubber (IGG), if any;

d) chemicals:

- chemicals used in the processes and utilities facilities;
- chemicals from laboratory.

For these four types of effluents, the regulatory requirements applicable to the facility will influence the design requirements, the monitoring and the validation requirements.

5.3.5.3.2 Regulatory requirements

Regarding wastewater discharges, two sets of limit values apply:

a) one set of values for the whole streams together discharged in water body (in the sea) and applicable after the mixing zone and corresponding to water body quality (see G.1.2 for details);

b) one set of values at point source for each type of streams that will depend on the nature and source of the streams as mentioned in Table 7 (see also Annex B).

Table 7 — Effluent sources and corresponding monitoring parameters

Source of effluent	Applicable regulation	Relevant parameters
Sewages	Most stringent between local regulation and MARPOL[a]	TSS, oil and fats, pH, BOD, COD and total coliform bacteria
Waste water from oil and gas activities processing	Local regulation[a]	TSS, oil and fat (to be understood here as THC), BOD, COD, pH, heavy metals (total), sulphides, chlorides
Storm water (e.g. rainfall, deck washing water)	Local regulation[a]	Drainage system accommodating the first flush principle
Firewater	[b]	All firewater (e.g. test firewater, cooling firewater) shall be first collected to ensure they are non-polluted and harmless for environment before release
Ballast water	MARPOL	
Bilge water	Most stringent between local regulation and MARPOL[a]	TSS, oil and fat
Sea water cooling or used for regasification	Local regulation[a,c]	Mainly chlorine
Sea water scrubbing (if any)	MARPOL	PH, PAH, NTU and nitrates
Chemicals	Local regulation [a] or consideration as a liquid waste if significant quantities and/or cannot be handled by the waste water treatment	Dependent on selected chemicals

[a] In absence of local legislation regarding the management of effluent sources, World Bank guidelines shall be followed.

[b] The collection of firewater and treatment before release to the water body shall be adapted to the configuration of the facility:

— in the case the facility is partly located onshore and offshore/nearshore, firewater on the onshore part shall be collected;

— for nearshore and offshore part, collection shall be investigated taking into account the technical feasibility and the quantity of water that will be sent overboard without reaching the bunds;

— as a principle, products used to fight against fires (e.g. foam) shall be selected in such a way that they are as friendly to environment as possible.

[c] Local authorities may limit the maximum difference in temperature between intake and outlet.

5.3.5.3.3 Wastewater treatment

A floating LNG installation will generate various wastewater streams (organic or inorganic) with various contamination load, low [≤10^5 µg/kg (≤100 ppm)], mean, and high [≥10^6µg/kg (≥1 000 ppm)], for instance:

— produced water can be defined as an organic stream with a high concentration;

— brine: inorganic (high);

— mono-ethylene glycol regeneration package: organic (mean);

— de-oiled open drain: organic (low);

— de-oiled bilge: organic (low).

The effluents should be sorted according to their contamination type and concentration. The effluents should be treated individually instead of mixed together.

A treatment facility shall only receive those pollutants with which it can cope. A treatment facility shall require treatment at sources instead of central (mixed) as per EHS Guidelines for offshore oil and gas development.

NOTE This is also in line with best available techniques in common wastewater and waste gas treatment[50].

5.3.5.3.4 Environmental monitoring at point source

Effluent monitoring induces an individual monitoring per stream just downstream treatment prior to effluent mixing. In this way, discharge limit values obtained through the dilution of the effluent with unpolluted water shall not be considered (e.g. supply water or water used in cooling).

Effluent monitoring includes measuring flow rate and a sampling point for quality analysis.

A list of physical and chemical parameters to be monitored is given in national regulations and/or World Bank standards (EHS Guidelines for offshore oil and gas development). The parameters can differ among the various streams, but as a minimum temperature, pH, TSS, oil and fats, and dissolved oxygen should be monitored.

5.3.5.3.5 Ambient water quality validation

Ambient water quality final compliance shall be demonstrated by a worldwide recognized mixing zone model, that is able to:

a) model single-port/multi-port diffuser discharges as well as surface discharges sources;

b) take into account different type of effluents (e.g. brine, heated, rich in sediments).

5.3.5.4 Solid/liquid waste

5.3.5.4.1 Waste management plans

When developing a floating LNG installation, specific plans to manage the wastes shall be established and maintained during all project phases. These plans and associated studies shall ensure that identification, segregation/handling, storage, treatment on-site as well as treatment and disposal off-site will be done in an appropriate way and by duly authorized companies.

5.3.5.4.2 Wastes identification

Each waste stream shall be inventoried, qualified, quantified and characterized, taking local/national regulations into account.

5.3.5.4.3 Segregation at sources

Wastes shall be segregated at sources, such as process units, workshops, administrative area, and canteen, prior to being sent to its dedicated secondary temporary storage.

The segregation shall be carried out so as to constitute pure waste streams, i.e. consisting of materials which present similar properties (e.g. chemical composition, hazardousness) to avoid incompatibility and to facilitate treatment and disposal.

5.3.5.4.4 On-site temporary storage

Two types of temporary storage areas shall be designed within the facilities:

1) local storage areas in closed proximity to waste generation sources;

2) lay down area dedicated to the waste collection prior to be shipped onshore for offshore/nearshore project, or specific temporary storage area for partially onshore project.

Before being regrouped in the lay down area or in the temporary storage area, waste should be collected in local storage areas. Each local storage area shall be designed to:

a) store waste in safe and controlled conditions;

b) provide an adequate accumulation time to collect a reasonable amount of waste (at least one full package).

Before being sent onshore by shipping containers for offshore and nearshore facilities or sent offsite by trucks, waste shall be collected in the lay down area. The lay down area shall be designed to:

a) store waste in safe and controlled conditions;

b) provide an adequate accumulation time to fulfil standard marine containers/trucks;

c) provide a storage spare capacity for waste generated during abnormal operating conditions.

5.3.5.4.5 Waste reduction strategy

For all offshore projects as well as some nearshore/onshore projects, space dedicated to storage will be necessarily limited and handling of some waste can turn out to be dangerous. Therefore, waste reduction strategy shall be implemented pending on space availability.

Examples of potential pre-treatments are:

— volume minimization;

— compactors (baling) to reduce the non-hazardous domestic waste volume (e.g. bottles, cans, packaging);

— crushers/macerators to break into pieces waste (e.g. organic waste, cylinders, glass, plastics, scrap metals);

— presses to compact small capacity drums;

— transformation of hazardous waste into non-hazardous waste (e.g. sterilization to transform infectious waste into non-hazardous waste).

5.3.5.4.6 Off-site treatment and disposal

Off-site treatment and disposal for each waste stream shall be clearly identified and performed by a company recognized by national authorities.

Sludge and liquid waste shall follow best available techniques. Sludge shall contain at least 20 % solids to be considered solid enough and cost-effective to be landfilled. Liquid waste shall not be landfilled.

5.3.5.5 Energy efficiency and greenhouse gas emissions

Greenhouse gas emission savings strategy shall be applied to the project. The facilities design of the floating LNG installation shall aim to:

a) maximize energy efficiency (e.g. opportunities for efficiency improvements in utilities, fired heaters, process optimization, heat exchangers, motor and motor applications);

b) minimize energy use in facilities;

c) reduce air emissions.

Greenhouse gas emissions shall be evaluated taking into account the global warming potential values for use in the Kyoto protocol and developed by the Intergovernmental Panel on Climate Change (IPCC).

NOTE As a guidance, equipment selection following the principles given in Reference [51] can be used.

5.3.5.6 Chemicals

5.3.5.6.1 Banned chemicals

The following chemical substances shall be prohibited as a minimum on the floating LNG installation.

NOTE National or local regulations on banned chemicals might exist.

a) ozone depleting substances according to Montreal Protocol;

b) asbestos;

c) persistent organic pollutants that are restricted following the Stockholm Convention (e.g. polychlorinated biphenyls);

d) organotin compound tributylin.

In addition, reduction of using global warming potential chemicals gases as per Kigali Amendment to the Montreal Protocol should be considered.

5.3.5.6.2 Chemical selection

Environmental impacts from chemicals shall be minimized through chemical selection and selection of their dosage levels. The following applies:

a) As per EHS Guidelines for offshore oil and gas development, chemicals known to contain heavy metals, other than in trace quantities, should be avoided.

b) As per EHS Guidelines for offshore oil and gas development, use of chemicals suspected to cause taint or known endocrine disruptors should be avoided.

c) As per maritime standards (i.e. MARPOL), each chemical on board shall be categorized according to its level of hazard for aquatic life (acute and chronicle). Chemicals categorized with a major hazard should be substituted by chemicals with minor hazard or with no harm to aquatic life. If substitution is not possible, effective mitigation measure shall be implemented to prevent chemicals discharge into the environment.

5.3.5.7 Other aspects (lighting and underwater noise)

Additional issues specifically linked to local ecosystem and community sensitivity shall be handled carefully on a case-by-case basis. These issues include:

— lighting, in particular on installations located under bird migratory channel;

— noise, in particular underwater noise in installations located in the vicinity of sea mammals nesting areas.

5.4 Safety considerations

5.4.1 General

Compared to onshore LNG facilities, the floating LNG facilities distinctive feature is its dual status, i.e.:

— ship whose characteristics are similar to an LNG carrier;

— LNG/regasification facility at the same time whose characteristics are similar to the ones that can be found in onshore plants.

As such, each safety aspect can be linked to:

— ship operation;

— oil and gas operation; or

— both operations.

5.4.2 Safety strategies and philosophies

The design shall endeavour to implement inherent safe measures in the early stage of the design in preference of engineered solution or operational procedures in managing risk. If this is not feasible, engineered solution shall be considered focussing on separation/segregation, engineered safety system, where this can maximize the benefits at much lower cost instead of procedurals and permitting system controls.

Early in the design (conceptual stage), the project development team shall establish a high-level safety strategy that outlines the measures to be considered to eliminate/manage hazard introduced by the design. The high-level safety strategy covers hazard prevention and hazard minimization including fire, explosion and cold spill strategy, and escape, evacuation and rescue strategy. The high-level safety strategy shall then be further matured into a set of safety philosophies, which will provide clear guidance and define design requirements to the design team, and further realized in detailed engineering as the design evolves. The safety philosophies shall include, but no limited to:

a) layout safety, including explosion protection;

b) fire and gas detection;

c) emergency shutdown;

d) emergency depressurizing;

e) fire protection, covering both active and passive protection;

f) cold spill protection;

g) ignition source management, including hazardous area classification;

h) drainage;

i) escape, evacuation and rescue.

5.4.3 Safety reviews

5.4.3.1 General

Safety reviews aim at reviewing the floating LNG installation through brainstorming activities involving several disciplines and confirming validity of the design or raising actions to increase the overall level of safety.

5.4.3.2 HAZID review

5.4.3.2.1 General principles

A HAZID review shall be organized for all new facilities as well as when changes are implemented on the facility. The HAZID review is a structured, keyword-based risk identification and analysis methodology that enables documented hazard identification of a project in its earliest phase. Using checklists enables a systematic recording. The HAZID review is a guided team brainstorming activity that benefits from the broad experience of a multidisciplinary team.

The result of the HAZID review is documented in a table where potential hazards, corresponding causes, consequences and associated safeguards are reported. When it is deemed necessary by the HAZID review team, actions are formulated. These actions are assigned to persons, followed-up and closed-out.

5.4.3.2.2 Scope of the review

The purpose of the HAZID review is to focus on hazardous/accidental situations in opposition to ENVID and health risk assessment review, which focus on normal operation.

The HAZID review shall cover at least normal operation, maintenance, start-up and shut down of all process units and utilities within the battery limits of the installation. Additional project phases (e.g. construction and commissioning activities) may be included as part of the overall review or through a dedicated session.

Hazards related to simultaneous operations, e.g. abnormal maintenance and production, LNG/LPG/condensate transfer operations and production, pigging activities and operation, shall be covered during the review under dedicated guidewords. Hazards related to the facility impacts on the neighbourhood during normal operation will be covered during the review under dedicated guidewords.

The review may be carried out in a qualitative or semi-quantitative/quantitative way (in this approach, each scenario identified is assessed by the team for their potential severity and likelihood of occurrence).

5.4.3.2.3 Methodology

The HAZID review process is divided into the following steps:

Step 1 - select a section of the facility (e.g. area such as LQ, hull, topsides) or unit (e.g. inlet facilities, utilities);

Step 2 - describe the section's design intent and process conditions;

Step 3 - select the first/next guideword;

Step 4 - determine by brainstorming all the potential causes relevant to this guideword and agree the credibility of each cause;

Step 5 - identify the potential consequences associated to each cause;

Step 6 - identify the safeguards in place or foreseen against each identified scenario;

Step 7 - assess associated risk (if quantitative or semi-quantitative);

Step 8 - propose actions when it appears necessary;

Step 9 - check that implementation of proposed action(s) will adequately solve the issue;

Step 10 - assess final risk after action implementation (if quantitative or semi-quantitative);

Step 11 - apply the next guide word until they all have been considered;

Step 12 - ensure that all accidents, listed in the accidentology, related to the section have been discussed;

Step 13 - move onto the next section until the whole scope of review is covered.

5.4.3.2.4 List of typical input information

The list of typical input information presented in ISO 17776:2016, Annex C may be used as a reference when developing the floating LNG installation. This applies to both new and modified facilities.

5.4.3.2.5 List of key words

The list of key words presented in ISO 17776:2016, Annex F may be used as a reference when developing the floating LNG installation. This applies to both new and modified facilities.

5.4.3.2.6 Report (template)

The content of the HAZID report and its appendices can be structured as follows:

- executive summary;
- introduction;
- scope;
- team composition;
- documents references;
- sections description;
- findings of the review;
- attachments:
  - attendees list;
  - copy of reference documents marked during the review;
  - risk assessment matrix;
  - HAZID worksheets;
  - HAZID action list.

5.4.3.3 HAZOP review

The purpose of the HAZOP review is to check whether process deviations from normal mode of operation are properly managed by the safeguards in place. This study is intended to identify latent faults or hazardous interactions and propose improvements to safety and operability as necessary. The HAZOP review is a brainstorming exercise guided by a checklist and involves a multi-discipline team.

A HAZOP review shall be organized for all new facilities as well as when design changes are implemented on the facility.

A reference to a standard or document listing the main key words can be more appropriate (see ISO 17776).

The sequence of the HAZOP review is similar to the HAZID one. The HAZOP report follows a similar structure as the HAZID report.

5.4.3.4 SIL review

The SIL analysis as described in the IEC 61508 series is considered to complement the HAZOP analysis and the risk assessment study by defining the level of confidence required from the instrumented safety systems including mechanical devices and software, intended to prevent hazardous situations affecting safety of persons and/or the environment or to mitigate their consequences. The IEC 61508 series also introduces the notion of safety life cycle that aims to secure the reliability of the implemented safety systems throughout the life of the system.

The SIL assessment should be based on layers of protection analysis (see the IEC 61508 series).

5.4.3.5 Risk register

A risk register shall be produced and maintained at each project phase to keep the tracking of all the actions raised during the safety reviews. Its purpose is to ensure that all actions will be addressed and closed with proper implementation of the results in the design.

5.4.4 Qualitative risk assessment, QRA and specific safety studies

5.4.4.1 General

Assessment of hazardous events on people and on the surroundings can be done following several approaches. These approaches vary from the simplest ones to the most complicated ones. Before performing a study of any kind, the following questions shall be answered:

a) What is the applicable regulation and its requirements?

b) What is the project phase?

c) What is the maturity of the available data?

d) What is the vulnerability (in particular presence of people) of the floating LNG installation and its surroundings (location)?

e) What is the level of similarity between the floating LNG installation and other facilities?

f) May the study to be done be dependent on the selected area of the floating LNG installation?

g) Is a part of the floating LNG installation entirely compliant with one or several codes and standards giving precise requirements?

The studies to be done and their complexity shall be adapted based on the answers to these questions.

EXAMPLE The hull part of the floating LNG installation can be entirely or almost entirely designed as per the various IMO codes, if it is similar to the hull of an LNG carrier. In the same way, the onshore part of the floating LNG installation will not face the same issues than the offshore part of the installation in terms of congestion, confinement of the facilities.

The schemes and studies presented in the following subclauses are intended as a guide rather than a mandatory workflow to be followed at any time.

5.4.4.2 General scheme

The scheme in Figure 1 presents the links between the various QRA and safety studies as well as with the design.

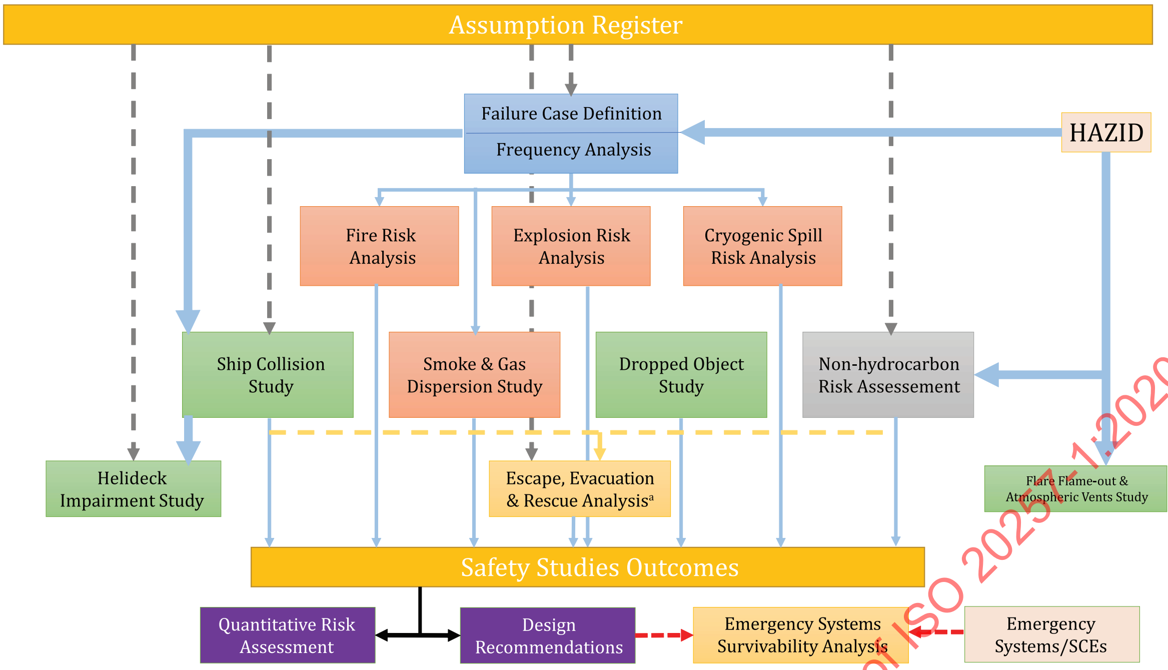


Figure 1 — Links between the various QRA and safety studies as well as with the design

5.4.4.3 Specific risk assessment studies (when applicable)

Table 8 provides an overview of different specific risk assessment studies. Depending on the project nature, specificities and project phase, these studies are recommended be performed. The purpose of the studies is described in the following subclauses.

Table 8 — Overview of specific risk assessment studies

Study	Location impact	Recommended use
Assumption register	For all locations	FSRU/FLNG
Failure case definition and release frequency analysis (process events)	For all locations	FSRU/FLNG
FRA	All environments where fire events can occur Attention should be paid to congested/confined and non-confined differences in methodology. Impact can be on location of protection measures and structural design.	FSRU/FLNG
CSRA	All environments where cryogenic release events can occur or accumulate Leak sources are more likely on FLNG	FSRU (more adapted to parts of the facility located on a vessel)/FLNG

Table 8 *(continued)*

Study	Location impact	Recommended use
ERA	All environments where flammable release events can occur On FLNG, congested/confined area and/or proximity of consequences can restrict use of some modelization method. Attention should be paid to deflagration to detonation	FSRU/FLNG
Smoke and gas dispersion analysis	For all locations where fire events and any gas release can impact EER means Evacuation and explosion analysis and fog formation should be considered	Study mainly recommended for FLNG as effects of smoke and gas dispersion analysis significantly impact facilities for which the number of escape and evacuation paths is limited
EERA including or not the temporary refuge impairment analysis	All environments Depending of the manning level and location, a qualitative layout review can be sufficient	Study mainly recommended for FLNG as congestion of the facilities and location make escape and evacuation for workers more difficult to achieve
ESSA	All environments This study is a check of the proper location and/or design of the main safety functions with respect to existing hazards. Main safety functions should be kept operating during and after hazardous event as appropriate.	FSRU/FLNG Use depends on facility complexity and application of risk-based/performance-based approaches vs. prescriptive approaches
Ship collision study	Mainly for nearshore and offshore parts Requirement of this study is project specific. This study can be required in sensitive area such as a port, a high marine traffic density area, or a sensitive environmental area	Study mainly recommended for FLNG
Dropped object study	For all locations Requirement of this study is depending on the relative location of the lifting devices towards hydrocarbon lines and equipment as well as subsea flowlines	Study mainly recommended for FLNG
Helideck impairment study	Mainly for nearshore and offshore parts Requirement for this study is depending on the requirement for medical evacuation with respect to hot plumes directions and crew changes	Study mainly recommended for FLNG
Flare flame-out and atmospheric vents study	All environments Refer to considerations on helideck impairment study and studies made to identification of ignition sources. Consider potential concerns with LNG carrier exhaust	FSRU/FLNG

Table 8 *(continued)*

Study	Location impact	Recommended use
Non-hydrocarbon risk assessment	All environments	FSRU/FLNG (study generally included in QRA and based on worldwide database)
QRA	All environments	FSRU/FLNG

For FSU, it is recommended to carry out an assessment to determine which of the safety studies listed in Table 8 might be relevant for the FSU operations, for example, where the operation deviates significantly from gas carriers operation.

5.4.4.4 QRA

A QRA shall be carried out to determine the risk levels to people associated with all operations and hydrocarbon handling facilities.

In addition to the QRA of the floating LNG installation (typically performed by the ship owner), a location-specific QRA shall be performed addressing effects of systems and/or other facilities located either offshore or onshore which can impact the overall safety of the floating LNG installation or can be impacted by the floating LNG installation.

The risk levels shall be calculated using the results of risk assessment studies listed in Table 8. In absence of definition of the thresholds in the local regulation, the recommended values defined in Annex A should be applied. The risk levels shall include the risks implied by collisions with the facility due to marine activities and risks due to the transfer of personnel to and from the facility.

The objectives of the QRA are to:

— integrate the results of all the safety studies specified in 5.4.4.3 and to get an overview of the risk related to the whole facility;

— determine the level of risk to personnel associated with all operations, including risk associated with offloading operations;

— allow an assessment of the risk levels with the project risk tolerability criteria (see Annex A for further guidance);

— propose risk reduction measures, if deemed necessary.

The battery limits for the systems to be analysed in the studies shall be clearly defined before the start of the studies.

In a first approach, the risk assessment does not necessarily consider the following subjects:

— quantitative environmental assessment;

— loss of production aspects and related economic impacts;

— public opinion/reputation;

— detailed occupational risk analysis;

— risks from/to third parties (except ship collisions).

For the presentation of results, see ISO/TS 16901.

5.4.5 Risk prevention measures (typical list)

5.4.5.1 Active measures

5.4.5.1.1 Internal over-pressure protection

Safety devices shall be provided to cover all internal over-pressure risks including those due to fire.

The discharges from conventional safety devices (e.g. safety valves, relief valves) should be routed to the flare/vent system or the storage tank. Tank and vaporiser safety valve releases, if not routed to the flare/vent systems, should be routed to a safe location as defined by hazard assessment.

If low and high pressure releases are routed to the same system, the risk of excessive back pressure shall be avoided. If excessive back-pressure can occur in low pressure release system due to high pressure release, then separate flare/vent systems may be considered for high and low pressure releases.

5.4.5.1.2 Emergency shutdown

The principle of the ESD operation is to minimize the release of hydrocarbons and the escalation of any hazardous event into adjacent areas.

An ESD activation will cause equipment shutdown and ESD valves operation to their fail safe position in order to contain inventories. The ESD system shall be designed to perform the timely and safe isolation and shutdown of equipment, systems and operations, following the detection of an abnormal or unsafe condition/incident.

All ESD shall be activated by the safety control system. ESD activation shall be automatic from the various systems (e.g. fire and gas system, safety control systems) with supplementary activation from local ESD station or central panel. ESD activation shall not cause a new hazard situation and shall avoid damage to a machine or other equipment, unless proven necessary to limit safety issues.

The ESD activation shall be transmitted to the process control system, which shall operate in a manner complimentary to the ESD action. The process control system shall put automatic sequences in such a position as to prevent unexpected equipment or valve operation which can occur at the time of ESD reset.

Hazard assessment conclusions shall be applied to the design of the safety control system. Type, redundancy, number and location of detectors or sensors shall be studied to ensure quick and reliable detection of a hazardous situation. A cause-and-effect matrix shall be produced in conformity with hazard assessment and HAZOP study requirements as well as SIL review (if any).

Facilities are generally divided into escalation zones to limit potential for escalation. Fire hazards in an escalation zone may be controlled by the operation of the ESD valves. The ESD shall isolate the fire zone(s) to minimize the release of hydrocarbon from the fire zone, and to minimize the flow of hydrocarbon needed to sustain the fire event. ESD valves are also used within fire zone to minimize the release of hazardous materials from vessels due to the failure of downstream equipment or piping.

ESD operation is usually provided as a structured response related to the hazardous event. Typical ESD levels are:

— ESD 0: pre-abandonment, applicable to at least permanently manned offshore/nearshore facilities, unless statutory requirements do not impose to do so and a risk assessment (size, lay-out and manning criteria) demonstrates the non-necessity of ESD 0.

— ESD 1: plant shutdown with the exception of certain safety items normally powered by the emergency generator or the UPS;

— ESD 2: shutdown of all hydrocarbon processing and transfer operations;

— ESD 3: local plant area, equipment or operation shutdown.

Names of ESD levels can vary while ESD2 and/or ESD3 levels can also be called PSD levels.

Typical ESD (also named offloading ESD or OESD, see 13.5.2.2) alignment for receiving and supplying products is:

— OESD-1: stop of transfer (can be activated by e.g. F&G, reach of transfer operating envelope limit, high level in tanks, power loss);

— OESD-2: disconnection of transfer (can be activated by e.g. reach of transfer maximal envelope, push button).

5.4.5.1.3 Depressurization and venting

5.4.5.1.3.1 General

Depressurising and venting systems shall be provided for pressurized hydrocarbons processing systems. All emissions to the atmosphere shall be monitored, controlled and registered.

In general, continuous operational venting shall be avoided (see 5.3). The intention of this measure is to:

— reduce risk of escalation;

— reduce the effect and duration of leakage;

— avoid the risk of failure of LNG, hydrocarbon refrigerant or gas filled pressure vessels and piping from external radiation.

Isolation valves, either activated from a control room or other remote location, or activated automatically, shall be provided so that the facility can be isolated into several subsystems and where it is required to isolate sensitive equipment. This will make it possible to depressurise only one part of the plant, while limiting the entry of hydrocarbons.

Devices for depressurising high pressure equipment shall allow the pressure of one or more item of one isolatable section to be reduced quickly.

Depressurization shall be in accordance with ISO 23251 or shall provide sufficient mitigation to the identified risk in the QRA. The gases shall be sent to the flare or vent systems, which shall be capable of handling the low temperatures generated during depressurizing. Non-flammable gases shall be separately vented.

5.4.5.1.3.2 Flare and vent systems

On the floating LNG installation, two main depressurizing systems may be implemented: flare systems or vents. The choice between the two systems or a combination of them shall be made on a case-by-case basis, depending on the quantities to be released, their hazardousness, the vulnerability of the surroundings, the local regulation, etc.

Whatever the system selected, both normal and accidental flows shall be considered when designing the system:

— The normal flow rate results from all operating configuration modes, either steady or transient, nominal or downgraded, but staying within the facility initial design intent.

— The accidental flow rate is the highest flow rate that results from an uncontrolled and/or unplanned event which can occur during operation. It is the sum of the normal flow rate and the highest total flow related to other possible uncontrolled/unplanned scenarios that can occur simultaneously. The hazard assessment shall determine the combination(s) of events which can actually occur simultaneously without double jeopardy (simultaneous unrelated events). High integrity protection system may be used to reduce the flowrate to the flare/vent system.

If for any reason, some downgraded situations are not included in the “normal flow rate” (e.g. commissioning, cooling down of warm LNG tanker from dry docking), the designer shall check that the related flow rate added to the normal flow rate is lower than the accidental flow rate.

5.4.5.1.3.3 Flare system

The sizing of the flare shall be determined on the basis of the flow rate of gas to flare, the process conditions, the maximum allowable radiation limits on the surroundings and at identified vulnerable targets (e.g. LNG carrier and supply vessel) and selected atmospheric conditions. Adequate system shall be provided for the flare headers to prevent air ingress and burn back.

The design of the flare shall take into account:

a) the possible presence of personnel, considering the permissible gas concentrations and the levels of thermal radiation in case of accidental ignition (also considering thermal radiation level at crane operator deck);

b) the direction of air and shipping traffic;

c) the direction of the prevailing wind;

d) the presence of equipment sensitive to high levels of heat radiation;

e) the distance of the living quarter/administrative area.

In dimensioning the flare, the following requirements apply:

a) The effect of cooling due to the gas expansion during depressurization shall be carefully evaluated under emergency conditions.

b) Flare stacks shall be designed to withstand the loads imposed by all known environmental conditions and accidental events (e.g. extreme weather, fire, explosion).

c) Tip selection shall take into account the maximum allowed noise levels in manned areas. The tip shall be suitable for the calculated flare size and capacity in order to ensure flame stability and flashback protection.

d) Tip and flare upper section material selection shall take into account the effects of possible flame impingement.

e) Flare tips shall be equipped with an adequate number of pilots, with a reliable means of remote ignition.

5.4.5.1.3.4 Vent system

All potentially hazardous vents shall be identified during the course of the project. Identification may be limited to the biggest hazardous vents in early phase, which shall then be extended to all hazardous vents including vendors' vents in final engineering and construction phases.

The safe location of the identified hazardous vents shall follow applicable industry standards, area classification codes and class requirements.

The potential toxic gas vents shall also be identified, if any.

Among all vents identified, dispersion calculations shall be performed for the main vents, function of the associated flow rate of flammable/toxic/anoxia gases and position of the vents, to determine safe locations for these discharge vents.

Accidental events shall be taken into account if they can have consequences on areas/items meant to keep operating in emergency situation (e.g. emergency diesel generator located close to vents).

In case of potential ignition of vent, snuffing systems shall be considered.

5.4.5.1.4 Active fire protection

The objective of the fixed fire protection systems is to supply the facility with resources to limit the possibility of fire propagation, to extinguish and/or to mitigate the consequences of a possible fire scenario. Active fire protection systems provide means of cooling and/or extinguishment of certain specific fire scenarios for the protection for personnel, equipment and structures.

The active fire protection system shall be designed to deliver the required quantities of firefighting media to the correct location, at the required pressure, within the time required and for the required duration, appropriate to the envisaged hazard.

NOTE The FSS Code can be used as guidance.

5.4.5.1.5 Fire, cold spill and gas detection system

The purpose of the F&G detection is to warn the personnel and to take appropriate actions in order to protect personnel, the environment and the asset.

The F&G detection system shall be designed to meet the following safety goals:

a) provide an early detection of flammable, and liquefied cryogenic gas leakage as well as toxic and asphyxiating gases;

b) provide an early detection of a fire;

c) alert, through PAGA system, F&G system or local control systems, personnel in the field and in buildings of the detected hazard by means of audible and visual alarms;

d) initiate manual and/or automatic remedial actions to avoid escalation of hazardous conditions (such as giving inputs to ESD system, or activating fire protection systems);

e) monitor all detectors connected by accepting analogue and/or digital inputs from the detectors/devices.

All input and output cables to the F&G system (e.g. F&G detectors, push-buttons, deluge valves, fire water pump) shall be fire resistant in accordance with the IEC 60331 series. F&G cables shall be separated and routed via two physically separate paths to avoid common causes of failure.

All F&G detectors and manual activated call points shall be dust tight, water tight, corrosion resistant and proven for the use in marine environment where necessary. All F&G detectors and manual call points shall be approved by the selected classification society and in accordance with applicable standards.

NOTE Applicable regulations might exist.

Table 9 lists the typical F&G detectors type. These F&G detectors shall be implemented depending on the area (outside or inside) with specific care to interfaces, and on the type of equipment/hazard are recommended (e.g. flammable gases, cables trays).

Table 9 — Overview of typical F&G detector types

Classification of detectors	Typical detectors type
Flame detectors	IR3 flame detectors
Heat detectors	Rate of rise heat detectors Frangible bulbs (sprinkler)
Smoke detectors (inside facilities)	Optical point type smoke detectors High sensitivity smoke detectors
Flammable gas detectors (hydrocarbons)	IR point gas detectors IR line of sight gas detectors

Table 9 *(continued)*

Classification of detectors	Typical detectors type
Hydrogen gas detectors (inside facilities)	Hydrogen catalytic gas detectors
Low oxygen detectors (inside facilities)	Electrochemical detectors
Cold spill detectors	Resistance temperature detectors
Oil mist detectors	IR beam detector (optical obscuration)
Toxic gas detector	H_2S line of sight Electrochemical cell Semiconductor cell Ultrasonic gas leak

In case of F&G detection, ESD activation shall be automatic in accordance with an agreed philosophy. The decision to depressurize shall be based on a case-by-case analysis comparing benefits and drawbacks in having a manual depressurization following an automatic detection.

When adopting the location of F&G detectors, and the voting logic and subsequent actions, the following shall be taken into account:

a) type of facility;

b) location,

c) encountered hazards and vulnerability, in particular the number of people inside and outside the facility.

F&G detectors shall be located in such a way to maximize their efficiency.

5.4.5.1.6 Communications

Internal transmission networks shall differentiate operation information (of process control system) from safety information (of safety control system). Internal transmission networks shall be made secure from external communication networks. No direct interface is recommended for manned plants.

Different and segregated means of communication shall be implemented on the facility to ensure redundancy.

The facility should be provided with telecommunication systems which include:

a) VHF radio — for general facility communications, communication with lifeboat/fast rescue craft and with others vessels as per Chapter 4 of the SOLAS Code;

b) CCTV monitoring (from the CCR) — for general control of process, safety and security monitoring;

c) telephones — general communication on facility plus lines to shore;

d) aeronautical radios — for helicopter landing/take-off operations;

e) telecommunication to shore via satellite;

f) fibre optic systems (e.g. for DCS overview from remote location).

An integrated PAGA system shall be provided for the broadcast of information throughout the facility (speech and/or alarms), including onshore part (if any), topsides (all decks), turret (if any), LQ and machinery spaces. Where the noise level is high, visual alarms (i.e. stroboscopic beacons) shall be used in replacement of PA system.

5.4.5.2 Passive measures

5.4.5.2.1 Layout philosophy

The layout shall be arranged so that sources of flammable products are segregated from sources of ignition and from non-hazardous areas as far as practicable. The location of each system shall be graded with respect to the nature of the hazard as in the following:

a) systems which have the potential to release flammable products;

b) systems which are possible sources of ignition;

c) systems which are considered non-hazardous;

d) systems which are located in a non-hazardous area.

e) the mooring location of the visiting carriers (e.g. LNG carriers, LPG carriers or condensate carriers) when moored to the floating LNG installation.

When developing the layout configuration, the following main risk parameters shall be taken into account:

a) The nature of hazards associated with the different materials processed, such as flammable gas heavier or lighter than air, LPGs, cryogenic fluids, condensates:

  — process units that contain large quantities of flammable fluids shall preferably be located so that the prevailing wind will blow any vapour from an accidental spill away from the vulnerable areas such as permanently manned areas, the safe areas, air intakes, and ignition sources;

  — utilities shall be used as much as possible as a "buffer" between hazardous products-handling areas and vulnerable areas.

b) The potential for escalation from the different areas, through gas dispersion and explosion, liquid release cascading or spreading to other adjacent modules/onshore units, fire impingement, etc.:

  — congestion, as far as practicable, shall be minimized to reduce the potential for blast;

  — separation (also called safety gaps) or passive protection between items with potential for flammable fluids leak and ignition sources shall be provided;

  — passive protections, such as fire walls and blast walls, shall be considered where distances/orientation cannot be optimized and to prevent escalation;

  — separation shall be provided between hydrocarbon-handling areas and emergency services, main safety equipment, and should be provided between hydrocarbon-handling areas and non-hazardous areas;

  — open flames shall be located upwind/crosswind restricted areas, as far as practicable;

  — hydrocarbon shall not be stored below the LQ, as far as practicable;

  — the main storage capacities (e.g. LNG, LPG, refrigerant, condensate) should be located within the hull to minimize topsides inventories;

c) The wind rose, in particular the prevailing wind if the facility is not weathervaning, and the weather conditions, in particular the wind speeds:

  — combustion equipment outlets and vent locations shall be considered with regard to potential gas dispersion and ignition sources;

  — all engines and enclosed areas, buildings air intake locations, including emergency diesel generator, LQ, secondary refuge (if any), shall be positioned taking into account prevailing wind directions;

— adequate arrangements shall provide access to the facilities, escape toward the muster areas and evacuation from the facilities.

Additional topics that are worth investigating are included in Clause A.5.

In any case, the adequacy of layout arrangement and spacing shall be verified during project phases with respect to the risk levels acceptable for the owner through:

a) reviews to be organized at early project stage and the following involving representatives from the main disciplines (e.g. piping, HSE, process, civil, structure, naval architecture);

b) adequate studies (see 5.4.3 and Annex B).

NOTE Applicable local regulations might exist.

5.4.5.2.2 Equipment and piping design

Collapse of equipment and piping can release significant liquid and gas inventories leading to major accidental events, in particular when flammable and/or toxic fluids are involved. Design pressures and temperatures of piping and equipment shall be selected to cover all anticipated towing (if any), start-up, shutdown, normal operation and upset conditions.

All external constraints that can affect equipment and piping shall be considered when designing them (see Clause 4 for details).

5.4.5.2.3 Passive fire protection

Passive fire protection is intended to increase the facility survivability in the event of a fire (if ignition of the flammable release), and to reduce the effect of such fire on process equipment, structural systems, safety systems and other critical aspects of the facility.

By providing a protection for a limited period of time, the main objectives of the passive fireproofing protection are to:

— prevent the escalation of fires to an unacceptable level;

— maintain the integrity of the modules/onshore units processing hydrocarbons for the duration of credible fires to protect against the risk of escalation on the facility;

— maintain the integrity of hull/substructure, machinery spaces (if necessary), LQs and helideck (if necessary);

— ensure the survivability and availability of critical process equipment and associated structures during a fire event;

— maintain the integrity of any critical buildings or enclosure (i.e. manned buildings and/or which include safety systems);

— maintain the integrity of escape and evacuation means if necessary (e.g. lifeboats and embarkation areas).

The type and duration of protection to ensure the survivability of safety and environmental barriers in case of fire is defined as the combination between their intrinsic resistance, the type of event they could be exposed to, their exposure duration to fires and the time during which these elements shall remain functional (e.g. time required for safe evacuation, time required for depressurization). Fireproofing of safety and environmental barriers can be applied, if necessary, to reach this objective of survivability.

FRA or fire part of QRA results are used to provide type and duration of protection for onshore and topsides areas (see Annex A for details).

Prescriptive fire partitioning requirement are provided in IMO standards for the hull, the LQ or within buildings and to these requirements shall be referred in a first approach.

The selection of the adequate passive fire protection material shall take into account the ISO 22899 series for jet fires and the ISO 834 series for hydrocarbon fire resistance tests. Survivability of material should not be limited to fire event; other accident event as blast event should be evaluated, if necessary with respect to blast events.

5.4.5.2.4 Ignition control

5.4.5.2.4.1 Methodology

The purpose of ignition control is to avoid ignition of flammable/combustible releases, which invariably occur in the operation of facilities handling flammable/combustible liquids and gases. The approach is to reduce the probability of coincidence of a flammable atmosphere and an electrical or other source of ignition to an acceptable level.

This goal is achieved by implementing the following methodology:

a) classification of hazardous areas, i.e. identification of areas where flammable gas clouds are likely to occur;

b) identification of potential ignition sources throughout the facility;

c) design selection of ignition sources depending on their location in hazardous or non-hazardous areas;

d) additional considerations.

The implementation of this methodology provides the means to:

— ensure that sources of ignition are segregated from sources of flammable gas in accordance with applicable code;

— perform the correct selection of instruments and electrical apparatus to be installed in areas according to their degree of hazardous area classification;

— select the location of ventilation and combustion air inlets for combustion equipment and buildings (e.g. LQ, machinery spaces, buildings);

— select the routing and/or ensure adequate insulation of hot surfaces (e.g. steam lines, exhausts of combustion equipment);

— ensure adequate electrical isolation philosophy or provide correct selection of equipment according to the hazardous area classification requirement.

In order to ensure that the ignition risk is minimized as far as practicable, an ignition source management philosophy covering the points above shall be developed at early project phase and maintained throughout the project development.

5.4.5.2.4.2 Hazardous area classifications

The classification of hazardous areas only consider events for which the probability of occurrence is significant enough to be described as “liable to occur during normal or abnormal plant operation conditions”. This does not apply to catastrophic failures.

The topside areas shall be classified in accordance with internationally recognized standards, such as API RP 505 or EIP15. The hull spaces shall be classified in accordance with IEC 60092-502. Both codes shall be considered for the interdeck space with the most stringent being used in case of discrepancy.

All facilities shall be subjected to a hazardous area analysis. The terms of reference for such analysis shall be laid down in accordance with EN 1127-1 and IEC 60079-10. The form and the extent of each zone may differ slightly depending on the national or professional code used, but shall be in line with the methodology set forward in IEC 60079-10. In addition, ISO 28460 can be considered for the jetty, particularly for the hazardous zones generated when the LNG ship is alongside.

On offshore installations, all equipment (hazardous and non-hazardous) might be located close to each other due to the limited space available. Any accidental and significant flammable gas/liquid release can quickly reach the non-hazardous areas. Subsequently, it is typical to minimize ignition risk by imposing that all equipment located outdoor on hull deck and topsides are suitable for use in Zone 2 hazardous area as a minimum gas group IIA, temperature class T3, even if located in an area which is not classified as hazardous.

On confirmed gas detection, most equipment (electrical and non-electrical) should be shutdown to reduce ignition risks. All electrical equipment and instruments located in open areas and maintained energized in an emergency situation (mainly flammable gas/liquid release) should be suitable for use in Zone 1 (e.g. F&G detection devices, emergency lighting) in accordance with IEC 61892-7. For items which cannot be certified for use in Zone 1 and that need to be kept energized, others mitigation means should be proposed on a case-by-case basis.

The aforementioned provisions are applicable to both onshore and offshore parts of the floating LNG installation.

Whatever the project configuration and in order to find the most appropriate solution, a risk analysis should be performed to maximize the safety of installation with respect to ignition sources through:

a) A layout review with focus on:

   — the wind rose;

   — the location of strong ignition sources (e.g. flare, combustion equipment);

   — the location of vulnerable areas (e.g. accommodations, administrative areas);

   — the location of fences and public.

b) The development of a consistent F&G detection philosophy with focus on:

   — outside areas;

   — inside areas, such as buildings, accommodations, administrative areas, machinery spaces;

   — actions in case of confirmed gas detection depending on the set points.

5.4.5.2.4.3 Potential ignition sources identification

In order to determine the explosion risk level associated to each hazardous area, the residual sources of ignition as well as their probability of occurrence should be assessed. For all pieces of equipment, it shall be checked whether their integration on the floating LNG installation generates residual sources of ignition.

Ignition sources can be of different categories. As guidance, the various ignition sources may be classified as per the categories listed in ISO 80079-36:

— hot surfaces;

— flames and hot gases;

— mechanically generated sparks;

— electrical apparatus;

— stray electric currents, cathodic corrosion protection;

— static electricity;

— lightning;

— radio frequency (RF) electromagnetic waves from 10^4 Hz to 3×10^{12} Hz;

— electromagnetic waves from 3×10^{11} Hz to 3×10^{15} Hz;

— ionising radiation;

— ultrasonics;

— adiabatic compression and shock waves;

— exothermic reactions, including self-ignition of dusts.

In order to select the appropriate design, it shall be identified which of the 13 types of ignition sources will be encountered on the floating LNG installation.

5.4.5.2.4.4 Ignition sources design selection

Once the ignition sources are identified, a description shall be made of the different preventive and mitigation measures (e.g. appropriate location of ignition source outside hazardous areas) that are applied in the design in order to avoid the ignition of a flammable gas cloud.

Equipment installed on the facility that are not suitable for Zone 1 and/or Zone 2 (e.g. some telecommunication equipment) shall be located outside hazardous areas. Depending on their final location with respect to hazardous areas, they may be linked to gas detectors installed in the vicinity and forced to shut down or reduce their power on confirmed detection.

The selection of equipment for use in particular locations shall be determined from the hazardous area classification of these locations in accordance with the IEC 60079 series, the ISO/IEC 80079 series and the applicable classification rules.

Electrical equipment/instrumentation installed in a hazardous area shall be either:

— intrinsically safe;

— designed for the appropriate hazardous area classification; or

— installed in an enclosure which is designed for the appropriate hazardous area classification.

All electrical equipment/instrumentation installed in hazardous area shall:

a) comply with the requirements of the IEC 60079 series;

b) demonstrate conformity to IEC standards (e.g. be IEC-Ex certified).

NOTE 1 Requirements of the European Directive 2014/34/EU (ATEX) can be used as a guidance.

All mechanical (non-electrical) equipment installed in hazardous area shall:

a) conform with ISO 80079-36 and ISO 80079-37;

b) demonstrate conformity to IEC standards (e.g. be IEC-Ex certified);

NOTE 2 Requirements of the European Directive 2014/34/EU (ATEX) can be used as a guidance.

c) be non-sparking and adequately protected against the generation of electrostatic charge.

All internal combustion engines to be installed in hazardous area shall be specified with suitable protections (e.g. protections for air intakes and flue gas discharges, automatic trip of the engine in case of over speed, dampers and fuel supply closed on confirmed gas detection at air intakes).

All exhausts from combustion equipment shall be regarded as ignition sources. They shall terminate outside of any hazardous areas and exhaust stack shall be insulated, if necessary.

The maximum surface temperature of any equipment/lines/exhausts located in a hazardous area, under normal operating and abnormal conditions, shall not exceed the temperature class of the designated hazardous area.

Earthing and lightning protection systems shall be provided to minimize potential ignition due to electrical faults, static charges, stay currents and lightning discharges (see relevant subclause in Clause 12).

5.4.5.2.4.5 Ventilation and pressurization

To minimize the classification of a hazardous area, adequate ventilation is necessary. In unrestricted open areas, natural airflow is sufficient to be considered adequately ventilated regarding area classification codes requirements.

For any enclosed areas in which flammable hydrocarbon processing equipment is to be installed, the specific ventilation requirements defined by international codes and standards shall be applied. Examples of relevant standards are SOLAS, IEC 60079-13, API RP 505 or EIP15.

As minimum a forced ventilation system in accordance with IEC 60079-13 shall be applied to:

a) enclosed hazardous areas where flammable gas accumulation can occur;

b) enclosed non-hazardous areas adjacent to open hazardous areas;

c) areas/rooms which are required to be operational during an emergency;

d) accommodation and temporary refuge needed to ensure comfortable environment for personnel and suitable conditions for operating equipment.

5.4.5.2.5 Drainage systems

Accidental release of cryogenic and non-cryogenic material should be addressed in a spill handling philosophy. The spill handling philosophy should ensure that:

a) spill likelihood is minimized by minimizing potential leak points (e.g. flanges);

b) leakages are handled in a controlled way.

Drainage systems shall be provided to convey drainages from all the facilities (topsides, hull and transfer systems) and systems to treatment, recovery or disposal facilities. Drainage systems shall be designed to:

a) prevent connection between different drainage systems;

b) safely dispose hydrocarbons during drain-down of process vessels and equipment;

c) contain any spillage of flammable or pollutant liquids;

d) minimize the spread and area exposure of spills and fires to prevent escalation of an accidental event;

e) collect direct spills to a safe location, where spills can be retained and either recovered or disposed if possible;

f) prevent backflow and fire spread through the system;

g) minimize any possible impact on the environment caused by accidental spills.

The following types of drainage systems shall be provided and can be classified, if applicable, in two main categories, open or closed drains systems:

a) hazardous hydrocarbon open drains: from drip pans and gutters of equipment installed in classified areas and drains from points with frequent oil drainage in classified areas, such as sampling points, transfer pump skids, pig launcher and receiver skids;

b) hazardous cryogenic hydrocarbon open drains: from drip pans (if any) and gutters of cryogenic equipment installed in classified areas;

c) non-hazardous open drains: from workshops, and/or from drip pans and gutters of equipment installed in non-classified areas;

d) hydrocarbon closed drains system: from topsides/onshore systems in wet and warm service;

e) cryogenic closed drain: from topsides/onshore systems in dry and cold services.

The purpose of the open drains is to collect and convey residual process and wash-down fluids, rain water and firewater/foam of protected equipment to an appropriate disposal system in such a way to protect personnel, plant and equipment, and to avoid environmental hydrocarbon contamination.

The design of open drains shall prevent gas and fire to be propagated through the system. In particular, drainage piping crossing two independent escalation zones should be avoided.

A cryogenic spill collection system shall be provided on the facilities, based on the identification and the assessment of the hazards associated with LNG, LPG or hazardous refrigerant spill that can occur from the different LNG, LPG or hazardous refrigerant handling equipment of the facilities:

a) In general, smaller spills may be collected locally in drip trays of suitable material (e.g. stainless steel) and are allowed to evaporate.

b) It should be assessed what the largest collected volume could be with regard to potential fire scenarios, gas dispersion scenarios, ship motion, permitted height of deck bunding for water drainage, etc.

c) Where the cryogenic spill can be of high pressure (e.g. upstream of regasification units at high pressure), spray guards should be considered at potential leak sources.

Depending on the considered inventories, specific collection systems may also be considered to segregate spillage contaminated with water soluble chemicals (e.g. glycol, amine), which can require special treatment.

The real physics of the cryogenic spill shall be identified and applied in developing the design solutions for the cryogenic spill control system. The following design solutions are provided:

— Onshore (impounding basin)

  The extent of the impounding basins and spillage collection channel for LNG and hydrocarbon pipe-systems and equipment shall be evaluated. In general it has been found that the collection of spill from interconnecting LNG and hydrocarbons piping, without branch, flanges or instrument connections, is not justified by hazard assessment.

  If required, it shall be designed to accommodate potential leaks that will be identified in the hazard assessment.

  Possible LNG and hydrocarbon spills should be drained into impounding basins, with foam generators or other measures for improved evaporation control.

  Provisions for water recovery shall be applied.

— Offshore and nearshore

Disposal overboard should be considered where larger inventories of cryogenic material are present.

As a first approach, direct discharge overboard in front of each module and areas where larger volumes of cryogenic fluid can leak is proposed, considering specific attention shall be given to the specific areas as LNG transfer areas liquefaction or regasification units and areas where carriers may moor (if any). Specific systems or protections may be implemented to protect the critical element which can be submitted to embrittlement if proven necessary.

EXAMPLE Water curtains can be considered to avoid damage to the hull of the floating installation in areas where cryogenic fluid is disposed of over the side.

In any case, a qualitative review of the various solutions that can be implemented to ensure control and/or safe disposal of the cryogenic releases shall be performed to find the most suitable solution adapted to the installation characteristics.

For protection of areas that can be exposed to cryogenic releases, see 5.4.5.2.6.

5.4.5.2.6 Cold spill protection

The main objectives and overall philosophy of the cryogenic protection are to:

— maintain the integrity of the topsides modules/onshore units and the hull deck for the duration of credible cryogenic liquid spillage and risk of embrittlement;

— maintain the integrity of all susceptible critical equipment and buildings required in case of cryogenic liquid spillage;

— reduce the risk of escalation on the facility;

— protect asset against catastrophic loss.

Refrigerated cryogenic liquids and gases exert an intense cooling effect when released. Such events can expose workers to cold burns while unprotected steel work can face the risk of embrittlement and subsequent fracture. In addition, if ignited then high thermal loading of exposed unprotected steel can lead to structural failure.

Cryogenic protection shall be provided where the effect of cold splash can occur, unless intrinsic resistance of the element is sufficient. In particular, deck areas with normal ship steel should be protected if spillage is possible by specification of low temperature steel or deck covering (e.g. specific cold spill protection material, wood or concrete).

Extent of protection time shall be optimized depending on the credible loss of containment scenarios, to be evaluated on an area-by-area basis (considering resistance of equipment and requirement for time of functionality) during risk analysis.

The cryogenic protection system shall be able to withstand the atmospheric boiling temperature of cryogenic fluids while the temperature of the underlying steel structure should not fall below the embrittlement temperature.

Cryogenic risk analysis results are used to provide type and duration of protection. The selection of the adequate cold spill protection material shall be made with in accordance with ISO 16903 and the ISO 20088 (series).

5.4.5.2.7 Explosion protection

The main objective and overall philosophy for explosion protection is the reduction of:

— the severity of the explosion (e.g. the overpressure effects);

— the risk of escalation on the facility in the event of credible and/or extreme explosion events.

Explosion risk analysis results are used to provide explosion loads.

Explosion protection is designed considering the following criteria:

a) ignition prevention;

b) design with limited congestion;

c) design with limited confinement;

d) implementation of vents/explosion relief panels to limit overpressure levels in buildings and close containments (if any);

e) optimize natural and/or mechanical ventilation;

f) implement suitable distances between vulnerable areas and high-risk process areas (e.g. safety gaps);

g) implement physical barriers (fire and blast walls to separate areas);

h) specifically design equipment against blast.

5.4.5.2.8 Protection against ship collision

Specific consideration shall be paid to design the facility against potential ship collision.

5.4.5.2.9 Protection against dropped objects

Specific consideration shall be paid to design the facility against potential dropped objects.

5.4.5.2.10 Environmental conditions

5.4.5.2.10.1 General

In order to ensure workers protection, several systems should be designed to withstand harsh environmental conditions. During the course of the project, these safety critical systems should be sorted out from the results of risk analysis and be designed accounting for the facility being on station as well as in towing mode.

5.4.5.2.10.2 Seismic protection

Specific events such as earthquakes shall be taken into account in the design with specific consideration for safety critical systems (see Clause 4 and Annex E).

5.4.5.2.10.3 Harsh weather conditions

As a main principle, safety critical systems to be kept operable during or after harsh weather conditions should be designed against 10 000 year return period (see Clause 4).

5.4.6 Emergency response

5.4.6.1 Escape, evacuation and rescue

The design of the EER facilities shall take into account the maximum POB, the expected manning distribution over the facility, the potential sources of hazards and the potential escalation scenarios.

The design intent of an EER system is to allow, in case of emergency situation, the escape of personnel from any place of the facility to a pre-determined muster area, the safe evacuation of all personnel on board and also the rescue of injured persons from any place of the facility. It typically comprises:

— escape routes;

— muster areas;

— temporary refuge/secondary refuges;

— evacuation means;

— rescue means;

— lifesaving equipment.

As a minimum, SOLAS requirements shall be implemented in the design and specific consideration with respect to the type of facility, the hazard location and vulnerability.

Each process and non-process area (whether outdoor or indoor) on the facility shall have at least two escape routes to the muster areas and to the evacuation point as a base case. Dead-ends shall not exceed 5 m. Deviations to the provisions of two escape routes as well as to the dead-end maximum length may be accepted for not normally manned spaces, where access is limited to few people for maintenance or occasional operations of short duration. Rooms in the hull may be considered as not normally manned where access is limited; in the same way, equipment top platforms may also be considered as accessed only in rare occasions. In any case, this is to be defined on a case-by-case basis depending on the project specificities (in particular the manning level and operating philosophy).

The design of the escape routes shall be such that, as minimum, one escape route to at least one muster area shall be available at all time, easily identified, and protected or segregated, as far as possible, from major hazards. The escape routes shall be marked in accordance with ISO 24409-1.

As a proposed value, all emergency devices required as part of EER process (e.g. emergency lighting, radio communications, PAGA), shall stay operational as minimum one hour until the safe evacuation of personnel is completed. Value may be revised depending on the results of the safety studies.

The POB shall be checked at each phase of the project. EER facilities shall be adapted to accommodate identified changes and maximum POB during normal operation at least.

For maintenance, construction, commissioning and decommissioning phases, the EER facilities might need to be adapted if not already designed for the maximum POB whatever the phase. Where needed, the implementation of additional EER facilities shall take into account the specific hazards and risks encountered during these phases.

Accommodations shall be considered as safe area from an EER perspective. Accommodations shall include the primary muster station.

The EER analysis shall be carried out to validate/confirm the adequacy of the EER facilities with respect to the identified emergency scenarios.

5.4.6.2 Coordination between parties involved

An emergency response plan shall be agreed between all parties including visiting LNGC or products carriers involved depending of type of operations.

Emergency check lists shall be prepared in accordance with applicable standards requirements (e.g. SOLAS, local authorities and owner rules).

5.5 Occupational health and industrial hygiene considerations

5.5.1 Occupational health and industrial hygiene aspects identification

Whatever the installation configuration, the following potential occupational health and industrial hygiene aspects shall be part of the design/procedures when developing the floating LNG installation:

a) chemical exposure;

b) biological factor;

c) legionella;

d) thermal stress;

e) hot/cold surfaces;

f) support function to operators;

g) lighting;

h) water quality and availability;

i) noise and vibration;

j) ergonomics and human factor.

5.5.2 Chemical exposure

5.5.2.1 Purpose

As regards the chemical exposure, it is necessary to:

a) define the toxic or lethal services which require specific design configuration (e.g. for vessel, rotating equipment, piping, valves) and hence limit workers' and public continuous exposure;

b) clarify the need for toxic gas detection associated with alarm and/or action.

5.5.2.2 Regulatory aspects

Regarding chemical exposure, two sets of limits apply:

a) one set of values inside working areas;

b) one set of values inside the LQ/accommodation for cases where workers are expected to spend long period of times by the facility.

5.5.2.3 Working areas

TLVs refer to airborne concentrations of chemical substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, over a working lifetime without adverse effects.

Generally, three categories of TLVs are specified:

— Threshold limit value time-weighted average: This concentration is given for a conventional 8-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, for a working lifetime without effect.

— Threshold limit value short-term exposure limit: This concentration is a 15-minute exposure that should not be exceeded at any time during a workday, even if the 8-hour TLV is respected.

— Threshold limit value ceiling: This concentration should not be exceeded during any part of the working exposure.

Workers are normally exposed to NOx, SO_2, PM, CO and BTEX during operations. In absence of local TLVs regarding worker exposure to chemical substances, it is recommended to apply TLVs from the ACGIH database.

The abovementioned limit values shall be adjusted taking into account:

a) The typical work hour schedules on board

In case of unusual work schedules (e.g. 12-hour shift), the TLVs shall be adjusted using mathematical models. Although several models have been recognized worldwide, the use of an easy model (e.g. Brief & Scala) is recommended, if national guidelines about this subject do not exist.

b) The toxicology combined effects

Most TLVs are developed for a single chemical substance. The work environment is often composed of multiple chemical exposure. In consequence, when two or more hazardous substances have a similar toxicological effect on the same target organ or system, their combined effect, rather than that of either individually, should be given primary consideration. The following condition shall be respected:

$$\sum_{i=1}^{n} \frac{Ci}{Ti} \leq 1$$

where

C indicates the observed atmospheric concentration;

T is the corresponding threshold limit.

If the sum exceeds unity (1), the threshold limit of the mixture should be considered as being exceeded.

5.5.2.4 Living quarters/Accommodations

For floating LNG installation that can be located a long way from shore and on which workers will be aboard for long periods of time, an additional set of values adapted to extended exposure shall apply. For nearshore and onshore installations, these sets of values shall also apply, if workers are expected to live by the facility.

TLVs set to protect people from adverse effects which can result from extended exposure apply, these TLVs are more stringent that those relating to working areas as the exposure may be for a longer period of time (24 hour as opposed to 8-12 hour shift).

Workers are normally exposed to NOx, SO_2, PM, CO and BTEX during operations. In absence of local TLVs regarding worker exposure to chemical substances in LQ, it is recommended to apply WHO Ambient Air Quality Guidelines.

NOTE Alternatively, the Europeans Directives 96/62/EC on ambient air quality assessment and management and 2004/107/EC relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air can be applied.

5.5.3 Biological factor

Biological factor is directly linked with project geographical location and should be subject to stringent and specific design requirements. As minimum, biological agents of Group 3 (i.e. Escherichia coli, verocytotoxigenic strains) as per approved list of biological agents (Advisory Committee on Dangerous Pathogens, HSE Book) are presented in this subclause for the following areas:

— the infirmary;

— the biological water treatment unit;

— the waste temporary storage area;

— the canteen;

— the sanitary facilities.

By consequence, work in these areas should be restricted only to those persons who have received specific verifiable training in working with and controlling such materials.

Areas used for handling of biological agents of Group 3 should be designed to enable their full segregation and isolation in emergency circumstances, include dependent ventilation systems and be subject to require routine disinfection and sterilization of the work surfaces.

HVAC systems serving areas handling biological agents of Group 3 should be equipped with high efficiency particulate air filtration systems. Equipment should readily enable their disinfection and sterilization, and maintained and operated so as to prevent growth and spreading of disease agents, amplification of the biological agents.

5.5.4 Legionella

Legionella bacteria can infect alveolar human macrophages upon inhalation, subverting the normal host cell machinery to create a niche where the bacteria can replicate.

NOTE At the present time, it has been proven that Legionnaires' disease and its lesser form Pontiac fever transmission is airborne via respiratory droplets containing the bacteria. Person-to-person transmission of Legionella has not been demonstrated.

The potential risk of legionella development on project site is associated with water supply network (e.g. piping and storage tanks) and wet cooling tower. Annex G provides details on prevention measures.

5.5.5 Thermal stress

5.5.5.1 Cold stress

Cold stress factors are intended to protect workers from the severest effects of cold stress (hypothermia) and cold injury. Cold stress factors describe exposures to cold working conditions under which it is believed nearly all workers can be repeatedly exposed without adverse health effects.

Cold stress factors are generally defined by national or local regulations. In absence of such factors, the floating LNG installation project design may use the cold stress factors defined in the ACGIH Publications to design working areas and/or to plan working operations.

5.5.5.2 Heat stress

Heat stress is the net heat load to which a worker may be exposed from the combined contributions of metabolic cost of work, environmental factors (i.e. air temperature, humidity, air movement, and radiant heat exchange) and clothing requirements. A mild or moderate heat stress can cause discomfort and can adversely affect performance and safety, but is not harmful to the health. When the heat stress approaches human tolerance limits, the risk of heat-related disorders increases.

The heat stress factors depend on work category and on local work habits (e.g. thermal criteria took into account worker acclimatization state, metabolic rate for the work, and work duration). Heat stress factors are generally defined by national or local authorities. In absence of such factors, the floating LNG installation project design may use the heat stress exposure defined in the ACGIH Publications or the index degree of comfort developed by Canadian Meteorologists “The Humiditex” to design working areas and/or working operations.

5.5.6 Hot/cold surfaces

For floating LNG installation projects, surfaces with a temperature above 60 °C or below −10 °C shall not be reached from work areas, walkways, ladders, stairs or other passageways. In cases temperatures are outside this range, personnel protection (e.g. thermal insulation or a physical barrier/handrail with warning signs) shall be provided.

In addition to the temperature of the surface, cold or hot skin injuries also depend on other factors including but not limited:

— the material of the surface;

— the period of contact between the skin and the surface;

— the structure of the surface;

— the sensitivity of the human being who comes into contact with the surface.

NOTE Other factors can also play a role but are of minor importance.

It is recommended to apply ISO 13732 (parts 1, 2 and 3), which defines the temperature limit values for hot surfaces and the safe time limits for hand/finger contact with various cold surfaces.

5.5.7 Support functions to operators - Project with permanent operators on-board or in the facility

Floating LNG installation with permanent operators on-board shall be fitted with LQ/accommodation including all support functions necessary to accommodate and cater them (e.g. cabins/room, kitchen, provision stores, dining room, lounges, exercise rooms, laundry, administration area, changing rooms, medical centre, sky lobby, technical rooms, lay-down deck).

The LQ/accommodation shall be dimensioned, designed and equipped for the maximum number of personnel required at any time during the field’s various operational phases. Requirements for the architectural design, engineering and development of the LQ/accommodation shall be in accordance with IMO rules.

NOTE National or local regulations might apply.

NORSOK C-001 and NORSOK C-002 can be used as a guidance for LQ. Additional guidance is provided in G.2.2.

Floating LNG installation without permanent operators present in the facility (e.g. floatel or onshore accommodation for offshore units and outside accommodation for onshore parts of the facility) shall be fitted with all support functions necessary to operator well-being during their shift period (e.g. lounge rooms, changing rooms, toilets, medical centre, canteen).

The LQ/accommodation shall be dimensioned, designed and equipped for the maximum number of personnel required at any time during the field’s various operational phases.

Additional guidance is provided in G.2.2.

5.5.8 Lighting

Floating LNG installation projects shall be fitted with the following three illumination systems:

a) normal operation lighting level;

b) emergency lighting level;

c) escape lighting level.

Project electrical philosophy shall provide an accurate definition of the lighting level per type of areas (indoor/outdoor) and per type of activities achieved in the area (e.g. non-working areas, workspace with occasional visual tasks only, medium precision work, precision work, high precision work) in accordance with IEC 61892-2 and the safety-related lighting requirements of the classification society and marine rules.

During the night, systematic lighting associated to normal operation lighting shall be avoided. Active working areas shall be enlightened only. Zones without activity shall be switched off. Measures to limit offshore lighting impact in the vicinity (e.g. non-reflective painting, illumination angle) should be selected.

5.5.9 Water availability and quality intended for human consumption

5.5.9.1 Water availability

Every person daily needs 20 litres to 50 litres of water not containing either dangerous chemicals or microbial contaminants according to WHO. As the operators on-board have a physical activity, water availability of around 100 litres per person per day should be adhered.

5.5.9.2 Water quality

Quality of water intended for human consumption (included water used for shower) shall at least conform with Guidelines for drinking water quality of the World Health Organization (WHO).

If the local piped water supply does not meet the minimum drinking water quality standards, water shall be purified before consumption. If it is not possible to provide pure, piped potable water, either for logistical or economic reasons, bottled water shall be obtained from a commercial source. Commercial suppliers shall be able to demonstrate to meet minimum drinking water quality standards.

5.5.10 Noise and vibration

5.5.10.1 Purpose of noise and vibration control

The noise and vibration control shall be developed in accordance with the relevant standards (see 5.5.10.3).

NOTE Applicable regulations might exist.

The control of noise is necessary for the following reasons:

— prevention of noise-induced hearing loss;

— reduction of work, speech and concentration interference;

— provision of quiet LQ/accommodation for personnel in sleeping and recreation areas;

— ensuring that the PAGA system is clearly audible and intelligible.

The control of vibrations is necessary in order to take into account the following aspects:

— HSE aspect (human beings subjected to vibrations) by:

  — ensuring that acceptable conditions are provided for all working activities on general working areas;

  - — preventing risk of injury to operators from vibrations solicitation close to vibrating equipment areas.
- — Mechanical aspect by:
  - — evaluating the level of vibration induced by equipment;
  - — defining the minimal dynamic stiffness of the structure;
  - — minimizing vibration levels on equipment to guarantee its long-life service.
- — Noise aspect by evaluating the structure-borne noise generated in technical buildings by vibrations of equipment.

5.5.10.2 Noise and vibration control work process

The following steps shall be followed to ensure the control of the noise and vibration level on the facility:

Step 1 - Define the maximum noise and vibration limits a human may be exposed to with and without protective measures associated with exposure duration

NOTE Applicable national or local regulations might exist.

Step 2 - List the noisy and/or vibrating equipment present on the facility.

Step 3 - Define the noise and vibration limits for the listed items before vendors' consultation.

Step 4 - Define the maximum noise and vibration limits a human may be exposed to with and without protective measures associated with exposure duration according to information provided by the vendors.

Step 5 - Perform the noise and vibration studies to anticipate future noise and vibration levels on the facility. The studies shall be carried out for:

- — normal condition: services required allowing normal operation for full production;
- — emergency condition: services required maintaining critical and vital equipment and allowing safe shutdown of the floating LNG installation.

Step 6 - Investigate mitigation measures if results show a non-conformance with defined limits. Measures can focus on:

- — equipment to reduce noise/vibration levels at source by:
  - — modification of equipment;
  - — addition of enclosures/acoustic blankets around equipment;
  - — addition of silencers;
  - — addition of acoustic insulation around pipes and piping fittings;
- — the area to reduce overall noise/vibration level in the area by:
  - — consideration of noise/vibration issues when developing the layout;
  - — installation of acoustic panels, curtains or equivalent;
  - — installation of anti-vibration devices to limit the vibration transfer from vibrating equipment to people and other items (surrounding structures in particular);
- — workers by:
  - — defining restricted area to limit workers' exposition;

— procedural and organisational means to limit duration of exposure;

— supplying protective devices.

Step 7 - Perform noise and vibration tests during equipment manufacturing to anticipate any issue.

Step 8 - Perform noise and vibration measures on side once the facility is operating to confirm the modelling, check the conformance with the limits, check efficiency of installed measures and/or investigate additional mitigation measures.

5.5.10.3 Applicable standards

A wide range of national or local regulations and international codes and standards can be applied to noise and vibration. International codes and standards such as World Bank Standards, IMO (MSC.337(91)), can provide applicable values. ISO standards such as ISO 1999, ISO 2631-1, ISO 2923, ISO 10816, ISO 15665 and ISO 20283, provide details on noise and vibration calculation methods as well as on measurements methods.

5.6 Ergonomics and human factor

Human engineering (ergonomics) is defined in ASTM F 1166 as scientific discipline concerned with the understanding of interactions among humans and other elements of a system and the profession that applies theory, principles, data, and methods to design to optimize human well-being and overall system performance.

For implementation on the floating LNG installation, ASTM F 1166 can be applied for ergonomic design criteria from a human-machine perspective for the design and construction of maritime vessels and structures and for equipment, systems, and subsystems contained therein, including vendor-purchased hardware and software.

6 Mooring and stationkeeping

6.1 General

The purpose of mooring and stationkeeping systems is the provision of reliable means to keep floating LNG installations on the desired location, with optimum operability and sufficient margin of safety.

The stationkeeping system shall be designed in such a way that the overall movements of the floating LNG installation remain within the limitations imposed by the fluid transfer system that connects the installation with earth-bound fluid conducts (seabed wellheads or pipelines, or jetty-bound pipelines, depending on the configuration). Ship-to-ship moorings will have to limit the relative movements between two vessels to remain within the envelope of allowable motions between the two ends of the fluid transfer system that connects the vessels.

The design of mooring and stationkeeping systems will depend on the type and the intended function of the system being considered.

The floating LNG installation can be moored in open waters or at a nearshore/inshore location. As described in 4.2.6.2 and 4.2.6.3, respectively, these two situations have each their typical set of design conditions. A floating LNG installation, whether an FSRU, an FLNG or an FSU, will generally be kept on station permanently for the full project life (permanent mooring).

The design requirements for mooring in open water are specified in 6.2 and for mooring in nearshore/inshore locations in 6.3.

The project location can be subject to certain adverse environmental events, such as iceberg impact or hurricanes, which would make a stationkeeping system design based on the principle that the floating LNG installation leaves the site in advance of the adverse event (disconnectable mooring) economically advantageous. When this concept is applied, the design of the disconnectable mooring as well as the applicable operational procedures shall ensure a timely and safe operation.

The design criteria for disconnectable moorings are described in 4.2.6.3. Further design requirements are specified in 6.4. The design requirements for permanent moorings with a limited design life are also specified in 6.4.

The design requirements for the mooring of an LNGC to a floating LNG installation are specified in 6.5. The design conditions for this mooring situation are described in 4.2.6.4.

6.2 Permanent stationkeeping in open waters

6.2.1 Stationkeeping concepts

6.2.1.1 Turret mooring

For the permanent mooring of a floating LNG installation in open waters, where the action of waves, wind and current can approach the mooring location from variable directions, the SPM concept is most suitable. An SPM allows the vessel to weathervane, so that the combined loading imposed by the environmental conditions is minimum.

A commonly applied type of SPM system is the so-called turret mooring. Turrets are generally cylindrical structures, which either penetrate the bow of the vessel (internal turret) or which remain external with respect to the hull (external turret).

The cylindrical turret structure is anchored to the seabed by a pattern of anchor lines, and the vessel can weathervane around it, via a structural bearing system. The bearing support structure is structurally integrated with the hull of the floating LNG installation (internal turret), or with a support structure protruding from the bow of the vessel (external turret).

Flexible risers connect the turret structure with the seabed infrastructure (well heads, pipeline end manifolds, or similar). Fluid/gas swivels are used to bridge the bearing system in order to connect the fluid/gas transfer piping on the weathervaning floating LNG installation with the piping in the turret structure, of which the orientation remains earth-bound.

6.2.1.2 Other SPM concepts

Turrets are currently the most commonly apply stationkeeping concept. Various other SPM systems have been used in offshore oil and gas projects and would be feasible also for the permanent stationkeeping of floating LNG installations in open waters.

The so-called tower-soft-yoke system is an example of a suitable solution for relatively shallow water. In this concept, a bottom-founded jacket type structure carries a mechanical bearing system and swivels on top, to which the floating LNG installation is connected through a usually triangular structural arm. The arm is suspended from the vessel through pendulum bars. The arrangement of vessel plus arm can weathervane around the centre of the jacket type structure under the influence of waves, wind and current.

6.2.1.3 Spread mooring

For the permanent mooring of a floating LNG installation in open waters, where the action of waves, wind and current is strongly directional (locations with a distinct prevailing direction for wind, waves and current), a spread mooring system can be feasible. In this case, the floating LNG installation is moored in between a spread of anchoring lines that provides adequate stationkeeping capacity for the floating LNG installation at its intended location. Different from an SPM, a spread mooring keeps the vessel at a constant average heading. A mechanical bearing system is therefore not required. Also no swivels are needed, since fluid/gas risers can be attached directly to the floating installation, usually to a so-called riser balcony at the side of the vessel.

The berthing of an LNGC alongside a spread moored floating LNG installation, for either loading or unloading LNG in a ship-to-ship configuration, is compromised by the anchoring lines of spread mooring. The applicability of a spread mooring therefore depends on a reliable LNG transfer system between the floating LNG installation and an LNGC moored in tandem behind the floating installation. Such transfer systems are presently under development, so that no requirements can be specified in this document.

6.2.1.4 Dynamic positioning

Dynamic positioning for the permanent stationkeeping of a floating LNG installation has not been proposed at date of publication of this document. Therefore, this document does not provide guidance for this solution.

Dynamic positioning may be applied for an LNGC that has to maintain station in the vicinity of a permanently moored FLNG to take-off produced LNG or in the vicinity of an FSRU to unload LNG cargo through flexible transfer systems. The dynamic positioning requirements to the LNGC are not covered by this document.

6.2.2 Design requirements

The design of the stationkeeping system of a floating LNG installation in open waters shall be in accordance with ISO 19901-7 for the stationkeeping system and ISO 19904-1 for the integration of the stationkeeping system with the vessel.

Dynamic analysis of the behaviour of the moored floating LNG installation and its stationkeeping system in the specified design conditions is reasonably well understood, and several recognized software packages are available to the designer. Requirements are specified in ISO 19901-7.

As stated in 4.2.6.2, the design shall take into account that the stationkeeping system accepts the loads incurred by the combination of the floating LNG installation with an LNGC moored to it, in the maximum environmental conditions in which loading or offloading of an LNGC is permitted. The fluid transfer and mooring of the LNGC are addressed in 6.5.

6.3 Permanent stationkeeping in nearshore or docked conditions

6.3.1 Stationkeeping concepts

6.3.1.1 Quayside or jetty mooring

When the desired permanent location of a floating LNG installation is nearshore or in docked conditions, the stationkeeping capacity can be provided by mooring to a quay or to a jetty.

Special structures that are built for the purpose of the mooring at the quayside, or jetty structures and facilities (if applicable) are part of the stationkeeping design and shall be subjected to the design criteria for the floating LNG installation (see 4.2.6.3).

When a floating LNG installation (FLNG or FSRU) is moored to a jetty, a second vessel can be moored to the same jetty. Depending on the overall configuration of the LNG facility, it can be an FSU (also permanently moored) or an LNGC (only moored for the short duration of LNG loading or unloading).

Also configurations are possible in which a floating LNG installation is moored against a jetty, while a second vessel is moored in a side-by-side situation at the other side of the floating LNG installation. This second vessel can be an FSU (also permanently moored) or an LNGC (only moored for the short duration of LNG loading or unloading).

The most common mooring configuration for the mooring in docked conditions or to a jetty is through the use of mooring lines, which tie the floating LNG installation to a quayside or a jetty. Spring lines restrain the longitudinal movements (surge) of the vessel along the quay/jetty, breasting lines are used to reduce lateral movements (sway and/or yaw) of the vessel, away from quay or jetty. Fenders are applied to absorb shock loads when the vessel approaches the quay or jetty.

The system of mooring lines shall be sufficiently compliant to accommodate variations in water level or draft of the vessel. The mooring lines are tied to strong points at the quayside or jetty, which may be built as dolphins, i.e. mooring points independent from the structure of quay or jetty.

Similar arrangement of mooring components is applied for ship-to-ship moorings, if a second vessel is moored alongside the floating LNG installation, which itself is moored to the quay or jetty.

In benign environmental conditions, a mooring system based on piles could be potentially feasible, as alternative to the use of mooring lines. The floating LNG installation shall be connected to the piles in such a way that draft and/or water level variations can be accommodated.

Fluid/gas transfer between the floating LNG installation and earth-bound structures (quayside or jetty) takes place via loading arms or flexible lines. The same applies for the fluid/gas transfer between a floating LNG installation and a potentially permanently moored second vessel along the side (FSU).

The design of the jetty infrastructure is discussed in 6.6.

6.3.1.2 Tower-soft-yoke mooring

If the local situation permits, and a weathervaning configuration is feasible and economically favoured, a tower-soft-yoke mooring can also be applied nearshore (see 6.2.1.2).

6.3.1.3 Spread mooring

Nearshore a spread mooring can be applied (see 6.2.1.3).

The spread mooring concept, in which the floating LNG installation is kept on station by a pattern of catenary anchor lines, has its limitations when the water depth is small. In benign metocean conditions, a spread mooring can be feasible. Similarly to the situation in open waters as described in 6.2.1.3, the transfer of LNG to or from the installation requires novel designs that are under development at the date of publication of this document. Therefore, this document does not specify design requirements.

6.3.2 Design requirements

For the case the floating LNG installation is moored in docked or nearshore conditions, site studies as described in 4.1, are particularly important for the selection and design of the lay-out of the overall mooring configuration in the local geographical setting.

The provisions, recommendations and guidelines in the following documents should also be considered:

a) SIGTTO: Site selection and design (IP no. 14) for LNG ports and jetties;

b) OCIMF: Mooring equipment guidelines;

c) EAU: Recommendations of the Committee for Waterfront structures — Harbours and waterways;

d) PIANC WG 145: Berthing velocities and fender design;

e) PIANC WG 153: Design of marine oil terminals.

For permanent moorings in nearshore or docked conditions, 4.2.6.3 specifies that design criteria (load cases [limit states] to be considered and return periods of loads for specific limit states) shall be in accordance with the relevant parts of ISO 19901-7. Because ISO 19901-7 does not focus on the particulars of moorings in nearshore or docked conditions, DNVGL-OTG-18 shall be considered for the design requirements to the specific particulars of moorings in nearshore or docked conditions.

A dynamic analysis is required to document the adequacy of the mooring system design. The principles of such analysis are specified in ISO 19901-7. Local site specifics can have large effect on the characteristics of the metocean conditions and other design criteria. Mathematical models that convert metocean conditions, known with sufficient certainty at a near-by offshore location in open water, towards the project location in docked or nearshore condition, are complex and difficult to validate.

The uncertainty in the design input data, and in the analysis methods applied, shall be quantified and accounted for in the design. The risk of a potential failure of the mooring, which depends on the local situation, shall be taken into account. When relevant, validation of computational methods against model tests is recommended.

In benign environmental conditions, a quasi-static mooring analysis can be acceptable, provided it is demonstrated that the effect of mooring line dynamics is negligible.

The mooring system and LNG transfer system design shall ensure that the movements of the floating LNG installation relative to the structure to which it is moored are within the envelope of allowable motions of the transfer system, with an adequate margin of safety. The design of the LNG transfer system is specified in Clause 9.

The design requirements specified in this subclause for the primary mooring of a floating LNG installation in nearshore or docked conditions apply to the same extent to the permanent mooring of a second vessel (FSU) side-by-side to the floating LNG installation (FSRU or FLNG).

Although the typical mooring configuration for a quayside or jetty mooring, as described in 6.3.1.1, seems similar to the short duration mooring for a visiting LNGC, described in 6.5, the nature of a permanent mooring system is different. The design shall take into account the effect of fatigue, aging, etc. of mooring lines and fenders. If necessary to achieve conformance with ISO 19901-7, the mooring design may be based on a prescribed regular change-out of certain mooring components. The operational manual shall provide the associated instructions.

6.3.3 Emergency departure of floating LNG installation

It is possible that a floating LNG installation, moored in nearshore or docked conditions, can be in the vicinity of another safety critical installation. A risk analysis, being part of the site selection procedure, will demonstrate the need for a potential emergency departure of the floating LNG installation in case of an accident, aiming at safeguarding of assets.

In case the risk analysis demonstrates the need for a potential emergency departure, the following requirements apply:

a) The mooring system design shall address the requirement for a rapid departure in case of emergency. Quick release hooks may be used to release mooring lines. The control logic shall enable a safe disconnection, without overloading any single line.

b) Operational procedures shall be in place to define the sequence of events — cease of onboard operation, disconnection of transfer systems, preparation for marine control of the vessel after disconnect — prior to disconnection.

c) Conditions that play a role in the decision for an emergency departure shall be monitored. The information shall be available to the officer responsible for the decision.

d) The vessel shall have the facilities to navigate under its own power, requiring a marine crew available on demand, or be controlled by tug assistance, provided tugs are available.

6.4 Mooring systems for special project design conditions

6.4.1 Disconnectable mooring

In both permanent stationkeeping in open waters and permanent stationkeeping in near shore or docked conditions, it can be the case that certain adverse environmental events, e.g. iceberg impact or hurricanes, impose design requirements that significantly exceed the normal statistical bandwidth of the conditions.

In accordance with ISO 19901-7 it is permitted to exclude the ULS design requirements following from the adverse environmental event, provided that the floating LNG installation is equipped with the technical facilities to disconnect from its mooring (and subsequently re-connect when the event has passed) and that adequate operational procedures are in place to avoid the adverse event.

In order to adopt such a disconnection philosophy, it shall be possible for the floating LNG installation to actually detect such an event and then to close down its operation, disconnect and move away to a planned safe location within a realistic time period. This time period should also be associated with the accuracy of forecasting the extreme event. The ability to move away should be related to availability of own propulsion machinery and necessary marine crew or the availability of tugs to facilitate the move.

The operating manual shall clearly describe the threshold level of environmental conditions for which the mooring system has been designed, and at which level of environmental conditions the decision for preparation of disconnect shall be taken.

For the disconnection of a mooring in nearshore or docked condition, based on mooring lines, quick release hooks may be applied to facilitate disconnection. Adequate operational procedures shall be in place to achieve disconnection in a controlled manner.

The design of the floating LNG installation itself shall cover the design situation in which the unit is disconnected from the mooring and operates as a self-propelled vessel, or a towed facility, whichever is applicable.

The design of the disconnectable mooring shall be in accordance with ISO 19901-7.

6.4.2 Permanent mooring for a limited project life

As stated in 4.2.6.4, ISO 19901-7 permits a reconsideration of design criteria when the design service life of the permanent mooring system is substantially lower than 20 years. Parameters characterizing ULS environmental design situations with return periods shorter than 100 years may be adopted. In such cases the return period shall be determined through a risk assessment, taking into account the possible consequences of mooring system failure.

For permanent moorings in nearshore or docked condition, this document also refers to the philosophy provided by ISO 19901-7. Additionally, DNVGL-OTG-18 shall be considered. DNVGL-OTG-18 is intended for moorings with a design service life of 5 years and more. Applications for shorter duration may also consider using DNVGL-OTG-18, in that respect that return periods for ULS environmental design situations may be reassessed similarly as described in this subclause.

6.5 Short-duration mooring of a visiting LNGC for loading/unloading

6.5.1 General

A floating LNG installation, whether an FSRU, an FSU or an FLNG, will receive LNGCs to either bring LNG (to FSRU or to FSU) or to collect LNG (from FLNG or FSU). Various configurations are possible:

— the LNGC is moored ship-to-ship (side-by-side, or in tandem) to a floating LNG installation that is kept on station offshore in open waters;

— the LNGC is moored side-by-side to a floating LNG installation that is kept on station at a docked or nearshore location;

— the LNGC is moored along the same jetty as the floating LNG installation, but at the opposite side;

— the LNGC is moored to an SPM terminal.

Design criteria are described in 4.2.6.5

Design requirements are specified in 6.5.5.

6.5.2 Ship-to-ship mooring in open waters

LNG transfer between a floating LNG installation moored in open waters generally takes place in a side-by-side arrangement. When applying SIGTTO 'Ship-to-ship transfer guide to petroleum, chemicals and liquefied gases' (see 6.5.5), it shall be taken into account that motions of both vessels shall be accommodated.

Mooring lines shall be connected at both sides, at LNGC and floating LNG installation, in such a way that minimum chafing and wear can occur. Particular attention shall be paid to draft changes of both vessels.

When the size (height of deck edge above the water line) of the LNGC differs substantially from the size of the floating LNG installation, relative motions between the two vessels can result in relatively large tension variations. The gradual change in vessel draft throughout the loading/unloading operation, by transferring cargo from one vessel into the other, might add to the vertical separation between the points of connection of each mooring line. The mooring design shall accommodate this situation adequately.

LNG transfer will take place through loading arms, located at the floating LNG installation, or via flexible transfer hoses. Design of the LNG transfer system is specified in Clause 9.

The LNGC can alternatively be moored to the floating LNG installation in tandem. In that arrangement, the LNGC (offtake carrier) is moored behind the FLNG or FSU, and fluids are transferred though flexible hoses (floating on the sea surface or in an aerial catenary shape). This concept is under development at the date of publication of this document. Therefore, this document does not provide guidance for the design. The tandem mooring principle is preferred for offshore crude oil transfer, and will likely be used once the flexible hoses for LNG have been fully qualified and proven.

6.5.3 Mooring in docked or nearshore conditions

The configurations of mooring an LNGC in docked or nearshore conditions are described in 6.5.1.

When the LNGC is moored side-by-side to a floating LNG installation that itself is moored on a jetty, the design requirements are equivalent to those specified in 6.5.2. and 6.5.5.

6.5.4 Mooring to an SPM terminal

Novel designs have been developed for SPM terminals, receiving LNGCs for loading/unloading LNG cargo. This solution is suitable for serving land-based LNG facilities at locations without harbour facilities. At date of publication of this document, the concept has not been proposed in combination with a floating LNG installation. Therefore, this document does not provide design requirements for this concept.

6.5.5 Design requirements

Design of the short-duration mooring system for an LNGC shall be in accordance with the latest editions of SIGTTO 'Ship-to-ship transfer guide to petroleum, chemicals and liquefied gases' and OCIMF 'Mooring equipment guideline'.

As stated in 4.2.6.5, the type and size range of the LNGCs that can be accommodated, and the limiting environmental conditions for berthing and LNG transfer, shall be clearly specified in an operating manual.

The LNG transfer operation shall only be executed when that can be done safely. To support the operation, continuous line load monitoring and recording shall take place and means to monitor vessel relative motions shall be provided. Adequate monitoring of the conditions that control the decision for disconnection shall be available. Consideration should be made with respect to line tension monitoring in the ESD cause and effect matrix of the floating LNG installation.

Operational support systems, such as environmental forecasting, berthing aid facilities, may be used to facilitate berthing and mooring operations.

As the LNGC, when moored, will be in the vicinity of a floating LNG installation in operation, the mooring system shall be executed so that an emergency departure can be effectuated in a safe and controlled manner, for the exceptional situation of a safety hazard.

6.6 Infrastucture design for jetty moorings

6.6.1 General

In the case a floating LNG installation is permanently or semi-permanently moored to a jetty, the jetty structure itself is considered part of the mooring system and thus covered by this document.

The jetty or quayside, the dolphins, fenders, bollards, mooring lines, fluid transfer system, access ways, etc. shall be designed to meet the operational and safety criteria. For the jetty, an appropriate standard for marine structures, such as the International Standards on offshore structures prepared by TC 67 (i.e. ISO 19900, the ISO 19901 series, ISO 19902, ISO 19903, ISO 19904-1, the ISO 19905 series, ISO 19906), the EN 199X series (Eurocodes), the BS 6349 series or API/ACI standards, shall be used to determine the selection of relevant design parameters, to derive applicable loads and to analyse the structure to demonstrate the adequacy of the design. The methodology shall take all design criteria into account as described in 4.2.6.3 or 4.2.6.5.

Loads shall comprise of direct loading on the jetty structure and those imposed by operational activities, such as berthing and mooring of the floating LNG facility, possible additional berthing of LNGC for delivery or collection of LNG, cargo handling and vehicles used during construction, operation and maintenance.

Requirements of ISO 28460 shall be followed where appropriate. In addition, the following provisions, recommendations and guidelines should be considered:

a) DNVGL-OTG-018: Guidance for nearshore mooring systems;

b) SIGTTO: Site selection and design for LNG ports and jetties (for incorporation into jetty design and ship-shore interface);

c) OCIMF: Mooring equipment guidelines;

d) EAU: Recommendations of the Committee for Waterfront structures — Harbours and waterways;

e) PIANC WG 145: Berthing velocities and fender design;

f) PIANC WG 153: Design of marine oil terminals.

6.6.2 Jetty elevation

Jetty deck elevation shall be defined according design water level and design wave height including some margins (also known as air gap) in order to avoid important loads due to waves on the jetty head structure. This air gap shall be at least 0,50 m above the combination of waves/water level with 100 year return period. Special attention shall be paid to the jetty elevation in case of tsunami events.

6.6.3 Corrosion protection of the marine infrastructure

Corrosion protection of steel elements can be realized either by corrosion allowance, cathodic protection, a coating system or the combination of these means.

Corrosion protection implemented shall be defined in accordance with the type of ambient conditions (atmospheric only, mix of water and air, submerged). If different systems are combined, compatibility of these systems shall be ensured.

6.6.4 LNG spillage containment

Within the design, the possibility of LNG spills, particularly in the area adjacent to the transfer systems, shall be considered by implementing provisions for containment of LNG spill and brittleness protection of carbon steel structural members, or by other appropriate measures.

LNG spills shall be routed away from the process/transfer area.

6.6.5 Power supply from/to jetty to the FSRU/FLNG

In case of utility connection between jetty and FSRU/FLNG to supply power, power connection shall comply with relevant parts of IEC 80005, depending on the voltage level of such connection. Safe emergency disconnection system shall be provided on the electrical connection in order to avoid any ignition hazard. In case such safe emergency disconnection system cannot be implemented, electrical connection shall be located outside any hazardous area.

6.6.6 Navigation aids

International recommendations and guidelines regarding to aids to navigation provided by the International Association of Marine Aids to Navigation And Lighthouses Authority (IALA) are recommended.

6.6.7 Emergency response and evacuation route

Provisions shall be made for rapid access and egress to the berth by emergency vehicles or vessels involved in fire-fighting, medical evacuation or pollution control. On jetties relying on vehicular access, it can be necessary to provide passing places on trestles and platforms.

Provisions shall be made for emergency escape routes from fire or liquid spill. From any point on the berth, it should be possible to escape to a place of safety. This is most easily achieved by providing two independent routes to safety from the berth, which may include additional walkways and provision of a manned standby boat(s).

Escape route shall be protected by water spray if found necessary by the hazard assessment.

Access to ship from jetty shall be in accordance with ISO 28460.

6.7 Transfer of material and personnel

Transfer of both material and personnel should be carried out in a safe manner.

NOTE Relevant regulatory requirements might exist.

Transfer may be carried out by use of:

a) helicopter;

b) crew boat/offshore support vessel;

c) personnel transport basket with use of crane;

d) gangway, bridge, accommodation/pilot ladder.

Helicopter transport is addressed by requirements from the International Civil Aviation Organization (ICAO). Requirements can be supplemented by local offshore regulations.

For floating facilities subject to requirements from maritime legislation, the requirements of IMO regarding design of accommodation and pilot ladders should be conformed to.

NOTE 1 See also SOLAS II-1 Regulation 3-9 and IMO MSC.1/Circ.1331 for guidance.

Similar requirements are likely to be applied by national authorities in cases where such units are not directly subject to maritime legislation.

When cranes are used for transportation from a vessel to the floating unit, the cranes should be designed for offshore use and should normally meet ILO requirements[52]. Where such cranes are used for the transportation of personnel, additional design features for man-riding should be considered. Individual flag states or national authorities can impose additional requirements.

NOTE 2 Further guidance is provided by the International Marine Contractors Association (IMCA), which is an international association representing offshore, marine and underwater engineering companies [see Guidance on the transfer of personnel to and from offshore vessels (IMCA HSSE 025; IMCA M 202)].

7 Hull design

7.1 Hull structural design

7.1.1 Design philosophy

The structural system, components and details of a floating LNG installation shall be designed, constructed and maintained so that they are suited to their intended use. The floating structure shall be designed to withstand all loads encountered during all phases of its operation and transit condition. Furthermore, the structure shall be designed so that if structural damage does occur, the damaged structure (possibly with temporary repairs, as applicable) is able to resist action combinations appropriate to these design situations without suffering extensive failure, free drifting, capsizing or sinking, and without causing extensive harm to the environment.

The design approach shall consider the location of the installation, the intended mode of operation, and all relevant loads, including accidental loads, acting on the installation.

For existing units to be converted to a floating LNG application, new loading regime shall be demonstrated and validated according the current state of the existing unit.

7.1.2 Design methods

Hull design may follow either of the following design methods:

a) The working stress design method, also known as the allowable stress method: This is a method by which the target safety level is achieved by comparing the calculated stress with the permissible stress by multiplying the characteristic strength, or capacity, with the applicable usage factor.

b) The load and resistance factor design method: This is a design method by which the target safety level is obtained by applying the load with a load factor, together with a material factor.

The design method shall be defined for the project and then be used consistently. Mixing between different design methods during the design is generally not accepted. Both methods are applicable for hull and topside structure.

7.1.3 Codes and standards

Codes, standards, RCS rules and regulations (collectively referred to as “standards” hereafter) applicable to the design and construction of the floating structure shall be clearly identified at the commencement of the project.

Mixing of standards should be avoided. When more than one standard is utilized in the design process, differences in the standards shall be identified and a decision shall be made concerning the appropriate measures to be undertaken. Such a decision shall be based upon sound engineering practice and include consultation with the responsible regulatory organization, as applicable.

The standards used in the design of structures shall be consistent and compatible with those utilized in the fabrication and in-service monitoring of the structure.

For innovative structural forms, or applications of unproven structural concepts where limited or no direct experience exists, appropriate analyses shall be performed to demonstrate that the safety level of the design is no lower than the safety level implicit in this document.

The design shall follow the principles outlined in ISO 19904-1. Where such installations are flagged, the requirements of the flag state shall also be followed.

7.1.4 Limit states for floating structures

The following limit state categories shall be used in the structural design of a floating structure:

a) ULS, which generally involves checking the floating structure's strength to resist the most severe actions and action effects;

b) SLS, which generally addresses the structure's performance during its normal intended use, and involves checking the floating structure's ability to resist normal operational actions;

c) FLS, which covers the structure's strength to resist fatigue damage related to repeated actions;

d) ALS, which addresses the structure's ability to resist accidental and abnormal events, including the structure's resistance to withstand specified environmental actions after damage has occurred.

7.1.5 Design situations for ULS

For ULS conditions, representative metocean actions shall be established with the intention of resulting in the most onerous metocean action effects with the return period of 100 years. Different structural elements can be differently affected by the same design situations, and consequently a range of different design situations shall be assessed in order to ensure that the most onerous conditions are identified.

7.1.6 Design situations for SLS

The identification of SLS design situations for floating offshore structures shall be based on at least the following considerations:

a) unacceptable deformations can affect the efficient use of structural elements or the functioning of equipment relying on them;

b) local damage (including corrosion, cracking, wear) can reduce the durability of the structure or affect the efficiency of the structural elements;

c) excessive motions, accelerations, vibrations or noise can cause discomfort to personnel and interfere with their capability to discharge their duties;

d) motions, accelerations or vibrations can exceed the range of effective functionality of topsides equipment (e.g. roll and pitch angles can seriously affect the performance of separators, heat exchangers).

The assessment criteria associated with SLS shall be based on motions, deflections or vibration limits during normal use.

The SLS criteria shall be defined by the owner of a structure, established practice, designers, or suppliers of motion-sensitive equipment, the primary aim being efficient and economical in-service performance without discomfort to onboard personnel or excessive routine maintenance.

The acceptable limits necessarily depend on the type, mission and configuration of the structure. In defining these limits, other disciplines such as equipment and machinery designers shall also be consulted.

7.1.7 Design situations for FLS

The following sources of cyclic loading should be considered in the design:

a) waves (high cycle fatigue);

b) repeated loads that imply significant yielding at hot spots (low cycle fatigue);

c) wind, especially when vortex shedding is induced (e.g. on slender members);

d) mechanical vibration (e.g. caused by operation of machinery).

7.1.8 Design situations for ALS

The main goal of the ALS verification is to ensure that the floating structure is designed to achieve to:

— withstand specified accidental and abnormal events such that any damage suffered does not affect the structure's overall structural integrity, stability and watertightness;

— maintain adequate structural integrity (residual strength), stability and watertightness in the event of damage from an accidental or abnormal event, for a sufficient period of time and under specified environmental conditions to enable some or all of the following activities, as applicable:

  — evacuation of personnel from the structure;

  — control over movement or motion of the structure;

  — temporary repairs;

  — fire fighting;

  — control of outflow of cargo or stored material liable to cause environmental damage or pollution.

Different types of accidental or abnormal events can require different methodologies or different levels of the same methodology to assess adequacy of the structural resistance during and following such events.

ALS design situations may include consideration of a reduced extreme environmental condition. This condition should be established with the intention of resulting in the most onerous action effects for a return period of one year. Recognized structural practices accounting for local structural damage may be utilized in design for the ALS.

Where abnormal environmental conditions are considered as an ALS condition, these should be taken as the 10 000 year return condition. This condition is then combined with an appropriate safety factor for ALS.

7.1.9 Site-specific design

With regard to structural strength of the hull, the design should consider the worst case conditions to which the hull can be exposed either on station or while in transit.

If the preliminary design modelling shows that the site-specific conditions are less severe than the standard RCS rule loads from seagoing service, a standard hull design can be applied as basis. For harsher environment locations, the site-specific loadings shall be used. Where the unit is intended for operation at more than one location, the most severe design criteria shall be applied.

Site-specific design is typically based on site-specific conditions with a return period of 100 years. Ship design practice for unrestricted service is based on Winter North Atlantic conditions with a return period of 25 years.

The design may account for operational measures to avoid certain extreme conditions, such as temporarily moving off location. The hull structure of disconnectable units (when disconnected) shall be assessed for unrestricted service as a seagoing vessel. Alternatively, the unit may be assessed to pre-defined transit routes. The hull structure of units that are not disconnectable (i.e. permanently moored) shall be assessed for proposed transit voyages, including the delivery voyage.

7.1.10 Cargo containment loads

Cargo containment loads, such as sloshing loads, coming from the liquid storage system affecting the hull shall be accounted for in the hull design. Sloshing loads affecting the cargo containment design are described in Clause 8 and 4.2.5.

7.1.11 Fatigue

Fatigue loads shall be addressed in accordance with ISO 19904-1 or RCS recommendations. Design criteria should take into account the intended philosophy for inspection, repair and replacement.

Accessibility for inspection will also determine the fatigue safety factors to be applied. Accessibility can be affected by whether or not the unit is intended to drydock or whether it intends to remain permanently on location. Accessibility of key structural details can also be affected by application of fire and cryogenic protective covering.

Fatigue design may be carried out by methods based on fatigue tests (S-N data) and estimation of cumulative damage (Palmgren — Miner’s rule).

The following factors that influence fatigue endurance should be taken into account in the design calculations:

a) stress range distribution;

b) structural design details (hot spots);

c) fabrication and tolerances;

d) corrosion.

The long-term stress range distribution is a fundamental requirement for fatigue analysis. This may be determined in various ways. Two of the most used methods for stress range calculation are:

— deterministic fatigue analysis, a postulated form of the long-term stress range distribution with a stress range based on dynamic loading as specified in design codes;

— spectral method for the estimation of long-term stress range.

In the first method, a Weibull distribution is assumed for the long-term stress ranges, leading to a simple formula for calculation of fatigue damage. The second method implies that the long-term stress range distribution is calculated from a specified wave climate.

7.1.12 Slamming

Where relevant, slamming effects shall be taken into account in the design of the bow, including bow flare, bow side and forward bottom, turret and stern. Slamming effects can be determined in accordance with RCS or equivalent procedures.

7.1.13 Green water

Green water is taken to mean the overtopping by water in severe wave conditions, resulting in loading on the deck structure, superstructure and any exposed equipment. Green water shall be addressed in the design. Green water effects can be determined in accordance with RCS or equivalent procedures.

7.1.14 Topsides and external loads

Loads acting on the hull as a result of installations on the deck or attached to the hull of the unit shall be taken into account. Major loads include items such as:

— topsides modules;

— lifting appliances;

— products transfer arrangements;

— flare or vent stacks;

— station keeping/position mooring arrangements;

— risers;

— helideck;

— berthing/fendering.

7.1.15 Accidental loads

Risk assessment is an integral part of the design process for floating LNG projects. The risk assessment will result in defining accidental loads which shall be addressed in the structural design. The magnitude of the loads shall be determined on a case-by-case basis depending on the detail design and layout of the unit and on its area of operation.

The structural design should quantify and consider the loads resulting from:

a) ships collision;

b) dropped objects;

c) fire;

d) explosion;

e) extreme weather condition (e.g. hurricane, typhoon, tsunami).

Cryogenic spill measures shall be considered in the hull design.

Helicopter operational procedures shall be put in place where required.

7.2 Stability and watertight integrity

7.2.1 General

Requirements for stability, weathertightness and watertightness of decks, deckhouses, doors, vents, etc. are generally provided by applicable flag state and national authorities regulations.

In the absence of mandatory requirements, for example where the floating LNG installation is not flagged, the applicable IMO standards shall be used to provide design requirements.

7.2.2 Stability

Adequacy of stability of a floating LNG installation shall be checked for all relevant in-service and temporary phases. The assessment of stability shall include consideration of both intact and damaged conditions. When recognized standards are utilized in the assessment of damage stability, it should be ensured that the basis for the design situations and criteria adopted in the standard is compatible with the accidental event being addressed.

For intact stability, the floating platforms shall satisfy all applicable IMO IGC Code provisions. The IMO IGC Code refers to IMO Intact Stability Code for intact stability requirements.

For the stability checks, relevant detrimental effects shall be considered, including those resulting from:

a) environmental actions, such as wind, wave (including green water effects), snow and ice accretion, and applicable damage scenarios (including owner-specified requirements);

b) rigid body motions;

c) free-surface effects in cargo and ballast tanks;

d) boundary interactions, such as mooring and riser systems.

The effects and consequences of accidental damage to the hull shall be considered. The effect of the extent of damage from penetration or flooding of one or more compartments shall be assessed in terms of stability, strength and impact on the environment, as outlined in IMO IGC Code and RCS rules.

The location of the down-flooding points is critical in stability assessment.

If site-specific ULS wind speeds exceed IMO IGC Code requirements, stability should be determined based on the site-specific data.

7.2.3 Watertight and weathertight integrity

The hull of a floating LNG installation shall be subdivided into a number of compartments to meet strength and stability requirements and to minimize consequence of damage, pollution risks, and possible risks of loss of the platform in the event of damage.

Additional subdivisions can be required in the design of the hull to account for ballast water needed to control hull stresses (in all design phases) and for the storage of LNG and other process-related liquids.

Requirements for watertight and weathertight integrity shall be in accordance with the IMO IGC Code.

As a minimum, watertight closing appliances shall be installed for those external openings up to the water levels corresponding to an angle of heel equal to the first intercept between the righting moment and wind heeling moment curves in any relevant intact or damaged condition.

The number of openings in watertight structural components shall be kept to a minimum. Where penetrations are necessary for access, piping, venting, cables, seawater intake (seachest), etc., arrangements shall be made to ensure that the watertight integrity of the structure is maintained through the appropriate design for the pressure and other action effects likely to occur in service and following damage (including wave impact effects). Closing appliances and their controls, indicators, actuators, power sources, etc., shall be arranged so that they remain capable of functioning effectively even in the damaged condition.

Openings above the waterplane in the damaged condition can be exposed to wave action and/or changes in the waterplane due to the dynamic response of the unit. Such openings should be weathertight.

Arrangements shall be provided to ensure that progressive flooding does not occur where individual lines, ducts or piping systems serve more than one watertight compartment or are within the extent of damage resulting from a relevant accidental event.

8 LNG storage

8.1 General

This clause is addressing the LNG storage systems only. Requirements related to other kind of products (such as LPG or condensate) storage are not addressed in this document.

The LNG containment system of a floating LNG installation shall be in accordance with IMO IGC Code Chapter 4. Monitoring system of the cargo tank shall be in accordance with IMO IGC Chapter 13. The following specific key parameters shall be included in the functional requirements of the LNG storage:

a) the LNG storage will be designed for long operating periods on a specific site, while the IMO IGC Code specifies only 20 years of operation for LNGCs (10^8 wave encounters and 1 000 thermal cycles [i.e. number of loading and unloading operations]);

b) loads from the topsides equipment/skids, such as vibrations, weight and acceleration, should be included into the hull structure design, and so potentially to LNG storage design;

c) the LNG storage will be operated at intermediate filling levels;

d) considerations for the BOG management shall be included in the design and operation of the floating LNG installation, and so of the LNG storage, such as design pressure and boil-off rate;

e) the LNG tanks can receive various LNG blends so stratifications or even rollover phenomenon can occur;

f) the commissioning and decommissioning of one LNG tank can be required while other LNG tanks are in service as a normal operation; also maintenance of equipment inside the LNG tank can be required with tank decommissioning.

8.2 Sloshing loads

8.2.1 Intermediate filling levels: Operating conditions of FSRU/FLNG

An FLNG/FSRU is operated over the full range of filling levels. Consequently, the sloshing loads induced by the liquid cargo motions inside the storage tanks shall be addressed accordingly.

Sloshing phenomena is known to be more severe in the intermediate filling range than in the low or high part of the tanks where LNGCs are used to be operated. This applies to both prismatic tanks and spherical tanks, and is caused by a combination of a change of the flow phenomena that occur in the tank and more unfavourable relationships between the sloshing resonance periods, the dominating wave periods encountered at sea, and in particular the roll resonance period of the vessel.

The structural design challenges related to liquid sloshing are:

— wave impact on tank walls;

— wave impact on internal structure in the tank, such as large stringers and girders where relevant;

— hydrodynamic drag forces on internal structure in the tank, such as pump towers and large stringers/girders.

The sloshing loads for the assessment of the containment system and the hull structure should be based on experimental model tests. For the internal structure, numerical simulations may be used.

The ship motions used for both experimental study and numerical study should be determined using a verified ship motions analysis program (basin tests and numerical simulations). The ship motion analysis should be performed on the actual floating unit geometry including its hydrodynamic characteristics resulting from its loading conditions and the mooring features.

The sloshing design loads should be based on long-term load distributions relevant for the actual floating unit taking into account its operational profile. The floating unit operational profile should include:

a) environmental data of the area including a description of significant wave heights (Hs), wave period (Tp or Tz), wave direction, wave spectra features, for both windsea and main swell components, if any;

b) loading and unloading sequence for all cargo tanks;

c) distribution of equilibrium positions of the floating unit (heading analysis).

The design sloshing loads shall be determined for each failure mode of the structure. These failure modes shall be identified and characterized according to a structural response analysis. The following effects shall be included to determine the strength capacity of the structure(s):

a) temperature variation through the thickness of the structure;

b) dynamic response effects in accordance with the dynamic sloshing loads.

The structure should be assessed according to the joint probability with the consequences of a failure. Consequences and their associated probabilities should be determined through a comprehensive failure analysis.

In order to guaranty the integrity of the structure(s), appropriate reinforcements should be applied up to reach the required probabilities of failure for each failure mode. To further reduce the probability of a failure, measures to reduce any sloshing effects, such as heading control or operational limits, may be undertaken.

8.2.2 Intermediate filling levels: Operating conditions of cargo transfers (STS)

Not only an FLNG/FSRU is operated over the full range of filling levels, but also the shuttle vessels that transfer the cargo. These LNGCs can also encounter sloshing risks, so procedures and measures to mitigate these risks shall be in place to the satisfaction of each shuttle vessel classification society and flag administration.

An availability study for the STS transfer operation should be performed to assess its downtime periods according to various operability criteria, such as the weather limitations (e.g. wave height, wind speed, tugs operability, the transfer limitations (e.g. relative motions and distance between the floating unit and the shuttle vessel, the mooring lines loads, the fenders loads, the transfer system operating envelope) and the sloshing loads inside the shuttle vessel. This availability study should be an input to decide the floating unit normal LNG storage tanks filling levels and their additional buffer size with potential extended filling levels.

8.3 Boil-off gas management

The floating LNG installation BOG management shall be performed to design associated equipment in particular during offloading operations and LNG storage tanks loading. In this regards, the thermal efficiency of the cargo containment system in thermal steady state, but also in transient conditions, shall be calculated in accordance to the site(s)-specific environmental conditions. The LNG storage design pressure should be selected to give some flexibility in the BOG handling, if needed.

8.4 Rollover prevention management

8.4.1 Background

“Rollover” refers to a phenomenon in which a large amount of LNG vapour is suddenly released as a result of the spontaneous mixing of LNG layers of different density and composition. It can only occur if stratification has taken place in a tank.

Rollover can lead to a potential over-pressurization resulting in possible damage or failure of the LNG tanks. For this reason, this phenomenon shall be assessed (see, for instance EN 1473:2016, Clause B.12). Based on the assessment, the design shall accommodate the phenomenon by operational measures to minimize venting and, when required for safety, by sizing the relief devices accordingly.

Roll-over is well known phenomenon for onshore storage.

NOTE Further guidance is provided in GIIGNL report “Rollover in LNG storage tanks” and SIGTTO report “Prevention of rollover in LNG ships”.

LNG stratification can occur by two different ways:

1) Two stable stratified layers can form in the LNG storage tanks with different density and composition, typically caused by an incorrect mixture of the LNG being loaded in the tank with the liquid already stored. Stratification with different LNG sources can occur in FSU or FSRU.

2) Nitrogen induced auto-stratification can form when LNG contains significant quantities of nitrogen (more than 1 %). Most LNG plants produce LNG with nitrogen content significantly lower than 1 %: This auto-stratification is unlikely to happen even for an FLNG.

8.4.2 Detection and prevention

Stratification can be detected by:

— a noticeable reduction of around 10 % in boil-off rate below the normal value should be taken as a warning of stratification.

— the measurement of temperature and/or density throughout the liquid column with accurate instruments.

If stratification risk has been identified for the project, stratification shall be monitored by the operator.

Stratification can be prevented by:

— mixing LNG of different densities using top and bottom fill procedures;

— recirculation of the tank inventory through jet nozzles or other mixing devices;

— limit the nitrogen content to 1 % for in produced LNG of FLNG.

If stratification has occurred, the following can be done to avoid rollover:

— Transfer of the liquid from the tank to another tank, if possible.

— Circulation of tank contents through jet nozzles, a top fill line or other mixing devices. For FSU and FSRU, it is recommended to have at least one LNG tank with top and bottom filling with LNG recirculation capability.

8.5 Vent systems for LNG storage

8.5.1 General

Vent systems of the LNG tanks shall be in accordance with IMO IGC Code Chapter 8. Vent systems shall also consider rules for shore storage. See for instance EN 1473:2016, 6.8, 9.7 and Annex B or NFPA 59A:2019, 8.4.10.

8.5.2 Pressure relief systems

The IMO IGC Code considers two events for the sizing of the LNG storage pressure relief valves for overpressure protection:

— fire exposure of the loaded tank;

— overpressure from the inert gas system (if relevant).

For an floating LNG installation, the relieving gas flowrate for LNG storage pressure relief valves design may be determined from different events that are combined in scenarios. This list of events for overpressure protection may include:

a) the LNG storage boil-off rate in full loaded condition and maximum ambient air temperature;

b) vapour displacement during LNG storage filling at maximum flow rate due to piston effect;

c) heat leakage through LNG piping during LNG storage filling;

d) LNG flash inside the LNG storage during filling;

e) vapour generated due to in-tank pumps running with internal recirculation;

f) a pressure drop of atmospheric pressure according to site location;

g) rollover, if relevant;

h) external fire exposure, as per IMO IGC code, for one or several LNG storages;

i) minimum relieving capacity as per NFPA 59A:2019, 8.4.10.5.3;

j) operational upset of the hot gas/vacuum break valve system, if relevant;

k) operational upset: a gas blow-by from the end flash column bottom, if relevant;

l) operational upset: back flow from end flash compressor suction, if relevant.

Each scenario is defined as a probable combination of events for the pressure relief valves sizing. This list of scenarios may include:

a) tank filling;

b) tank filling with operational upset;

c) tank with pumps recirculation;

d) tank fire exposure;

e) tank rollover, if relevant.

All scenarios and associated events should be confirmed by the HAZID study.

8.5.3 Vacuum relief systems

On board LNGCs, the LNG tank pressure relief valves are also vacuum relief valves (dual function). The IMO IGC Code considers one event for the sizing of the vacuum relief valves which is a gas flow at least equal to the maximum cargo discharge rate of the cargo tank. For a floating LNG installation, the relieving gas flowrate for LNG storage vacuum relief valves design may be determined from different events that are combined in scenarios. This list of events for vacuum protection may include:

a) LNG withdrawal at the discharge pumps maximum rate;

b) a pressure rise of atmospheric pressure according to site location;

c) vapour withdrawal at maximum end flash/boil-off gas compressor(s) suction flow rate, if relevant;

d) vapour space pressure reduction due to filling with rundown subcooled liquid, if relevant.

Each scenario is defined as a probable combination of events for the vacuum relief valves sizing. This list of scenarios may include:

a) tank discharging;

b) tank with compressors running.

All scenarios and associated events should be confirmed by the HAZID study.

9 LNG transfer system

9.1 Functional requirements

To transfer the LNG from production or storage floating unit to LNGC or at the opposite direction, a specific equipment is required to connect both units and to carry in the LNG product. To achieve this connection and the LNG transfer operation in safe conditions, the transfer system shall at least offer functions to:

a) have controlled mobility to reach the manifold connection of the carrier under the climatic operating conditions, such as wind, motions due to sea conditions, rain, ice, hot or cold temperature;

b) positively connect its extremity to the manifold connection, keeping connected without needs of any external energy in the operating conditions;

c) freely follow the relative carrier motions in the 6 degrees of displacement after connection;

d) transfer LNG through its product line from one extremity to the other, from the cooling down start to the end of loading operation;

e) limit the loads applied to the manifold connection to the allowable values given in the relevant SIGTTO publication where standard ship manifold is involved;

f) comply with the flow rate and maximum pressure drop requirements and to comply with the installation process, taking into account the maximum flow velocity which is limited by specification and experience;

g) have possibility to be disconnected in empty condition in all allowable and required operating conditions (i.e. with ice coating);

h) operate in the full required operating envelope without clashes with adjacent transfers systems and all around infrastructure and other equipment;

i) be stored in empty condition, without need of external energy, and to sustain the extreme environmental conditions of the installation;

j) be disconnected without clashes with adjacent transfers systems and all around infrastructure and other equipment in emergency condition, with no flow, to ensure safe operation and also taking into account potential surge issues, keeping isolated each side of the break separation, and to be manoeuvred back towards its stored position in either empty or full condition under extreme operating conditions;

k) be drained and/or to be purged from its product in order to be gas free after operation, before normal disconnection or after an emergency disconnection;

l) be electrically isolated towards one extremity, avoiding bonding by contact or other accessories continuity, to avoid consequences of potential differences between the two connected units.

For drainage or purging of transfer system, this operation does not necessarily be achieved through specific equipment, but can also be achieved by a suitable procedure.

9.2 Design of transfer systems

9.2.1 Operating envelope

9.2.1.1 General

The operating envelope of a transfer system is composed of the following areas:

— A green zone corresponding to the normal operating positions for which the offloading is ensured. The green zone is generally composed of:

  — a flanging area corresponding to the theoretical location of the manifold linked to the geometrical dimensions of the installation, the range of carriers to be loaded, spotting line offset (± 0,5 m is generally considered) and fender compression for onshore and side-by-side applications;

  — a motion envelope made with the maximum relative motions in all directions (X, Y, Z) of the ship manifold regarding a reference point at the basis of the transfer system.

— An ESD envelope covering the complete OESD-1 sequence (stop of the transfer and potentially closure of the valves). The OESD-1 sequence is initiated as soon as the limits of the green zone are exceeded.

  NOTE According to OCIMF, the OESD-1 sequence is composed of the ERS valves closure and the product pump shutdown whereas based on ISO 16904 and SIGTTO only the product pump shutdown is considered.

— An emergency disconnection envelope covering the complete OESD-2 sequence (physical emergency disconnection of the offloading system and beforehand ERS valves closure if not performed during OESD-1 sequence). The OESD-2 sequence is initiated as soon as the limits of the ESD envelope are exceeded.

Design basis and criteria of an LNG transfer system which shall be considered are described in Annex D.

9.2.1.2 Operating envelope for transfer system in non-dynamic sensitive areas

The maximum operating envelope shall be defined taking into account:

a) the geometrical dimensions of the LNGCs range to be used;

b) the difference of levels of the floating units considering the various ballasted conditions (from empty to full of product);

c) the type of mooring arrangement, within the required operable conditions, including the relative motions due to sea waves, current and wind, and potential drift.

A pre-positioning of the manifold connection spotting line should be taken into account in the operating envelope dimensioning, depending of the installation, generally a value of ±0,5 m is considered.

9.2.1.3 Operating envelope for transfer system in dynamic sensitive areas

A static envelope shall be defined taking into account:

a) the geometrical dimensions of the LNGCs range to be used;

b) the difference of levels of the floating units considering the various ballasted conditions (from empty to full of product).

A pre-positioning of the manifold connection spotting line should be taken into account in the operating envelope dimensioning, depending of the installation, generally a value of ±0,5 m is considered.

The maximum motion envelope shall be defined by adding to the static envelope the maximum relative motions in the three volumetric dimensions, resulting from sway, surge, heave, roll, pitch and yaw motions of each floating units in side-by-side moored conditions.

The maximum motion envelope can be shaped according to the maximum relative motion values calculated at the different relative static position. The maximum operating envelope shall be defined taking into account the type of mooring units in the three volumetric directions, due to sea waves, current and wind.

9.2.2 Transfer system design

9.2.2.1 Transfer lines

The transfer systems shall be designed in accordance with ISO 16904, EN 1474-2 and EN1474-3 when relevant, with all the relative precautions as specified. ISO 1431-1 and ISO 4649 provide information on external wear and ageing.

In addition, the following precautions apply, particularly for flexible hoses and hybrid solutions:

a) In case of solutions using flexible hoses, particular attention shall be paid to the bending radius and risk of twist of the flexible hoses taking into account the product weight, the operating envelope to cover, the distances between the carrier and jetty or floating unit, the saddles locations, handrails and other equipment on the decks or jetty.

b) The flexible hoses shall be dimensioned to cover the operating envelope to the ESD2 limits and additional distance to keep time of physical disconnection before clashes or damage of equipment.

c) At time of connection, in case of lifting equipment on board, the receiving carrier shall be used in conjunction with the lifting equipment of the flexible hose solution. The lifting equipment shall be considered as part of the transfer system and shall be checked for compatible design according to marine lifting equipment and with additional precautions due to potential induced pulling forces in non-vertical direction.

An emergency release of receiving lifting point should be accommodated in case of excessive pulling force generated by excessive relative displacement between the receiving unit and the other floating unit or the jetty. If the ERS installed on the flexible hoses should be used between the two lifting points during the connection and disconnection operations, additional features, control system and procedure shall be applied to avoid possibility of emergency disconnection without being secured by the lifting equipment installed on board the receiving unit.

9.2.2.2 Saddles

Supporting saddles are principally used on flexible hose solutions, installed towards extremities on both sides and defined to support the flexible hoses during the operations.

The saddles shall be designed with the minimum radius curve and sliding protection or shall be made of adequate material to avoid damage to flexible hoses and components at connection/disconnection, during operations with relative motions and at emergency disconnection, and also to avoid sparkling. The saddles shall be designed to support the loads applied by the flexible hoses in the extreme conditions using safety factors applicable to marine loading arms in regards with the attitude and the combinations of loads.

The distributed loads of the saddle to the deck should cope with the allowable loads acceptable by the hull design.

9.2.2.3 Lifting crane

For not self-supported transfer systems, lifting crane can be required to operate.

Any fixed, floating or ancillary structures, material and equipment used to support, lift or move LNG transfer systems, should be designed, constructed and tested to meet applicable codes, standards and requirements.

The supporting structures shall:

a) be designed for all operational and survival metocean loads as specified in applicable codes;

b) incorporate all loadings resulting from the LNG transfer system operation;

c) be designed for both operational conditions and accidental conditions as recommended in EN 1474-3.

Suitable handling equipment shall be provided to ensure the safe and easy connection, disconnection and storing of the mobile parts transfer system and its dismountable parts, if any. Handling system necessary for the emergency disconnection shall be designed for this operation and shall remain in place during the transfer operations.

9.2.2.4 Connecting/disconnecting device

Connecting/disconnecting device shall be installed at the extremity of the transfer system to facilitate the connection.

The connecting/disconnecting device arrangement shall satisfy containment tightness and prevent or minimize spillage in case of normal operating or emergency disconnection.

The connection of the transfers system is achieved using different means which are not synchronized and/or automated and requires manual operations. Therefore, particular attention should be paid to the conditions and the procedure. Additional tooling should be provided, if necessary, to achieve a safe connection of the transfer system even with relative motions between the vessels. A procedure should describe the different tasks to be performed and the way to accomplish them as well as the condition limits (e.g. sea state, wind).

9.2.2.5 Emergency disconnecting device

The design of the transfer system shall consider, in addition to the normal operation, the emergency release of the system in both the empty condition, when applicable (i.e. for systems allowing to be drained before emergency disconnection), and the full condition.

Specific emergency release device shall be installed on the transfer system to achieve the emergency release without any clash of the transfer system with the ship or the terminal.

The emergency disconnection system shall be able to operate with its components ice covered.

9.2.2.6 Clearance and clash study

The design shall respect the minimum clearances defined by the owner for the different attitudes of the transfer system. The specified recommended minimum clearances are operating requirements, i.e. after any deflections and fabrication and erection tolerances. The location of main clearance checkpoints shall be defined. Vendor's clearance study shall be based on a drawing of the LNG terminal layout in elevation and plan including any expansion for future transfer systems.

The transfer system vendor has the responsibility to identify all check points where there is the potential for interference of all transfer systems, including future systems.

Chance of geometrical interferences and potential clash between the transfer system and LNGC or terminal, and between transfer systems themselves, should be avoided. Minimum distances between the terminal and the tanker shall be clearly specified. All required means to make the transfer reliable shall be provided.

10 Boil-off gas handling and recovery

10.1 General

Due to heat inleak into the LNG storage tanks and pipe works of the floating LNG installation, BOG is continuously generated. During the loading operation of an LNG carrier (FLNG), or if LNG is received from an LNG carrier (FSRU, FSU), additional BOG is generated due to the heat inleak into the LNGC, pressure differentials and other heat input, e.g. through the LNG transfer pumps.

The floating LNG installation shall provide BOG recovery plants, which collect the BOG and which are adequately designed for all operating modes and LNG compositions to maintain the pressure in the vapour space of the LNG storage tanks within the operating limits.

The floating LNG installation shall be designed such that no continuous flaring of BOG is required.

If the floating LNG installation uses pressurized LNG cargo tank, the BOG recovery plant might not be mandatory provided that it doesn't result in continuous flaring/venting for the installation.

The BOG shall be safely managed through reliquefaction, use as fuel gas, vapour return to LNG carriers (or FSRU, FSU), recompression to fuel gas or feed gas, or — as a last resort — flaring or release to the atmosphere.

The BOG recovery plant generally comprises:

— boil-off collection pipe-work;

— system(s) of gas transfer to/from the LNG carrier;

— boil-off gas compressors;

— boil-off recovery systems as listed in 10.4;

— over-pressure protection instrumentation, safeguarding and relief systems.

10.2 BOG collection system

The BOG collection system shall be designed such that no direct emission of cold gas into the atmosphere can arise during normal operation. The system shall be designed for at least the following:

a) boil off of tanks and all receivers containing LNG;

b) degassing systems of piping and equipment containing LNG;

c) gas displaced from/to a LNG carrier during (un)loading operation.

The BOG collection system shall be designed applying the same sizing rules as those defined in Clause 11. The constituent materials shall have cryogenic properties (the boil-off gases can reach temperatures close to or below −160 °C).

The different pressure levels that can appear on BOG collection system and gas systems shall be properly segregated.

Valved drain points, connected to the drain system, shall be installed at low points of all main lines or flare lines if any (upstream of flare knock out drum). The connections between the tanks and BOG collection system are recommended with valving and instrumentation enabling isolation of individual tanks.

The various reference flow rates which shall be taken into account for sizing the boil-off collection system and the pressure relief valves are defined in Annex C.

10.3 System of gas return to LNGC or to FLNG facility

The gas return system connects the boil-off collection systems from both floating LNG installation and LNG carrier, e.g. via a dedicated vapour return system.

The gas return system shall provide for the transfer of gas from the tanks to the LNGC carrier or reverse, in order to compensate for the volume of liquid displaced during unloading or loading, and the collection of boil-off from the tanker while it is moored to the floating LNG installation.

If necessary, blower or booster compressor can be used.

The pipes shall have the same characteristics as those of the BOG collection systems.

10.4 Boil-off gas recovery

The BOG shall be either:

— reliquefied;

— recondensed in the LNG send out prior to vaporization;

— used as fuel gas;

— compressed and sent to gas network or to feed gas; or

— temporarily and to a limited extent stored in LNG storage tank in accordance with LNG storage tank design pressure.

In FLNG facilities, the BOG is usually compressed and used as fuel gas, while FSRU facilities usually mix the compressed BOG with the natural gas sent out or oxidized in gas combustion unit. Oxidization in gas combustion unit shall only be used when no other possible solutions are available and shall not be a preferred solution neither a recommended design for normal operation.

FSU facilities typically require BOG recovery and management via onshore facilities.

10.5 Gas compressor

The gas compressor shall be equipped with:

a) systems to limit the pressure downstream to avoid the risk of exceeding the maximum design pressure of the equipment that is installed downstream;

b) a shutdown sequence either manually or automatically initiated, which enables them to be isolated in the event of serious damage.

Adequate ventilation shall be provided in any space of a gas compressor, such as the crankcase, that can become over-pressurized.

Vents shall be led to a safe area.

10.6 Flare/vent

See 5.4.5.1.3 for flare/vent requirements.

11 Low temperature pipework

11.1 General

This clause provides requirements for low temperature pipework related to the gas processing, vaporization and liquefaction of floating LNG installations.

11.2 Piping components

11.2.1 General

The materials of construction for pipes and accessories shall be chosen according to the conditions of use. Examples of these materials are given in ISO 16903.

Two cases shall be considered:

1) materials in permanent or occasional contact with LNG;

2) materials in accidental contact with LNG due to a leakage or spillage of LNG.

In the first case, the materials shall have cryogenic properties so there is no risk of brittleness due to the temperature of the LNG. In the second case, according to the results of the risk assessment (see Clause 5), special precautions shall be taken (e.g. use of cryogenic materials, insulation with a suitable material).

In order to improve fire resistance process, pipe-work that can be exposed to fire or heat shall not be fabricated from material with a melting point lower than steel. The fire exposed piping can exist in areas where spilled hydrocarbon could collect or accumulate and be on fire, or subject to a jet fire, following an accident or a hydrocarbon release.

For LNG or cold gas pipes, arrangements shall be made to prevent:

a) any differential contractions sufficient to cause deformation, jamming of moving parts, alignment defects, etc.;

b) icing up of components in contact with the atmosphere; if this phenomenon cannot be avoided, the weight of accumulated ice shall be considered for the calculation of supports.

Positive isolation shall be provided where it is necessary to protect personnel undertaking internal inspection or maintenance of equipment. This can be in the form of a removable spool piece or a spectacle blind or spade and spacer.

11.3 Pipe

11.3.1 General

Piping shall be in accordance with recognized codes and standards, such as ASME B31.3 or EN 13480.

Piping interfaces between topsides and hull areas shall be clearly identified. Design conditions compatibility shall be carefully checked and ensured in any case.

11.3.2 Pipe joints

Joints between pipes made by welding shall be in accordance with the following specifications:

a) exclusive use of filler metals approved and recognized for the use;

b) welding according to a procedure in accordance with ISO 15614-1;

c) use of welders and/or operators qualified according to the ISO 9606 series;

d) inspection before, during and after welding in accordance with ISO 9712.

Welding of different pipe materials shall be made with special care, especially with regard to thermal stresses arising from differential contraction and electrochemical corrosion.

Flange joints are potential sources of leaks and therefore shall be limited to a minimum in particular for maintenance operations. If these types of junctions are used, special precautions shall be taken when the bolts are tightened. More particularly, for cryogenic services, precautions shall be taken to prevent leakage during cooldown (e.g. bolt pre-tensioning, spring washers).

Flanges and gaskets shall be in accordance with recognized standards compatible with the piping design code.

11.3.3 Pipe supports

The support shall permit the movement of the pipe due to thermal contraction or expansion without exceeding allowable stresses. The support design shall suit this function and shall prevent any cold bridge between the pipe and the structure on which it is resting or from which it is hanging.

The design of the supports and related piping shall consider the loads cases as defined in 4.2.7.

11.3.4 Compensation of contractions due to cold

All piping systems shall be subject to stress analysis using recognized piping codes.

Special measures shall be taken into account to absorb dimensional variations of pipes linked with changes of temperatures (e.g. expansion loops, hinge type compensators capable of oscillating about its longitudinal axis [circa 5°], hinged systems).

It is recommended that bellows expansion joints be avoided.

Special care should be taken for small branch connections to headers to avoid any rupture or buckling of the main headers where these have thin walls, due to the application of external loads.

11.3.5 Differential displacement between offshore structures

All piping systems design shall consider differential displacements between marine structures. Marine structures might be relatively flexible under normal operating conditions, deflecting under wind, current, or wave loads. Extreme environmental conditions (e.g. storm or tsunami) as well as seismic displacements, shall be considered.

11.4 Valves

Valves shall be designed, manufactured and tested in accordance with recognized codes and standards, such as API/ANSI standards or ISO 28921, taking into account the following:

a) cryogenic valves shall be capable of operating even in the presence of ice;

b) in-line split body valves should not be used in cryogenic services;

c) valves to be installed in cryogenic hydrocarbon and toxic systems should have butt-welded ends;

d) cryogenic and high temperature welded valves should be designed to enable the maintenance of the internal components without removal of the valve body from the line;

e) valves in hydrocarbon service shall be fire safe in accordance with ISO 10497.

The number of valves should be limited to reduce the potential for leakage. Consideration shall be given to the following:

a) requirements for sectional depressurization of pipe and equipment systems;

b) safe isolation of LNG or any hazardous fluid sources or specific equipment or tankage;

c) limitation of the volume of LNG or any hazardous fluid spilt in the event of a leak.

ESD valves for equipment shall be located as close as possible to the equipment. ESD valves should not be used as a part of process control system. ESD valves shall be fail-safe with pneumatic or hydraulic actuators. Preference is given to fail-safe position spring return actuators. If this type is not possible, local accumulators sized for 3 single operations shall be provided. If the ESD valves are not fail-safe, actuators and aboveground connecting devices and cables shall be fire proofed (e.g. at 1 100 °C during the time needed to implement ESD, see 5.4.5.1.2).

The ESD valves stroke time shall be compatible with the assumptions made during the hazard assessment (see Clause 5). The designer shall ensure that any actions, for example due to hydraulic pressure hammer (surges) on the tank or equipment nozzles caused by closing of the ESD valves shall be kept in acceptable limits.

Cryogenic extended bonnet valves shall be installed with the stem in the vertical upwards position or within 45° of vertical. Before installation in any other position, it shall be verified and tested to show in the foreseen position that the valve design does not present any risk of leakage or seizure. This requirement does not apply to small bore instrument isolating valves.

11.4.1 Relief valves

Relief valves should be normally installed un-insulated.

Relief valves shall be sized in accordance with the ISO 4126 series or alternatively API Std 520 and API Std 521 including the formulae for heat input from fires.

Thermal relief valves for the protection of equipment, piping and hoses from over-pressure resulting from ambient heat input to blocked in LNG or other refrigerated light hydrocarbon liquids shall be installed. They are required where the pressure of the fluid at the maximum ambient temperature including that obtained as the result of solar radiation can exceed the design pressure, at least in the following locations:

a) any volume of piping or equipment containing liquid within the section limits of the process plant;

b) any volume of piping or equipment capable of isolation in particular all sections pipe between two valves where LNG or cold gas (if the achievable pressure in blocked-in scenario exceeds the line design pressure) risks being trapped in process areas.

The discharge of the relief valves is defined in 5.4.5.1.1.

When relief valves can be isolated from the equipment and/or system that they are protecting, special provisions shall be implemented to ensure that the pressure in the equipment and/or system is continuously monitored and controlled in case of isolation valve closure. These provisions can be:

— interlocked valves in case of several relief valves;

— locked or sealed valves with safety management system;

— special working procedure under safety permit system.

11.5 Thermal insulation

11.5.1 General

The quality and type of insulation materials shall be determined in accordance with the following requirements:

a) their degree of flammability and gas absorption;

b) sensitivity of the insulation materials to moisture;

c) large temperature gradients;

d) low temperatures.

The features of the insulating materials shall be provided in accordance with the relevant codes and standards.

Low chloride content insulation shall be used to avoid corrosion of stainless steel.

11.5.2 Piping insulation

Piping systems shall be insulated, where required, to:

a) minimize energy consumption;

b) provide protection against condensation and/or frost;

c) protect employees.

Insulation can be provided by applying:

— an insulating material;

— a vapour barrier, for cold piping, to prevent ingress of moist air leading to condensation and freezing of water vapour;

— mechanical/weather protection, which can also ensure fire resistance where required according to 11.5.3.

When insulation is put into place, precautions shall be taken at:

a) flanges, in order to provide enough space for the bolts to be satisfactorily tightened and removed;

b) moving parts of piping;

c) pipe supports and hangers.

Insulation should not be put into place before proof test of the piping.

Consideration should be given to shop pre-insulated pipe work.

11.5.3 Fire behaviour

When designing multi-component insulation systems, the fire behaviour of all components, including mastic, sealants, vapour barriers and adhesives, shall be proved and documented to ensure that the system will not cause the fire to spread and any vapours emitted will not cause an unacceptable risk of toxicity.

11.5.4 Gas absorption

For safety reasons, porous insulation products likely to absorb gaseous methane shall be avoided.

11.5.5 Moisture resistance

Moisture present in insulation systems very quickly impairs the performance of the insulation materials. Water can penetrate into an insulation material either in the liquid state or as water vapour which condenses within the insulation material.

Some insulation materials are waterproof to a certain extent, but most of them are permeable to gases and thus to water vapour. To avoid water vapour ingress, an efficient vapour barrier shall be provided and placed around the insulation material, except when the insulation is itself water vapour tight.

11.5.6 Differential movements

A water vapour tight insulation system should be achieved. This system shall be designed to remain gas tight even after undergoing the anticipated differential movements between the pipe and the various products that make up the insulation system (including the vapour barrier(s), coatings, cell fillers, metal jackets).

The joints, mostly contraction joints, shall be designed to resist differential movement cycles in relation to both internal and external temperature variations.

The thickness of each insulation layer shall, if necessary, be limited in order to reduce the shear stresses due to the temperature gradient between the warm and the cold side, to a value less than the maximum acceptable shear stress, whilst taking into account a safety factor.

11.5.7 Thickness determination

Thickness should be calculated in accordance with ISO 12241, taking into account the following provisions:

a) safety (sizing of the over-pressure valves);

b) boil-off limitation, which is determined for reasons as cost, sizing of the gas treatment equipment (re-condensers, disposal flares/vents), and control of surface condensation.

Consequences of condensation can be:

— In temperate or cold zones: outside surface condensation can turn into ice, which can lead to premature ageing of the vapour barriers or protective coatings.

— In humid regions: a large quantity of condensation can cause corrosion and has a negative influence on plant, algae and micro-organism proliferation, which in turn would accelerate ageing of the vapour barriers or external coatings.

Alternative methods for thickness calculation can be acceptable. In this case, the designer shall justify that the method proposed is validated.

11.6 Prevention of zinc contamination of austenitic steel

Galvanized surfaces should be located so as to avoid the possibility of molten zinc contaminating austenitic stainless steel piping and equipment in the event of a fire possibly leading to brittle fracture or rapid failure.

Attention should be paid to the installation of zinc and aluminium above unprotected steel and copper systems. If aluminium or zinc is heated for a long time with a steel or copper object, that object can develop pits or holes from alloying during future operation. This phenomenon will not be instantaneous, but will affect the integrity of the plant in future operation.

12 Utilities systems

12.1 Classification of systems

12.1.1 Essential services

Non availability of essential power can cause precautionary demanning, personnel discomfort, interruption of non-safety operational activities, loss of business communications, delay of production restoration, malfunction of process, damage to equipment, etc.

When defined as required by the user, the essential source of electrical power shall supply those services that are needed to maintain the installation in a defined state of readiness and habitation for a period defined by the user (typically measured in days) for situations other than normal (production) operation and without recourse to the emergency source of power except than in an emergency situation.

The minimum services that should be supplied by the essential source of power are:

a) minimum comfortable conditions of habitability;

b) maintaining control and safety systems and stored energy for these in a fully charged condition;

c) machinery space ventilation;

d) navigation, steering or manoeuvring of the floating LNG installation, when required;

e) main generator gas turbine auxiliaries, if relevant;

f) instrument air compressors;

g) other services as required by the appropriate authority.

The provision of essential power is more likely on large manned facilities, on far from shore manned facilities, on manned facilities on which the main source of power is a single imported power cable connection, or on facilities where the main generating sets are unsuited to operation outside normal production conditions (e.g. due to lack of fuel flexibility or excessive starting time), or where the restart power requirements are too large to be supported by the emergency source of power. Dedicated essential power generation may not be required for units equipped with main generating sets capable of running on diesel and that can start quickly in case of upset (e.g. dual fuel gas engines).

12.1.2 Emergency services

The emergency services are the services considered mandatory and safety oriented in case of emergency, also taking into account the process facilities.

The list of emergency services shall be as defined in codes (e.g. SOLAS/MODU code) with in addition all services required to maintain process facilities integrity including:

a) process instrumented safeguarding systems;

b) F&G detection systems;

c) firefighting equipment;

d) compressors seals;

e) venting and flaring equipment;

f) emergency air compressors and cooling water pumps.

12.2 Electrical

12.2.1 Design and engineering principles

12.2.1.1 General

The electrical system design shall take into account:

a) safety of personnel;

b) operability and maintainability;

c) availability and reliability;

d) requirements of the user regarding the possibility for future expansion (if required) and maintenance.

12.2.1.2 Codes and standards

Electrical systems and equipment shall be designed and selected in accordance with the following codes and standards:

a) international convention for the safety of life at sea (SOLAS);

b) international code for the construction and equipment of ships carrying liquefied gases in bulk (IGC);

c) IALA O-139, Marking of offshore structures;

d) CAA CAP 437, Standards for offshore helicopter landing areas;

e) IEC 60092-502;

f) the IEC 61892 series.

If part or all of the facility is subject to Marine Classification Society rules, these shall apply.

12.2.1.3 Hazardous areas

Electrical equipment installed in hazardous areas shall demonstrate conformity to IEC standards (e.g. be IEC-Ex certified) and shall be selected and installed in accordance with IEC 60079-14. Equipment selection shall be appropriate to the zone, gas group and temperature class.

12.2.2 Electrical system design

12.2.2.1 General

Electrical loads shall be categorized as 'Normal' (i.e. there is no effect either on the safety or the safeguarding of the installation or equipment in case of main power generation failure), 'Essential' (see 12.1.1) or 'Emergency' (see 12.1.2).

Onshore and offshore parts of the floating LNG installation shall be treated in a different way considering location of power sources, redundancy of power sources, vulnerability of installation.

12.2.2.2 'Normal', 'Essential', 'Emergency' and UPS systems

12.2.2.2.1 Normal system

The normal power generation system shall supply continuously all the electrical loads and in particular users needed for the normal activities of production.

12.2.2.2.2 Essential system

Loads may be categorised as essential (e.g. required for restarting of the process facilities after main power generation shutdown). These loads comprise the utility facilities as well as some process facilities auxiliary loads.

The essential power generation system shall supply the utilities considered essential to guaranty the services for the people, all administration and accommodation buildings with necessary auxiliaries systems. All these loads are available when normal generation is stopped.

Typical utilities included in the essential system are:

— all living quarters/administrative area systems (e.g. water treatment, heating, sewage, galley);

— HVAC for living quarters and facilities;

— normal lighting, including process area;

— ballast pumps;

— cooling water pumps for essential services;

— air compressors and inert gas generator;

— equipment (auxiliaries) required for start-up of the main power generation.

The list of essential power generation system shall be revised and adjusted to the facility specificities and agreed between all parties.

The loads should be considered for the foreseen operating scenarios including transfer, towing of the vessel to the location and testing and pre-commissioning of equipment at the fabrication location.

12.2.2.2.3 Emergency system

The emergency system shall supply loads (e.g. control and safety systems) which are important for personnel safety, when essential power generation is not running. It can allow the evacuation of the facility and can be used to restart the normal generation.

The emergency power generation system shall be located in a dedicated safe area to prevent an accidental event resulting in the loss of both emergency and main power from the main power generation system. A specific protection shall be considered for the system integrity against fire or explosion events.

The emergency power generation system shall supply the loads with the required availability as defined in codes (e.g. SOLAS/MODU code). For a floating LNG installation they shall additionally supply the electrical power required to maintain process integrity. The typical list of emergency services is provided in 12.1.2. This list shall be revised and adjusted to the facility specificities and agreed between all parties.

12.2.2.2.4 UPS system

In case of electrical shutdown, a transitional power can cater some equipment in the meantime the essential generator or the emergency generator is starting. Duration of the UPS power supply shall be adjusted in accordance with the safety objectives. As a minimum, duration defined in IMO standards (i.e. SOLAS/MODU code) shall be considered.

The transitional power comes from UPS systems. These transitional sources of power prevent the shutdown of the electronic systems. The UPS system(s) shall serve the most critical elements used to control the orderly evacuation and/or abandon of the ship when normal, essential and emergency systems are out of service.

The UPS system(s) shall be provided and located in a dedicated safe area. The UPS system(s) can supply the following utilities:

— integrated control and safety system;

— power management system and the electrical control system;

— global maritime distress safety system fed from an independent and dedicated UPS;

— PAGA system;

— navigation aids system (fed from an independent and dedicated UPS);

— beacon lights;

— various uninterruptible control panels;

— various control systems;

— safety systems (e.g. F&G and ESD systems);

— escape lighting.

The list shall be revised and adjusted to the facility specificities and agreed between all parties.

12.2.2.3 Power supply system characteristics

The number of voltage levels shall be kept to a minimum, to achieve a robust, reliable and simple distribution system. The selection of voltage and frequency as well as the acceptable variations during normal operation and transient conditions are described in IEC 61892-1.

12.2.2.4 System earthing

System earthing shall be selected from the options in IEC 61892-2. System earthing shall reflect the operational practices of the facility owner. The IMO IGC Code requires IT earthing of submerged LNG cargo pump motors.

12.2.2.5 Sources of electrical power

The requirements for main and emergency power are described in IEC 61892-2.

If required, essential power generation shall:

a) have the ability to black-start via 2 independent systems (e.g. battery and compressed air) in the event of loss of main power generation;

b) provide black-start capability of the main power generation;

c) provide power to all essential consumers on the vessel during a prolonged main power generation plant shutdown and maintenance turnaround;

d) provide power to the essential consumers during the manned tow to the integration yard and production site;

e) provide power to consumers necessary to bring the process to a safe state;

f) provide early power during pre-commissioning.

Provisions shall be made for:

a) synchronisation of generators;

b) transfer of load between generators in different operating modes;

c) periodic load testing of the essential generators, including dead-bus closure, synchronization and loading.

The emergency power generation shall provide power to enable the start of the essential power generation (if provided) and transfer of load from the emergency generator without interruption to supply.

12.2.2.6 Protection

System protection shall be in accordance with IEC 61892-2.

For switchgear tested with an internal arc withstand time, the protection shall operate within the withstand time for the full range of arcing fault currents.

12.2.2.7 Control

Control of power generation and the electrical system shall be incorporated in the design, if required, and cover the expected operating modes and operational practices of the owner.

12.2.3 Design and selection of equipment and cables

12.2.3.1 General

Electrical equipment shall have a minimum ingress protection in accordance with IEC 61892-2.

All electrical equipment shall be selected according to the metocean and environmental conditions described in 4.2.4. Equipment and systems should have the ability to withstand the specified vessel motions (pitch, roll and heave), accelerations, deflections and vibrations.

With the exception of the general requirements for environmental conditions, electrical equipment shall be in accordance with IEC 61892-3.

12.2.3.2 Navigational aids system

The navigational aids system shall be in accordance with IALA O-139. Marking and lighting of the helicopter landing area and aviation obstacles shall be in accordance with ICAO CAP 437.

NOTE Additional temporary navigational aids can be required during towing of the facility.

12.2.3.3 Engineering and installation requirements

Engineering and installation of electrical equipment and cables shall be in accordance with IEC 61892-6.

12.2.3.4 Earthing and bonding

Equipment earthing and bonding shall be in accordance with IEC 61892-6.

If stray currents can be present or if impressed currents are used on loading and unloading systems (e.g. for cathodic protection), protective measures to prevent ignition, such as the use of insulating flanges, shall be taken.

12.2.3.5 Lightning protection

Lightning shall be designed in accordance with the IEC 62305 series.

High equipment such as flare, LQ, cranes, columns, turret or transfer systems shall be included in the design and installation of the lightning protection system.

12.2.3.6 Lighting

The lighting system shall be based on the following separation of the system in accordance with IEC 61892-2:

a) general lighting system supplied from the main source of electrical power;

b) emergency lighting system supplied from the emergency source of electrical power;

c) escape lighting system supplied from a battery backup source of electrical power.

12.3 Instrument air system

Air systems shall be designed so that, in the event of failure of one air compressor or other essential services, the air supply to such services can be maintained. The air system shall usually be provided with at least two air compressors, each capable of supplying the total requirement.

Instrument air supplies shall be guaranteed for the time interval needed to put the floating LNG facilities in a safe condition on failure of the main power source. If electrical power is required to meet this requirement, at least one compressor, capable of supplying the total requirements, should have its power supplied from an emergency power supply.

The instrument air system is to be independent of the service air systems.

12.4 Hydraulic systems

Hydraulic systems shall be designed so that, in the event of failure of one essential components, the hydraulic power supply to essential services can be maintained.

The hydraulic fluid shall have a flash point not lower than 150 °C. The hydraulic fluid shall be suitable for the entire service temperature range.

Safety valves shall be fitted to protect hydraulic installation against overpressure.

13 Process and safety control and monitoring systems

13.1 General description

The floating LNG installation control and monitoring systems shall enable as a minimum the operator to:

a) monitor and control gas/liquid processing, marine and utilities systems;

b) be rapidly and accurately informed about any incident that may lead to a hazardous situation;

c) monitor and control plant safety;

d) monitor and control of facilities access and egress ;

e) exchange information internally and externally under both normal and emergency conditions.

The main plant functions will be performed by:

— the process control system;

— the marine control system;

— the safety instrumented system;

— the F&G control system;

— the subsea control system (for offshore floating LNG installations only);

— the metering systems;

— the power management system;

— the access control system and the anti-intrusion system;

— the internal and external communication networks.

The safety instruments and F&G control systems shall be independent from the other systems.

13.2 Process control system

13.2.1 Principle

The process control system shall provide the operator with real time information to allow safe and efficient operation of the plant.

13.2.2 Process control system design

The control system shall have the appropriate reliability level according to the application. The control system shall be configured to defined position in case of failure (i.e. fail open, fail close or fail last position).

Failure of all or a part of the process control system shall not cause a hazard situation.

Provisions shall be taken to reduce the consequences of component failure (i.e. common mode failure). Possible provisions can be:

— splitting of process equipment with a same function between different processing modules;

— studying of consequences of a common mode failure, plant-wide or local;

— designing of data transmission routes to maximise the reliability; including having spare processing capacity and I/O modules available with the plant in full operation.

Location and design of the control systems and associated items shall be such that they can withstand specific hazardous events. In particular, the location of redundant cables and control system cabinets should be carefully studied to avoid cable and equipment impairment in the case a hazardous situation occur (e.g. fire).

Design reviews described in 5.4.3 shall be performed on control systems. The acceptance procedures shall include confirmation of the safe operation of the process control system during malfunction and failure mode.

Remotely controlled equipment shall be capable of being stopped locally in case of an emergency or malfunction.

The process control system shall indicate, store and/or print all information returned by the process control devices necessary for the safe and efficient operation of the plant. In order to analyse an incident, the system shall chronologically discriminate and store all information occurred during this time and all actions performing by the operator before and after the event.

The process control system design should present the operator with the optimum amount of data required for safe and efficient operation of the facility. The process control system shall prevent alarm overload in case of incident or a sudden state change.

13.3 Marine control system

The marine control system shall be in accordance with requirements set in international codes, such as SOLAS.

13.4 Interfaces floating LNG installation/onshore

At the highest level, the purpose of the floating LNG installation/onshore link is to transmit, without delay, a signal from one party to the other, i.e. ship to shore or vice versa.

The floating LNG installation/onshore interfaces, especially for the one located shore side, are described in ISO 28460 and SIGTTO recommendations.

13.5 Safety control system (safety instrumented and F&G control systems)

13.5.1 Principle

The safety control system shall be designed for detecting hazard situations and reducing their consequences. The safety control system shall have the following functions as a minimum:

a) oil mist detection;

b) gas detection (LNG, refrigerant gas, natural gas, nitrogen, CO_2, H_2 and oxygen as appropriate);

c) spillage detection;

d) fire detection (flame and/or smoke);

e) ESD activation from a central system and/or local ESD station;

f) monitoring, activation and control of safety devices;

g) monitoring and control of parameters to keep the installation in a safe situation.

All modifications of safety control system shall be performed in accordance with the safety management system.

13.5.2 ESD and safety actions

13.5.2.1 General description

General requirements for ESD and safety actions are provided in 5.4.5.1.2.

13.5.2.2 Interfaces between floating LNG installation and LPG/LNG carriers

The purpose of floating LNG installation/shuttle interfaces is to give offloading ESD signals to secure the transfers during offloading operation between the floating LNG installation and the LNG shuttle or LPG shuttle. Interfaces shall take into account ESD signals coming from the shuttle (e.g. HH cargo level, fire detection) to floating LNG installation and ESD signals coming from FLNG units (e.g. fire detection, process ESD) to shuttle. This interface shall be managed by an international recognized interface ship-to-shore technology.

Ship-to-shore recommendations for offloading ESD-1 and offloading ESD-2 initiation provided by SIGTTO are not strictly applicable for offshore transfer. In the offshore transfer scenario, the role of ESD initiation, which in the SIGTTO recommendation is performed by the terminal, shall be transferred to the floating LNG installation.

Manual activation of offloading ESD-1 and offloading ESD-2 shall be studied case by case on the basis of the risk assessment. Manual activation can be initiated by the shuttle and can also be available at the floating LNG installation side.

The function of the offloading ESD-1 is to safely initiate stop of the cargo transfer while avoiding the risk of generating potential excessive surge pressures in the pipework of the transfer system. The function of the offloading ESD-2 is to safely initiate a quick release of the fluid transfer lines with no risk of cargo spillages.

13.5.2.3 Ship-shore link or ship-ship link description

Ship-shore link systems have been in use almost universally in the LNG industry since the introduction of the SIGTTO recommendations and guidelines for linked ship/shore emergency shutdown of liquefied gas cargo transfer. See ISO 2860 and SIGGTO recommendations for further guidance on this matter.

13.5.3 System capabilities

13.5.3.1 Main functions

The safety control system shall:

a) initiate automatically the appropriate ESD actions in order to shutdown non-essential and electrical systems non-certified for use in Zone 1; manual activation of an ESD system is only permitted when fully justified by the hazard assessment with the approval of the appropriate authorities;

b) where appropriate, activate automatically the necessary protection equipment (e.g. active fire protection);

c) inform the process control system of ESD activation;

d) control visual and sound emergency communication devices defined in emergency plans (i.e. siren);

e) open gates/doors to allow access of emergency crew and staff evacuation, where required by emergency plans;

f) activate automatic depressurising sequence.

13.5.3.2 Process shutdown

Some equipment can have an individual process shutdown (PSD or ESD). Common process parameters can lead to a PSD or ESD of groups of equipment. This PSD or ESD may be activated by either process control system or the safety instrumented system.

13.5.3.3 Safety integrity levels

Since safety functions are designed to lead to a certain risk reduction, SIL can be assigned to them (see 5.4.3.4). The safety control system shall be designed and operated in accordance with the IEC 61511 series.

If SIL is applied (see 5.4.3.4), the ESD logic solver shall be SIL 3 or better.

13.6 Closed circuit TV

The system should integrate a CCTV system that monitors process areas and accesses which present a risk (as mentioned in hazard assessment).

Remote operated cameras should be installed for viewing all events which can occur in hazardous and unmanned areas. Under abnormal circumstances the operator should have the ability to use the CCTV system to analyse the situation.

The CCTV system shall be considered an emergency service and is connected to the UPS system. The system should automatically respond to alarms, and focus information presented on visual display units in the appropriate control room(s).

The CCTV system can also be used as monitoring tool for the security management.

13.7 Metering

13.7.1 Background

Metering can be required for fiscal, custody transfer or material balance purposes. The accuracy of the metering systems shall be sufficient for the purpose.

13.7.2 Cargo metering

Metering of the transferred cargo is generally conducted in accordance with local authorities requirements. Local authorities are usually relying on the following standards:

— ISO 4267;

— ISO 8943;

— ISO 13686;

— ISO 18132;

— EN 1776;

— GIIGNL LNG Custody Transfer Handbook;

— LNG sampling: AGA Report 5;

— SGMF Contractual guidelines — quantity and quality.

13.8 Communications

Internal transmission networks shall differentiate operation information (of process control system) from safety information (of safety control system). Internal transmission networks shall be made secure from external communication networks. No direct interface is recommended for manned plants.

The floating LNG installation should be provided with telecommunication systems which include:

a) radio for general facility communications and communication with lifeboat/man overboard boat;

b) CCTV monitoring (from the CCR) for general control of process;

c) telephones for general communication on facility plus lines to shore;

d) marine radio for routine communications with other vessels;

e) aeronautical radios for helicopter landing/take-off operations;

f) telecommunication to shore via satellite;

g) fibre optic systems.

An integrated PAGA system shall be provided for the broadcast of information throughout the vessel (speech and/or alarms), including topsides (all decks), turret, LQ and machinery spaces. Where the noise level is high, visual alarms (i.e. stroboscopic beacons) shall be used in replacement of PA system.

13.9 Environmental monitoring and control

Emissions (liquid effluents and gas) of the plant shall be monitored and unless more stringent local regulations applies, EHS guidelines (associated with MARPOL requirements when imposed by regulation) may be used in a preliminary approach.

Basel convention requirements should be applied for the management of solids and liquids wastes (see 5.3).

14 Security management

14.1 General

Access to certain areas (e.g. topsides, confined spaces, turret area) shall be controlled. Depending on the size and configuration of the plant, such control can be limited to process zones or extended to a wider area. Access control can be put into practice either by security guards or by using a physical device (e.g. lock, magnetic badge).

The access control procedure shall comply with local authorities requirements.

The measures to be implemented shall consider the following aspects:

a) country risk;

b) offshore or docked facilities;

c) surrounding facilities;

d) ship traffic in the vicinity of the facilities;

e) type of security threats (e.g. piracy, terrorism, protestors, refugees).

The philosophy for security management shall consider:

a) safeguard the safety of personnel on board;

b) contain personnel boarding the floating LNG installation and prevent access to LQ;

c) mitigate the consequence;

d) facilitate host country security forces.

14.2 Offshore access

Unauthorized access from the sea shall be prevented. Prevention measures (e.g. security guards) or automated detection systems (e.g. perimeter intrusion) shall be put in place to prevent intrusion prior enter of intruder in the facilities hazardous area.

Controlled access of pilot landing shall be enforced.

14.3 Onshore access

Access points for entering inside the facilities boundary (e.g. jetties, onshore control room) shall be controlled through separate, specially adapted barriers for vehicles and personnel. A minimum of two accesses shall be provided to facilitate access for firefighting and emergency vehicles. It should not be possible for unauthorized persons to gain access to the jetty area.

The minimum security requirements shall be in accordance with the IMO international ships and ports security code (ISPS Code).

When security arrangements restrict access, consideration should be given to means of emergency egress to a safe area.

15 Commissioning

15.1 General

Commissioning covers the project phase between construction completion and normal operations. Detailed planning of commissioning activities, resources, cost, systemization and schedule shall be performed before commissioning execution.

15.2 Systemization and schedule

At an early stage of the project, commissioning and operations personnel working together with process designers shall divide the floating LNG installation into commissioning systems to facilitate a phased commissioning and handover from the contractor to the operator using an integrated construction and commissioning schedule.

The commissioning systems shall be grouped to form handover packages, capable as far as possible of stand-alone operation to allow start-up and testing immediately on handover. The commissioning systems shall be aligned with the construction modules. Systems/sub-systems/test packs shall be used throughout the project development, from start of FEED.

For each commissioning system, all activities shall be broken up into tasks. Tasks shall be weighted, timed for duration, resource/manpower loaded and put into a logical sequence (based on dependencies). The logic shall then be translated into a resource loaded commissioning schedule for integration with the project schedule. In addition, all required temporary equipment to enable commissioning activities shall be identified.

The utilities CSU logic is critical, as basic utilities are required (e.g. instrument air, power) before pre-commissioning (e.g. loop testing) can start.

15.3 Implementation

Preparations for implementation of commissioning activities should commence during the FEED phase in order to define the high level CSU plan, cost and schedule.

The CSU plan shall include:

a) the commissioning contracting strategy;

b) definition of the completions process and associated database tool;

c) which activities will be executed during which completion phase and against which specification;

d) yard infrastructure support capabilities including requirements for temporary facilities as well as logistics;

e) commissioning part of the project' master document register;

f) information management information technology support requirements;

g) integration with upstream facilities;

h) commissioning organization and resource requirements;

i) inspection & test plan;

j) specialist services including external certification and/or validation requirements;

k) permits and consents.

The completions process shall define the subsequent phases each hardware system will go through, starting from construction completion, pre-commissioning, commissioning, early operations, and start-up and ramp-up as well as the corresponding milestone completion certificates and punch listing requirements. Once the completion process has been defined, the associated activities shall be mapped against the main assembly stages of the FLNG/FSRU: onshore (yard) — hull before integration, modules before integration, hull + modules post integration, tow, offshore — mooring and hook-up, commissioning and start-up. Table 10 provides a typical activity breakdown per completion phase.

Table 10 — Typical activity breakdown per completion phase

Construction completion	Pre-commissioning	Commissioning	Start-up and ramp-up
Static equipment checks and equipment SAT Rotating equipment checks and equipment SAT Equipment cold alignment Piping pressure testing Piping flushing and reinstatement Instrument system SAT, pre-calibration, Megger testing, etc. Electrical system SAT, Megger testing cables, circuit breaker testing, etc. Preservation, lubrication, etc.	Catalyst loading and vessel box up Flushing of lube oil/ seal oil systems Chemical cleaning, pipe cleaning, air blowing of system, etc. Final reinstatement, bolt torqueing and bolt tensioning Instrument loop checks, DCS/ESD/F&G system testing, valve stroke test Relief valve calibration and installation, Electrical energization testing, uncoupled motor bump test Preservation, lubrication, etc.	Functional testing of process equipment and instrumentation Steam boiler boil out and steam blowing Tightness testing (leak test) Inerting Electrical equipment functional testing Utility systems and equipment testing and preservation or put in service Testing of accommodation facilities Tank testing including gas trials	Start-up of inlet facilities and gas treating units Defrost liquefaction units Start-up refrigerant compressors Pre-cool down and final cool down of liquefaction units Ramp up production Load first cargo Performance test

As part of the project specification, the CSU cost shall be defined. The CSU cost shall be divided in EPC and/or contractor/yard cost and owner's cost. The CSU cost shall include man power, specialist services contracts, vendor support, temporary facilities and consumables/utilities.

15.4 Safety

In order to ensure safety during commissioning, a commissioning safety plan shall be developed and implemented. The commissioning safety plan shall include, but not limited to:

a) Hazards of the commissioning activities shall be identified in advance as well as the required mitigations to control the associated risks. The mitigations shall be incorporated in the commissioning procedures and method statements/job cards.

b) A commissioning permit to work system shall be implemented to cover all activities that should be performed within commissioning areas.

c) A simultaneous operations plan shall be put in place covering coinciding construction and commissioning activities.

d) All staff required to work inside commissioning areas shall undergo commissioning safety induction.

e) Any temporary facilities that are required to be connected to permanent FLNG/FSRU systems (e.g. for utility supply) shall be subjected to similar engineering review as the base FLNG/FSRU design.

f) Frequent safety surveillance and monitoring of commissioning activities shall be performed. Any incident shall be investigated and associated findings shall be implemented to prevent recurrence.

g) Assurance of the technical integrity of the hardware scope to prevent equipment failures by for example conformance with engineering & manufacturing standards, quality control inspections and certification, staff training and certification, and preservation programs.

h) Management of change procedure.

Once control of the floating LNG installation safety management has been handed over to the owner's organization, its HSE management system will apply.

15.5 Organization

The commissioning organization includes the owner's CSU team, the contractor and/or yard commissioning team as well as specialist contractors and vendor service engineers. The roles and responsibilities of each team within the commissioning organization shall be defined in the contract.

The ramp-up of these teams shall be aligned with the CSU schedule.

15.6 Handover

The FSRU handover philosophy can be aligned with the handover process applied for LNG carriers.

The FLNG handover philosophy shall take into account the additional utility and process system hardware scope as well as offshore hook-up and commissioning activities. Therefore, it can be considered for the owner's team to accept care and control responsibility for those systems and facilities that have been commissioned onshore before commencing the tow, whilst the contractor retains custody. The remaining systems shall be handed over offshore before the FLNG is declared ready for start-up and gas is introduced.

Before sign-off of the ready for start-up certificate, the readiness of the FLNG as well as the owner and contractor organizations to commence start-up activities shall be verified.

Project handover scope additional to the FLNG/FSRU includes amongst others documentation, movables, spares, IT systems, contracts. It is essential that the total scope is grouped into blocks that are handed over at a limited number of major project milestones.

15.7 Start-up and performance test

After successful onshore and offshore commissioning including tank testing, start-up of the facility can commence to introduce feed gas after achieving the facility ready for start-up milestone. Since the start-up will be the first time that production will commence a number of tests to verify functionality on actual process conditions shall be incorporated in the start-up activity list and schedule.

16 Inspection and maintenance

16.1 General

The floating LNG installation is subject to inspection and maintenance plan.

The FSRU installation shall normally at least comply with RCS rules for inspection and maintenance. The principles of ISO 19904-1 may also be considered.

The FLNG installation shall follow the principles for inspection and maintenance in ISO 19904-1.

16.2 Specific requirements for floating LNG installations

16.2.1 Cargo tank

As defined in ISO 19904-1:2019, which specifies minimum requirements for the type of inspection and the frequency, all LNG tanks shall be subject to internal inspections every 5 years. Alternatively, a risk-based inspection may be acceptable if it is accepted by all interested parties (owner/cargo tank and inside tank equipment designers/classification society and authorities). In this case, an initial maintenance plan for tanks visits and testing shall be developed and agreed between owner/cargo tank and inside tank equipment designers/classification society and authorities through a risk-based inspection program.

According to the results of cargo tanks and inside tank equipment continuous monitoring, tests and planned visits, the initial maintenance plan shall be adapted with agreement of all stakeholders throughout the floating LNG installation life.

The maintenance plan shall be typically reviewed on an annual basis. In case of an abnormal event relative to a cargo tank or inside equipment or tank surrounding environment, this maintenance plan may be adapted immediately.

Consideration should be paid to the maintenance of equipment or instrumentation inside the LNG storage, such cargo pumps where fixe type or retractable type can be selected.

The commissioning and decommissioning of one or two LNG storages may be required while others are in service for maintenance, inspection or tests. So, the segregation of the LNG tanks shall be possible with the required level of safety.

16.2.2 Mooring

In-service inspection, monitoring and maintenance of moorings systems shall be in accordance with ISO 19901-7.

16.2.3 Process piping systems

Process piping systems shall be included in the facility maintenance system to record maintenance and inspection plans including corresponding results. Frequency and tasks are based on local regulations, industry experience and identified risks. Due to the humid environment, there is a potential risk of corrosion under insulation, especially in combination with temperature cycles. .

16.2.4 Transfer systems

Requirements for inspection and maintenance for transfer systems shall be included in the facility maintenance system to record maintenance and inspection plans including corresponding results. The requirements shall be at least complying with transfer systems manufacturer recommendations.

17 Preservation and corrosion protection

17.1 Specific requirements for non-seagoing vessels

Considerations shall be given to fixed location operation compared to sea going vessels.

17.2 Painting and coating

Metal surfaces subject to corrosion shall be protected. Concrete structures may also be painted to protect them from wear and tear.

Surface preparation, paint systems and application of coatings to steel structures shall be in accordance with the ISO 12944 series.

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

High quality hot-dip galvanizing in accordance with ISO 1460 and ISO 1461 is required on all platforms and platform support steel work, stairway and handrail assemblies, ladder side rails and cages, plates, stair treads and open grid flooring, etc., unless impracticable. Tubular sections shall be galvanized internally and externally.

Galvanized surfaces may normally be left unpainted, except for marine environment for which additional painting is recommended. Galvanized metal jackets used to cover insulation of piping or equipment can receive further anticorrosion coating. For zinc contamination of austenitic stainless steel, provisions in case of fire should be considered.

For safety reasons, all equipment and piping in LNG installations shall have a specific colour or marking for identification of the contents.

All painting, galvanizing, colour coding and marking shall be designed and executed in accordance with local rules.

17.3 Cathodic protection

All underground/subsea metallic parts should be protected where necessary against corrosion using appropriate coating and/or cathodic protection in accordance with the relevant codes and standards, such as ISO 13174.

17.4 Impact of use of seawater as heating medium and active fire protection

The design of the facilities shall consider a proper drainage of the seawater used for active fire protection systems to avoid remaining water on certain location of the facilities (e.g. after fire systems testing), which can generate moisture ingress and corrosion.

The material selection for fire water piping and deluge systems shall be such that no detrimental corrosion can occur which would invalidate the proper functioning of the fire water deluge systems.

Material selection of piping systems intended to contain seawater (e.g. seawater piping for regasification or for active fire protection) shall consider the corrosive effect of seawater

18 Preparation for operations

Operational considerations shall be taken into account in the design. Operational procedures are outside of the scope of this document. For further guidance on these matters, reference is made to:

— SIGTTO, Liquefied gas handling principles on ships and terminals;

— OCIMF, Safe transfer of liquefied gases in offshore environment.

For reliability management and associated reliability and availability analysis and data, guidance is provided in ISO 20815, and ISO/TR 12489.

19 Specific requirements for conversion of existing installations to floating LNG installations

For a converted unit, an assessment of the status of existing installation prior to the start of the conversion shall be performed. The assessment shall be based on conditions at the intended area of operation and the new mode of operation. This assessment shall include:

a) condition of existing structural items and need for steel replacement;

b) need for coating upgrade to accommodate any anticipated increase in corrosion;

c) consideration of fatigue and corrosion conditions at intended location and necessary upgrade;

d) lifetime consideration also considering intended inspection/repair and maintenance possibilities and philosophy;

e) need for additional structure and reinforcement to accommodate additional topside plant;

f) suitability of existing containment system where sloshing loads can be anticipated;

g) consideration of additional isolation in the cargo handling system where it is intended to continue production while tank inspection is underway;

h) consideration of adequacy of existing marine systems for the new application;

i) consideration of need for modification and increased capacity of the power generation system;

j) consideration of effects of new area classification on existing potential ignition sources;

k) consideration of whether new accidental loads will require modifications to existing hull and systems;

l) consideration of need for modification to accommodate inspection in situ of the hull or marine systems;

m) consideration of how the converted unit will be moored for long term location at one location;

n) awareness of additional regulatory requirements at area of operation.

In general, existing items which will remain in place may follow their original design code/rule requirements provided that they are not directly influenced by either the provision of additional structure or plant and machinery or directly affected by the new mode of operation.

Any items installed as part of the conversion should meet the most updated edition of the relevant code/standard/rules.

Annex A
(informative)

Risk-based analysis

A.1 Thermal radiation threshold values

A.1.1 Thermal radiation thresholds to human vulnerability

As per OGP Guidelines “Vulnerability of humans”, Report No. 434-14.1, March 2010, the thermal radiation threshold values and associated human vulnerability can be selected per Table A.1.

Table A.1 — Thermal radiation threshold values and associated human vulnerability

Thermal radiation [kW/m^2]	**Effect**
Direct impact on human	
35	Immediate fatality (100 % lethality)
20	Incapacitation, leading to fatality unless rescue is effected quickly
12,5	Significant chance of fatality for medium duration exposure *Extreme pain within 20 s; movement to shelter is instinctive; fatality if escape is not possible.* *Outdoors/offshore: 70 % lethality* *Indoors onshore: 30 % lethality* *People indoors are only vulnerable if they have line-of-sight exposure to thermal radiation, hence a lower lethality than for people outdoors*
>6	Pain within approximately 10 seconds; rapid escape only is possible *This threshold is considered as the value for which the escape routes become impaired due to impossibility for people to use them without being severely injured.*
4<5	Less than 5 will cause pain in 15 to 20 seconds and injury after 30 seconds’ exposure *Impairment due to impossibility for people to muster in these areas without being severely injured*
2	Minimum to cause pain after 1 minute
1,2	Received from the sun at noon in summer

A.1.2 Thermal radiation thresholds to human vulnerability

For damages to equipment, reference is made to OGP Guidelines “Vulnerability of plant/structure”, Report No. 434-15, March 2010 which provides first guess values for various assets. This OGP report provides only indicative values. They should be adjusted on a case-by-case basis as the time to equipment collapse when exposed to a fire is dependent on several factors. These factors are the following (extract from OGP report):

— the fire scenario or design fire;

— heat flow characteristics from the fire to the plant/structure;

— the behaviour of material properties of the plant/structure at elevated temperatures;

— the properties of fire protection systems.

In addition, behaviour of the process assets in case of fire will also depend, in particular on:

— the phase, inventory and pressure of the fluids they handle;

— the characteristics and efficiency of the pressure relief system and blowdown system (if any).

A.2 Overpressure threshold values

A.2.1 Overpressure thresholds to human vulnerability

As per OGP Guidelines “Vulnerability of humans”, Report No. 434-14.1, March 2010, the overpressure threshold values and associated human vulnerability can be selected as per Table A.2.

Table A.2 — Overpressure threshold values and associated human vulnerability

Over-pressure [bar]	Effect
Onshore, outdoors and in the open	
0,35	15 % lethality for people outdoors, in the open
0,5	50 % lethality for people outdoors, in the open
Onshore, outdoors but adjacent to buildings or in unprotected structures	
0,35	30 % lethality for people outdoors
0,5	100 % lethality for people outdoors
Onshore and offshore, indoor	
Depending on building type and resistance	
Offshore	
>0,2 to 0,3	100 % lethality for personnel in the module where the explosion occurs
>0,2 to 0,3	100 % lethality in adjacent modules if the intervening partition (wall or deck) is destroyed by the explosion.

A.2.2 Overpressure thresholds to assets vulnerability

For damages to assets, reference is made to OGP Guidelines “Vulnerability of plant/structure”, Report No. 434-15, March 2010 which provides first guess values for various assets. The values presented in this OGP report are only indicative and should be adjusted taking into account various elements, such as actual shape of the assets or refined overpressure values — pulse durations couples.

A.3 Cryogenic effect threshold values

A.3.1 Cryogenic thresholds to human vulnerability

For people, typical criteria are the following:

— immediate fatality when exposed to liquid cryogenic releases;

— immediate fatality when exposed to gaseous, 2-phase cryogenic releases with a temperature below a given criteria (criteria to be defined based on research and development).

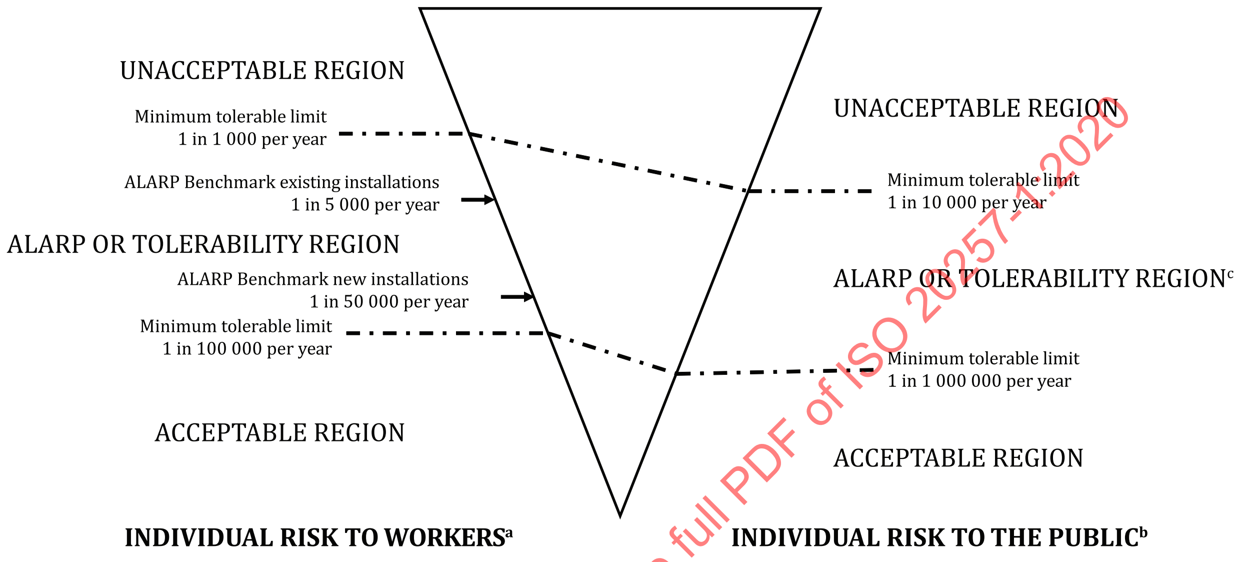
A.3.2 Cryogenic thresholds to asset vulnerability

For assets, material damages and embrittlement are directly linked to the considered material. For instance, it is generally considered that stainless steel and concrete-based materials are not as heavily impacted by cryogenic releases than regular steel-based materials.

The retained criteria shall be project-specific and shall be adjusted depending on material characteristics and behaviour when exposed to cryogenic releases.

A.4 Levels of risk

When no local regulations exist, in terms of individual risk per annum for humans (workers or the public), the criteria corresponding to widely accepted values as shown in Figure A.1 may be used:



Key

a including contractor employed

b all those not directly involved in organization's activities

c risk to be demonstrated to have been reduced to a level which is practicable with a view to cost/benefit

Figure A.1 — Levels of individual risks to workers and the public

A.5 Layout considerations

In addition to the layout considerations described in 5.4.5.2.1, the following should be duly considered:

a) The respective arrangement of interconnected process/storage units and of power generation/electrical consumers directly impacting the quantities of piping (and therefore the hazardous material inventories) or electrical equipment/cables which affect in turn the congestion/confinement of the modules/onshore units. As such, the arrangement of process and utility equipment should preferentially follow a logical sequence in order to reduce the piping and cabling pathways. The objective is to minimize hydrocarbon inventories.

b) The flare radiations contours and levels.

c) Vents and relief valves should be collected and discharged in a safe location to be located so as to cause minimum interference or hazard to plant and personnel.

d) Flares, incinerators, atmospheric vents and exhausts location and height should ensure that acceptable levels of radiation and pollutants concentrations are not exceeded in working and unrestricted areas of the plant as well as outside (i.e. LNG carrier or supply boats).

e) Approach, landing and take-off sectors for helicopters, supply vessel, tanker, etc. should be free of obstacles/live equipment.

f) The possibility of hazardous accumulations of both liquid and gaseous hydrocarbons should be minimized. Means for the rapid removal of any accumulations which do occur should be provided.

g) All basic design principles for minimizing dropped objects and collisions should be applied to layout.

h) Emergency equipment such as the emergency generator and firewater pumps should not be installed in unprotected and/or exposed areas. Therefore, firewater pumps should preferably be located in the hull.

i) The use of connections in pipes carrying flammable fluids should be minimized (i.e. reduction of flanged connections and instrumentation penetrations).

j) For cryogenic lines, use of welded connections should be preferred, compatibly with maintenance requirements.

k) Provision should be made for the safe berthing of carrier/supply boats, clear from other manoeuvring ships. The configuration of the berthing/mooring area should allow the ship to sail away in case of fire or emergency.

l) Wherever possible, plant and equipment containing flammable fluid should be located in the open. Maintenance and climatic conditions can affect this decision.

m) Enclosure may be considered to limit workers' exposure to noise.

Annex B
(informative)

Safety studies

B.1 Assumption register

A set of assumptions should be developed along with the performance of the safety studies. All the assumptions should be gathered to form an assumptions register that should be developed in the form of individual assumptions sheets covering specific aspects of the study.

The assumptions register should cover as a minimum:

a) detailed methodology for each study;

b) key assumptions and rule-sets;

c) consequence modelling assumptions including among others:

- the selected weather conditions (e.g. wind speed and direction, atmospheric stability, ambient temperature, relative humidity);
- the thermal properties and the topography of the ground including any impounding area;

d) principles to be used for the event/failure probabilities calculation;

e) impact/damage criteria for people and buildings (vulnerability model) regarding major accidental events in line with owner specifications and project criteria;

f) specific models used for the studies (e.g. commercial or in-house calculation tools, spreadsheets).

B.2 Failure case definition and release frequency analysis (process events)

B.2.1 General

The failure case definition and frequency analysis is the starting point for all the other project technical safety studies.

B.2.2 Failure case definition

The failure case identification aims at:

- identifying hazards in the facility;
- defining the failure cases for further risk quantification through identification of isolatable sections;
- identifying location, inventories, process conditions, stream compositions for each identified failure event, which will help define the rate and the duration of the leakage;

— assessing the consequences of flammable gas events:

  — main hazards: fire events, cryogenic releases, explosions, smoke and gas dispersions;

— other hazards:

  — rapid phase transition, which is the very fast evaporation of a cryogenic release usually after liquid/liquid contact (e.g. LNG and water);

  — secondary hazard, such as boiling liquid expanding vapour explosion;

  — loss of containment of the subsea items which can lead to sea surface fire, water ingress into the flow line, gas, chemicals, mono-ethylene glycol and condensates release into the sea, and then gas to atmosphere, ultimately surrounding the facility; released amount of gas can affect the buoyancy of the facility, potential major process upset due to gaseous/oily water at sea chest (impact to cooling, water system).

B.2.3 Frequency analysis

The QRA and safety studies considers uncontrolled (accidental) releases of fluids due to loss of containment leading to hazardous event (e.g. fire, explosion). The likelihood of loss of containment is determined using historical failure rate data for standard plant components (e.g. pumps, valves, flanges).

A part-count activity should be performed to determine the release frequency for each isolatable section defined in the failure case definition.

Methods that can be used to assess leak frequencies are provided in ISO/TS 16901.

B.3 Fire risk analysis

The purpose of the FRA is to address the fire scenarios and their consequences all over the facility. Potential jet and pool fire scenarios on the facility, from the risers, turret (if any), process (including offloading facilities) and non-process failure cases should be evaluated.

Calculation of the radiation caused by ignition of the vapour from a pool or jet of flammable product or flammable gas release should be carried out using appropriate validated models. The model should take into account:

a) area of the pool fire or the dimensions of the flame;

b) surface emissive power of the pool fire or of the flame (see ISO 16903);

c) ambient temperature, wind speed and relative humidity.

The model should enable the determination of the incident radiation at various distances and elevations.

The use of CFD fire simulation tool should be discussed on a case-by-case basis depending on the project phase and on the congestion/confinement of the facility (or part of it).

FRA results should be used to:

a) provide input to the QRA;

b) help identification of protection and mitigation measures for the protection of SECEs, such as primary structures, muster areas, LQ, escape means.

The approach conducted throughout this study helps identifying the areas requiring protection against fire events and will therefore constitute one of the bases for the passive fire protection recommendations.

B.4 Cryogenic spill risk analysis

The purpose of CSRA is to address the cryogenic scenarios and their consequence all over the facility. Potential liquid/spray cryogenic scenarios on the facility, from the liquefaction area, the offloading facilities and the storages should be evaluated.

The model should enable the determination of the cryogenic effect at various distances and elevations.

CSRA results should be used to:

a) provide input to the QRA;

b) help identification of protection and mitigation measures for the protection of safety and SECEs, such as primary structures, muster areas, LQ, administrative area, escape means.

The approach conducted throughout this study helps identifying the areas requiring protection against cryogenic events and will therefore constitute one of the bases for the cold spill protection recommendations.

B.5 Explosion risk analysis

The purpose of the ERA is to calculate the explosion dynamic pressure and blast overpressure levels and associated frequency on the facility and to recommend providing, if necessary, additional protective measures.

The ignition of natural gas can create in certain circumstances (e.g. congested areas) an explosion generating an overpressure wave. The flammability range of mixtures of gas and air is given in ISO 16903.

Recognized methods and models, for example the multi-energy method and/or deflagration at constant speed method which have been validated, can be used to calculate the overpressure. This overpressure should be specified where applicable for equipment, buildings and structures.

In offshore and onshore modularized environment where high congestion and confinement are expected on a limited area, recognized CFD software/approach should be used to properly assess the flammable gas cloud build-up, the flammable volume/mass that can take part to an explosion event and the resulting maximum overpressure in near-field in the case an ignition occur. Then, the approach/software used in near-field may be coupled with other approaches (e.g. multi-energy method) to deduce overpressure levels in far-field.

Where overpressure on a tank, equipment item, building or structure is specified, it should always be the incoming wave characteristics. In this case, it may be assumed that a deflagrating explosion near the tank gives rise to an overpressure that is applied, as a worst case assumption, to a half perimeter of the tank. The stresses in the tank caused by over pressure should be determined by dynamic calculation. For the other structures, the stresses may be determined by static calculation.

The effect of potential overpressure under elevated tank basis due to the ignition of a flammable mixture under the tank should be considered.

The effects of wave reflection on the objects should be the responsibility of the supplier.

ERA results should be used to:

a) provide input to the QRA;

b) help identification of protection and mitigation measures for the protection of SECEs, such as primary structures, muster areas, LQ, escape means.

The approach conducted throughout this study helps identifying the areas requiring protection against explosions and will therefore constitute one of the bases for the blast design recommendations.

B.6 Smoke and gas dispersion analysis

A smoke and gas dispersion analysis is performed with following objectives:

— to address the potential for smoke dispersion hazards generated by fire events and their effects on the impairment of escape routes (visibility and breathable atmosphere), embarkation areas, LQ, HVAC systems, etc.;

— to quantify the extent of atmospheric dispersion of accidental asphyxiating gases, if relevant;

— to address the potential for gas dispersion hazards generated by un-ignited events and their effects on the impairment of escape routes (in particular visibility due to condensation of humidity), embarkation areas, LQ, HVAC systems, etc.

The use of CFD simulation tool should be discussed on a case-by-case basis depending on the project phase and on the congestion/confinement of the facility (or part of it).

Gas generation and dispersion should be modelled considering:

a) Evaporation of spilled LNG/LPG/vaporizing liquid

The phenomenon of instantaneous vaporization (flash, including possible aerosol formation) should be taken into account.

Calculation of evaporation due to heat transfer should be carried out using appropriate validated models. The model should take into account:

— stream flow rate and duration;

— stream composition;

— nature of the ground (e.g. thermal conductivity, specific heat, density);

— temperature of the ground or of the water;

— atmospheric conditions (ambient temperature, humidity, wind velocity);

— atmospheric stability or temperature gradient.

The model used to assess the evaporation flowrate should enable to determine:

— pool propagation speed;

— wetted area in terms of time, and, in particular, the maximum wetted surface;

— rate of evaporation in terms of time and, in particular, the maximum evaporation rate.

b) Atmospheric dispersion of vapours

Calculation of the atmospheric dispersion of the cloud resulting from evaporation of vaporizing liquid due to flashing and evaporation when in contact with the ground or water should be carried out using appropriate validated models.

The determination of dispersion should, as a minimum, take into account:

— the dimensions (expressed by an actual dimensions or equivalent diameter) of the evaporating pool;

— the evaporation rate;

— properties of the vapour;

— the nature of the ground (e.g. thermal conductivity, specific heat, density);

— the temperature of the ground or water;

— the atmospheric conditions (ambient temperature, humidity, wind speed);

— atmospheric stability or temperature gradient;

— site topography (e.g. surface roughness).

The model should enable to determine:

— concentration contours;

— the distance to the lower flammability/toxicity/anoxia limit.

c) Jet release of gases and 2-phase

Calculation of atmospheric dispersion resulting from jet release should be carried out using appropriate validated models to determine as minimum, the height or the distance reached by the jet and the concentration of gas at any given point.

Sources of jet releases should include releases from atmospheric safety valves, unignited flare and vents (see Clause 5). Where appropriate, possible aerosol formation should be considered.

B.7 Escape, evacuation and rescue analysis

An EERA for the facility should be carried out to ensure that the required adequate escape and evacuation facilities are identified and incorporated in the design and layout. The main objectives of the study are therefore to demonstrate that escape and evacuation means could be safely used and that POB could be rapidly rescued with respect to major accidental scenarios identified.

The EERA may include the temporary refuge impairment analysis, i.e. the analysis what will demonstrate that the temporary refuge/muster areas are adequately designed against MAE.

B.8 Emergency systems survivability analysis

The purpose of the ESSA is to check if the emergency systems are capable of fulfilling their designated role following a major accident, such as a fire, explosion, ship collision event, or if not, to recommend design modifications.

The ESSA should also evaluate the vulnerability and survivability of the emergency systems, which are identified as the critical systems having a major role in the control and mitigation of accidents and in any subsequent escape, evacuation and rescue activity, with respect to identified hazardous events.

All emergency control systems should be designed to remain operational for the duration they are required. These systems should be designed to achieve at least one of the following:

— fail-safe;

— be protected from the effects of the major accident scenarios to ensure their continued operation;

— have sufficient redundancy to minimize inoperability due to single component or single point failure.

B.9 Ship collision study

The ship collision accidental event is the possibility for a floating/fixed near shore/onshore unit to be impacted by a vessel. Depending on the type of collision, this accidental event can damage the hull and in return jeopardize the whole facility stability.

