



BSI Standards Publication

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

Part 1: General requirements

National foreword

This British Standard is the UK implementation of EN ISO 20257-1:2020. It is identical to ISO 20257-1:2020.

The UK participation in its preparation was entrusted to Technical Committee PSE/17/-/9, Liquefied Natural Gas (LNG) installations and equipment.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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English Version

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Design of floating LNG installations - Part 1: General
requirements (ISO 20257-1:2020, Corrected version 2020-
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Installations et équipements de gaz naturel liquéfié -
Conception des installations flottantes de GNL - Partie
1: Exigences générales (ISO 20257-1:2020, Version
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COMITÉ EUROPÉEN DE NORMALISATION
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CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

This document (EN ISO 20257-1:2020) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" in collaboration with Technical Committee CEN/TC 282 "Installation and equipment for LNG" the secretariat of which is held by AFNOR.

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Endorsement notice

The text of ISO 20257-1:2020, Corrected version 2020-10 has been approved by CEN as EN ISO 20257-1:2020 without any modification.

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Foreword

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

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

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
NO _x	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
SO _x	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 lives 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 lives 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 $f \cdot L = C$, 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 $f_1 \cdot L = C/f_2$, where f_1 is a partial factor applied to the loading, and f_2 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 (S_d) for pressure containing and non-pressure containing structural components shall be the lower of either
 - (yield strength/1,5) or
 - (ultimate tensile strength/3) for austenitic steels, and (ultimate tensile strength/2,4) for ferritic steels.
- S = allowable design stress = $K \times S_d$.

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) $K \times S_d$	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) $K \times S_d$	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 operat- ing (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 meto- cean 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 sce- nario 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:

- quasistatic analysis in transit and stored conditions;
- 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) $K \times S_d$	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 black-out 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) $K \times S_d$
1	Stored extreme	$DL + WL_{S2} + WIIL_e$	1,2 Sd
2	Stored survival	$DL + WL_{S3} + WIIL_s$	1,5 Sd
3	Manoeuvring	$DL + WL_0 + WIIL$	1 Sd
4	Connected	$DL + WL_0 + WIIL$	1 Sd
5	Connected	$DL + FL + PL + WL_0 + WIIL$	1 Sd
6	Connected	$DL + FL + PL + WL_0 + TL + WIIL$	1,5 Sd
7	Emergency release	$DL + WL_0 + WIIL$	1,2 Sd
8	Emergency release	$DL + FL + PL + WL_0 + WIIL$	1,2 Sd
9	Maintenance	$DL + WL_M + WIIL$	1 Sd
10	Hydrostatic test	$DL + FL + PL_T + WL_0 + WIIL$	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_0 : 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 $WIIL_s$: 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		
	<i>Transit</i>	<i>Operation^a</i>	<i>Survival</i>
Wave environment	Specific for transit route ^b	Relevant significant wave height (H_s) and corresponding period (T_p or T_z)	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	
	<i>Transit</i>	<i>Operation (at site)</i>
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 Cos^2 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	
	<i>Transit</i>	<i>Operation (at site)</i>
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 Liquefied 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}	NO _x , SO _x , PM, CO and in some cases for H ₂ S and heavy metals ^c
Boilers	Local regulation ^{a,b}	NO _x , SO _x , PM, CO and in some cases for H ₂ S and heavy metals ^c
Emergency generators	Most stringent between local regulation and MARPOL ^{a,b}	NO _x , SO _x , PM, CO and in some cases for H ₂ S and heavy metals ^c
Essential generators	Most stringent between local regulation and MARPOL ^{a,b}	NO _x , SO _x , PM, CO and in some cases for H ₂ S 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 NO_x, SO_x, PM, CO_x 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 NO_x, SO₂, PM, CO and/or O₃, 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 [$\leq 10^5$ µg/kg (≤ 100 ppm)], mean, and high [$\geq 10^6$ µg/kg ($\geq 1\ 000$ 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 tributyltin.

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 chronic). 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.