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

Part 2: Specific FSRU issues

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

Partie 2: Questions spécifiques aux FSRU

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Foreword

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

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For an explanation 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.

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

Part 2: Specific FSRU issues

1 Scope

This document provides specific requirements and guidance for the design and operation of floating LNG storage and regasification units (FSRU) described in ISO 20257-1.

This document is applicable to offshore, near-shore or docked FSRUs and to both new-built and converted FSRUs.

This document includes requirements to the jetty when an FSRU is moored to a jetty.

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 20257-1:2020, *Installation and equipment for liquefied natural gas — Design of floating LNG installations — Part 1: General requirements*

AGA 9, *Measurement of Gas by Multipath Ultrasonic Meters*

AGA 10, *Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases*

EN 1776, *Gas infrastructure — Gas measuring systems — Functional requirements*

EN 12186, *Gas infrastructure — Gas pressure regulating stations for transmission and distribution - Functional requirements*

ISO 13734, *Natural gas — Organic components used as odorants — Requirements and test methods*

EN 14382, *Safety devices for gas pressure regulating stations and installations — Gas safety shut-off devices for inlet pressures up to 100 bar*

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

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

ISO 5168, *Measurement of fluid flow — Procedures for the evaluation of uncertainties*

ISO 6976, *Natural gas — Calculation of calorific values, density, relative density and Wobbe indices from composition*

ISO 8943, *Refrigerated light hydrocarbon fluids — Sampling of liquefied natural gas — Continuous and intermittent methods*

ISO 12213-1, *Natural gas — Calculation of compression factor — Part 1: Introduction and guidelines*

ISO 12213-2, *Natural gas — Calculation of compression factor — Part 2: Calculation using molar-composition analysis*

ISO 13709, *Centrifugal pumps for petroleum, petrochemical and natural gas industries*

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

ISO 17089-1, *Measurement of fluid flow in closed conduits — Ultrasonic meters for gas — Part 1: Meters for custody transfer and allocation measurement*

CODE IGC *International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk*, International Maritime Organization (IMO)

OIML R 137-1, *Gas meters — Part 1: Metrological and technical requirements*

OIML R 137-2, *Gas meters — Part 2: Metrological controls and performance tests*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20257-1:2020 and the following 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
fiscal metering
metering aimed to define the quantity and financial value of hydrocarbon product transaction

3.1.2
custody transfer
physical transfer of hydrocarbon product that results in change in ownership and/or a change in responsibility

3.2 Abbreviated terms

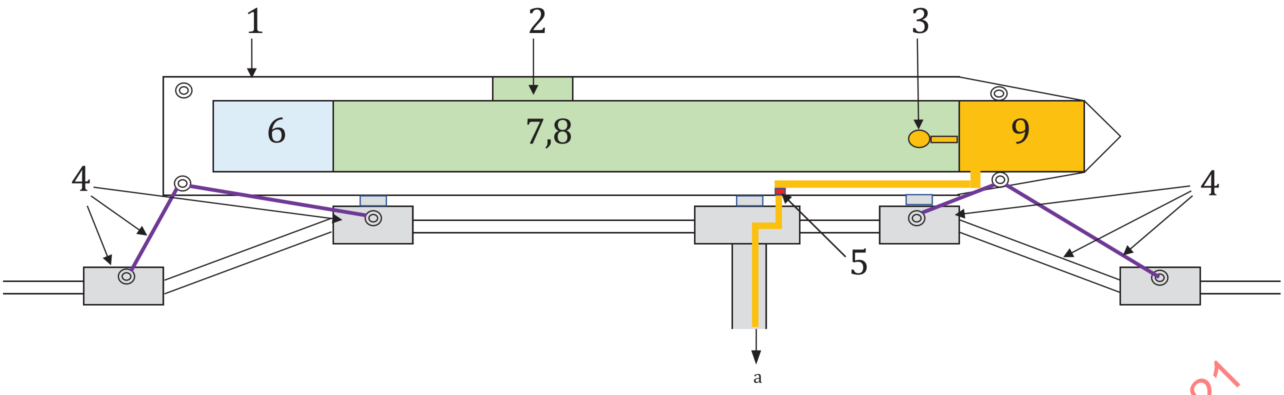
ALARP	as low as reasonably practicable
BOG	boil-off gas
CLV	closed loop vaporizer
EDS	emergency disconnection system
ERC	emergency release coupling
ESD	emergency shut down
FSRU	floating storage and regasification unit
GCU	gas combustion unit
HAZOP	hazard and operability (study)

HD	high duty
HIPPS	high integrity pressure protection system
HP	high pressure
HVAC	heating, ventilation and air conditioning
HW	hot water
IFV	intermediate fluid vaporizer
IR	infrared
LD	low duty
LNG	liquefied natural gas
LP	low pressure
MAC	manual alarm call
MOP	maximum operating pressure
MSO	minimum send out
NG	natural gas
NPSH	net positive suction head
OEM	original equipment manufacturer
OESD	Offloading Emergency Shut Down
OLV	open loop (direct contact) vaporizer
ORV	open rack vaporizer
QRA	quantitative risk analysis
RAM	reliability, availability, maintainability
SCV	submerged combustion vaporizer
SIL	safety integrity level
SIS	safety instrumented system
UV	ultraviolet

4 Basis of design

4.1 General description of FSRU

Figure 1 illustrates a typical arrangement of FSRU facilities, showing an FSRU berthed to a single jetty. The arrangement can differ in case of use of other mooring designs.



Key

1 hull (see Clause 7)

2 LNG transfer (see ISO 20257-1:2020, Clause 10)

3 regasification vent mast

4 mooring (see Clause 4)

5 HP manifold and FSRU ESD valve (see Clause 9)

6 living quarters

7 cargo containment system (see Clause 8)

8 cargo handling system – BOG handling system (see Clause 10)

9 regasification system (see Clause 11)

a Gas send out (see Clause 12).

Figure 1 — Example of FSRU arrangement (berthed to a jetty)

For safe loading, storage and regasification of LNG and discharging NG through HP manifolds to the shore, an FSRU is typically equipped with integrated systems for:

a) cargo handling;

b) cargo containment;

c) regasification.

Associated systems and equipment for cargo, such as BOG management systems, cargo tank spray systems, inert gas system, nitrogen system, venting system, auxiliary system., are provided in accordance with applicable (project, class, ...) requirements.

Figure 2 illustrates the terminology typically used in descriptions of the regasification system.

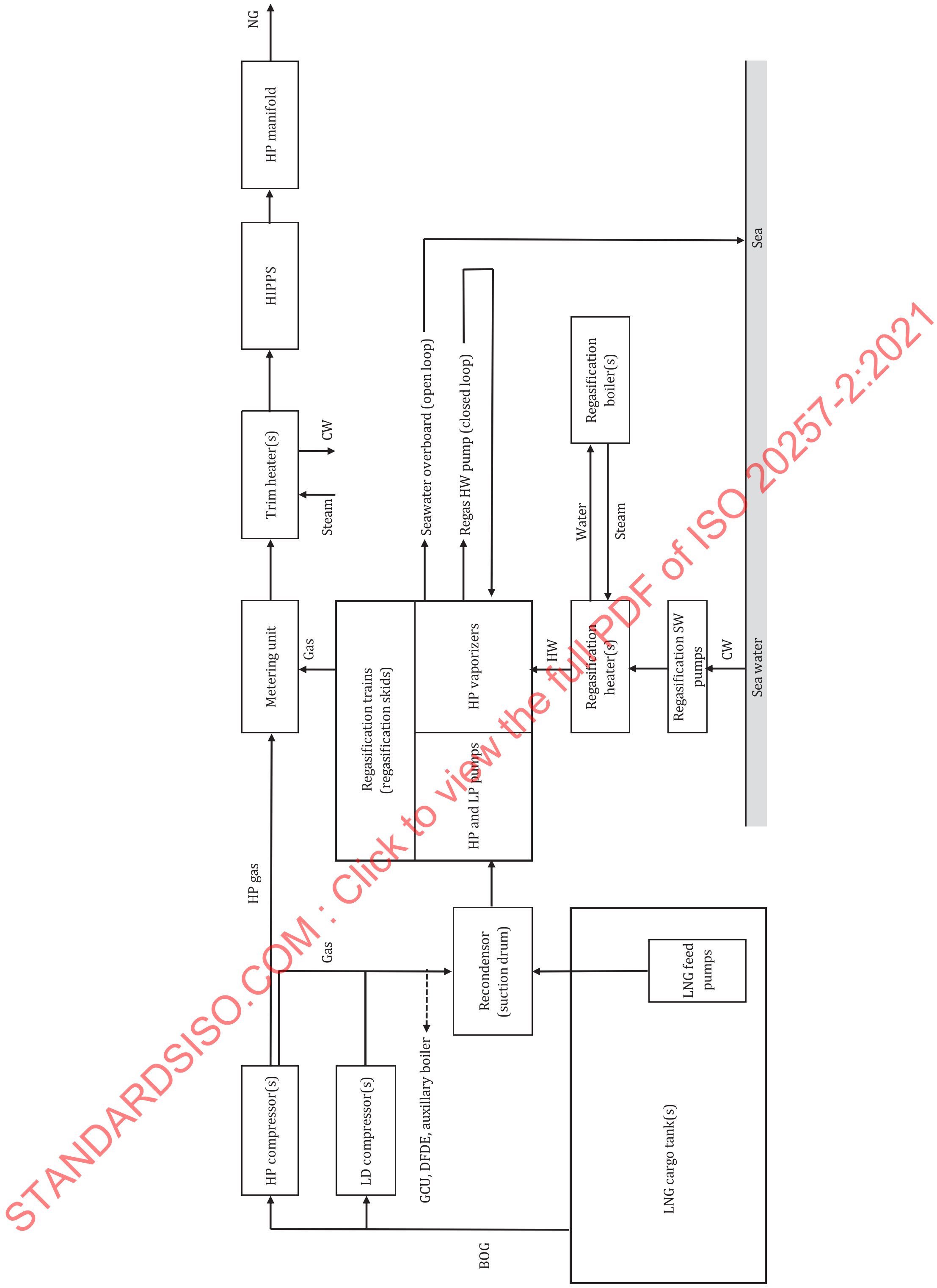


Figure 2 — Description of the regasification system

4.2 Main design criteria for process facilities

The process facilities of FSRU shall be designed considering the following conditions:

a) NG send-out capacity, which can be minimum, nominal, peak and zero;

b) redundancy, holding period and turn-down requirements of process facilities;

c) regasification type (e.g. open loop, combined or closed loop);

d) regasification operation (e.g. metocean and site conditions during regasification operation);

e) maximum operating and design send-out pressure at HP manifold;

f) minimum and maximum send-out temperature at HP manifold;

g) design range of seawater temperature and flowrate for regasification;

h) LNG loading rate concurrent with regasification (minimum send-out capacity to be considered);

i) LNG quality and chemical composition;

j) odorization, if required;

k) discharge seawater conditions (i.e. seawater used for regasification process);

l) BOG management (e.g. venting and flaring philosophy required);

m) dual operation FSRU and LNG carrier requirements.

4.3 Reliability, availability and maintainability of LNG floating installation

A RAM analysis should be performed to determine the availability of gas export from FSRU given a certain demand profile. Availability curves should be prepared for various demand scenarios.

Metocean conditions shall be considered while operating regasification facilities to define availability.

The design should consider N+1 configurations for all key equipment to ensure a high availability of gas export. Typically based on operational experience, the HD compressor and HP compressors would not be subject to the N+1 philosophy.

4.4 Specific requirements for FSRU operating as LNG carrier

When an FSRU is operating as LNG carrier (part time or after extended stay on location), provisions shall be taken to

a) shutdown and isolate the regasification facilities, and

b) fasten potential transfer systems.

After extended stay on location, additional requirements such as revision of drydock plan before starting operating as LNG carrier can be required by flag and/or class requirements.

4.5 Specific FSRU studies

4.5.1 General

The relevant studies mentioned in ISO 20257-1:2020, Clause 4 shall be performed. In addition, the process and environmental aspects described in 4.5.2 to 4.5.4 shall be addressed.

4.5.2 Environmental impact of seawater intake and discharge study

Specific studies related to environmental impact of seawater intake and discharge shall be performed in accordance with 5.2. Local requirements can have an impact on the regasification type selection.

4.5.3 Recirculation study

During the regasification process, an FSRU takes in seawater, extracts heat from it for regasification of LNG, and discharges the seawater at a lower temperature. The recirculation pattern of the discharged effluent towards the intake point can lead to lower intake temperature and reduce the unit's efficiency.

The aim of a recirculation study is to assess the risk of recirculating the cold water effluent based on the discharge characteristics during FSRU operations and the ambient characteristics of the receiving water body. A recirculation study can also assist the FSRU owner and builder by optimizing the intake and outlet locations in the design.

To assess the recirculation risk, the behaviour of the cold water plume in a mid-field, far-field and near-field model shall be analysed. A 3D far-field model can be used to analyse the large-scale circulation patterns and their influence on the recirculation risk and to generate the boundary conditions for a 3D near-field model. In a detailed near-field model, different scenarios are assessed on their potential for recirculation.

The following scenarios shall be considered:

a) For the far-field model: evaluation of the far-field transitional phase behaviour under varying hydrodynamic conditions.

b) For the near-field model:

   1) sensitivity analysis to evaluate near-field model performance and variation of ambient water characteristics and flow conditions;

   2) analysis of recirculation risk for varying water level conditions and draughts of FSRU, for flood conditions;

   3) analysis of recirculation risk with alternative outlet configurations, for varying water levels and draughts of FSRU, for both flood and ebb flow conditions;

   4) similar setup of conditions as in 2) and 3) adding an LNG carrier berthed alongside the FSRU, if this is a realistic scenario.

4.5.4 Scour protection study

Additional investigation concerning scour protection, where relevant, shall be performed due to water intake/outfall of regasification system.

5 Specific health, safety and environmental issues

5.1 General

This clause describes the specificities of FSRU application and shall be applied in addition to ISO 20257-1:2020, Clause 5.

5.2 Environmental considerations related to water heating and cooling issues

Systems used for seawater heating/cooling should follow the environmental recommendations of the World Bank Group[15]. Where chemicals are used to prevent marine fouling in the shipboard facilities, these should be minimized and alternate measures should be considered. This can involve taking water from depth where this is possible. For a near-shore FSRU, the limited water depth and limited potential for marine growth should be considered. Providing screens on water intakes to avoid entrainment of marine organisms should also be considered.

Change in ambient seawater temperature due to discharge of seawater should be limited to less than 3 °C at the edge of a defined mixing zone. In case of use of a chlorination system, free chlorine (total residual oxidant in seawater) concentration in seawater water discharges at water disposal outlets should be maintained below 0,2 ppm (see Reference [13]).

5.3 Safety considerations

5.3.1 General requirements

The project development team shall establish early in the design (conceptual stage) a high-level safety strategy (hazard prevention and hazard minimization) that outlines the measures to be considered to eliminate/manage hazard introduced by the design. These measures 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 philosophies shall include but are not limited to the following:

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.

NOTE Most principles specified in ISO 20257-1:2020 also apply to this document.

The regasification system of the FSRU shall be verified as part of the overall risk studies as described in ISO 20257-1:2020.

5.3.2 Layout constrains

A risk analysis including the whole facilities and surroundings (and not only the FSRU itself) shall be performed to maximize the safety of installation with respect to ignition sources through a layout review (see also ISO 20257-1:2020, 5.4.4). The risk analysis shall focus on

a) the wind rose,

b) the location of significant ignition sources (e.g. flare, combustion equipment),

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

d) the location of fences and public in case of docked floating LNG installations, and

e) the influence of other shipping passing nearby.

The acceptance criteria for risk can differ depending whether the LNG floating installation is at shore/docked or offshore considering the risk to public.

5.3.3 Layout constraints with respect to surroundings

5.3.3.1 Applicability

Subclause 5.3.3 is applicable in the case the facility is docked at or close to shore (either in an existing harbour or at a new location).

5.3.3.2 Qualitative analysis

Whatever the exact configuration of the facility, the choice of the location shall be based on a thorough review of the surroundings. The following areas shall be identified in this review:

a) industrial areas;

b) commercial areas;

c) dense areas with high population;

d) rural areas.

5.3.3.3 Confirmation by calculation

The identification of areas will help to find the most suitable site location with respect to the risks inherent to the kind of facility. In addition, prior to the development of any detailed safety study as required by this document or local regulation, it is recommended to perform a set of safety distances calculations due to jet fires, explosions, pool fires, etc. These calculations can include the following:

a) Large leak release: The objective of these calculations is to define the area where control of the surroundings is required. This will help defining the location of the potential onshore fence.

b) Worst case scenarios (e.g. full bore rupture): The objective of these calculations is to provide the local authorities with a clear picture of the worst case existing/future risks leading to:

   — the definition of restrictions with respect to urban development (e.g. high building constructions limitations);

   — the elaboration of emergency response plans with close coordination between operator and local/national authorities .

Calculations shall account for the following:

a) the variety of hazardous streams handled in the facility (liquefied products such as LNG, propane, liquid hydrocarbons, toxic fluids, nitrogen);

b) their phase (gas, liquid, 2-phase);

c) their pressure and temperature;

d) their size of inventory.

The retained set of calculations shall be representative to ensure proper site location. For the performance of this simplified set of calculations, refer to ISO 20257-1:2020, Annex B.

5.3.4 Layout constraints with respect to facility arrangement

5.3.4.1 Qualitative analysis

The first step to ensure the facility inherent safety is linked to the layout based on the safety studies. The following principles shall be applied:

a) The strong ignition sources (e.g. flare [if any and if possible], power generation [turbines or large transformers when electricity is brought from outside]) shall be located upwind, when looking at the prevailing wind.

b) The accommodations and administrative area shall be located:

   1) upwind from the other parts of the facility;

   2) at the farthest from the area handling hydrocarbons (process units).

   NOTE 1 There is no restriction with respect to the fence location and surroundings.

   NOTE 2 Special consideration will need to be given to FSRUs that are designed to weathervane rather than using spread mooring or jetty mooring systems

c) The utility areas shall preferably be located between the accommodation/administrative area and the process units to maximize the separation distance between the high-risk area and the vulnerable area. Utility areas present less hazards than process units. Nevertheless, their location with respect to the fence location and surroundings shall be carefully selected after reviewing their purpose and the products they can handle.

d) The process facilities (mainly regasification units) shall be located

   1) downwind other facilities, and

   2) at the farthest from accommodation/administrative area.

e) Within the group of process units, the following applies:

   1) they shall be grouped by type of hazards encountered to avoid the spreading of various hazards throughout the facility;

   2) they shall be separated by distance or by physical means to avoid escalation in the case one part of the process units faces a major accident;

   3) when several identical process trains are present within the facilities, distance or physical means can be employed to avoid escalation from one train to another (when maintenance is to be carried out train by train for instance);

   4) the hazardous material storages shall be isolated from other units to avoid escalation to/from them.

Isolation can be achieved by implementing a physical separation philosophy. This is the only solution when the entire facility is located on a docked ship where the storages are in the hull while the regasification units are on the decks above. In these conditions, the implementation of a plated deck to ensure hazards segregation is recommended.

The occurrence of major accidents in this area can be lower, but consequences can be severe when looking at the contained inventories.

5.3.4.2 Confirmation by calculation

Whatever the proposed configuration, the final arrangement shall be confirmed by the performance of safety studies (see ISO 20257-1:2020, 5.4.3).

At least, the following safety studies shall be carried out to confirm the layout:

a) Failure case identification: This preliminary study aims at identifying all potential scenarios that can arise on the facility. The scenarios shall include HP gas leak on jetty and LNG leak on regasification units.

b) Cryogenic risk analysis: The purpose of this study is to identify all areas where cryogenic release can occur and to assess:

   1) cryogenic effect distances and duration to be used to define protection means against embrittlement;

   2) cryogenic pool formation, duration and released inventories to be used to define protection means against embrittlement and drainage system definition.

c) Fire risk analysis: The purpose of this study is to identify all areas where fire events can occur and assess thermal effect distances, thermal levels and duration (from jets and pools) to be used to define protection means against fire.

d) Explosion risk analysis: The purpose of this study is to identify all areas where explosion events can occur and to assess overpressure effect distances, overpressure levels to be used to define protection means against blast. This study shall account for the exact level of congestion/confinement once the facility is in operation.

   NOTE High congestion and/or high confinement will tend to increase overpressure levels, which will increase overpressure values to be considered in the design.

e) Quantitative risk assessment: This study uses the results coming from other studies and estimates the risk to people and compliance with ALARP principles.

These studies shall

a) consider the entire facility (FSRU itself as well as the jetty and any other unit pertaining to the facility),

b) confirm that the distance between process units is sufficient, most importantly with respect to vulnerable areas and/or various trains, and

c) provide design requirements for physical barriers and equipment to limit escalation (e.g. blast loads, duration of protection against fire/cryogenic events).

Refer to ISO 20257-1:2020, Annex B.

5.3.5 Risk prevention measures

5.3.5.1 General

The elements described in this subclause shall be applied in addition to the ones detailed in ISO 20257-1:2020, Clause 5.

5.3.5.2 Active fire protection

5.3.5.2.1 Active fire protection philosophy

This subclause provides requirements with regards to specific active fire protection systems or fire-fighting systems required for FSRU facilities. General requirements for active fire protection are described in ISO 20257-1:2020, Clause 5.

Active fire protection philosophy to be implemented shall be the result of the fire risks identified during risk assessment performed for the overall LNG floating installation taking into account the FSRU itself, all related facilities (such as a jetty) and appendices, and neighbour facilities.

Active fire protection can be achieved by several means, including support vessels, permanent systems and/or mobile/portable systems.

Active fire protection systems shall be installed in areas where a major risk of fire exists. Typical areas for FSRU, in addition to other standard risk areas on a floating installation, include the following:

a) regasification system area;

b) gas compressors area;

c) LNG transfer connecting area;

d) HP gas transfer area;

e) equipment located on a jetty deck, if applicable.

Overall active fire protection philosophy is typically based on several types of fire-protection systems including the following:

a) water systems;

b) high expansion foam systems;

c) low expansion foam systems;

d) dry chemicals systems.

Guidance on different types of fire and the use of extinguishing agents can be found in Reference [13].

5.3.5.2.2 Systems design

Active fire protection systems shall be sized to withstand the expected fire risks identified during risk assessment. Capacity and application rates of active fire protection shall be determined and supported by recognized standard practice or detailed engineering evaluation.

Any fire-fighting equipment shall be designed and manufactured in accordance with recognized standards such as standards from NFPA (National Fire Protection Association).

ISO 13702 provides typical examples of design requirements for offshore production installations, such as minimum water application flowrate, and can be used as guidance for designing the FSRU active fire protection systems.

5.3.5.2.3 Water systems

Permanent fire water systems are not used to extinguish LNG, NG or hydrocarbons fire, but to mitigate escalation risks by using water as

a) a cooling means, protecting the neighbouring facilities or structural members/equipment in the vicinity of the accident area, and

b) a mitigation means, providing (gas or smoke) control and radiation protection mean to protect personnel evacuation.

These systems can include deluge systems, hydrants and/or fire monitors systems.

Fire water system shall be compatible with seawater as it will be the primary source of water in most of the cases. In the case periodic functional testing of water systems is required, contamination with seawater of areas under deluge systems shall be addressed.

Fire water systems shall be sized and designed to ensure the following:

a) firewater supply in proper quantities according to fire risks identified during risk assessment;

b) proper firewater drainage systems preventing increase of LNG spills vaporization;

c) availability of firewater supply for the time duration defined in accordance with risk assessment, which can imply redundant equipment, independent source of power for the firewater pumps, independent fire system network section.

Fire water systems, e.g. fire monitors and/or water curtains systems, are typically located at jetty-FSRU interface in the case of a docked FSRU to protect the FSRU and/or jetty topsides facilities from a fire occurring on the FSRU, in gas and/or LNG manifolds areas or in the jetty facilities.

5.3.5.2.4 Foam systems

Foam systems can be permanent and/or portable foam systems.

Low expansion foam can be required to protect areas with significant flammable liquid storage.

High expansion foam systems are used to control LNG pool fires by isolating combustible from air access. If provided, any LNG spill collection impounding shall be fitted with remote operated permanent high expansion foam systems.

Portable foam systems shall be installed where a risk has been identified during risk assessment.

5.3.5.2.5 Dry chemicals systems

Dry chemicals systems (such as carbon dioxide systems) are recommended to extinguish LNG fires. These systems can be portable and/or permanent according to the level of risks identified during risk assessment.

Dry chemicals systems shall be located where hydrocarbon leakage can occur in areas such as transfer areas (HP and LNG transfer from/to FSRU), ESD/HIPPS valves location, oil hydraulic unit, and compressors,

Dry chemicals systems should also be used to suppress the fire in instrumentation and electrical rooms when required.

5.3.5.3 Fire, cold spill and gas detection system

In addition to the requirements described in ISO 20257-1:2020, fire, cold spill and gas detectors shall be selected and located considering the following factors:

a) the expected type of events that need to be detected (e.g. gas release, hydrocarbon fire, electrical fire, cellulosic fire);

b) the location of the event that needs to be detected (e.g. indoor or outdoor);

c) the most likely sources of leakage;

d) the proximity to possible sources of ignition;

e) the prevailing wind direction and wind speed;

NOTE 1 This parameter has limited (or no) influence in closed areas as well as in congested and confined areas where the wind speed tends to significantly decrease. Similarly, the wind speed and direction have limited (or no) influence in the area located close to the release; the release direction and speed will be driven by the release momentum, i.e. its initial pressure.

f) the density of gas leak (heavier than air fluids tend to move downwards when the momentum is lost while lighter than air gases tend to move upwards when the momentum is lost).

NOTE 2 This parameter has limited or no influence in the area located close to the release; the release direction and speed will be driven by the release momentum, i.e. its initial pressure and not by the fluid density.

Table 1 provides an overview of the detectors that shall be installed as minimum in specific areas (non-exhaustive list).

Table 1 — Type of detectors per area

Area	Type of detector				
	Flammable gas detector	**Fire detector [a]**	**Cold spill detector**	**Low oxygen detector**	**Hydrogen detectors**
Near equipment handling flammable or combustible liquids	Yes	Yes			
Near equipment handling flammable gas	Yes	Yes			
Around manifolds (export and import)	Yes	Yes			
Around fired equipment		Yes			
Battery rooms (inside the room)		Yes			Yes
Jetty head	Yes	Yes	Yes		
Impounding basins	Yes	Yes	Yes		
Control rooms and substations	Yes [b]	Yes [c]			
Other buildings	Yes [b]	Yes [c]			
Laboratory and analyser house	Yes [d]			Yes	

[a] The type of fire detectors to be selected (UV/IR flame, heat, smoke) will depend on the type of fire and on the location. Hydrocarbon fires will be detected using UV/IR detectors, while cellulosic and electrical fires will be detected by heat and/or smoke detectors.

[b] Gas detectors will be located at the HVAC air intakes and air locks to be informed from gas coming from outside.

[c] Not all the rooms will be provided with fire detectors. The type and location of the detectors shall depend on whether the room is permanently manned, what it contains, and whether the rooms contain equipment critical for the operation, control or safety of the plant.

[d] Gas detectors will be located at the HVAC air intakes and air locks to be informed from gas coming from outside and inside the rooms to be informed from gas releases coming from the outside.

In addition, MAC points shall be located throughout the facility to enable personnel to raise an alarm:

a) along process escape routes and stairs at regular intervals;

b) inside buildings near exit doors.

Detectors shall be installed per location to make voting possible:

a) when one detector is triggered, it generally leads to visual and audible alarm in the concerned area and in the control rooms;

b) when several detectors are triggered, it additionally leads to automatic actions, which can include but are not limited to the following:

   1) process shutdown;

   2) electrical isolation of equipment not suitable for zone 1;

   3) normal power generation shutdown;

   4) HVAC air intakes dampers closures and HVAC system shutdown or recirculation;

   5) activation of fire water pumps sequence;

   6) activation of fire water deluge, water curtains.

5.3.5.4 Drainage systems

Quick and remote disposal of cryogenic liquid spills from where the leakage occurs to avoid uncontrolled evaporation in a congested/confined process area shall be applied in accordance with ISO 20257-1:2020.

A suitable number and volume of drip pans and fire wall shall be provided around the suction drum/recondenser, HP pumps and HP vaporizers. Flange shields, intended to prevent jet or uncontrolled sprays, shall be provided at all HP liquid and NG flanged connections (see also ISO 20257-1:2020, 5.4.5.2.6).

Concerning the drainage of cryogenic spills arising on a docked facility, the area where evaporation will be controlled shall be considered. As such, the possibility to control the direction of the spillage and collect it in specific impounding basins provided with foam generators and remote from the docked facility shall be investigated.

The design of the impounding basins shall be based on the cryogenic risk analysis results.

NOTE This will prevent any cryogenic liquid release from running down the hull side and reaching the sea surface.

5.3.5.5 Emergency response

In addition to the requirements described in ISO 20257-1:2020, the evacuation from docked facilities shall also be taken into account.

If evacuation cannot be achieved by walkway from the facility to shore, evacuation shall be performed by the means of lifeboats and/or liferafts.

The location shall account for the presence of elements potentially blocking the area to access the evacuation means, such as the following:

a) LNG carriers and any other vessels;

b) the mooring lines between the facility and LNG carriers/vessels;,

c) the mooring lines between the facility and the shore/jetty.

The evacuation means shall be designed and installed in a way that they take into account all the potential hazardous events (internal and external, human and natural) that lead to evacuation. As such, the focus shall be put on redundancy and installation of evacuation means at various areas of the facility (aft vs. forward, starboard vs. portside).

5.3.5.6 Safety integrity levels

A SIL review shall be considered to determine the safety integrity levels of the various safety instrumented functions that control the process systems (see ISO 20257-1:2020, 5.4.2.3).

The SIL review shall at least cover the following:

a) HIPPS, which is generally installed at the inlet and/or outlet of the facility in areas where the piping rating changes and is meant to protect the upstream facilities and/or downstream facilities from sudden rise in pressure;

b) safety functions pertaining to the HP transfer units.

For the listed safety functions, the SIL shall at least reach SIL 2, when SIL is required, taking into account that the final level will depend on the facility specificities. The necessary SIL depends on the residual risk level to be achieved as per used matrix, which in turn depends on the following:

a) the initial scenario frequency without the safety function;

b) the consequence that the failure of the safety instrumented functions would have in terms of damages to people, environment and assets.

The SIL assessment should be based on layers of protection analysis (LOPA). See the IEC 61508 series for more guidance.

6 Mooring and stationkeeping

In addition to the requirements in ISO 20257-1:2020, Clause 6, the following applies:

a) the mooring of a visiting LNG carrier shall be considered in the design of FSRU mooring, whatever the mooring arrangement selected;

b) In the case the FSRU is designed to reload smaller vessels, the design of the mooring system shall address the size range of visiting small scale LNG carriers.

7 Hull design

In addition to the requirements in ISO 20257-1:2020, Clause 7, the following requirements apply to an FSRU intended to operate also as an LNG carrier.

The business and operating model of the FSRU can have an impact on the hull design requirements. Models can be but are not limited to the following:

a) An FSRU being a barge type unit with no propulsion, which intends to remain in one location for its design life or possibly relocate to several different locations.

b) An FSRU being a ship-shaped unit originally with propulsion, but where this propulsion is disconnected (i.e. the unit can be considered a barge during operation). Propulsion can be subsequently recommissioned to allow for moving to other locations.

c) A vessel operating as an FSRU for shorter periods interspersed with periods acting as an LNG carrier.

d) An FSRU remaining on location during the worst anticipated environmental conditions at the operating location or being moved to a more benign area for the period of a storm before returning.

The following principles apply when determining design environmental conditions:

a) All FSRUs should consider the environmental conditions during any transit phase to/from operating site.

b) A FSRU/barge should consider the most severe environmental conditions at its site of operation.

c) Where there can be multiple sites of operation, the design should account for the most severe conditions that can be experienced at these sites.

d) Where movement to a more benign location is planned in severe weather conditions, the limiting weather condition for moving can be used as a basis of design.

e) Where an FSRU will also act as an LNG carrier, both modes of operation shall be considered and the most severe condition should be used. Operation of an LNG carrier can be either limited to a specific trade, in which case conditions for that trade should be considered or be intended to operate worldwide as an LNG carrier. In the latter case, the environmental conditions shall be considered as specified by the IGC Code or Flag State Authority, whichever is more stringent.

8 LNG storage

8.1 Specific requirements for cargo tank pressure management

The pressure of the LNG tanks on an FSRU should be kept low before ship-to-ship transfer and should be increased during the LNG transfer in accordance with the loading rate, the temperature of the loaded LNG, and the regasification send-out rate.

The temperature of the emptied LNG tanks on an FSRU should be in cooled-down condition before ship-to-ship transfer.

For a given loaded LNG temperature (or saturated pressure), the higher the operating pressure of the LNG tanks on an FSRU is, the higher the maximum possible loading rate.

Consequently, the maximum allowable pressure of the LNG tanks on an FSRU is usually higher than that of conventional LNG carriers.

The range of acceptable pressures of the LNG tanks on an FSRU and loaded LNG temperature before ship-to-ship transfer and their effects on BOG generation shall be analysed and confirmed with regards to the design loading rate.

8.2 Specific requirements for LNGC overpressure protection

As the allowable operating pressure of the LNG tanks on an FSRU is usually higher than the one of the feeder LNG carrier, protection for over pressurization of LNG carrier tanks by vapour return flow during ship-to-ship transfer shall be considered.

8.3 Rollover risk

An FSRU will receive LNG from various sources with different density and composition. The loading procedure shall assure that the LNG tanks on an FSRU will always be nearly empty before refill to avoid the risk of having LNG stratification in the tanks. If stratification risk has been identified for the project, stratification shall be monitored by the operator of the FSRU, considering the mitigation measures as described in ISO 20257-1:2020, 8.4.2.

9 Transfer systems

9.1 General

This clause describes the specificities of the LNG transfer system and shall be applied in addition, to ISO 20257-1:2020, Clause 9.

9.2 Send-out natural gas: NG gas transfer requirements

9.2.1 Functional requirements

A dedicated transfer system connecting the FSRU to shore is required to transfer (typically high pressure) NG. To achieve high-pressure NG transfer operation in safe conditions, the transfer system shall offer at least the following functions:

a) freely follow the FSRU motions in the 6 degrees of displacement after connection;

b) transfer high pressure NG through its product line from one extremity to the other within design and operating temperature and pressure limits defined by the design requirements;

c) limit the loads applied to the HP gas manifold connection to the allowable values given by design requirements, in which maximum loads on HP gas transfer manifold shall be determined as input to transfer system design;

d) conform to the flow rate and maximum pressure drop requirements and conform to the installation process, taking into account the maximum allowable flow speeds;

e) operate in the full required operating envelope without clashes with adjacent transfers systems and all-around infrastructure and other equipment;

f) be drained and/or be purged of its product in order to be gas free after operation, before normal disconnection or before/after an emergency disconnection;

NOTE This operation need not necessarily be achieved through specific equipment but can also be achieved by a suitable procedure.

g) be electrically isolated towards one extremity, avoiding bonding by contact or other accessories continuity, to avoid consequences of potential differences between the two connected units;

h) if an EDS or ERC is provided, provide for automatic retraction and securing of the transfer system from the immediate location of the HP manifold of the FSRU, so that the manifold and the transfer system are both clear from any damage arising from further motion or displacement across the marine interface.

9.2.2 Transfer systems design

9.2.2.1 Composition

Transfer system can be composed of either articulated rigid piping or flexible piping.

9.2.2.2 Articulated piping solutions

An articulated piping solution is a compass arrangement of articulated piping for vertical plane motion, installed on base riser or arrangement, supported by a dedicated structure (i.e. marine loading arm) or self-supported (i.e. articulated jumper) with slew capacity to cover a 3D envelope. At its extremity, additional articulations allow the relative roll, yaw and pitch motion angles of the connected manifold.

Relevant aspects for the design of HP gas articulated piping solutions are described in ISO 16904, EN 1474-3 and Reference [15].

9.2.2.3 Flexible pipe solutions

A flexible pipe solution is a self-supported arrangement using flexible pipes as product line, which can be declined as follows:

a) Aerial flexible pipes: individual flexible pipes installed with lifting crane or winch on board and/or on shore, with no direct contact with seawater during normal operation. After connection, the flexible pipes are no longer supported by any lifting crane or winch.

b) Semi-submerged flexible pipes: individual flexible pipes installed with lifting crane or winch on board and/or on shore, partially submerged during normal operation. After connection, the flexible pipes are no longer supported by any lifting crane or winch.

c) Fully submerged flexible pipes: individual flexible pipes installed with lifting crane or winch on board and/or on shore, fully submerged during normal operation. After connection, the flexible pipes are no longer supported by any lifting crane or winch.

Relevant aspects of EN 1474-3 can be applied in developing a system design philosophy for flexible pipe solutions in conjunction with ISO 13628-2, which includes provisions for flexible jumper hoses in subsea and offshore topsides applications.

The bending radius and risk of twist of the flexible hoses at its extremities shall be considered, taking into account the operating envelope to cover, the distances between the jetty and the floating unit, and dynamic motions.

Depending on the situation, API RP 17B, ISO/IEC 10027 and ISO 14113 can be applied.

9.2.3 Emergency disconnection

9.2.3.1 Quantitative risk analysis inputs

The QRA shall conclude on the maximum time allocated for the disconnection of the HP gas transfer system depending on the FSRU configuration:

a) The FSRU can accidently drift away from its moored position due to mooring failure. The transfer system shall therefore be equipped with an EDS (sequence to be confirmed by mooring and drifting study). The transfer system shall be controlled and secured after the emergency disconnection.

b) The FSRU can face emergency departures from its moored position. The transfer system can be equipped with an ERC to ease the disconnection (typically 30-minutes sequence). The transfer system shall be controlled and secured after the emergency release.

c) The FSRU is permanently moored and no risks of emergency departure or mooring failure are identified in the QRA. The transfer system can be connected via flange-to-flange connection to the FSRU.

9.2.3.2 Emergency disconnection system

The transfer system can be equipped with an EDS (Emergency Disconnection System) typically composed of an isolating valve assembly and ERC in between, or composed of ERC (Emergency Release Coupler) and isolating valves at each extremity of the transfer line for release of the transfer system in case of emergency situations. In this case, the emergency disconnection sequence can be:

a) the gas flow shall be stopped;

b) the transfer system shall be isolated by closing the isolating valves at the transfer line extremities;

c) the volume of gas trapped across the transfer line shall be depressurized and send out back to the jetty or to the floating unit;

NOTE This step could be skipped in case of low-pressure gas transfer according risk analysis results

d) the transfer lines shall be purged;

e) upon release of the transfer system gas content, the system can be disconnected and secured.

9.2.3.3 Flange-to-flange connection

In the particular case where mooring failure is not considered a realistic scenario (e.g. non-disconnectable turret mooring system), it is possible that the transfer system does not need to be equipped with an emergency disconnection device or quick coupling device.

9.2.4 Operating envelope

9.2.4.1 General

The operating envelope design is output from the emergency disconnection philosophy of the transfer system.

9.2.4.2 Operating of transfer systems equipped with EDS

The operating envelope of a transfer system equipped with an EDS as described in 9.2.3.2 is composed of the following areas:

a) A green zone: corresponding to the normal operating positions for which the offloading is ensured. The green zone is generally composed of:

   1) A flanging area corresponding to the theoretical location of the HP gas manifold from a reference point of the transfer system on shore side. The flanging area is defined by the geometrical dimensions of the FSRU and the jetty as well as the water level variation due to tide, and fender compression for jetty moored applications.

   2) A motion envelope made with the maximum relative motions in all directions (X, Y, Z) of the FSRU manifold regarding a reference point of the transfer system on shore side.

b) An ESD envelope covering the complete OESD1 sequence (e.g. stop of the transfer, closure of the ESD isolating valves, and depressurization of the volume of gas trapped between the EDS isolating valves). The OESD 1 sequence is initiated as soon as the limits of the green zone are exceeded.

c) An Emergency Disconnection Envelope covering the complete OESD2 sequence (physical emergency disconnection of the transfer system system). The OESD 2 sequence is initiated as soon as the limits of the Emergency Shutdown Envelope are exceeded.

d) A mechanical limit corresponding to the maximum allowable reach for the transfer system.

9.2.4.3 Operating of transfer systems not equipped with EDS

The operating envelope of a transfer system with a connection interface with the FSRU as described in 9.2.3.2 and 9.2.3.3 is at least composed of the following:

a) a green zone corresponding to the normal operating positions for which the offloading is ensured. The green zone is generally composed of

   1) a flanging area corresponding to the theoretical location of the HP gas manifold from a reference point of the transfer system on shore side. The flanging area is defined by the geometrical dimensions of the FSRU and the jetty as well as the water level variation due to tide, and fender compression for jetty moored applications, and

   2) a motion envelope determined by the maximum relative motions in all directions (X, Y, Z) of the FSRU manifold regarding a reference point of the transfer system on shore side.

b) a mechanical limit corresponding to the maximum allowable reach for the transfer system.

Intermediate envelops between the green zone and the mechanical limit associated with different alarm levels can be implemented.

9.3 LNG sampling

While transferring LNG from an LNG carrier to the FSRU, when LNG custody transfer shall be achieved, an LNG sampling system shall be installed whatever the transfer arrangement will be selected (e.g. ship-to-ship, across jetty).

LNG sampling systems shall be in accordance with ISO 8943.

Guidance about LNG custody transfer can be found in Reference [18].

10 BOG handling and recovery

10.1 General

This clause describes the specificities of the FSRU BOG handling and recovery system and shall be applied in addition to ISO 20257-1:2020, Clause 10.

When extended no-send out periods are anticipated, a reliquefaction or subcooling unit should be considered to prevent ageing/weathering of LNG cargo.

10.2 LNG tank design pressure flexibility

For FSRU mode of operation, the cargo tanks design pressure can be re-rated to a higher pressure as indicated in 8.1. This helps in managing the boil-off during a loading operation or during a limited period of low or zero send out. Typically, the operating pressure is around 500 mbarg in FSRU mode compared to LNG carrier mode when the operating pressure is below 200 mbarg. However, to re-rate an existing LNG carrier to a higher cargo tank pressure, the designer of the tanks shall be consulted and adequate reinforcements shall be carried out as necessary. A certification from the approving Class Society is required in such case.

10.3 Specific requirements for recondenser

When the BOG is recondensed in a vessel in the LNG send out prior to vaporization, this vessel is called "recondenser" and shall be designed in accordance with a recognized pressure vessel code (e.g. ASME BPVC-VIII-1 or the EN 13445 series).

The recondenser has two purposes:

— recondensation of the BOG into the sub-cooled LNG stream from LP pumps;

— feeding the LNG HP pumps with liquid and provide liquid hold-up capacity between the LP and HP pumps.

The in-tank LNG pumps transfer LNG from the FSRU cargo tanks to the recondenser. The LD compressor transfers some BOG from the FSRU cargo tanks to the recondenser. The recondenser shall have internal device to promote the BOG recondensation.

The recondenser shall handle a specified minimum send-out rate, below which BOG cannot be entirely condensed. Send-out rate required during LNG unloading operations to enable recondensation of additional BOG generated during unloading shall be specified.

A BOG cooler can be installed upstream to reduce the inlet BOG temperature and consequently the size of the recondenser section of the drum.

Cryogenic insulation shall be provided at on outside of the recondenser to minimize the heat ingress. Installation of passive fire protection on this vessel shall be considered in accordance with the results of risk assessment.

The recondenser pressure can be adjusted in accordance with the in-tank pumps operating head by a vapour return pressure control valve to the main vapour line of the FSRU.

Multiple level switches of different technologies shall be installed for process control and shutdown in case of low or high level. Level instrumentation shall be in operation at any time.

Protection for vessel overfilling should be considered (e.g. interlock closure of LNG inlet valves and any overflow of LNG to the main vapour line in case trip gas compressors).

Nitrogen injection in the recondenser can be considered to prevent any accidental depressurization or low-pressure situation.

Low level in the drum/closed LNG outlet valve shall trip the regasification HP pumps.

Depending on the design and operating philosophy, critical instruments on the recondenser should be duplicated and arranged for replacement without taking the recondenser out of service.

NOTE Some alternative recondensing arrangements in LNG send out could be implemented such as inline pipe recondensing. These arrangements could not be compatible with some of the requirements for recondenser listed in this subclause since the functional requirements and operation could be different.

10.4 Specific requirements for gas compressors

10.4.1 General

An FSRU is typically fitted with LD, HD, and MSO or HP compressors. Final Compressors arrangement is dependent on the specific project requirements.

10.4.2 Specific functional requirements for LD compressors

The LD compressor of an FSRU should be provided for the following operations:

a) to supply fuel gas to engines;

b) to supply excess BOG to GCU;

c) to transfer excess BOG to recondenser,

d) to transfer excess BOG to inlet of MSO compressor, if relevant.

Also, during a ship-to-ship transfer, the excess BOG can be accumulated in the FSRU cargo tanks by pressure increasing.

10.4.3 Specific functional requirements for HD compressors

The HD compressor of an FSRU should be provided for the following operations:

a) to return vapour to LNG carrier during ship-to-ship transfer, if necessary;

b) to return vapour to shore terminal during initial cooling down, after dry-dock;

c) to circulate hot vapour for warming-up of cargo tank for decommissioning.

10.4.4 Specific functional requirements for HP or MSO compressors

The FSRU can have extended periods of low regasification send out or no regasification send out. In those cases, the MSO compressor should be in operation to control FSRU cargo tanks pressure.

The MSO compressor can be operated simultaneously with regasification plant and should be connected upstream of HPPS valves.

The MSO compressor should be provided for the following operations:

a) to supply excess BOG to the shore via the HP gas manifolds;

b) to control FSRU cargo tank at a pre-set pressure.

Due to HP rating of MSO compressors, this equipment is typically of reciprocating type compressors. When such type of compressors is selected, a pulsation study shall be performed.

11 Regasification equipment requirements

11.1 LNG pumps

11.1.1 General

The LNG pumps for regasification are typically composed of two types of pumps:

— the in-tank LNG pumps feeding the regasification trains;

— the HP LNG pumps pressurizing the LNG up to required send-out pressure before vaporization when required.

11.1.2 Functional requirements

For a specified LNG density, the following performance data shall be ensured by the manufacturer:

a) differential head at shutoff;

b) differential head at the minimum flow rate of the operating range;

c) differential head at the nominal flow rate;

d) differential head at the maximum flow rate of the operating range;

e) NPSH required at the minimum flow rate of the operating range;

f) NPSH required at the nominal flow rate;

g) NPSH required at the maximum flow rate of the operating range;

h) power consumption at the nominal flow rate;

i) pump efficiency at the nominal flow rate and of its drive and speed converter, if any;

j) pump down level in the case of an in tank pump;

k) power consumption at the minimum continuous and maximum flow rates.

The tolerances of these performances shall be in accordance with ISO 13709.

11.1.3 Materials selection

Materials shall be selected from suitable materials as listed in ISO 16903. Compatibility between material classes shall be taken into account. Other materials can be used, provided supplier can demonstrate their suitability.

11.1.4 In-tank LNG pump

The design of in-tank LNG pump shall be in accordance with the IGC code.

Provisions shall be made to ensure that the in-tank LNG pump will not be damaged due to low flow. Lower capacity in-tank LNG pump can be required for minimum send out. Provisions could also be required for pump removal system from the tank and condition monitoring in the cargo tank.

11.1.5 HP LNG pump

The HP LNG pump shall be designed, manufactured and tested in accordance with ISO 9906 or ISO 13709. Additional guidance can be found in EN 1473.

The HP LNG pump type shall be canned type. The HP LNG pump can shall be designed and manufactured in accordance with a recognized pressure vessel design code (e.g. ASME BPVC-VIII-1 or EN 13445 series).

The HP LNG pump shall be suitable for operation in a marine environment on a floating LNG installation (e.g. motion during operation). In case HP LNG pumps run in parallel, a check valve shall be installed. Provision shall be made to avoid hydraulic hammer from this check valve.

Provisions shall be made to ensure that the HP LNG pump will not be damaged due to low flow. Lower capacity HP LNG pump can be required for start-up and/or minimum send out. Locking device on the HP LNG pump shall be foreseen to avoid pump damage during shut down of regasification system, emergency departure and/or journey/operation as LNG carrier.

Condition monitoring should be installed on the HP LNG pump.

11.2 LNG vaporization system

11.2.1 Functional requirements

The function of a vaporizer is to vaporize and heat the LNG in order to send out the natural gas into the offshore/onshore gas grid at a temperature compatible with the downstream pipeline. The following nominal values of the performance data of the vaporizers shall be ensured by the manufacturer:

a) minimum and maximum flow;

b) minimum outlet temperature;

c) maximum pressure drop;

d) minimum and maximum heating medium requirements;

e) minimum pressure for rated duty.

f) maximum number of thermal cycles per annum permitted by mechanical design.

Additional guidance for design conditions and performance data for vaporizer can be found in EN 1473.

11.2.2 Vaporization type

Table 2 provides an overview of types of vaporization systems that can be envisaged for an FSRU.

Table 2 — Types of vaporization systems

Type	Heating medium
Open loop	Seawater
	Seawater with intermediate fluid (glycol)
	Air
Closed loop	Glycol
	Propane
	Steam
	Other suitable heating media

If using a hazardous (inflammable) intermediate fluid (e.g. propane), it shall be considered in the risk assessment carried out to determine the overall impact from the leak and ignition of such fluids.

If using a hazardous heating medium (e.g. propane), seawater lift from engine room to the top deck shall be designed for heat exchange. This will avoid the heating medium exchanging heat with seawater in the engine room, introducing ignition sources at the engine level. If non-hazardous medium (e.g. glycol) is used, the heat exchange can take place in the engine room and avoid seawater lifting. This will reduce power requirements substantially.

Further description of these vaporization types is provided in Annex A.

11.2.3 Materials selection

Materials can be selected from the LNG suitable materials listed in ISO 16903.

Vaporizers are also in contact with a heating fluid. Compatibility of materials between different parts of the process equipment/piping and with the fluids shall be taken into account, including the following cases:

a) In case some equipment/piping is made from different materials (e.g. aluminium alloys and stainless steel), joint strategy shall consider material compatibility.

b) Either the material is compatible (no corrosion or erosion) with the heating fluid for which the characteristics shall be properly specified beforehand or a protective coating shall be applied onto parts in contact with the heating fluid.

c) At the vaporizer outlet, piping materials shall be chosen in terms of the lowest temperature that can occur in normal and transient conditions. Sufficient length of cryogenic temperature material shall be provided after vaporizer isolation valves (which close in case of too low temperature compared to the specified threshold) according to the control system reaction time. Detailed transient analysis shall be performed to check the risk of cold propagation on piping downstream the vaporizer.

11.2.4 Protective coating

When a protective coating (e.g. paint, metal spraying, galvanisation) is applied to protect the vaporizer against chemical or physical attack from the heating fluid, that coating shall be stable both at the temperature of the LNG and at the maximum temperature of the heating fluid.

The protective coating can gradually erode and/or corrode. The maximum rate of loss of the coating shall be specified taking into account the operating conditions (e.g. flow velocities, temperature, composition, duration of utilization).

11.2.5 Marine growth

In case of use of seawater as heating medium, a chlorination system should be provided to prevent marine growth in the seawater piping system.

In the event that a chlorine based system is used, chlorine concentration shall be continuously adjusted to the seawater flowrate and monitored through residual chlorine measurement devices at water disposal outlets.

Environmental aspects are described in 5.2.

11.2.6 Stability/vibration

Vaporizers shall operate in a stable condition without any vibration for the specified operating range.

An analysis shall be carried out to check that global freezing will not occur at the HP vaporizer during ESD conditions.

11.2.7 Safety relief valves

To avoid overpressure, any vaporizer that can be isolated (blocked in) shall have at least one safety relief valve. The flowrate required for the safety relief valve shall be calculated using the following assumptions:

a) the vaporization section is filled with LNG at working temperature;

b) the isolation valves of the section are closed and assumed to have a tight shut-off;

c) the heating system (e.g. heating fluid, bath) remains in service at maximum power (i.e. at maximum possible temperature and at maximum flow rate for the heating medium);

d) unless the shut-in overall heat transfer coefficient is known, the heat transfer coefficient shall be based on clean operation (i.e. zero fouling resistance) and the rated LNG flow;

e) the safety relief valve shall discharge directly to the atmosphere to a safe location. If this is not possible, the discharge of the safety relief valve shall be routed to the flare or to the vent.

11.3 Trim heater

Trim heater investigation can be needed for specific project location and/or project setup according gas delivery conditions. In some cases, an NG trim heater can be added at the outlet of the LNG vaporizers to adjust the gas temperature going to the grid (typically >5 °C). Trimming can also be done onshore, hence the options should be studied to determine if adding a trim heater in the FSRU is necessary or not.

11.4 Venting from regasification systems

As for BOG handling and recovery facilities, the regasification system shall be designed to prevent venting and/or flaring except in commissioning and emergency situation.

Dedicated vent mast(s) for regasification system shall be installed to vent gas from relief valves of regasification trains (e.g. HP pumps, vaporizers), from suction drum, and from emergency depressurisation of send-out NG lines.

A knock-out drum can be required for dedicated regasification system vent mast(s) in accordance with blow-down calculations.

The location and height of the dedicated vent mast(s) for regasification system shall be confirmed after proper risk analysis (e.g. fire radiation and gas dispersion studies).

12 Gas send out

12.1 High integrity pressure protection system

12.1.1 Send-out pressure control

Typically, an FSRU delivers gas flow at the following:

a) a defined minimum temperature (typically above dew point(s) and above 0 °C);

b) a defined pressure.

The temperature and pressure at the battery limit is project specific and shall be defined in accordance with the design conditions of the downstream system. The pressure at this battery limit between the FSRU and the downstream system shall be kept in all circumstances below the MOP of the downstream system.

NOTE Downstream system can be an onshore/subsea pipeline or a piping system on a jetty, for example.

The FSRU send-out system is designed for the shut-off pressure of HP pumps supplying the vaporization system. To maintain the flow at the defined value acceptable for the downstream system, a pressure reducing or flow control valve shall be installed in the FSRU send-out system. The potential pressure reduction necessitates increasing the temperature at the outlet of the FSRU regasification system either by vaporizers outlet temperature control or via additional heating system.

If the design pressure in the downstream system is not compatible with the MOP of the FSRU send-out system and according to the risk assessment, an ESD system, such as HIPPS, shall be provided in the FSRU send-out system to prevent an unacceptable pressure level in the downstream system. This HIPPS shall be designed as described in 12.1.3. When SIL is required, this shall be studied for integrity requirement during a SIL session.

The maximum pressure occurring in the system downstream the battery limit is the shutdown of the first downstream valve.

12.1.2 Typical description of HIPPS

HIPPS is a system that closes the source of overpressure within a few seconds with at least the same reliability as a safety relief valve. The HIPPS system shall be segregated from the other safety systems. It is a complete functional loop consisting of the following:

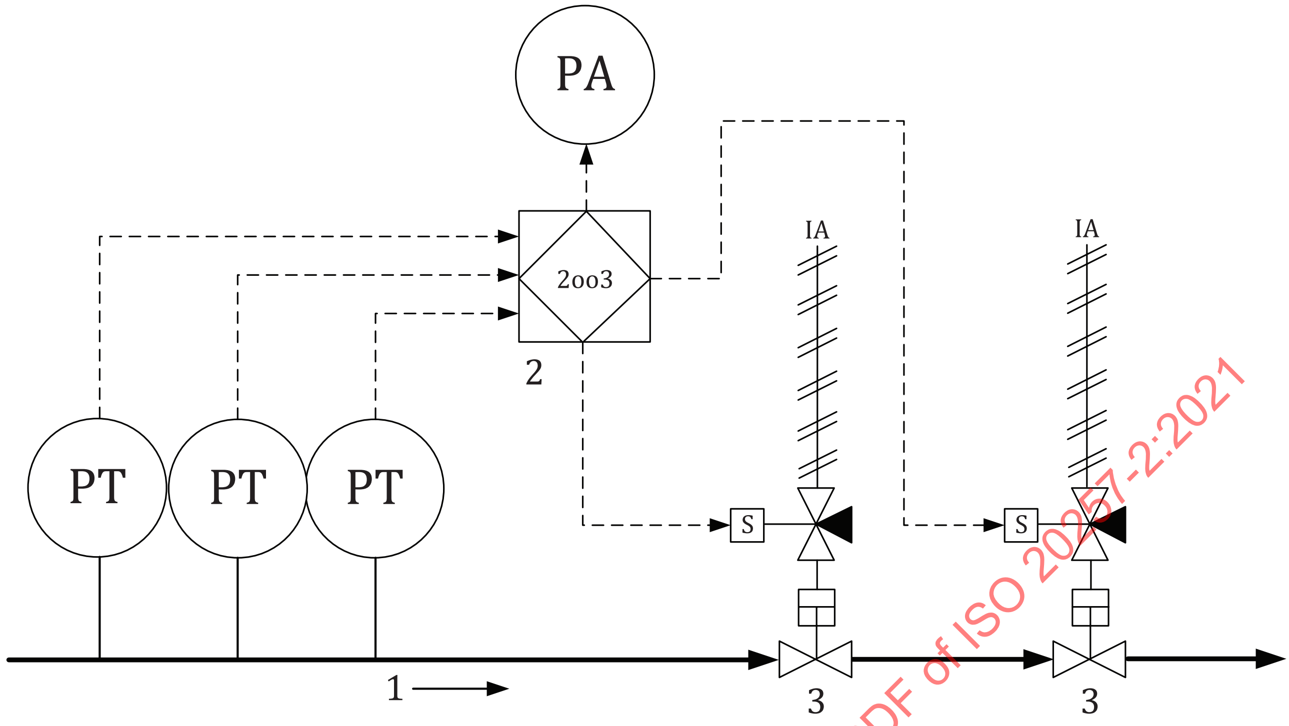
a) One or more sensors/initiators, that detect the high pressure, for which high reliability pressure switches or pressure transmitters can be used. The number of sensors to be used shall be dictated by the SIL to be reached, where required, and the device reliability. For a SIL 3 certified HIPPS, a set of three transmitters used in a two out of three voting (2oo3) configuration shall be used.

b) A logic solver, which processes the signals from the sensors and closes the final element, e.g. by de-energizing the solenoids. A system based on pressure switches does not require a separate logic solver. A SIS or HIPPS utilizing pressure transmitters and a logic solver are typically used when remote sensing is required. The logic solver is usually the most complex device in the loop, especially the programmable ones.

   NOTE Several logic solvers are available with certificates showing suitability in SIL 3 safety loops.

c) One or more final elements, consisting of a valve, actuator and possible solenoids that perform the corrective actions in the field by bringing the process to a safe state, which are high reliability quick-closing valves that are closed by de-energizing one or more solenoid valves on each main valve. As the main valves are generally permanently open during normal operation, partial stroking test devices shall be installed on these valves to fulfil the SIL requirement considering the required periodic maintenance.

Figure 3 provides an illustration of a typical HIPPS.



Key

1 flow direction

2 logic solver

3 block valve

FC fail close

PA pressure analyser

PT pressure transmitter

S solenoid

Figure 3 — Typical HIPPS description

12.1.3 Design requirements for HIPPS

The HIPPS shall be designed considering the requirements of EN 12186, EN 14382, the IEC 61508 series and the IEC 61511 series.

NOTE EN 12186 and EN 14382 refer to mechanical devices and provides requirements for the overpressure protection systems and their components in gas plants. They are both performance-based standards, which provide a detailed framework and a life-cycle approach for the design, implementation and management of safety systems applicable to a variety of sectors with various levels of risk definition. These standards also apply to HIPPS. The IEC 61508 series mainly focus on electrical, electronic and programmable safety-related systems. It also provides a framework for safety-related systems based on other technologies including mechanical systems. The IEC 61511 series covers the other parts of the safety loop (sensors and final elements) in greater detail.

The HIPPS shall be considered a SIS. When required, a SIL shall be assigned to HIPPS in accordance with IEC 61508 series and IEC 61511 series.

The HIPPS design shall include requirements concerning the following:

a) the reliability and availability, which are required according to HAZOP and SIL study;

b) the pressure setting of the HIPPS trip and the HIPPS valves closing time, which shall be determined in such way that in case of closure of any valve downstream of the FSRU delivery battery limit, the pressure downstream of the HIPPS will not exceed the MOP of the downstream system.

12.2 Send-out gas metering

12.2.1 Uses of send-out gas metering

Send-out gas metering can be used as custody transfer metering.

The primary requirements for design of the send-out gas metering system are the agreement between involved parties in the contract and/or the authorities.

12.2.2 Measurement devices type

The ultrasonic meter is the recommended flow metering device, considering the FSRU environment.

All equipment used in the metering station should be type certified in accordance with applicable standards issued by recognized bodies (e.g. OIML).

The ultrasonic meter and metering system shall be in accordance with EN 1776, ISO 17089-1, AGA 9, OIML R 137-1 and OIML R 137-2.

12.2.3 Accuracy

The accuracy of the send-out gas metering system shall be in accordance with local standards and relevant requirements.

Pressure, temperature, compressibility compensation (i.e. P, T, Z correction) shall use type certified pressure transmitters, gas chromatograph and flow computer. The pressure transmitter shall be absolute pressure transmitters.

For the accuracy of the send-out gas metering system, ISO 12213-1, ISO 12213-2 and ISO 6976 shall be used for compressibility factor, density and calorific value in base conditions, and AGA 10 shall be used for speed of sound calculation.

The send-out gas meter shall be type certified class 0,5 according to OIML R 137-1. The manufacturer shall ensure a measurement repeatability of 0,05 % for flow above Q_t, in which Q_t corresponds to a gas velocity of 1,5 m/s, and of 0,1 % between than velocity Q_t and Q_{min}.

The manufacturer shall specify the most suitable upstream straight length arrangement to reduce the installation effect on the global uncertainty as reasonably as possible within the FSRU installation constrains.

To achieve the best possible accuracy in the case of custody transfer or fiscal metering station, the send-out gas meter shall be:

a) Dry calibrated by the manufacturer according to their standard procedure.

b) Wet calibrated by a contractually chosen laboratory conforming to ISO/IEC 17025. Wet calibration shall be performed with upstream and downstream straight lengths. Wet calibration shall be in accordance with ISO 17089-1 for transition flow rate for defining accuracy requirements for 25 %, 50 %, 75 % and 100 % meter flow capacity or range.

As the meters used can require re-calibration at specific intervals, the design shall permit for the physical removal of such equipment without compromising the safety of the facility, in particular if it remains in operation.

12.2.4 External influences

To avoid vibration and/or noise effects from FSRU operation and from pressure reducing valve downstream of the send-out gas metering, appropriate precautions in the piping design should be taken (e.g. use of Brandenberger gates upstream and downstream of the metering lines).

12.2.5 Gas chromatograph – Gas analyser

One or two redundant gas chromatographs can be installed on the FSRU to determine the gas composition for evaluation of the gas compressibility factor and density.

In the case of failure of a single gas chromatograph, the flow computer shall choose between the last valid measurement or operator entered composition. An 11-components analysis is sufficient for the metering purpose in the case of LNG.

Project requirements can impose the need for additional analysis like H_2S, 0_2. In that case, additional components shall be analysed by the gas chromatograph, or if not possible, by another gas analyser taking into account the specific standards related to this analysis.

12.2.6 Sparing philosophy

As the send-out gas metering operates permanently, it shall be designed in N+1 metering lines, in which N is the minimum required number of lines to measure accurately the maximum and minimum expected flow rate. Influence of the number of lines on the global uncertainty shall also be analysed to reduce the global uncertainty as reasonably as possible.

12.2.7 Z-configuration

Z-configuration can be provided and used as described in ISO 17089-1 as periodic check of the send-out gas meter. In that case, one line shall be used as a reference line or in case of unavailability of one of the other line.

12.3 Odorization systems

Gas odorization is generally not used for HP gas. Odorization can be required by contractual agreement or by national regulation.

The odorization system shall be supplied

a) as a completely independent package including gas flow measurement, odorant requirement evaluation and odorant injection device, and

b) with means of verification on FSRU of the odorization efficiency.

If required, the odorization systems shall be designed in accordance with ISO 13734.

Additional guidelines are provided in ISO/TR 16922.

13 Utilities

13.1 General

This clause describes the specificities of the FSRU utilities and shall be applied in addition to ISO 20257-1:2020, Clause 12.

13.2 Cooling and heating medium

13.2.1 Cooling medium

13.2.1.1 General

Depending on type of FSRU different requirements for cooling duty will apply. Cooling will mainly be required for machinery and less for process function. Each cooling system serving an essential service item equipment or installation, as determined by a risk and availability study, shall be designed to preserve the cooling function in the event one or more of the essential components will be inoperative.

13.2.1.2 Seawater for equipment

Seawater cooling system shall be capable of being supplied by two different means. At least two sea inlets shall be provided for the seawater cooling system, one for each means of cooling required. The design of the seawater intake often requires detailed study to ensure that the filtrations of the seawater pumps are correctly addressed.

13.2.1.3 Freshwater for equipment

Freshwater cooling system shall be capable of being supplied by two different means. Freshwater cooling system of essential equipment, as determined by a risk and availability study, shall at least have

a) one main cooling water pump, and

b) one independently driven standby pump.

13.2.2 Heating medium

13.2.2.1 Seawater

During the regasification process, an FSRU can take in seawater, extract heat from it for regasification of the LNG, and discharge the seawater at a lower temperature. Specific requirements are addressed in 4.5 and 5.2.

13.2.2.2 Steam

In the case a single boiler is installed, the steam system can supply only non-essential services, as determined by a risk and availability study. In the case more than one boiler is installed, the steam system shall be designed such that the steam supply to essential service(s) will be maintained in the event a boiler is out of action.

A suitable reducing valve, relief valve and pressure gauge shall be fitted to protect steam pipe or fitting against overpressure. A dump valve shall be fitted to discharge to the condenser to avoid overpressure in steam lines due to excessive steam production.

Steam lines shall not pass through accommodation spaces, unless they are intended for heating purposes.

13.2.3 Nitrogen system

Nitrogen is used for many purposes (e.g. tank blanketing, purging of LNG loading arms and maintenance activities). Nitrogen system shall be in accordance with sections 9.4 and 9.5 of IGC Code.

The purity of the nitrogen generation should at least be 97 %, with dew point appropriate for use. Nitrogen shall not be used as back up of instrument air systems.

In the event that nitrogen is used for Wobbe Index correction, it shall be supplied from a dedicated system with a purity level as required by the outlet gas specification, in particular with regard to permitted oxygen content.

13.2.4 Fuel gas

Fuel gas has the advantage that emissions are lower than heavy fuel oil or marine diesel oil options. Fuel gas can be sourced from BOG of the LNG tanks, from LNG forced vaporization or from the regasification system. Fuel gas can be used for power generation or for heaters for process equipment.

The complete system for treatment of gas to fuel quality, including compressors, separators, filters, pressure control valves, shall be located in the hazardous area and separated from the engine and boiler room by gas-tight bulkheads. The fuel quality specifications, such as heating value, temperature and pressure, will depend on OEM data related to the installed equipment.

Gas detectors shall be fitted in all machinery spaces where gas is utilized. Gas fuel piping shall not pass through accommodation spaces, services spaces, or control stations. All gas supply piping within machinery space boundaries should be enclosed in a gastight enclosure, i.e. double wall piping or ducting (as per IGC Code, section 16.4.3).

14 Process and safety control systems

14.1 General requirements

Process and safety control systems shall be in accordance with ISO 20157-1:2020, Clause 13.

14.2 Interfaces between FSRU and gas export connection

In addition to the requirements of ISO 20257-1:2020, 13.5, separate ESD levels from LNG transfer ESD levels shall be defined for gas send-out transfer from FSRU to shore (e.g. ESD3 and ESD4 or OESD-3 and OESD-4).

14.3 Communication onshore/offshore

If the FSRU is intended to export gas to shore, communication and process control philosophy between onshore facilities and FSRU shall be integrated into the design at an early stage. FSRU control room, onshore gas dispatching centre facilities as well as any other parties involved shall be properly interfaced. Clear roles shall be defined for each of the parties involved.

15 Security management

Security management shall be in accordance with ISO 20257-1:2020, Cause 14.

16 Commissioning

The principles of commissioning as described in ISO 20257-1:2020, Clause 15 are applicable for an FSRU, acknowledging that some components, equipment or parts of the facilities addressed there might not be applicable to an FSRU.

For operational and safety purposes, cooldown of the FSRU at existing LNG onshore facilities should be carried out, considering that the FSRU could need to be able to travel with LNG. Variable extent of testing at this existing facility should be performed depending on the project requirements and constraints at final location.

The following specific commissioning items should be considered for FSRU projects:

a) If permanent mooring is selected and the FSRU is not able to relocate, the commissioning and start-up efforts will be lower compared to a disconnectable FSRU (e.g. regarding propulsion or mooring).

b) The FSRU scope versus the onshore scope regarding commissioning responsibilities and handover clarification should be defined. Overall interface philosophy during commissioning should be agreed early in the project.

c) Venting and/or flaring during commissioning can interfere with nearby facilities, ships and/or traffic and should be integrated within the overall safety approach.

d) Where possible, commissioning should be performed without venting or flaring.