TECHNICAL SPECIFICATION

ISO/TS 18683

Second edition
2021-11

Guidelines for safety and risk assessment of LNG fuel bunkering operations

Lignes directrices pour la sécurité et l'évaluation des risques des opérations de soutage de GNL

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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*.

This second edition cancels and replaces the first edition (ISO/TS 18683:2015), which has been technically revised.

The main changes are as follows:

— title and scope restricted to Guidelines for safety and risk assessment of LNG fuel bunkering operations;

— list of bunkering supply scenarios updated with experience gained since 2015 in Clause 4;

— addition of concept of design stage risk assessment and operational risk assessment in 7.1;

— addition of Quantitative Consequence Assessment in 7.2;

— addition of roles and responsibilities of stakeholders in 7.3;

— design requirements removed from Clause 8 to avoid duplication with ISO 20519;

— individual Risk Criteria added in Annex A;

— three methods added to determine safety zone in Annex B;

— to avoid duplication with ISO 20519, the following clauses and annexes have been removed:

  — Clause 9 Requirements to components and systems;

  — Clause 11 Requirements for documentation;

  — Annex C Functional requirements;

- Annex D Sample Ship supplier checklist;
- Annex E Sample LNG delivery note;
- Annex F Arrangement and types of presenting connection;
- Annex G Dry disconnect coupling.

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

Introduction

The properties, characteristics, and behaviour of LNG differ significantly from conventional marine fuels, such as heavy fuel oils and distillate fuels as marine diesel oil (MDO) or marine gas oil (MGO).

For these reasons, it is essential that all LNG bunkering operations are undertaken with diligence and due attention is paid to prevent leakage of LNG liquid or vapour and to control all sources of ignition. Therefore, it is important that throughout the LNG bunkering chain, each element is carefully designed and has dedicated safety and operational procedures executed by trained personnel.

It is important that the basic requirements laid down in this document are understood and applied to each operation in order to ensure the safe, secure, and efficient transfer of LNG as a fuel to the ship.

The objective of this document is to provide guidance for the risk assessment of LNG fuel bunkering operations and thereby ensuring that an LNG fuelled vessel and bunkering supply facilities are operating with a high level of safety, integrity, and reliability regardless of the type of bunkering supply scenario.

The LNG bunkering interface comprises the area of LNG transfer and includes manifold, valves, safety and security systems and other equipment, and the personnel involved in the LNG bunkering operations.

This document is based on the assumption that the receiving ships and LNG bunkering supply facilities are designed according to the relevant and applicable codes, regulations, and guidelines such as the International Maritime Organization (IMO), ISO, EN, and NFPA standards and the Society for Gas as a Marine Fuel (SGMF) and other recognized documents during LNG bunkering. Relevant publications by these and other organizations are listed in the Bibliography.

This document should be combined with the requirements set on ISO 20519.

In cases where the distance to third parties is too close and the risk exceeds acceptance criteria, the bunkering location should not to be considered.

Guidelines for safety and risk assessment of LNG fuel bunkering operations

1 Scope

This document gives guidance on the risk-based approach to follow for the design and operation of the LNG bunker transfer system, including the interface between the LNG bunkering supply facilities and receiving LNG fuelled vessels.

This document provides requirements and recommendations for the development of a bunkering site and facility and the LNG bunker transfer system, providing the minimum functional requirements qualified by a structured risk assessment approach taking into consideration LNG properties and behaviour, simultaneous operations and all parties involved in the operation.

This document is applicable to bunkering of both seagoing and inland trading vessels. It covers LNG bunkering from shore or ship, mobile to ship and ship to ship LNG supply scenarios, as described in Clause 4.

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/IEC Guide 73, *Risk management — Vocabulary*

ISO 31010, *Risk management — Guidelines on principles and implementation of risk management*

ISO 20519, *Ships and marine technology — Specification for bunkering of liquefied natural gas fuelled vessels*

IMO, IGF Code of Safety for Ships using Gases or other Low flashpoint fuels

IMO, IGC International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk

IMO, International Convention on Standards of Training, Certification and Watchkeeping for Seafarers

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC Guide 73 and the following apply.

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

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

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

3.1.1
as low as reasonably practical
ALARP
reducing a risk to a level that represents the point, objectively assessed, at which the time, trouble, difficulty, and cost of further reduction measures become unreasonably disproportionate to the additional risk reduction obtained

3.1.2
boiling liquid expanding vapour explosion
BLEVE
sudden release of the content of a vessel containing a pressurized flammable liquid followed by a fireball

3.1.3
bunkering
process of transferring fuel to a ship

3.1.4
bunkering facility
system designed to be used to transfer/bunker liquefied gas as fuel to a gas-fuelled vessel

Note 1 to entry: It may consist of a floating, shore-based, fixed or mobile fuel-supply facility, such as a bunker vessel, terminal or road tanker.

3.1.5
bunkering site
location dedicated for bunkering comprising the bunkering installations, port and jetty, and other facilities and equipment that should be considered in the planning of bunkering

3.1.6
competent authority
organization or organizations that implement the requirements of legislation and regulate installations that must comply with the requirements of legislation

3.1.7
consequence
outcome of an event

3.1.8
drip tray
spill containment manufactured of material that can tolerate cryogenic temperatures

3.1.9
emergency shut-down
ESD
method that safely and effectively stops the bunker/transfer of natural gas and vapour between the supply facilities and receiving ship

3.1.10
gas-fuelled vessel
GFV
vessel using gas as marine fuel

3.1.11
hazard
potential source of harm

3.1.12
hazard identification
HAZID
brainstorming exercise using checklists where the potential hazards in a project are identified and gathered in a risk register for follow up in the project

3.1.13
impact assessment
assessment of how consequences (fires, explosions, etc.) affect people, structures the environment, etc.

3.1.14
individual risk
probability on an annual basis for an individual to be killed due to accidental events arising from the activity

3.1.15
mist
fog
cloud that will be generated by condensing humidity in air when in contact with cold surfaces during bunkering

Note 1 to entry: This mist will reduce visibility and can mask minor leaks.

3.1.16
monitoring and security area
area around the bunkering facility and ship where ship traffic and other activities are monitored (and controlled) to mitigate harmful effects

3.1.17
probability
extent to which an event is likely to occur

3.1.18
rapid phase transition
RPT
shock wave forces generated by instantaneous vaporization of LNG upon coming in contact with water

3.1.19
receiver
one or more organizations with ownership, operational and/or legal interests in a gas-fuelled vessel

Note 1 to entry: The receiver can be the vessel owner(s), the charterer or the operator.

[SOURCE: Reference [24]]

3.1.20
risk
combination of the probability of occurrence of harm and the severity of that harm

3.1.21
risk analysis
systematic use of information to identify sources and to estimate the risk

3.1.22
risk assessment
overall process of risk analysis and risk evaluation

3.1.23
risk contour
two-dimensional representation of risk (e.g. individual risk on a map)

3.1.24
risk evaluation
procedure based on the risk analysis to determine whether the tolerable risk has been achieved

3.1.25
safety
freedom from unacceptable risk

3.1.26
safety zone
area around the bunkering station where only dedicated and essential personnel and activities are allowed during bunkering

3.1.27
stakeholder
individual, group, or organization that can affect, be affected by, or perceive itself to be affected by a risk

3.28
supplier
one or more organizations with ownership, operational and/ or legal interests in a bunkering facility

Note 1 to entry: The supplier can be the bunker vessel owner, charterer or operator; the LNG bunkering terminal owner or operator; the road tanker fleet manager; the LNG producer; and so on.

[SOURCE: Reference [24]]

3.1.29
tolerable risk
risk that is accepted in a given context based on the current values of society

3.1.30
topping up
final sequence of LNG transfer to ensure correct filling level in receiving tank

3.1.31
water curtain
sprinkler arrangement to protect steel surfaces from direct contact with LNG

3.2 Abbreviated terms

BASiL	bunkering area safety information for LNG
ERC	emergency release coupling
ERS	emergency release system
HFO	heavy fuel oil
HSE	health, safety, and environment
IMO	international maritime organization
LNG	liquefied natural gas
MGO	marine gas oil
PPE	personal protective equipment
QualRA	qualitative risk assessment
QCA	quantitative consequence assessment
QRA	quantitative risk assessment
SGMF	society for gas as marine fuel
SIMOPS	simultaneous operations
STCW	seafarers' training, certification and watch-keeping

NOTE LNG is defined in ISO 16903.

4 Bunkering supply scenarios

Selection of the bunkering supply scenario should consider the following factors:

a) LNG process conditions (e.g. LNG bunkering volumes, transfer rates and LNG pressure and temperature);

b) simultaneous operations (e.g. loading/unloading cargo, embarkation of passengers, transfer of other bunker fuels);

c) possible interference with other activities in the bunkering location (e.g. port area);

d) bunker transfer equipment;

e) type of receiving LNG fuelled ship and bunkering facility;

f) safety studies undertaken for the bunkering operations (e.g. risk assessment and safety zone defined in Clause 7);

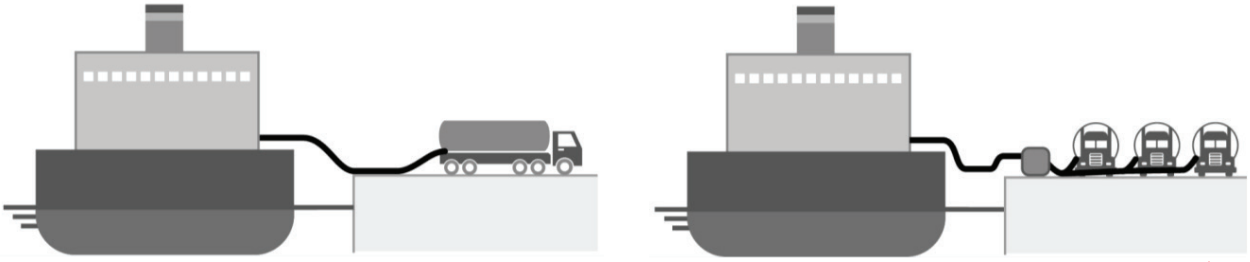
g) local conditions (e.g. weather, traffic).

Three typical LNG bunkering supply scenarios have been considered in this document (see Figure 1):

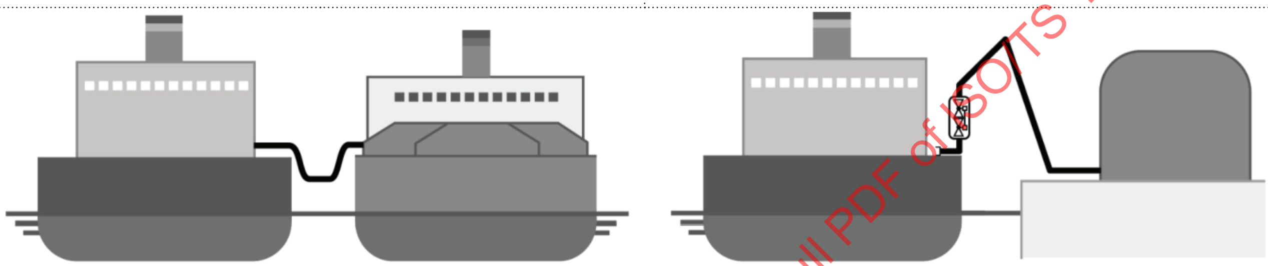
— Mobile-to-Ship: An LNG bunkering operation to a gas-fuelled vessel from a mobile bunkering facility located onshore. Mobile bunkering facilities can consist of a truck, rail car or other mobile device (including portable tanks) used to bunker LNG (see Figure 1).

— Shore-to-Ship: An LNG bunkering operation to a gas-fuelled vessel from a fixed bunkering facility or terminal (see Figure 1).

— Ship-to-Ship: An LNG bunkering operation to a gas-fuelled vessel from a floating storage or bunker vessel (see Figure 1).



Receiver	Supplier	Receiver	Supplier
Gas-fuelled vessel	Bunkering facility	Gas-fuelled vessel	Bunkering facility
Mobile to Ship bunkering from a truck		Mobile to Ship bunkering from multiple trucks/portable tanks, throughout a jointed manifold/pumping station	



Receiver	Supplier	Receiver	Supplier
Gas-fuelled vessel	Bunkering facility	Gas-fuelled vessel	Bunkering facility
Ship to ship bunkering from a floating storage or bunker vessel		Shore to ship bunkering from a fixed bunkering facility/terminal	

Figure 1 — Typical LNG supply bunkering scenarios

5 Properties and behaviour of LNG

5.1 General

The properties, characteristics and behaviour of LNG differ significantly from conventional marine fuels for example HFO and MGO, etc. For these reasons, it is essential that all LNG bunkering operations are undertaken with diligence, that due attention is paid to prevent leakage of LNG liquid or vapour and that sources of ignition in the vicinity (i.e. inside the safety zone) of the bunkering operation are strictly controlled. Therefore, it is necessary that throughout the LNG bunkering supply chain, each element is carefully designed and has dedicated safety operational and maintenance procedures executed by trained and competent personnel.

5.2 Description and hazards of LNG

Description of LNG is fully covered in ISO 16903 but for the purposes of LNG bunkering, the most important characteristics compared with marine gas fuel are described in this subclause.

At atmospheric pressure, depending upon composition, LNG boils at approximately −160 °C. Released LNG will form a boiling pool on the ground or on the water where the evaporation rate (and vapour generation) depends on the heat transfer to the pool.

LNG for fuel supply may be delivered at an elevated pressure and at a temperature exceeding its boiling point at atmospheric conditions (e.g. at 5 bar and at −155 °C). Release of LNG under such conditions will result in instantaneous flashing and larger vapour release compared to evaporation from liquid pools. The vapour release will form a flammable cloud which at these temperatures is denser than air. The dispersing gas becomes lighter than air (buoyant) at approximately −110 °C so will drift with wind and be diluted by atmospheric turbulence and diffusion. The coldness of the gas will condense moisture in the air making the dispersing gas visible as a white cloud.

Cold surfaces in the bunker transfer system can also cause mist or fog by condensing humidity in the air that might mask a release.

LNG can cause brittle fracture if spilled on unprotected carbon steel.

Natural gas has a flammable range between 5 % and 15 % when mixed with air.

Natural gas has a flashpoint of −187 °C and a high self-ignition temperature (theoretically, approximately 540 °C. The properties of traditional fuels are different; MGO has a flashpoint in excess of 60 °C and a self-ignition temperature of 300 °C for MGO or a gas oil vapour/aerosol air mixture.

The ignition energy of natural gas/air mixtures is 0,25 mJ, which is lower than most other hydrocarbons.

Natural gas releases are not easily ignited by hot surfaces that ignite most conventional fuel oil fires in engine rooms, but low energy sparks represent a higher risk.

Methane has a high greenhouse gas potential and venting to the atmosphere shall not be part of normal operations.

The following are the main hazards associated with LNG applicable to bunkering operations:

— fire (pool fire, jet/torch fire, flash fire) explosion (in confined spaces) from ignited natural gas evaporating from spilled LNG;

— vapour dispersion;

— brittle fracture of the steel structure exposed to LNG spills;

— frostbite or cold burn from liquid or cold vapour spills;

— asphyxiation from vapour release;

— over-pressure or pressure surge of the bunker system caused by thermal expansion or vaporization of trapped LNG;

NOTE The thermal expansion coefficient of LNG is high.

— release in confined spaces causing over-pressure due to vaporization of liquid;

— possible RPT (rapid phase transition from liquid to gas);

— possible stratification with existing LNG in tanks (might later lead to inadvertent venting of gas);

— possible BLEVE of a pressurized tank subjected to a fire.

5.3 Potential hazardous situations associated with LNG bunker transfer

The planning, design, and operation should focus on preventing release of LNG and vapour and avoiding occupational accidents related to the handling of equipment. The risk and hazards related to the LNG bunkering are closely linked to the potential rate of release in accidental situations and factors such as transfer rates, inventories in hoses and piping, protective systems such as detection systems, ESD, and spill protection are essential.

5.4 Composition of LNG as a bunker fuel

The specification of the LNG supplied as fuel is defined in ISO 23306.

The composition will change with ageing also known as weathering (due to preferential evaporation), commingling from different sources/suppliers and will modify the fuel composition.

6 Safety

6.1 Objectives

Safety shall be the primary objective for the planning, design, and operation of facilities for the delivery of LNG as marine fuel taking into consideration simultaneous operations and the interaction with third parties.

LNG bunkering might be carried out without simultaneous operations (SIMOPS), but more often some SIMOPS such as cargo operations, bunkering with passengers on-board or embarking/disembarking is occurring at the same time and these need acceptance by all parties involved as competent authority, port authorities, terminal, ship and bunkering operator, and supplier operator.

Furthermore, in all LNG bunkering cases a risk assessment must be performed for the specific bunkering operations, location, bunkering scenario and process conditions. This risk assessment should be appropriate to the operation and risks and it should provide evidence that risks have been identified and sufficiently mitigated to allow their acceptance by the competent authority. Risk assessment methodology for the different conditions as described in factors above are recommended in Clause 7.

The safety of the bunkering operation shall not be compromised by commercial requirements.

6.2 General safety principles

The planning, design, procurement, construction, and operation should be implemented through quality, health, safety, and environmental management systems.

6.3 Approach

The safety targets for the operation of the bunkering scenarios shall be demonstrated by meeting the requirements as defined in Clause 8, and supported by a risk assessment as outlined in Clause 7.

7 Risk assessment

7.1 General

An assessment of risk to individuals, local populations, assets and the environment shall be undertaken as a part of the development of the bunkering facility and the gas fuelled vessel and their operations.

The purpose of the risk assessment is to provide confidence to all stakeholders that the specific risks of LNG bunkering have been appropriately considered and assessed.

The risk assessment will also help with the determination of the required controlled zones around the bunkering operation, as per 7.6 that limit access, equipment and activities within them.

The risk assessment shall be conducted in accordance with IEC 31010:2019 or equivalent. ISO/TS 16901 and ISO 17776 provide guidance on risk assessment techniques used in other sectors. They can also be a useful reference, although the risk criteria might not be directly applicable to the bunkering of LNG.

The risk assessment shall be undertaken by suitably qualified and experienced individuals and ensure an objective and independent assessment.

The main steps in the risk assessment shall be to

a) identify what can go wrong (hazard identification),

b) determine the effects (consequence and impact assessment),

c) assess the likelihood,

d) determine the level of risk,

e) compare the risk against agreed criteria, and

f) if the risk is unacceptable, identify risk reducing measures.

After applying risk reduction measures, the above steps shall be repeated until the risk is deemed to satisfy the agreed criteria.

An LNG bunkering risk assessment shall be completed before any operations can be undertaken, however different parties might decide to carry out only one or multiple risk assessments at different stages of the LNG fuelled vessel and bunkering facility development.

For example, a design stage risk assessment might be performed. This is carried out in the early design stage of a bunkering facility or gas-fuelled vessel as it provides specific design recommendations which, if considered at this stage, mitigate more substantial costs of implementation later during construction or after the build. At this stage, the design and particulars of the gas-fuelled vessel and bunkering facility as well as the specific bunkering location might not be fully available, and a number of assumptions might be required, which will need to be validated at the next stage.

In addition, an operational risk assessment is performed to identify and address operational, and location specific risks and mitigations based on the previous design stage risk assessment. At this stage, the design and particulars of the gas-fuelled vessel and bunkering facility as well as the specific bunkering location should be available. This stage might be repeated/validated as bunkering operations become clearer or change over time, e.g. different bunkering location or bunkering scenario.

The risk acceptance criteria are defined in Annex A.

7.2 Types of risk assessment

The risk assessment can follow one of several forms. Typically, these include:

a) Qualitative Risk Assessment (QualRA) where analysis is undertaken to categorize the likelihood of events and their consequences using judgements to provide a combined assessment in the form of a grading that can be compared against criteria.

b) Quantitative Consequence Assessment (QCA) of the predicted outcome of selected events in terms of magnitude and distance, etc. to determine the extent to which casualties and damage can occur.

c) Quantitative Risk Assessment (QRA) where numerical analysis is undertaken for a range of event likelihoods and their consequences to provide a combined assessment in the form of a number, rate or contour that can be compared against criteria.

The principal differences between the risk assessment types are as follows:

a) QualRA uses expert judgement to identify events and categorize their likelihood and consequences based upon experience, knowledge and reference to appropriate work and research.

b) QCA uses expert judgement to identify the events to be analysed and numerical models to estimate the potential consequences of those events.

c) QRA uses expert judgement to select a representative set of events; numerical models to estimate the potential consequences of those events; operational and empirical data to estimate their likelihood; and numerical models to calculate and sum the risk from each likelihood and consequence combination.

The type of risk assessment to be undertaken will depend upon a number of factors, such as the requirements of the competent authorities, the type and number of persons potentially at risk, and the complexity of the bunkering operation. The stakeholders shall agree which type(s) is used.

A QualRA is the minimum required by this document and can suffice where the bunkering supply scenarios are as outlined in Clause 4. Furthermore, in some cases, QualRA can be sufficient to demonstrate that the agreed risk acceptance criteria are met, and risks are ALARP. In other cases, it may be used as an initial evaluation prior to carrying out a QCA and/or a QRA.

A QCA or QRA can be appropriate when

— the bunkering operation is considered complex,

— many persons can be in close proximity, for example, when bunkering is close to population centres,

— bunkering deviates from the standard bunkering supply scenarios outlined in Clause 4; and/or,

— simultaneous operations (SIMOPS) are anticipated, for example, bunkering with passengers disembarking.

A QCA or QRA can also be necessary to adequately determine the Safety Zone and/or the Monitoring and Security Area.

A QCA can be the preferred tool in non-sensitive locations (e.g. remote areas not in proximity to populations centres).

A QRA can be used, if the competent authority allows, to reduce the size of QCA events by considering the likelihood of occurrence

7.3 Roles and responsibilities of stakeholders

The bunkering operation can involve and impact many organizations with differing interests and views. These stakeholders and their roles and responsibilities should be identified during the planning of the risk assessment and they should be considered when undertaking the risk assessment. As a minimum, the following stakeholders should be taken into consideration:

a) LNG supplier;

b) LNG receiver;

c) designer;

d) regulator;

e) port authority;

f) terminal operator;

g) emergency services;

h) port users;

i) neighbours and the public.

The typical roles and responsibilities of these stakeholders are noted in Table 1.

Table 1 — Typical Stakeholders - roles and responsibilities

Stakeholder	Role	Responsibility
LNG supplier	Conduct/organize risk assessment and obtain permit/license to operate	Make available technical specification of bunkering facility and operating conditions and procedures
LNG receiver	Input to risk assessment covering specific vessel and operation	Make available technical specification of vessel and operating procedures
Designer	Can provide input to risk assessment covering equipment and system design	Make available design criteria and technical specifications of equipment
Regulator	Can be involved as subject matter expert or approve risk assessment	Will set the risk assessment criteria and define applicability of local legislation
Port authority	Consider impact of LNG bunkering on port activities and vice versa. Can conduct port level risk assessment and set permit requirement	Make available detailed information concerning port activities, as required. Issue permit or license
Terminal operator	Consider impact of LNG bunkering on terminal activities and vice versa	Make available detailed information concerning terminal activities, as required
Emergency services	Informed party and/or input to risk assessment covering emergency response	Make available information as applicable
Port users	Informed party	Make available information through port authority if required
Neighbouring facilities	Informed party	Make available information through port authority/local authority if required
Public	Informed party	None

NOTE 1 Port authority/regulator role can be interchangeable or be the same entity and acting as competent authority with jurisdiction over the bunkering operation/location.

NOTE 2 Designer, includes facility(s), vessel(s) and equipment designers, as applicable.

NOTE 3 All stakeholders are responsible for the implementation of agreed mitigation measures, as applicable.

This table should be reviewed for each area/application.

7.4 Approach, scope and basis

The core activities of the risk assessment are listed in steps ‘a’ to ‘f’ in 7.1 above but prior to commencement of the risk assessment there is a need to define the scope and basis of the study. For example, it is important to identify and agree the equipment, facilities, operations, vessels and locations to be studied, and the risk criteria to be used. Table 2 summarizes information requirements and the principal considerations in determining the scope and the study basis.

Table 2 — Scope and study basis – information requirements and considerations

Risk criteria	Identification of the risk criteria to be used (e.g. qualitative or quantitative criteria used by the competent authority)
Location	Description of the bunkering location together with details of port operations, marine traffic, neighbouring facilities and the type and number of persons normally in proximity (e.g. bunkering personnel, port workers and members of the public)
Layout	General description of the bunkering installation including the layout and arrangement of the equipment
Equipment	Detailed description, including function and design, of mechanical and electrical equipment, control systems, safety systems and their sub-systems and components
Process conditions	Detailed description of the process conditions for each bunkering supply scenario e.g. flowrates, pressures, temperatures, etc.

a More details on the operations can be found in SGMF bunkering guidelines[24] the IACS[35] and SGMF FP10-01[28].

Table 2 *(continued)*

Operations [a]	Description of the sequence, duration and number of operations, and operational limitations with respect to: Pre-bunkering phase - ensuring all the assessment and authorizations have been completed and/or obtained and procedures are agreed between the LNG supplier and receiver before commencing the operations. Preparation for bunker phase - Covering the mooring of the vessel(s) and the preparation of the transfer and safety equipment including checking that the location, quantity, suitability, condition etc. are all as assessed and agreed during the pre-bunkering phase. Connection and testing phase - safe transfer, connection and testing of all the necessary equipment, including leak testing and inerting. Bunkering Phase - Cooling down followed by the LNG bunker transfer and including the topping up/ramp down phase. Completion Phase - Draining, purging and inerting before the secure, safe disconnection and retrieval of the transfer and safety equipment prior to separation of the receiving ship and bunkering facilities Other and special operations - Commissioning, security, vessel traffic and port/harbour specific issues and characteristics, de-bunkering, warming up, etc.
Management control	Organization of the bunkering activities with clear definitions of the roles, responsibilities and communication/documentation for the gas fuelled vessel crew and the bunkering facility personnel
SIMOPS	Description of simultaneous operations being undertaken by the receiving vessel and other vessels in proximity to the bunkering operation
Environmental Conditions	Review of local met ocean information and weather data

[a] More details on the operations can be found in SGMF bunkering guidelines[24] the IACS[35] and SGMF FP10-01[28].

A summary of the study basis shall be documented or referenced in the risk assessment report, as appropriate.

To facilitate the risk assessment process, example causes and consequences of hazardous events and commonly adopted safeguards/mitigation measures are provided in Tables 3 and 4, respectively.

Table 3 — Example hazardous events and consequences

Causes		**Consequences**
Failure of vessels pipes etc. containing LNG or NG		**Release of LNG and/or NG leading to large flammable vapour cloud which could result in:**
Use of unsuitable materials due to incorrect design criteria, material specification or fabrication		Brittle fracture of metal structures and other nearby equipment
Failure due to high/low pressure or high/low temperature		Rapid phase transition
Failure due to corrosion		Injuries to personnel due to exposure to cold (e.g. frostbite)
		Environmental impacts
Failure due to over pressurization		Damage to equipment
Malfunction of pressure control systems and devices		
Inadequate protection against thermal expansion		
Overfilling of tank		
Pressure surge in transfer line		

NOTE 1 Some causes or consequences might not always be applicable.

NOTE 2 Some causes can also be consequences, and some consequences can be causes.

Table 3 *(continued)*

Causes		**Consequences**
LNG rollover Poor/inadequate inspection and maintenance of pressure containing equipment Incorrect written procedures Operational error Fire in the vicinity due to other fuel release or cargo fire		
Failure due to low temperature Brittle fracture due to release of LNG or other cryogenic fluid Blockage due to ice formation		
Failure due to impact Collision with ship, truck or other vessel/vehicle Falling object Sabotage, vandalism or malicious act Failure of quay berthing equipment or structure Explosion in the vicinity due to other fuel release, cargo fire or dust release Failure due to brittle fracture from LNG or Liquid Nitrogen spill Subsidence		
Ignition sources present in hazardous area due to: Use of non-compliant electrical or control equipment Inadequate maintenance of mechanical equipment Inadequate protection against lightning Static from personnel clothing or cargo equipment Use of mobile equipment Incorrect operational procedures Incorrect operation (human error) Sabotage, vandalism or malicious act		Fire/explosion/BLEVE if ignition of gas release occurs Secondary fires
Failure of vessels pipes etc. containing Liquid Nitrogen		**Release of Liquid Nitrogen** Asphyxiation of personnel Brittle fracture of equipment
NOTE 1 Some causes or consequences might not always be applicable. NOTE 2 Some causes can also be consequences, and some consequences can be causes.		

The risk assessment shall assess all hazard scenarios identified and agreed and, as a minimum, consider:

a) flash fires;

b) jet/torch fires;

c) pool fires;

d) explosions;

e) Rapid Phase Transitions (RPTs);

f) structural damage.

7.5 Mitigation measures

The measures or safeguards to be taken to mitigate a potentially hazardous event can be classified into three categories:

— A passive safeguard - one that is always in place, for example a physical barrier. It does not depend upon any action, either manual or automated, to be taken in response to a potentially hazardous event.

— An active safeguard - one that requires the activation of a protective device in order to implement a measure(s) to mitigate the hazard. For example, a signal from a gas detector initiating the closure of a valve.

— A procedural/operational safeguard - one that is an active following a human response.

Passive, active and procedural/operational safeguards are essential for safe bunkering. Examples of typical safeguards are listed Table 4. This table is non-exhaustive, and as illustrated by the examples, a safeguard could be active, passive or procedural dependent upon the context of use and design.

Wherever possible, passive safeguards should be adopted in preference to active safeguards, and an automated active safeguard is preferable to a procedural/operational safeguard.

Table 4 — Safeguard examples (risk reduction measures and controls)

Safeguards	**Passive**	**Active**	**Procedural/ Operational**
Separation e.g. (1) distant equipment arrangement or physical boundary; (2) bunkering safety zone or security zone	✓(1)	✓(2)	
Containment e.g. drip trays and double-walled pipework	✓		
Fire protection e.g. (1) A-60 boundary; (2) water spray on fire detection; (3) portable fire extinguishers	✓(1)	✓(2)	✓(3)
Structural protection e.g. (1) fixed sheath to protect hull from LNG spills; (2) water curtain initiated on leak detection to protect hull from LNG spills	✓(1)	✓(2)	
Design specification e.g. more dependable and robust equipment, materials & design standards	✓		
Insulation and coatings e.g. (1) foam/block insulation of liquefied storage tanks; (2) vacuum insulation system for liquefied storage tanks	✓(1)	✓(2)	
Control of ignition sources e.g. (1) ex-rated equipment; (2) access control of portable equipment and personnel	✓(1)		✓(2)

Table 4 *(continued)*

Safeguards	Passive	Active	Procedural/ Operational
Venting e.g. (1) tank PRVs & burst discs; (2) automated opening of valves on set pressure value; (3) manual opening of vent valves	✓(1)	✓(2)	✓(3)
Ventilation e.g. (1) air rate change upon gas detection; (2) closure of ventilation inlets on gas detection	✓(1)	✓(2)	
Process Monitoring e.g. (1) automated warning for specified pressure increase; (2) operator monitoring;	✓(1)	✓(2)	
ESD system/ESD link e.g. detection of vessel separation, overfilling, overpressure, etc.		✓	
ERS (Emergency Release System) e.g. (1) break-away coupling; (2) disconnection of hose given leak detection onboard ship	✓(1	✓(2)	
Release detection e.g. low temperature detectors, gas detectors		✓	
Low oxygen detection e.g. oxygen detectors		✓	
Mooring monitoring e.g. manual observation and warning			✓
Procedures e.g. task sheets, manuals, checklists, compatibility checks			✓
Training and qualifications e.g. courses/tests to provide knowledge and proficiency			✓
Maintenance and Inspection e.g. planned periodic maintenance and inspection			✓
Evacuation and emergency response plans e.g. crew procedures in the event of a gas release			✓
Access restriction and controls e.g. restricting access to appropriately trained personnel			✓
Port/terminal rules, procedures and security e.g. vessel traffic management			✓
Weather forecasting e.g. checking weather and met-ocean forecasts before bunkering			✓
Personal Protective Equipment (PPE) e.g. use of appropriate clothing, hand and eye wear			✓

7.6 Reporting

The risk assessment shall be documented in a report that, as a minimum, describes the following:

a) study basis including description of design, operations, software and assumptions;

b) description of the risk assessment process;

c) information on the relevant qualifications and expertise of the risk assessment team;

d) summary of the identified hazards and results of the risk assessment;

e) failure scenario(s) to be used as a basis for determination of the Safety Zone;

f) summary of follow up actions, if any;

g) detailed records from the workshop.

It also might include the following where determined during the course of the risk assessment:

h) determined Safety Zone;

i) determined Monitoring & Security Area.

The risk assessment report should be shared with the relevant stakeholders.

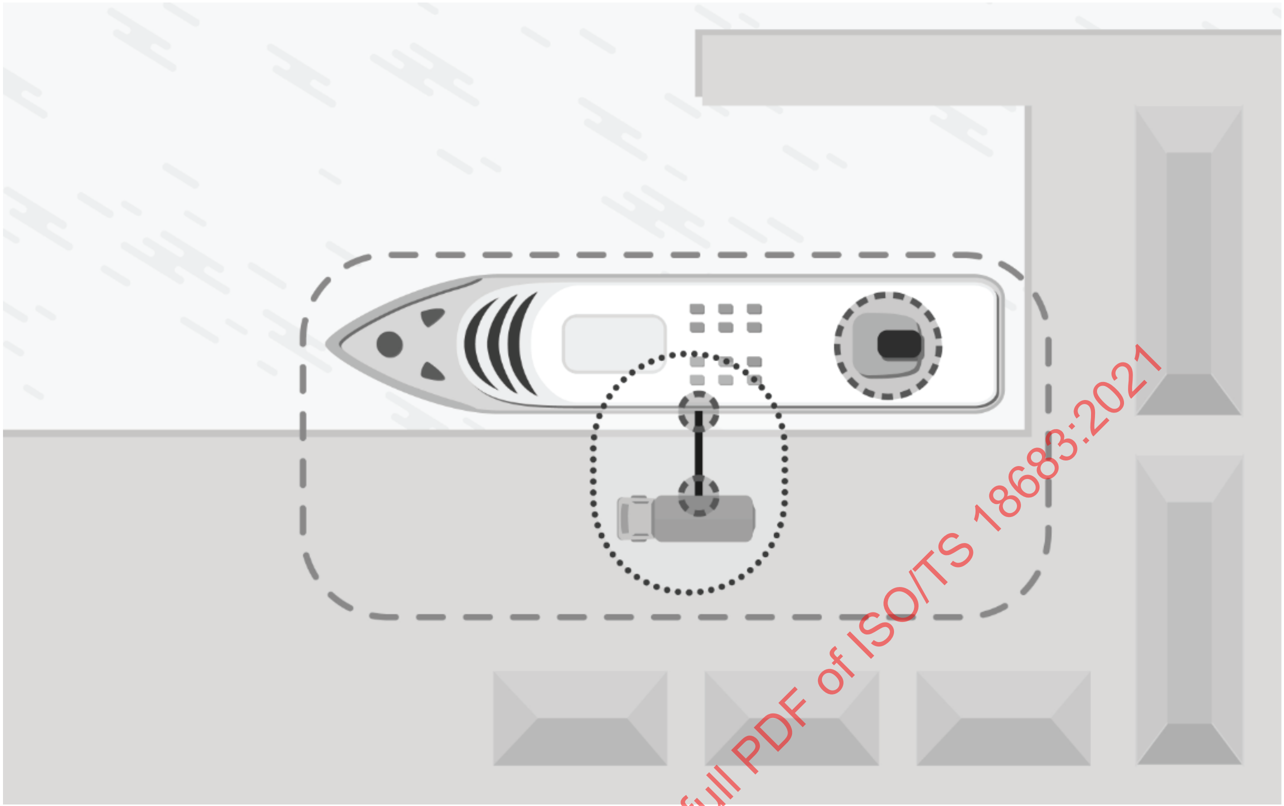
7.7 Safety Zone and controlled areas

A Safety Zone is required during the bunkering operation. Its purpose is to ensure that non-essential personnel and potential ignition sources are not in close proximity to LNG/NG containing equipment.

The Safety Zone is active as soon as connections between the supplier and receiving vessel are being prepared, and until the bunkering operation is complete.

Permitted entry to the Safety Zone and other restrictions shall be clearly communicated to those involved in the bunkering operation, and the zone shall be clearly designated/marked as illustrated in Figure 2.

In addition to the Safety Zone, Hazardous Zones are also present. The purpose of these is to minimize the likelihood of ignition where LNG/NG might be present near to connections, equipment and ventilation outlets, etc., e.g. flanges, couplings, valves and ventilation exhausts. These zones are determined by reference to hazardous area classification standards, such as IEC 60079-10-1 (or similar). Typically, zones are referred to as Zone 1 or Zone 2, and place requirements on electrical equipment located within these zones.



Key

hazardous zones

safety zone

monitoring and security area

Figure 2 — Safety zone and controlled areas

The Monitoring and Security Area is a defined three-dimensional space established around a bunkering facility within which activities, including vessel and personnel movements, need to be identified and monitored to ensure that they do not affect the safety of the bunkering operation by encroaching on the Safety Zone of the gas-fuelled ship, the quayside or the LNG bunkering infrastructure. Activities in the Monitoring and Security Area can be subject to regulatory restrictions. The Monitoring and Security Area is only relevant during bunkering operations.

7.8 Safety zone determination

The determination of the Safety Zone is specific to each bunkering scenario, and can be determined

— as the calculated distance to a specified level of harm, e.g. for the maximum credible release, the dispersion distance to the lower flammable limit (LFL), or

— as the calculated distance to a specified level of individual risk.

The approach to determining the Safety Zone needs to be agreed with the relevant stakeholders. and should reflect the project specific factors such as but not limited to the following:

— LNG inventory in the bunkering facilities;

— properties of the LNG in the bunkering system (temperature, pressure);

— operational modes (e.g. hose bunker system, loading arm);

— implemented safeguards (e.g. bunkering ESD system);

— LNG transfer rates and pressures;

— weather conditions;

— failure scenarios (e.g. release rate, quantity and duration).

The inputs and constraints used for determining the boundaries of the Safety Zone should be clearly defined.

Regardless of the calculation method

— the Safety Zone shall fully encompass the Hazardous Zones, and

— it is presupposed that the size and configuration of the Safety Zone will not be less than the minimum distances defined by the competent authorities.

Examples of the determination of Safety Zone are provided in Annex B.

7.9 Determination of monitoring and security areas

Detailed procedures for establishing Monitoring and Security Areas are beyond the scope of this document.

The size and configuration of the Monitoring and Security Area are established by the LNG supplier, the local authorities and other stakeholders, as appropriate.

As the reasons for creating the Monitoring and Security Area are many and wide-ranging, it is generally not possible to define or justify its size by calculation. It should be considered as an extension of the Safety Zone.

All the findings from the risk assessment shall be taken into account in the determination of the Monitoring and Security Area in order to:

a) ensure that all port activities (e.g. ship movements) that could put the bunkering operation at risk are strictly monitored and controlled;

b) all areas where personnel could be at risk from the bunkering operations are identified.

Any restrictions caused by the Monitoring and Security Area that might limit access for emergency personnel and/or impact specific actions required by the emergency response plan shall be considered.

The Monitoring and Security Area shall always be larger than the Safety Zone and shall extend well beyond the boundaries of the Safety Zone.

Monitoring and Security Areas can fall within, or partially within, Restricted Areas within the port facility, required by the International Ship and Port Security (ISPS) Code, but are typically smaller than these Restricted Areas.

7.10 Simultaneous Operations (SIMOPs)

Where it is proposed to carry out bunkering operations concurrently with other operations that can impact or be impacted by the bunkering, then a further risk assessment should be carried out to demonstrate that the required level of safety can be maintained.

SIMOPs are defined as: LNG bunkering plus one, or more, other activity and/or operation conducted at the same time where their interaction may adversely impact safety, ship integrity and/or the environment. It might affect the extent of the safety zone.

SIMOPs can take place anywhere in the locality of the bunkering operations, including on the receiving ship, on the bunker vessel, on the quayside, or in surrounding waters.

SIMOPs involve the actions taken by several parties including but not limited to crew of the receiving ship, personnel of the bunker facility, terminal/port personnel and third-party people and personnel.

Before any SIMOPs are carried out, the risk level for each SIMOP should be shown by risk assessment to be at an acceptable level and shall be agreed by all parties involved. A permit is issued by the relevant authority before any simultaneous operations are carried out.

The following list gives examples of where risk assessment for simultaneous operations should be considered (the list is not exhaustive):

— cargo handling;

— ballasting operations;

— passenger embarking/disembarking;

— vehicles embarking/disembarking;

— dangerous goods loading/unloading;

— loading or unloading of any other good (i.e. stores and provisions);

— chemical products handling including toxic cargos;

— bunkering of fuels other than LNG;

— maintenance and testing of equipment and systems including software;

— any hot work or activity that could create sparks.

The risk assessment should take into account as a minimum, but not be limited to, the following:

— size of the bunkering Safety Zone and the Monitoring and Security Area;

— SIMOPs and how this interacts with the bunkering Safety Zone;

— failure scenarios;

— access, egress and escape/evacuation routes;

— access, including evacuation routes and times;

— the type of cargo operation;

— safeguards in place to control passenger/cargo movements;

— dropped objects;

— positions of vent mast and air intakes;

— locations of hazardous cargo handling;

— other restrictions that can apply.

8 Functional requirements for LNG bunker transfer system

8.1 General

The functional requirements for LNG bunker transfer systems have been determined assuming:

a) internationally recognized standards, such as ISO 20519, and good engineering practices for LNG bunkering (e.g. Reference [24]) shall be adopted for the supplier and the LNG fuelled ship;

b) systems shall be designed and operated to prevent releases of LNG/natural gas, and venting shall be only undertaken to prevent or mitigate an emergency situation;

c) engineering and procedural means shall be provided to safely vent, disperse, contain and detect an LNG/natural gas release, and prevent subsequent ignition;

d) engineering and procedural means shall be provided to safely contain, detect and extinguish fires, and protect against radiation and explosion;

e) emergency preparedness procedures and plans shall be established to minimize escalation following an accidental release and to protect individuals and the environment.

The functional requirements are numbered as [Fx] in this document for easy cross-referencing.

8.2 Functional requirements

[F1] The compatibility assessment between supplier and LNG fuelled ship shall be confirmed and documented prior to commencement of bunkering operations as part of the LNG bunker checklist as given in ISO 20519 or in a suitable equivalent agreed by involved parties.

[F2] The bunker transfer system shall be arranged so that it can be commissioned, decommissioned, and operated (including purging and inerting) without release of LNG/natural gas to the atmosphere. Appropriate operating procedures shall be established.

[F3] LNG transfer shall be carried out in closed systems where the components are connected, and leak tested before commencement of LNG transfer.

[F4] The design shall reflect the full range of operating conditions and shall conform to the applicable standards published by IMO and ISO. It should reflect good engineering practice and guidance published by SDOs and industry organizations (e.g. SGMF).

[F5] The design shall reflect the conditions under which bunkering will be undertaken (local conditions, e.g. ship motions, weather, and visibility).

[F6] The bunker transfer system shall be capable of being drained, de-pressurized, and inerted before connections and disconnections are made.

[F7] The bunker transfer system shall be designed to avoid liquid lock (trapped liquids in absence of relief valve).

[F7bis] The bunker transfer system shall prevent air and moisture ingress into the ship fuel gas system.

[F8] Operating procedures shall be established and documented to define the bunkering process and ensure that components and systems are safely operated within their design parameters during all operational phases:

a) receiving tank(s) is sufficiently empty to commence bunkering;

b) monitoring and control instrumentation is in working order and appropriately calibrated;

c) monitoring and control of ship traffic and other activities within the security zone that can influence the bunkering process are aligned with regulatory requirements;

d) equipment and procedures for safe mooring;

e) connection and inerting/purging;

f) leak testing;

g) cool down/testing;

h) monitoring of the operation;

i) transfer;

j) topping up and shutdown;

k) draining/purging/inerting;

l) disconnection;

m) storage and handling of components.

[F9] All systems and components shall be operated, maintained, inspected and tested according to the vendor requirements and recommendations.

[F9bis] All individuals involved with the bunkering operation shall be appropriately trained, competent and equipped with PPE.

[F10] An organizational plan shall be prepared and implemented in operational plans and reflected in qualification requirements. The plan shall describe the following:

a) organization;

b) roles and responsibilities for the ship crew and bunkering personnel;

c) communication lines and language for communication.

[F11] Operating procedures shall include a checklist to be completed and confirmed by the involved parties prior to the commencement of bunkering (see F.1).

[F12] Emergency equipment and personnel shall be mobilized in accordance with the approved emergency response plan.

[F13] Prevention of ignition of natural gas releases by the elimination of ignition sources in classified hazardous areas and by controlling activities in the safety zone for the bunkering operation.

[F14] Elimination of the potential spark or high currents from static or galvanic cells when the bunkering system is connected or disconnected (see ISO 20519).

[F15] Effective leak detection of LNG and natural gas. Selection of sensors and their location should consider possible presence of dust, mist and fog that can mask the leak.

[F16] The bunker transfer operation shall be capable of being safely shut down without release of LNG/natural gas.

[F16bis] In event of emergency, a linked emergency shutdown system shall automatically or manually initiate an emergency shutdown signal to the LNG fuelled ship and to the supplier to ensure that appropriate actions are taken both on the supplier, as well as on the LNG fuelled ship.

[F17] The bunker transfer system shall be equipped with an emergency release system (ERS) that allows it to be disconnected rapidly and minimize damage in the event of a potential emergency, e.g. ships drifting or vehicle movement.

[F18] The release of LNG or cold vapour should not lead to an escalation due to brittle fractures of steel structure. Arrangements shall be installed as required on bunkering facilities and on LNG fuelled ships according to ISO 20519 and the IGF code as applicable.

[F19] A safety zone shall be implemented around the bunkering operation (see Annex B).

[F20] A monitoring and security area shall be established around the bunkering facility. Activities in this area shall be monitored to reduce harmful effects on the bunkering operation.

[F21] A contingency plan shall be in place outlining the requirements for the following:

a) evacuation of personnel and third parties;

b) mobilizing fire-fighting;

c) mobilizing first aid, hospitals, and ambulances;

d) communication to authorities and third parties;

e) copies of the plan shall be communicated to all parties involved in the bunkering operation including the planned emergency response team and be part of the training programme. This should be practiced at regular intervals both as “table top” and practical exercises. Key information from this plan related to access, evacuation, and ignition minimization shall be communicated.

9 Training

All personnel involved in LNG bunkering operations shall be adequately trained. Such training shall be appropriate for the purpose and a record of training shall be maintained.

Personnel on the supply side and receiving vessels shall meet the applicable training requirements outlined in the Seafarers’ Training, Certification and Watchkeeping (STCW), IGF Code, IGC Code and ISO 20519 whether the vessel is involved in international service or is under IMO size limits.

Annex A
(informative)

Risk acceptance criteria

A.1 General

Qualitative Risk Assessment (QualRA), Quantitative Consequence Assessment (QCA) and Quantitative Risk Assessment (QRA) provide a means to estimate the level or magnitude of risk presented by bunkering LNG. Risk criteria are required to help judge if this risk is 'acceptable', 'tolerable' or 'unacceptable'.

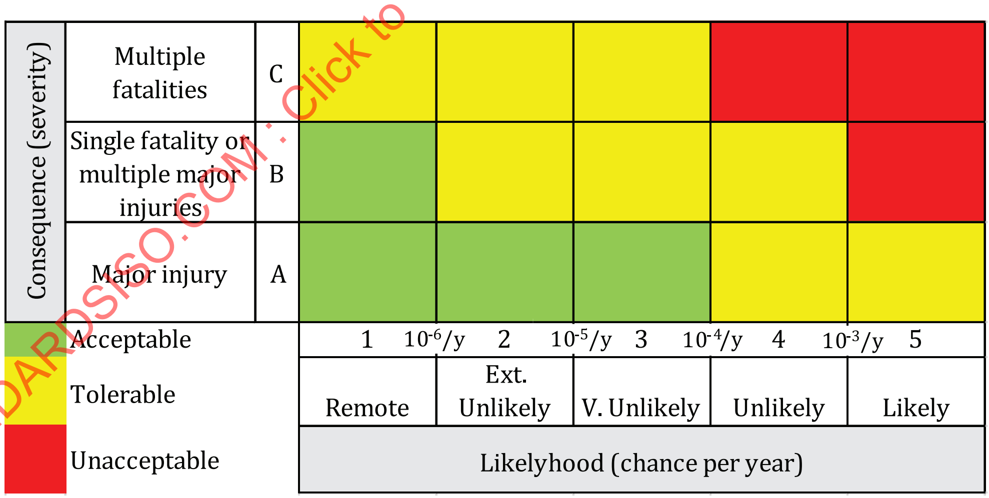
As with the numerous approaches to risk assessment, there are many different types of risk criteria. It is therefore important that all stakeholders agree appropriate criteria to assist transparent and consistent judgements on risk.

Examples of criteria for QualRA and QRA are given in A.2, A.3 and A.4.

A.2 Example of Risk Criteria for QualRA

The following example is based upon a review of risk criteria used by industry and governments in assessing the risks from the oil, gas and chemical industries other. Alternative risk matrices are also available and used.

The following matrix criteria might be used to rank major LNG bunkering operation risk only.



NOTE Above 10-2/year Consequence (severity) categories A, B and C are unacceptable. Similar examples can be given for asset, societal or environmental risks.

Figure A.1 — Example of matrix criteria

Consequence Categories

A Major injury

Long-term disability/health effect

B Single fatality or multiple major injuries

One death or multiple individuals suffering long-term disability/health effects

C Multiple fatalities

Two or more deaths for third party people

NOTE Third party person and crew consequence category ranking might differ depending on the matrix criteria chosen.

Likelihood Categories

1	**Remote**	1 in a million or less per year
2	**Extremely Unlikely**	between 1 in a million and 1 in 100 000 per year
3	**Very Unlikely**	between 1 in 100 000 and 1 in 10 000 per year
4	**Unlikely**	between 1 in 10 000 and 1 in 1 000 per year
5	**Likely**	between 1 in 1 000 and 1 in 100 per year

Risk Ratings

Acceptable

The risk can be accepted. Where practical and cost-effective it is good practice to implement safeguards to further reduce the risk.

Tolerable

The risk can be tolerated and considered As Low As Reasonably Practicable (ALARP) provided additional or alternative safeguards have been considered and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.

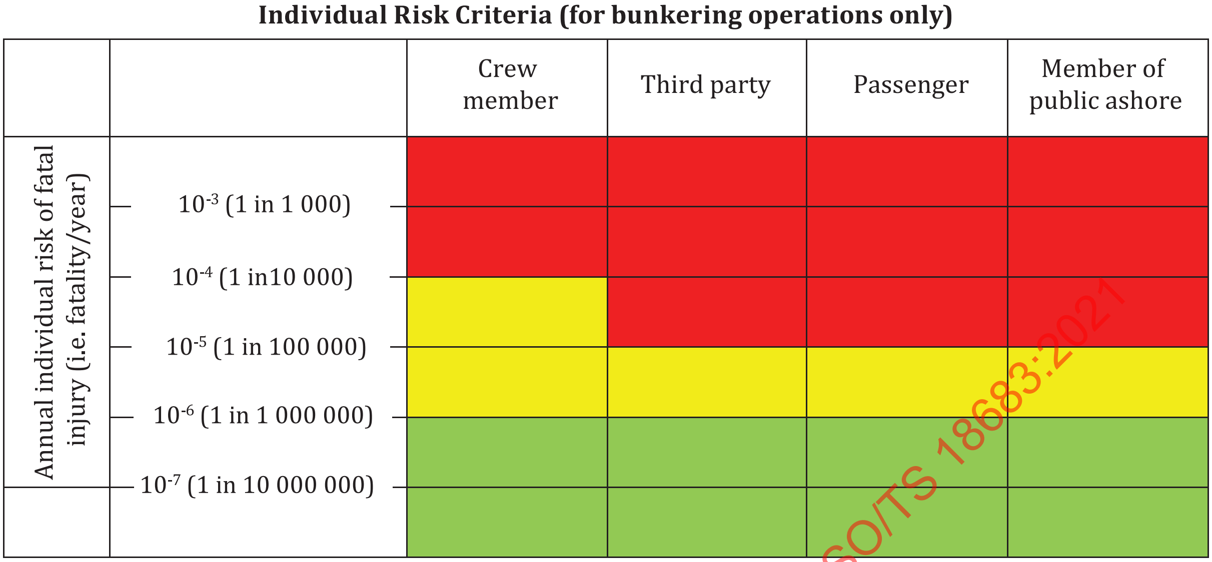
Unacceptable

The risk cannot be accepted. Additional or alternative safeguards should be identified and implemented before commencement of bunkering, and these safeguards should reduce the risk to tolerable or acceptable.

A.3 Example of Individual Risk Criteria for QRA

Individual risk is a measure of the likelihood that a specified person incurs a certain level of harm. Typically, this translates to an annual likelihood of fatal injury for a worker involved in the activity or a member of the public (e.g. a bunkering operative, a third-party individual working at the harbour, a passenger, or a member of the public at a given location onshore).

The following matrix criteria might be used to rank major LNG bunkering operation risk only.



Key

- **acceptable ≤10^{-6}** The risk can be accepted. Where practical and cost-effective it is good practice to implement safeguards to further reduce the risk
- **tolerable >10^{-6} – 10^{-4}** The risk can be tolerated and considered As Low As Reasonably Practicable (ALARP) provided additional or alternative safeguards have been considered and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk
- **unacceptable >10^{-4}** The risk cannot be accepted. Additional or alternative safeguards should be identified and implemented before commencement of bunkering, and these safeguards should reduce the risk to tolerable or acceptable

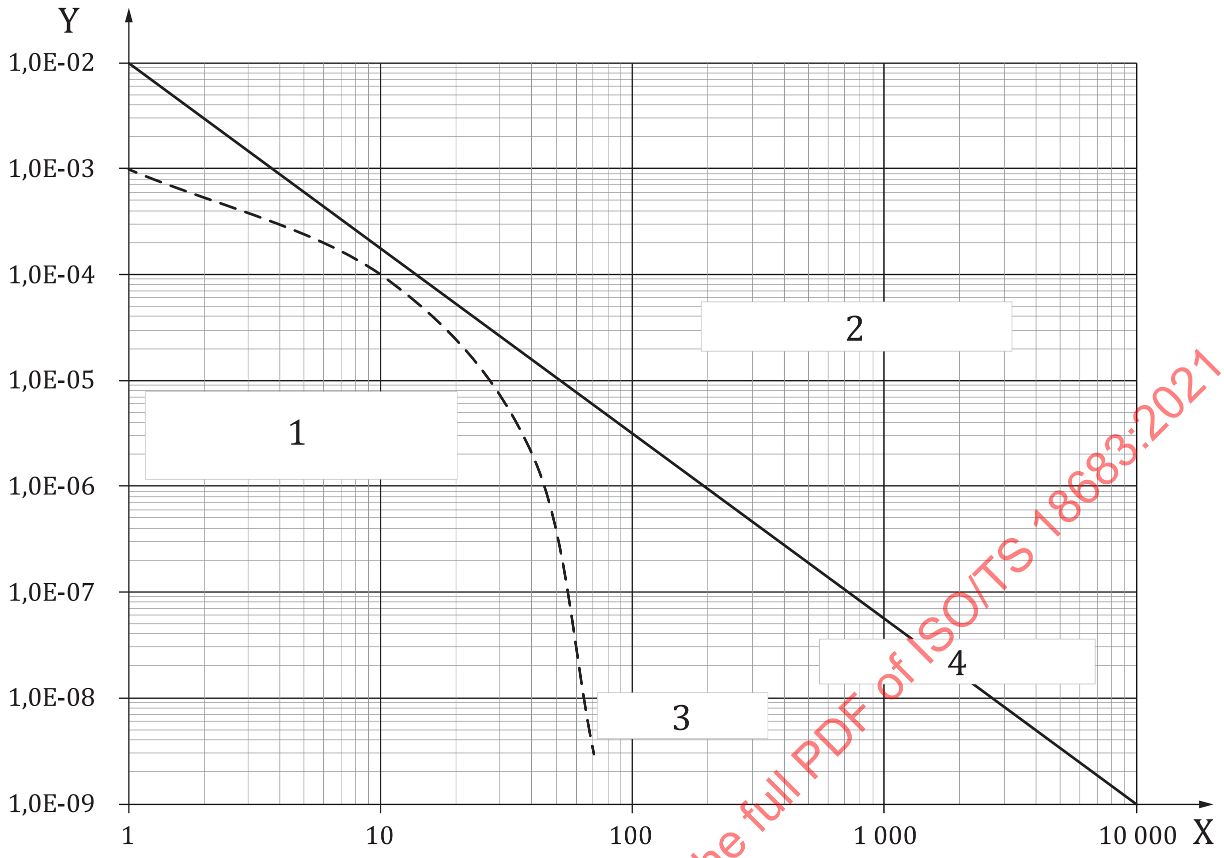
Figure A.2 — Example of matrix criteria with individual risk

The individual risk criteria are in-line with publications issued by the Health & Safety Executive (HSE) [34] and the International Maritime Organization (IMO) [36].

A.4 Examples of Societal (Group) Risk Criteria for QRA

The following are examples of societal (group) risk criteria, referred to as FN Criterion Lines. This might be used in some circumstances to assess the larger risk to people and society.

Figure A.3 illustrates an FN Criterion line and the QRA results as an FN Curve, that is the frequency (F) of incurring a certain number of fatalities (N) or more. The FN Curve is shown below the FN Criterion Line and so in this example the risk is considered 'broadly acceptable' provided the risk is as low as reasonably practicable (ALARP).



Key

X number of fatalities

Y frequency of N or more fatalities (per year)

1 broadly acceptable ALARP region

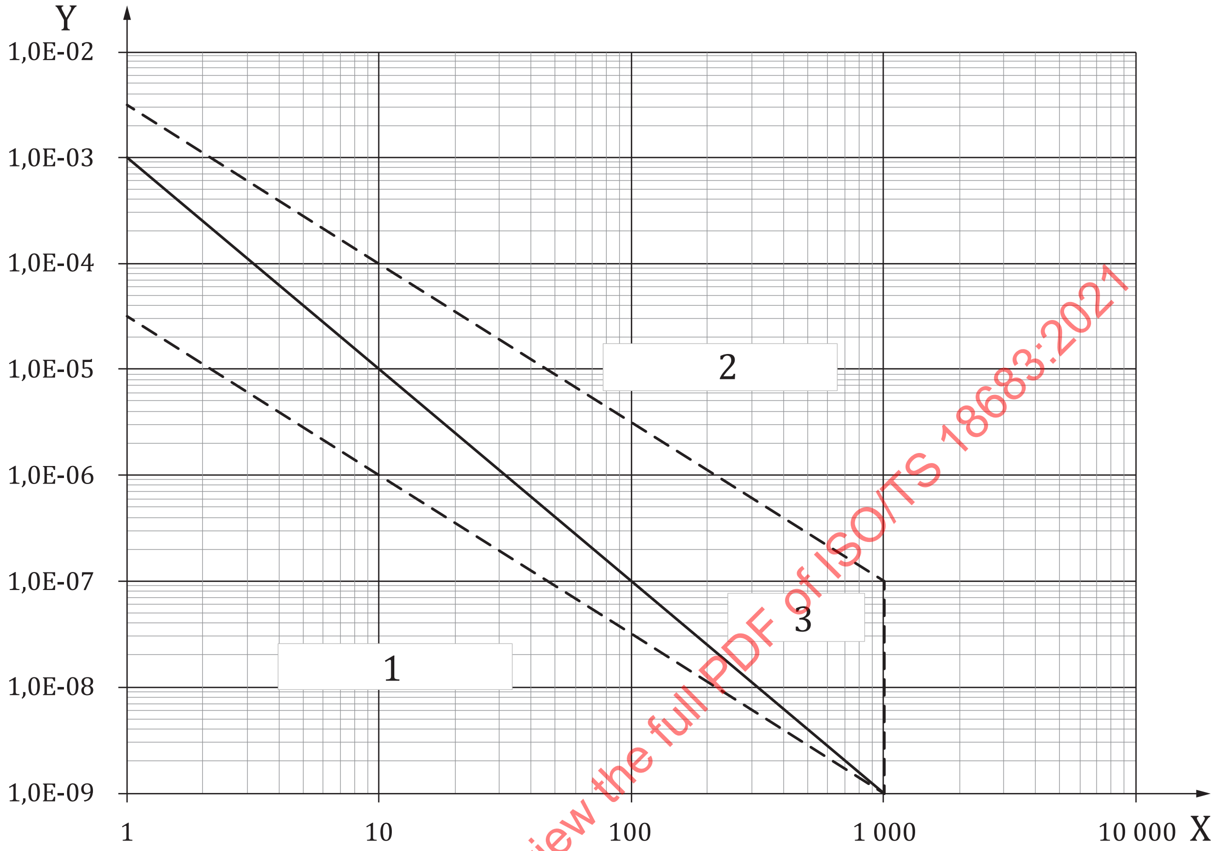
2 intolerable region

3 FN curve

4 FN criterion line

Figure A.3 — Example 1: Fictitious FN Criterion Line and FN Curve

Figure A.4 illustrates differences in terminology, aversion to multiple fatalities, and categorization of risk using one or more FN Criterion Lines.



Key

X number of fatalities

Y frequency of N or more fatalities (per year)

1 acceptable (Netherlands) negligible (Australia New South Wales)

2 unacceptable (Netherlands) intolerable (Australia New South Wales)

3 ALARP

——— Netherlands

– – – Australia New South Wales

Figure A.4 — Example 2: Netherlands & Australia NSW FN Criterion Line – Petrochemical Industry

Netherlands government expectation is that the criterion will be met[37]; but where it is exceeded the societal risk might be tolerated following a detailed deliberation and demonstration process outlined in the Societal Risk Accountability Guidelines[38].

Australia New South Wales (NSW) government expectation is that the criteria will be met. However, the criteria are not mandatory, being referred to as "indicative and provisional"[39].

Annex B
(informative)

Examples of safety zone calculations

B.1 General

The safety zone is defined in Clause 7. In this annex, different methods of calculation are presented.

Figure 2 illustrates the relative location of the safety zone and the hazardous areas related to a mobile to ship bunkering supply scenario with a truck bunkering from the quayside.

The calculation of the Safety Zone is specific to each bunkering supply scenario.

B.2 Approaches for calculating the safety zone

The safety zone can be determined by the following:

a) a consequence-based approach that for selected release scenario(s) calculates the distance to a defined gas concentration. The chosen concentration is typically dependant on the lower flammability limit (LFL);

b) a risk-based approach that considers the likelihood of a range of release scenarios to determine the distance to a defined risk value (e.g. an annual individual risk).

The consequence-based approach

— determines the distance using a recognized and validated dispersion model, and

— selects a scenario(s) for specific release parameters and weather conditions as agreed between the bunkering stakeholders.

Compared to the risk-based approach, the consequence-based approach is simpler and requires less time and effort. It can also in some cases result in a relatively large safety zone compared to the risk-based approach.

The risk-based approach

— uses a recognized and validated risk calculation method,

— uses recognized and validated dispersion and consequence calculation models,

— selects a range of scenarios for specific release likelihood, release parameters and weather conditions as agreed between the bunkering stakeholders, and

— sets zone extent based upon agreement of the bunkering stakeholders of the risk criterion or criteria (e.g. the risk of a stated methane-air concentration, individual risk of fatality).

Compared to the consequence-based approach, the risk-based approach is generally a more detailed process requiring more time and effort. It can also result in a smaller safety zone compared to the risk-based approach.

A consequence-based approach is often the preferred approach to setting the safety zone. However, the risk-based approach can be required by local or national regulators, or it can be used to provide additional insight to control and set a practical zone.

Regardless of the chosen calculation method, the selected scenario(s) should reflect the characteristics of the bunkering supply and release conditions. For example, consideration of the following:

— bunker supply pressure and temperature;

— release mass/volume, flow rate and duration;

— release orientation, elevation, impingement and impacted surface;

— weather conditions (i.e. wind speed and atmospheric stability).

It should be recognized that all calculation methods have limitations and generally provide an indicative result. For example, it can be difficult to account for pool spreading onto the sea or quayside, the influence of obstacles such as the ship or nearby buildings, or gas ingress to buildings via entrances and ventilation inlets, etc.

B.3 Methods for the consequence-based calculation of the safety zone

In the consequence-based approach, the safety zone is defined as the area within the distance to the LFL as determined by a recognized and validated dispersion model for the maximum credible release.

Three examples of a consequence-based method to calculate the safety zone are presented below:

a) BASiL calculation tool;

b) Phenomenological consequence modelling;

c) Computational fluid dynamics (CFD).

All are based on a calculated distance to the LFL.

a) BASiL calculation tool

BASiL (Bunkering Area Safety Information for LNG) is a modelling tool developed by the Society for Gas as Marine Fuel (SGMF) specifically to help determine safety zone distances (see Figure B.1) in the three dimensions.

BASil inputs, variables and outputs are summarized below.

BASiL inputs/variables	Remarks
Bunkering Location Latitude and Longitude	BASiL will select from its database the closest information about the bunkering location environmental condition using a Pasquill atmospheric stability factor D. NOTE D is not always the most representative stability class and it might not provide the maximum distances.
Primary Leak Source Hose Failure or Fitting/Flange Failure	Depending on the selection BASiL will use different hole size representation based on statistical data extrapolated from Process Leak for Offshore installation Frequency Assessment Model[40].
Volume Transfer, Transfer System Diameter Transfer Pressure Supply Storage Pressure LNG Storage Temperature LNG Net Calorific Value LNG Density	Bunkering transfer process data.
ESD Type	Based on the user selection BASiL will consider the ESD system safeguard effect on the dispersion calculation.

BASiL inputs/variables	Remarks
Bunkering type Road Tanker or Bunker Vessel	Reflecting a mobile to ship or ship to ship bunkering scenario.
Minimum Hose Elevation Hose Entry Location Distance Below Deck	Specific bunkering scenario configuration data, used in BASiL calculation to improve the accuracy of the results for a specific application.
Gas fuelled Vessel - Particulars Road tanker - Particulars LNG bunker vessel - Particulars	Particulars of the size and dimensions of the supplier and receiver used for graphical representation of the bunkering scenario.

The calculation provides as output representative distances (from the point of leakage) for the extent of a flammable vapour cloud assuming a jet release and LNG pool leak over land, deck or water.

BASiL outputs	Remarks
Horizontal and Vertically upwards jet R1 and H1	Horizontal and vertical distances representative of a jet leak.
Downward release onto land/deck R2, H2 and R4	Horizontal and vertical distances representative of an LNG pool over land or the deck of the vessel.
Downward release onto water R3 and H3	Horizontal and vertical distances representative of an LNG pool over water.

Figure B.1 provides an example of a BASiL calculation. This example should not be used in place of a BASiL calculation based on the actual bunkering scenario.