No. 142

(June 2016)

LNG BUNKERING GUIDELINES

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Annex: Guidance on HAZID and HAZOP for LNG bunkering operations

Chapter 1 - General

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1.1 Introduction

LNG bunkering is developing worldwide in line with the increase of use of natural gas as a fuel compliant with environmental legislation.

This guideline provides recommendations for the responsibilities, procedures and equipment required for LNG bunkering operations and sets harmonised minimum baseline recommendations for bunkering risk assessment, equipment and operations.

These guidelines do not consider commercial aspects of the bunker transfer such as Bunker Delivery Notes and measurement of quantity or quality of LNG.

1.2 Purpose

The purpose of these guidelines is mainly to define and cover the additional risks associated with bunkering LNG and to propose a methodology to deal with those additional risks in order to provide a similar level of safety as is achieved for traditional oil fuel bunkering operations.

This document is designed to complement the requirements from the existing applicable guidelines and regulations, such as port and terminal checklists, operator's procedures, industry guidelines and local regulations. This guide provides guidance to clarify the gaps that have been identified in the existing guidance and regulations. In particular, the following items are covered:

- The responsibility of different parties involved in the LNG transfer,
- The LNG bunkering process,
- SIMOPS
- Safety distances,
- QRA and HAZID

1.3 LNG Bunkering process and guideline structure

LNG bunkering is the process of transferring LNG fuel to a ship from a bunkering facility.

The sequence for a bunkering operation carried out between two parties for the first time is described in the following diagram; the references identify the applicable sections of the guideline.

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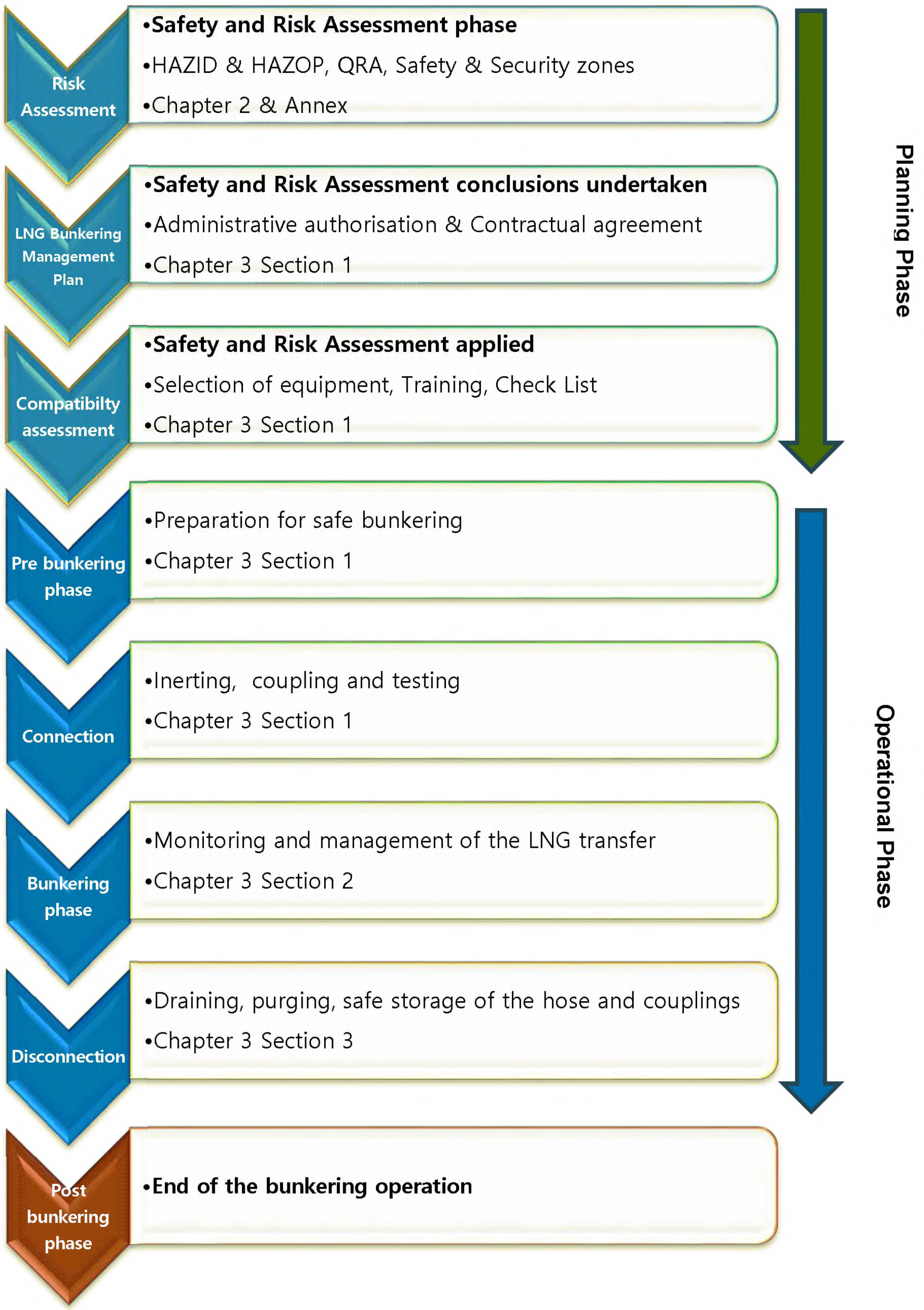

Figure 1: Bunkering process

1.4 Applicability

These guidelines are applicable to LNG bunkering operations for:

- Different methods,
- Different ship types, and
- Different locations (in port, off shore and terminal) worldwide.

1.5 LNG Bunker Management Plan (LNGBMP)

An LNG bunker management plan should be established in order for the involved parties to agree technically and commercially on methodology, flow rate, temperature, pressure of the delivery of LNG and receiving tank. This plan gathers together all the information, certificates, procedures, and checklist(s) necessary for an effective and safe LNG Bunkering operation.

The LNG Bunker Management Plan should be referenced as part of the safety management system of the RSO.

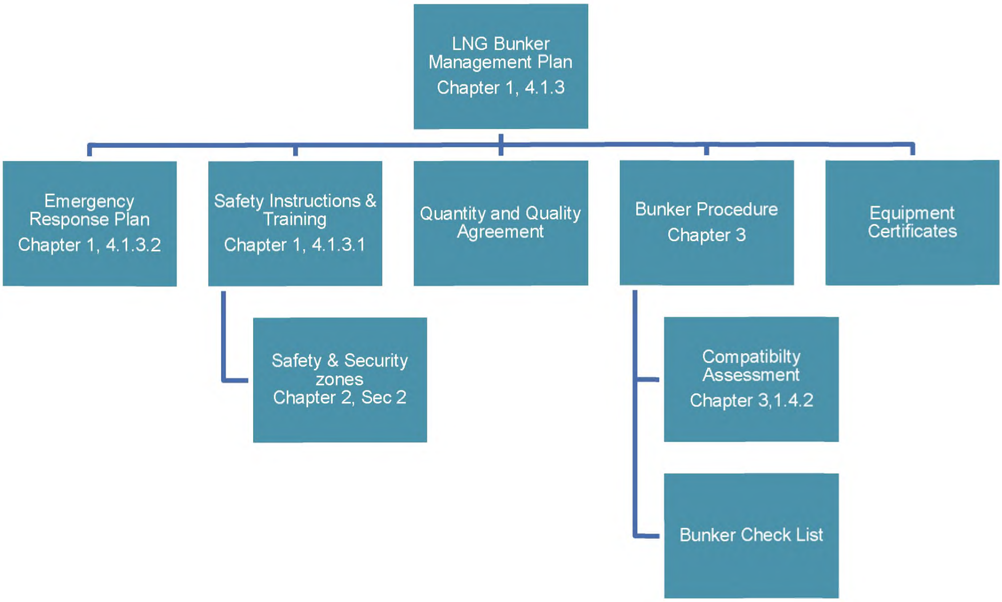

Figure 2: Breakdown of LNGBMP content showing related sections of this guide

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Section 2 - Definitions, applicable standards and rules

2.1 Terms and definitions

2.1.1 Atmospheric tanks

Atmospheric tanks mean tanks of the types A or B or membrane tanks as defined in:

- IGC Code, regulations 4.21, 4.22 and 4.24; and
- IGF Code, regulations 6.4.15.1, 6.4.15.2 and 6.4.15.4.

2.1.2 Bunkering Facility Organisation (BFO)

This is the organisation in charge of the operation of the bunkering facility.

2.1.3 Breakaway Coupling (BRC)

A breakaway coupling is a safety coupling located in the LNG transfer system (at one end of the transfer system, either the receiving ship end or the bunkering facility end, or in the middle of the transfer system), which separates at a predetermined section at a determined break-load or relative separation distance each separated section containing a self-closing shut-off valve, which seals automatically.

2.1.4 Bunkering facility

A bunkering facility is normally composed of a LNG storage and a LNG transfer installation, a bunkering facility may be (a stationary shore-based installation or a mobile facility, i.e. a LNG bunker ship or barge or a tank truck).

A bunkering facility may be designed with a vapour return line and associated equipment to manage the returned vapour.

2.1.5 Dry disconnect

This applies when the transfer system between two vessels or a vessel and a port facility is disconnected as part of normal operations. The objective is that no LNG or natural gas should be released into the atmosphere. If this objective cannot be achieved, the amount released can be reduced to negligible amounts consistent with safety. Dry disconnect can be achieved by:

- Draining and inerting process before the disconnection; or
- Use of dry connect / disconnect coupling.

2.1.6 Emergency Shut-Down (ESD)

These are systems installed as part of the LNG transfer system that are designed to stop the flow of LNG and or prevent damage to the transfer system in an emergency. The ESD may consist of two parts, they are;

- ESD - stage 1, is a system that shuts the LNG transfer process down in a controlled manner when it receives inputs from one or more of the following; transfer personnel, high or low level LNG tank pressure alarms, cables or other means designed to detect excessive movement between transfer vessels or vessel and an LNG bunkering facility, or other alarms.

- ESD - stage 2, is a system that activates decoupling of the transfer system between the transfer vessels or between a vessel and an LNG bunkering facility. The decoupling mechanism contains quick acting valves designed to contain the contents of the LNG transfer line (dry break) during decoupling.

2.1.7 Emergency Release Coupling (ERC)

The ERC is normally linked to the ESD system where this may be referred to as ESD2 as per SIGTTO "ESD arrangements & linked ship/shore systems for liquefied gas carriers".

An emergency release coupling is activated:

- By excessive forces applied to the predetermined section, or

- By manual or automated control, in case of emergency.

2.1.8 Emergency Release System (ERS)

A system that provides a positive means of quick release of the transfer system and safe isolation of receiving vessel from the supply source.

2.1.9 Flash Gas

Boil-off Gas instantly generated during LNG transfer due to the warmer temperature of the receiving ship tanks, sudden pressure drop or friction.

2.1.10 HAZOP

A structured and systematic examination of a planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment, or prevent efficient operation. A HAZOP is a qualitative technique based on guide-words and is carried out by a multi-disciplinary team of experts during a set of meetings.

2.1.11 HAZID

Hazard identification exercise, there are a number of recognised methods for the formal identification of hazards. For example: a brainstorming exercise using checklists where the potential hazards in an operation are identified and gathered in a risk register these will then be assessed and managed as required.

2.1.12 Hazardous zones

Bunkering-related hazardous zone means any hazardous area zone 1 or zone 2 defined for:

- The receiving ship in accordance with IGF Code[1], regulation 12.5;

[1] The IGF Code adopted by Resolution MSC.391(95)

- The bunkering ship in accordance with IGC Code[2], regulation 1.2.24 and where gas may be present as a result of the bunkering operation; and
- The bunkering shore facility or truck tanker facility in accordance with IEC 60079-10-1.

2.1.13 IAPH

International Association of Ports and Harbours.

2.1.14 IGC Code

International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (Gas Carrier Code). The revised IGC Code was adopted by Resolution MSC.370(93). It will enter into force on 1 July 2016.

2.1.15 IGF Code

International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels. IGF Code refers to Resolution MSC.391(95). It will enter into force on 1 January 2017.

2.1.16 LNG Bunkering

The process of transferring LNG to be used as fuel on board the receiving ship.

2.1.17 Vapour return line

A vapour return line is a connection between the bunkering facility and the receiving ship to allow excess vapour generated during the bunkering operation to be returned to the bunkering facility and remove any need to vent to atmosphere. It is used to control the pressure in the receiving tank due to the liquid transfer, flash gas and boil-off gas generation.

2.1.18 LNG transfer system

A system consisting of all equipment contained between the manifold used to deliver LNG bunker (and to handle vapour return) and the manifold receiving the LNG (and delivering vapour return) including but not limited to:

- Loading arms and supporting structures,
- LNG articulated rigid piping,
- Hoses, swivels, valves, couplings,
- Emergency Release Coupling (ERC),
- Insulating flanges,
- Quick connect / disconnect couplings (QC/DC),
- Handling system and its control / monitoring system,

[2] The IGC Code adopted by Resolution MSC.370(93)

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- Communication system,
- ESD Ship/Shore Link or Ship/Ship Link used to connect the supplying and receiving ESD systems.

It can also include the compressors or blowers intended for the boil-off gas handling system where provided depending on the design of the transfer system. However, liquefaction systems used to maintain pressure in the bunker vessel tanks are not to be considered as part of the LNG transfer system.

2.1.19 MARVS

Maximum Allowable Relief Valve Setting.

2.1.20 MSC

Maritime Safety Committee of the IMO.

2.1.21 Person in Charge (PIC)

The Person in Charge (PIC) is a person who is responsible for the overall management of the bunkering operation. The PIC may also be referred to as Person in Overall Advisory Control (POAC).

2.1.22 PPE

Personal Protective Equipment.

2.1.23 Qualitative Risk Assessment (Q_{ual}RA)

A risk assessment method using relative measure of risk value based on ranking or separation into descriptive categories such as low, medium, high; not important, important, very important; or on a scale, for example from 1 to 10 or 1 to 5.

2.1.24 Quantitative Risk Assessment (QRA)

This is a formalised statistical risk assessment method for calculating a numerical risk level for comparison with defined regulatory risk criteria.

2.1.25 Receiving Ship

Receiving ship is the ship that receives LNG fuel.

2.1.26 Receiving Ship Operator (RSO)

The receiving ship operator (RSO) is the company responsible for the operation of the receiving ship, in particular during the bunkering operations.

2.1.27 Risk

A combination of the likelihood of an event and the consequences if the event occurs.

2.1.28 Risk matrix

A risk matrix is a tool for displaying combinations of likelihood and consequence, used as the basis for risk determination. Multiple consequence categories can be included: impact on people, assets, environment and reputation. Plotting the intersection of the two considerations on the matrix provides an estimate of the risk. Acceptable levels of risk are normally shown by color coding the boxes.

2.1.29 Safety zone

The safety zone is a zone around the bunkering facility, the bunkering station of the receiving ship and the LNG transfer system.

The purpose of the zone is to set an area that is put in place during LNG bunkering and within which only essential authorised and qualified personnel are allowed and potential ignition sources are controlled.

2.1.30 Security zone

The Security Zone is the area around the bunkering facility and receiving ship where ship traffic and other activities are monitored (and controlled) to prevent entry and provide a 'stand-off' distance during the bunkering operation; this will be larger than the safety zone.

The security zone may also be referred to as the "exclusion zone".

The security zone is site dependent and is often determined by the Port Authorities.

2.1.31 SIGTTO

Society of International Gas Tanker and Terminal Operators.

2.1.32 Simultaneous Operations (SIMOPS)

Carrying out LNG bunkering operations concurrently with any other transfers between ship and shore (or between ships if ship-to-ship bunkering method is used). This includes loading or unloading cargo operations, dangerous goods loading or unloading and any kind of other goods loading or unloading (i.e. stores and provisions), passenger embarkation/disembarkation, chemical and other low flash product handling, bunkering of fuels other than LNG, and any other activity that can impact or distract from bunkering operations (e.g. cargo movements on board, heli-ops, etc.).

Special attention is to be paid to any of the above activities occurring within the bunkering safety zone as well as any on board testing that may impact on the bunker operation.

2.1.33 STCW Code

IMO Code for Seafarers' Training, Certification and Watchkeeping.

2.1.34 Independent Type A, B, C and Membrane tank

These tank types are defined in the IGC and IGF Code.

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2.2 Standards and rules

The following tables provide an overview of existing standards related to LNG and risk assessment. The lists are not exhaustive.

2.2.1 Standards and rules for LNG

No.	Reference	Title
1	EN 1160	General characteristics of liquefied natural gas
2	EN 1473	Design of onshore installations
3	EN ISO 16904:2016	Design and testing of marine transfer systems. Design and testing of transfer arms
4	EN 1474-2	Design and testing of marine transfer systems. Design and testing of transfer hoses
5	EN 1474-3	Design and testing of marine transfer systems. Offshore transfer systems
6	EN 12308	Suitability testing of gaskets designed for flanged joints used on LNG piping
7	EN 12838	Suitability testing of LNG sampling systems
8	EN 13645	Design of onshore installations with a storage capacity between 5 t and 200 t
9	EN ISO 28460	Ship-to-shore interface and port operations
10	ISO 16903	Characteristics of LNG influencing design and material selection
11	ISO/TS 18683	Guidelines for systems and installations for supply of LNG as fuel to ships
12	CSA Z276	Standard for production, storage and handling of LNG in Canada

2.2.2 Draft Standards and rules for LNG

No.	Reference	Title
13	ISO 20519	Specification for bunkering of gas fuelled ships
14	CTAC	Recommendations for LNG Unmanned Barge Policy Letter

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2.2.3 Standards for Risk Analysis

No.	Reference	Title
15	ISO/IEC Guide 73	Risk Management - Vocabulary
16	ISO/TS 16901	Guidance on performing risk assessments in the design of onshore LNG installations including the ship/shore interface
17	ISO 31000	Risk Management - Principles and Guidelines
18	ISO 31010	Risk Management - Guidelines on principles and implementation of risk management

2.2.4 Other standards & guidelines

No.	Reference	Title
19	SGMF	Gas as a marine fuel - Bunkering safety guidelines
20	IEC 60079	Explosive Atmosphere Standards
21	IEC 60092-502	Electrical installations in ships - Tankers - Special features
22	EN13463-1	Non electric equipment for use in potentially explosive atmospheres
23	SIGTTO	ESD arrangements & linked ship/shore systems for liquefied gas carriers
24	USCG (CG-OES) Policy Letter No. 01-15	Guidelines for Liquefied Natural Gas Fuel Transfer Operations and Training of Personnel on Vessels using Natural Gas as Fuel (19 Feb 2015)
25	USCG (CG-OES) Policy Letter No. 02-15	Guidelines Related to Vessels and Waterfront Facilities Conducting Liquefied Natural Gas (LNG) Marine Fuel Transfer (Bunkering) Operations (19 Feb 2015)
26	USCG CG-521 Policy Letter 01-12	Equivalency Determination: Design Criteria for Natural Gas Fuel Systems
27	NFPA 52	Vehicular Gaseous Fuel Systems Code
28	NFPA 59A	Standard for the Production, Storage, and Handling of LNG
29	49 CFR 193	Liquefied Natural Gas Facilities: Federal Safety Standards (DOT)

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Section 3 - Bunkering methods

3.1 Description of typical ship bunkering arrangements

Four methods of bunker supply are detailed in the following sections.

The duration of the bunkering will depend mainly on the transfer rate from the bunkering facility; different pump sizes or pressurised supply can be selected depending on the specific needs. Other parameters influencing the duration include the testing procedures, BOG and flash gas handling, purging and draining method and pre- and post-bunkering procedures.

3.1.1 Ship-to-ship LNG bunkering

LNG bunker ships are a common solution when there is a significant volume of LNG to be transferred. Current capacities of LNG bunker ships, in operation and under construction, are in the range of a few hundred to several thousand cubic meters.

The bunker ship is loaded either in a purpose-built, small-scale terminal, a standard LNG terminal adapted for small scale LNG carriers or ship-to-ship bunkering from a larger LNG carrier.

3.1.2 Truck-to-ship LNG bunkering

LNG bunkering operations are carried out from standardised LNG trucks (typically about 40 cubic meter capacity). More than one truck may be required to bunker a single ship, depending on the required bunker volume.

The LNG bunkering operation duration is dependent on the transfer capacity of the truck which is relatively small. Depending on the shore side arrangement it may be possible to increase the bunker rate to some extent by simultaneous bunkering from multiple trucks via a common manifold or using a permanently installed buffer station on the quay side.

This LNG bunkering method is recognised to be flexible as it offers the possibility for many different ships to be bunkered in different port locations. Depending on the port arrangement it may be possible to park the trucks close to the bunker station on the receiving ship allowing short hoses to be used, this potentially reduces the heat flux into the LNG, minimises the pressure drop and also reduces the size of a potential spill if the hose is damaged.

This method is recognised as most suitable where the amount of LNG to be transferred is less than 200 cubic meters and when the commercial operation of the ship allows a sufficient duration for bunkering.

In some cases, LNG trucks may bunker Ro-Ro ferries directly from the ship's main open cargo deck to the bunker station. This bunkering method derives from normal practices of oil fuel bunkering methods used in Ro-Ro ferries.

3.1.3 Terminal (or shore-based facility) to ship LNG bunkering

A permanent bunkering facility may be used by ships such as short sea shipping ferries, ro-ro ships, OSV and IWW vessels.
LNG bunkering takes place through a rigid cryogenic pipe and a flexible hose or loading arm for final connection with the ship. The tanks for the storage of the LNG should generally be as close as possible to the bunkering terminal.

It is expected that this type of facility will be manned such that there will be shore side personnel able to manually activate the ESD and stop the bunker transfer in case of an emergency.

3.1.4 Containerised LNG tanks used as fuel tanks

This bunkering method may also be referred to as using portable tanks (see IGF code 18.4.6.3 and 18.4.6.4).

Instead of transferring LNG into the receiving ship's tanks pre-loaded LNG containers are lifted on board the vessel as a complete fuelling package. Each container is connected to three different piping systems: the LNG fuelling line to the engines, piping to the vent mast for the pressure relief valves (PRV) of each container and the inert gas system.

In case of use of ISO containerised LNG tanks used on board some small container carriers (feeders), the LNG tanks are provided in standard container sizes and consist of a Type C LNG tank, similar to a road tanker, inside a container shaped steel frame. The connection system for the LNG tank is also located within the frame.

For trailer tanks, used on-board some ferries, they are parked in specific location, usually IMDG areas, where they are fixed to the deck and connected through adequate hoses for the LNG fuelling in navigation. The specific LNG trailers (and its connecting equipment) used as portable LNG fuel tanks on board should be approved according to IGF code in addition to approval according to national, regional or international standards, e.g. ADR, Transport Canada or US DOT.

3.2 Examples of ship bunkering arrangements

Possible ship bunkering options are given in Table 1 below with corresponding arrangements (Figures 3 to 7).

Table 1: Bunkering options and arrangements

		Bunkering facility				
		Type C tank			Atmospheric tank	
		Bunker ship	Tank truck	Shore-based facility	Bunker ship	Shore-based facility
Receiving ship	Type C tank	Fig.3	Fig.6	(*)	(*)	Fig.7
	Atmospheric tank	Fig.4	(*)	(*)	Fig.5	(*)

(*) This arrangement is possible but not shown.

Note: For small scale bunker supply using Type C tanks, the LNG supply pressure may be generated by pump (as shown in the figures below) or by a Pressure Built Up unit.

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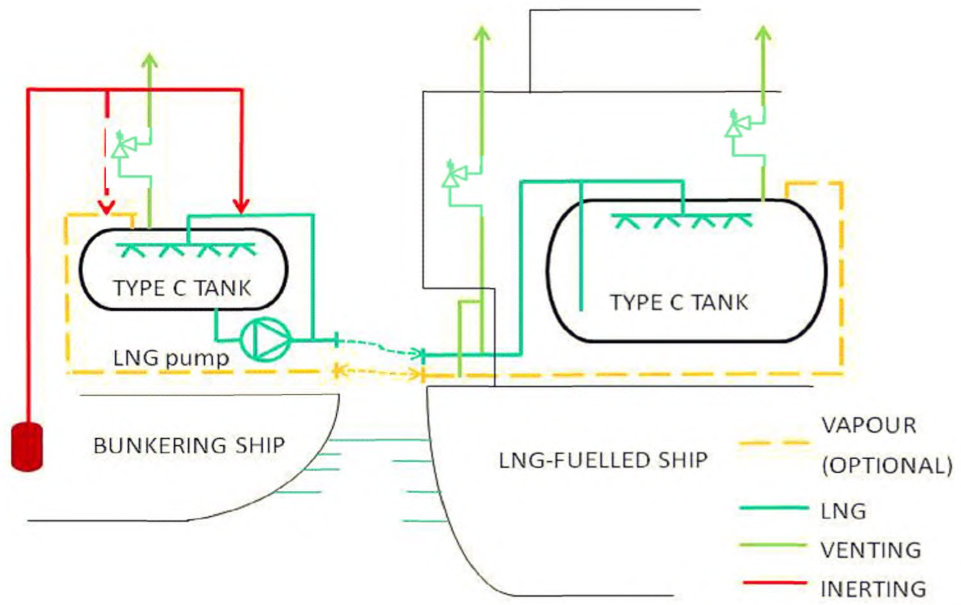

Figure 3: Ship-to-ship bunkering - typical arrangement of bunkering ship and LNG fuelled ship with type C tank

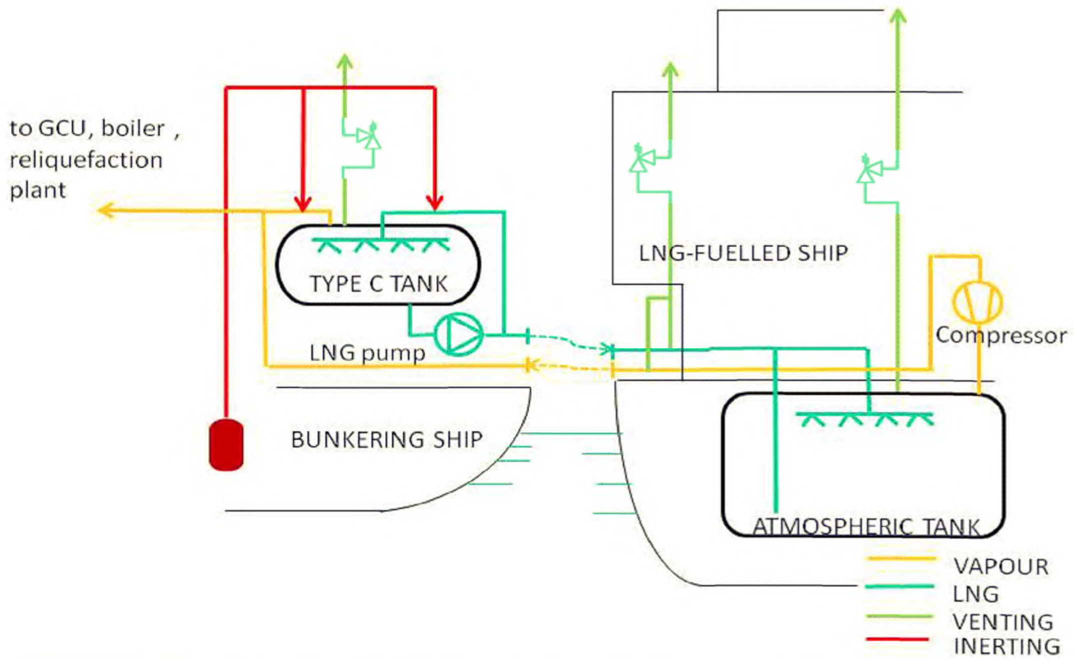

Figure 4: Ship-to-ship bunkering - typical arrangement of bunkering ship with type C tank and LNG fuelled ship with atmospheric tank

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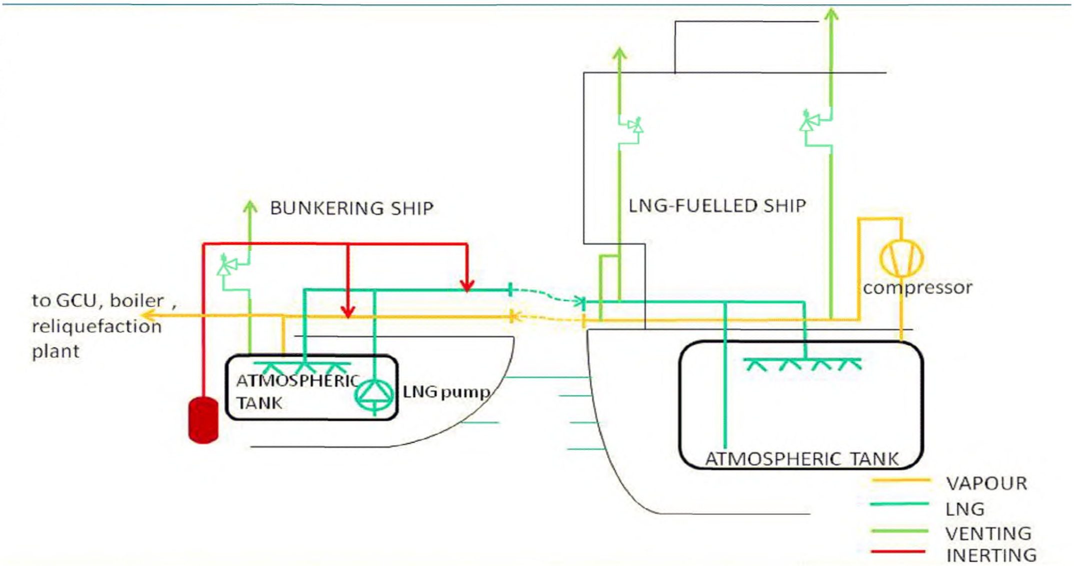

Figure 5: Ship-to-ship bunkering - typical arrangement of bunkering ship and LNG fuelled ship with atmospheric tank

* Compressor is optional, only necessary if free flow is not possible. Normally there is no need for a compressor if the bunker ship uses atmospheric tanks or uses type C tanks operated at very low pressure (using discharge pump and not PBU). It is only required in cases where there is likely to be large quantities of flash gas generated during bunkering and the pressure gradient between the bunker ship and receiving ship does not allow free flow of vapour.

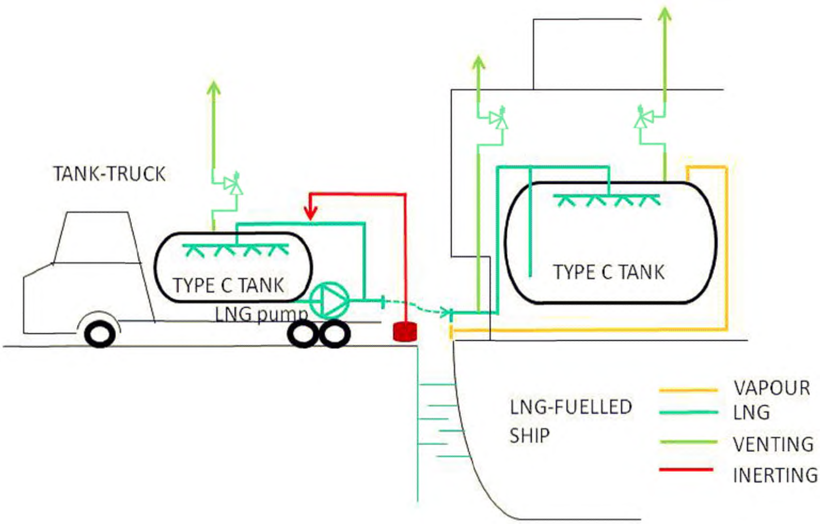

Figure 6: Truck-to-ship bunkering - typical arrangement of LNG fuelled ship with type C tank

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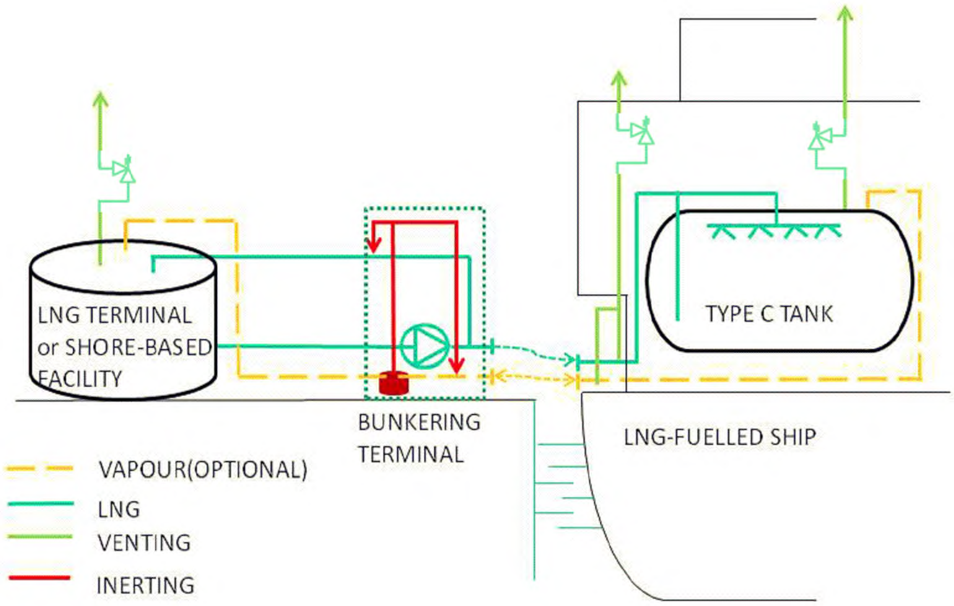

Figure 7: Terminal to ship bunkering - typical arrangement of LNG fuelled ship with type C tank

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Section 4 - Responsibilities during LNG bunkering

4.1 Responsibilities during planning stage

The involvement of port or other authorities, LNG supplier and receiving ship in the planning of a bunkering operation are detailed below.

4.1.1 Port, National Authority and Flag Administration responsibilities

Decisions and requirements for LNG bunkering should be based on a risk analysis carried out in advance of any bunkering operation. The Port authority and/or national or other authority with jurisdiction should consider:

- Approval of the risk acceptance criteria,
- Overall responsibility for the good governance and framework for LNG bunker operations in the port,
- Applicability of an accreditation scheme for LNG bunker operators in the ports under their authority,
- Acceptability of the location of bunkering facilities, (bunkering may be limited to specific locations within the port/anchorage),
- Restrictions on bunkering operations such as simultaneous operations,
- Shore side contingency plans, emergency response systems,
- General procedures for traffic control and restrictions,
- Whether additional requirements should be applied.

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4.1.2 Receiving ship operator (RSO) and bunkering facility organisation (BFO) responsibilities

Before setting up a ship bunkering operation, the receiving ship operator (RSO) and bunkering facility organisation (BFO) should perform the actions listed below.

Table 2: Receiving ship operator (RSO) and bunkering facility organisation (BFO) responsibilities

No.	Actions	to be performed by:		Observations
		RSO	BFO	
1	Review the applicable International, National and Local Regulations, Port by-laws, industry guidelines, standards, checklists, and Classification Societies Rules and Guidelines.	X	X	Prior to the operation.
2	Identify all documents, information, analysis, procedures, licences, accreditations, etc. required by Authorities.	X	X	Prior to the operation.
3	Check that the bunkering equipment is certified by the relevant Classification Society (on-board equipment) or by relevant Authorities (on-shore equipment).		X	Prior to the operation.
4	Check that the receiving ship and the bunkering facility are compatible.	X	X	This action should be carried out jointly by RSO and BFO.
5	Develop a specific LNG bunkering procedure for the concerned ship and bunkering facility based on preselected LNG bunkering guideline.	X	X	The LNG bunkering procedure should take into account any instructions and check-lists issued by the Port. This procedure should be developed jointly by RSO and BFO.
6	Perform the bunkering risk assessment (as part of an initial in-depth study).	X	X	Normally required by the Port Authorities and Flag authorities. Bunkering risk assessment study should involve RSO and BFO.
7	Develop an emergency response plan and bunkering safety instructions.	X	X	This action should be carried out jointly by RSO and BFO with local authorities, fire brigade and hospital premises involvement.
8	Ensure that all bunkering personnel are adequately trained.	X	X	
9	Develop bunkering plans and procedures reflecting the status of the facility.		X	
10	Prepare, compile and share the LNG bunkering management plan with stakeholders.	X		

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4.1.3 LNG Bunker Management Plan (LNGBMP)

A bunker management plan should be compiled to allow for easy availability of all relevant documentation for communication between the receiving vessel and the BFO and if applicable the terminal and/or third parties.

The Bunker Management plan should be stored and maintained by both RSO and BFO. For onboard bunkering this may not be the best scenario and should include the following aspects:

- Description of LNG, its handling hazards as a liquid or as a gas, including frostbite and asphyxiation, necessary safety equipment, personal protection equipment (PPE) and description of first aid measures

- Description of the dangers of asphyxiation from inert gas on the ship

- Bunkering safety instructions and emergency response plan

- Description of the bunker facility LNG tank measurement and instrumentation system for level, pressure, and temperature control

- Definition of the operating envelope for which safe LNG bunkering operations can be undertaken in reference to temperature, pressure, maximum flow, weather and mooring restrictions etc.

- A procedure for the avoidance of stratification and potential rollover, including comparison of the relative temperature and density of the remaining LNG in the receiving tank and that in the bunker provider tank and action to be taken to promote mixing during bunkering

- The description of all risk mitigation measures to comply with during an LNG bunkering

- The description of the hazardous areas, safety zone, and security zone and a description of the requirements in the zones to be complied with by the receiving vessel, the bunkering facilities, and if applicable the terminal and third parties

- Descriptions and diagrams of the bunker facility LNG bunkering system, including, but not limited to, the following as applicable:

  - Recirculating and vapour return line system
  - LNG fuel tank cooling down procedure
  - Procedure for collapsing the pressure of the receiving tank before and during bunkering
  - LNG fuel tank pressure relief valve
  - Ventilation and inlet/outlet location
  - Inerting system and components
  - Boil-off gas compressor or reliquefaction system
  - Gas detection system including locations of detectors and alarms
  - List of alarms or safety indication systems linked to the gas fuel installation
  - LNG transfer line and connectors
  - Emergency Shutdown System description
  - Communication systems and controls protocol

In addition to the above list of description and schematic drawings, the LNGBMP should include:

- Documents/reports on periodic inspections of the BFO LNG installation (components), and safety equipment.
- A checklist to verify that the ship's crew have received proper training for bunkering LNG.
- Bunkering safety instructions and safety management plan, (see below).

4.1.3.1 Bunkering safety instructions

RSO and BFO specific safety instructions should be prepared by both parties based on the conclusions and outputs of the LNG Bunkering Operations Risk Assessment (see Chapter 2 Sec 1 and Annex).
The specific LNG Bunkering safety instructions should cover at least:

- Sudden change of ambient / sea conditions,
- Breaching of safety and security zones,
- Loss of power (receiving ship or bunkering facility),
- Loss of monitoring / control / safety systems (ESD),
- Loss of communication, and
- Abnormal operating parameters.

In addition, the safety instructions for LNG bunkering may contain technical, RSO and BFO company-internal and operational regulations. The safety instructions should identify conditions under which bunkering will be stopped and in each case the actions required/conditions to be reinstated before the bunkering operation can be restarted

4.1.3.2 Emergency Response Plan

An Emergency Response Plan should be prepared to address cryogenic hazards, potential cold burn injuries to personnel and firefighting techniques for controlling, mitigating and elimination of a gas cloud fire, jet fire and/or a LNG pool fire.

The Emergency Response Plan should cover all emergency situations identified in the LNG Bunkering Operations Risk Assessment and may designate responsibilities for local authorities, hospitals, local fire brigades, PIC, Master and selected personnel from the bunkering facility. As a minimum, the following situations should be covered where appropriate:

- LNG leakage and spill on the receiving ship, on the bunkering facility or from the LNG transfer system
- Gas detection
- Fire in the bunkering area
- Unexpected movement of the vessel due to failure or loosening of mooring lines
- Unexpected moving of the truck tanker

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- Unexpected venting on the receiving ship or on the bunkering facility
- Loss of power

4.2 Responsibilities during bunkering operations

The involvement of port, national and/or other LNG supplier, receiving ship and specific individuals in the different phases of LNG bunkering are indicated below. In some situations there may be no port authority with direct responsibility for oversight of the bunkering operation (for example when the port/terminal is owned and managed by the BFO or RSO) in those cases the responsibilities listed in 4.1.1 and 4.2.1 should be adopted by either the BFO or the RSO.

4.2.1 Port Authorities general responsibilities

Port Authority regulations and procedures may impose requirements or criteria for:

- Accreditation of the BFO,
- Qualification of the PIC,
- Mooring of the receiving ship and bunker facility, industry standards may be referenced (e.g. OCIMF Effective Mooring 3rd Edition 2010),
- Immobilisation / braking of the tank truck,
- Establishment of a Safety zone / Security zone in way of the bunkering area,
- Simultaneous operations,
- Spatial planning and approval of bunker locations,
- Enforcement,
- Use of checklists,
- Environmental protection (Releases of NG, purging),
- Approval of safety and emergency response plans,
- Bunkering risk assessment, and
- Conditions in which LNG bunkering operations are allowed: weather conditions, sea state, wind speed and visibility.

4.2.2 LNG Bunkering facilities organisation (BFO) responsibilities

The LNG bunkering facilities organisation should be responsible for the operation of the LNG bunkering installations including:

- Planning of the specific operation (liaising with the RSO),
- Operation of the facility in line with plans and procedures; and
- Maintenance of the bunkering equipment.

4.2.3 Receiving ship operator (RSO)

Receiving ship operator has responsibilities for bunkering operation including:

- Informing the BFO and the Port Authority in advance for necessary preparation of the bunkering operation; and
- Attending the pre-bunkering meeting to ensure: compatibility with local requirements for equipment, quantity and flow rate of LNG to be bunkered, and coordination of crew and safety communication systems and procedures.

4.2.4 Master

The master of the receiving ship retains overall control for the safe operation of the ship throughout the bunkering operation. If the bunkering operation deviates from the planned and agreed process the master retains the right to terminate the process.

The master has overall responsibility for the following aspects of the bunkering operation. However, these tasks may be delegated to the PIC or other responsible crew member but the overall responsibility should be retained by the master:

- Approving the quantity of LNG to be bunkered
- Approving the composition, temperature and delivery pressure of LNG that is available from the bunkering facility operator. (Aspects of this may have been agreed prior to the bunkering operation as part of the LNG supply contract)
- Ensuring that the approved safe bunkering process is followed including compliance with any environmental protection requirements required by international, national or local port regulations
- Agreeing in writing the transfer procedure, including cooling down and if necessary, gassing up; the maximum transfer rate at all stages and volume to be transferred
- Completing and signing the bunkering checklist

4.2.5 Person in Charge (PIC)

A person in charge of the bunkering operation (PIC) should be agreed by the receiving ship and the bunkering facility. It is noted that in case of ship-to-ship transfer the role of PIC should be undertaken by either the Master or Chief Engineer of the receiving ship, or the Master of the bunker ship, for other bunker transfer methods a person of equivalent authority should be selected. In the case of distinct Master and PIC, the division of responsibilities between the two parties should be agreed before commencing bunkering operations.

The PIC should have an appropriate level of competence and be accepted to operate in the bunkering location. This may require authorisation or certification to act as PIC for bunkering operations, issued by the Port Authority or other Authority with jurisdiction over the bunkering location. The PIC should have adequate education, training and authorisation to ensure safe bunkering operations.

The PIC should be responsible for the bunkering operation and for the personnel involved, in all aspects of the bunkering operation, in particular safety, until completion.

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The PIC should ensure that:

- Relevant approved procedures are properly applied; and
- Safety standards are complied with, in particular within the hazardous zone and safety zone.

To achieve this, the PIC should be responsible for:

- Ensuring that company specific operating procedures are followed, and that the operation is conducted in compliance with all applicable port regulatory requirements;
- Ensuring that all required reports are made to the appropriate Authorities;
- Conducting a pre-operation safety meeting with the responsible officers of both the bunkering facility and the receiving ship;
- Ensuring that all bunkering documentation is completed (checklists, bunker delivery note, etc.);
- Agreeing the mooring arrangement and where applicable nominated Mooring Master during the operation;
- Ensuring all safeguards and risk prevention measures are in place prior to initiating the fuel flow;
- Being familiar with the results of the location risk assessment and ensuring that all specific risk mitigation means are in place and operating (water curtain, fire protection, etc.);
- The activation of Emergency Procedures related to the bunkering system operation;
- Ensuring operation will remain within the accepted environmental window for the duration of bunkering;
- Ensuring safe procedures are followed and the connection of liquid and vapour transfer hoses and associated ERS is successfully completed;
- Ensuring the safe procedures are followed and purging and leak testing of the bunkering system prior to transfer is successfully completed;
- Monitoring fuel transfer and discharge rates including vapour management;
- Monitoring climatic conditions throughout operation;
- Monitoring mooring arrangement integrity (in communication with mooring master);
- Monitoring communications throughout the operation;
- Ensuring the safe procedures are followed for drainage and purging of the bunkering system prior to disconnection;
- Supervising disconnection of liquid and vapour hoses/pipes;

- Supervising unmooring and separation of ships or in the case of truck bunkering, departure of the truck; and

- Supervising deployment/return of fenders and/or additional support utility to the bunker ship.

4.3 Crew and Personnel Training and LNG awareness

4.3.1 General LNG bunkering operational training

The RSO is responsible for ensuring that the personnel on board the receiving ship involved in the bunkering operation should be suitably trained and certified by a recognised organisation, to fulfil requirements according to STCW.7/Circ.23 "Interim guidance on training for seafarers on board ships using gases or other low flashpoint fuels".

Reference is also made to Resolution MSC.396(95) – (adopted on 11 June 2015) on AMENDMENTS TO THE INTERNATIONAL CONVENTION ON STANDARDS OF TRAINING, CERTIFICATION AND WATCHKEEPING FOR SEAFARERS (STCW), 1978, AS AMENDED and corresponding sections to Parts A and B of the 1978 STCW Convention containing training and qualifications of personnel that work on ships subject to the IGF Code.

The BFO is responsible for ensuring that all bunkering facility personnel involved with the bunkering operations are suitably trained and certified as required by the regulations governing the bunkering method.

- For ship-to-ship bunkering these are the requirements of STCW Regulation V/1-2 – "Mandatory minimum requirements for the training and qualifications of masters, officers and ratings on liquefied gas tankers" and equivalent requirements as provided by the governing authority for the inland waterway where the vessel is operating.

- For truck-to-ship or shore based terminal-to-ship bunkering these are the requirements of the local authorities governing activities within the port area. The personnel to be trained include but are not limited to personnel involved in LNG bunkering, personnel from authorities and emergency response services.

The person in charge (PIC) is to be trained in all aspects involving LNG. For the introduction of LNG bunkering operations within Port, sufficient training courses should be introduced in order to provide adequate competency to the role of PIC. This is especially the case with the development of novel bunkering systems or methods. The responsibility for verifying that the PIC is adequately trained falls on the RSO and BFO, the responsibility for certifying the PIC may be taken by the port authority.

4.3.2 Specific LNG bunkering safety training

Each bunkering method introduces different hazards. Specific training should be developed, based on the different possible failure scenarios and external events identified during the risk assessment study. Specific safety instructions as defined in 4.1.3.1 should be prepared based on the conclusions and outputs of the LNG Bunkering Risk Assessment.

The specific LNG Bunkering safety training should cover at least:

- Sudden change of ambient / sea conditions,

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- Loss of power (receiving ship or bunkering facility),
- Loss of monitoring / control / safety systems (ESD),
- Loss of communication,
- Abnormal operating parameters, and
- Rapid situation assessment technique with focus of restabilising unstable situations.

No. 142 (cont) Section 5 - Technical requirements for bunkering systems

5.1 General

The LNG / vapour transfer system should be designed and the bunkering procedure carried out so as to avoid the release of LNG or natural gas. The transfer system should be designed such that leakage from the system cannot cause danger to personnel, the receiving ship, the bunkering facility or the environment when the system is well maintained and properly used. Where any spillage of LNG can occur provisions should be taken protect personnel, ship's structure and equipment from cryogenic hazards. The consequences of other natural gas fuel related hazards (such as flammability) should be limited to a minimum through the arrangement of the transfer system and the corresponding equipment.

Specific means should be provided to purge the lines efficiently without release of natural gas with all purged gasses either retained by the receiving ship or returned to the bunkering facility.

Accidental leakage from the LNG / vapour transfer systems including the connections with the receiving ship bunkering manifold and with the bunkering facility should be detected by appropriate means.

5.2 Loading arms and hoses arrangements

5.2.1 Transfer installation

Arrangements should be made for:

- Purging and inerting the bunkering lines (or between designated ESD valves for systems with long LNG transfer lines) prior to the LNG transfer,
- Draining, purging and inerting the transfer system after completion of the LNG transfer.

LNG and vapour transfer systems (loading arm and/or flexible hose) should be fit for marine LNG bunkering operations. Design should be according to Tables 1 and 2 in ISO/TS 18683. The hoses and loading arms should be specially designed and constructed for the transfer products (LNG and Nitrogen) with a minimum temperature of -196°C.

Pressure relief devices should be provided so that the hose or loading arm is not over-pressurised in the event that liquid is trapped between its isolating valves (for example if the ERS is activated).

Hoses, loading arms and parts of the ship manifold should be designed for loads which may be experienced during operation such as self-weight (including fully loaded), loads due to relative motion between receiving ship and bunker supplier, and loads due to any lifting equipment used to handle the hose. The loading arms and parts of the ships manifold may also need to be designed to support the weight of an emergency release coupling.

Care should be taken when choosing the transfer system particularly with regards to:

- Potential movements between the receiving ship and the bunkering facility,

- Operating envelope of transfer system,
- Minimum bending radius allowed for hoses,
- ESD system functionality,
- Means of purging and draining the transfer lines,
- Material selection and structural support,
- Type of connectors,
- Electrical insulation,
- Continuity of earthing system,
- System design to address potential surge pressures developed during an ESD,
- Flash gas handling system, and
- Arrangements for pressure relief.

5.2.2 Hoses

Hoses should comply with appropriate recognized standards such as EN 1474-2, EN 12434 or BS 4089.
Transfer hose manufacturer's instructions, regarding testing and number of temperature and pressure operating cycles before removal from service, should be strictly followed.

Depending on which party owns the bunkering hose, a document should be included in the LNG Bunker management plan and a copy kept by the receiving ship containing the following information as applicable:

- Hose identification number
- Date of initial entry into service
- Initial test certificate and all subsequent test reports and certificates

The cryogenic hose should be subjected to hydrostatic testing once a year, if any defects appears during this inspection, the hose should be replaced. In addition the manufacturer of these hoses may lay down requirements relating to service life, inspection and maintenance. The manufacturer's instructions should be followed.

5.2.3 Lifting and supporting devices

The lifting devices, where fitted, should be of suitable capacity to handle the LNG transfer hoses and associated equipment.
Hoses should be suitably supported in such a way that the allowable bending radius is satisfied. They should normally not lie directly on the ground and should be arranged with enough slack to allow for all possible movements between the receiving ship and the bunkering facility.

Lifting and supporting devices should be suitably electrically insulated and should not impair the operation of any emergency release coupling or other safety devices.

5.3 Couplings and connecting flanges

5.3.1 General

The use of dry disconnect couplings is recommended for day-to-day bunkering operations using small hose diameters that will require several connections and disconnections.

5.3.2 Standard

An ISO standard for LNG bunkering connections is currently under development within TC8 WG8. In the meantime, couplings used for LNG Bunkering operation should be designed according to the requirements in ISO EN 16904:2016 and 1474-3 or any other applicable standards.

5.3.3 Isolation flange

The bunker transfer system should contain an isolation flange/of a non-electrically conductive material to prevent stray currents between the bunkering facility and the receiving ship. The isolation flange is generally fitted at the receiving ship end of the transfer system.

5.3.4 Spool piece

When spool pieces are used to connect to different sizes and geometries of connectors, they should be installed and tested as part of the preparation for bunkering. The leak testing would be applicable to ensure that the arrangement including spool piece is fully inerted and gas tight before transfer.

5.4 Leakage detection

As a minimum, in an enclosed or semi enclosed bunker station (on the receiving ship) or discharging station (of the bunker facility), the following safety devices should be in place:

- Gas detector(s), in suitable location(s) taking into consideration the rate of dispersion of cold vapour in the space, or temperature detection sensor(s), installed in the drip trays, or any combination to immediately detect leakage.

- CCTV is recommended to observe the bunkering operation from the bridge or operation control room. The CCTV should provide images of the bunker connection and also if possible the bunker hose such that movement of transfer system during bunkering are visible. CCTV is particularly recommended for enclosed bunker stations. Where CCTV is not provided, a permanent watch should be maintained from a safe location.

Gas detectors should be connected to the ESD system for monitoring leakage detection on the receiving ship.

Consideration may be given to the use of thermal imaging equipment or other suitable technology for leakage detection, especially in semi-enclosed bunkering stations.

A gas dispersion analysis will aid in identifying the critical locations and the extent of the LEL range where gas detectors should be fitted to enable early detection of any leakage.

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5.5 ESD systems

The bunkering facility and receiving ship should be fitted with a linked ESD system such that any activation of the ESD systems should be implemented simultaneously on both bunkering facility and receiving ship. Any pumps and vapour return compressors should be designed with consideration to surge pressure in the event of ESD activation.
The bunkering line should be designed and arranged to withstand the surge pressure that may result from the activation of the emergency release coupling and quick closing of ESD valves.

On ESD activation, manifold valves on the receiving ship and bunkering facility and any pump or compressor associated with the bunkering operation are to be shut down except where this would result in a more hazardous situation (see Table 3).

An ESD activation should not lead to LNG being trapped in a pipe between closed valves. An automatic pressure relief system is to be provided that is designed to release the natural gas to a safe location without release to the environment.

If not demonstrated to be required at a higher value due to pressure surge considerations, a suitably selected closing time up to 5 seconds should be selected, depending on the pipe size and bunkering rate from the trigger of the alarm to full closure of the ESD valves, in accordance with the IGF Code.

The emergency shutdown system ESD should be suitable for the capacity of the installation. The minimum alarms and safety actions required for the transfer system are given in Table 3 below:

Table 3: Alarms and safety actions required for the transfer system

Parameter/ Alarm trigger	Alarm	Action[1]
Low pressure in the supply tank	X	X
Sudden pressure drop at the transfer pump discharge	X	X
High level in the receiving tank[2]	X	X
High pressure in the receiving tank	X	X
LNG leakage in bunker station (gas detection/low temperature detection)	X	X
Gas detection in the ducting around the bunkering lines (if applicable)	20% of LEL	Alert at 20% LEL ESD activation at 40% of LEL
Manual activation of shutdown from either the ship to be bunkered or the bunkering installation (ESD1)	X	X
Manual activation of the emergency release coupling from either the ship to be bunkered or the bunkering installation (ESD2)	X	X
Safe working envelope of the loading arm exceeded	X	X
Fire detection (any fire detection on receiving ship or bunker facility)	X	X
Electrical power failure (supplied by independent source of energy, e.g. battery)	X	X

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Notes:
1. Alert is to be made at both the delivery and receiving ends of the transfer system to clearly identify the reasons for the ESD activation. X = Audible/visual alert to be made at bunker station/discharging station and ESD system to be activated. 2. Where the parameter that triggers the ESD is such that closure of vapour connection valves and shut down of vapour return compressors would increase the potential hazard (for example a receiving tank high level alarm) these are to remain open/active where appropriate.

The manual activation position for the ESD system should be outside the bunker station and should have a clear view of the manifold area (the 'clear view' may be provided via CCTV).

LNG bunker transfer should not be resumed until the transfer system and associated safety systems (fire detection, etc.) are returned to normal operation condition.
All electrical components of the emergency release coupling actuator and of the ESD systems that are considered as provided by the ship side should be type approved/certified by the classification society. When the ESD hardware and components are part of the onshore facility they should be designed and tested according to the industry standards.

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5.6 Emergency Release Coupling (ERC)

5.6.1 General

Transfer arms and hoses should be fitted with an emergency release coupling (ERC) designed to minimize the release of LNG on emergency disconnection. The emergency release coupling may be designed for:

- Manual or automatic activation, and
- Activation as a result of excessive forces i.e. automatic disconnection in case the safe working envelope of the transfer system is exceeded.

The breakaway coupling (BRC) should be subjected to a type test to confirm the values of axial and shear forces at which it automatically separates. For an emergency release coupling (ERC), the tightness of the self-closing shut-off valves after separation should be checked.

The ERC coupling should be designed and installed so that, in the worst allowable conditions for current, waves and wind declared in the bunkering conditions, it will not be subjected to excessive axial and shear forces likely to result in the loss of tightness or opening of the coupling. When the Safe working envelope of the transfer system is exceeded, the ERC system should be triggered.

Means should be provided in order to avoid a pressure surge in the bunker hose after release of the ERC when the connecting end of the hose is fitted with a dry disconnect coupling type.
Full operating instructions, testing and inspection schedules, necessary records and any limitations of all emergency release systems should be detailed in the ship's operating manuals.

5.6.2 ERC Activation

Where manual activation type ERC is fitted, the means of remotely operating the ERC should be positioned in a suitability protected area both on bunkering facility and receiving ship allowing visual monitoring of the bunkering system operation. A physical ESD link should bond the two parties. This does not apply to a dry breakaway coupling as this is a passive component which cannot be remotely activated.

5.6.3 Hose Handling after ERC Release

An integrated hose/support handling system should be in place, capable of handling and controlling the bunker transfer hoses after release of the ERC. In addition, it should be capable of absorbing all shock loadings imposed by the release of ERC during maximum capacity transfer conditions.

The system should ensure that, as far as practicable, upon release the hoses, couplings and supports do not contact the metal structure of the ship and bunkering facility, thereby reducing the risk of sparking at the contact point, injury to personnel or mechanical damage.

5.7 Communication systems

A communication system with back-up should be provided between the bunkering facility and the receiving ship.

The components of the communication system located in hazardous and safety zones should be type approved according to IEC 60079.

5.8 Bunkering transfer rate

The maximum LNG transfer rate from the BFO should be adjusted, taking into consideration:

- Maximum allowable flow rate of the bunker station manifold,
- Maximum allowable cooling down rate acceptable regarding induced thermal stresses in the LNG receiving ship piping and tank,
- Management of the flash gas generated during bunkering,
- Temperature of the LNG supplied from the bunkering facility,
- Temperature of the LNG remaining in the receiving ship tank, and
- Pressure in both bunkering facility tank and receiving ship tank.

Adequate provisions should be made for the management of the flash gas generated during the bunkering operation, without release to the atmosphere. This may be done by:

- Considering the capacity of the available vapour spaces and allowable pressure build-up of both ships, or
- Burning additional volumes in boilers, gas combustion units or gas engines, or
- Cooling the vapour space to control the pressure by using LNG spray in the receiving tank, or
- Reliquefaction.

The LNG velocity in the piping system should not exceed 12.0 m/sec under the rated equipment capacity in order to avoid the generation of static electricity, additional heat, and consecutive boil off gas due to nonlinear flow.

5.9 Vapour return line

Vapour return line(s) may be used in order to control the pressure in the receiving tank or to reduce the time required for bunkering (refer to 2.4.6 of Chapter 3). This is particularly applicable to atmospheric pressure fuel storage tanks (type A, prismatic type B or membrane tanks). The most relevant factors that will affect the amount of flash gas generation in a typical bunkering operation are as follows:

- Cool down of the transfer system
- Difference in the conditions prevailing between the bunkering facility tanks and the receiving tanks (particularly the temperature of the receiving tank)
- Transfer rates (ramp up, full flow, ramp down/topping up)
- Heat gain in pipe line between bunkering facility tank and receiving ship tank
- Pumping energy

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5.10 Lighting

Lighting should illuminate the bunker station area, and if installed in a hazardous area should be compliant with applicable hazardous area equipment requirements. Lighting should adequately illuminate the bunkering operation work area especially:

- LNG bunker hose(s),
- Connection and couplings on both receiving ship and bunkering facility,
- ESD system call points,
- Communication systems,
- Fire-fighting equipment,
- Passage ways / gangways intended to be used by the personnel in charge of the bunkering operation, and
- Vent mast(s).

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Chapter 2 - Risk Assessment

Section 1 **LNG Bunkering operations risk assessment**

Section 2 **Safety and security zones**

No. 142 (cont) Section 1 - LNG Bunkering operations risk assessment

1.1 General

A bunkering operations risk assessment should be undertaken in accordance with ISO/TS 18683. This technical specification is specific to the supply of LNG as fuel to ships and refers to recognised standards that provide detailed guidance on the use and application of risk assessment. The objectives of the bunkering operations risk assessment are to:

- Demonstrate that risks to people and the environment have been eliminated where possible, and if not, mitigated as necessary, and
- Provide insight and information to help set the required safety zone and security zone around the bunkering operation.

In order to meet these objectives, as a minimum, the bunkering operations risk assessment should cover the following operations:

- Preparations before and on ship's arrival, approach and mooring
- Preparation, testing and connection of equipment
- LNG transfer and boil-off gas (BOG) management
- Completion of bunker transfer and disconnection of equipment
- Simultaneous operations (SIMOPS) as noted in 1.3.3

1.2 Risk assessment approach

1.2.1 Qualitative Risk Assessment ($Q_{ual}RA$)

A Qualitative Risk Assessment ($Q_{ual}RA$) should be undertaken prior to introduction of a new bunkering operation procedure that follows the guidance in this document and the guidance given in ISO/TS 18683 guidelines.

Provided the bunkering operation is one of the three standard bunkering scenarios below, and guidance in this document and ISO/TS 18683 is followed, i.e. there are no deviations from the functional requirements, , then the qualitative approach (i.e. $Q_{ual}RA$) is sufficient to meet the objectives of the bunkering operations risk assessment.

Standard bunkering is characterised by three bunkering scenarios, as noted in ISO/TS 18683:

1. Shore-to-ship (that is, LNG transfer from an onshore facility to a gas fuelled ship)
2. Truck-to-ship (that is, LNG transfer from a road truck to a gas fuelled ship)
3. Ship-to-ship (that is, LNG transfer from a ship, such as a bunker barge, to a gas fuelled ship)

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1.2.2 Quantitative Risk Assessment (QRA)

As a supplement to the Q_{ual}RA, a Quantitative Risk Assessment (QRA) may be required where:

1. bunkering is not of a standard type (as described above);
2. design, arrangements and operations differ from the guidance given in this document; and
3. bunkering is undertaken alongside other transfer operations (SIMOPS), see 1.3.3.

A QRA is also appropriate where further insight is required to: judge the overall level of risk (since this is not typically provided by a Q_{ual}RA); appraise design options and mitigation alternatives; and/or to support a reduced safety zone and/or security zone.

The requirement for a QRA (in addition to a Q_{ual}RA) is normally determined by the Administration or Port Authority based on the conclusions and outcomes of the Q_{ual}RA and accepted by the concerned parties.

1.2.3 Risk Assessment Minimum Scope for LNG bunkering

Whether only a Q_{ual}RA is required or both a Q_{ual}RA and QRA are required, as a minimum the risk assessment should detail:

a. How the bunkering operation could potentially cause harm. That is, systematic identification of potential accidents/incidents that could result in fatality or injury or damage to the environment;

b. The potential severity of harm. That is, the worst case consequences of the accidents/incidents identified in 'a', in terms of single and multiple fatalities and environmental damage caused;

c. The likelihood of harm. That is, the probability or frequency with which the worst case consequences might occur;

d. A measure of risk, where risk is a combination of (b) and (c); and

e. How the functional requirements are met.

In addition, the risk assessment should help identify the scenarios to be used to determine the safety zone; and as a minimum, consider SIMOPS within the safety zone.

A typical approach to Q_{ual}RA and QRA is described in ISO/TS 18683. These approaches or similarly established approaches should be used provided they cover items (a) to (e) above.

Regardless of the approach used, the risk assessment should be carried out by a team of suitably qualified and experienced individuals with collective knowledge of, and expertise in: risk assessment application; engineering design; emergency response, and bunkering operations.

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1.3 Risk criteria

Examples of qualitative and quantitative risk criteria are outlined in ISO/TS 18683. In addition, guidance on selection of appropriate criteria may be given by government organisations. Furthermore, many industry organisations, such as the international oil companies, have specific risk criteria extensively used to demonstrate safe onshore and offshore operations to governments and regulators.

Although criteria from different sources may appear similar, it is important to note that there are no universally agreed risk criteria: there are differences between governments, regulators and organisations. Therefore, prior to the commencement of the risk assessment, risk criteria should be agreed with appropriate stakeholders, in particular the port and regulatory authorities, the Administration and the ship operator.

1.3.1 Risk Levels in Qualitative Risk Assessment ($Q_{ual}RA$)

Risk levels in qualitative risk assessments are commonly incorporated within a risk matrix and indicate a level of risk associated with a specific combination of consequence and likelihood. For example, the risk may be:

1. Sufficiently 'low' that it need not be reduced further,

2. At a level where mitigation should be considered and implemented if practicable, or

3. At a 'high' level where mitigation is required to reduce it.

An important point to note is that the risk level is indicative of one or more but not all potential accidents/incidents. That is, the assessment does not provide a collective or overall indication of the risk level from all potential accidents/incidents; rather it provides a relative ranking of the accidents/incidents considered. If the overall risk level is required then this can be determined using QRA.

1.3.2 Risk Criteria in Quantitative Risk Assessment (QRA)

Risk criteria in quantitative risk assessments commonly refer to individual risk and societal risk (or group risk), and these are related to fatality or some other measure of harm. Where a significant number of people are exposed to the bunkering operations then both should be assessed. This is because the risk to any individual may be 'low' but the risk of harming many people in a single accident/incident might be sufficient to warrant risk reduction. Stakeholders should consider what constitutes a significant number of people to require assessment of societal risk. Dependent upon specifics this might be exposure of ten or more people.

It is important to note that the criteria are typically expressed on a per annum basis (i.e. per year). For hazards that are present for a relatively short time (over a year) the per annum criteria may not be appropriate. This is because the risk is not spread uniformly across the year but peaks intermittently, and for long periods of time it does not exist. As such, if this is not recognised then proposed risk mitigation may not offer the protection envisaged. As a guide, per annum criteria may not be appropriate for a hazard present less than a third of the year.

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1.3.3 Risk assessment for simultaneous operations (SIMOPS)

Where it is proposed to carry out bunkering operations concurrently with other operations that may impact or be impacted by the bunkering then further risk assessment should be carried out to demonstrate that the required level of safety can be maintained.
Note: Risk assessment for simultaneous operations should be considered when the following operations are intended to be carried out simultaneously with the bunkering operations:

- Cargo handling
- Ballasting operations
- Passenger embarking / disembarking
- Dangerous goods loading / unloading and any kind of other goods loading or unloading (i.e. stores and provisions)
- Chemical products handling
- Other low-flash point products handling
- Bunkering of fuels other than LNG

Simultaneous operations should be investigated for any of the above activities occurring within the safety zone calculated as described in 2.3.

Any simultaneous shipboard technical operations such as testing systems that might affect the stability of the receiving ship, for example, changes to the mooring situation, testing of power generations systems or fire-fighting systems, are not to be carried out during LNG bunkering operations.

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1.4 Guidance on a typical Risk Assessment for LNG bunkering operations

The scale of risk assessment required for the bunkering process will depend on the bunkering method and equipment used with additional, more detailed, levels of risk assessment potentially required where novel procedures and/or equipment are selected.

It is generally expected that the risk assessment activities will be broken into two main parts, a higher level HAZID activity followed by a more detailed HAZOP activity. It is recommended that both of these activities are conducted with professional guidance to ensure an appropriately detailed risk assessment outcome is achieved.

Where designs or operational methods are modified after the risk assessment(s) have been conducted this may result in the risk assessments needing to be revised accordingly.

1.4.1 HAZID

The hazard identification process should provide sufficient detail for an operator to fully understand the nature of each hazard and to identify the controls necessary for the management of each hazard. The outcomes of the HAZID include risk rankings and recommendations for additional safeguards and analysis.

As a minimum, the HAZID should include the scope as described in the ISO/TS 18683.

Guidance for conducting a HAZID for LNG bunkering operation is detailed in the Annex of this guideline.

1.4.2 HAZOP

The HAZOP study is a structured and methodical examination of a planned process or operation in order to identify causes and consequences from a deviation to ensure the ability of equipment to perform in accordance with the design intent. It aims to ensure that appropriate safeguards are in place to help prevent accidents. Guidewords are used in combination with process conditions to systematically consider all credible deviations from normal conditions.

Guidance for conducting a HAZOP for LNG bunkering operation is detailed in the Annex of this guideline.

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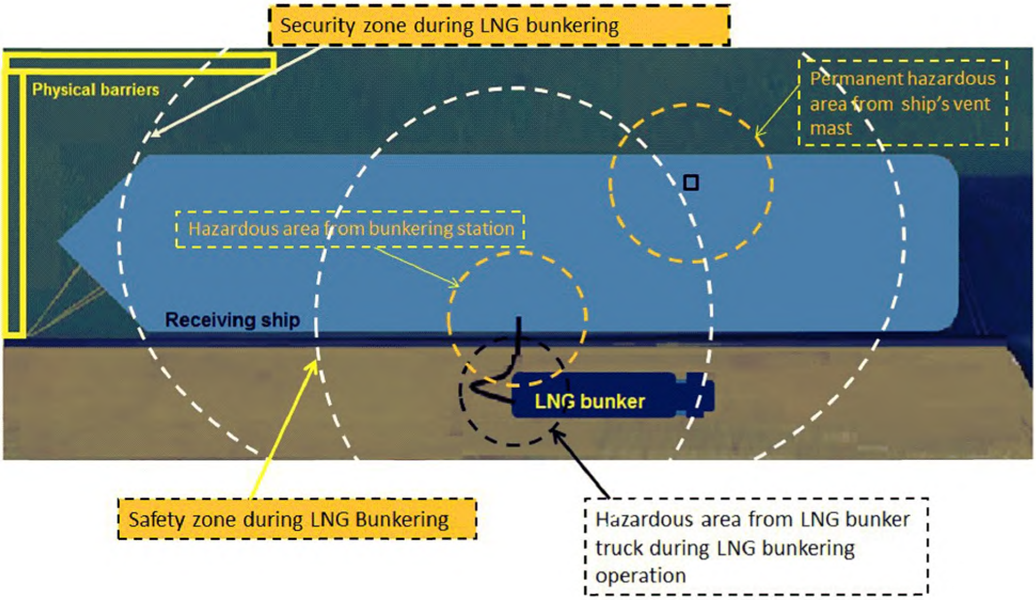
Section 2 - Safety and security zones

2.1 General

A safety zone and a security zone should be established around the bunkering operation in accordance with ISO/TS 18683. These zones are in addition to the established practice of setting hazardous area classification zones that will be required around areas with potential for explosive atmospheres such as the bunkering connections. A pictorial example of these zones is illustrated below.



Both the safety and security zones should be enforced and monitored at all times during bunkering, at all other times these zones are not enforced.

The purpose of the safety zone is to set an area within which only essential personnel are allowed and potential ignition sources are controlled. Essential personnel are those required to monitor and control the bunkering operation. Similarly, the purpose of the security zone is to set an area within which ship/port traffic is monitored and controlled.

Together, the safety and security zones help further minimise the low likelihood of a fuel release and its possible ignition, and help protect individuals and property via physical separation.

2.2 Hazardous area classification

Bunkering-related hazardous areas means any hazardous area zone 1 and zone 2 defined for:

- The receiving ship in accordance with IGF Code, regulation 12.5,
- The bunkering ship in accordance with IGC Code, regulation 1.2.24, and

Example minimum hazardous zone sizes include:

- Areas on open deck, or semi-enclosed spaces on deck, within 3 m of any gas tank outlet, gas or vapour outlet, bunker / supply manifold valve, other gas valve, gas pipe flange and gas tank openings for pressure release,
- Areas on the open deck within spillage coamings surrounding gas bunker / supply manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck,
- Semi-enclosed bunkering stations, and
- Areas within 1.5 m surrounding spaces listed above.

The bunkering-related hazardous area also includes areas around the truck, LNG bunker vessel or shore-based bunkering facility. Depending on the outcomes of the risk assessment and the specific details of the bunkering process (equipment and transfer flow rates and pressures) the size of these areas may be increased.

In the hazardous area, only electrical equipment certified in accordance with IEC 60079 is permitted. Other electrical equipment should be de-energised prior to the bunkering operations. Attention is drawn to the following equipment, which is not intrinsically safe and should therefore be disabled, except if otherwise justified:

- The radar equipment, which may emit high power densities,
- Other electrical equipment of the ship, such as radio equipment and satellite communication equipment, when they may cause arcing.

2.3 Safety zones

In the safety zone, the following restrictions normally apply during the bunkering operations, except if otherwise justified by the safety analysis or agreed by the Local Port Authorities or National Administration:

- Smoking is not permitted.
- Naked lights, mobile phones, cameras and other non-certified portable electrical equipment are strictly prohibited.
- Cranes and other lifting appliances not essential to the bunkering operation are not to be operated.
- No vehicle (except the tank truck) should be present in the safety zone.
- No ship or craft should normally enter the safety zone, except if duly authorised by the Port Authorities.
- Other possible sources of ignition should be eliminated.
- Access to the safety zone is restricted to the authorised staff, provided they are fitted with personal protective equipment (PPE) with anti-static properties and portable gas detector.

2.3.1 Determination of the safety zone distance

There are two different approaches which are outlined in the following paragraphs.

2.3.1.1 Deterministic approach

The safety zone should be set based upon the flammable extent of a maximum credible release scenario. In ISO/TS 18683 this approach to setting the safety zone is referred to as the 'deterministic approach'. Specific requirements for the determination of the safety zone may be set by national and local authorities.

The flammable extent is the distance at which the lower flammable limit (LFL) is reached as the vapour/gas (from the released fuel) disperses in the atmosphere. For LNG, the LFL is approximately 5% of natural gas in air.

As a minimum, the following information should be taken into account in the maximum credible release scenario:

- The physical properties of the released fuel.
- Weather conditions at the bunkering location; wind speed, humidity, air temperature and the temperature of the surface upon which the fuel leaks. The chosen conditions should reflect the worst-case conditions that result in the greatest distance to LFL.
- Roughness of the surface over which the vapour/gas disperses, (i.e. land or water).
- Structures and physical features that that could significantly increase or decrease dispersion distances.

- Release rate, release orientation, available inventory and rate of vapour generation.

In addition, release height is to be considered as this can significantly affect the extent of the calculated safety zone. The vertical extent of the safety zone may require special consideration, especially in cases where persons can be at elevated positions, such as located in cabins many metres above the bunker station.

Large objects, such as buildings and ships, and topography, such as cliffs and sloping ground, can constrain or direct dispersion. This should be recognised in setting the safety zone. Failure to do this can result in inappropriate safety zones that include areas that would not be affected by any release of natural gas or exclude areas that would be affected if there was a release. In certain cases, advanced modelling techniques, such as computational fluid dynamics (CFD) might be required to justify the zone's shape and extent.

Regardless of the technique(s) used in setting the safety zone it should be applied by a suitably qualified and experienced individual.

ISO/TS 18683 provides two examples of a maximum credible release scenario, where the one resulting in the greatest LFL extent is used to set the safety zone:

a. A release of the 'trapped inventory' between emergency shutdown valves in the liquid bunkering line (i.e. bunker hose), and

b. A 'continuous release' from an instrument connection where emergency valves do not close to isolate the release and delivery pressure is maintained.

To set the safety zone either:

- The ISO/TS 18683 release cases as described above should be used (i.e. 'a' and 'b'), or
- A maximum credible release scenario should be used that has been identified and justified using the risk assessment method described in ISO/TS 18683. This option allows for consideration of mitigation measures and other factors specific to the bunkering operation.

2.3.1.2 Probabilistic approach

An alternative approach to setting the safety zone should use quantitative risk assessment (QRA) whereby consideration is given within a predefined scenario to a representative set of potential releases and the likelihood with which they occur. This approach is often referred to as the "probabilistic" or "risk based" approach.

In theory, this approach could lead to a safety zone of less than the hazardous area or even 0 metres. This is not acceptable. The Safety Zone should at least extend beyond the hazardous areas and/or the minimum distance defined by the authorities from any part of the bunkering installation.

A key feature of QRA is that it accounts for both the consequence and likelihood of releases and can consider the location of people, the probability of ignition, and the effectiveness of mitigation measures and other emergency actions. As such, it can provide increased understanding of those releases that contribute most to the risk, and this can be useful in identifying and testing the suitability of mitigation measures, and optimizing zone extent. If this approach is selected then it is important that appropriate risk criteria are used.

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2.4 Security zones

A security zone should be set based upon ship/port operations. In setting the zone consideration should be given to activities and installations that could endanger the bunkering operation or exacerbate an emergency situation. For example, consideration of the following is required when setting the security zone:

- Other ship/ship movements
- Surrounding road traffic, industrial plants, factories and public facilities
- Crane and other loading/unloading operations
- Construction and maintenance works
- Utilities and telecommunication activities and infrastructure

Many of the above are considered in the risk assessment described in this document. Therefore, to help inform setting of the zone, reference should be made to this risk assessment.

No. 142 (cont) Chapter 3 - Functional and General Requirements for LNG Bunkering Operation

Section 1 Pre-bunkering phase

Section 2 Bunkering phase

Section 3 Bunkering completion phase

No. 142 (cont)

Section 1 - Pre-bunkering phase

1.1 Definition

The pre-bunkering phase starts from the first communication between receiving ship and bunkering facility for ordering a bunker of LNG, and ends with the physical connection of the bunker line to the bunker station.

1.2 Goal

The goal of the pre-bunkering phase is the preparation and the completion of a safe connection between the transfer systems of the bunkering facility and the receiving ship.

1.3 Functional requirements

The following functional requirements should be considered during the pre-bunkering phase:

- The risk assessment has been conducted and the findings have been implemented.
- An LNG Bunker Management Plan has been established and is applicable to the ship.
- A compatibility check demonstrates that the safety and bunkering systems of the bunkering facility and the ship to be bunkered match.
- The necessary authorities have been informed regarding the LNG bunkering operation.
- The permission for the transfer operation is available from the relevant authority.
- The boundary conditions such as transfer rate, boil-off handling and loading limit have been agreed between the supplier and the ship to be bunkered.
- Initial checks of the bunkering and safety system are conducted to ensure a safe transfer of LNG during the bunkering phase.

1.4 General requirements

1.4.1 Personnel on duty

During the transfer operation, personnel in the safety zone should be limited to essential staff only. All staff engaged in duties or working in the vicinity of the operations should wear appropriate personal protective equipment (PPE) and an individual portable gas detector as required by the LNG Bunker Management Plan.

1.4.2 Compatibility assessment (prior to confirming the bunkering operation)

A compatibility assessment of the bunkering facility and receiving ship should be undertaken prior to confirming the bunkering operation to identify any aspects that require particular management.

The compatibility assessment should be undertaken with the assistance of an appropriate Checklist to be completed and agreed by Master(s) and PIC prior to engaging in the bunkering operation.

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As a minimum, compatibility of the following equipment and installation should be checked prior to engaging further in any LNG bunkering operation:

- Communication system (hardware, software if any and language) between the PIC, ship's crew and BFO personnel
- ESD system
- Bunker connection
- Emergency release system (ERS) or coupling (ERC)
- Vapour return line when appropriate
- Nitrogen lines availability and connection
- Mooring equipment
- Bunker Station location
- Transfer system sizing and loading on manifold
- Location of ERS
- Closure speed of valves
- HAZOP results as applicable

1.5 Preparation for bunker transfer

1.5.1 Environmental conditions

The environmental conditions (weather (especially lightening), sea state, temperature, and visibility limitation such as fog or mist) should be acceptable in terms of safety for all the parties involved.

1.5.2 Mooring

1.5.2.1 Mooring condition of receiving ship

The ship should be securely moored to the bunker supplier to prevent excessive relative movement during the bunkering operation.

1.5.2.2 Mooring condition of bunker ship

For ship-to-ship bunkering the bunker ship should be securely moored according to the result of the compatibility check, so that excessive movements and overstressing of the bunkering connections can be avoided. Refer to 1.7.3 below. For the mooring of the bunker ship the limiting conditions should be considered such as weather, tide, strong wind and waves.

1.5.2.3 Parking condition of truck LNG tanker(s)

The truck LNG tanker(s) should be securely parked, to prevent unintended movements.

All ignition sources linked to the truck are to be managed in accordance with the bunkering management plan/procedure taking into account Hazardous areas and Safety Zones. Any situation whereby this requirement cannot be met, special consideration must be provided (i.e. non-standard) to ensure the risk of ignition is managed to ALARP.

In any case, the truck engine should not be running during connection and disconnection of the transfer system.

1.5.3 Communication

Communication should be satisfactorily established between the bunkering facility and the receiving ship prior to any transfer operation. If they are to be used, visible signals should be agreed by and clear to all the personnel involved in the LNG bunkering operation.

In case of communication failure, bunkering operations should be stopped and not resumed until communication is re-established.

1.5.4 Agreement of the transfer conditions

The following should be agreed before commencing the bunker transfer:

- Transfer time, temperature and pressure of the delivered LNG, pressure inside the receiving ship tank, delivery line measurement, vapour return line measurement (if any) should be agreed and checked prior to engaging in any LNG Bunkering Operation.

- The maximum LNG temperature that the receiving ship can handle should be stated by the receiving ship in order to avoid excessive boil-off generation.

- Liquid levels, temperature and pressure for the LNG bunker tanks of the receiving ship should be checked and noted on the bunkering checklist.

- The maximum loading level and transfer rate, including cool down and topping up should be agreed upon. This includes the pressure capacity of pumps and relieving devices in the connected transfer system. The filling limit of the receiving tank depends on MARVS (as per IGC / IGF codes) and accounts for the possible expansion of cold LNG.

The agreed transfer conditions should be included in the LNG Bunker Management Plan.

1.5.5 Individual safety equipment in place (PPE)

All personnel involved in the LNG bunkering operation should properly wear adequate Personal Protective Equipment (PPE). It should be ensured that all the PPEs have been checked for compliance and are ready and suitable for use.

1.5.6 Protection of the hull plate, shell side and ship structure

Protection from cryogenic brittle fracture of the receiving ship deck and structure caused by leakage of LNG should be fitted as per IGF code requirements.

When appropriate one or more of the following protective measures may be utilised:

- A water curtain may be installed to protect the ship's hull.

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- A cover of suitable material grade to withstand LNG temperatures may be installed underneath the transfer hose to protect deck plating.
- A drip tray of suitable material grade to withstand LNG temperatures may be fitted below the pipe coupling to collect LNG spill.

It is recommended that spill protection is also provided for the BFO equipment, this may be governed by local regulations for truck-to-ship bunkering and shore based facilities.

1.5.7 Safety zone requirements and mark out

- The boundaries of the safety zone associated with bunker station and BFO connection should be clearly marked out.
- Any non-EX equipment installed in hazardous areas and/or in safety zone, such as the bunker station, should be electrically isolated before the bunkering operation commences and throughout the bunkering process until such time as the area is free of any gas leak hazard. Any such arrangement where there is non-Ex rated equipment installed in a hazardous zone should be subject to special consideration by the classification society.
- Radio communications equipment not needed during bunkering and cell phones should be switched off as appropriate.

1.5.8 Electric isolation

A single isolation flange should be provided, in each arm or hose of the transfer system, between the receiving ship manifold and the bunker pipeline. The installation should not permit shorting out of this insulation for example by, leaving the flange resting in stainless steel drip tray. This flange prevents galvanic current flow between the receiving ship and the bunkering facility. Steel to steel contact between receiving ship and bunkering facility e.g. via mooring lines, ladders, gangways, chains for fender support etc. should be avoided through the use of insulation. Bunker hoses/pipes should be supported and isolated to prevent electrical contact with the receiving ship.

When bunkering from trucks, the truck should be grounded to an earthing point at the quay to prevent static electricity build up. Where approval has been given for the bunkering truck to be parked on the deck of the ship then the truck should be grounded to the receiving ship.

Ship-shore bonding cables/straps should not be used unless required by national or local regulations.

If national or local regulations require a bonding cable/strap to be used, the circuit continuity should be made via a 'certified safe' switch (e.g. one housed inside a flame proof enclosure) and the connection on board the receiving ship should be in a location remote safe area from the hazardous area. The switch should not be closed until the bonding cable/strap has been connected, and it should be opened prior to disconnection of the bonding strap.

1.5.9 ERS

Simulated testing of all types of coupling having the function of ERC within the ERS should be performed according to a recognised standard. Testing records should be retained with the bunkering operator or organisation responsible for such equipment ready for immediate inspection by authorities. Any transfer /support system should be proved operational (if necessary by inspection of marine loading arm or supported hose) and be confirmed as part of the pre-transfer checklist.

Testing of the system prior to each bunkering operation should prove all components are satisfactory, with the exception of actually releasing the ERC. The system used to link the ERS system with the ships' ESD1 trip circuit should be tested and proved operational.

1.5.10 Emergency Release Coupling (Break away coupling)

The disconnection can be triggered manually or automatically. In either case, activation of the ERS system should trigger activation of the ESD (ESD1) before release of the ERC (ESD2).

Where applicable, step-by-step operating instructions should be permanently affixed to the ERC equipment and all personnel involved in its operations should be trained and made familiar with its correct use. Additionally, clear procedures should be in place identifying the process for authorisation to remotely activate the ERC.

In the event of ESD2 activation, i.e. breakaway coupling sudden release triggered due to emergency event or overstress on the transfer line induced by ship movement, the backlashing hoses can damage hull structure and injure personnel in the absence of an appropriate supporting arrangement. This supporting arrangement, if fitted, should not prevent the correct operation of the breakaway coupling, any relative motion between the receiving ship and the bunkering facility should act directly on the ERC to ensure its correct operation if the event of vessel drift or unexpected truck movement.

Routine inspection and testing of the release equipment is required, responsibility for this testing will depend on agreements between the BFO and RSO.

1.5.11 ESD testing

The bunkering facility and receiving ship should both test their emergency shutdown systems not more than 24 hours before bunkering operations commence. The PIC should then be advised of the successful completion of these tests. These tests should be documented in accordance with the bunkering procedure.

1.5.12 Visual inspection of bunker hose or arm before physical connection

Bunker hoses and connecting systems should be visually examined for wear and tear, physical damage and cleanliness. If any defects are found during this inspection, the bunkering operation is cancelled until the transfer hose is replaced.

1.5.13 Liquid and gas leakage detection systems activated

The gas detection system as described in Chapter 1, 5.4 should be activated. Temperature sensor(s) should be installed in the bunker station below the drip tray and their temperature calibration(s) should be checked. Their function should also be tested.

1.5.14 Preparation of the transfer system

The piping at the bunkering facility should be inerted and cooled down (as far as practicable) prior to the connection with the ship to be bunkered. If this operation may cause any specific hazards when connecting to the transfer line it should be carried out after the connection has been carried out. The specific cooling down procedure for the transfer system in terms of cooling down rate should be observed with special care regarding the potential for induced thermal stresses and damage and leaks that may occur. Connections to the bunkering facility and the receiving ship should be visually checked and if necessary retightened. During this operation there should be no release of any LNG or natural gas.

1.6 Pre-bunkering checklist

The LNG Bunker Management Plan should include a checklist to be used during LNG bunkering operation by all involved personnel. This checklist should be elaborated once the full agreement on: procedures to apply, equipment to be used, quantity and quality of LNG to bunker, and training is obtained by all involved parties.

At the time of writing this guideline a LNG bunkering operation checklist is under development within ISO and IMO. In the meantime the LNG Bunkering operation specific checklist should be therefore adapted from the examples checklists for truck-to-ship, shore-to-ship and ship-to-ship LNG bunkering that have been elaborated by WPCI and IAPH. These can be downloaded from: _________________.

1.7 Connection of the transfer system

1.7.1 Connecting

Equipment utilised with the transfer system such as couplings and hoses should be approved and tested both before and after installation. For emergency release coupling requirements (ERC), see Chapter 1, 5.6.

The transfer system should be connected such that all the forces acting during the transfer operation are within the operating range.

1.7.2 Condition of flange and sealing surfaces prior to connection

During connecting of the transfer system, humidity at the flange mating surfaces should be avoided and it should be ensured that all mating surfaces are clean. When necessary, compressed air should be used for cleaning the contact surface of flanges and seals before physical connection and clamping of the couplings. Heating of the connections to dry them prior to connecting may be considered in some circumstances.

1.7.3 Minimum bending radius of the hose

Hoses should be suitably supported in a manner that the minimum acceptable bending radius according to the qualification standard of the hose is not exceeded. Equipment utilised with the transfer system such as hose rests, saddles, and guidance systems (as applicable) should be approved and tested.
A LNG transfer hose should normally not lie directly on the deck plate and should be isolated thermally from the deck. As a minimum, suitable protection such as wooden boards should also be provided to avoid damage from friction on the quay.

The hose arrangement should be so designed with enough slack to allow for all possible movements between the receiving ship and the bunkering facility.

1.7.4 Transfer line purging

After connection of the transfer system it should be purged to ensure that no oxygen or humidity remains in the transfer system. Nitrogen should be used for purging of any parts of the system that will be cooled to cryogenic temperatures during the bunkering operation.

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Attention is drawn to quantity of the inert gas used for purging / inerting, which may result in high inert gas content in the LNG tank of the receiving ship, which may affect the proper operation of engines. A typical purging sequence of the transfer line involves the injection of five (5) times the volume of the bunker line. The volume of inert gas required may be minimised by the design of the transfer system (i.e. using shorter lengths of hose).

1.7.5 Transfer line pressure testing

During inerting of the transfer system the leak test according to the bunkering procedure should be carried out. As a minimum, a leak test of the connection points and flanges in the system from the bunkering facility up to the ESD valve on the receiving ship should be performed prior to any transfer operation.

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Section 2 - Bunkering phase

2.1 Definition

The bunkering phase begins after the physical connection between the bunkering facility and the receiving ship's bunker station has been safely completed with the opening of the LNG transfer valve from the bunker ship, the truck tanker or the onshore bunkering facility.

It continues with the cooling down of the transfer line followed by the LNG bunker transfer and ends at the end of the topping up phase and the closure of the LNG valve from the bunkering facility.

2.2 Goal

Transfer of the required quantity of LNG without release of LNG and/or natural gas to the surrounding environment in a safe and efficient operation.

2.3 Functional requirements

- During the whole transfer process a suitable ESD and ERS system should be provided for the transfer system.
- After connection of the transfer system a suitable cooling down procedure should be carried out in accordance with the specification of the transfer system and the receiving tank supplier requirements.
- Flash gas or boil-off gas will not be released to atmosphere during normal transfer operations.
- Bunker lines, transfer system and tank condition should be continuously monitored for the duration of the transfer operation.

2.4 General requirements

2.4.1 ERS

The ERS control signals and actuators should be checked and tested and should be ready for use.

The mechanical release mechanism of the ERS system should be proven operational and ready for use before fuel bunkering operation commences.

2.4.2 ESD connection testing

It should be ensured that a linked ESD system connected, tested and ready for use is available. There are two phases of testing Warm ESD testing and Cold ESD testing.

2.4.2.1 Warm ESD Testing

The ESD system should be tested following completion of manifold connection & ESD link. The testing should take place between the receiving ship and the bunkering facility prior to commencement of operation (warm ESD1) to confirm that the systems are compatible and correctly connected. The initiation of the warm ESD1 signal should be done from either one of the receiving ship or the bunkering facility.

2.4.3 Cool down of transfer system

As far as practicable, cooling down of the transfer lines should be carried out according to the requirements of the transfer system and according to the bunkering procedure with special care regarding the potential leaks that may occur as components shrink as they are cooled. Connections to the bunkering facility and the receiving ship should be monitored and, if necessary, tightened.

If a pump is used to deliver the required pressure for the tank to be filled, it is necessary to cool it to operating temperature before starting. This is done by filling the pump circuit with liquid from the tank.

2.4.3.1 Cold ESD Testing

Following the successful completion of cool down operation the cold test should be carried out as far as practicable to ensure that the ESD valves operate correctly in cold conditions before initiating the main LNG bunker transfer.

2.4.4 Main bunker transfer

After proper cooling down of the transfer system and a stable condition of the system the transfer rate can be increased to the agreed amount according to the bunkering procedure. The transfer process should be continuously monitored with regard to the operating limits of the system.

If there are any deviations from the operation limits of the system the transfer of LNG should be immediately stopped.

2.4.5 Monitoring pressure and temperature

Receiving tank pressure and temperature should be monitored and controlled during the bunkering process to prevent over pressurisation and subsequent release of natural gas or liquid natural gas through the tank pressure relief valve and the vent mast.

2.4.6 Vapour management

The vapour management methodology will vary depending on tank type, system type and system condition, but should be agreed on during the compatibility check.
For atmospheric tanks a vapour return line may be used but also other systems like reliquefaction units or pressurised auxiliary systems can also be used to regulate the pressure of the return vapour.

If the receiving tank is a Type C tank, the above remains valid. An alternative practise of LNG bunkering widely used, especially in a truck-to-ship bunkering situation or when no vapour return line is available, is to spray LNG into the top of the receiving tank through diffusers in order to cool the vapour space. As a result the tank pressure will be reduced and therefore the pressure increase due to flash gas can be contained and managed for the duration of the LNG bunkering.

2.4.7 Topping up of the tank

The topping up of the tank should be carefully surveyed by the Person in Charge and/or the Chief Engineer surveying the filling up of the LNG tank(s). The LNG fuel transfer flow rate should be slowed with an appropriate declining value when the receiving tank LNG level approaches the agreed loading limit. The loading limit of the tank and the tank pressure should be paid special attention by the PIC during this operational step. The opening of the tank's Pressure Relief Valve (PRV) due to overpressure in tank, for example following overfilling, should be avoided.

2.4.8 Selection of measurement equipment

The impact on the safety of the transfer system by any equipment used for the measurement of LNG quantity during the bunkering operation should be considered. The measurement method selected, and the equipment used (flow meters, etc.), should minimise disruption to the flow of LNG to prevent pressure surge, excess flash gas generation, or pressure losses in the transfer system.

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Section 3 - Bunkering completion phase

3.1 Definition

The post bunkering phase begins once the bunker transfer (final topping up phase) has been completed and the bunkering facility LNG delivering valve has been closed. It ends once the receiving ship and bunkering facility have safely separated and all required documentation has been completed.

3.2 Goal

This phase should secure a safe separation of the transfer systems of the receiving ship and bunkering facility without release of LNG or excess vapour to the surrounding environment.

3.3 Functional requirements

The following functional requirements should be considered during the Post Bunkering Phase:

- The draining, purging and inerting sequences as described in 3.4 below for the different bunkering cases are fulfilled without release of excess natural gas to the atmosphere.
- The securing and safe storage of transfer system equipment is ensured.
- The unmooring operation and separation of ship(s) is completed safely.

3.4 Draining, purging and inerting sequence

This part of the process is intended to ensure that the transfer system is in a safe condition before separation, the couplings should not be separated unless there is an inert atmosphere on both sides of the coupling.

The details of this process will be design dependent but should include the following steps:

- Shut down of the supply.
- Safe isolation of the supply.
- Draining of any remaining LNG out of the transfer system.
- Purging of natural gas from the transfer system.
- Safe separation of the transfer system coupling(s).
- Safe storage of the transfer system equipment in a manner that the introduction of moisture or oxygen into the system.

3.4.1 LNG Bunkering from Truck LNG Tank

The process of purging and inerting will follow the general outline described above, all purged gasses are generally returned to the receiving ship tank.

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3.4.2 LNG Bunkering from Bunker ship

The process of purging and inerting will follow the general outline described above, all purged gasses are generally returned to the bunker ship tank.

3.4.3 LNG Bunkering from shore based terminal

The process of purging and inerting will follow the general outline described above, all purged gasses are generally returned to the shore facility.

3.4.4 LNG Bunkering using portable tanks

The method for safe disconnection of portable tanks will vary depending on the specific design of the system. The general principles remain the same:

- All pipe connections to be isolated at the delivery and receiving ends.
- The connecting hose(s) should be purged and inerted to below the lower flammable limit to prevent risk of ignition and minimise release of natural gas during disconnection.
- Hoses and connections should be securely blanked or otherwise protected to avoid introduction of moisture and oxygen into the system.

3.5 Post-bunkering documentation

Upon completion of bunkering operations the checklist in the LNG bunkering management plan (as described in the pre-bunkering section above) should be completed to document that the operation has been concluded in accordance with the agreed safe procedure. The vessel PIC should receive and sign a Bunker Delivery Note for the fuel delivered, the details of the bunker delivery note are specified in the annex to part C-1 of IGF Code.

No. 142 (cont) Annex: Guidance on HAZID and HAZOP for LNG bunkering operations

This annex presents the minimum scope for Risk Analysis related to LNG Bunkering.

Section 1 - HAZID for LNG bunkering

1.1 Objectives

The principal objectives of the HAZID should identify:

- Hazards and how they can be realised (i.e. the accident scenarios);
- The consequences that may result;
- Existing measures/safeguards that minimise leaks, ignition and potential consequences, and maximise spill containment; and
- Recommendations to eliminate or minimise risks.

1.2 Scope

As a minimum the HAZID should include the scope as described in Chapter 2. It may be complemented with an HAZOP (Hazard and Operability) assessment after all safeguards have been implemented.

1.3 Process

The HAZID process should be carried out in accordance with a recognised process using appropriately experienced subject matter experts. It is recommended that professional guidance is sought to ensure that the process is carried out to an adequate and appropriate level of detail.

The outcomes of the HAZID include hazard rankings and recommendations for additional safeguards and analysis. This may include detailed analysis or studies to establish that the measure in place meet the acceptance criteria agreed by the Administration.

1.4 Technique

To facilitate the HAZID process, the bunkering process may be divided into smaller steps each of which are then addressed systematically.

It is recommended that the following list is used to structure the HAZID exercise for LNG bunkering:

- Preparation (compatibility, testing, mooring)
- Connection
- Inerting of relevant pipe sections
- Cooling down

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- Transfer start
- Transfer at nominal flow
- Transfer stop including topping-up
- Draining & purging
- Inerting
- Disconnection
- Commissioning
- Security

1.5 Guidewords

To guide and help the HAZID workshop process, the following guidewords may be used:

- Leakage
- Rupture
- Corrosion
- Impact
- Fire/Explosion
- Structural integrity
- Mechanical failure
- Control/electrical failure
- Human error
- Manufacturing defects
- Material selection
- Flange or connector failure
- BOG management during bunkering
- Control failure
- ESD valves control failure
- ERC actuator failure
- ERC spring failure causing not closing
- Loss of containment (piping, valves)
- Cryogenic leaks (minor, major)
- Hose damage
- Hose rupture
- Major structural damage
- Gas leak
- Gas dispersion
- Gas in air intake
- Potential fire & explosion
- Cooling down operation wrong
- Excessive transfer rate
- Hydraulic Power Unit failure
- Communication failure
- Black out
- Relative motions of vessels
- SIMOPS
- Unexpected venting
- Harsh weather

No. 142 (cont) Section 2 - HAZOP for LNG bunkering operations

2.1 Definition

The HAZOP study is a structured and methodical examination of a planned process or operation in order to identify causes and consequences from a deviation to ensure the ability of equipment to perform in accordance with the design intent. It aims to ensure that appropriate safeguards are in place to help prevent accidents. Guidewords are used in combination with process conditions to systematically consider all credible deviations from normal conditions.

2.2 Process

The HAZOP should be realised with a focus on the LNG bunkering, storage and delivery to the engines. The operational modes for the receiving ship to be considered are:

- Start-up
- Normal Operations
- Normal Shutdown, and
- Emergency Shutdown

2.3 Scope

The HAZOP should review the following cases but not limited to:

- Joining together of the emergency shutdown systems of the Bunkering Facility, Receiving Ship and transfer system
- Emergency procedures in the event of abnormal operations
- Leakage from hoses
- Overpressure of the containment system
- Emergency unmooring
- Emergency venting of LNG or vapour
- Additional protection for the ship's hull in case of fuel leakage in way of the manifolds
- Emergency shut down and quick release protocol
- Requirements for outside assistance such as tugs
- Loss of power

The following should be analysed:

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- Connection
- Inerting of relevant pipe sections
- Cooling down
- Transfer start
- Transfer at nominal flow
- Transfer stop including topping-up
- Draining
- Inerting
- Disconnection
- Fatigue, stress and human errors

It is recommended that emergency disconnection at the receiving ship's manifold should be addressed by the bunkering operations risk assessment in order for any potential impact of the system within the receiving ship's bunker station lay-out to be identified and additional mitigation or support utilities to be incorporated as appropriate.

Both HAZID and HAZOP processes will produce a list of recommendations and an action plan. These action plans will address each recommendation developed and provides a means for tracking the hazards for assessment and implementation.

End of Document

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Risk assessment as required by the IGF Code

1.1 General

To help eliminate or mitigate risks a risk assessment is required by the IGF Code[1]. In this regard it requires that the risk assessment is undertaken using acceptable and recognised techniques, and the risks and their mitigation are documented to the satisfaction of the Administration.

It is recognised that there are many acceptable and recognised techniques and means to document a risk assessment. As such, it is not the intent of this document to limit a risk assessment to a particular technique or means of documentation. This document does, however, describe recommended practice and examples to help satisfy the IGF Code.

1.2 Risk assessment - Objective

The objective or goal of the risk assessment, as noted in the IGF Code, is to help *"eliminate or mitigate any adverse effect to the persons on board, the environment or the ship"*[2]. That is, to eliminate or mitigate unwanted events related to the use of low-flashpoint fuels that could harm individuals, the environment or the ship.

1.3 Risk assessment - Scope

The IGF Code requires the risk assessment to cover the use of low-flashpoint fuel[3]. This is taken to mean assessment of the supply of such fuel to consumers and covers:

- equipment installed on board to receive, store, condition as necessary and transfer fuel to one or more engines, boilers or other fuel consumers;
  Such equipment includes manifolds, valves, pipes/lines, tanks, pumps/compressors, heat exchangers and process instrumentation from the bunker manifold(s) to delivery of fuel to the consumers.

- equipment to control the operation;
  For example, pressure and temperature regulators and monitors, flow controllers, signal processors and control panels.

- equipment to detect, alarm and initiate safety actions;
  For example, detectors to identify fuel releases and subsequent fires, and to initiate shutdown of the fuel supply to consumers.

- equipment to vent, contain or handle operations outside of that intended (i.e. outside of process norms);
  For example, vent lines, masts and valves, overflow tanks, secondary containment, and ventilation arrangements.

- fire-fighting appliances and arrangements to protect surfaces from fire, fuel contact and escalation of fire;
  For example, water sprays, water curtains and fire dampers.

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1. International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code) - as adopted at MSC 95 (June 2015).
2. IGF Code (ref 1 of this document), Part A, Chapter 4.1.
3. IGF Code (ref 1 of this document), Part A, Chapter 4.2, Paragraph 4.2.1.

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- equipment to purge and inert fuel lines;
  For example, equipment to store and supply nitrogen for the purposes of purging/inerting bunker lines, and equipment used for the safe transfer/disposal of fuel.
- structures and constructions to house equipment;
  For example, fuel storage hold spaces, tank connection spaces and fuel preparation rooms.

In agreement with stakeholders (e.g. the Administration) the scope can exclude items that have been previously subjected to a risk assessment, provided there are no changes to 'context of use' and mitigation measures taken as a result of previous risk assessment are to be included. This can help reduce assessment time and effort.

The term 'context of use' (used above) refers to differences, such as differences in design or arrangement, installed location, mode of operation, use of surrounding spaces, and the number and type of persons exposed. For example, if an item is located on a cargo ship on-deck, it is a change to the 'context of use' if the same item is then installed below deck on a passenger ship. In addressing 'context of use' it is important to recognise that these 'differences' can significantly decrease or increase risk resulting in the need for fewer, more, changed or alternative means to eliminate or mitigate the risks.

With regards to liquefied natural gas (LNG), the IGF Code states that risk assessment "need only be conducted where explicitly required by paragraphs 5.10.5, 5.12.3, 6.4.1.1, 6.4.15.4.7.2, 8.3.1.1, 13.4.1, 13.7 and 15.8.1.10 as well as by paragraphs 4.4 and 6.8 of the annex". Hence, the IGF Code allows the scope of the risk assessment to be limited to these paragraphs. It is important to note that there are differences of opinion on the scope of risk assessment required by these paragraphs. Therefore, the views of stakeholders and approval by the Administration should be sought when finalising the scope of the risk assessment.

The risk assessment includes consideration of bunkering equipment installed on board but does not cover the bunkering operation of: ship arrival, approach and mooring, preparation, testing and connection, fuel transfer, and completion and disconnection. Bunkering of fuel is the subject of separate assessment as per ISO/TC18683 and reference should be made to appropriate and specific guidance.

The IGF Code requires that consideration is given to physical layout, operation and maintenance. Typically, the risks associated with maintenance are controlled by job specific risk assessments before the activity is undertaken. Therefore, consideration of maintenance is taken to mean high-level consideration of design and arrangements to facilitate a safe and appropriate working environment. This requires consideration of, for example, equipment isolation, ventilation of spaces, emergency evacuation, heating and lighting, and access to equipment. The purpose of this is to minimise the likelihood of unwanted events resulting in harm during maintenance. In addition, the purpose is to minimise the likelihood of unwanted events after maintenance, as a result of deficient work where a contributory cause was 'a poor working environment'.

The assessment should also appreciate potential systems integration issues such as equipment control and connection compatibility. This is particularly important where a number of stakeholders are involved in separate elements of design, supply, construction and installation.

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4. IGF Code (ref 1 of this document), Part A-1, Chapter 4.2, Paragraph 4.2.2.

Occupational risks can be excluded from the risk assessment. They are an important safety consideration and are expected to be covered by the safety management system of the ship.

The scope should obviously cover the design and arrangement as installed on board. Therefore, where the risk assessment is undertaken prior to finalising the design, it may require revision to ensure that the risks remain 'mitigated as necessary'.

The IGF Code makes no reference to periodic update of the risk assessment. This should be undertaken where changes to the design/arrangement and/or its operation have been made, and in response to changes in performance of equipment and controls. This helps ensure the risks are 'mitigated as necessary' through-out the life of the fuel system.

The final scope of the risk assessment should be agreed with appropriate stakeholders (e.g. the Administration) and guided by applicable classification rules and the IGF Code.

1.4 Risk assessment - Approach

IMO has published guidance on formal safety assessment (FSA) and this provides useful information on risk assessment approaches and criteria[5]. The purpose of the guidance is to help evaluate new regulations on maritime safety and protection of the environment. In this regard, assessment is focused on risk quantification and cost benefit analysis to inform decision-making. As such, it is a useful reference to IMO's views on risk assessment and criteria. However, the IGF Code does not require a quantitative measure of risk to people, the environment or assets from the use of fuel. The risk assessment is simply required to provide information to help determine if further measures are needed to 'eliminate' risks or to ensure they are 'mitigated as necessary'. Therefore, a qualitative or semi-quantitative approach to the risk assessment is appropriate (i.e. Qualitative Risk Assessment, QualRA[6]). That is not to say that a fully quantitative approach is inappropriate or that circumstances might not favour its use (i.e. Quantitative Risk Assessment, QRA). What is important is that the risk assessment is of sufficient depth to help demonstrate that risks have been 'eliminated' or 'mitigated as necessary'.

As a minimum, the risk assessment should detail:

A. how the low-flashpoint fuel could potentially cause harm – Hazard identification;
That is, systematic identification of unwanted events that could result in, for example, major injuries or fatality, damage to the environment, and/or loss of structural strength or integrity of the ship.

B. the potential severity of harm – Consequence analysis;
That is, the potential severity of harm (i.e. consequences) expressed in terms of, for example, major injuries, single and multiple fatalities, adverse environmental impact, and structural/ship damage sufficient to compromise safe operations.

C. the likelihood of harm – Likelihood analysis;
That is, the probability or frequency with which harm might occur.

D. a measure of risk – Risk analysis;
That is, a combination of consequence (B) and likelihood (C).

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5. Revised Guidelines for formal safety assessment for use in the IMO rule-making process. MSC-MEPC.2/Circ.12, 8th July 2013.
6. Where some form of quantification occurs, then the approach is semi-quantitative. However, such approaches are often referred to as qualitative and this term is used throughout this document.

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E. judgements on risk acceptance – Risk assessment.
The measure of risk (D) should be compared against criteria to judge if the risk has been 'mitigated as necessary'.

Acceptable and recognised techniques to address the requirements noted above (i.e. A-D) are described in, for example, ISO 31010[7], ISO 17776[8], ISO 16901[9], NORSOK Z-013[10], CPR 12E[11], and publications by CCPS[12] and HSE[13], etc.

The following sub-section, A1.4.1, outlines an approach to meeting the above requirements.

1.4.1 An approach to satisfying the IGF Code requirements - Qualitative Risk Assessment (QualRA)

A. Hazard identification

1. Divide the fuel system into discrete parts with respects to equipment function and location.
This promotes systematic consideration of each part of the system and helps identify specific causes of unwanted events related to a particular item, activity or section. A typical division of the system might be, for example: (a) the bunker station and fuel lines to the storage tank; (b) the fuel storage hold space; (c) the tank connection space; (d) the fuel preparation room; and (e) the fuel lines and valves 'regulating' fuel delivery to the engine.

2. Develop a set of guidewords/phrases and example causes that could result in unwanted events (e.g. a release of fuel or fuel system failure resulting in loss of power).
The guidewords/phrases and example causes are used as prompts. A typical, but not exhaustive list of prompts is given in Appendix 1.

3. By reference to design and arrangement information, location plans, process flow diagrams, mitigation measures and planned emergency actions use the prompts to identify potential causes of unwanted events (e.g. fuel releases and loss of power).
The prompts are used to stimulate discussion and ideas within a workshop led by a facilitator and attended by subject matter experts (SMEs).

4. Record the potential causes of unwanted events and mitigation measures
An example of a record sheet or worksheet is given in Appendix 2. This worksheet is also used to record steps B to E below, and forms part of the overall documentation of the risk assessment.

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7. Risk management: Risk assessment techniques. IEC/ISO 31010:2009.
8. Petroleum and natural gas industries - Offshore production installations - Guidelines on tools and techniques for hazard identification and risk assessment. EN ISO 17776:2002.
9. Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface. ISO/TS 16901:2015.
10. Risk and emergency preparedness assessment. NORSOK Standard Z-013, Edition 3, October 2010.
11. Methods for determining and processing probabilities. CPR 12E, 1997/2005.
12. e.g. Guidelines for chemical process quantitative risk analysis. Centre for Chemical Process Safety, American Institute of Chemical Engineers, Second Edition, 2000.
13. e.g. Marine risk assessment. Health & Safety Executive, 2001.

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B. Consequence analysis

5. For each identified cause, estimate the potential consequences in terms of, for example, major injuries, single and multiple fatalities, adverse environmental impact and damage sufficient to compromise safe operations.
The potential consequences can be estimated by the SMEs using judgement and reference to: (a) the fuel's properties/hazards; (b) the release location; (c) dispersion/leak pathways; (d) location and 'strength' of ignition sources; (e) proximity of vulnerable receptors; (f) generic or (if commissioned) specific fire and explosion modelling; and (f) expected effectiveness of existing/planned mitigation measures. The properties and hazards of liquefied natural gas (LNG) noted in (a) are summarised in Appendix 3.

6. Categorise the consequence estimates.
The consequences can be categorised by the SMEs to provide an indication of severity. For example, categories for harm to persons can distinguish between major injury, single fatality and multiple fatalities. Example consequence categories are given in Appendix 4.

C. Likelihood analysis

7. Estimate the annual likelihood of occurrence of 'cause and consequence'.
Likelihood can be estimated by the SMEs (or a suitably qualified individual) for each 'cause-consequence' pair or a grouping of causes with the same consequence. The estimation can be informed by reference to accident and near-miss reports, accident and equipment release data, analogy to accidents in similar or other industries and consideration of the reliability and effectiveness of mitigation measures. It is not always apparent if the likelihood of a 'cause-consequence' combination is credible (i.e. reasonably foreseeable). As a guide, an unwanted event may be considered credible if: (a) it has happened before and it could happen again; (b) it has not happened but is considered possible with an annual likelihood of 1 in a million or more; and (c) it is planned for, that is, emergency actions cover such a situation or maintenance is undertaken to prevent it. A guide to the likelihood of releases relevant to LNG equipment and operations is given in Appendix 5.

8. Categorise the likelihood estimates.
Likelihood can be categorised by the SMEs (or a suitably qualified individual) to provide an indication of accident/incident occurrence or other unwanted event occurrence. Example likelihood categories are given in Appendix 4.

D. Risk analysis

9. Estimate the risk.
Risk can be estimated by the SMEs (or a suitably qualified individual) by combining the consequence and likelihood categories to provide a risk rating. For example, if a 'cause-consequence' pair is categorised as, say 'A', and associated 'likelihood' as, say '1', then the risk rating is 'A1'. An example of a risk rating scheme is given in Appendix 4.

E. Risk assessment

10. Judge if the risk has been 'mitigated as necessary'.
The estimated risk can be compared against risk criteria embedded within a risk matrix. The matrix shows the risk rating (with respects to consequence and likelihood) and the criteria illustrate whether the risk has been 'mitigated as necessary'. An example of a risk rating scheme and its associated risk criteria are given in Appendix 4.

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With respects to D and E above, it is important to note that there are no universally agreed risk rating schemes or risk criteria: there are differences between governments, regulators and organisations. Therefore, prior to the commencement of the risk assessment, risk rating/criteria should be agreed with appropriate stakeholders (e.g. the Administration).

It should also be recognised that the risk rating of individual or grouped 'cause-consequence' pairs does not provide an indication of the collective (overall) risk from all potential 'cause-consequence' pairs. If the overall risk level is required then this can be determined using QRA.

Practically, the risk rating is an indication that additional or alternative mitigation measures:

- must be provided; or
- must be considered and implemented if practical and cost effective; or
- need not be considered further, beyond accepted good practice of reducing risk where practicable.

In each of the steps above many assumptions are made and there is uncertainty. Therefore, it is good practice for SMEs to list assumptions and 'test' the sensitivity of results to changes in any of these steps. For example, a change to an assigned consequence or likelihood category could alter the risk rating and the judgement on whether a risk is 'mitigated as necessary'.

1.4.1.1 Mitigated as necessary

The phrase 'mitigated as necessary' is used in the IGF Code and is akin to the phrase 'As Low As Reasonably Practicable', commonly referred to as ALARP. Essentially, a risk is considered ALARP if all reasonably practicable mitigation measures have been implemented. This means that additional or alternative measures have been identified and implemented unless they are demonstrated as impractical or the cost of implementation is disproportionate to the reduction in risk. This concept of ALARP is established practice in many industries and recognised as best practice by IMO[14].

Where 'mitigated as necessary' is not proven then the SMEs should consider additional and/or alternative mitigation measures[15] and re-evaluate the risk. **The risk cannot be 'accepted' until 'mitigated as necessary' is achieved**. In this regard, additional study can be undertaken to help the SMEs decide if existing, additional or alternative measures can provide 'mitigated as necessary'.

14. Revised Guidelines for formal safety assessment for use in the IMO rule-making process. MSC-MEPC.2/Circ.12, 8th July 2013.

15. Within the IGF Code, measures to reduce likelihood and measures to reduce consequences are both understood to be mitigation measures (i.e. they mitigate the risk). To align with the IGF Code this understanding is maintained within this document. It is recognised that in many other industries it is common to use the terms 'prevention measures' and 'mitigation measures', where the former reduces likelihood and the latter reduces consequences. Prevention and mitigation measures are often referred to as 'safeguards' or 'barriers'.

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When considering mitigation measures the following **hierarchy of mitigation** is considered best practice:

- firstly, measures to prevent an unwanted event;
  That is, to ensure the unwanted event cannot occur or its likelihood of occurrence is greatly reduced;

- secondly, measures to protect against harm given an unwanted event.
  That is, to reduce the consequences after the unwanted event has occurred.

In addition, when considering mitigation measures it is good practice to consider **engineering solutions in preference to procedural controls**. This helps promote an inherently safer design. Furthermore, it is good practice to consider **passive measures in preference to active measures**. For example, a passive measure is one where no manual or automated action is required for it to function on demand and as intended. Whereas, an active measure requires some means of activation for it to operate. Both passive and active measures may be required to demonstrate that the risk has been mitigated as necessary. Examples of mitigation measures are listed in Appendix 6.

To help judge if mitigation measures are effective it can be useful to illustrate or map the pathway from 'cause' to 'consequence' and review the effectiveness of the mitigation measures. An example of such mapping and review is given in Appendix 7.

Whether a single mitigation measure or a collection of mitigation measures is practical and cost-effective is in some respects relative to the resources and skills available. If the SMEs cannot decide then the use of cost benefit analysis can be helpful. In any case, a documented justification for not implementing a mitigation measure should be made where SMEs judge the measure to be practical and cost-effective.

1.5 Risk assessment - Team

The team conducting the risk assessment should comprise of subject matter experts (SMEs) who are, collectively, suitably qualified and experienced. For the QualRA noted above, this means the workshop team includes individuals who are degree qualified and/or chartered/professional engineers, have operational ship experience and are experienced in risk assessment. Such qualifications and experience should be in relevant disciplines to cover engineering design and safe use of the fuel.

It is unlikely that one SME can satisfy the above team requirements. In any case, to ensure investigative discussion, generation of ideas, challenge and coverage of, for example, mechanical, process, electrical and operational aspects, a typical number of SMEs might be four to eight.

In addition to the SMEs, the team should be led by a facilitator (also referred to as the chair or chairman). The facilitator should be impartial with no vested interests in the fuel system, and experienced in leading such risk assessments. The facilitator may be supported by a scribe (also referred to as a secretary) to aid reporting.

The time expended by the team depends upon the agreed scope and the designs' 'complexity'. For example, a QualRA workshop for a new design might require two or three working days, whereas, a minor variation to a previously assessed and approved design might require only half a day.

1.6 Risk assessment - Reporting

1.6.1 Main report

A written report documenting the risk assessment should be produced. This needs to be sufficiently detailed to support results, conclusions, recommendations and any actions taken. This is because the assessment will inform important design and operational decisions. Furthermore, the report is a record in helping to demonstrate 'mitigated as necessary'. A report only consisting of a completed worksheet is insufficient.

The specific contents of the report and its structure are dependent upon design and assessment specifics, and reporting preferences. However, for a QualRA, the report should provide:

- an overview of the design and arrangement;
  This is a simple explanation of the design and arrangement with respects to its intended operation and process conditions. Technical appendices should include process flow diagrams, general arrangement plans and all information used during the assessment. Where this is too cumbersome to include in the report in full, reference to this material is sufficient provided it remains accessible.

- an explanation of the risk assessment process;
  This is a description of the risk assessment method and includes how the design was divided into parts for assessment, how hazard identification was undertaken, and the selection of consequence and likelihood categories and risk criteria.

- information on the relevant qualifications and expertise of the team;
  This can be a table listing the names, job titles, relevant qualifications, expertise and experience of all team members (including the facilitator and scribe). It is not sufficient to simply list names and job titles.

- the time taken to complete the assessment and whether SMEs were present to provide their expert input;
  For a workshop, this can be a table listing the schedule/duration and attendance of each SME (i.e. full-time or part-time, and if part-time the 'parts' for which the person was absent). The purpose of this is to indicate if sufficient time was taken to assess the design/arrangement, and to highlight any SME absences that could be detrimental to results, conclusions and actions. For any SME absences, a note should be made by the facilitator as to whether this impacted adversely upon the assumptions and judgements made.

- risk results and conclusions;
  This is a listing or discussion of the results and a judgement on whether or not the risk has been 'mitigated as necessary'.

- recommendations and actions.
  This can include requests for modelling and analysis (e.g. gas dispersion or thermal radiation extent, etc.) and will most likely include additional and alternative mitigation measures to be investigated and/or implemented, who is responsible for these and, if known, an expected completion date. It is important that these recommendations and actions are suitably documented because they are likely to be used to plan a response and monitor progress until the recommendations/actions have been addressed.

An example report contents is given in Appendix 8.

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1.6.2 Terms of reference (ToR)

Prior to the workshop it is good practice for the facilitator to issue relevant information to the team. This is sometimes referred to as a terms of reference (ToR). This helps the team familiarise with the design and intended approach before the workshop. It also provides time for clarifications and agreement with the proposed consequence and likelihood categories and risk criteria. Importantly, it provides time to confirm the suitability of the proposed schedule and team. The ToR can form an appendix to the main report.

Typically, a ToR includes:

- objectives and scope of the assessment;
  This is to ensure all team members understand the objective and what equipment and operations are to be covered in the assessment.

- technical description of the proposed design and arrangements;
  This can include copies of process flow diagrams (PFDs) or schematics detailing process conditions of equipment and pipework, and a scaled layout drawing illustrating equipment and pipework arrangements, size and location.

- overview of the potential consequences of a fuel release;
  For LNG, this could refer to Appendix 3 of this document.

- technique to be used;
  This includes proposed consequence and likelihood categories and risk criteria.

- intended workshop schedule;
  This highlights the time to be given to the workshop and when SME input is required.

- team details.
  This includes the name and job title, relevant qualifications, expertise and experience of each SME and team member/workshop attendee.

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Appendix 1
Prompts - guidewords and phrases

Example prompts for use in QualRA

Failure of fuel containing equipment* – a hole/crack leading to release of fuel	
Wear and tear	*vibration, loading, cycling, prolonged use*
Erosion	*fuel contaminants, high stream velocity, prolonged use*
Stress and strain	*vibration, loading, cycling, ship movement, prolonged use*
Fatigue	*vibration, loading, cycling, ship movement, prolonged use*
Corrosion	*exposure to weather, exposure to sea water, humidity, loss of dry air supply, contact with corrosive materials*
Collision	*ship collides with another vessel, ship hits rocks, ship strikes the harbour wall or jetty*
Grounding	*ship runs aground*
Impact	*dropped object (e.g. during maintenance or cargo loading), collapse of supporting structure, maloperation during loading/maintenance*
Fire	*ignition of flammable materials, fire in adjacent spaces/areas*
** plus equipment containing gases or other substances that could release into spaces resulting in harm (e.g. asphyxiation, burns)*	
Failure of process control – operation outside of design conditions leading to subsequent release of fuel	
Temperature high	*loss of insulation, instrument failure, software failure, actuator failure, maloperation by operator, external fire, exposure to extreme weather, decomposition*
Temperature low	*loss of heating medium circulation, heating medium contamination, instrument failure, software failure, actuator failure, maloperation by operator, exposure to extreme weather*
Pressure high	*maloperation by operator (e.g. closed valve), loss of utilities (e.g. instrument air), external fire, loss of power supply, rollover, excess generation of boil-off gas, actuator failure*
Pressure low (vacuum)	*maloperation by operator, loss of utilities (e.g. instrument air), loss of power supply (electricity), actuator failure*
Flow high	*instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions*
Flow low	*instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions*
Flow reversed	*instrument failure, software failure, maloperation by operator (e.g. closed valve), exposure to extreme sea conditions*
No Flow	*instrument failure, software failure, maloperation by operator (e.g. closed valve), actuator failure*
Level high	*instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions*
Level low	*instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions*
Fuel left in pipe/line	*maloperation by operator, closed valves, no inert/purge supply, limited inert/purge supply*
No fuel in pipe/line	*instrument failure, software failure, maloperation by operator, closed valves*
Loss of power	*loss of electrical signals, blackout, loss of instrument air, loss of hydraulic fluid*

Note: Poor manufacturing, installation and commissioning of equipment can increase the likelihood and/or consequences of fuel releases. If these aspects are not covered and controlled by, for example, class rules, then they should be included in the risk assessment. The assessment should cover intended operation, shutdown and start-up.

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Appendix 2
Record sheet / Worksheet

Worksheet Example

Worksheet for [project title]											
Part or Section [title]											
						Category & Rating					
Item / Activity	Guideword / Phrase	Causes (accident / incident)	Consequences	Mitigation (existing safeguards)	Additional / Alternative Mitigation (safeguards)	Consequence	Likelihood	Risk	Mitigated as necessary	Recommendations Comments / Actions	Action by / date

Note: The worksheet can be used to record risk ratings before and after consideration of additional/alternative safeguards by using one row for 'existing safeguards' and one row for 'additional/alternative safeguards'. If preferred, the 'Additional/Alternative Mitigation (safeguards)' column can be moved after the 'Category & Rating' columns followed by additional 'Category & Rating' columns.

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Appendix 3
Properties & hazards of liquefied natural gas

3.1 LNG Properties

Liquefied natural gas (LNG) is a cryogenic liquid. It consists of methane with small amounts of ethane, propane and inert nitrogen. When used as a fuel, typically 94% or more is methane. Stored at ambient or near ambient pressure, its temperature approximates minus 162 deg.C and its specific gravity is about 0.42. Hence, if released onto the sea LNG floats (and can rapidly 'boil' – refer to 3.2.7). When stored at pressures of up to 10 bar the temperature typically remains below minus 130 deg.C with a specific gravity of approximately 0.4.

Released into atmospheric conditions, LNG rapidly boils forming a colourless, odourless and non-toxic gas. Although colourless, due to its very low temperature, water vapour in the air condenses forming a visible mist or cloud. The cold gas is initially heavier than air and it remains negatively buoyant until its temperature rises to about minus 100 deg.C. At this stage the gas becomes lighter than air, and in an open environment it is thought that this coincides with a gas concentration of less than 5%. At this temperature and concentration the gas is still within the visible cloud. As the gas continues to warm to ambient conditions its volume is approximately 600 times that of the liquid with a relative vapour density of about 0.55, and so the gas is much lighter than air (air = 1).

As the gas disperses, its concentration reduces. At a concentration in air of between 5% and 15% the mix is flammable and can ignite in the presence of ignition sources or in contact with hot sources at or above a temperature of approximately 595 deg.C (referred to as the auto-ignition temperature). Once below a concentration of 5% the mix is no longer flammable and cannot be ignited (and this is the case if the concentration remains above 15%). The 15% and 5% concentrations of LNG in air are commonly known as the upper and lower flammability limits, respectively. More recently, the limits are referred to as the upper and lower explosion limits, although ignition may not necessarily result in explosion.

3.2 LNG Hazards

3.2.1 Cryogenic burns

Owing to its very low liquid temperature, in contact with the skin LNG causes burns. In addition, breathing the cold gas as it 'boils' can damage the lungs. The severity of burns and lung damage is directly related to the surface area contacted by the liquid/gas and duration of exposure.

3.2.2 Low temperature embrittlement

In contact with low temperature LNG, many materials lose ductility and become brittle. This includes carbon and low alloy steels typically used in ship structures and decking. Such low temperature embrittlement can result in material fracture, such that existing stresses in the contacted material cause cracking and failure even without additional impact, pressure or use. For LNG duty, materials resistant to low temperature embrittlement are used. These materials include stainless steel, aluminium, and alloy steels with a high-nickel content.

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3.2.3 Asphyxiation

LNG is non-toxic and is not a known carcinogen. However, as it boils to gas it can cause asphyxiation as it displaces and then mixes with the surrounding air. The likelihood of asphyxiation is related to the concentration of gas in air and duration of exposure.

3.2.4 Expansion and pressure

Released into the atmosphere LNG will rapidly boil with the volume of gas produced being hundreds of times that of the liquid (approximately 600 times at ambient conditions). Hence, if confined and unrelieved, the pressure will increase and this can damage surrounding structures and equipment.

3.2.5 Fire

3.2.5.1 Pool fire

A ‘small’ release of LNG will rapidly boil and ‘flash’ to gas (i.e. evaporate). However, given a ‘large’ and sudden release, a cold pool of LNG will form with gas boiling from the pool and mixing and dispersing with the surrounding air. If this mix is within the flammable range (i.e. 5% to 15% with air) and contacts an ignition source or a heated surface above the auto-ignition temperature (595 deg.C) it will ignite and the resultant flame will ‘travel back’ to the pool resulting in a pool fire.

3.2.5.2 Jet fire

If stored under pressure then a release of LNG may discharge as a jet of liquid, entraining, vapourising and mixing with air. If the mix disperses and reaches an ignition source or a heated surface (above the auto-ignition temperature) whilst in the flammable range it will ignite. The resultant flame will ‘travel back’ and may result in a pressurised jet fire from the release source. Similarly, where contained LNG has been heated to form gas, a pressurised release of this gas could ignite and result in a jet fire.

3.2.5.3 Flash fire

Release of LNG to atmosphere and ignition within a few tens of seconds is likely to result in a pool fire or jet fire (as noted above) with no damaging overpressure. This is because the flammable part of the cloud is likely to be relatively small and close to the release point upon ignition. However, if ignition is delayed, the gas cloud will be larger and may have travelled further from the release point. Ignition will then result in a flash fire as the flammable part of the cloud is rapidly consumed within a few seconds. This ignition is likely to be violent and audible, and is often mistaken for an explosion, although there is little appreciable overpressure.

3.2.5.4 Thermal radiation from a pool fire, jet fire and flash fire

Harm to people and damage to structures and equipment from fire is dependent upon the size of the fire, distance from the fire, and exposure duration. Within a metre of the fire, thermal radiation may approximate 170 kW/m^2 but this rapidly falls with distance from the fire.

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(cont)

As a rough guide:

- 6 kW/m^2 or more and escape routes are impaired and persons only have a few minutes or less to avoid injury or fatality[16];
- 35 kW/m^2 results in immediate fatality[16];
- 37.5 kW/m^2 has long been considered as the onset of damage to industrial equipment and structures exposed to a steady state fire[17];
- industrial equipment and structures within a flash fire are unlikely to be significantly damaged; and
- persons within a pool, jet or flash fire are likely to be fatally injured.

An LNG fire on a ship could result in fatalities and damage to equipment and structures (including the hull).

3.2.6 Explosion

Release of LNG to atmosphere and delayed ignition of the resultant flammable cloud beyond a few tens of seconds can result in an explosion. This is because the cloud may have dispersed in and around equipment and structures causing a degree of confinement and increased surface area over which to increase flame speed as it travels (i.e. burns) through the flammable mixture. The resultant overpressure may be sufficient to harm individuals, and damage structures and equipment. Such an explosion is most likely to be a deflagration (rather than a detonation), categorised by high-speed subsonic combustion (i.e. the rate at which the flame travels through the flammable cloud).

3.2.6.1 Overpressure from an explosion

Harm to people and damage to structures and equipment from an explosion is dependent upon the magnitude of overpressure generated and the rate at which the overpressure is delivered (known as impulse). In addition, harm is often a result of falling or being thrown against hard surfaces or being struck by objects and debris as a result of the blast. As a rough guide:

- the probability of fatality from exposure to an explosion of 0.25 bar and 1 bar is about 1% and 50%, respectively[18];
- less than 0.25 bar could throw an individual against a hard surface resulting in injury or fatality[18]; and
- 0.3 bar is typically the limit of damage to structures and industrial equipment[18].

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16. There are many quoted values from many sources and with inconsistencies. Thermal dose might be alternatively used. The values quoted here are based on: Health & Safety Executive, Indicative human vulnerability to the hazardous agents present offshore for application in risk assessment of major accidents, SPC/Tech/OSD/30, 2011, and supporting document: Methods of approximation and determination of human vulnerability for offshore major accident hazard assessment, http://www.hse.gov.uk/foi/internalops/hid_circs/technical_osd/spc_tech_osd_30/spctecosd30.pdf
17. Risk Analysis of Six Potentially Hazardous Industrial Objects in the Rijnmond Area, A Pilot Study. (1982). D. Reidel Publishing Company, The Netherlands.
18. There are many quoted values from many sources and with inconsistencies. Impulse might be alternatively used. The values quoted here for fatality and damage are based on Ref 16 and Methods for the determination of possible damage to people and objects resulting from releases of hazardous materials, CPR 16E, Labour Inspectorate, The Netherlands.

An explosion of vapourised LNG on a ship could result in fatalities and damage to equipment and structures (including the hull).

3.2.7 Rapid phase transition

Upon release, LNG rapidly boils due to heat from the surrounds, be this from the air, water/sea, steel or ground. However, this rapid and sometimes violent boiling is not rapid phase transition (RPT); RPT is an explosive vaporisation of the liquid, that is, a near instantaneous transition from liquid to gas. This is a more violent event than rapid boiling and it can result in liquid ejection and damaging overpressure[19]. The phenomenon is well known in the steel industry, where accidental contact between molten metal and water can result in RPT.

3.2.8 Rollover

Slowly, stored refrigerated LNG evaporates (i.e. 'boils-off') as heat from the surrounds gradually 'leaks' into the tank. Essentially, liquid in contact with the wall of the tank warms, becomes less dense and rises to the top. This top-layer then begins to evaporate (i.e. boil-off) increasing the liquid layer's density. Liquid further away from the walls also warms but at a slower rate and because of this a less dense layer below the top layer forms. Owing to the hydrostatic head, the saturation condition of this layer changes and although it heats-up, it does not evaporate but remains in the liquid state and becomes 'superheated'. As the heating continues, the trapped layer's density reduces; this is an unstable state and when the density of this layer is similar to the top layer the two layers rapidly mix and the superheated lower layer vaporises. This rapid mixing and vaporisation is known as rollover and can cause damaging over-pressure and release of gas if not appropriately controlled.

The heating mechanism described above can result in a number of differing layers and is referred to as stratification. It is a phenomenon that is well known and is safely managed through venting, mixing and temperature control.

The above phenomenon is hastened by, or can directly occur when differing densities of LNG are bunkered.

3.3 References

The information and facts given in this appendix are well known and have been recorded in numerous papers and reports on LNG. However, original sources are not always readily available (or known) and so the information given in this section was cross-checked by reference to:

1. Chamberlain, G. (2006). Management of Large LNG Hazards. 23rd World Gas Conference, Amsterdam.

2. International Maritime Organization, Marine Safety Committee. (2007). FSA - Liquefied Natural Gas (LNG) Carriers, Details of the Formal Safety Assessment. MSC 83/INF.3.

3. Bull, D. and Strachan, D. (1992). Liquefied natural gas safety research.

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19. Chamberlain, G. (2006). Management of Large LNG Hazards. 23rd World Gas Conference, Amsterdam.

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4. Sheats, D. & Capers, M. (1999). Density Stratification in LNG Storage. Cold Facts, 15/2.

5. Bashiri, A. & Fatehnejad, L. (2006). Modeling and Simulation of Rollover in LNG Storage Tanks. 23rd World Gas Conference, Amsterdam.

Reference can also be made to ISGOTT (International Safety Guide for Oil Tankers and Terminals) Publication (2009) - Report on the Effects of Fire on LNG Carrier Containment Systems.

No. 146 (cont)

Comparison of the Hazards of LNG and Fuel Oil

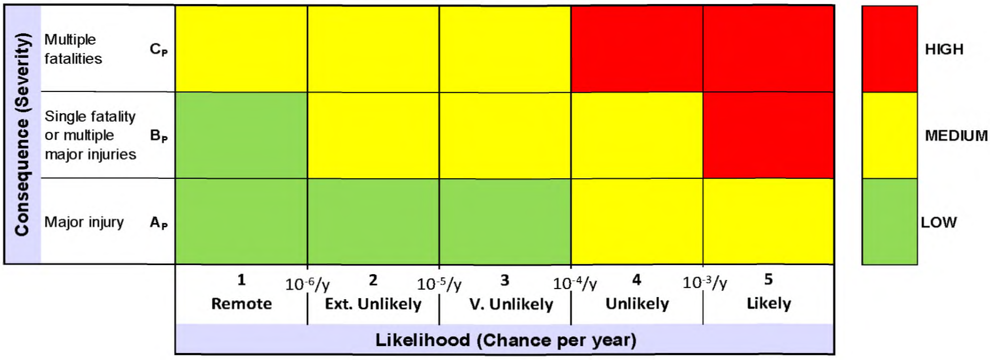
Hazards	LNG	Fuel Oil[1]
1. **Cryogenic Burns** Liquid contact with skin will cause burns and can result in fatality. Inhalation of gas can cause burns to the lungs and lead to fatal injury.	✓	X
2. **Low Temperature Embrittlement** Equipment/structures can fail on contact with liquid.	✓	X
3. **Rapid Phase Transition (RPT)** Released onto the sea a near instantaneous 'explosive' transition from liquid to gas can occur. This can result in structural damage to the hull.	✓	X
4. **Gas Expansion** A liquid pool rapidly boils, and as the gas warms and expands it requires a volume 600 times that of the liquid. This can result in equipment damage.	✓	X
5. **Asphyxiation** In a confined space, displacement and mixing of the gas in the air will reduce oxygen content and can cause asphyxiation.	✓	✓
6. **Pool Fire** Gas/vapour above the pool can ignite resulting in a pool fire. The intensity of the radiation can cause fatal injury and fail structure and critical equipment.	✓	✓
7. **Flash Fire** Gas/vapour can disperse away from the pool and ignite resulting in a flash fire. The short-duration and intense radiation can instigate secondary fires, and cause fatal injuries to those within the fire and to critical equipment. Most probably the fire will burn back to the pool and result in a pool fire.	✓	X[2]
8. **Explosion** Gas/vapour can disperse and collect in confined areas and ignite resulting in an explosion. The explosion can cause fatal injuries, instigate secondary fires, and fail structure and critical equipment. Most probably the explosion will burn back to the pool/gas source and result in a pool fire or jet fire.	✓	X[2]
9. **Rollover** Stored liquid can stratify, that is different layers can have different densities and temperatures. This can cause the layers to 'rollover' resulting in significant gas/vapour generation that must be contained. If released, this can result in flash fire or explosion.	✓	X
10. **Boil-off Gas (BoG)** LNG continually boils and must be re-liquefied or burnt-off. A release of BoG can ignite and result in a jet fire (given sufficient release pressure), flash fire or explosion.	✓	X

Note:
1. Fuel oil – heavy fuel oil (HFO) (ISO 8217).
2. If a fuel oil is 'sprayed' as an aerosol resulting in fine air-borne droplets, ignition can result in flash fire or explosion.

No. 146 (cont)

Appendix 4
Risk Matrix

Risk Matrix Example – persons on board



Consequence Category Examples

A_P Major injury - *long-term disability / health effect*
B_P Single fatality or multiple major injuries - *one death or multiple individuals suffering long-term disability / health effects*
C_P Multiple fatalities - *two or more deaths*

Likelihood Category Examples

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*

The likelihood categories can be related to a ship life. For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship's lifetime is 1 in 40,000 (i.e. $1/(10^{-6} \times 25)$).

Risk Rating and Risk Criteria Examples

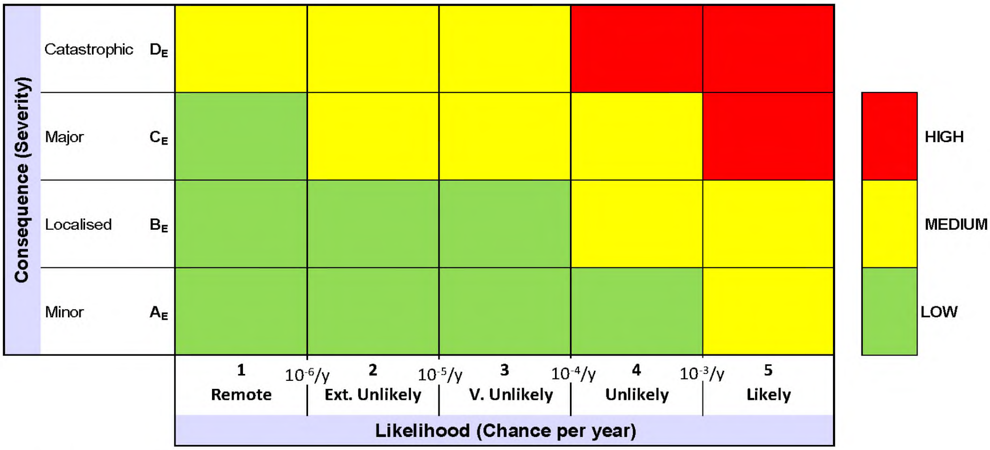
Low Risk – A_P1, A_P2, A_P3 & B_P1
The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective it is good practice to implement mitigation measures that would further reduce the risk.

Medium Risk – A_P4, A_P5, B_P2, B_P3, B_P4, C_P1, C_P2 & C_P3
The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.

High Risk – B_P5, C_P4 & C_P5
The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

No. 146 (cont)

Risk Matrix Example – environment



Consequence Category Examples

A_E Minor - *limited and reversible damage to sensitive areas/species in the immediate vicinity*
B_E Localised - *significant but reversible damage to sensitive areas/species in the immediate vicinity*
C_E Major - *extensive or persistent damage to sensitive areas/species*
D_E Catastrophic - *irreversible or chronic damage to sensitive areas/species*

Likelihood Category Examples

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*

The likelihood categories can be related to a ship life. For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship's lifetime is 1 in 40,000 (i.e. $1/(10^{-6} \times 25)$).

Risk Rating and Risk Criteria Examples

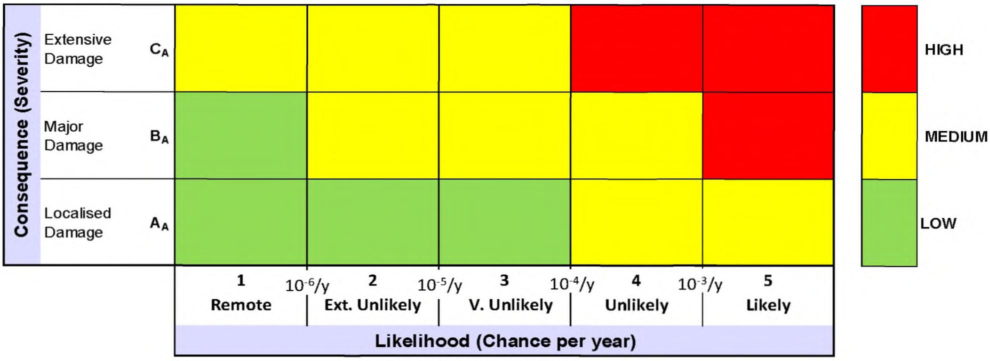
Low Risk – A_E1, A_E2, A_E3, A_E4, B_E1, B_E2, B_E3 & C_E1
The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective it is good practice to implement mitigation measures that would further reduce the risk.

Medium Risk – A_E5, B_E4, B_E5, C_E2, C_E3, C_E4, D_E1, D_E2 & D_E3
The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.

High Risk – C_E5, D_E4 & D_E5
The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

No. 146 (cont)

Risk Matrix Example – ship assets (equipment, spaces and structure)



Consequence Category Examples

A_A Localised damage - *an event halting operations for more than x days*
B_A Major damage - *an event halting operations for more than y days*
C_A Extensive damage - *loss of ship, an event halting operations for more than z days*

Likelihood Category Examples

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*

The likelihood categories can be related to a ship life. For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship's lifetime is 1 in 40,000 (i.e. $1/(10^{-6} \times 25)$).

Risk Rating and Risk Criteria Examples

Low Risk – A_A1, A_A2, A_A3 & B_A1
The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective it is good practice to implement mitigation measures that would further reduce the risk.

Medium Risk – A_A4, A_A5, B_A2, B_A3, B_A4, C_A1, C_A2 & C_A3
The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.

High Risk – B_A5, C_A4 & C_A5
The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

Appendix 5
Likelihood of releases

Indicative likelihood categories

The following table provides indicative likelihood categories as follows: (a) named equipment item fails and releases fuel[20], and (b) collisions and groundings[21].

Likelihood values differ dependent upon source, assumptions made and the inclusion/ exclusion of causes, etc. Therefore, it is important to refer to the original data sources to ensure the indicative likelihood category remains valid for specific cases of interest.

Indicative Likelihood Values by Likelihood Category

1. Remote - 1 in a million or less per year (10^{-6}/y or less)			
Type C Fuel Tank	$<1 \times 10^{-6}$		
2. Extremely Unlikely - *between 1 in a million and 1 in 100,000 per year (10^{-6}/y to 10^{-5}/y)*			
Leak ≥ 10 mm Ø	**50 mm or less Ø**	**51-150 mm Ø**	**151-300 mm Ø**
Pipework / per metre	7×10^{-6}	3×10^{-6}	3×10^{-6}
Flange	4×10^{-6}	5×10^{-6}	7×10^{-6}
Manual Valve	---	7×10^{-6}	9×10^{-6}
3. Very Unlikely - *between 1 in 100,000 and 1 in 10,000 per year (10^{-5}/y to 10^{-4}/y)*			
	50 mm or less Ø	**51-150 mm Ø**	**151-300 mm Ø**
Pipework / per metre	8×10^{-5}	4×10^{-5}	3×10^{-5}
Flange	4×10^{-5}	5×10^{-5}	8×10^{-5}
Manual Valve	3×10^{-5}	5×10^{-5}	7×10^{-5}
4. Unlikely - *between 1 in 10,000 and 1 in 1,000 per year (10^{-4}/y to 10^{-3}/y)*			
	50 mm or less Ø	**51-150 mm Ø**	**151-300 mm Ø**
Actuated Valve	3×10^{-4}	3×10^{-4}	3×10^{-4}
Instrument Connection	3×10^{-4} includes flange		
Process Vessel	7×10^{-4} pressurised vessel		
5. Likely - *between 1 in 1,000 and 1 in 100 per year (10^{-3}/y to 10^{-2}/y)*			
		50-150 mm Ø	**>151 mm Ø**
Heat Exchanger / Evaporator / Heater		2×10^{-3}	2×10^{-3}
Pumps (centrifugal or reciprocating)		5×10^{-3}	1×10^{-3}
Ro-Pax	1×10^{-2} collision / 1×10^{-2} grounding		
Cruise Ship	5×10^{-3} collision / 1×10^{-2} grounding		
Container Ship	2×10^{-2} collision / 7×10^{-3} grounding (data refers to wrecked/stranded)		
The likelihood values include all collisions and groundings. For collisions this means all collisions where the ship is 'struck' and where the ship is the 'striking ship'. The likelihood of interest might be less than the values above when consideration is given to ship, route and incident specifics. For example, assuming a release requires a Ro-Pax ship to be 'struck' and the collision to be 'serious' then the likelihood value approximates 5×10^{-4} (i.e. category 4 'Unlikely' where 'struck/striking' is assumed 50/50 and about 10% of collisions are 'serious'[21]).			

20. Indicative values are based on (a) and (b) and summarised in (c): (a) International Association of Oil & Gas Producers. (1 March 2010). Risk Assessment Data Directory – Process Release Frequencies, Report No. 434 – 1; (b) Health and Safety Executive. (1992-2006). Hydrocarbon Releases (HCR) System. https://www.hse.gov.uk/hcr3/; (c) LNG as a Marine Fuel - Likelihood of LNG Releases. Journal of Marine Engineering & Technology (JMET), Vol. 12, Issue 3, September 2013.
21. Formal Safety Assessment (FSA): FSA Container Vessels, MSC 83/21/2 (Table 3), 3 July 2007; FSA Cruise Ships, MSC 85/17/1 (Table 1), 21 July 2008; and FSA RoPax Ships, MSC 85/17/2 (Table 1), 21 July 2008.

No. 146 (cont)

Appendix 6
Mitigation measures

Example mitigation measures

Engineering Mitigation Measures
Protection from mechanical impact damage
Protection from vibration / vibration monitoring
Protection from wind, waves and weather
Pressure relief, venting
Increased separation or increased physical protection from collision / grounding
Secondary containment (e.g. double-walled pipework)
Welded connections in preference to flanged connections
Alarmed and self-closing doors
Bulkhead separation / cofferdam
Drip tray capacity, liquid detection
Spray shield coverage
Protection of structure from cryogenic temperatures and pressure from evolved vapour / gas
Independent bilge
Fire and gas detection, monitoring, audible / visual alarm and shutdown
Pressure and temperature detection, audible / visual monitoring, alarm and shutdown
Level detection
Forced / natural ventilation - airlock
Minimisation of ignition sources - Ex proof electrical equipment
Fire-fighting fire and cooling appliances - foam, water spray
Fire dampers
Separation of spaces
Access arrangements
Physical shielding
Mooring tension monitoring / alarm
Strain monitoring of supports
Buffer / overflow tank - Fuel recycling
Independent safety critical controls to IEC 61508
Radar monitoring
Service fluid - level / gas detection, alarm and shutdown
Flame arrestor
Procedural Mitigation Measures
Increased frequency of inspection (and maintenance)
Reduced parts replacement frequency
Specific training for low-flashpoint fuels
Restricted access
Monitoring

Note:

1. The mitigation measures above are largely generic and in no particular order. They are listed as a simple *aide memoir* when considering mitigation.
2. Within the IGF Code, measures to reduce likelihood and measures to reduce consequences are both understood to be mitigation measures (i.e. they mitigate the risk). To align with the IGF Code this understanding is maintained within this document. It is recognised that in many other industries it is common to use the terms 'prevention measures' and 'mitigation measures', where the former reduces likelihood and the latter reduces consequences. Prevention and mitigation measures are often referred to as 'safeguards' or 'barriers'.

No. 146 (cont)

Appendix 7
Cause to Consequence Mapping

An established means to illustrate or map the pathway from 'cause' to 'consequence' is known as Bowtie. There are a number of variations on this theme and differing terminologies but essentially the Bowtie helps to visualise: threats or causes of an unwanted event; the barriers or mitigation measures to prevent the unwanted event; and the barriers to mitigate the consequences.

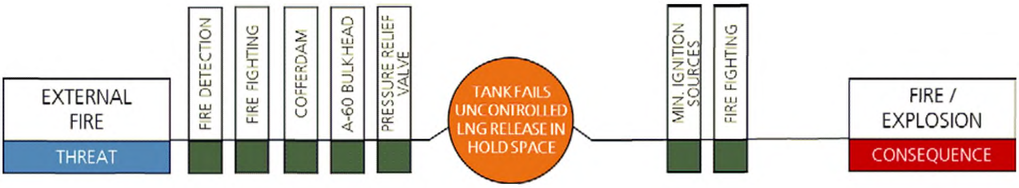
Bowtie examples

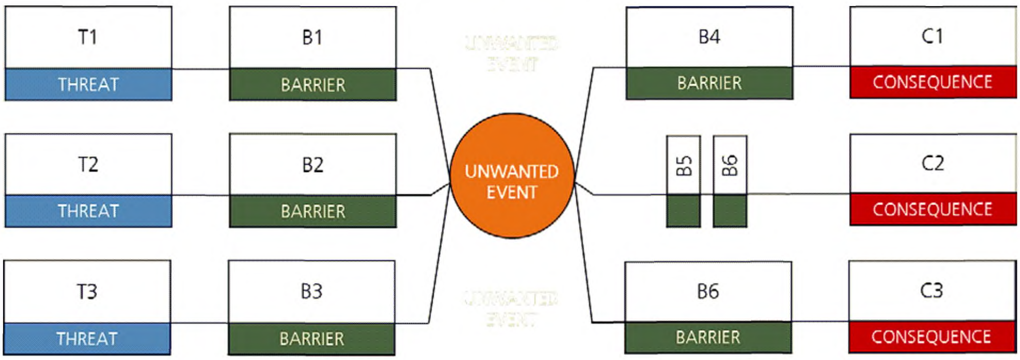
Threat – *A cause that can potentially lead to the unwanted event.*

Barrier – *A mitigation measure that can potentially prevent the unwanted event or its consequences.*

Unwanted Event – *A situation to be avoided e.g. a release of fuel or a loss of ship propulsion.*

Consequence – *An outcome of a threat and an unwanted event not being mitigated by the barriers.*





In respect of 'mitigation measures' (i.e. barriers) those prior to the unwanted event are often referred to as preventative barriers or prevention measures.

No. 146 (cont)

Appendix 8
Report Contents

Example report contents

Executive summary	
An overview of the assessment and main results and conclusions.	
1. Introduction	
A brief statement on the purpose of the assessment and the parties involved.	
2. Objective and Scope	
The principal objective is, for example, to demonstrate that the safety-risk is, or can be made acceptable/tolerable for Class approval. The scope is, for example, limited to the design/arrangement, the specific environment/location and the intended modes of operation.	
3. Description	
A simple explanation of the design and arrangement with respects to its intended operation and process conditions.	
4. Approach	
Overview of the risk assessment technique/method. This includes how the design was divided into sections for assessment, how hazard identification was undertaken, the selection of risk criteria, and the mechanism of risk rating and recording. In addition, a note on the actual workshop schedule illustrating the time expended on each section.	
5. Team	
The names, job titles, relevant qualifications, expertise and experience of the facilitator and SMEs. This can be recorded in a table, together with a record of workshop attendance. If this information is particularly large and would detract from the approach and results, the information can be included as an appendix.	
6. Results	
Discussion of the main findings and issues.	
7. Conclusions	
A summary judgement on whether the risks are 'mitigated as necessary'.	
8. Actions	
A listing of additional/alternative safeguards, including who is responsible and expected completion date.	
Appendices	
A.	Worksheets (as recorded in the workshop, including guidewords and phrases i.e. prompts).
B.	Drawings, Process Information and Reference Documents (including the Terms of Reference).

End of Document