UKP&I

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Risk Focus: Safe LNG Bunkering Operations

A guide to good LNG bunkering practice

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A guide to good LNG bunkering practice

The advent of the 2020 global sulphur cap regulation has been driving marine engine technology towards achieving environmental compliance.

The marine engine manufacturers have been developing ship's engines capable of using alternative low-flashpoint and low-sulphur fuels as a way to meet the stringent environmental requirements. In addition, abatement technologies for the reduction of harmful emissions, such as scrubbers, have also been developed.

The use of gas as an alternative low-flashpoint fuel to propel ships is recognised as having certain advantages. Firstly, it allows for an immediate compliance with the latest environmental regulations. Furthermore, being a clean burning fuel, there is potential for reduced maintenance costs and avoiding the necessity for fuel treatment, which is needed for most of the fossil fuels currently used on ships.

Today, the technology required for using LNG as ship's fuel is readily available for reciprocating piston engines and gas turbines, several LNG storage tank types, as well as process equipment, are also commercially available. However, the inevitable long-term growth in demand for LNG fuel used for general shipping will require additional investment in global LNG bunkering infrastructure.

The most common gases used in this respect are Liquefied Petroleum Gas (LPG) and Liquefied Natural Gas (LNG). LNG bunker operations have started to gain momentum. There are many ports in Europe, North America and Asia, where LNG, as a low-flashpoint fuel, can be supplied to ships. However, there is presently insufficient data relating to LNG bunkering incidents and claims.

LNG carriers have been safely using cargo "boil off" as fuel for many years. However, introducing LNG as a fuel on other types of vessels requires crews and management companies to address additional safety measures and operational procedures.

Introduction

Traditional oil fuel bunkering is a routine and yet critical shipboard activity. However, the additional risks involved with LNG bunkering need to be carefully managed by all maritime industry stakeholders. Different methods of bunkering will expose the vessel to different risks.

Liquefied Natural Gas is almost odourless, colourless, and consists predominantly of methane (usually over 80%) with some mixtures of ethane. The methane vapour can liquefy at temperatures below -82°C, and it is stored at near atmospheric pressure at temperatures of around -162°C.

In order to contain LNG, the International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF Code) recognises the use of four types of fuel containment tanks:

- Type A – an independent tank constructed primarily of flat surfaces, having a maximum design vapour pressure of 0.07 MPa. This is an atmospheric type fitted with a complete secondary barrier.

- Type B – an independent tank constructed of flat surfaces or a spherical type, having a maximum design vapour pressure of 0.07 MPa. This is an atmospheric type fitted with a partial secondary barrier.

- Type C – an independent tank constructed of spherical or cylindrical pressure vessels having a design pressure higher than 0.2 MPa. Secondary barriers are not required.

- Membrane tanks – a non-self-supporting tank consisting of a thin liquid and gastight layer (membrane). This is an atmospheric type which requires a complete secondary barrier.

In general, there are four recognised main LNG bunker delivery methods to LNG-fuelled ships:

- Ship-to-ship (STS) LNG bunkering
- Truck-to-ship LNG bunkering
- Terminal-to-ship LNG bunkering
- Containerised (portable) LNG tanks used as fuel tanks

The first method involves two vessels, a bunker receiving vessel and an LNG bunker delivering tanker (LNG bunker vessel) conducting a Ship-to-Ship (STS) transfer operation. A specialised LNG bunker vessel should be expected to be fully equipped with all necessary STS mooring, fendering and LNG transfer equipment.

Current LNG bunker vessel capacities range between 180 m^3 (the 1974-built, 2013-converted, LNG bunker tanker SEAGAS) and up to 7,500 m^3 (the 2018-built KAIROS). Reportedly, LNG bunker vessels of up to 18,600 m^3 are on order and are scheduled to be delivered in 2020.

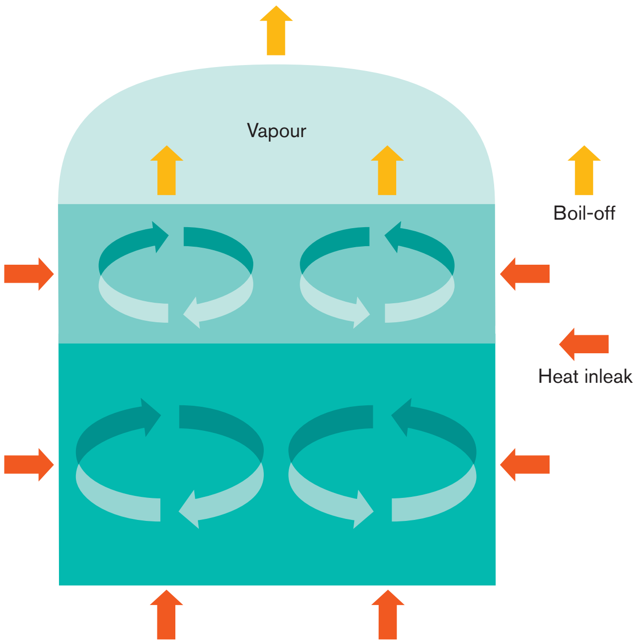
LNG-fuelled vessels currently in service typically have a bunker tank capacity of between 300 m^3 and 600 m^3. The tanks can be of an atmospheric or pressurised type.

LNG bunker hazards

Given the characteristics of LNG, there are a number of potential hazards that should be considered during LNG bunkering:

Rollover phenomenon

The process of rapid release of LNG vapour as a result of spontaneous mixing-up of LNG from different densities in one storage tank. For the rollover to occur, a stratification of two layers is created as a result of density differentiation. When there is little vertical heat or mass transfer, both layers establish their own convection currents. The lighter upper layer releases vapour and loses heat. Its density increases and equalises to the lower layer one. The lower layer, having a higher temperature, will roll over the upper layer resulting into the release of superheat and thereby generating large volumes of boil-off gas in a short period of time. An over-pressurisation of the tank can occur, causing some structural damage. Historically, there were a few occasions of rollover occurring ashore and on-board LNG tankers. The La Spezia incident in 1971 is probably one of the most significant. In 2008, a Moss-type LNG carrier experienced an increase of pressure in some of the cargo tanks.[1] This phenomenon is more likely to occur in large tanks. However, there is a potential for this phenomenon to develop during LNG bunkering operation, if the receiving tank is partly filled with aged LNG material.



A tank where stable stratification has taken place caused by a storage tank with liquids of different densities. The higher-density layer is the lower layer.

Rapid phase transition

This phenomenon has been well researched. It represents a very rapid physical phase transformation of liquefied natural gas to vapour, when the LNG comes in contact with water. Previous incidents include LNG spills on water. The research and incidents resulted in establishing safe zones as well as the development of emergency stop devices. The SGMF defines the safety zone as the three-dimensional envelope where natural gas/LNG may be present as the result of a leak/incident during bunkering.[2]

[1] Guidance for the Prevention of Rollover in LNG Ships, Society of International Gas Tanker and Terminal Operators (SIGTTO)
[2] SGMF – The Society for Gas as a Marine Fuel

Vapour dispersion and remote flash fire

The potential for a cloud of gas to burn without the generation of any significant over-pressure. For this to occur, the LNG should first evaporate and then form a concentration of explosive atmosphere between the Lower Flammable Limit (LFL) and the Upper Flammable Limit (UFL) of the methane. These limits are 5% and 15% respectively. The duration of the fire is relatively short unless there is a continuous supply of methane gas.

Possible BLEVE (Boiling Liquid Expanding Vapour Explosion)

This phenomenon, also known as a fireball, is a sudden release of the pressurised gas caused by a rupture of a tank containing a pressurised liquid above its boiling point. For this reason, it is typical for pressurised liquids and not applicable for atmospheric LNG tanks.

Asphyxiation

A potential release of LNG and the formation of cold gas will result in the gas spreading above the water and on deck. When cold, the methane is heavier than air. Methane is not a poisonous gas; however, it will deplete the oxygen present in the air and will likely cause asphyxiation. When only 25% of the released gas is diluted in the air, the oxygen level will go down to below 16%.

Low temperature

A leakage will cause severe frostbite or death.

Sloshing

The surge of liquid inside the tank. In accordance with the IGF Code, the sloshing loads on a liquefied gas fuel containment system and internal components should be evaluated for a full range of filling levels.

Cryogenic damage to steel

A release of LNG, as well as other liquids at temperatures below -40°C can cause serious structural damage to steel and other materials, other than cryogenic steel. While stainless steel will remain ductile, carbon steel and low-alloy steel will become brittle, and fractures are likely if it is exposed to the low temperatures of the liquefied natural gas.

Cryogenic embrittlement

Trapped LNG in bunker transfer pipes and hoses

Where LNG remains trapped and not properly purged with nitrogen, a potential is created for the development of rapid phase transition, pressure build-up, structural failure of the transfer pipe/hose, and the release of the LNG to the atmosphere.

STS LNG transfer operations

All hazards associated with STS LNG transfer operations, such as collision/allision, mooring failure, cargo transfer hose failure, fatigue and availability of personnel, concurrent operations and others.

The human element

The training requirements for seafarers engaged in LNG bunkering operations are covered by the IGF Code, STCW, and the industry codes and international guidelines, such as SIGTTO, SGMF, OCIMF and ISO/TS 18683.[3] With respect to LNG bunker vessels and LNG-fuelled vessels, the following regulatory instruments should be referred to as a minimum:

- STCW Convention Chapter V “Special Training Requirements for Personnel on Certain Types of Ships”, Regulation V/1-2 “Mandatory minimum requirements for the training and qualifications of masters, officers and ratings on liquefied gas tankers” and Regulation V/3 “Mandatory minimum requirements for the training and qualifications of masters, officers, ratings and other personnel on ships subject to the IGF Code”.
- STCW Code, Chapter V “Standards regarding Special Training Requirements for Personnel on Certain Types of Ships”, Section A-V/1-2 “Mandatory minimum requirements for the training and qualifications of masters, officers and ratings on liquefied gas tankers” and Section A-V/3 “Mandatory minimum requirements for the training and qualification of masters, officers, ratings and other personnel on ships subject to the IGF Code”.
- STCW.7/Circ.23 “Interim Guidance on Training for Seafarers on Ships Using Gases or Other Low-Flashpoint Fuels” and the associated addendum 1.
- IMO Resolution MSC.285(86), Chapter 8 “Operational and Training Requirements”.
- International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF Code), as amended.
- SGMF – Bunkering of Ships with LNG – Competency and Assessment Guidelines, and the remaining guidelines.
- The SGMF Guidelines and recommendations with respect to LNG bunkering (for LNG bunker vessels).
- SIGTTO – LNG shipping suggested competency standards (for LNG bunker vessels).
- SIGTTO – LNG and LPG Experience Matrix Guidelines for Use (for LNG bunker vessels).
- The Ship to Ship Transfer Guide for Petroleum, Chemicals and Liquefied Gases (for LNG bunker vessels).

[3] ISO/TS 18683 – Guidelines for systems and installations for supply of LNG as fuel to ships. OCIMF – Oil Companies International Marine Forum

- Local Ports requirements and regulations.
- Individual Classification Societies and Flag States requirements on training.

All shipboard personnel involved with LNG bunkering operations should be suitably trained and authorised to work with cryogenic and flammable liquids, as well as to safely conduct STS operations. For STS LNG bunkering activities, both vessels should have maintenance and repair procedures for the relevant gas-related installations, LNG bunker transfer operational procedures, suitable emergency procedures, and/or fuel handling manual as part of the Safety Management System of their companies.

The proper training level and experience of all personnel involved with LNG bunkering operations are important. This will assist with eliminating the potential of complacency and managing work and rest hours to avoid fatigue. All involved crew must be fully familiarised with the equipment, systems and on-board procedures.

Bunkering fundamentals

The ship-to-ship LNG bunkering operation may be conducted alongside berths and at anchorages within the limits of ports. An LNG bunkering operation with the vessels underway is not customary and should not be performed without proper STS mooring and fendering equipment. Reference should be made to the company's own procedures and the port state requirements.

The Working Group on LNG Fuelled Vessels, which was first established under IAPH's World Ports Climate Initiative in 2014, has published bunker checklists, including guidelines on safe procedures for LNG bunkering operations.[4] A number of ports refer to these checklists as part of their LNG bunkering safety procedures. Rigorous observance of checklists is essential for safe LNG bunkering. Compliance with the documented procedures should include the operation being properly risk assessed and ensuring all relevant stakeholders are informed before proceeding with the operation.

A bunker operation broadly has four stages:

Pre-arrival (planning) stage

This is the stage with potentially the highest level of information exchange. Prior to arrival at the STS location, certain elements will need to be addressed by the LNG bunker vessel, the LNG-fuelled vessel and port/terminal. Once done, the LNG bunker vessel's operators should apply and obtain all relevant permits from the port and terminal for the forthcoming bunker operation.

Each STS LNG bunkering operation should follow an LNG Bunker Management Plan (LNGBMP) agreed by both vessels, specific for the relevant operation. All limitations with respect to pressures, alarms, moorings, and type of LNG tanks (whether atmospheric or pressurised) should be communicated. The relevant risk assessments should be completed and communicated. The compatibility between both vessels should be assessed. This extends beyond the bunker transfer equipment; for example, mooring compatibility should be examined.

The LNGBMP should, as a minimum, address the following points:

- Contingency plan and emergency response plan
- Safety instructions and training setting out the safety and security zones

[4] IAPH – The International Association of Ports and Harbours

- Quality and quantity agreement
- Bunker procedure, which should cover the compatibility assessment and set out the use of appropriate bunker checklists
- Equipment certificates and condition verification

Emergency exercises, trainings and drills should be conducted by the crew at regular intervals. It will be important that all newly joined key personnel undergo relevant drills and training on their vessel prior to bunkering. Their relevant duties and responsibilities should be understood.

As an example, the following should be considered as part of the training (IGF Code, Part C-1, Regulation 17):

- Table-top exercise
- Review of fuelling procedures
- Responses to potential contingences
- Tests of equipment intended for contingency response
- Reviews that assigned seafarers are trained to perform specific duties during fuelling and contingency response

Checkpoints to be considered at this stage are, but not limited to:

1. Notification to, and approval from, port authorities and Flag Administration, if applicable, should be completed. All applicable local and national regulations and guidelines should be reviewed. Ports where the STS bunkering operations are conducted will have their own regulations, plans and procedures. These should be familiar to those involved with supervision of the operation.
2. The LNGBMPs and operations manuals of both vessels have been confirmed to be available and the necessary approval certificates have been exchanged.
3. All alarms and safety devices should be tested, following the company procedures. There may also be a local requirement for the tests to be completed not more than 24 hours or, in some cases, 48 hours prior to the operation.
4. Own bunker transfer equipment and pipelines should be visually inspected.
5. The condition of lights, PPE, spill equipment, radio communication equipment, Emergency Shut Down System, mooring equipment, fenders, if available, and transfer equipment should be verified.
6. The responsible persons for the operation from both vessels, and the person of overall advisory control, should be identified.
7. The date, time, geographical location, bunker quantities and quality should be discussed between the vessels.
8. The ship-to-ship LNG bunker safety checklist has been agreed and exchanged between the vessels.
9. If the LNG-fuelled vessel is alongside, whether any simultaneous activities have been planned. If so, permission from the port/terminal should also be obtained.
10. The use of specific checklists should be agreed.

IAPH has developed LNG bunker checklists that can be obtained and used from the World Ports Climate Initiative (WPCI) website: www.lngbunkering.org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Pre-bunkering

During this stage, a pre-bunkering conference should be held. This is an important and integral part of LNG bunkering.

Where the bunkering is to be conducted at anchor, the safety of the personnel transferred between the ships should be discussed. Cranes, if used for transfer, should be designed, built and maintained to the appropriate rules of an International Association of Classification Societies (IACS) member for transferring of personnel. An alternative arrangement for access between both vessels at anchor can be the use of a launch service from the sea side of both vessels prior to and following the completion of the bunker transfer. Any personnel transfer between vessels should be considered as a simultaneous activity and should ideally be avoided when the bunker transfer is in progress.

Depending on the location of the STS LNG bunkering activity, the safety zones around the vessels should be agreed between the two vessels. If required, they should be coordinated with, and approved by, the local port authorities and terminal.

The readiness of both vessels with respect to the transfer should be discussed and all operational parameters established and agreed. Below is an example of items to be considered:

1. The weather and sea criteria, and limits for aborting the operation.

2. The condition of the jetty/anchorage/traffic.

3. The moorings and fendering should be inspected, assessed and confirmed by the responsible personnel.

4. The compatibility of both vessels should be verified and confirmed.

5. The main and emergency means of communication should be agreed and tested.

6. Bunker line connection, pre-cooling, inerting, cooling down, vapour management, and rates of transfer during the initial, bulk and topping stages. Visual inspections for leaks of the transfer hoses and equipment should be carried out during the cool-down.

7. The compatibility and testing of the Emergency Release System (ERS) and Emergency Shutdown System (ESDS) should be performed and confirmed.

8. An agreement should be obtained, and restrictions imposed, with respect to potential simultaneous operations, such as cargo transfer, passenger movement, vehicles on ferries, other oil bunkering, stores and provision supply, personnel transfer and other activities that may distract or engage key shipboard personnel during LNG bunkering activity.

9. Other limitations by the receiving and delivering vessels with respect to the LNG bunkering activity.

10. Initial pre-cooling of the LNG transfer systems of both vessels. This can be completed either with the use of nitrogen or with LNG. During this activity, there are risks of cryogenic hazards, introducing oxygen in confined spaces, and boil-off-gas (if inerting with LNG).

11. Grounding, inerting and leak testing of the transfer hoses.

12. Filling sequence.

13. Smoking regulations and other fire prevention measures.

During bunkering

When the bunker hose is connected, inerted and tested, the LNG bunker transfer can be started. On commencement, the manifold pressures and rate should be kept to a minimum and in accordance with the pre-transfer agreement. The temperatures should be monitored and verified. Once the LNG is confirmed to have reached the designated tank, and the system has been set to the normal operational transfer parameter, a visual inspection of the surrounding area should be made.

During the bunker transfer, one important element to be addressed is the management of the vapours. The displaced gas and the boiled-off gas will require to be either stored or transferred back to the bunker vessel via a vapour return line. Depending on the method in use, the parameters associated with the vapours should be constantly monitored.

The manning level of the bunker station should be in accordance with the plan. Any necessary change of personnel can be done following a proper hand-over procedure. All agreed items from the bunker transfer checklist, which will require verification, should be confirmed at regular intervals. The communication between both vessels should be periodically checked.

The weather conditions should be monitored, and any unexpected deterioration should result in stopping of the transfer and, if necessary, disconnection.

The relevant LNG transfer sensors and bunker quantity levels should be monitored. If a vapour balancing line is in use, the flow and pressures should be also closely monitored. When the topping-off levels are reached, the supplying vessel should be informed, and the transfer rate reduced in accordance with the pre-transfer agreement.

Post-bunkering

On completion of the bunker transfer, the fixed pipelines and bunker hoses should be drained/stripped. The transfer pump should be drained. All drain lines and valves should be verified to be empty. All pressure release valves and vents should be checked to prevent potential over pressurisation.

The bunker transfer pipeline and hose should be then inerted with nitrogen prior to the disconnection. Great care should be exercised at disconnection as significant cold vapour may be around, which may be inhaled. Cold vapour and cold pipelines may cause frost bite.

The bunker and LNG-fuelled vessels will then prepare for departure. In the event of an incident, the vessels involved are required to report the incident to the relevant international, national and local authorities.

Summary – Key points

The LNG bunkering requires all personnel engaged with the operation to be knowledgeable and familiar with their own vessel's equipment and systems, the nature of the bunker fuel, and the hazards associated with the activity, including:

- Rollover
- Rapid phase transition
- Vapour dispersion and remote flash fire
- Boiling Liquid Expanding Vapour Explosion (BLEVE)
- Asphyxiation
- Low temperature
- Sloshing
- Cryogenic damage to steel
- Ship-to-ship transfer associated hazards – collision/allision, mooring failure, cargo transfer hose failure, fatigue and availability of personnel, concurrent operations and others.

Proper certification of personnel as well as a continuous training and development with respect to LNG bunkering operations should be in place. Procedures should be in place to avoid complacency, high work load and fatigue, unfamiliarity and poor communication.

In addition, the procedures should include:

- Risk assessment for bunker operations
- Bunkering fundamentals and LNGBMP
- Maintenance and testing of bunker transfer equipment
- Emergency response
- Regular drills and training on board ships

Pre-arrival preparations should include:

- Planning for the personnel availability, addressing the rest periods
- Information exchange between all stakeholders and obtaining the relevant permits from the authorities
- Completion of all relevant tests and checks
- Completion of all sections of the relevant checklist after each question has been addressed
- Completion of the relevant drills, trainings, tool box meetings on board the vessels in accordance with the company procedures
- Inspection and verification that the spill equipment, the emergency response equipment and PPE are all ready

The pre-bunkering preparations should include:

- Meeting between the responsible people engaged with the bunkering, including any third-party bunker surveying companies
- Verification of the vessels' compatibility and their bunker transfer equipment
- Establishing the safety zones and discussion of potential simultaneous activities
- Inerting, testing and pre-cooling of the bunker transfer system. Visual inspection for leaks should be made
- The ERS and ESDS should be tested
- Final test of the system once the connection has been completed
- Completion of all sections of the relevant checklist after each question has been addressed

During bunkering:

- The transfer should start at the agreed rates
- The temperatures, flow, pressure and all bunker transfer sensors should be monitored
- The bunker transfer quantities should be monitored
- The vented and boil-off gas should be managed in accordance with the agreed plan
- The communication between the bunker supplier and the LNG-fuelled ship should be periodically tested

Post-bunkering:

- The bunker transfer systems, pumps, pipelines and hoses should be drained/stripped, inerted, closed and blanked off
- Care should be taken to avoid frost bite and inhalation from accidental contact with cold equipment and release of cold nitrogen
- The systems should be realigned for normal operation
- All relevant parties and authorities should be informed for the completion of the operation
- All documentation should be completed prior to the departure of the vessels
- In the event of an incident, the prompt and accurate reporting should be completed

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