SIGTTO

Society of International Gas Tanker & Terminal Operators Ltd

Gas as Fuel on Gas Carriers

Review of Practice

First Edition

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The Society of International Gas Tanker and Terminal Operators (SIGTTO) *is a non-profit making organisation dedicated to protecting and promoting the mutual interests of its members in matters related to the safe and reliable operation of gas tankers and terminals within a sound environment. The Society was founded in 1979 and was granted consultative status at the International Maritime Organization in November 1983.*

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1 Introduction and Scope

1.1 Introduction

To help with the development of new rules and guidance for the use of LPG and ammonia fuel on gas carriers, a review of current safety philosophy was carried out. This document covers the cases when the cargo is used as a fuel and when liquefied gas fuel is carried separately. The gases considered as part of this review are LPG,[1] ammonia and LNG (methane).

This document uses risk-based language to review the hazards from first principles and uses existing control measures in the IGC Code,[2] standards and industry best practice. The approach is based on experience in the use of LNG as a fuel and the carriage of LPG and ammonia as a cargo on gas carriers. The purpose is to help develop the regulatory framework for gas carriers to use LPG and ammonia as a fuel. This document only introduces the issues to be considered at the very early stages of the process. More work needs to be carried out to cover all safety aspects.

The vision statement on the IMO's greenhouse gas (GHG) strategy[3] states: *"IMO remains committed to reducing GHG emissions from international shipping and, as a matter of urgency, aims to phase them out as soon as possible in this century".* It is SIGTTO's policy to support IMO's environmental goals and this document helps to achieve these targets.

[1] Propane, butane, or mixture of both

[2] IMO – International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk

[3] IMO – Resolution MEPC.304(72) – Initial IMO Strategy on Reduction of GHG Emissions from Ships

1.2 Scope

This document aims to provide information to organisations that are involved in the development of standards and design of liquefied gas fuel systems on gas carriers. This document reviews specific hazards and safety issues of LPG and ammonia as fuel, but it does not provide specific guidance for ship design and operational practice.

The level of technical detail assumes that the reader is familiar with the design and operation of liquefied gas carriers. Not all concepts are simplified or explained at an introductory level.

2

Overview of Current Practice

2 Overview of Current Practice

Existing regulations, standards and best practice ensure that the risk of transporting liquefied gases by ship is managed at acceptable levels. This is continuously improved as new information and methods become available. Liquefied gases have been transported for over 50 years and there is significant experience in managing the hazards safely.

There is also a lot of experience in the use of LNG as a fuel on gas carriers, some experience with LPG as a fuel, but no experience yet with ammonia as a fuel. It is practical to extend existing knowledge and experience to the new fuels as a starting point to ensure a minimum safety level. Recognising that the hazards are different and unique to each product, care should be taken to address the hazards in a structured manner.

2.1 Safety Level

Safety level is the target level of risk reduction. Risk is defined as the product of probability and consequence. Risk is typically lowered by risk reduction measures to a safety level that is acceptable to all stakeholders.

The safety level for the use of ammonia and LPG as fuel should, as a minimum, be the same as the safety level for the use of LNG as a fuel. As an example, this approach can result in the same risk exposure for the crew when LNG is used as fuel and when LPG and ammonia are used as a fuel. Maintaining the same safety level may require additional risk reduction measures due to the unique hazards of ammonia and LPG and the unique parameters, eg pressure and toxicity. The goal of the design should be that it is *inherently safe* and not rely only on the skill and expertise of personnel.

As these fuels can also be carried as cargo, the safety level for the use of ammonia and LPG as fuel should, as a minimum, be the same safety level for carriage of ammonia and LPG as cargo.

2.2 IGC Code

The IGC Code specifies the safety requirements for gas carriers to carry cargoes that are listed in Chapter 19. Ammonia, LPG and LNG are listed in Chapter 19 and are covered by the IGC Code for carriage as cargo.

Chapter 16 addresses the additional aspects relevant to the use of LNG cargo as a fuel. Only safety aspects that arise from the use of LNG as a *fuel* are covered by Chapter 16, as all other safety aspects for the carriage of LNG as a *cargo* are covered elsewhere in the IGC Code.

This document builds on this approach and provides considerations for the additional aspects specifically when ammonia and LPG are used as fuel. All other general safety aspects relating to the presence of ammonia and LPG on a gas carrier are addressed by the IGC Code, and these should be applied whether these products are carried as cargo or separately as fuel.

2.3 Main Hazard Overview

IGC Code Chapter 16, *Use of cargo as fuel*, provides requirements for the use of LNG in Category A machinery spaces.[4] The primary hazard of methane is that it is flammable. For propane, butane and ethane the primary hazard is the same, but for ammonia the primary hazard is toxicity. The primary hazard, along with the differences in temperature and vapour density of products, can affect the design.

The primary hazard for gases that are being considered for use as fuel and a few key properties relevant to the discussion in this document are listed in Table 1. Note that ammonia has an affinity to water. It is initially lighter than air but can combine quickly with humidity to become heavier than air.

[4] For the definition of *Category A*, see IGC Code 1.2.32

	Primary hazard	Atmospheric boiling point °C	Relative vapour density to air	Flammable range volume in air (v/v %)	Auto ignition °C	TLV[5] ppm
Ammonia	Toxic	–33.4	0.597	14.0–28.0	650	25
i-Butane	Flammable	–11.7	2.07	1.5–9.0	500	1,000
n-Butane	Flammable	–0.5	2.09	1.5–9.0	365	1,000
Ethane	Flammable	–88.6	1.048	3.0–12.5	510	1,000
Propane	Flammable	–42.3	1.55	2.1–9.5	468	1,000
Methane	Flammable	–162	0.554	5.3–14.0	595	1,000

Table 1: Key properties of gas fuels

2.4 Carriage of LPG Cargo

The IGC Code has many detailed requirements that affect the carriage of LPG as a cargo. These include cargo tank and piping protection, firefighting requirements, relief systems, emergency shutdown (ESD) systems and many more. The cargo area is designated as a hazardous area[6] and has safety measures for hazardous cargoes. The accommodation area and the engine room are non-hazardous areas[7] and are not designed for presence of explosive gas atmospheres.

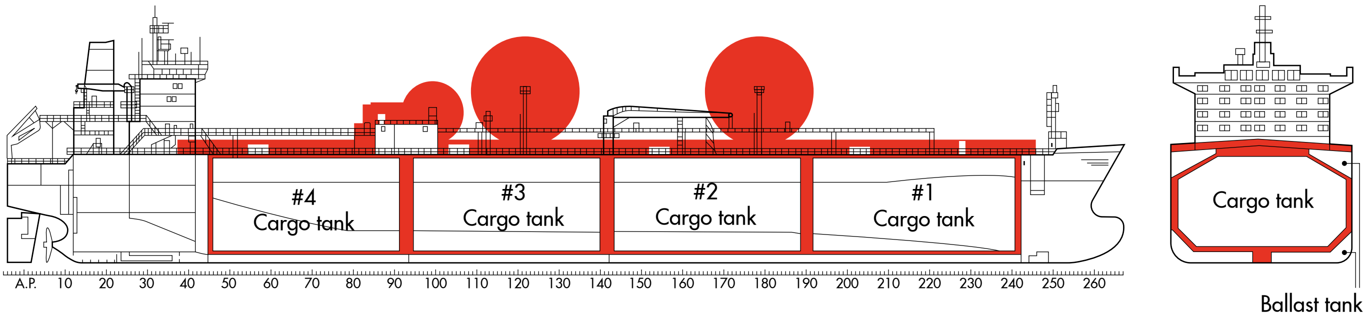

Figure 1: Hazardous area on an LPG carrier

LPG carriers may be fitted with compressor rooms that have reliquefaction equipment to manage cargo pressure. LPG carriers may also be fitted with cargo heaters and booster pumps which enable them to carry out heated and pressurised cargo transfer operations. LPG carriers may engage in ship to ship transfer activities.

Cargo manifold layout, strength and dimensions including drip trays and ESD systems are well established on LPG carriers which lead to safer and more efficient operations. Currently the recommendation[8] for LPG carrier bunker manifolds provides location, strength, size specification for LNG bunkers in addition to fuel oil. This can be adapted for LPG and ammonia bunker fuels. Below is an example of current layout from SIGTTO's *Recommendations for Liquefied Gas Carrier Manifolds.*

[5] American Conference of Governmental Industrial Hygienists (ACGIH) – Threshold Limit Values and Biological Exposure Indices

[6] See IGC Code 1.2.24

[7] See IGC Code 1.2.25

[8] SIGTTO – Recommendations for Liquefied Gas Carrier Manifolds

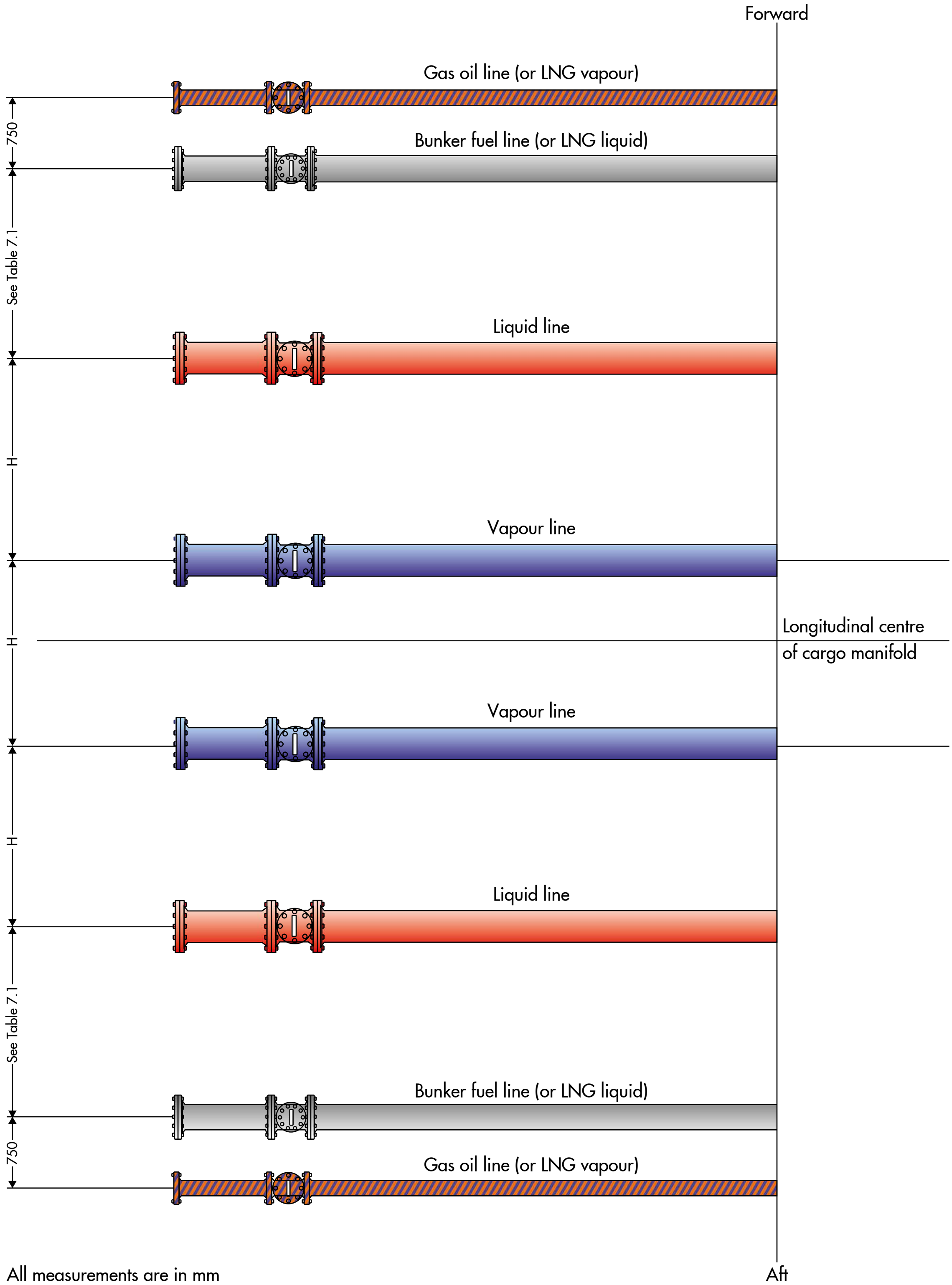

Figure 2: LPG carrier 'LVVL' arrangement

2.5 Carriage of Ammonia Cargo

Approximately 16.5 million tons of ammonia[9] cargo was transported by sea in 2022. There is knowledge and experience in carrying it as a cargo for many decades. Ammonia cargo is typically carried on LPG carriers that have additional specifications such as materials of construction, and additional protection equipment for personnel, such as showers, eyewash stations, safety equipment etc.

Ammonia carriers may be fitted with compressor rooms that have reliquefaction equipment to manage cargo pressure and may engage in ship to ship transfer activities. Cargo manifold layout, strength and dimensions including drip trays and linked ESD systems are well established as well.

2.6 Use of LNG as a Fuel

IGC Code Chapter 16 contains many requirements for the use of LNG as a fuel in the engine room. These include monitoring for leaks and automatic and manual shutdown controls. A design feature to note is that the deck area outside the accommodation and the engine room are typically designed to be non-hazardous areas.[10]

This means that although cargo vapour may pass through those areas, there are suitable design measures to ensure the risk of a leak is very low. Where the presence of gas is expected, such as the gas valve room shown in Figure 3, there are additional control measures to reduce risk to low levels.

[9] clarksons.com/home/news-and-insights/2022/an-introduction-to-green-ammonia/

[10] See IGC Code 1.2.25 *Non-hazardous area* is an area other than a hazardous area

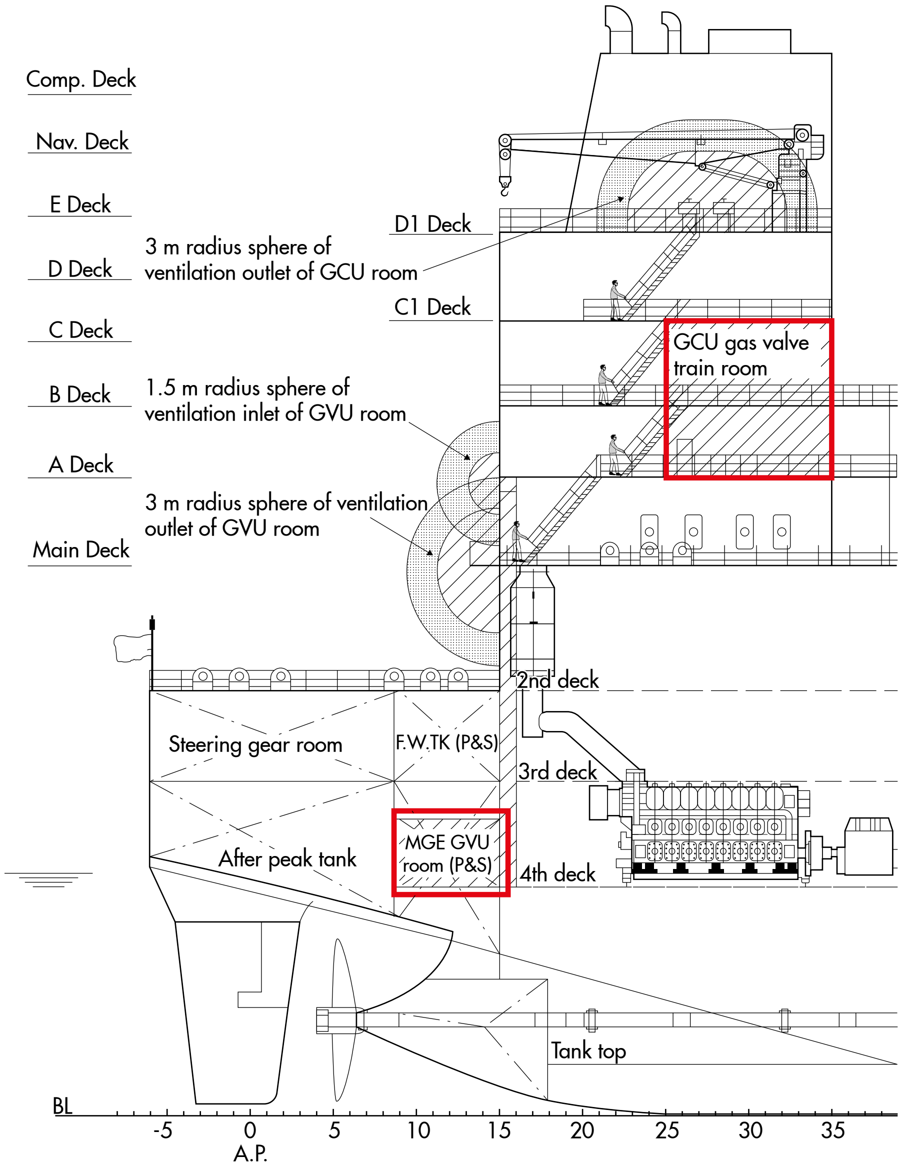

Figure 3: Gas valve room is a hazardous area

2.7 Regulatory Gap

Current regulations and best practice are not sufficient for the use of ammonia as a fuel on gas carriers. Use of LPG as fuel on gas carriers requires additional approval by Flag States.

	LNG	LPG	Ammonia
Carriage as a cargo	✓	✓	✓
Use as a fuel	✓	Subject to approval	Not allowed[11]

Table 2: Availability of regulations and best practice in 2023

[11] This is an active work item at IMO

As the rest of the IGC Code is prescriptive, the use of LPG and ammonia as fuel is expected to have prescriptive requirements to manage risk to acceptable levels. The typical approach by the IGC Code is to prescribe sufficient requirements to meet a minimum safety level. In addition, a risk assessment can be carried out to check that the safety level of the design is equivalent to that of LNG as a fuel.

2.8 IMO Goal-based Approach

IMO guidelines[12] for developing goal-based standards (GBS) provide a useful approach to structure information that may be helpful to develop standards for the use of ammonia and LPG as a fuel. GBS are high-level standards and procedures that are achieved through regulations. Functional requirements provide the criteria to be complied with in order to meet the goals. GBS comprise of at least one goal and functional requirements associated with that goal. The complete system is shown in the diagram below.

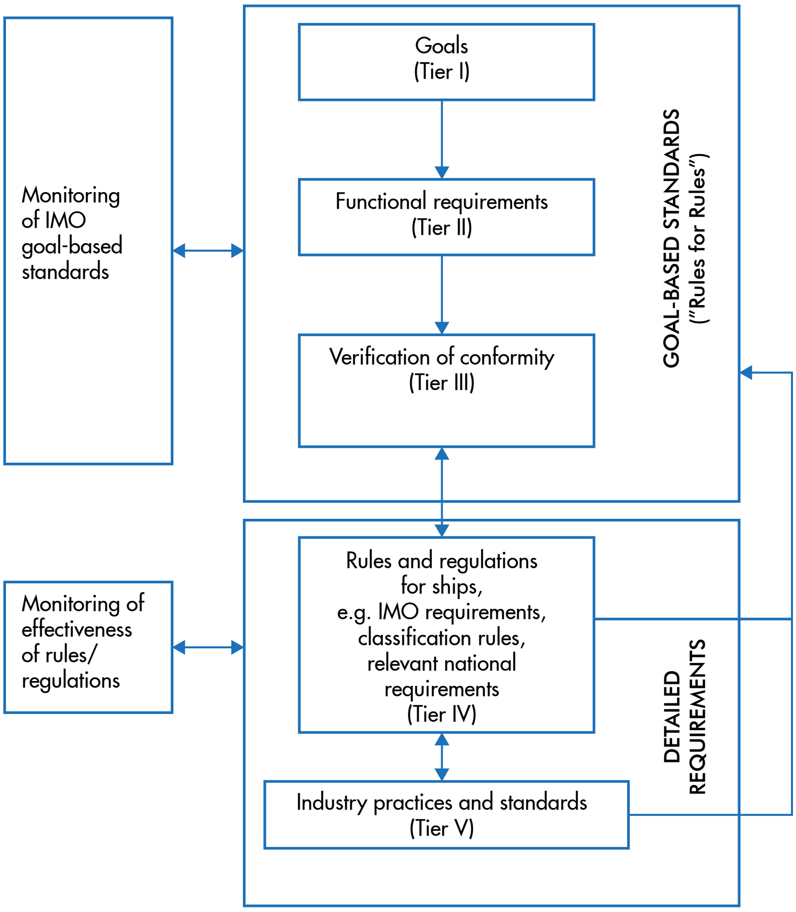

Figure 4: Goal-based standards framework

[12] IMO – MSC.1/Circ.1394/Rev.2 – Generic Guidelines for Developing IMO Goal-Based Standards

3

Goals and Functional Requirements

3 Goals and Functional Requirements

This chapter suggests goals and functional requirements for the use of LPG and ammonia as a fuel. This is not a complete list of all possible goals and functional requirements. It is necessary to carry out a comprehensive review of all risks during the design of fuel systems.

3.1 Goal with Supporting Information

Goal – To ensure safety of people, environment and the ship when liquefied gas is used as a fuel

The IGC Code has specific requirements based on the type of liquefied gas on board. Whether the product is carried on board as a cargo or a fuel, all relevant IGC Code sections should be complied with. There should be no exemptions because the product is 'only carried as a fuel'. The cargo area of an LPG and ammonia carrier is currently designed to a specific safety level that helps to reduce risk to acceptable levels. The aim is to ensure that the use of LPG and ammonia as a fuel maintains the current level of safety on gas carriers.

The equipment used for fuel systems on a gas carrier is located in the cargo area. The safety philosophy in the cargo area and machinery space is different as they have different designations. The cargo area is a *hazardous area*[13] and the machinery space is a *non-hazardous area*.[14]

A typical machinery space on a gas carrier is not suitable for the presence of hazardous fuel gas. This is due to the type of equipment fitted. The design philosophy of fuel gas systems for the machinery space should be such that there is no credible failure scenario that could lead to the release of gas. Maintenance activities and normal operating conditions should be considered during the design.

The properties of ammonia differ from LNG and LPG because the main hazard is toxicity. Additional measures need to be taken to comply with IGC Code requirements for carriage of ammonia. Irrespective of whether ammonia is transported as a cargo or used as a fuel, full compliance with all IGC Code requirements for ammonia is essential.

The main hazard of LPG is flammability which is similar to LNG, which is already used as a fuel, so existing requirements in Chapter 16 can be used to guide the development of new rules. The additional hazards are due to the density of LPG vapour, which is heavier than air, and that LPG may be delivered as a pressurised liquid in some designs.

Emissions to the atmosphere, as a result of the incomplete combustion or purging, should be considered and reduced to an acceptable level, or eliminated by design. All emissions should be directed to a safe place. Additional requirements can be added to IGC Code Chapter 16 for LPG as fuel to ensure the same safety level of LNG as fuel is achieved. To meet this goal the next section provides functional requirements for consideration.

3.2 Functional Requirements with Supporting Information for LPG

3.2.1 Inherently safe design to prevent a leak in non-hazardous area

The engine room and deck area around the accommodation are non-hazardous areas and are not designed for the presence of LPG liquid or vapour. The design of fuel delivery piping, equipment and consumers in these non-hazardous areas should be such that no single failure can lead to a release. This should be ensured by an inherently safe design and not rely on frequent maintenance or human intervention to ensure that the integrity of the barrier is maintained.

[13] See IGC Code 1.2.24

[14] See IGC Code 1.2.25

Double wall piping (IGC Code 16.4.3) is one of the typical methods to reduce the possibility of gas release in the engine room. Double wall piping is a critical line and should be analysed or evaluated for stress and fatigue damage. The length of the fuel pipe should be the minimum possible by using the shortest route.

The main hazard for double wall piping is from the impact of a dropped object or an object breaking free in heavy weather. A dropped object study should be carried out to ensure the protection of the double wall piping. The study should include the engine room crane and any lifting devices that have the potential to create an accident. Physical stops should be installed on cranes in addition to limit switches to prevent potential damage to double wall pipes.

The IGF Code Section 5.4, *Machinery space concept,*[15] refers to two concepts for a machinery space. For gas carriers, only the gas safe machinery space concept should be used. The ESD protected machinery space concept is not recommended for gas carriers.

The design should ensure that under both normal and emergency conditions, both liquid and vapour in LPG fuel pipe line should be capable of being purged with an inert gas. The back pressure in the collecting tank should be considered during design to ensure a proper function.

3.2.2 Prevent operational emissions to atmosphere

Gas fuel operations typically require purging of fuel lines. LPG liquid or vapour should not be released to the atmosphere or sea but should instead be collected in a suitable tank and handled appropriately. Release of vapour when a relief valve lifts is a safety function and may be directed to a vent mast.

Only closed gauging (not restricted gauging) should be used as currently indicated in the IGC Code. This means that the use of slip tubes or similar gauging methods that allow the release of LPG should not be used.

3.2.3 Gas detection and ventilation

The design should not accept major leaks or any minor leaks that cause gas levels to rise above 60% lower flammable limit (LFL) under normal design ventilation conditions. The ventilation system should be designed with sufficient capacity to be able to maintain the level of gas in the engine room. This should take into account the density, leak source and dispersion properties of LPG. The ventilation outlet should be led to a safe place, away from ignition sources or intakes of other systems.

A comprehensive study should be carried out to determine the type, number and location of gas detector heads for fuel gas systems. The density of the vapour and the concentration of the expected released gas will influence detector selection and placement and the ventilation system design.

Gas detection should not be used as an independent prevention barrier in the design of fuel gas systems. It should only be used as a mitigating barrier to monitor for minor leaks.

3.2.4 Safe location of equipment

Gas fuel equipment should be located in the cargo area (hazardous area) as much as possible. If gas fuel equipment is located adjacent to a safe area (non-hazardous area), then access should be through an airlock[16] to ensure adequate separation between the hazardous area and non-hazardous area.

[15] IMO – The International Code of Safety for Ships using Gases or other Low-flashpoint Fuels

[16] See IEC 60092-502 for the definition and design of an airlock

3.2.5 Safe bunkering operations

Bunkering operations should be carried out at dedicated fuel manifold amidships. The standard of the transfer equipment should be as per *Recommendations for Liquefied Gas Carrier Manifolds*. The design should enable the manifold connection to be drained and purged safely.

3.3 Functional Requirements with Supporting Information for Ammonia

3.3.1 Inherently safe design to prevent a leak in non-hazardous area

The engine room and deck area around the accommodation are non-hazardous areas and are not designed for the presence of ammonia liquid or vapour. The design of fuel delivery piping, equipment and consumers in these non-hazardous areas should be such that no single failure can lead to a release. This should be ensured by an inherently safe design and not rely on regular maintenance or human intervention to ensure that the integrity of the barrier is maintained.

Double wall piping (IGC Code 16.4.3) is one of the typical methods to reduce the possibility of gas release in the engine room. Double wall piping is a critical line and should be analysed or evaluated for stress and fatigue damage. The length of the fuel pipe should be the minimum possible by using the shortest route.

The main hazard for double wall piping is from the impact of a dropped object or an object breaking free in heavy weather. A dropped object study should be carried out to ensure the protection of the double wall piping. The study should include the engine room crane and any lifting devices that have the potential to create an accident. Physical stops should be installed on cranes in addition to limit switches to prevent potential damage to double wall pipes.

Considering the toxicity and unique properties of ammonia, careful attention should be paid to the connections from the fuel pipe to the engine.

The IGF Code Section 5.4, *Machinery space concept,*[17] refers to two concepts for a machinery space. For gas carriers, only the gas safe machinery space concept should be used. The ESD protected machinery space concept is not recommended for gas carriers.

The design should ensure that under both normal and emergency conditions, both liquid or vapour in the ammonia fuel pipe line should be capable of being purged with an inert gas. The back pressure in the collecting tank should be considered during design to ensure a proper function.

3.3.2 Prevent operational emissions to atmosphere

Gas fuel operations typically require purging of fuel lines. Ammonia liquid or vapour should not be released to the atmosphere or sea but should instead be collected and treated suitably. Safety functions, such as the lifting of a safety relief valve on a fuel tank, should be rare occurrences and are typically directed to a vent mast.

3.3.3 Gas detection and ventilation

The design should not accept major leaks or any minor leaks that cause gas levels to rise above 25 ppm under normal design ventilation conditions. The ventilation system should be designed with sufficient capacity to be able to maintain the level of gas in the engine room below TLV. This should take into account the density, leak source and dispersion properties of ammonia. The ventilation outlet should lead to a safe place, away from ignition sources or intakes of other systems.

[17] IMO – The International Code of Safety for Ships using Gases or other Low-flashpoint Fuels

A comprehensive study should be carried out to determine the type, number and location of gas detector heads for fuel gas systems. The density of the vapour and the concentration of the expected released gas will influence detector selection and placement.

Gas detection should not be used as an independent prevention barrier in the design of fuel gas systems. It should only be used as a mitigating barrier to monitor for minor leaks.

3.3.4 Safe location of equipment

Gas fuel equipment should be located in the cargo area (hazardous area) as much as possible. If gas fuel equipment is located adjacent to a safe area (non-hazardous area) then access should be through an airlock to ensure adequate separation between a hazardous area and non-hazardous area.

3.3.5 Special requirements for ammonia as a fuel

Special requirements for the carriage of ammonia as a cargo in the IGC Code should fully apply to ammonia as a fuel. This is summarised in IGC Code Chapter 19, *Summary of minimum requirements*, table under:

column f – Toxic vapour detection

column g – Closed gauging

column I	14.4	Personnel protection requirements for individual products
	17.2.1	Materials of construction
	17.12	Ammonia

If there is any interconnection between the fuel system and the cargo system, then the entire cargo system should be compatible with ammonia especially materials of construction 17.2.1 and 17.12.

The above requirements are not exhaustive and additional measures should be considered taking into account the unique properties of ammonia.

3.3.6 Other systems

In spaces and systems where there is the possibility of ammonia presence, eg crankcase, lubrication oil and cooling water system, due consideration should be given to understand the risks and mitigate them appropriately. Measures include detection, monitoring and handling of ammonia in these systems.

3.3.7 Maintenance

The unique properties of ammonia should be considered when determining maintenance intervals and procedures. Where appropriate the design should consider suitable means to purge relevant sections of equipment of ammonia before dismantling. Considerations should include the time taken to isolate and purge the section of machinery before maintenance can be carried out.

3.3.8 Training and procedures

Structured training programmes should be in place to ensure that the crew are aware of the properties of ammonia, the use of safety equipment and the design and safety features of the fuel system and engine.

Clear procedures should be provided to help ensure that equipment is operated in a safe manner. The procedures should highlight the unique steps that should be taken considering the special properties of ammonia.

Annexes

Annex 1 – Glossary of Terms and Abbreviations

ACGIH American Conference of Governmental Industrial Hygienists

C Celsius

ESD Emergency Shutdown

GBS Goal-Based Standards

GHG Greenhouse Gas

IMO International Maritime Organization

LFL Lower Flammable Limit

LNG Liquefied Natural Gas

LPG Liquefied Petroleum Gas

ppm Parts Per Million

TLV Threshold Limit Value (8 hours/day)

Annex 2 – Reference List

- IMO – International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
- IMO – Resolution MEPC.304(72) – Initial IMO Strategy on Reduction of GHG Emissions from Ships
- ACGIH – Threshold Limit Values and Biological Exposure Indices
- SIGTTO – Recommendations for Liquefied Gas Carrier Manifolds
- clarksons.com/home/news-and-insights/2022/an-introduction-to-green-ammonia/
- IMO – MSC.1/Circ.1394/Rev.2 – Generic Guidelines for Developing IMO Goal-Based Standards
- IEC – 60092-502 – Electrical installations in ships – Tankers – Special features
- IMO – The International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code)

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