gas as a marine fuel

Recommendation of Controlled Zones during LNG bunkering.

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Disclaimer

While the advice given in this "Recommendation of Controlled Zones during LNG bunkering" has been developed using the best currently available information, it is intended solely as guidance to be used at the owner's own risk.

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Foreword

The LNG industry has an excellent safety record. This has been achieved because the industry understands the hazards associated with LNG and how these can be managed effectively. As the maritime industry moves towards using LNG as a fuel, it is important that this knowledge is also transferred. In this respect, guidance developed by SGMF plays a key role.

One critical difference between LNG and other maritime fuels is that in the highly unlikely event of an accidental spillage, the hazard can extend some distance from the LNG installation because of the formation of a gas cloud. Controlling the hazard requires an understanding of the extent of the zone that might be affected and the measures that can be taken to reduce risks.

Previously published SGMF guidance for LNG bunkering operations defines a number of zones, most of which do not need quantification in terms of distance. However, we have thought long and hard about how to define the "Safety Zone" – which does need to be quantified.

We understood what we needed: it had to be simple to apply, representative of the hazard, and practicable for the industry. Importantly, it also had to be based on a methodology understood by SGMF. We concluded that explicit quantified risk assessment was not the route to take because, generally, it is not simple to apply, there are significant uncertainties regarding the likelihood of any release, and it is difficult to define a tolerable level of risk.

Instead, we have based the calculated distances on the consequences of an LNG release, particularly vapour dispersion, where there is much less uncertainty. We used single representative release sizes, determined using the best available information combined with engineering judgement. We deliberately use the term "representative" – avoiding the terms "credible" or "maximum credible", the meanings of which are problematic.

This has resulted in the development of a safety distance calculator that can be used by SGMF members for many situations, with the option for more detailed analysis for more complex or sensitive operations,

if required. We believe that, when combined with existing SGMF guidance, it is a significant step forward in promoting safe LNG bunkering operations.

Mike Johnson
DNV GL / Chairman, SGMF WG2 Recommendation of Controlled Zones during LNG bunkering

Summary

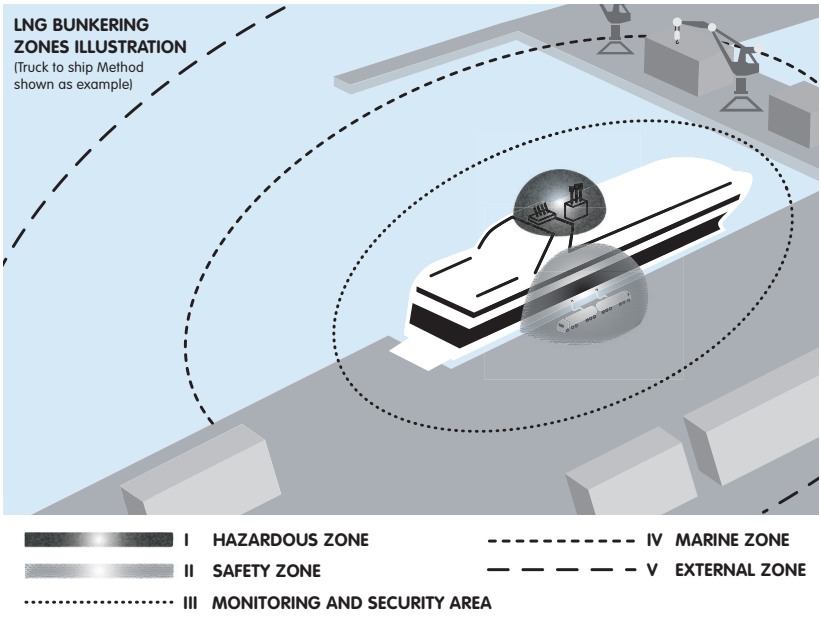
This safety document provides guidance on how to determine the size and location of controlled zones around the bunkering infrastructure of an LNG supplier and gas-receiving ship to facilitate the safe transfer of LNG during bunkering. It specifically looks at how the Safety Zone can be calculated and implemented. It covers only bunkering, the transfer of LNG to a gas-fuelled vessel, and, where relevant, the handling of vapour return.

LNG and natural gas behave differently from traditional fuel oils when released into the air or onto water or land. So safety precautions have to be assessed differently than for traditional bunkering operations. The guidelines address the following operational scenarios:

- ship-to-ship bunkering
- truck-to-ship bunkering
- shore-based terminal-to-ship bunkering

Controlled Zones

Five controlled zones are defined below and shown in the Figure.



1: Hazardous Zone

The Hazardous Zone is a three-dimensional space in which a combustible or explosive atmosphere can be expected to be present frequently enough to require special precautions for the control of potential ignition sources. Hazardous zones are always present but addressed via appropriate design techniques and safety practices.

Hazardous zones must be defined for all components of the LNG bunkering system by their respective owners. These components can include gas-fuelled ships, bunker vessels, road tankers and terminals.

The LNG supplier, or the infrastructure owner on the supplier's behalf, is responsible for checking and confirming the compatibility of the multiple

Hazardous Zones between the infrastructure and the gas-fuelled ship. This check must be performed for each new combination of gas-fuelled vessel, location and bunkering infrastructure configuration. If individual zones do not add up to make an acceptable combined zone, bunkering should not proceed.

2: Safety Zone

The Safety Zone can be defined as the three-dimensional envelope of distances inside which the majority of leak events occur and where, in exceptional circumstances, there is a recognised potential for a leak of natural gas or LNG to harm life or damage equipment/infrastructure.

The zone is temporary by nature, present only during bunkering. It may extend beyond the gas-fuelled ship/LNG road tanker/bunker vessel, interconnecting pipework, and so on, and will be larger than the Hazardous Zone.

The purpose of the Safety Zone is to minimise the likelihood of harm to people and damage to equipment by:

- controlling leaks and spills
- avoiding ignition and a subsequent fire or explosion
- excluding non-essential people (to avoid additional injuries or deaths in the event of an accident)
- protecting essential staff through the use of PPE (to minimise the likelihood of injury or death in the event of an accident)

The Safety Zone should always be under the control of the Person In Charge (PIC). It must therefore lie within the port or another entity that allows the PIC the required degree of control.

The size of the Safety Zone will depend on:

- the design of the LNG bunkering infrastructure/gas-fuelled ship
- the configuration of the LNG transfer system
- the duration, flow-rate and pressure of the potential leak source

- weather conditions and ambient temperature
- the layout of the location where spills could occur

3: Marine Exclusion Zone

The purpose of the Marine Exclusion Zone is to protect the bunkering vessel from other marine traffic, primarily by defining minimum distances and speeds for passing vessels.

Definition of the Marine Exclusion Zone is for each port to decide and implement in port rules, based on specific port and ship studies. All ships and bunker vessels must comply with these rules in the normal way.

4: Monitoring & Security Area

The Monitoring & Security Area is defined as the three-dimensional space inside which activities (including people and vehicle movements) need to be identified and monitored to ensure that they do not affect the safety of the bunkering operation by encroaching on the Safety Zone of the gas-fuelled ship, quayside or LNG bunkering infrastructure. Its primary purpose is to prevent impacts from the actions of people not involved in the bunkering process.

The Monitoring & Security Area will always be larger than the Safety Zone. As the reasons for the Monitoring & Security Area are many and wide-ranging, it is unlikely that it will be possible to define or justify the size of the Monitoring & Security Area by calculation. It should be considered as a contingency on, or factor to, the Safety Zone. This area is only relevant during bunkering.

5: External Zone

In some jurisdictions – for example, much of Europe – an External Zone is required. A port cannot influence how the general public behaves outside the port area so the risk level outside must be kept low. This zone is defined by the level of risk general members of the public can be exposed to, based on local regulatory requirements.

Hose, Piping, Valve and Flange Leaks

SGMF has conducted research to develop a calculation methodology that allows the Safety Zone dimensions to be conservatively estimated – reliably and consistently – for a wide range of bunkering configurations, flow rates and locations.

After extensive consultation with SGMF members and cryogenic industry bodies, SGMF has yet to identify a failure mode where a hose or loading arm rupture, where the failure creates a hole so large that it covers most of the surface area of the hose or breaks the hose in two (also called a guillotine failure) is likely to occur. All the evidence from the industry suggests that hoses fail before rupture, allowing the transfer to be stopped and the hose removed from service and disposed of. The only possibility of a hose or loading arm rupture is from a vessel or road tanker pulling away with the transfer system still attached. The IGF Code (Section 8.4) has a requirement for a breakaway device that will split the loading arm/hose in a controlled manner and keep LNG outflow to a minimum. In the light of this requirement, a hose rupture is not considered in these guidelines.

SGMF has collated a variety of experience (on a confidential basis) from the filling of LNG road tankers and cryogenic gas (liquid nitrogen, liquid oxygen) operations to assess good practice. About five million LNG truck transfers are estimated to have occurred. The findings of this work are that:

- no guillotine failures have been recorded
- hose handling determines hose life; the main cause of failure is fatigue from temperature, pressure and movement cycles, particularly bending
- fatigue failures produce small leaks – at least initially – so they are detectable at an early stage, allowing the hose to be removed from service and destroyed
- small leaks can occur through poor hose management, such as inadequate leak checking, worn couplings damaged gaskets, dirt and debris on flange faces and gaskets, and operator errors and bad habits

There is no reliable information available describing how LNG hoses fail. Using limited experimental work, information from other industries, and reliability assessment work on piping in the offshore oil and gas industry and failure behaviour in rubber LPG/oil hoses, a link between hole size to pipe/hose size has been developed. Given the available information, SGMF estimates that a hole size of 6% of the hose diameter is appropriate. Anecdotal comments from industry experience suggest this is conservative.

If the design of the hose can be demonstrated to give a significant reduction in the likelihood of releases from the hose itself, then releases from the flanges and valves at either end of the hose will dictate the release distance. In this case, the Safety Zone should be based on releases from these locations.

SGMF recommends that the following hole sizes are appropriate for estimating the size of the LNG/gas cloud/pool and therefore the size of the Safety Zone.

Hole sizes used in SGMF's Bunkering Area Safety Information for LNG (BASiL) model

Size	Metal or composite hose	Fitting/gasket/valve, fixed piping or hard arm
2 inch / 50 mm	3 mm	3 mm
3 inch / 75 mm	4.5 mm	4 mm
4 inch / 100 mm	6 mm	4 mm
6 inch / 150 mm	9 mm	4 mm
8 inch / 200 mm	12 mm	5 mm
10 inch / 250 mm	15 mm	5 mm

These hole sizes are based on the following criteria:

- the Safety Zone is under the control of the PIC of the bunkering operation; when the PIC or another operative identifies a leak, the system will be shut down to limit the consequences of the incident
- management systems have been developed and implemented to ensure that damaged hoses are identified prior to use through inspection
- if a leak is found during inspection or during the bunkering operation, and cannot immediately be sealed, the hose should be immediately removed and destroyed
- the scenario of a ship and bunkering facility (vessel or road tanker) moving away from each other is controlled both by the procedures and requirements in the IGF Code for a dry-break coupling
- the potential for other impact damage is controlled by appropriate procedures, particularly in relation to allowable operations being conducted simultaneously with LNG bunkering (SIMOPs)

Leak Behaviour

Gas clouds formed by leaking LNG can travel significant distances before they ignite. The Safety Zone is defined by the maximum distance the gas evaporating from a pool of LNG or from a pressurised LNG release can subsequently be ignited, based on the hole sizes above. On this basis, the delayed ignition of a gas cloud causing a flash fire is argued to be the event that defines the safety distance.

Many factors determine how far a gas cloud will spread and remain within flammable limits. The parameters considered by SGMF include:

- LNG transfer flow rate, temperature and pressure
- hole size
- different orientations of leaks – vertically, horizontally and downwards

- various climatic conditions around wind speed, climatic stability, ambient temperature and humidity
- a range of LNG compositions and physical properties
- different geometries/topographies for releases over land and water and at different elevations
- various durations of release (depending on the type of emergency shut-down system)

Importantly, these parameters interact with each other. This means that some effects must be considered together, which increases the complexity of the model and results in the need to consider some 1.4 million data points for eight parameters.

Safety Zone Distance Calculations

SGMF has created a model called Bunkering Area Safety Information for LNG (BASiL) to estimate the size of the Safety Zone based on the extent of the gas cloud to 100% LFL. The BASiL model is available on SGMF's website (www.sgmf.info).

BASiL estimates several distances to LFL which, when combined together in the model, produce a three-dimensional envelope defining the Safety Zone.

Reviews of accuracy against the dispersion models have shown that the vast majority of the BASiL calculations result in safety distances within ±10% of the actual values.

Contents

Abbreviations and Definitions

ADN – Accord Européen Relatif au Transport International des Marchandises Dangereuses par Voies de Navigation Intérieures. (European Agreement Concerning the International Carriage of Dangerous Goods by Inland Waterways)

ADR – Accord Européen Relatif au Transport International des Marchandises Dangereuses par Route. (European Agreement Concerning the International Carriage of Dangerous Goods by Road)

ALARP/ALARA – As Low As Reasonably Practicable/ Achievable without incurring excessive costs

Alkane – A member of the family of saturated hydrocarbon compounds consisting solely of carbon and hydrogen atoms with all bonds between them consisting of single bonds. The most common are methane, ethane, propane and butane

ATEX – Appareils destinés à être utilisés en ATmosphères EXplosibles. (Equipment destined for use in potentially explosive atmospheres.) The European Union ATEX Directive 2014/34/ EU covers equipment and protective systems intended for use in potentially explosive atmospheres

Atmospheric stability – A measure of the atmosphere's tendency to encourage or deter vertical motion

Auto-ignition temperature – The minimum temperature required to ignite a gas or vapour in air in the absence of a spark or flame

bara – Pressure stated as absolute pressure, meaning the pressure zero-referenced to that of a perfect vacuum

barg – Pressure stated as gauge pressure, meaning the pressure zero-referenced to ambient atmospheric pressure

BAT/BACT – Best Available Technology/ Best Available Control Technology. The environmental equivalent of ALARP

BOG – Boil-Off Gas. The vapour created by evaporation from the surface of a volume of LNG

CCNR – Central Commission for Navigation of the Rhine. The body that controls regulations on the major international inland waterways of Europe

Competent Authority – Any national, regional or local authority or other authorities empowered, alone or together, to act as the regulatory body on LNG bunkering

Controlled Zones – Areas extending from the bunkering equipment, pipework connections, and emergency vent locations that have restrictions in place continuously or during bunkering

Dry Breakaway Coupling – A safety coupling located in the LNG transfer system which separates at a predetermined break-load. Each separated section contains a self-closing shut-off valve, which seals automatically to prevent any spill during a breakaway. Also known as a dry disconnect coupling

Dry Disconnect Coupling – See Dry Break-away Coupling above

Emergency Release Coupling (ERC) – A coupling installed on LNG and vapour lines, as a component of the Emergency Release System (ERS), to ensure the quick physical disconnection of the transfer system from the unit to which it is connected. It is designed to prevent damage to loading/unloading equipment in the event that the transfer system's operational envelope and/or parameters are exceeded beyond a predetermined point

Emergency Relief System – A system that relieves the pressure within a pipe or storage tank by allowing a fluid to be transferred to another location, normally the atmosphere, when the pressure exceeds a set limit. Relief to atmosphere is only allowed under emergency scenarios where equipment may be damaged

EN – European (Standard) Norm

ESD – Emergency Shut-Down. A control system and associated components that when activated stop operations in a controlled manner and return the system to a safe state.

An ESD system may have several sequential stages, with the operation of each stage dependent on the potential consequences of the situation. During bunkering these stages are commonly designated ESD-1 and ESD-2:

- ESD-1 – where transfer of LNG to the bunkering vessel is stopped

- ESD-2 – where the transfer system is disconnected from the bunkering ship

In some ship types there may be additional definitions of the ESD system but these are outside the scope of this document

External Zone – The distance to a defined risk level, frequently places where the public may be present, required by some regulatory regimes

Flag state – The organisation that enforces international regulations, including those relating to safety and pollution prevention, over commercial vessels registered under its flag

Flammable range – The range of hydrocarbon gas concentrations in air between the Lower and Upper Flammable Limits. Mixtures within this range are capable of being ignited and burnt

Flash point – The lowest temperature at which a liquid gives off sufficient vapour to form a flammable mixture with air above the liquid surface

GIIGNL – Groupe International des Importateurs de Gaz Naturel Liquéfié. The industry group made up of the world's main LNG importers

Hazardous Zone – The three-dimensional space where there is a probability that a flammable atmosphere is present. Defined by national regulation and both the IGF and IGC codes

HAZID – HAZard IDentification. 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 to be addressed and managed

IACS – The International Association of Classification Societies

IAPH – The International Association of Ports and Harbours

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

IGF Code – The International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels

IMDG – The IMO International Maritime Dangerous Goods Code

IMO – The International Maritime Organization. The United Nation's maritime regulatory body

ISM – The International Safety Management Code published by the IMO

ISPS – The International Ship and Port Security Code

ISO – The International Organization for Standardisation. An international standard - setting body composed of representatives from various national standards organisations

ISO Container – A container manufactured according to specifications from ISO which define its size, strength, and durability requirements

LFL/LEL – Lower Flammable Limit/Lower Explosive Limit. The low end of the concentration range over which a flammable mixture of gas and vapour in air can ignite at a given temperature and pressure (see also UFL/UEL)

LNG – Liquefied Natural Gas. Natural gas that has been cooled to the point where it is liquid at stated pressure. GNL in French, Spanish and Italian (French Gaz Naturel Liquéfié)

Marine Exclusion Zone – A zone of sufficient size to prevent passing shipping from impacting the LNG transfer operation

Monitoring & Security Area – An area around the LNG transfer equipment that needs to be monitored as a precautionary measure to prevent interference with the LNG transfer operation

Natural gas (NG) – A mixture of hydrocarbon gases, mostly methane, used as a fuel or chemical feedstock. Also used to refer to regasified LNG

NFPA – The National Fire Protection Association. A US-based standards body for fire, electrical and related hazards

NGO – Non-Governmental Organisation. A not-for-profit organisation independent of governments or international governmental organisations

OCIMF – The Oil Companies

International Marine Forum. An association representing operators of oil tankers and terminals, dealing with safety and environmental issues and specifically associated with mooring and berthing guidelines

OPITO – Offshore Petroleum Industry Training Organisation. The offshore oil and gas industry's focal point for skills, training and workforce development

PIC – Person In Charge. The person responsible for the management of an operation such as bunkering. There may be several PICs, each responsible for an operation

POAC – Person in Overall Control. The person responsible for the management of the LNG bunkering process and any SIMOPs being undertaken through one or more PICs

Port authority – a governmental, regional or local, usually public body that develops and manages port safety, port infrastructure and other transportation related infrastructure

Port/terminal owner – a company which owns a terminal or port in a wider port area

Port/terminal operator – a company which is operating a terminal within a wider port area

PPE – Personal Protective Equipment

QRA – Quantitative Risk Assessment. A formalised, numerical risk assessment method for calculating a risk level for comparison with defined risk criteria

Risk – A combination of the likelihood of an event and the consequences if the event occurs

Safety Zone – The three-dimensional envelope of distances inside which the majority of leak events occur and where, in exceptional circumstances, there is a recognised potential to harm life or damage equipment/ infrastructure in the event of a leak of gas and/or LNG

SGMF – The Society for Gas as a Marine Fuel. An association for companies involved in the use of LNG as a marine fuel

SIGTTO – The Society of International Gas Tanker and Terminal Operators. An organisation representing operators of gas tankers and import and export terminals, covering all liquefied gases in bulk

SIMOP – SIMultaneous OPeration. Defined in this document as "LNG bunkering plus one, or more, other independent operations conducted together within the control of the PIC(s), where the operations may impact, or increase the impacts on personnel safety, ship integrity and/or the environment"

SMS – Safety Management System, as defined by the ISM Code

Surface roughness – The size of obstacles that cause or increase turbulence along the bottom surface of a dispersing gas plume which affect the degree of mixing between the gas and the surrounding air

Thermal relief valves (TRV) – Used to relieve pressure caused by thermal expansion of process fluids in vessels and long lengths of pipework

UFL/UEL – Upper Flammable Limit/Upper Explosive Limit. The high end of the concentration range over which a flammable mixture of gas and vapour in air can ignite at a given temperature and pressure (see also LFL/LEL)

Vapour return line – A connection between the bunkering facility and the receiving ship that allows excess vapour generated during the bunkering operation to be returned to the bunkering facility, removing 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

1. Purpose and Scope

This document provides guidance on how to determine the size and location of controlled zones, particularly the Safety Zone, around the bunkering infrastructure of an LNG supplier and a gas-receiving ship to facilitate the safe transfer of LNG during bunkering operations. This safety guide considers only bunkering, the transfer of LNG to a gas-fuelled vessel and, where relevant, the handling of vapour return. It does not cover the use of LNG or vaporised natural gas on board the gas-fuelled vessel during normal operations.

Moreover, this document is specifically about LNG. Many of the comments are equally appropriate to other fuels allowed by the IGF Code. However, each fuel has its own specialities – for example, the cryogenic nature of LNG or the toxic hazard associated with methanol – and therefore this guidance should only be used in its entirety for LNG.

At this early stage of development in the LNG bunkering industry, risks cannot be directly compared with long-established conventional bunkering. So risk assessment and mitigation needs to have a much higher profile. If the industry continues to grow safely and successfully, these additional practices may have less emphasis in future years.

LNG and natural gas behave differently from traditional fuel oils when released into the air or onto water or land. This means that safety precautions have to be assessed differently than for traditional bunkering operations. This guide provides an overview of how the controlled zones around LNG bunkering operations can be defined. It specifically looks at how the Safety Zone can be calculated and implemented.

This publication is a technical book which primarily provides the necessary information for individuals and organisations to start developing operational and safety guidance. The book does not provide rules or definitive safety distances but the framework to base more detailed rules and procedures on.

Parts of these guidelines talk about mitigation for LNG/gas hazards. This does not include emergency response (including fire fighting). How the emergency services approach a LNG/gas scenario is independent of the

precautionary safety distances presented here. Once a hazardous event has occurred, the risk assessments discussed here become irrelevant and emergency service protocols take over. Guidance for the emergency services is being developed or has been covered elsewhere by other industry bodies (such as SIGTTO, CCNR and OPITO).

These guidelines address the following operational scenarios:

- ship-to-ship bunkering
- truck-to-ship bunkering
- shore-based terminal-to-ship bunkering

More details of each are provided in SGMF's publication "FR07-1 gas as a marine fuel, safety guidelines, bunkering". Portable LNG tanks – such as ISO containers used as fuel tanks – are outside the scope of this guidance.

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