The European Union’s TEN-T programe supporting

LNG Masterplan for Rhine-Main-Danube

Sub-activity 2.4 Technical Evidence & Safety & Risk Assessment

Deliverable 2.4.4
Emergency and incident response study
(Havenbedrijf Rotterdam N.V.)

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LNG MASTERPLAN FOR RHINE-MAIN-DANUBE

D 2.4.4 Emergency and incident response study

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Introductory notes

The emergency and incident response study was subcontracted to a consortium formed by Falck RISC and the Unified Fire Department (Gezamenlijke Brandweer) after the tendering procedure. The final deliverable was approved by involved beneficiaries and contractor(s) in December 2014.

PREFACE

The LNG Masterplan aims to promote LNG as a fuel and cargo for the inland navigation industry. It also formulates and enforces the necessary (safety) regulations for the use and transport of LNG.

The LNG Masterplan is supported by a forty million Euro European Commission grant through the TEN-T Programme and is implemented by a consortium of thirty-three companies and organisations from the public and private sectors from twelve European member states. The project is supervised and coordinated by Pro Danube Management GmbH and the Port of Rotterdam Authority.

The Masterplan will also drive the construction and pilot deployment of several LNG bunker barges, LNG bunker stations, LNG fuelled push-boats, a containership and tankers. The containership Eiger Nordwand of Danser Group and the LNG propelled tanker Sirocco of Chemgas are already sailing.

The Rhine Port Group, which consists of the Port of Rotterdam Authority together with the Port of Antwerp, the Port of Mannheim, the Port of Strasbourg and the Port of Switzerland has asked the consulting consortium consisting of Falck RISC and Unified Fire Department Rotterdam to provide guidelines and recommendations for emergency response organisations.

The target group is the inland navigation sector and incident and emergency control which operate in this field. This study supplies an overview of existing knowledge on emergency and incident response and newly developed guidelines regarding LNG incident response along the Rhine Corridor.

This document is the final result of half a year research by the project team.

A first word of thanks goes to project management of Port of Rotterdam for their ongoing engagement and orderly coordination. A second word of thanks goes to the addressed contact persons of the Port Authorities within the Rhine Port Group who took the time and effort to fill in and return the questionnaire. Without their help the project team would not have been able to describe how LNG, the operational preparedness on (unforeseen) scenarios and the emergency response in the ports along the Rhine Corridor has been implemented so far.

On behalf of Rhine Port Group, we invite you to read this document. We are confident that by reading it you will gather new knowledge and insights about LNG emergency and incident response along the Rhine Corridor.

You will be informed on:

- the current state of emergency response along the Rhine Corridor
- the latest developments in emergency and incident guidelines
- the development of tools for operators and port authorities to manage credible scenarios caused by man or technical failures.

Best regards,

Robbert van der Veen	Jan Waals
Director Falck RISC	*Director Unified Fire Department*

Rotterdam, December 2014.

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LIST OF ABBREVIATIONS

ADN	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
BLEVE	Boiling Liquid Expanding Vapour Explosion
BOG	Boil Off Gas
CNG	Compressed Natural Gas
CVCE	Confined Vapour Cloud Explosion
DF	Duel Fuel
ESD	Emergency Shut Down
EPA	Environmental Protection Agency
FCP	Forward Control Point
GVU	Gas Valve Unit
IGC code	The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IMO	International Maritime organisation
LFL	Lower Flammable Limit
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MLI	Multi-Layer Insulation
MDO	Marine Diesel OIL
MSDS	Material Safety Data Sheet
PBU	Pressure Build-up Unit
PPE	Personal Protective Equipment
PPM	Parts Per Million
RPT	Rapid Phase Transition
UVCE	Unconfined Vapour Cloud Explosion
UFL	Upper Flammable Limit
UN	United Nations

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1. INTRODUCTION

1.1 MOTIVATION

The Port of Rotterdam Authority (Port Authority) together with the Port of Antwerp, the Port of Mannheim, the Port of Strasbourg and the Port of Switzerland (Rhine Port Group) have commissioned a study on emergency and incident response for LNG on the inland waterways as part of the LNG Master plan for Rhine-Main-Danube.

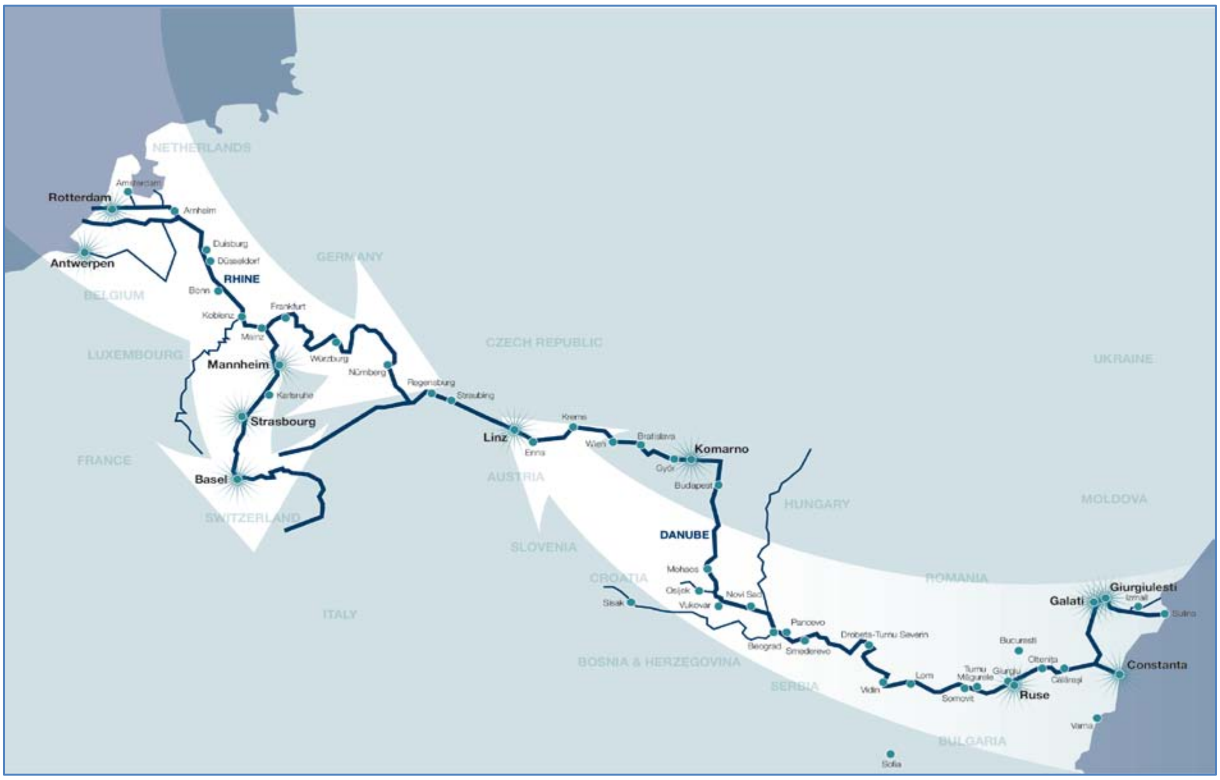


Figure 1 Areas of LNG Master plan for Rhine/Meuse-Main-Danube

The LNG Master plan aims to create a platform for the cooperation of authorities and industry stakeholders with the purpose of facilitating the creation of a harmonized European regulatory framework for LNG as fuel and cargo in inland navigation and promoting the introduction of LNG as a fuel and cargo for inland shipping.

It delivers technical concepts for new and retrofitted vessels being propelled by LNG and transporting LNG as well as a significant number of pilot deployments of vessels and terminals. It also develops a comprehensive strategy together with a detailed roadmap for the implementation of LNG in line with the EU transport/energy/environmental policy goals and actions.

The LNG Master plan not only considers inland navigation to be a pioneer market for LNG as a transport fuel but also a facilitator in delivering LNG cost-effectively from the seaports to the customers (fuel & energy) in major industrial areas along the inland waterways. This promotes a wide-scale development of LNG as a fuel and as an energy source.

LNG is considered to be an important opportunity for the inland waterway transport sector, but it certainly will not be a remedy for all the structural and economic problems in Inland Water Transport (ITW).

All the work will be based on a realistic and integrated European approach. One of the visions of the LNG Master plan is that the inland ports on the Rhine-Main-Danube axis will become key distribution centres for LNG.

Inland terminals will function as satellites to the interior, enabling LNG to reach other pioneer markets like the public (transport) sector and the heavy duty transport industry (buses, garbage collection trucks, city logistics) and the energy industry.

1.2 AIMS AND OBJECTIVES

The aim of the study is to explore the existing knowledge regarding the transportation of LNG and the use of LNG powered vessels on the waterways as well as to determine the possible scenarios involving an LNG leak that an incident response team could face.

Incident response is defined as the response required by local authorities, such as fire brigade, police, ambulance and harbour/river authorities, to deal with situations which have escalated outside the capability of initial responders, such as the ship's crew, operators etc.

The information gained as a result of the study will be used to increase awareness in handling such incidents, make recommendations concerning the resources required for a response and provide guidelines for the training required for incident response.

1.3 SCOPE

1.3.1 GENERAL

The study provides an overall picture outlining the incidents that could emerge in dealing with LNG in inland navigation and how to respond to them. The study focuses on:

- Development of spill, emission and escalation scenarios for small scale LNG activities
- Development of incident response scenarios for small scale LNG
- Development of guidelines for incident preparedness
- Development of guidelines for education and training on incident response LNG
- Knowledge dissemination and emergency advice

Much is already known regarding LNG specifically in shipping; however, that is relevant to sea-going transportation on a bulk scale – the emphasis of this study is "small scale", which is reflected in the reduced quantities and limitations of inland shipping.

1.3.2 DELIVERABLES

The study is split in 3 phases.

PART 1: *Overview of existing knowledge of LNG incident response, training and education along the Rhine corridor.*

This is achieved according to a desk study method and the deliverables are:

- Overview of existing knowledge and existing guidelines for incident response on small-scale LNG along the Rhine corridor for inland navigation;
- Overview of existing emission and escalation scenarios for LNG as a fuel and LNG as a cargo on small-scale LNG along the Rhine corridor for inland navigation.
- Emergency and incident response scenarios on small-scale LNG along the Rhine corridor for inland navigation. Scenarios should include all incidents which could occur with an LNG fuelled vessel and a vessel which has LNG as cargo.
- Incidents and emergencies should be presented in a matrix sorted row wise and column wise, displaying the types of LNG fuelled vessels and vessels sailing with LNG as cargo.
- Overview including an identification of gaps in the response equipment necessary for emergency response on small-scale LNG along the Rhine corridor for inland navigation.

PART 2: *Development of guidelines for incident preparedness and for education and training on incident response for small-scale LNG in inland navigation.*

The deliverables are:

- Development of incident preparedness guidelines for small-scale LNG in inland navigation. These guidelines are included in an enlarged version of the matrix in part one.
- Development of guidelines for education and training on incident response applied to small-scale LNG in inland navigation. Where training is necessary, these guidelines describe the requirements for training for each of the scenarios.

PART 3: *Advice and strategic approach on how findings of phases 1 and 2 shall be communicated to the stakeholders in need of this information.*

An extra column describing the various options as how to publish or communicate the details to the relevant parties is the deliverable.

These deliverables are combined in this final document: ‘Guidelines and recommendations for Emergency Response Organisations’.

PART 1 OVERVIEW OF EXISTING KNOWLEDGE

LNG INCIDENT RESPONSE TRAINING AND EDUCATION

ALONG THE RHINE CORRIDOR

2 EXISTING TECHNOLOGY

2.1 LNG PROPELLED VESSELS

2.1.1 LNG AS FUEL

2.1.1.1 INTRODUCTION

Liquefied Natural Gas used for the propulsion systems on LNG carriers has been common technology for decades. The safety record for the loading/unloading of such vessels and the use of boil-off gas for propulsion systems is very good. In recent years, experience in this technology has been gaining ground in Norway where small ships have been equipped with LNG propulsion, e. g. ferries and offshore supply vessels.

Liquefied Natural Gas will also be used as fuel for the inland waterway vessels. Pursuant to the ADN Regulations, the tanker vessel “MTS Argonon” is the first ship on inland waterways that is authorised to use Liquefied Natural Gas (LNG) as fuel for the propulsion installation, subject to the condition that the vessel fully complies with the regulations of the ADN, except for the following:

Both marine diesel oil and LNG will be used for the vessels’ propulsion installation. The flashpoint of LNG, however, is below 55 degrees Celsius, as prescribed in the ADN regulations. A HAZID assessment has been carried out by Lloyd’s Register to determine the safety of the system and to adopt the measures to be taken to have a similar safety level as for diesel-fuelled vessels.

2.1.1.2 LNG VERSUS MDO AS FUEL

Liquefied Natural Gas is a mixture of various hydrocarbons, with a very high percentage of methane (generally more than 91%). Its actual composition is variable depending on the composition of the original natural gas and its liquefaction process.

The LNG composition is likely to change in time ("ageing"). Ageing is the tendency of the lighter components of the LNG mixture to vaporize before the heavy components. In other words, methane will be the first component to vaporize, leaving the higher fractions.

There are two main drivers for considering LNG as a fuel for marine propulsion systems. The first relates to air pollution emissions legislation and the second to the availability and price uncertainty of liquid fuels in the future. LNG is quite different from the traditional MDO and these differences must be well understood when LNG is considered for vessel propulsion:

- LNG is stored at very low temperature (approx. -162 °C)
- Any contact with carbon steel will lead to brittle fractures
- Skin contact will result in severe burn injuries
- LNG is a constantly boiling liquid
- The LNG is kept stable by constantly boiling off the cargo
- During a cargo transfer, excessive BOG is generated and must be handled
- Highly flammable
- Hazardous areas are to be determined and classified

- LNG has approximately 50% of energy density of MDO therefore requires twice the bunkering capacity to achieve the same range
- he LNG is a clean fuel and its introduction has clear benefits in reducing pollution on inland waterways. Table 1 (below) demonstrates the emissions savings with gas propulsion systems compared to conventional MDO engines

No.	Characteristics	MDO engine	LNG engine	Dual-fuel engine
1	Thermal efficiency	38%	50%	Gas mode: 47% Diesel mode: 38%
2	CO_2 emissions	NO	25 - 30%	Gas mode: 30% Diesel mode: NO
3	NO_x emissions	NO	85%	Gas mode: 85% Diesel mode: NO
4	SO_x emissions	NO	100%	Gas mode: 100% Diesel mode: NO
5	Particles emission reduction	NO	100%	Gas mode: 47% Diesel mode: NO
6	Fuel flexibility	NO	NO	YES

Table 1– The difference in air emission reductions between LNG, diesel fuel and dual-fuel powered engines.

2.1.1.3 DUAL-FUEL SYSTEM

Dual-fuel vessels, also known as bi-fuel, are vessels with multi-fuel engines capable of running on two fuels: an internal combustion engine with one fuel, such as diesel, and an alternative fuel, such as natural gas (CNG).

The two fuels are stored in separate tanks and the engine can run either on one fuel at a time or, in some cases, both fuels are used in unison. Dual-fuel vessels have the capability to switch back and forth from diesel to the other fuel, manually or automatically.

The design of LNG bunker tanks can be the same as the standard designs normally used for the cargo tanks of the LNG carriers.

2.1.2 LNG DUAL-FUEL ENGINE TECHNOLOGY

The dual-fuel diesel engine can operator in either ‘gas mode’ or ‘diesel mode’ or both simultaneously.

<u>Gas mode;</u>
The engine runs with a fuel supply at 80-95 % NG and 5-20% MDO. The engine can automatically and instantly switch to diesel operation during an alarm and/or emergency situation. During operation, it is possible to transfer the engine to diesel operation and any load on request.

<u>Diesel mode;</u>
The engine runs on 100% MDO and is operated as an ordinary diesel engine. During operation, it is possible to transfer the engine to gas mode at any load below 80% power. The MDO fuel injection of the engine will always be in operation.

2.1.3 THE PROPULSION SYSTEM

Mechanical propulsion systems generally consist of a motor or engine turning a propeller. In addition to traditional fixed and controllable pitch propellers, there are many specialized variations, such as contra-rotating and nozzle-style propellers.

Most vessels have a single propeller, but some larger inland vessels may have up to two propellers supplemented with transverse thrusters for manoeuvring at ports.

The propeller is connected to the main engine via a propeller shaft and, in medium and high-speed engines, a reduction gearbox. Some modern vessels have a fuel-electric power train in which the propeller is turned by an electric motor powered by the ship's generators.

There are several types of fuel-powered vessel propulsion systems;

Conventional direct propulsion by gas (boil-off gas or vaporised LNG) or a dual-fuel engine

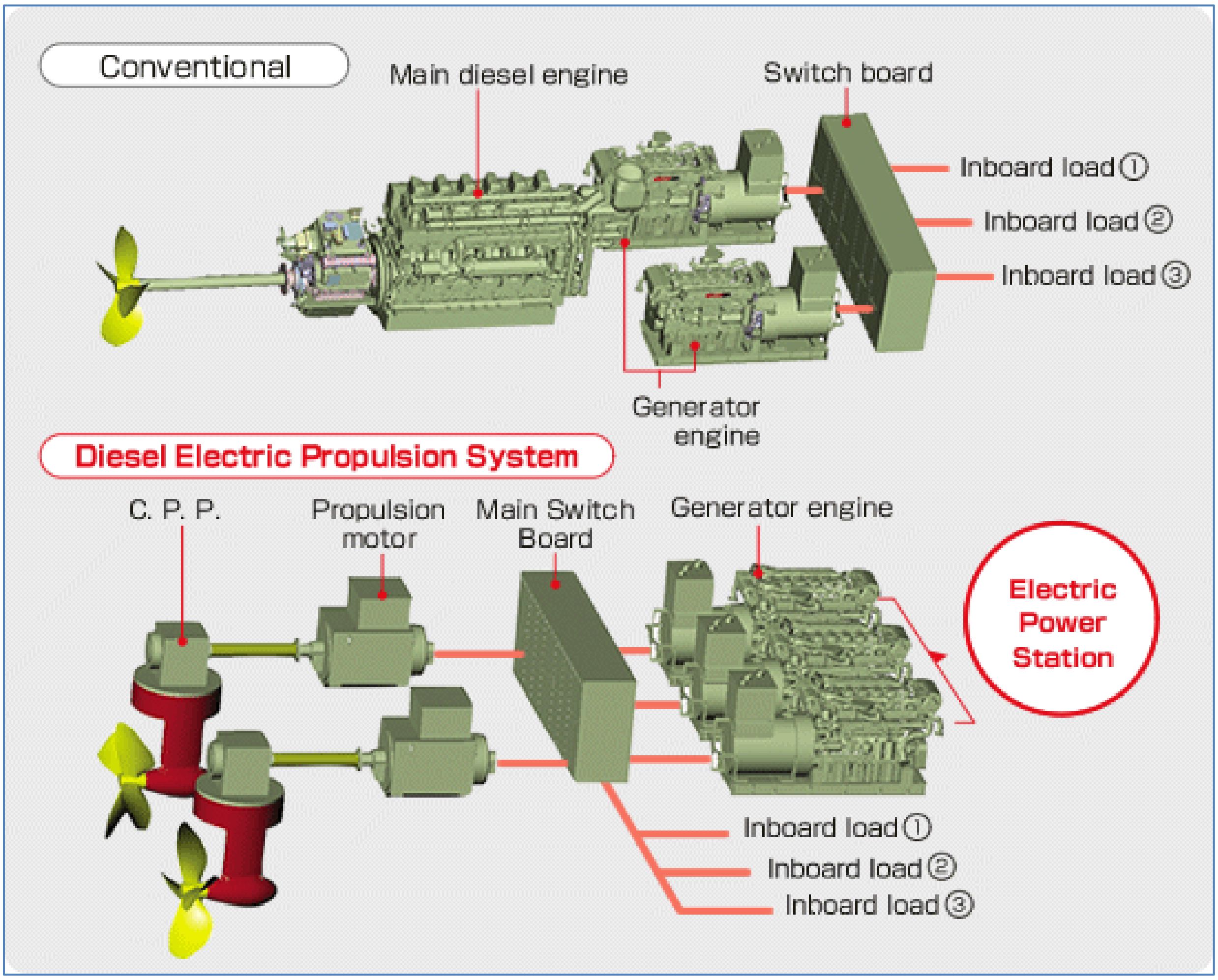


Figure 2 Overview of conventional and diesel electric propulsion systems

Indirect gas or dual-fuel / electric propulsion system with an electric generator and electrically powered propulsion (hybrid).

There are three hybrid configurations (with many variations), combustion engine/electric, serial hybrid & parallel hybrid.

LNG-Diesel/Electric

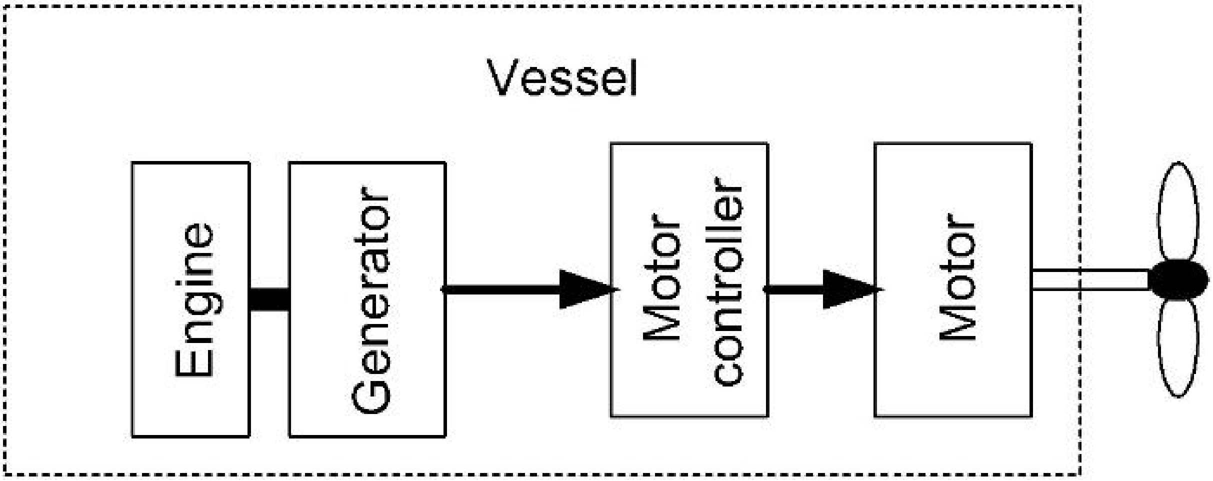


Figure 3 Configuration of an LNG – diesel/electric propulsion system

The combustion engine (gas, diesel or dual-fuel) is connected directly to an electric generator. From this point on, the power in the system is transferred electrically to the propeller shaft via a motor controller and electric motor.

The system may have multiple generators and multiple motors connected to a common electrical bus. It is used in diesel/electric trains, for instance, and the LNG/electric powered inland vessel ‘Greenstream’. By strict definition, this is not a hybrid since there is no electric storage of energy.

Figure 4 LNG/electric powered tanker. Source: Shell.

Serial Hybrid

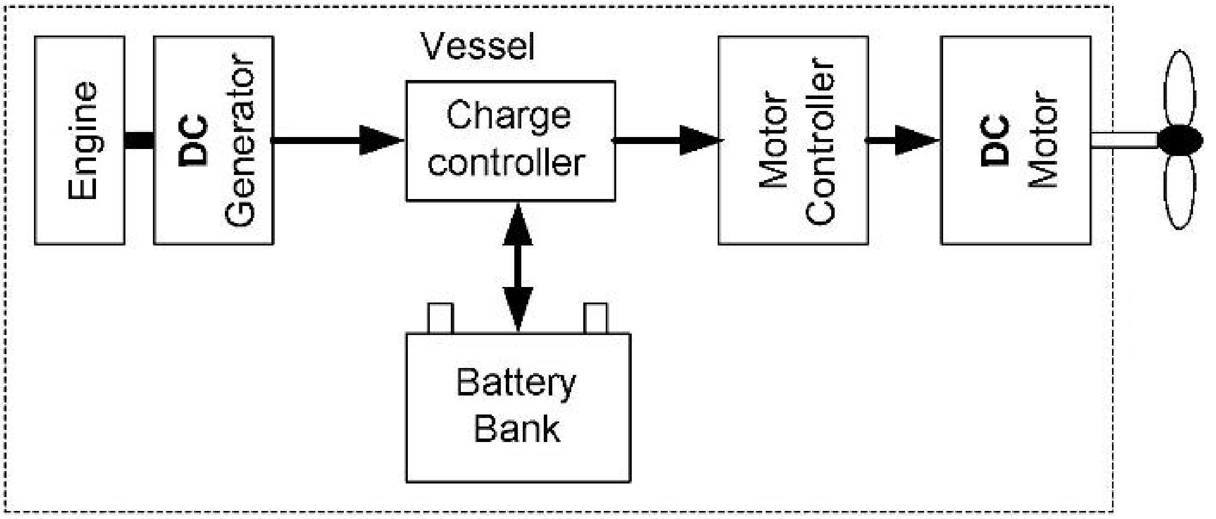


Figure 5 Serial engine configuration

The serial hybrid is similar to the LNG-diesel/electric in that it breaks the mechanical connection between the engine and propeller shaft. However, a battery bank is also connected to the common electric power bus. In this system, an operator can stop the engine and use the stored energy in the battery bank.

With large batteries, the ship can have long periods of electric propulsion (and/or power on-board electrical appliances) without resorting to the generator.

Parallel Hybrid

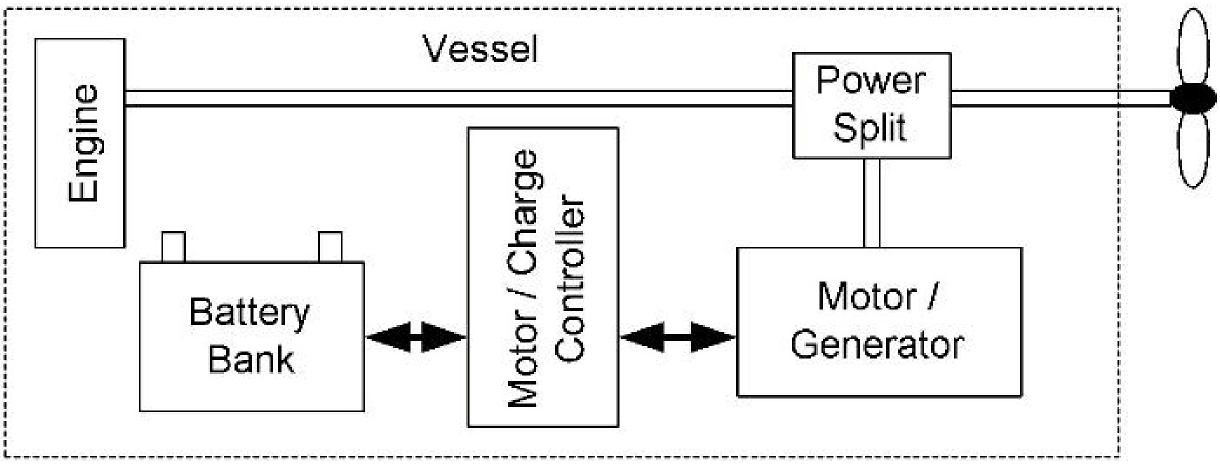


Figure 6 Parallel engine configuration

A parallel hybrid maintains the mechanical connection between the engine and propeller shaft. As its name implies the electric motor acts on the drive shaft in parallel with the engine.

The power split is a mechanical device that allows transfer of power between its connections. The operator can drive the propeller directly from the engine or from the electric motor, or from both.

The operator can also disconnect the propeller for a stand-alone generator function. During regeneration the engine is disconnected.

Figure 7 Study model of the Tonbo solar electric ferry from Eco Marine Power

2.1.4 LNG FUEL STORAGE

LNG fuel is stored in independent LNG fuel tanks. The volume of the tanks will be dependent on the range, function and the type of the ship. The expected LNG fuel tank volume will be between 40 – 160 m³ for inland shipping vessels. The LNG fuel tanks are placed on deck or below deck.

The design of the LNG fuel tanks for a dual-fuel vessel other than a gas carrier may adopt the same standard specification designs normally used for the fuel tanks of seagoing LNG carriers. These systems are shown in the following table, titled 'IMO classification of LNG vessels';

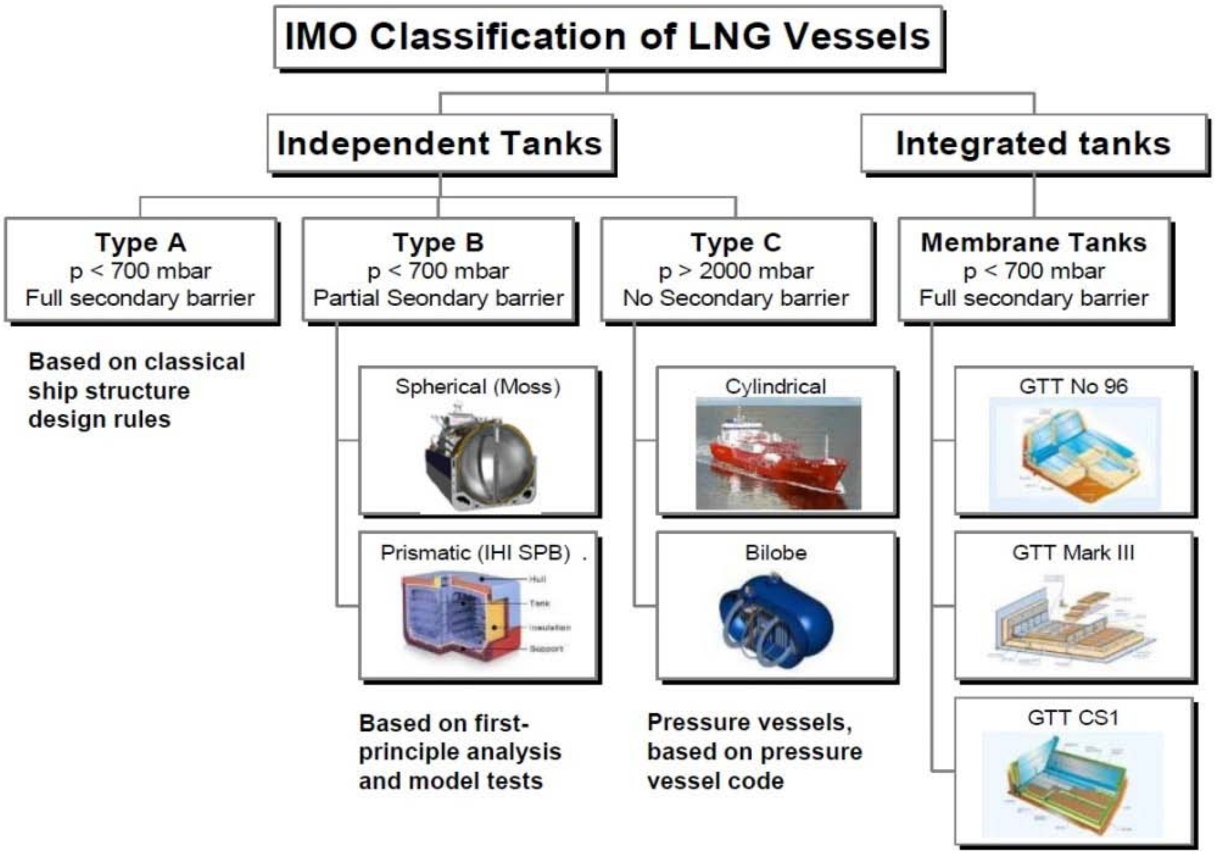


Figure 8 IMO classification of LNG vessels

According to the current IMO Guidelines, the LNG fuel tanks have to be selected from among the “Independent Types A, B, or C”. The LNG fuel tanks are designed according to type C requirements. Type C tanks have several advantages, such as:

- The IGC Code does not require secondary barriers for this containment system.
- Small and medium tanks can be designed for vacuum insulation, saving insulation material and increasing the effectiveness of the insulation.
- Easy installation, as the tank is supported by just two appropriately shaped saddles.
- Possibility to design the tanks for high pressure, which is advantageous for handling boil-off and for operation.
- It is suitable for installation on open decks.

The pressurized fuel storage tank is cylindrically shaped with dished ends. The tank will be designed in accordance with the IMO IGC Code, the “International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk”, and EN 13458-2 "Cryogenic vessels. Static vacuum insulated vessels".

LNG vacuum tanks are insulated with perlite/vacuum. The tank consists of a stainless steel inner vessel, which is designed for internal pressure, and an outer vessel that acts as a secondary barrier. The outer vessel can be made of either stainless steel or carbon steel.

- Typical tank design: double wall type C
- Capacity range from 40-750 m³
- Austenitic stainless steel or 9% Ni steel
- Outer tank: function of secondary barrier
- Perlite / vacuum insulation or optional Multi-Layer Insulation (MLI) / vacuum
- Class acceptance of bottom pipe connection
- Tank connection directly attached

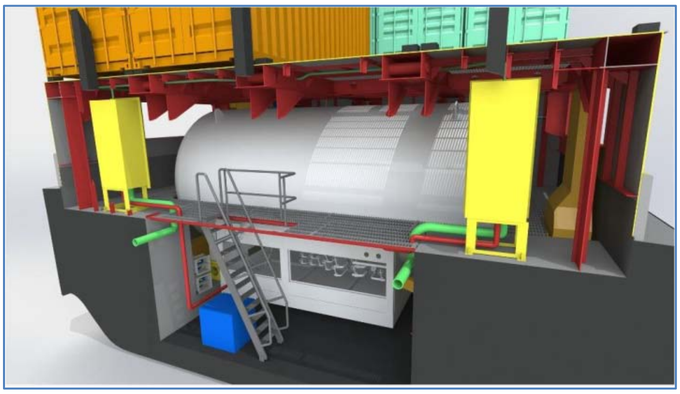
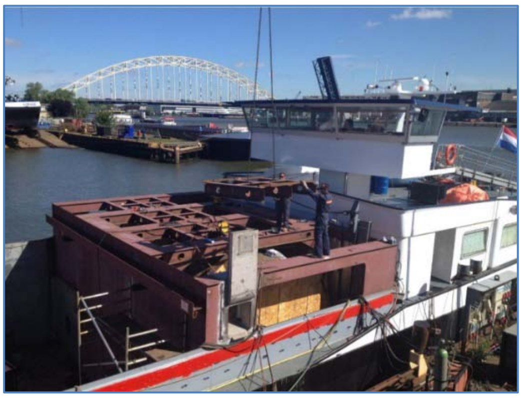



Figure 9 Eiger-Norwand LNG tank below deck. Source: Danser.

2.1.5 REQUIREMENTS OF STORAGE TANKS

2.1.5.1 REQUIREMENTS FOR THE LOCATION OF AN LNG FUEL TANK (C-CLASS)

Based on the IGC-code (document BLG 15/Inf.2):

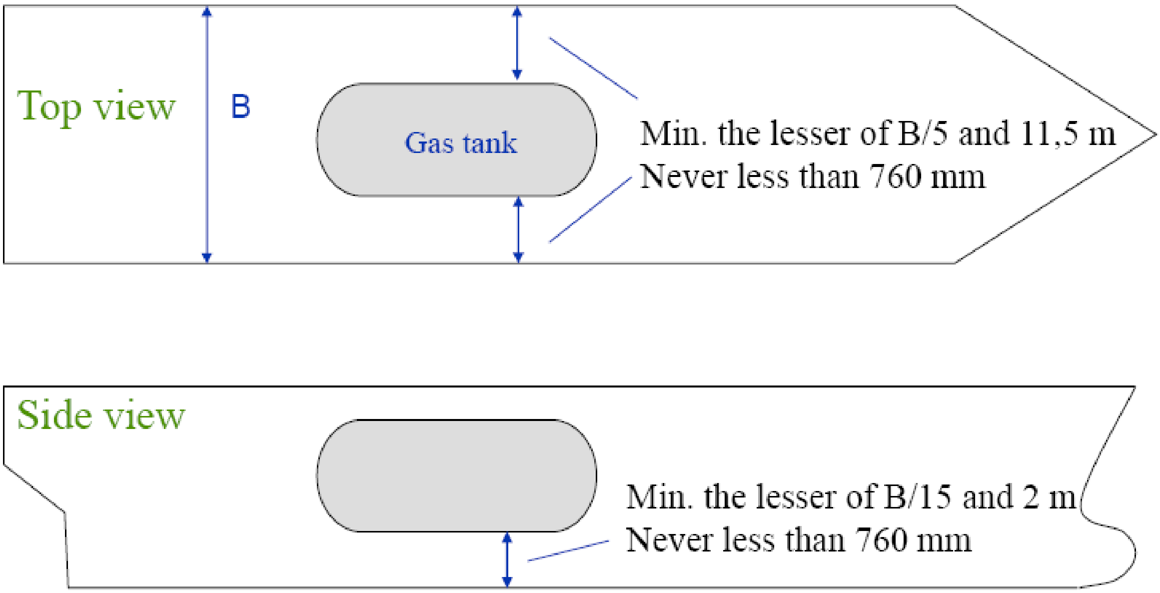


Figure 10 Diagram tank configuration. Source: DNV GL

2.1.5.2 REQUIREMENTS FOR GAS STORAGE TANKS ON OPEN DECK:

Requirements are:

- Located B/5 from side shell.
- On ships other than passenger ships, tanks may be located closer, depending on tank volume, from 0.8 - 2.0 m but never less than 760 mm.
- Stainless steel drip trays for tanks with low level connections and hull thermal insulation.
- A-60 shielding towards living quarters, service spaces, cargo spaces, machinery spaces and control stations.

2.1.5.3 REQUIREMENTS FOR GAS STORAGE TANKS IN ENCLOSED SPACES:

Requirements are:

- 10bar - maximum allowable working pressure for LNG tanks in enclosed spaces.
- Located lesser of B/5 or 11.5m from side shell.
- Located lesser of B/15 or 2m from bottom.
- On ships other than passenger ships, tanks may be located closer, depending on tank volume, from 0.8 - 2.0 m but never less than 760 mm.

Fuel containment systems requiring full or partial secondary barrier must be shielded from the sea by double hull.

2.1.6 LNG FUEL SYSTEM

2.1.6.1 TYPICAL LNG FUEL ARRANGEMENT

The basic LNG fuel system components for inland shipping will be identical to the fuel systems for seagoing LNG powered vessels. These components are:

- Bunker connection
- LNG containment system (tank)
- Fuel gas conditioning systems
- Master gas valve
- Natural gas powered combustion engine

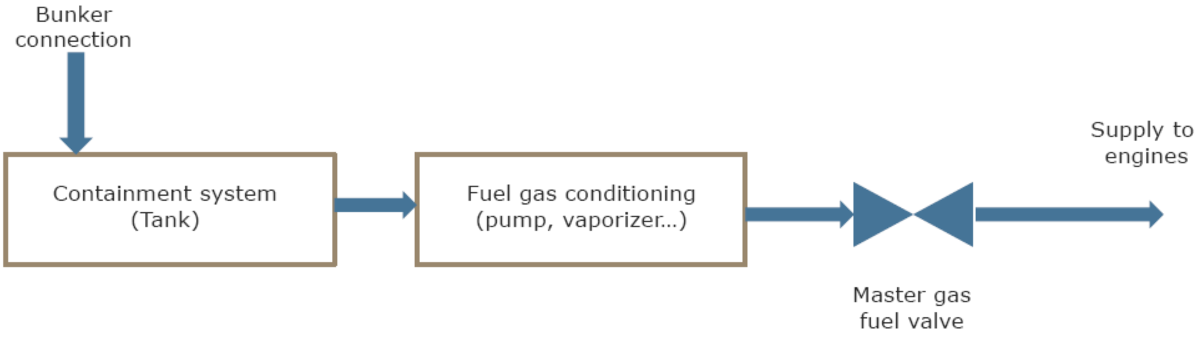


Figure 11 Basic components LNG fuel arrangement

Figure 12 C-class LNG tank vacuum isolated with integrated cold box. Source: Wärtsilä

2.1.6.2. THE LNG COLD BOX

A cold box consists of a carbon steel casing, usually rectangular in shape, that supports and houses heat exchangers, piping, other related cryogenic equipment, and insulation material in an inert atmosphere.

There are standalone versions and integrated versions on the LNG fuel tank. There are different terms referred to in literature, essentially describing the same installation parts: for example, cold box – tank room – process skid.

To create an integrated design for the “cold box”, a stainless steel barrier is welded to the outer vessel of the tank. The structure contains the process skid and all the pipe penetrations to the tank.

In the unlikely event of an LNG leakage, the cold box acts as a barrier that prevents damage to the external compartments and facilitates the quick ventilation of the evaporated gas.

The tank room and ventilation system must be fire protected to A-60/A-0 insulation class, depending on the safety designation of the adjacent space. Some cold boxes can be inerted using nitrogen.

2.1.6.3 PRESSURE BUILD-UP UNIT (PBU) AND PRODUCT EVAPORATOR

The cold box (shown as tank room in the picture) for the LNG fuel system contains a minimal pressure build-up unit (PBU) and the product evaporator.

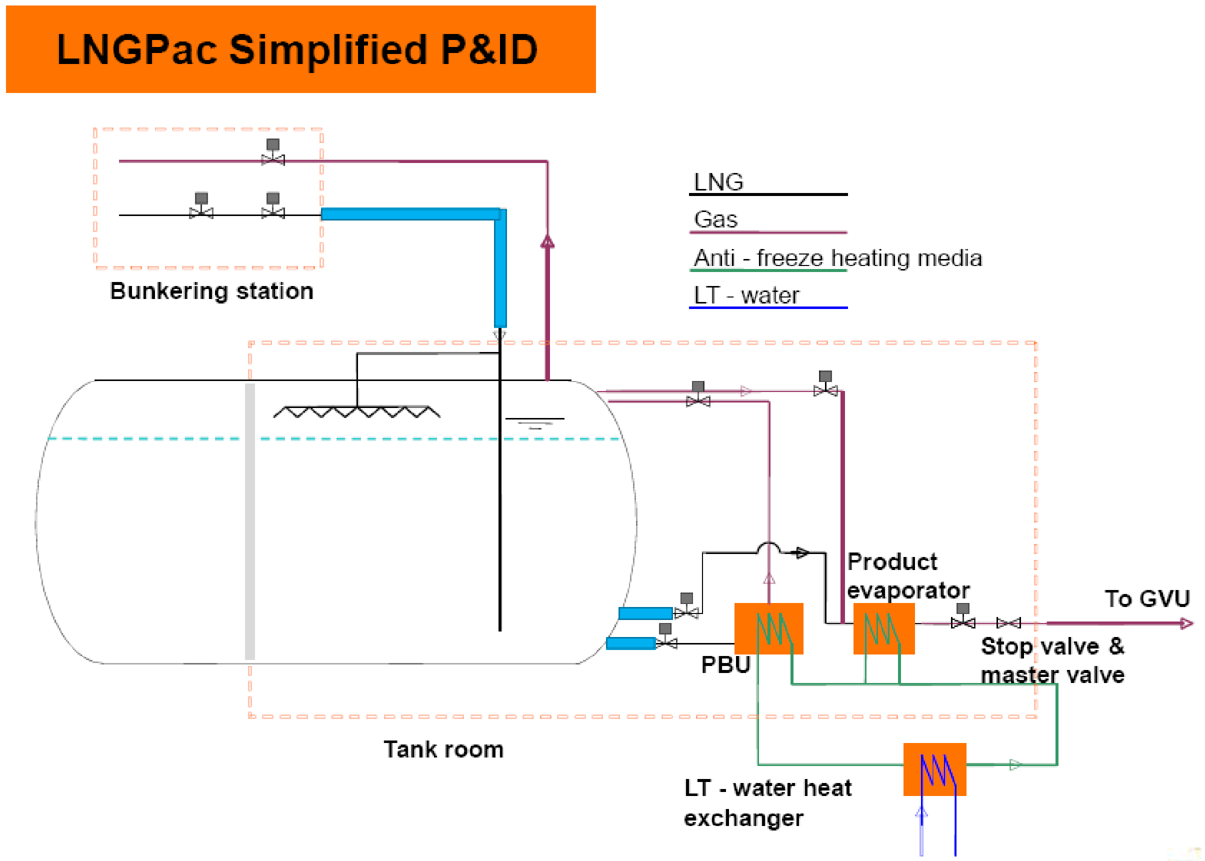


Figure 13 Cold box configuration

The cold box (tank room) includes all the connections and valves between the tank, the *pressure build-up unit (PBU)* and the *product evaporator*, together with the evaporators themselves.

The PBU consists of an insulated pipe, an evaporator, valves, a single wall pipe and sensors. The mission of the PBU is to build up the pressure in the tank after bunkering LNG and to maintain the required pressure in the tank (around 5 bar(g)), during normal operation.

Maintaining the correct pressure in the tank ensures that the dual-fuel engines are able to meet the maximum power (100% MCR) at any time. Since the LNG system doesn't have any cryogenic pump or compressor, the engine gas inlet pressure requirements are met by achieving the correct storage pressure inside the LNG tank.

The circulation of LNG to the PBU evaporator is achieved by the hydrostatic pressure difference between the top and bottom of the tank, with LNG from the bottom of the tank being fed to the evaporator.

The evaporated gas is then returned to the top of the tank. The natural circulation through the PBU continues until the required pressure in the tank is achieved.

The *product evaporator* circuit consists of an insulated pipe, an evaporator, valves, a single wall pipe, and sensors. The task of the product evaporator is to evaporate the LNG into gas and heat it to a minimum of 0°C as per engine specifications. The gas is then fed to the Gas Valve Unit (GVU) in front of the engines.

Both the PBU and product evaporator are heated by a water/glycol mixture, which is re-circulated to an external cooler. Here, the mixture is heated by the waste heat from the engine cooling water circuit.

2.1.6.4 GAS VALVE UNIT (GVU)

Gas valve unit (GVU) is a module between the LNG storage system and the (dual-fuel) DF engine:

- To regulate the base gas pressure
- To ensure the safety disconnection of the gas system and putting it in inert mode if needed

Figure 14. Horizontal and vertical enclosed GVU.

Figure 15. Open GVU. Source: Wärtsilä

2.1.7 THE ENGINE ROOM SAFETY FOR LNG POWERED VESSELS

2.1.7.1 INTRODUCTION

The IMO Interim Guidelines accept two alternative engine room concepts: gas safe machinery spaces and ESD-protected machinery spaces (Emergency Shut Down). (Refer to Section 2.6 of IMO Resolution MSC.285(86)).The same configurations can be used in inland navigation.

Gas-safe machinery spaces: Arrangements in machinery spaces which are considered gas safe under all conditions – in normal as well as abnormal conditions – i.e. inherently gas safe.

ESD-protected machinery spaces: Arrangements in machinery spaces which are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous.

In the event of abnormal conditions involving gas hazards, emergency shutdown (ESD) of non-safe equipment (ignition sources) and machinery must be executed automatically, while other equipment or machinery in use or active during these conditions must be certified safe.

2.1.7.2 GAS SAFE MACHINERY SPACES

All gas supply piping within machinery space boundaries should be enclosed in a gas-tight enclosure, i.e. double wall piping or ducting. In case of leakage in a gas supply pipe making shutdown of the gas supply necessary, a secondary independent fuel supply should be available.

Alternatively, in the case of multi-engine installations, independent and separate gas supply systems for each engine or group of engines may be accepted.

Gas supply lines passing through enclosed spaces should be completely enclosed by a double pipe or duct. This double pipe or duct should fulfil one of the following:

- The gas piping should be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes should be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms should be provided to indicate a loss of inert gas pressure between the pipes;

  Or

- The gas fuel piping should be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct should be equipped with mechanical pressure control ventilation having a capacity of at least 30 air changes per hour.

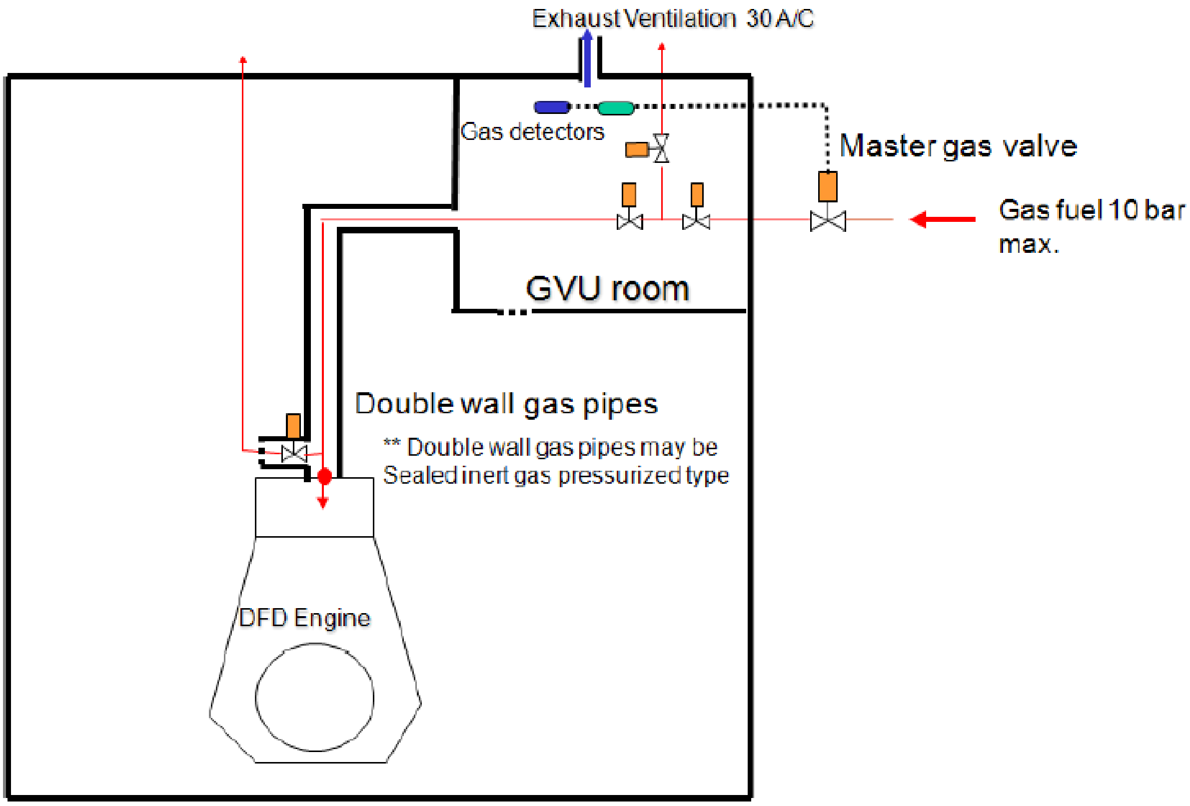


Figure 16 Typical layout of a gas-safe machinery space. Source: ABS.

2.1.7.3 ESD PROTECTED MACHINERY SPACES

Gas supply piping within machinery spaces may be accepted without a gas-tight external enclosure on the following conditions:

- Engines for generating propulsion power and electric power should be located in two or more machinery spaces.
- The gas machinery, tank and valve installation spaces should contain only a minimum of such necessary equipment.
- Pressure in gas supply lines within machinery spaces should be less than 10 bar(g).
- A gas detection system arranged to automatically shut down the gas supply.

ESD-protected machinery spaces should have ventilation with a capacity of at least 30 air changes per hour. The ventilation system should ensure a good air circulation in all spaces, and in particular ensure that any formations of gas pockets in the room are detected.

As an alternative, arrangements where the machinery spaces are ventilated with at least 15 air changes an hour under normal operation. This is acceptable provided that, if gas is detected in the machinery space, the number of air changes will automatically be increased to 30 an hour.

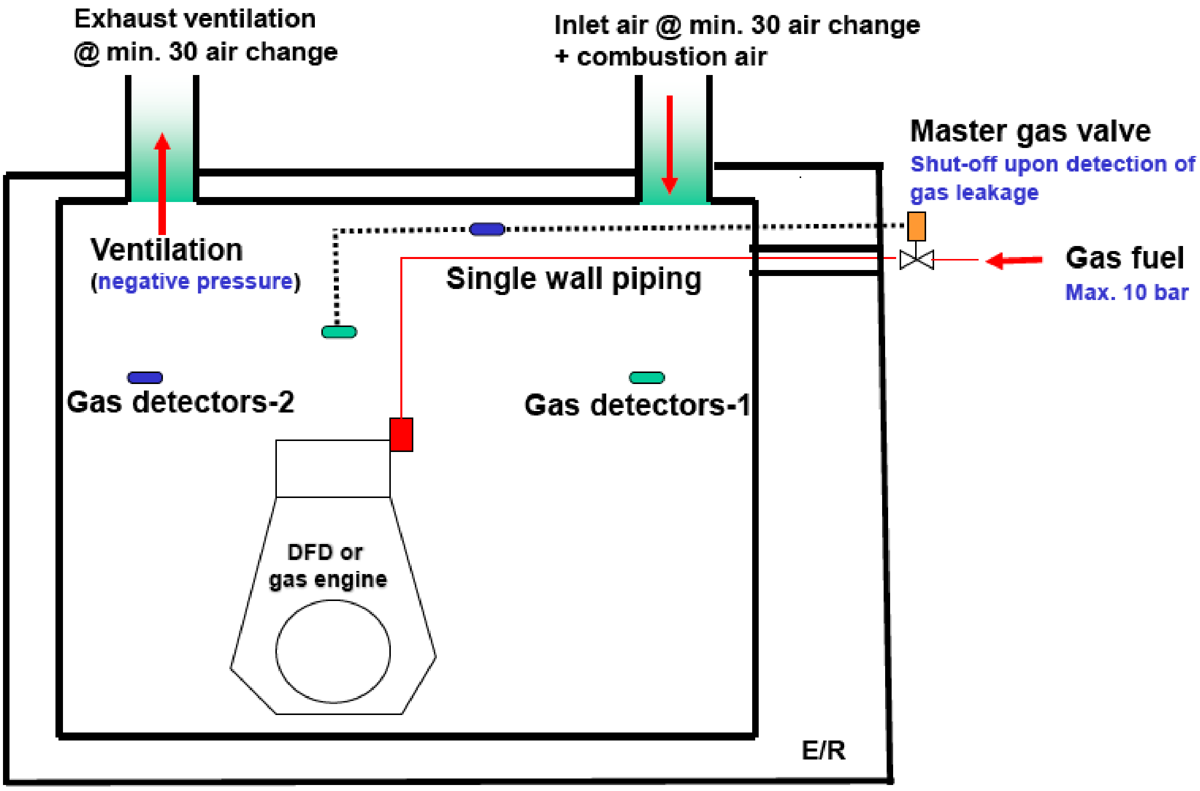


Figure 17 Typical layout of an ESD protected engine room. Source: ABS.

2.1.8 HAZARDOUS AREAS

Hazards are due to the presence of gas, vapours or mists of flammable substances. The European directive 1999/92/EC envisages a classification in three zones (see Table 2) defined as follows:

Zone 0
Areas constantly susceptible to an explosive atmosphere, or for long periods of time. Power equipment with double insulation must be installed in this area.

Zone 1
Areas where an explosive atmosphere is likely to develop during normal conditions. Flameproof electric motors or motors with added protection can be installed in this zone (for the latter, standard restrictions apply).

Zone 2
Areas rarely susceptible to an explosive atmosphere and for a short period of time. Flameproof motors or motors with added protection can be installed in this zone, as well as non-sparking motors.

	With source of release [1]		Without source of release	
	With ventilation [2]	Without Ventilation	With ventilation [2]	Without ventilation
Zone 0	Zone 1 for example, cargo pump room (See annex A Clause A.1)	Zone 0 for example, cofferdams with cargo pipe flanges (See annex A Clause A.4)	Zone 2 For example, ballast pump room adjacent to cargo tanks (See annex A Clause A.7)	Zone 1 For example, cofferdam, void space (See annex A Clause A.10)
Zone 1	Zone 2 For example, rooms with cargo pipe flanges (See annex A Clause A.2)	Zone 1 For example, rooms with cargo pipe flanges (See annex A Clause A.5)	Non-hazardous areas (See annex A Clause A.8)	Non-hazardous areas (See annex A Clause A.11)
Zone 2	Zone 2 For example, rooms with cargo pipe flanges (See annex A Clause A.3)	Zone 1 For example, rooms with cargo pipe flanges (See annex A Clause A.6)	Non-hazardous areas (See annex A Clause A.9)	Non-hazardous areas (See annex A Clause A.12)

[1]The following are examples of some sources of release
- Venting and other openings to cargo tanks, slop tanks and cargo piping
- Seals of cargo pumps, cargo compressors and process equipment
- Seals of valves and flanges and other connections and pipe fittings
-

[2]Where the area classification of a space is dependent upon its ventilation, the arrangements shall be such that discontinuities in ventilation are not expected to occur for long periods and there is no accumulation of gas or vapour in the vicinity of any source of release, or where electrical equipment is installed

Table 2 - Spaces separated by one gas-tight boundary from the zones (Hazardous areas conform IEC 60092-502-1999)

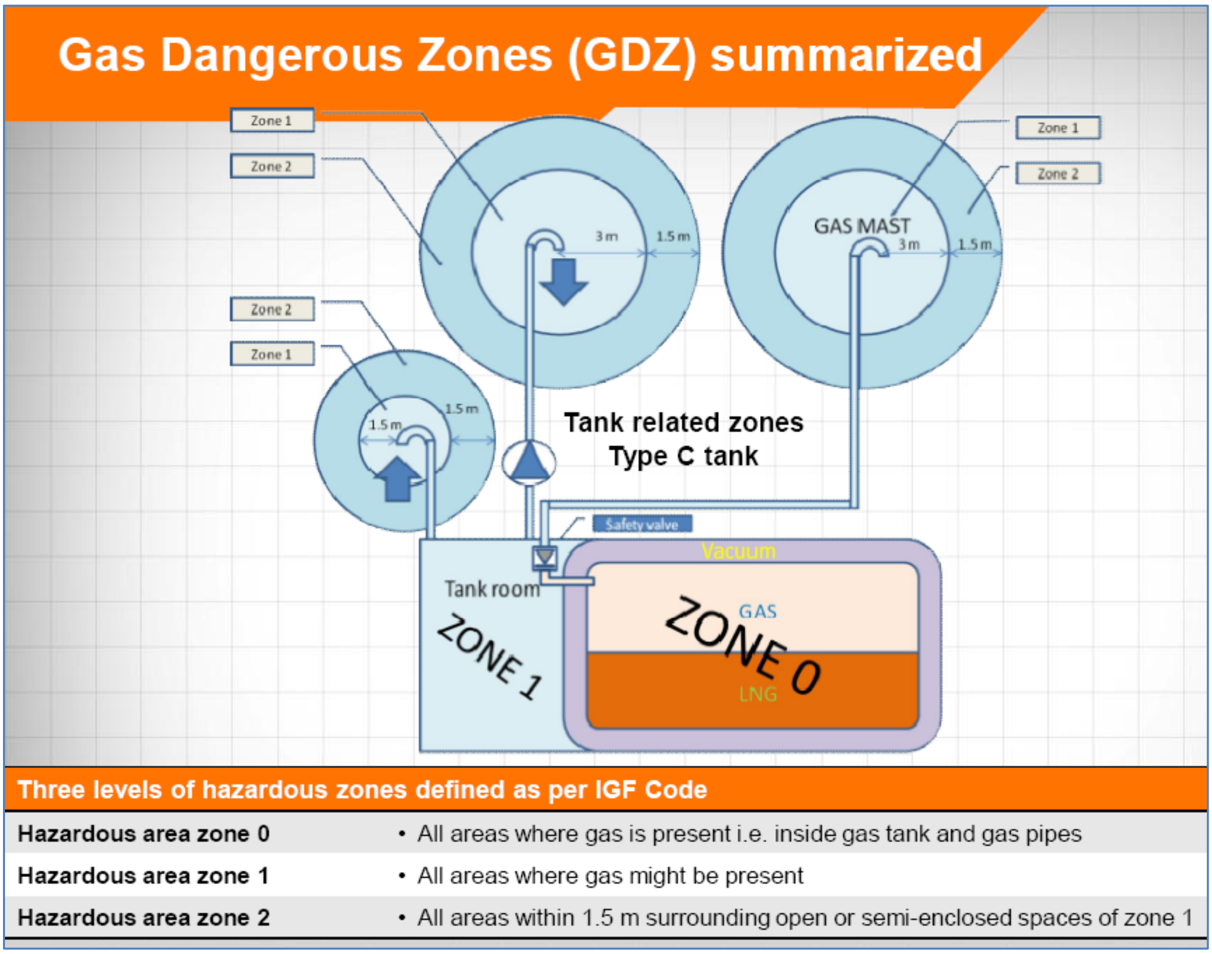


Figure 18 *Three levels of hazardous areas. Source: Wärtsilä.*

2.2 SMALL LNG CARRIERS

2.2.1 INTRODUCTION

Even though an established worldwide infrastructure for LNG exists, it has not met the requirements for LNG bunkering, until now.

There is a significant gap between the large scale LNG terminals served by large carriers (140.000 m³ and up) in order to supply millions of tons of natural gas to the gas grids and small installations for LNG as a bunker fuel.

To close this gap, small LNG carriers are required that are large enough to call at the major terminals for loading, but also being small enough to serve the bunkering infrastructure.

First developments were made in 2004 with the introduction of the “Pioneer Knudsen” carrying 1.100 m³ and later with the vessel “Coral Methane”, a 7.500 m³ combined LNG/Ethylene/LPG carrier designed by TGE and operating since 2009 for Anthony Veder Group/NL. The later ship has loaded several LNG cargoes at large European import terminals such as Zeebrugge. A next generation ship, “Coral Energy” was built (2012) at Meyer Werft in Germany – a 15.600 m³ LNG carrier for Anthony Veder Group with a gas handling system from TGE.

Both ships have dual fuel propulsion systems to control the tank pressure as well as to reduce emissions. The same company built the “Coral Anthelia” in 2013/14 – a 6.500 m³ combined LNG/Ethylene/LPG carrier. These small scale LNG carriers are not sized for the inland waterways; however, these ships are seen as the forerunners of the LNG tankers for inland navigation.

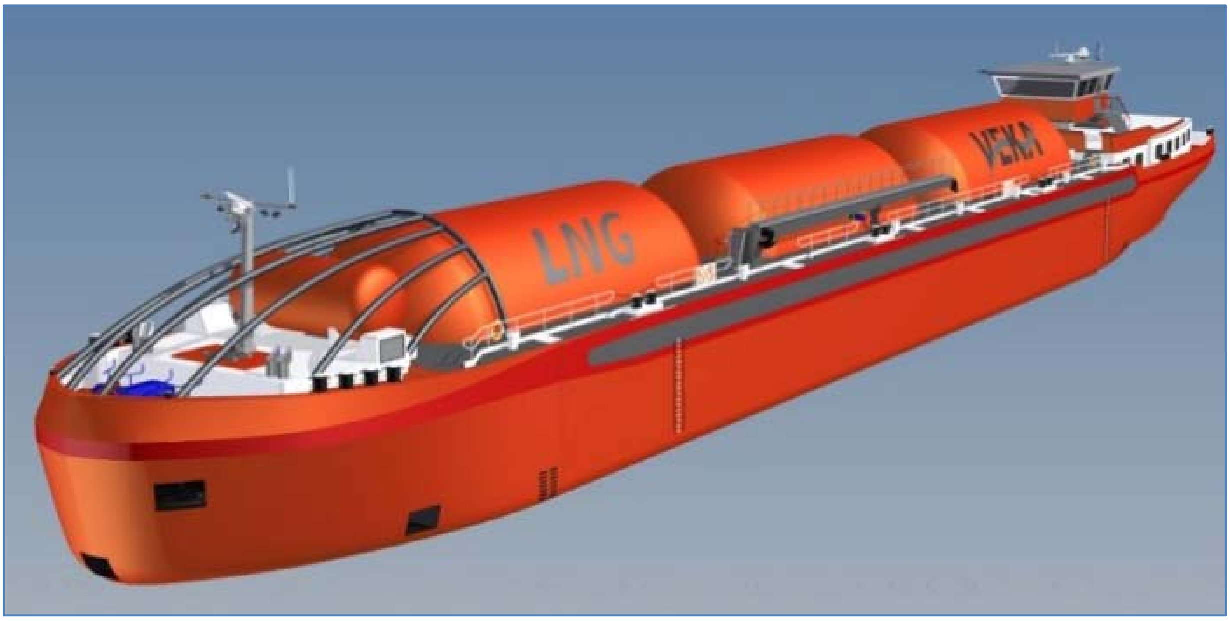


Figure 19 Some LNG carrier study models. Source: VEKA.

2.2.2 LNG STORAGE ON INLAND LNG TANKERS

2.2.2.1 GENERAL

It is estimated that all types of LNG tanks used under the IMO class will also be used for the inland shipping industry. The big difference is the size; the size of the inland vessel is limited to the size of the waterway. The expected maximal volume (load) for one inland LNG tanker vessel is maximal 3,000 m³ LNG total volume, based on the LNG inland tanker developments in the summer of 2014.

Based on IMO type C tanks, LNG carriers of 40.000 m³ or even more are feasible; maximum 10.000 m³ per cylindrical or 20.000 m³ per bi-Lobe tank have been studied.

The major advantages of this very reliable tank type are the flexibility in pressure management (BOG) and the fact that no secondary barrier is required.

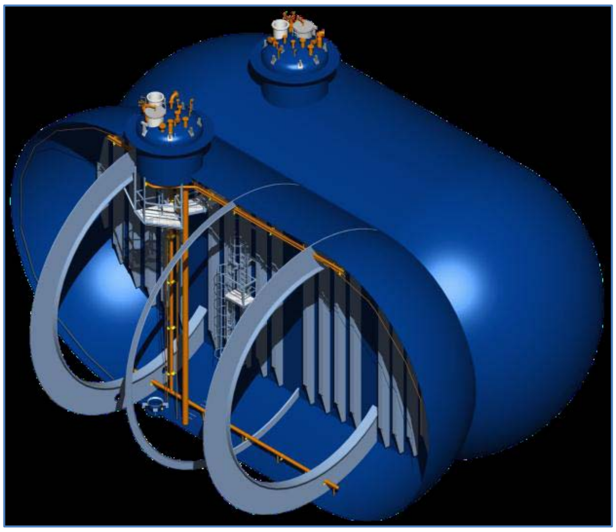


Figure 20 Example of a bi-Lobe LNG storage tank

In the development of LNG inland tankers in 2014, type C-tanks seems to be the most popular system chosen. For example, the LNG inland tanker as shown in the design from the Veka-Deen Group, has three type C tanks, each with a capacity 750 m³. A similar design with three tanks, each with 1.000 m³, is also in the design stage.

Figure 21 VEKA-Deen designed LNG tanker. Source: Veka.

However, the newly built Argos Combined LNG Bunker vessel will employ a GTT Mark III Membrane Containment System affording some 1.870 m³ of LNG capacity in each of two compartments, more than half again as much as the capacity of an initial design using four Type C tanks.

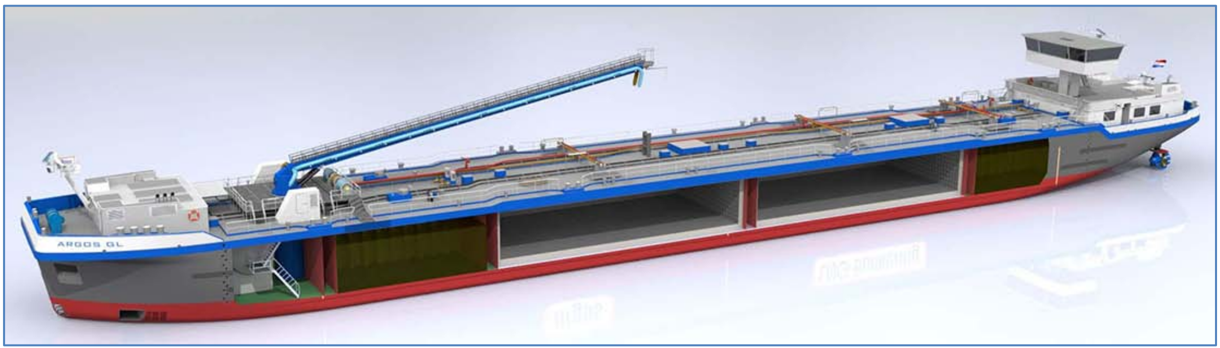


Figure 22 The final design of the Argos combined LNG bunker vessel. Source: Argos.

2.2.2.2 THE MAXIMAL SIZE OF LNG STORAGE TANK

The use of a GTT Mark III Membrane Containment System is more space efficient then the type C tanks. Based on a typical inland tank ship size (length 110 m, with 11.40 m, draft 3.50 m and loading capacity 3.000t), the maximal volume of LNG transported by an inland LNG carrier can reach more than 4.000 m³ in volume.

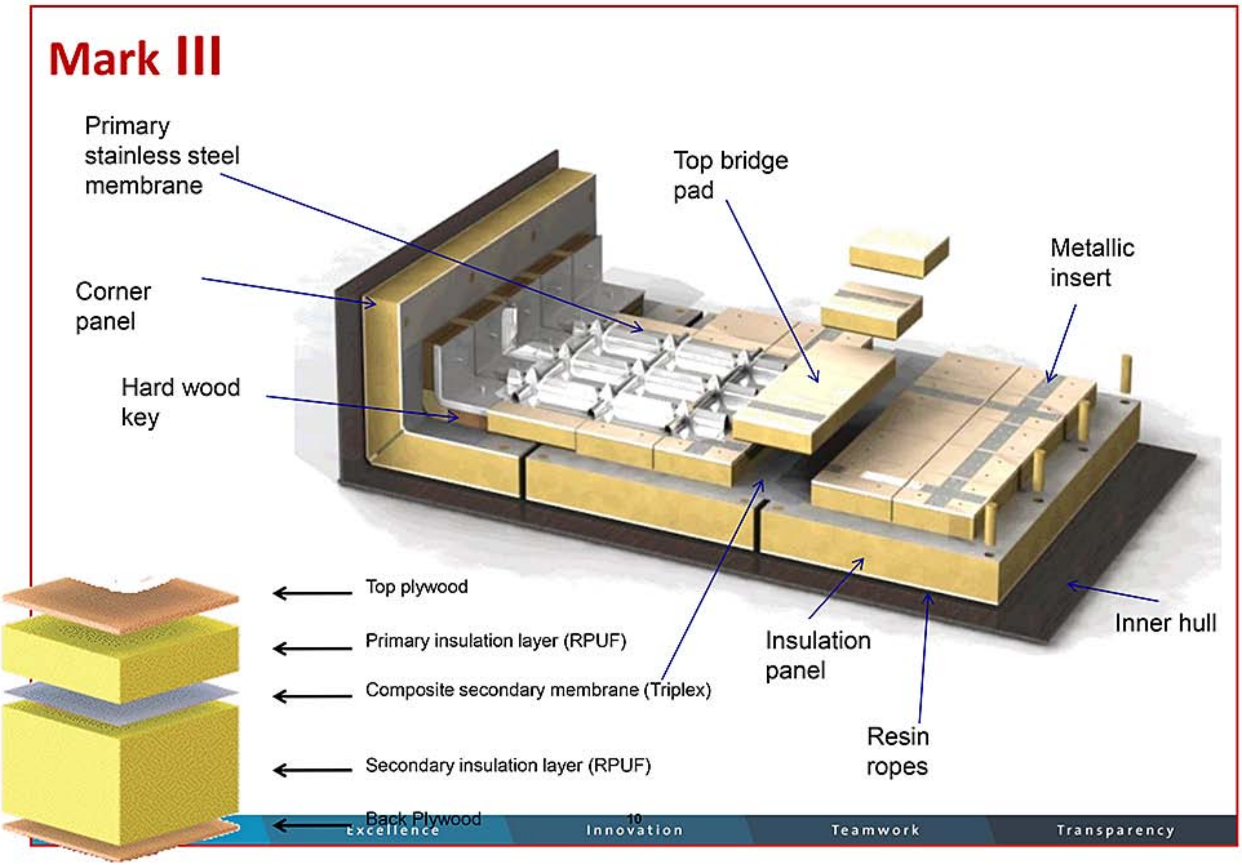


Figure 23 Typical design of a GTT Mark III Membrane Containment System. Source: HHP Insight.

2.2.3 SHIPBOARD SYSTEMS

2.2.3.1 CARGO PIPELINES AND VALVES

Gas carriers are fitted with liquid and vapour manifolds. These are connected to liquid and vapour headers — or pipelines — with branches leading into each cargo tank. The liquid loading line is led through the tank dome to the top and bottom off each cargo tank to pre-cooling of the tank; the vapour connection is taken from the top of each cargo tank.

Cargo pipelines are not allowed beneath deck level on gas carriers; therefore, all pipe connections to tanks must be taken through the cargo tank domes which penetrate the main deck.

Vapour relief valves are also fitted on the tank domes; these are piped, via a vent header, to the vent riser. The vent risers are fitted at a safe height and safe distances from accommodation spaces and other such gas-safe zones as specified in the applicable Gas Codes.

2.2.3.2 CARGO VALVES

Isolating valves for cargo tanks must be provided in accordance with applicable Gas Codes. Where cargo tanks have a MARVS (maximum allowable relief valve setting) greater than 0.7 barg (type ‘C’ tanks according to the IGC code), the liquid and vapour connections on the tank dome (except relief valve connections) should be fitted with a double valve arrangement.

This should comprise one manually operated valve and a remotely operated isolation valve fitted in series.

2.2.3.3 EMERGENCY SHUT-DOWN (ESD) SYSTEMS

At a number of locations around the tanker, pneumatic valves or electric push buttons are provided. When operated, these controls close remotely actuated valves and stop cargo pumps. This provides an emergency-stop facility for cargo handling. Such emergency shut-down (ESD) systems are also required to be automatic upon loss of electric control or valve actuator power. Individual tank filling valves are required to close automatically upon the actuation of an overfill sensor in the tank to which they are connected. ESD valves may be either pneumatically or hydraulically operated, but in either case they must be fail-safe; in other words they must close automatically upon loss of actuating power.

A vital consideration, particularly during loading, is the possibility of surge pressure generation when the tanker’s ESD system is actuated. The situation varies from terminal to terminal and is a function of the loading rate, the length of the terminal pipeline, the rate of valve closure and the valve characteristic itself. The phenomenon of surge pressure generation is complex and its effects can be extreme, such as the rupture of hoses or hard arm joints.

2.2.3.4 RELIEF VALVES FOR CARGO TANKS AND PIPELINES

Best practice requires at least two pressure relief valves of equal capacity to be fitted to any cargo tank, including a system to avoid both valves being closed at the same time. Both valves must be open during operation. The types of valves normally fitted are either spring-loaded or pilot-operated.

Pilot-operated relief valves may be found on all tank-types, while spring-loaded relief valves are usually only used on pressurised type ‘C’ tanks.

The use of pilot-operated relief valves on fully refrigerated tanks ensures accurate operation at the low-pressure conditions prevailing; their use on type 'C' tanks allows variable relief settings to be Achieved using the same valve. This may be done by changing the pilot spring.

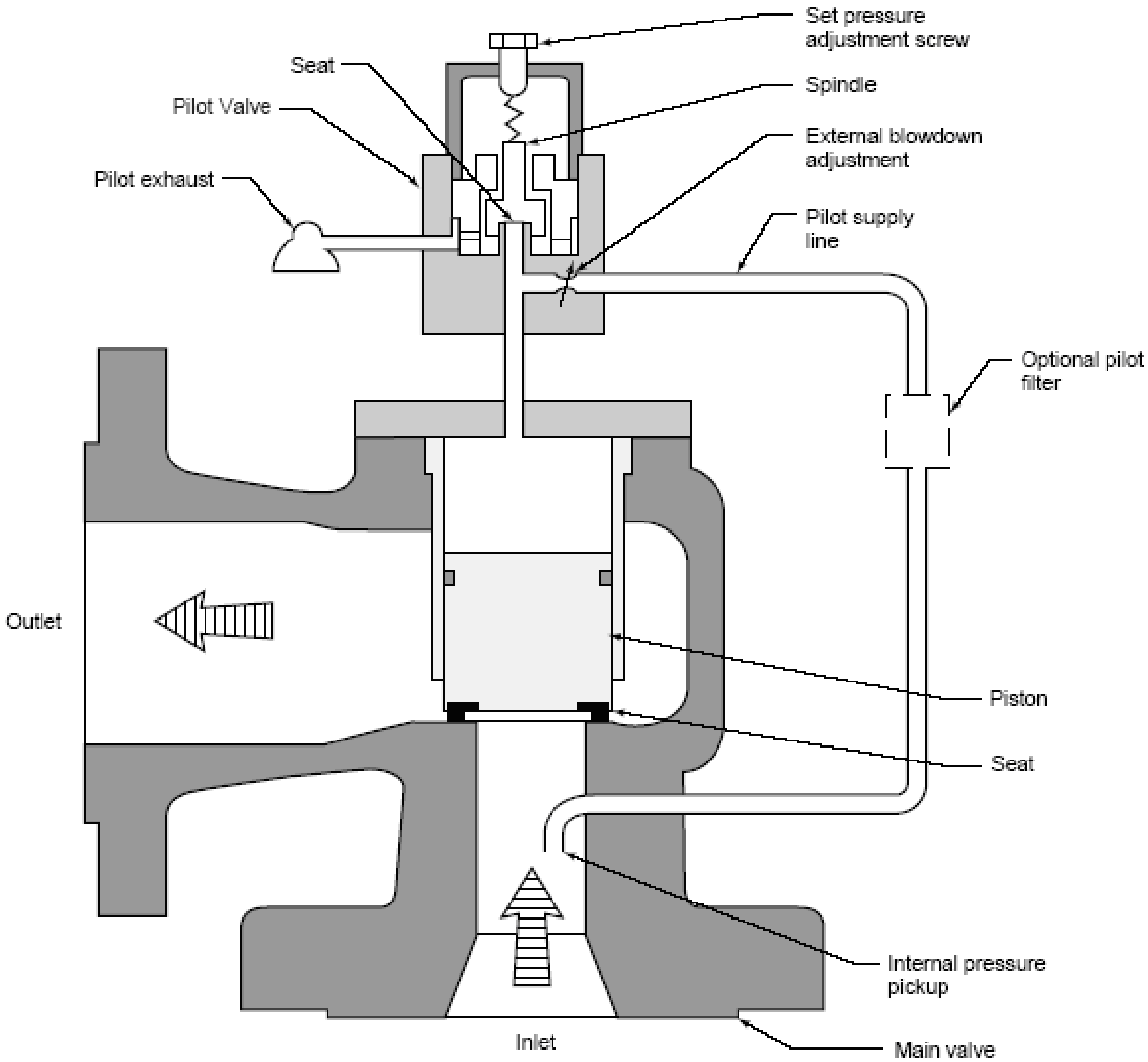


Figure 24 shows a typical pilot-operated relief valve.

Other types of pilot valve are available for adjustment of set pressure and blow down pressure.

2.2.3.5 CARGO PUMPS

Cargo pumps fitted on board LNG carriers are normally of centrifugal design and may be either of the deep well or submerged type. They may operate alone or in parallel with one another. Some fully pressurised tankers discharge cargo by pressurising tanks with vapour, and booster pumps are fitted to speed up the cargo transfer.

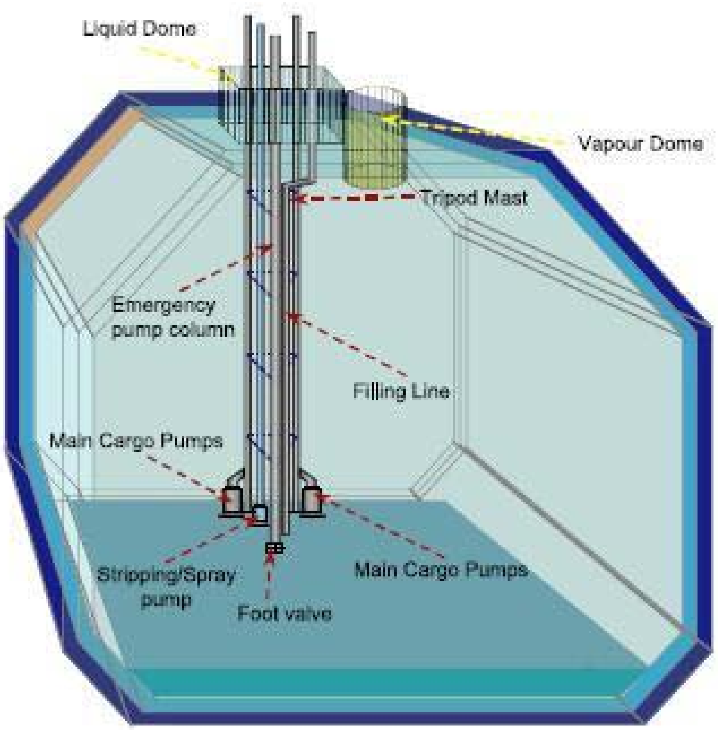


Figure 25 *Typical arrangement of cargo pumps for an LNG membrane cargo tank.*

2.2.3.6 INERT GAS AND NITROGEN SYSTEMS

LNG carriers use inert gas for:

- General purging/cargo tank stripping purpose.
- Leak detection in insulation spaces on board LNG vessels.
- LNG propulsion; purging of fuel pipes etc.

The most common system utilised for the production of nitrogen on tankers is an air separation process. This system works by separating air into its component gases by passing compressed air over hollow fibre membranes.

The membranes divide the air into two streams - one is essentially nitrogen and the other contains oxygen, carbon dioxide plus some trace gases. This system can produce nitrogen of about 95 to 99.8 per cent purity.

2.3 BUNKERING OF LNG

2.3.1 LNG BUNKERING DEFINITION

The definition of LNG bunkering is the small scale transfer of LNG to vessels requiring LNG as a fuel for use within gas or dual fuelled engines. LNG bunkering takes place within ports or other sheltered locations at the base case.

Bunkering should not be considered in the same context as the large scale commercial transfer of cargo between LNG carriers (tankers). This larger operation is covered in separate regulations and standards.

2.3.2 LNG BUNKERING SCENARIOS

Truck–to-Ship (TTS):
micro bunkering, discharging unit is LNG road tanker size approximately < 100 m³.

Ship-to-Ship transfer (STS):
discharging unit is a bunker vessel or barge with size < 10.000 m³.

Terminal (Pipeline)-to-Ship PTS):
satellite terminal bunkering serves as a discharging unit and supply size is approximately 100- 10.000 m³.

PTS and TTS are the most established bunkering scenarios used to date and they are both classified as onshore supply.

For this purpose, a connection is made between the LNG supplier and the receiver by means of a two inch cryogen-resistant hose. The pipes are pre-flushed with nitrogen to remove oxygen and the moisture. Then the pipes and fittings are pre-cooled by LNG. Only when the pipe is cold enough, will the pure LNG be pumped. Pumping will be achieved either by increasing the LNG tank vapour pressure or using the special cryogenic LNG pump. The loading pressure will be about 7 bar.

The general steps for bunkering are:

- Initial pre-cooling
- Connection of bunker hose
- Inerting the connection system
- Checking ESD systems function
- Purging the connection system
- Filling sequence
- Liquid line stripping
- Liquid line inerting

Figure 26 First LNG bunkering of the barge Eiger-Norwand. Source: Danser.

2.3.3 MOBILE LNG FUEL TANKS

Another option is to have a replaceable LNG fuel tank (containerized) instead of a fixed LNG fuel tank. The empty tank is simply replaced by a full container by means of a crane at a container terminal.

In some additional documentation it is named a 'LNG Fuel Cell'. It is an ISO containerised type C tank with the same safety qualification as the prescribed fuel tank.

Figure 27 LNG fuel tank container. Source : Marine Services LNG.

The following marine service LNG fuel gas system is used:

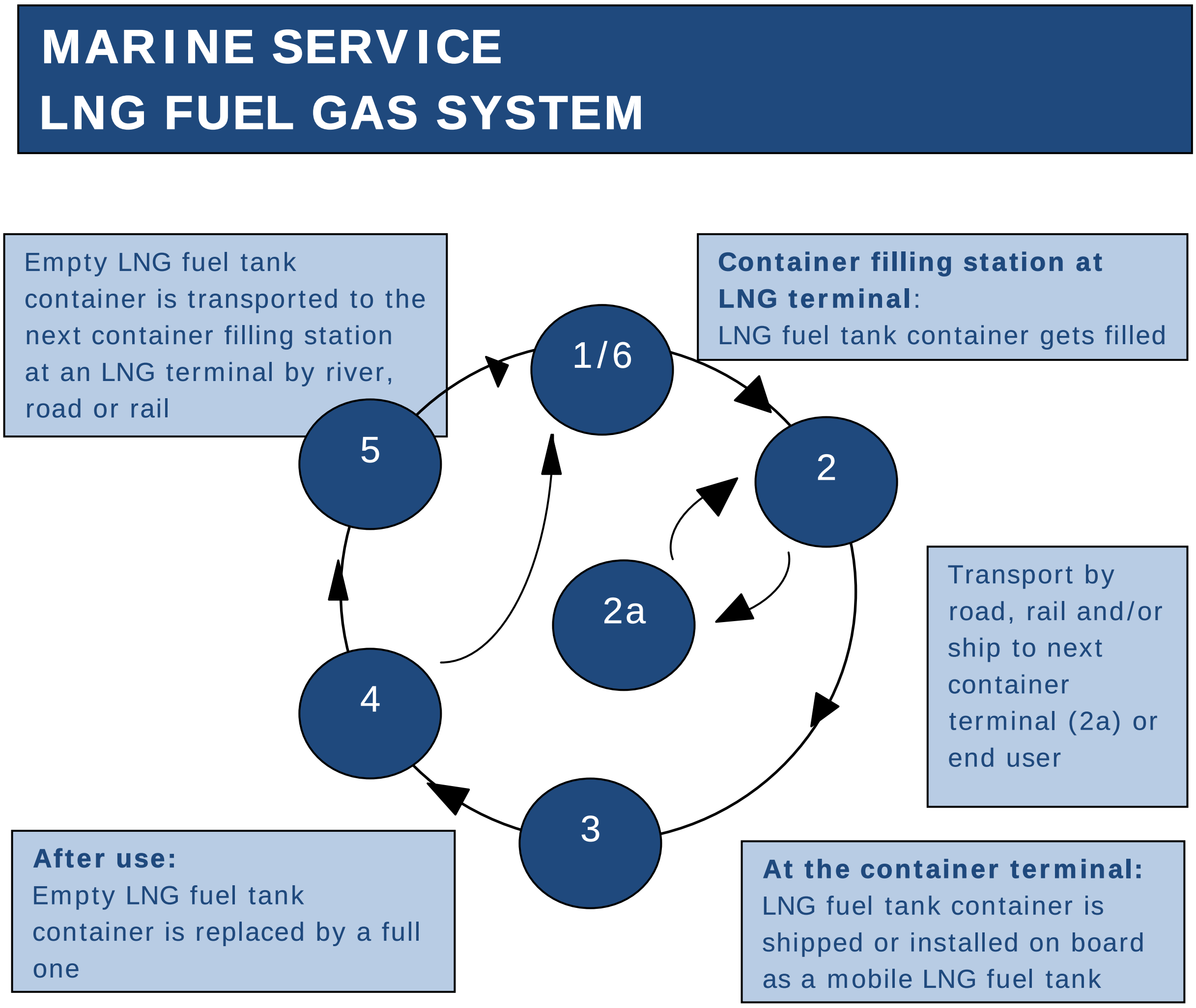


Figure 28 LNG Fuel tank Container logistic system

3. EXISTING SCENARIOS

3.1 LNG RELEASES

3.1.1 GENERAL

It is first important to understand the general behaviour of LNG before it is applied to the inland shipping setting.

Several studies have been conducted regarding this matter by reliable sources who have performed tests and practical demonstrations.

In general there are two behavioural patterns for LNG emerging, namely LNG stored at atmospheric pressure and LNG stored at an increased pressure/temperature.

The main difference is that in LNG stored at increased pressures, a jet fire could occur, and in certain conditions, if there is a catastrophic failure of the containment vessel, a BLEVE, as explained below in figures 29 and 30, could result.

The following event trees summarize the possible events from a loss of containment of LNG stored at atmospheric and elevated pressures.

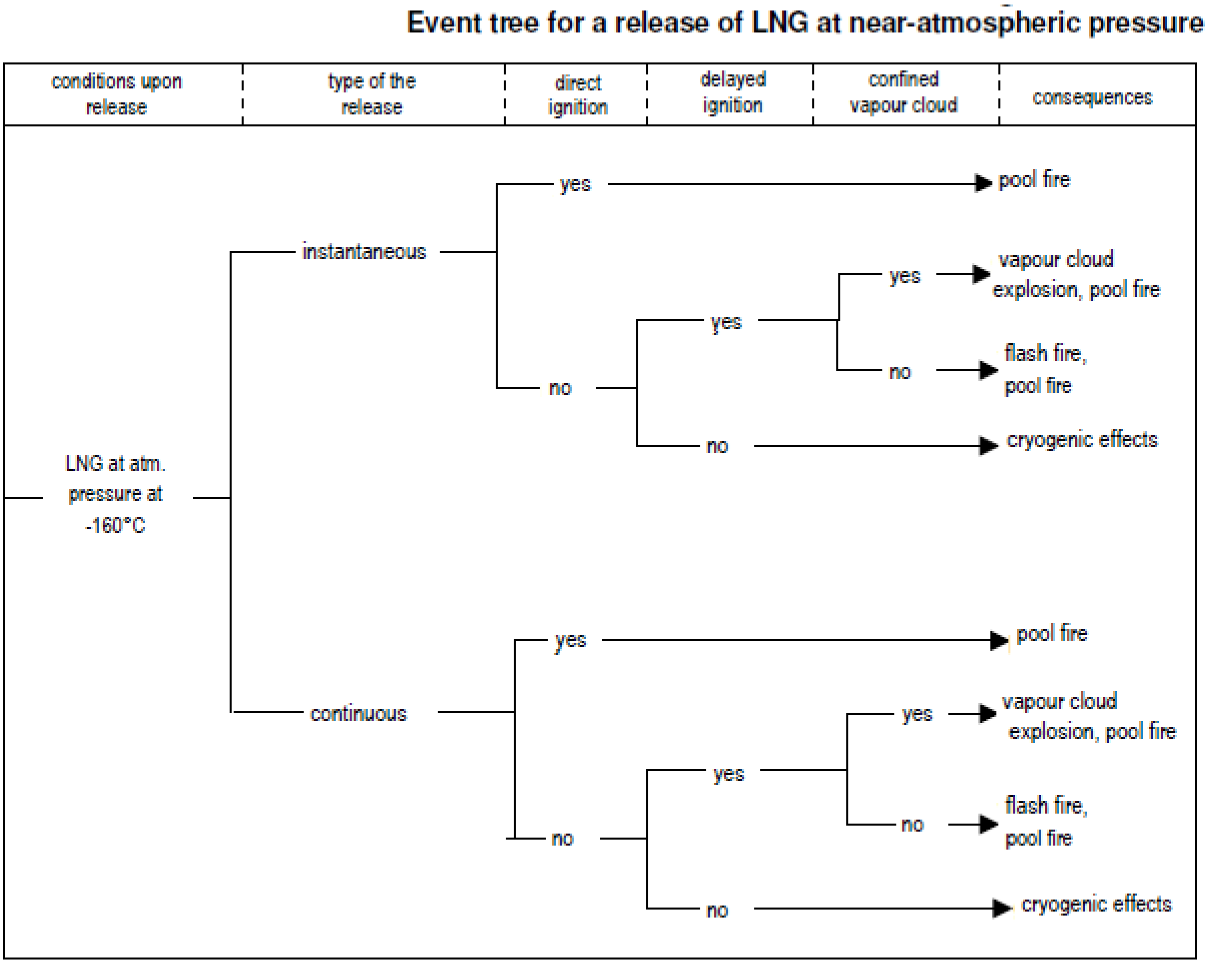


Figure 29 Event tree for a release of LNG at near atmospheric pressure.

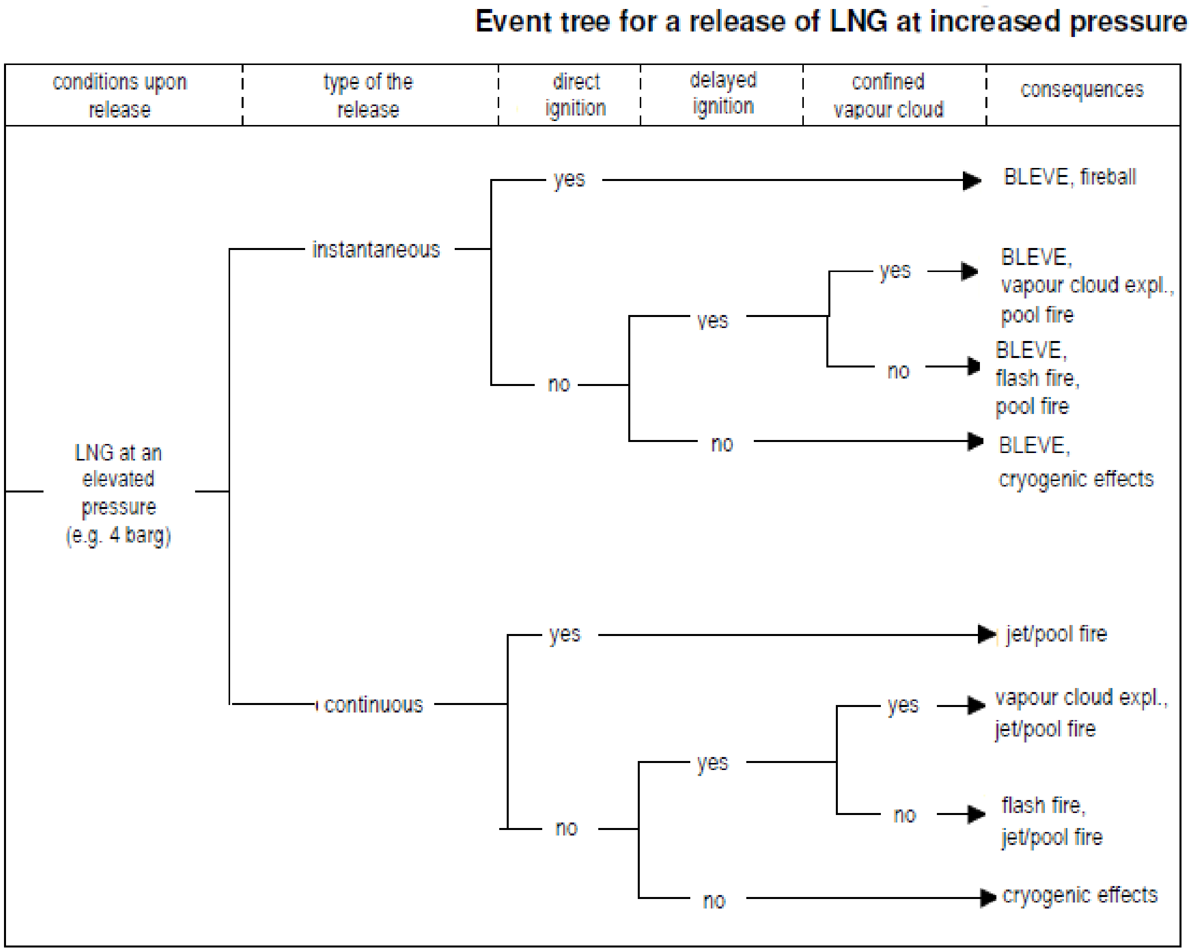


Figure 30 Event tree for a release of LNG at increased pressure.

3.1.2 VAPOUR RELEASES

A vapour release is an event where an instantaneous or continuous release of LNG at or near atmospheric pressure results in a pool forming, which initially evaporates quickly due to the warming effect of the land or water.

A vapour release from an atmospheric tank would result in a pool forming, and the rate of release would depend on the size of the release. Releases from tanks with elevated pressures or temperatures would result in a two phase release, meaning that 17% is a pressure release (aerosol) and the remaining forms a pool.

3.1.3 POOL FIRES

In the event of direct ignition of the gas vapour above the LNG pool, the LNG will burn off at different rates depending on whether the pool is on land or on water.

The heat intensity is significantly higher than other fuels due to the lack of soot deposits in the combustion process, particularly at the base of the pool fire formation, giving rise to possible fire spread to adjacent materials/equipment via the heat radiating from the flame column.

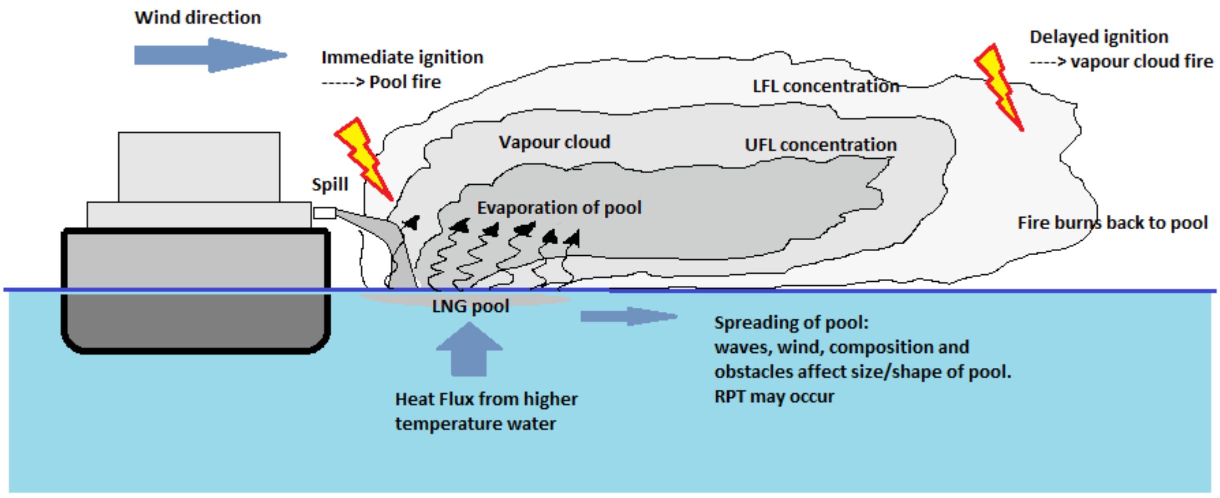


Figure 31 Possible fire scenarios when LNG is spilled on water. Source: Luketa, Hanlin (2006).

3.1.4 FLASH FIRES

A flash fire event occurs when vapours from an instantaneous or continuous release drift in a downwind direction to an ignition source and ignite.

When the portion of the vapour cloud between the lower flammable limit (LFL) and upper flammable limit (UFL) finds an ignition source, the flames will travel (propagate) through the cloud, although at relatively slow speeds 10-12 m/sec, provided the vapour cloud is not confined or in a high obstacle density (congested) environment.

This is termed a flash fire because the ignition flashes back to the source (pool or point release).

3.1.5 JET FIRES

A jet fire event occurs when a pressurized gas or liquid release forms a vapour cloud that ignites. Should the vapour cloud be ignited, flames will propagate back to the source, however a jet fire will result from the point of pressurized release. The intensity of the heat is very high > 300Kw/m².

A jet fire can have a dramatic effect on equipment such as tanks and pipe work should the flame impinge on equipment that is not effectively insulated. Unprotected steel will fail rapidly and cause further escalation of the situation.

Single skin LNG pressure tanks are very vulnerable to jet fires; failure of the containment would cause a sudden release of vaporizing product and a fire ball (BLEVE).

3.1.6 VAPOUR CLOUD EXPLOSIONS

A release of LNG, as already discussed, will rapidly form a combustible vapour cloud. Should there be a delay in its ignition and the cloud be in an enclosed or high obstacle density (congested) space, then the resulting flame propagation will increase in velocity to such an extent that it creates overpressure and blast damage.

3.1.7 BLEVE

A BLEVE event occurs when an LNG tank fails catastrophically at increased pressure, often due to the result of flame impingement (jet fire) or mechanical impact on the containment element of the tank shell. The resulting drop in pressure and ignition of the huge vapour release results in a Boiling Liquid Expanding Vapour Explosion (BLEVE), often recognized as a fire ball and subsequent blast damage.

Tanks with increased pressure and single wall construction are more likely to BLEVE.

3.1.8 RAPID PHASE TRANSITION RPT

In the event of an LNG release on water, in addition to the accidents described above, a so-called rapid phase transition (RPT) can take place.

A RPT is a physical explosion that occurs as the result of the violent boiling of cryogenic LNG through intense contact with warm water. Because the overpressures caused by an RPT remain confined to the immediate vicinity of the release, this accident scenario is not usually considered when determining the external human risk.

Tests have indicated that this phenomenon could happen when the water temperature is high (12-17^{0}C depending on the mixing intensity) and a low composition of methane is present in the cryogenic mixture.

Recent events have shown that a RPT can also occur if warm gas is introduced to a pipe containing LNG.

3.1.9 OTHER HAZARDS

3.1.9.1 ASPHYXIATION

Asphyxiation or asphyxia is a condition of severely deficient supply of oxygen to the body that arises from abnormal breathing. An example of asphyxia is choking. Asphyxia causes generalized hypoxia, which affects primarily the tissues and organs.

There are many circumstances that can induce asphyxia, all of which are characterized by an inability of an individual to acquire sufficient oxygen through breathing for an extended period of time. Asphyxia can cause coma or death.

Methane is also an asphyxiate and may displace oxygen in an enclosed space. Asphyxia may result if the oxygen concentration is reduced to below about 16% by displacement, as most people can tolerate a reduction from 21% to 16% without ill effects. The concentration of methane at which asphyxiation risk becomes significant is much higher than the 5–15% concentration in a flammable or explosive mixture.

Methane off-gas can penetrate the interiors of accommodations and expose ship board crew to significant levels of methane. Some ship stays have specially engineered recovery systems below their main deck level to actively capture this gas and vent it away from the area.

3.1.9.2 CRYOGENIC EFFECTS

LNG storage tanks are designed to prevent LNG from contacting the inner and outer hulls, but incidents can be postulated that would place LNG in contact with the hulls. It is possible that a release of liquid LNG to the inner hull would cause low temperatures for areas of the hull structure that are not designed for cryogenic temperatures.

The international ship design rules require areas where cargo tank leakage might be expected to be designed for contact with cryogenic LNG.

A study by Lloyds (2001) includes brief descriptions of 10 LNG spills involving LNG carriers that occurred between 1965 and 1989. Seven of these ten spills led to brittle fracture of the deck or tank covers and some has lead to the vessel being out of service for several weeks for urgent repairs. Given where the damage occurred (e.g., to the deck or tank cover), it is likely that all of these releases occurred from piping systems used during LNG transfers.

Modern vessels also have to comply with current ship design rules and are designed with steel rated for low temperatures in areas where LNG leakage might be expected to contact decking or internal structures.

3.2 SCENARIOS FOR SMALL SCALE LNG ON INLAND WATERWAY SHIPPING

3.2.1 INTRODUCTION

This study details the possible scenarios that could involve a release of LNG, with or without fire as a consequence. The study does not calculate the likelihood of the event taking place. The consequences have been mapped and categorised in order to unify a response strategy for each scenario consequence. Figure 32 below identifies the possible scenarios that could lead to a loss of containment with the generic escalation possibilities. Each scenario will be discussed in more detail individually.

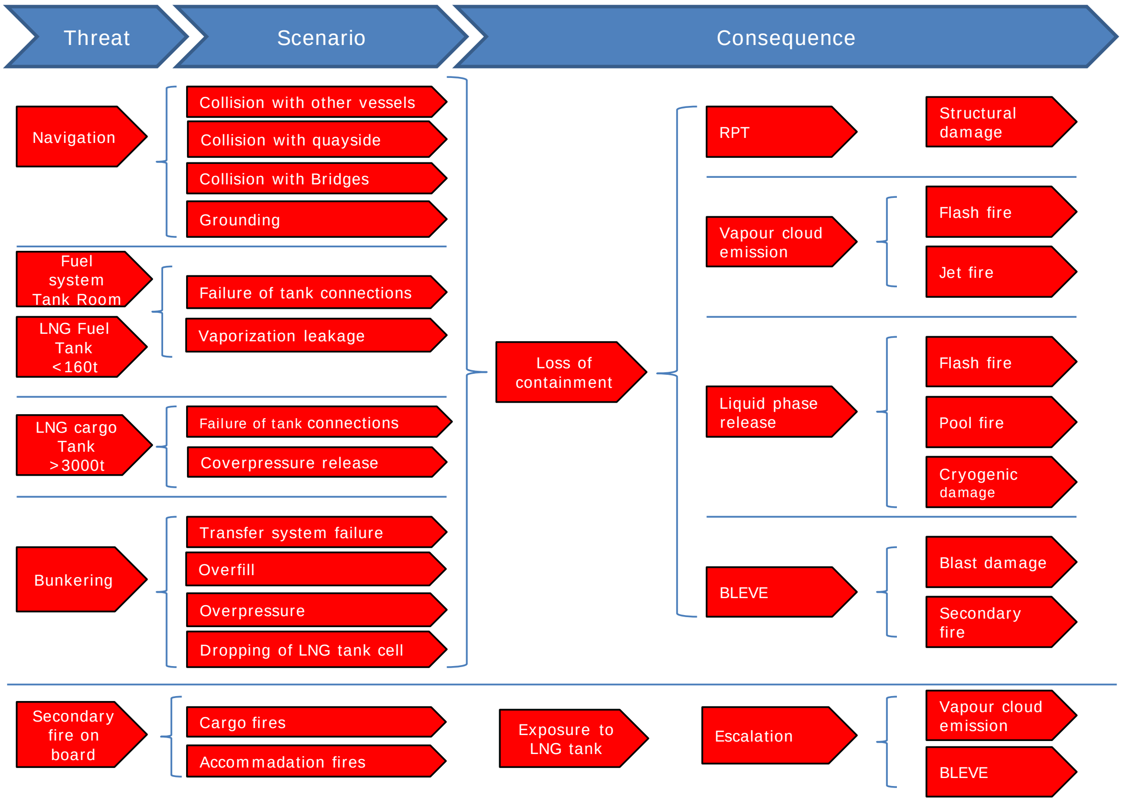


Figure 32 Overview of possible scenarios

3.2.2 POTENTIAL HAZARDS

Potential hazards resulting from intentional or accidental spilling of large quantities of LNG include thermal radiation from vapour cloud fires (also referred to as flash fires) and pool fires.

There is general agreement among LNG experts [1] regarding the following aspects of potential LNG fire and explosion hazards:

- Vapours from un-ignited spills of LNG do not have to travel far into developed areas before finding an ignition source and burning back to the source.
- Once delayed ignition of the vapour cloud occurs, and provided that the cloud is unconfined and rich in methane, the LNG vapours will burn in the form of a vapour cloud fire.
- A vapour cloud traversing over commercial and/or residential terrain will almost certainly encounter an ignition source early in its downwind drift and the resulting vapour cloud fire will burn back to the source.
- The vapour cloud fire will burn back to the source and cause a pool fire at the source if the release is a continuous release and the release duration is longer than the time it takes the cloud to find an ignition source.
- If the vapour cloud is confined then the flame can accelerate and result in an explosion. The magnitude of the explosion and explosion damage will depend on several factors, including the amount of vapours above the lower flammable limit, the presence of obstacles and degree of confinement, the composition of the vapour cloud, and the strength of the ignition source.
- If immediate ignition occurs, a pool fire will result. The extent of the pool spreading (diameter) and flame height will depend on several factors, including the flow rate of LNG, the spill surface type (water or land), the spill surface geometry, spill surface roughness, release composition, release temperature, ambient wind speed, ambient temperature, and ambient relative humidity.
- If the liquid pool is unconfined and the inventory of LNG is large, the fire will continue to burn until all the fuel is exhausted by the pool fire. It is not practical or even possible to extinguish large LNG pool fires resulting from large spills of LNG unless the flow of LNG feeding the pool can be stopped.
- The maximum vapour cloud fire hazard area from large LNG spills is typically estimated by calculating a downwind dispersion distance to the lower flammable limit (LFL) and a cross-wind dispersion distance to ½ LFL at low wind speed and stable atmospheric conditions. This maximum fire hazard zone is very unlikely to be experienced in any situation where the cloud drifts over populated areas. As indicated in point 3 above, the cloud will soon encounter an ignition source and burn back to the source well before the maximum hazard area is reached.
- Only the outdoor population present within the flammable boundaries of the vapour cloud is assumed to be injured due to short exposure to very high thermal radiation fluxes from the vapour cloud fire, direct flame contact, secondary fires of clothing, and inhalation of hot combustion products.
- It is assumed that people inside the vessel at the time of the flash fire will not be injured; however, should there be a pool fire, people inside the vessel will not be able to escape from the burning structure without direct thermal impact injuries. A flash fire will ignite the shipboard accommodation from the outside and cut off the emergency escape routes.

3.2.3 NAVIGATIONAL INCIDENTS

3.2.3.1 INTRODUCTION

Although there have been many navigational incidents in ports internationally (17 from 80.000 LNG tanker shipments), to date there have been any uncontrolled loss of containment of LNG reported.

The result of these collision incidents could result in the deformation of the LNG containment and a subsequent release of the LNG to the environment from either the LNG fuel tank or the LNG cargo tank.

Incidents where there is a heightened risk of loss of containment are as follows:

- Collision with other vessels
- Collision with jetty
- Collision with bridges
- Accidental grounding of the ship

3.2.3.2 COLLISION WITH OTHER VESSEL

The scenarios listed below would be associated with a loss of containment for LNG fuel tanks and LNG cargo tanks. The release quantities for a fuel tank would be up to 160m³ and a cargo tank up to 1.000m³ per compartment (1.870m³ for a membrane tank).

The kinetic energy and location of the tank will influence the amount released and consequence of events. A 90° impact of one vessel with another is a likely scenario in a harbour area, whereas on the river a collision is more likely to involve bow to stern scenarios which have a lesser impact. As stated earlier in this report, if the tanker and ship fuel tanks are designed in accordance with IMO standards, then there should at least 780mm separation distance between the hull and the tank unit.

Previous studies have led to the definition of three release scenarios for collision situations. These can be referenced from the Fluxys Report in order to determine the consequence/escalation possibilities. Breaches in the containment have been defined for holes with a diameter of 1.000 mm, 150 mm and 75 mm, in order to estimate the release rates and consequential pool fire sizes.

The consensus from shipbuilders is that the maximum capacity for one tank on inland waterways would be around 800m³; therefore, a direct correlation can be made for the estimated release quantities for the above hole sizes from the table below.

Ship capacity	Hole (Ø= 75mm)			Hole (Ø= 150mm)			Hole (Ø= 1,000mm)		
	Rate [kg/s]	Duration [s]	Released mass [ton]	Rate [kg/s]	Duration [s]	Released mass [ton]	Rate [kg/s]	Duration [s]	Released mass [ton]
800m³	48,3	1.800	86,7	193,3	1.032	198,2	8.592	24	213,1

Table 3 Representative release rates for LNG in nautical incidents involving LNG ships and warm LNG (-138°C, 4 Barg), Source: Fluxys.

A collision resulting in a breach of the LNG tank could result in a release of liquid into the separation between the tank and the ship's hull; with a large breach, a release directly into the water is possible.

There is a possibility that the cryogenic spill affects the vessel structure and might increase the size of the event due to the brittle fracture of the ship's structure. While this is possible, there are designs and physical features that may also limit escalation due to cryogenic effects (e.g. tank separation, water ingress, interaction with colliding vessel).

The point of breach could also influence the release outcomes. A breach of containment above the water level would cause a partial spill of the tank contents (69%).

The spill floating on the water will be warmed causing increased evaporation of the LNG. The depth of fuel in the unrestricted pool could be 100mm near the outflow and thinning out to 1mm on the extremities. The spread of LNG across the water will be influenced by the wind and the effects of river flow.

The pool size will stabilize when the output from the release matches the evaporation rate of the pool at the outer limits. The diameter of the release pool before a delayed ignition has also been estimated and can be seen in the table below, taking the 800m³ as the most applicable.

Ship Type	800m³
Hole (Ø – 75 mm)	9,2 m
Hole (Ø – 150 mm)	18,3 m
Hole (Ø – 1.000 mm)	115,7 m

Table 4 Calculated pool fire diameters that could occur following a release of cold LNG as the result of a nautical accident and delayed ignition.

Breach to the containment under the water level would have a different reaction as the outflow would be stemmed due to the back pressure from the water against the LNG product; However, unlike the above water line scenario, 100% of the cargo could be lost.

Water ingress into the tank is unlikely, but increased vapour pressure would build up causing safety pressure relief valve activation. Another concern is the sudden reaction with LNG in the water (RPT) causing possible structural damage.

Should the gas release and LFL reach an ignition source, then a flash fire would result with the extremities burning away in seconds and a flame front moving back to the main pool at around 10 m/sec. The pool will burn away.

Effects from the surrounding environment should also be taken into account. The possible consequences of a delayed ignition in congested areas such as urban areas or heavily wooden shorelines, could result in overpressure build up and subsequent blast damage.

Similarly, smaller releases into the confined spaces between the tank and ship's hull could also result in a vapour cloud explosion, should there be a build-up of gas and a delayed ignition of the gas.

The diagram below illustrates the possible scenarios and consequences for navigational incidents.

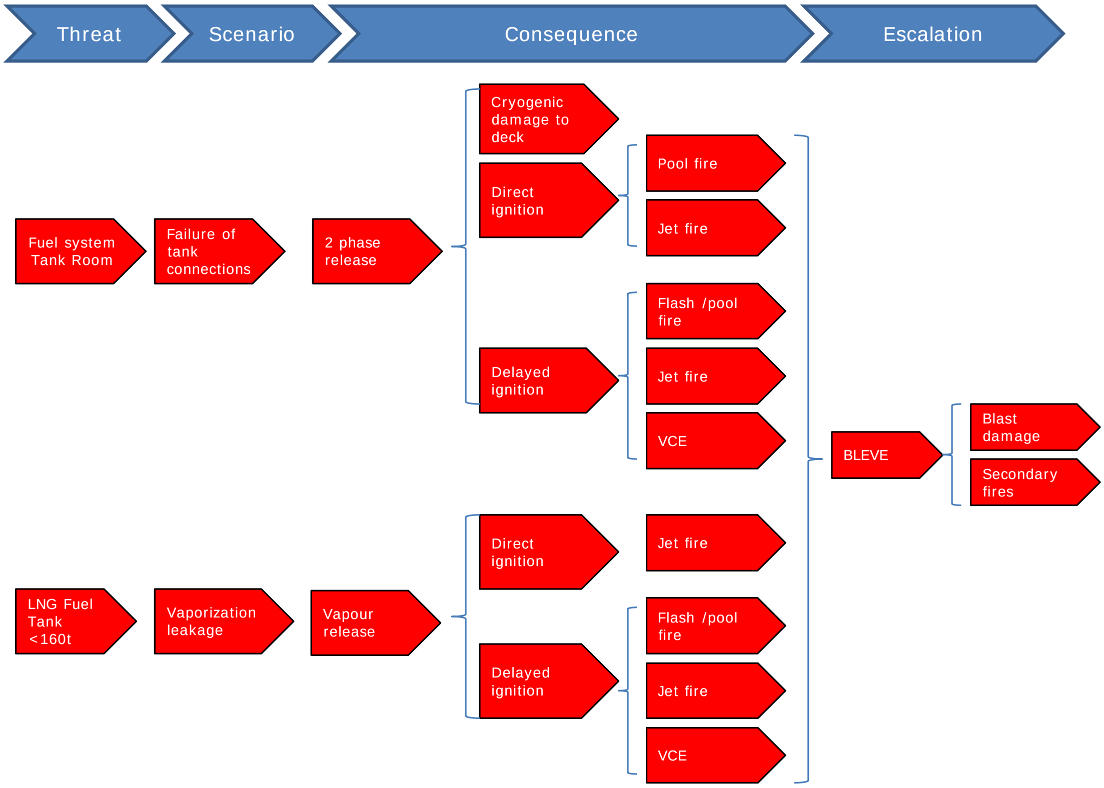


Figure 33 Event tree for navigational incidents.

3.2.3.3 COLLISION WITH QUAYSIDE

A collision with the berth whilst manoeuvring is a likely navigation incident, but due to the low speeds during manoeuvring, an LNG release is unlikely.

An incident occurring to a LNG vessel on a berth, being struck by another vessel for example, would more likely be a realistic scenario.

This type of event can result in loss of containment, such as an LNG release during a bunkering operation or a direct breach of the tank containment.

3.2.3.4 COLLISION WITH BRIDGE

The LNG storage tanks on deck are not protected against damage from the outside, therefore it would be realistic to expect damage to the tank and possible releases of LNG or gas vapour should the ship collide with a bridge. Ignition would result in pool, flash and jet fire depending on the pressure within the tank.

Figure 34 Damage after a collision on the Elbe (Germany).

3.2.3.5 GROUNDING

Most groundings are not a direct issue for the safety of the crew and residents. This depends on the damage to the cargo hold or fuel tank and the possibility of leakage of hazards materials into the water and air.

When a vessel is powered with LNG, there will be LNG fuel storage on board. If the LNG fuel tank is stored on deck, the tank will not be damaged during grounding.

When the LNG fuel tank is stored below deck, there is a small risk the tank will be damaged when the grounding impact on the hull is more than 0.8 meters. When the LNG fuel tank is damaged and leaking, LNG will come directly into contact with the water and could lead to RPT's and a gas/vapour cloud developing on the water surface. The most plausible damage will be small cracks in the distorted metal casing of the LNG fuel tank.

When the vacuum insulation from the LNG fuel tank is damaged and the inner metal casing of the tank is intact, the LNG will be warmed up by the ambient temperature of air or the water (when the hull is leaking). The LNG boil off gas pressure will increase and the safety valve will open. The LNG tank will blow off by the emergency relief valve on the LNG fuel tank for a long period (depending on the amount of LNG).

3.2.4 FUEL INSTALLATION INCIDENTS (LNG PROPELLED VESSELS)

The design and safety precautions for storage tanks and on-board fuel management systems minimize the chance of an incident; however, a number of scenarios have been identified as possible incidents resulting in a loss of containment with known consequences. This scenarios are;

- Failure of tank connections
- Failure of gas handling systems, such as the vaporiser in the tank room
- Release of vapour in engine room

Liquid releases due to leakage or failure of a tank/pipe connection could have a number of consequences. Firstly, the cryogenic effect of the liquid can damage the deck and structural elements should those elements not be protected against the extreme low temperatures. The photograph below depicts damage to deck plates caused by an LNG leak.

Figure 35 Deck plate cold crack. Source: DNV GL.

The generic events for a vapour gas release and its consequences can be applied here, namely a liquid release forms a combustible pool where direct ignition would result in a pool fire and delayed ignition would result in a flash fire or vapour cloud explosion in confined areas.

Pressure releases from tanks would result in a jet fire and possible pool fires. Should the flames impinge on the pressurized tank, causing catastrophic failure of the tank, then a BLEVE would result.

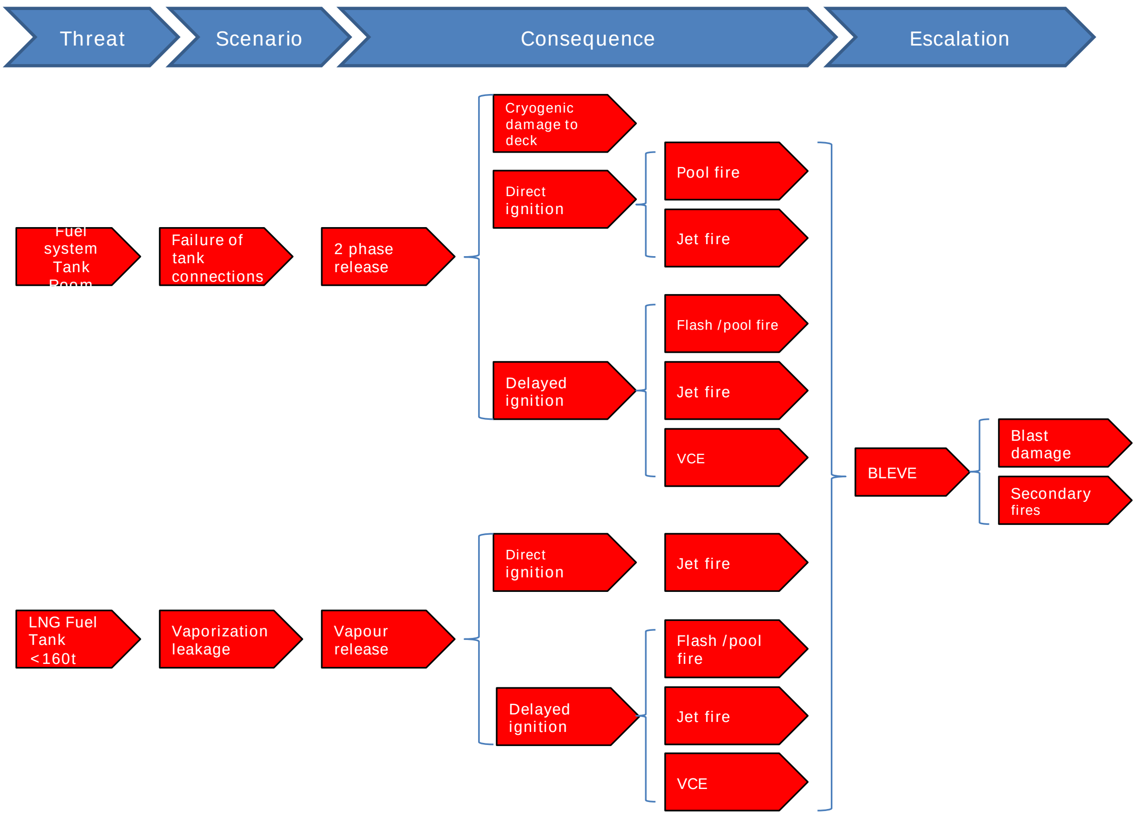


Figure 36 Event tree for fuel system components.

3.2.5 SCENARIO FOR CARGO TANK INCIDENTS

The scenarios concerning a cargo tank containment system for bunker vessels are similar to the fuel tank system described above, except the quantities of the release are higher (up to 1000m^3).

In addition to liquid leak scenarios from the tank, there could be situations involving the boiling of the gas management system on those tanks. These scenarios include vapour releases into the atmosphere from vent stacks should the pressure inside the tank exceed operational limits. A credible scenario could be a simple ignition of vapour from a vent, such as a lightning strike on the vessel's vent stack.

3.2.6 SCENARIO RELATING TO BUNKERING ACTIVITIES

3.2.6.1 INTRODUCTION

This report concentrates on ship to ship transfer and truck to ship transfer; however, larger terminal to ship transfer maybe also possible. Although the quantities of product transfer are different, the scenarios will be similar.

One other method discussed, apart from product transfer through flexible hoses, will be the loading of a tank cell – a container loaded onto the deck of the ship, which is then coupled to the fuel system of the ship.

The main scenarios identified are:

- Failure of transfer system (hose, arms and couplings)
- Overfill of the bunkering tank
- Over-pressurisation of the bunkering tank.
- Dropping of a tank cell during crane operation

The table below illustrates the quantities and hose sizes expected on the different bunkering operations.

Bunkering types	*Bunker capacity (receiver)*	*Rate of transfer*	*Hose or arm diameter*
Truck to ship	*≤160m³*	*100m³/hr*	*≤3″*
Ship to ship	*≤3.000m³*	*1.000m³/hr*	*≤6″*
Terminal to ship	*≤4.000m³*	*3.000m³/hr*	*≤10″*

Table 5 *Examples of transfer rates and hose diameters.* Source Fluxys.

A hose line can rupture or leak continuously during bunkering until the automatic/manual emergency shutdown has been activated. The amount discharged depends on the hose sizes. First is a truck transfer where a 3” line is used and then higher transfer rates from ship to ship or terminal to ship where a vapour return lines are employed. The corresponding pools have been estimated in the previous tables.

3.2.6.2 RELEASES FOR TRUCK TO SHIP BUNKERING

The following releases for truck to ship bunkering can be used:

Type of (un)loading hose or arm	Conditions: -160°C, 5 barg		Conditions: -138°C, 9 barg	
	Rupture	Leak	Rupture	Leak
3” LNG (50 m³/h)	8,9 kg/s	0,56 kg/s	8,0 kg/s	0,72 kg/s
3” LNG (100 m³/h)	17,7kg/s	0,56 kg/s	16,0 kg/s	0,72 kg/s

Table 6 *Release of LNG following failure of (un)loading hose or arm during a truck (un)loading, Source: Fluxys.*

The following pool diameters can be used:

Installation	Type of failure	Direct ignition	Delayed ignition
3” hose or arm (50 m³/h)	Rupture	149 m² (Ø = 138 m)	1.089 m² (Ø = 138 m
	Leak	10 m² (Ø = 138 m	34 m² (Ø = 138 m
3” hose or arm (100 m³/h)	Rupture	84 m² (Ø = 138 m	542 m² (Ø = 138 m
	Leak	10 m² (Ø = 138 m	34 m² (Ø = 138 m
(un)loading pump	Leak	10 m² (Ø = 138 m	34 m² (Ø = 138 m

Table 7 Maximum size of pool fire on load in case of direct or delayed ignition of the incidentally released LNG (no containment, -160°C) on land. Source: Fluxys.

3.2.6.3 RELEASES FOR SHIP TO SHIP / TERMINAL TO SHIP BUNKERING

The following releases for ship to ship / terminal to ship bunkering can be used for *unloading hose or arm*:

Type of (un)loading hose or arm	Conditions: -160°C, 5 barg		Conditions: -138°C, 9 barg	
	Rupture	Leak	Rupture	Leak
4” LNG	35,42 kg/s	1,0 kg/s	32,1 kg/s	1,3 kg/s
6” LNG	88,55 kg/s	2,3 kg/s	80,2 kg/s	2,9 kg/s
8” LNG	177,1 kg/s	4,0 kg/s	160,4 kg/s	5,1 kg/s
10” LNG	265,6 kg/s	6,3 kg/s	240,6 kg/s	8,0 kg/s
12” LNG	354,2 kg/s	9,0 kg/s	320,8 kg/s	11,5 kg/s
14” LNG	531,3 kg/s	12,3 kg/s	481,3 kg/s	15,6 kg/s

Table 8 Release of LNG following failure of a (un)loading hose or arm during (un)loading of a ship. Source: Fluxys.

The following releases for ship to ship / terminal to ship bunkering can be used for *vapour return hose or arm*:

Type of (un)loading hose or arm	Conditions: -160°C, 5 barg		Conditions: -138°C, 9 barg	
	Rupture	Leak	Rupture	Leak
4” vapour return	0,7 kg/s	0,007 kg/s	4,2 kg/s	0,04 kg/s
6” vapour return	1,3 kg/s	0,01 kg/s	7,5 kg/s	0,08 kg/s
8” vapour return	2,8 kg/s	0,03 kg/s	16,9 kg/s	0,17 kg/s
10” vapour return	3,9 kg/s	0,04 kg/s	23,0 kg/s	0,23 kg/s
12” vapour return	5,0 kg/s	0,05 kg/s	30,1 kg/s	0,30 kg/s
14” vapour return	7,8 kg/s	0,08 kg/s	47,0 kg/s	0,47 kg/s

Table 9 *Release of LNG following failure of a vapour return hose or arm during (un)loading of a ship. Source: Fluxys.*

The following pool diameters can be used:

Type of (un)loading hose or arm	Direct ignition		Delayed ignition	
	Rupture	Leak	Rupture	Leak
4”LNG	127 m² (Ø = 12,7m)	13,5 m² (Ø = 12,7m)	201 m² (Ø = 12,7m)	5,7 m² (Ø = 12,7m)
6”LNG	314 m² (Ø = 12,7m)	8,0 m² (Ø = 12,7m)	507 m² (Ø = 12,7m)	12,6 m² (Ø = 12,7m)
8”LNG	629 m² (Ø = 12,7m)	14,5 m² (Ø = 12,7m)	1.012 m² (Ø = 12,7m)	22,9 m² (Ø = 12,7m)
10”LNG	940 m² (Ø = 12,7m)	22,1 m² (Ø = 12,7m)	1.514 m² (Ø = 12,7m)	35,3 m² (Ø = 12,7m)
12”LNG	1.257 m² (Ø = 12,7m)	32,2 m² (Ø = 12,7m)	2.019 m² (Ø = 12,7m)	51,5 m² (Ø = 12,7m)
14”LNG	1.886 m² (Ø = 12,7m)	44,2 m² (Ø = 12,7m)	3.039 m² (Ø = 12,7m)	69,4 m² (Ø = 12,7m)

Table 10 *Maximum pool fire size for a release on water in case of direct or delayed ignition. Source: Fluxys.*

The above quantities are based on the assumption that an emergency shutdown system (automatic or manual system) operates within 120 seconds. Scenarios where the ship, whether it is the receiving ship or the bunker vessel, breaks accidentally from its moorings and the dry break coupling fails to operate, then the above discharge rates can be applied. Leaks of the flexible hose lines or arms will result in a pool which forms a vapour cloud that could ignite directly or be subject to a delayed ignition. The consequences are already documented in the previous event trees for pool fires.

Cryogenic damage to the ship’s deck plates must also be taken into account, although escalation here is unlikely.

3.2.7 OVERFILLING

Overfill prevention measures should eliminate this particular scenario, but cannot be fully discounted as a possible scenario. Should a tank be overfilled, then the vapour pressure inside the tank would increase causing the relief valve to activate via the vent stack above deck.

3.2.8 OVER PRESSURIZATION OF BUNKER TANK

During the bunkering operation, sloshing due to high transfer rates could also generate warming of the LNG and increase pressure within the tank until the pressure relief activates. The discharge to atmosphere should not be an issue unless an ignition source is within the vicinity of the vent, e.g. positioning to ignition sources on the bunkering ship.

3.2.9 LNG FUEL CELL

LNG tank containers could be loaded on a ship for supply of fuel to power the ships engines or be loaded as part of the cargo. In any event, there is a risk that the tank may be dropped during craning operations. The consequences of a dropped container would be similar to a pool or a pressure release scenario, with or without fire, and where the containment fails catastrophically, a cold BLEVE could result.

3.2.10 SECONDARY FIRES ON BOARD NOT INVOLVING LNG

A fire on board, whether it is from the cargo (other than LNG), accommodation areas or even other incidents nearby, could affect the LNG stored aboard. Realistic events would involve exposure of the tank or ancillary equipment to high temperatures, which in turn would escalate in the initial stages to a vapour release and in extreme situations to a total failure of the containment system or a possible BLEVE.

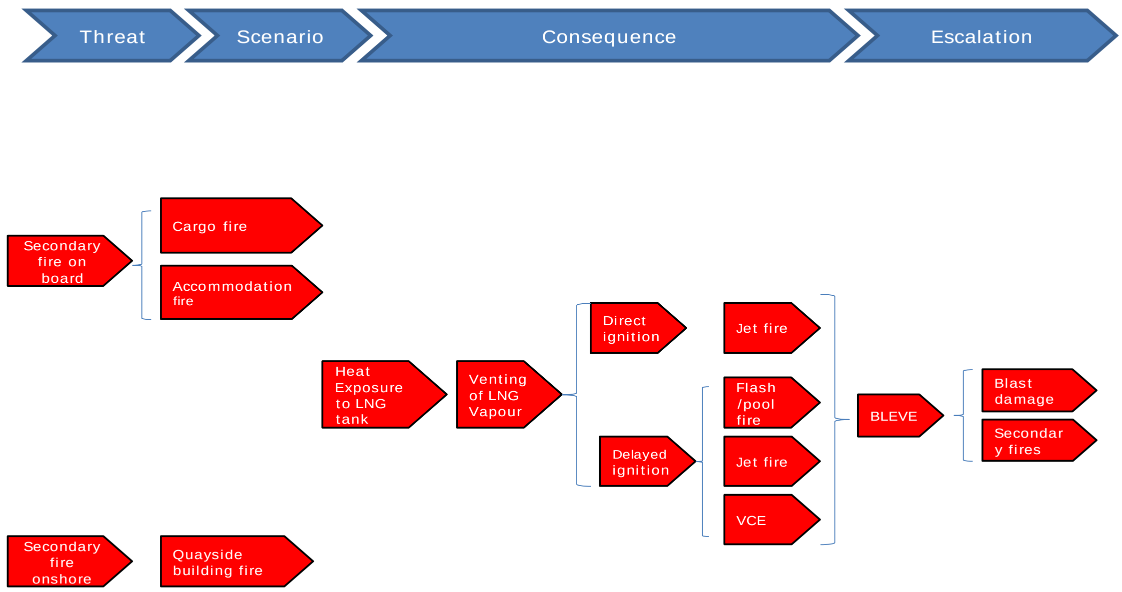


Figure 37 Event tree for fires other than LNG.

3.3 STATE OF READINESS: OVERVIEW PORTS

The Rhine-Main-Danube ports involved in the study received a questionnaire from the project group. The information these five ports along the Rhine corridor have shared with Falck has been used to describe how LNG, the operational preparedness on (unforeseen) scenarios and the emergency response has been implemented so far.

In this chapter, the results of the participating ports are presented, in alphabetic order.

3.3.1 PORT OF ANTWERP

The Port of Antwerp commissioned an independent third party to do a risk assessment (study) to get an indication of the impact of LNG, not just for inland purposes but also on a large scale (import terminals with seagoing vessels).

The study has presented a scope on the LNG risks in the Antwerp domain. Six risks have been identified based on losses of containments due to situations like:

- Small scale storage
- Inland vessel loading
- Bunkering
- Ship to ship collision

Measures have been organized to reduce the identified risks and are based on studies and experiences, some partly on common sense and knowledge in the company or elsewhere.

Some of the organized measures can be addressed as regulatory guidelines.

Antwerp has procedures available to manage LNG. The information source used for these procedures is partly based on private and public parties.

The port has mentioned it has no adequate emergency team(s) to respond in case of emergency situations. The (regular) available emergency responders are not appropriately sized (or only partly) and not competent enough to deal with probable LNG scenarios. But at the same time, the respondent of the questionnaire mentioned that personnel have been adequately trained to ensure an effective emergency response relating to common incidents.

No information is available on scenario guidance and no emergency plans have been developed. The scenario requirements in the emergency plans aren't available. Also, the present facilities of extinguishing (firefighting) systems (e.g. dry powder and foam) don't meet the minimum good (industrial) practice. Mobile firefighting (FiFi) appliances are only partly available.

Comprehensive facilities for emergency shutdown situations are only partly available.

The incident commander is trained in crisis management. The commander has direct lines with other competent authorities and other government agencies in the sphere of influence of small scale LNG. Finally there are good contacts with (independent) media to inform the public in case of an LNG emergency.

The stakeholders in relation to LNG are the environmental protection agency (EPA), port authority and fire & rescue services. With a key role for the last two mentioned.

3.3.2. PORT OF MANNHEIM

The area of Mannheim has no study results as a trigger for their operational preparedness on LNG accidents. The port has partly produced some procedures to manage LNG scenarios.

It has a partly adequately trained emergency team to respond in case of an emergency. This team is partly of appropriate size and slightly competent to deal with LNG emergency situations.

There's no information available on scenario guides.

The present extinguishing systems (dry powder and foam) and available capacities and properties meet with the minimum good (industrial) practices.

There's a key role for the EPA in regulations on the LNG aspects.

Next to the EPA, the port authority and the fire services play just a small role in the LNG domain.

However, no party plays a key role in LNG incident management.

The incident commander is trained in crisis management, for regular incident response. The commander has direct contacts with (other) governmental agencies.

3.3.3. PORT OF ROTTERDAM

Similar to Antwerp, Rotterdam has commissioned an independent third party perform a risk study to get an indication of the impact of LNG, not just for inland purposes but also on a larger scale.

The assessment has presented a scope on the LNG risks: several risks have been identified, such as truck and rail loading, vehicle filling stations and also LNG on a larger scale.

Measures have been organised to reduce the identified risks and are based on studies and experiences.

There are also basic scenario guides which can be used by personnel on terminals and ships, but these are based on handling small incidents, such as fires in wheelhouses or engine rooms. But there are no guidelines concerning what the crew members must do in case an incident can't be contained.

Some of the organised measures can be addressed to regulatory guidelines. The present procedures are not adequate emergency situations. The information source used for these procedures is a product of collaboration between private and public parties.

In case of emergency situations, the port has mentioned it has partly adequate emergency team(s) to respond (in Rotterdam the intervention is being organised by a public private partnership). The (regular) available emergency responders are only partly of appropriate size and also partly competent to deal with probable LNG scenarios.

There is information available on scenario guidance and some emergency plans have been developed. Nevertheless, the present facilities of extinguishing dry powder don't meet the minimum good (industrial) practice. On the other hand, mobile FiFi appliances are completely available.

Comprehensive facilities' emergency shutdown situations are available.

The incident commander is trained in crisis management. The commander has direct lines with other competent authorities and other government agencies in the sphere of influence of small scale LNG. Also, in Rotterdam there are good contacts with (independent) media to inform the public in case of an LNG emergency.

The stakeholders in relation to LNG are the environmental protection agency, port authority and fire & rescue services (integrated in a so called Safety Region), which all play a key role for the last two mentioned. Note: the fire service (department which is responsible for the implementation of intervention) was not involved in the pre-planning.

3.3.4. PORT OF STRASBOURG

The port has mentioned that no risk assessments on LNG accident have been done nor are there any contingency or emergency plans available in case a LOC occurs.

3.3.5. PORT OF SWITZERLAND (BASEL)

The situation is similar to the port of Strasbourg.

3.4 EXISTING EMERGENCY RESPONSE EDUCATION AND TRAINING

No standardized education and training curriculums on incident response LNG for in inland waterway navigation are available yet.

Nevertheless, specialised awareness education and training for emergency response organisations is already developed and operational at a few training institutes.

These institutes use their own LNG awareness education and training curriculum. Learning objectives and methods differ from one another.

3.5 GAPS

As a result of this desk study (part 1 of this document) the following gaps are identified:

Planning
- There is no existing specific validated tailor made incident preparedness for small-scale LNG in inland waterway navigation.

People
- There is no existing specific validated tailor made education and training curriculum on incident response LNG for in inland waterway navigation.

Equipment
- There is no existing specific validated incident response equipment for small-scale LNG in inland waterway navigation.

It is to be emphasized here that these identified gaps refer to professional emergency response organisations such as fire, police and medical services, port and river authorities. These are not identified gaps that refer to ship’s crew, deck-officers, engineers or shore personnel.

3.6 MATRIX

As a result of the desk study regarding the existing knowledge on LNG incident response the following basic matrix is derived.

Explanation in advance:

Rows : 5 types of LNG vessels (based on existing technology)
Columns : 11 categories of events (that can occur along the Rhine corridor)
Cells : 7 different effects (A to D) as a possible result (and starting point for part 2)

Incidents and emergencies / **LNG fuelled vessels and vessels sailing with LNG as cargo**			**Events:**										
Types:			1. Collision with another vessel	2. collision with quayside	3. collision with bridges	4. grounding	5. failure of tank connections	6. vaporisation leakage	7. overpressure release	8. transfer system failure	9. overfill	10. drop of LNG tank cell	11. secondary fire (e.g. cargo fire)
	LNG propelled vessels	Fuel tank(s) on deck – Fixed			**B,C D,E**		**B,C E**	**B,C**	**C**	**B,C D,E**			**F,G**
	LNG propelled vessels	Fuel tank(s) on deck – Portable			**B,C D,E**		**B,C E**	**B,C**	**C**	**B,C**		**B,C D,E F,G**	**F,G**
	LNG propelled vessels	Fuel tank(s) below deck	**A,B C,D E**			**A**	**B,C D,E**	**B,C**	**C**	**B,C D,E**			
	LNG carriers / bunker ships	Type C tank(s)	**A,B C,D E**			**A**	**B,C D,E**	**B,C**	**C**	**B,C D,E**			
	LNG carriers / bunker ships	Membrane tanks	**A,B C,D E**	**B**		**A**	**B,C D,E**	**B,C**	**C**	**B,C D,E**			

Table 11 Scenario and effect matrix (by expert judgment).

Explanation of effects:

A. RPT – structural damage
B. Vapour cloud emission – flash fire
C. Vapour cloud emission – jet fire
D. Liquid release – pool fire
E. Liquid release – cryogenic damage
F. BLEVE – blast damage
G. BLEVE – domino / (more) secondary fire(s)

This matrix will be the basis on which the next phase of the desk study will continue – the development of guidelines for incident preparedness for small-scale LNG in inland navigation. This will focus on the credibility of events and visualisation of effects for each type of vessel.

PART 2

DEVELOPMENT OF GUIDELINES FOR

INCIDENT PREPAREDNESS EDUCATION AND TRAINING ON INCIDENT RESPONSE

FOR SMALL-SCALE LNG IN INLAND NAVIGATION

4 EMERGENCY PREPAREDNESS

4.1 SCOPE

This second phase of study focuses on ‘giving advice to’ and ‘providing guidelines for’ all stakeholders, that are in need of information on which field improvements need to be made.

4.2 DELIVERABLES

This part 2 of document includes a supplement of the matrix of the first part, with advice and recommendations for the identified gaps and items that were addressed in the matrix in the first part.

This part also covers:

- development of incident preparedness guidelines for small-scale LNG in inland navigation. These guidelines are included as a supplement of the matrix in part one.
- Development of guidelines for education and training on incident response applied to small-scale LNG in inland navigation.

Where training is necessary, these guidelines describe the requirements for training for each of the scenarios.

4.3 ROADMAP

4.3.1 MAIN TOPICS

Within phase 2 the two main topics are ‘incident preparedness’ and ‘education and training’. Starting point is the basic matrix indicated in 3.6.

4.3.2 POSITION

Incident preparedness is based on credible incident scenarios and leads to identification of required education and training elements for this purpose (consequence based approach).

4.3.3 MIND MAP

The following mind map (diagram) is used by project team to visualize the steps taken (numbers 1 to 4) and to organise research sub-topics and associated key words.

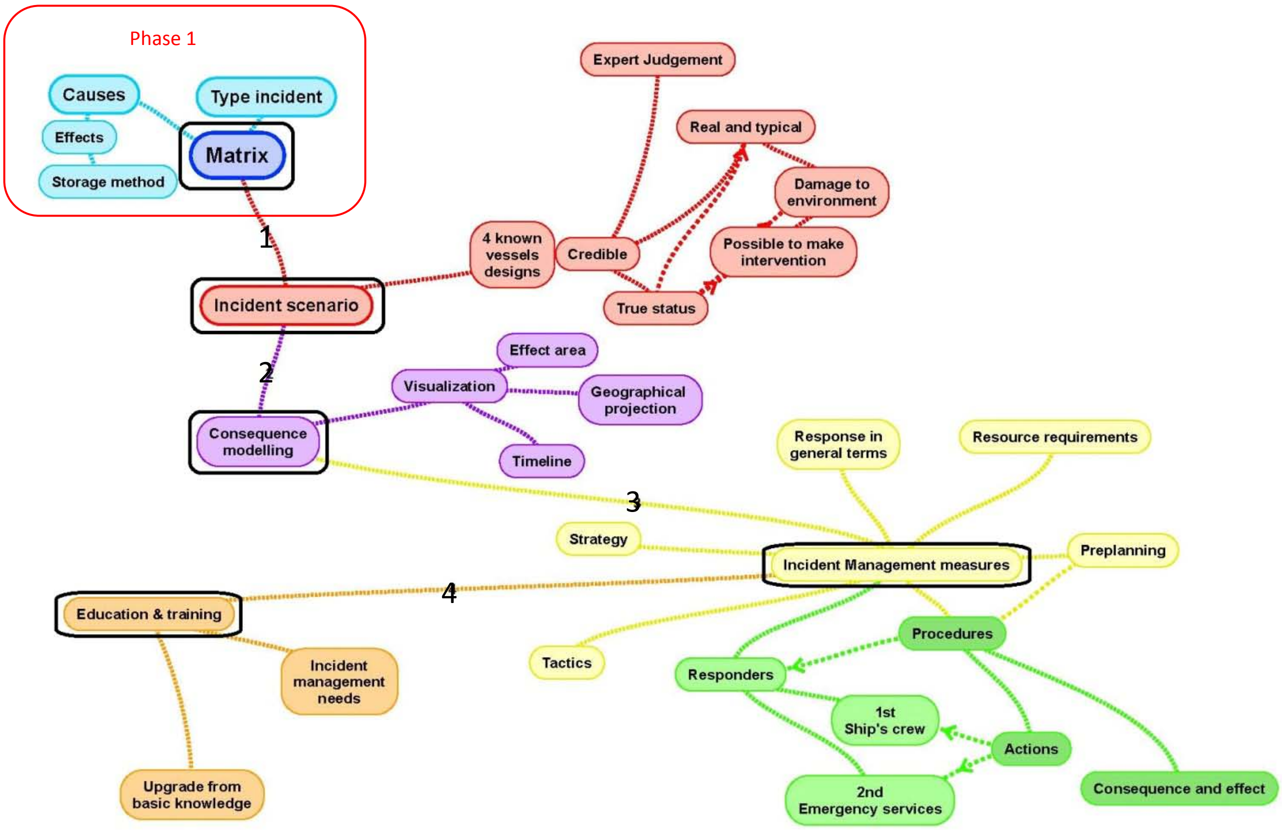


Figure 38 Mind map of visualisation of project steps.

4.3.3.1 SUB-TOPICS

Within this project, the following sub-topics haven been studied, analysed and further developed in chronological order.

1. <u>Technological descriptions</u>

   TECHNOLOGY: This is based on the desk study method of existing

   - system technology LNG vessels,
   - preventive safety measures provided, and
   - geographical characteristics of the Rhine Corridor

   (See part 1).

2. <u>Significant spill, emission and escalation scenarios</u>

   SIMPLIFY: The overview of significant spill, emission and escalation scenarios are a result of analysing and simplifying the existing knowledge available (see part 1).

3. Credible emergency and incident response scenarios

FILTER: All significant spill, emission and escalation scenarios are filtered by answering the following three questions (this approach is derived from Seveso-directive methodology):

1. The scenario is realistic and typical,
2. The scenario can cause relevant damage to assets or people in the vicinity,
3. Intervention of scenario will lead to obvious effect, in order to prevent escalation.

Only the scenarios that meet all of these three criteria are selected (by expert judgement) as credible emergency and incident response scenarios. Source intensity and effects are important parameters.

Implausible catastrophic scenarios (such as plane crash on vessel) or scenarios whose likelihood of emergence is virtually nil are not taken into account.

4. Consequence modelling

DESCRIBE: Selected credible scenarios are sorted in reverse order per type (technology and consequence).

A representative scenario per type (credible to prepare for) is described and visualized by a fire / dispersion map. Four different scenario maps are developed.

5. Emergency response planning

Based on those fire / dispersion maps, four scenario specific emergency response plans (SSERP's) are developed. In each plan is specified:

- Incident response strategy
- Outline of actions/tasks for incident responders
- The 'to deploy capacity' (emergency response equipment / resources).
- Unified command considerations

6. Education and training

IDENTIFY: Based on the outline of tasks for incident response (1st and 2nd responders) the required LNG training elements are identified.

These training elements aim for professional competence of emergency response organisations along the Rhine Corridor in dealing with incidents that could emerge with LNG in inland waterways navigation and how to respond to them.

4.3.3.2 FLOW CHART

The steps taken can also be visualised in the following flow chart. Colours of cells are consistent with cells of previous mind map.

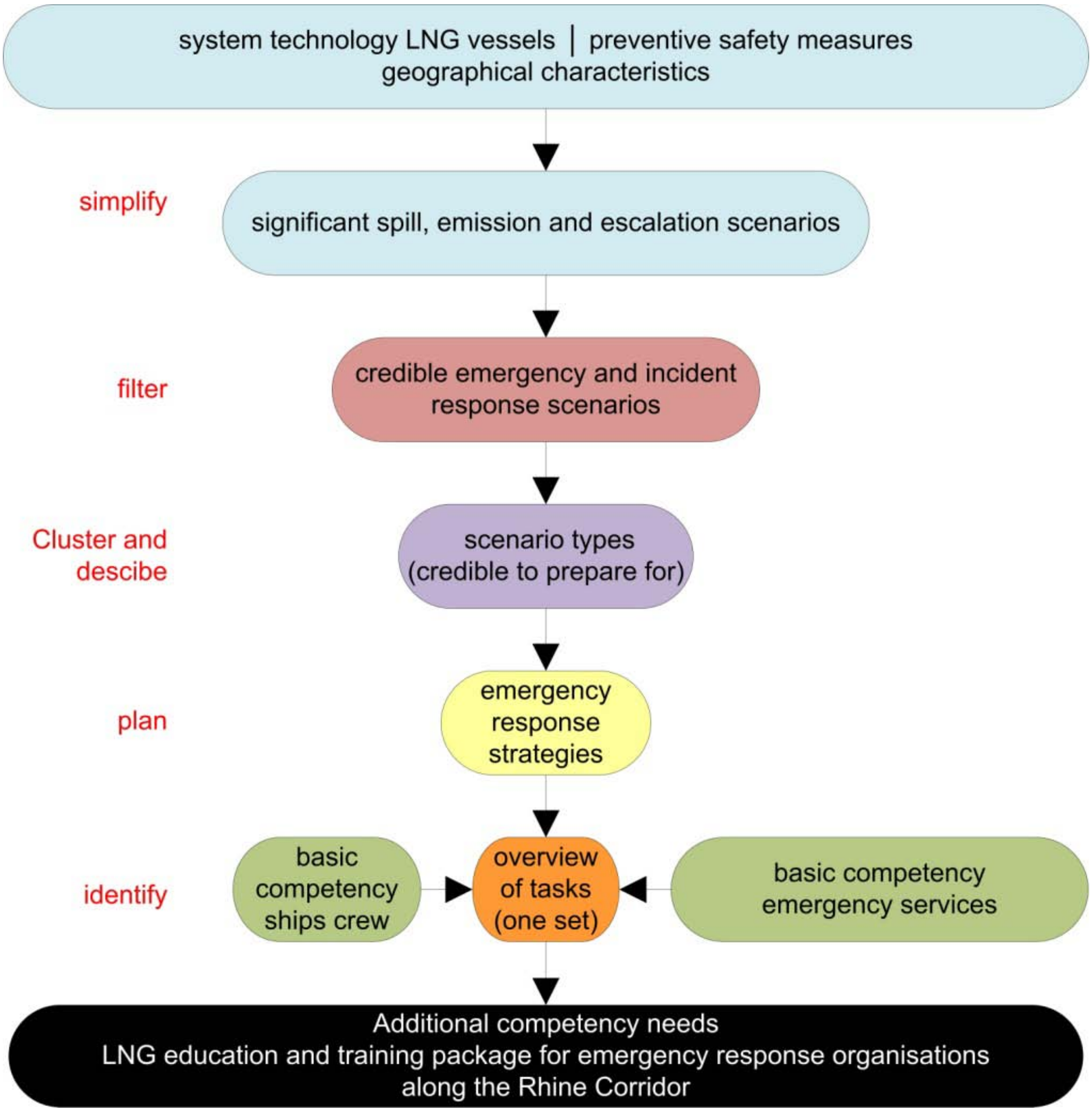


Figure 39 The systematic approach to identification of the required education and training elements.

4.4 GUIDELINES FOR INCIDENT PREPAREDNESS

4.4.1 INTRODUCTION

In preparing for LNG incidents, decisions will need to be taken at the various levels within the emergency response organisation in order to effectively manage the incident. Emergency response management is a key element of Emergency Response Preparedness. We differentiate three decision making levels within the emergency response:

- Strategic decision making
- Tactical decision making
- Technical decision making

The form of incident management will not be discussed further in this document because it does not fall into the scope of this project. In order for the responsible persons to make an informed decision, we offer a number of suggestions to support that process. Only the specific strategies, tactics and techniques for incidents involving LNG incidents on inland water will be addressed. It is assumed that the emergency services have the general knowledge regarding shipping incidents involving hazardous materials on the inland waterways.

4.4.2 KNOWLEDGE AND UNDERSTANDING OF LNG INCIDENT ON INLAND WATERWAYS NAVIGATION

The strategies describe how to deal with incidents, the effect of which could apply to one or more incident scenarios:

- LNG Vapour cloud
- LNG pool
- Rapid Phase Transition (RPT)
- Fire (unconfined and confined pool fire / jet fire / BLEVE)

To deal with LNG spills on water, the emergency response services need some general information for optimal decision making.

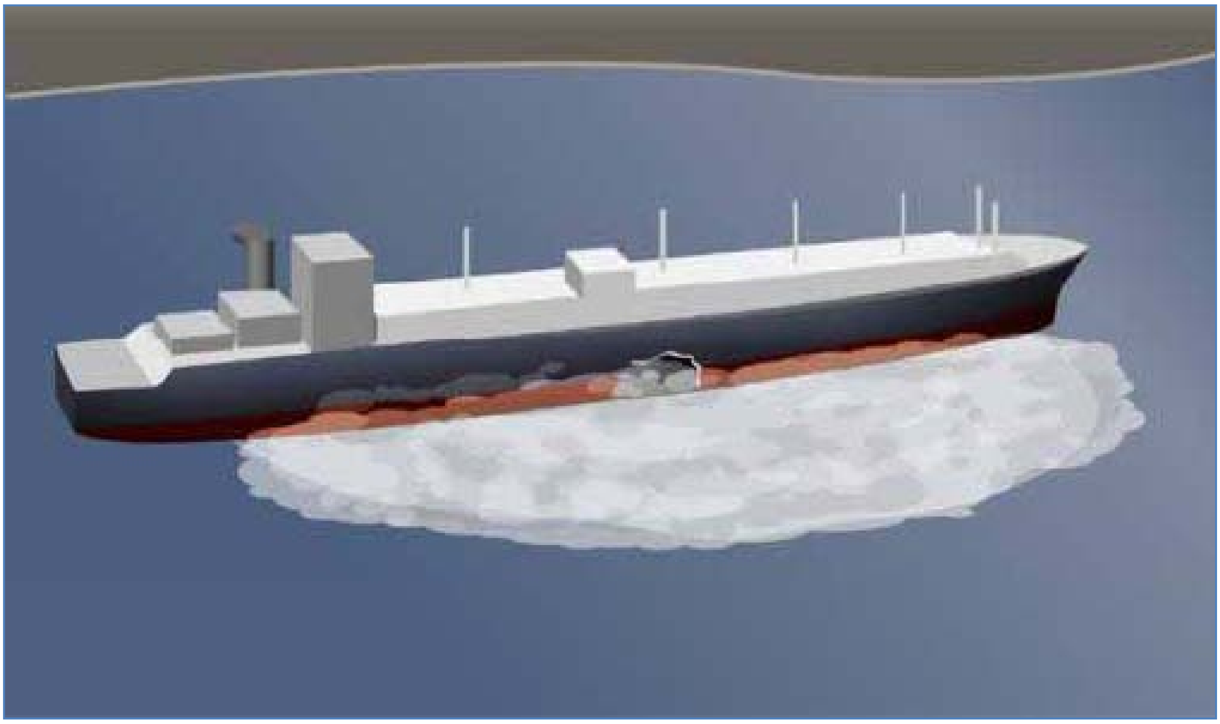


Figure 40 Spill on water [2]

The liquid spill duration, release rate, expansion rate and rate of vaporization are important factors for the estimation of safe separation distance for (flammable) vapour dispersion and radiation from pool fires.

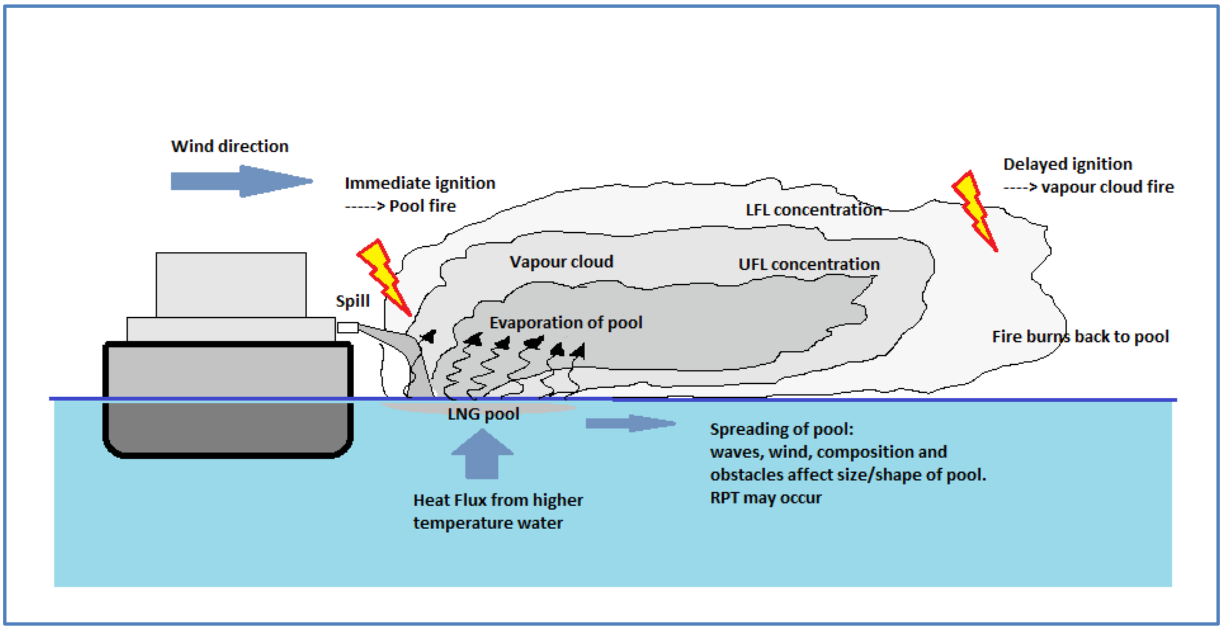


Figure 41 Possible fire scenarios when LNG is spilled on water [2].

Also, insight into the momentum of time-dependent events that occur one after the other within the incident on-scene is relevant:

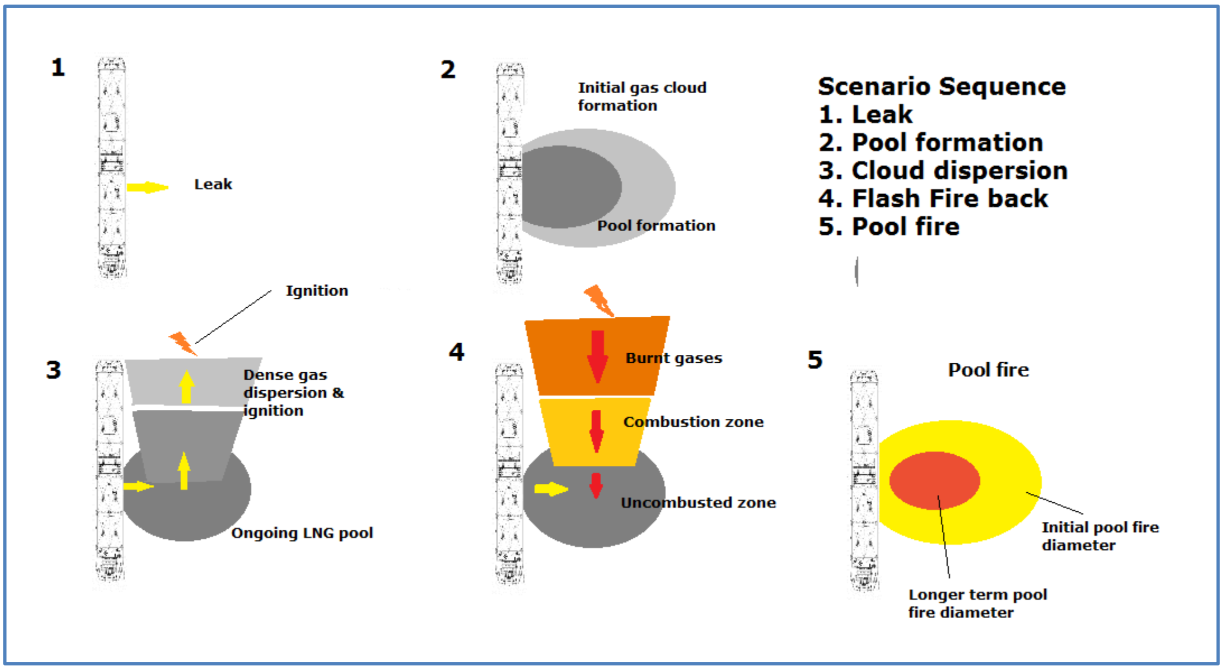


Figure 42 Scenario sequence [4].

4.4.3 LNG EXPANSION

LNG is a liquid (liquid natural gas) with at least 82% methane. However, often the content is about 91% methane (benchmark) or even more. The boiling point of LNG is about -162 ^{0}C under normal atmospheric pressure (1 bar).

When the liquid (-162^{0}C) releases during an LNG incident, the expansion rate (liquid / gas equivalent) depends on the ambient temperature.

Liquid (at boiling point) / gas equivalent under atmospheric pressure (1 bar)	
Ambient temperature (^{0}C)	Equivalent (mol/mol)
0	589
15	621
25	643

Table 12 Ratio liquid / gas equivalent at atmospheric pressure

4.4.4 LNG EVAPORATION

4.4.4.1 PARAMETERS EVAPORATION RATE

LNG evaporation can vary significantly depending on:

- turbulence intensity
- liquid layer thickness
- water and air temperature, and
- wind speed.

All of these different parameters result in different LNG evaporation rates. Field tests are shown in the following figure.

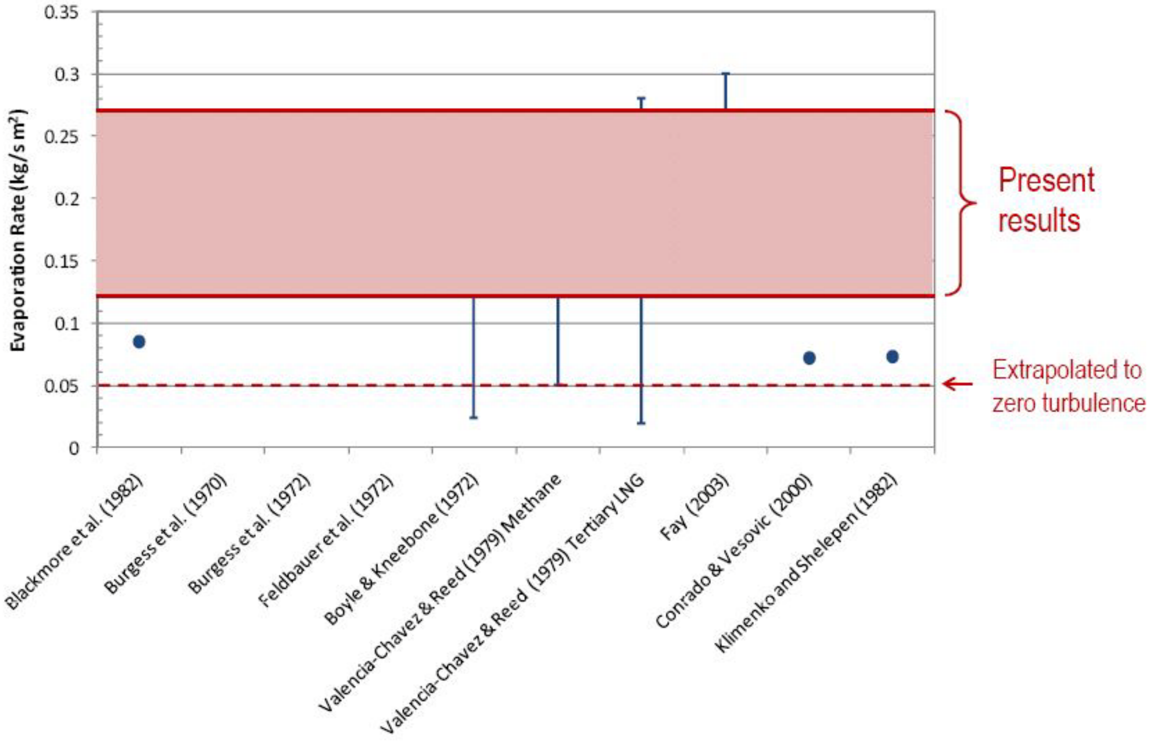


Figure 43 Evaporation rates [2].

4.4.4.2 EVAPORATION RATES FOR EMERGENCY RESPONSE

Following a study of field tests [5] for the evaporate rates and the situation for inland shipping (shallow water), the following evaporation and regression rates for LNG spills on water have been validated.

LNG evaporation rates* (LNG pool on water)	Density	Evaporation rate*		Regression rate*
	kg/m^3	$kg/m^2/s$	$m^3/m^2/min$	mm/minute
LNG	430-470	0,16	15	20

Table 13 Evaporation rate on water

**) all numbers are rounded, and the average at several field test results and evaporation times.*

4.4.4.3 CONTROLLING LNG VAPOUR CLOUD BY WATER SPRAY

A leakage of LNG is interpreted as a liquid release with a temperature between -170°C and -107°C. The release rate is proportional to the vapour pressure and the size of the hole (diameter).

When LNG is released into water, the vaporization rate is around 15 $m^3/m^2/min$. This is a rough indication.

Rate of evaporation of LNG on water is about: 15 $m^3/m^2/min$

The cold LNG vapour is initially heavier than air and can forms a visible condensed water cloud when the humidity is > 55%.

The visual limits of the condensed cloud in the horizontal plane could be approximated to 100% LFL of methane. The length of the gas cloud is dependent on factors such as temperature, wind direction and the rate of LNG vaporization.

The flammable limits of a gas cloud can be defined using a suitable gas detection apparatus. A special gas detection apparatus is required, as not all standard equipment will give a speedy and accurate reading.

The extent of an LNG vapour cloud release over water will often be limited by dikes and/or influenced by the geographical / structural features. Depending on the height of the dikes and the rates of release, the LNG could spill over and spread further beyond the limits of the waterways.

In other circumstances, the LNG vapour cloud could be contained by high river banks, buildings and mountain sides; the effect will result in the channelling of the cloud. In these situations, computer modelling programmes to determine the extent of the cloud are ineffective.

The extent of an LNG vapour cloud migration is influenced by:

- The warming of the cold LNG vapour so that the methane gas becomes lighter than air and as a consequence rises into atmosphere. This can be accelerated by using water spray from water monitors or water curtains. NB: Methane gas is not soluble in water!
- The use of a water screen or water curtain, where by a small cold vapour cloud can be held back or contained.
- At ground level there can be around 18% minimum and 65% maximum reduction in gas/vapour concentrations due the good application of water sprays.

For standard downward spray configuration, a 65% reduction in methane mass fraction occurs at the lowest wind speed of 1 m/s, but at the highest evaporation considered.

At wind speeds of 4 m/s, the decrease is only 18% and the highest cloud temperature at the layer is 2^0C for the lowest wind speed.

Range of 18% to 65% reduction of the impact area by application of water spray

A vapour cloud must not be allowed to migrate into confined space environments, inside watercraft or buildings, as ignition of the vapour would create a confined vapour cloud explosion (CVCE) and subsequent secondary fires.

This phenomenon is also known as 'gas-pocketing'. The following preventative measures can be used to prevent injury to persons;

- If indeed the gas/vapour cloud threatens inland water craft or adjacent buildings, then the first priority is to remove all shipping out of the danger zone or evacuate the occupancy.
- The residents or workers inside building along the waterway must be evacuated. Instructions to shut down ventilation systems within the risk area should also be strongly advised.
- Any ignition sources must be isolated or removed.

4.4.4.4 CONTROLLING VAPOUR DISPERSION BY FOAM

Vapour dispersion from a contained LNG pool can be suppressed by applying high expansion finished foam to the surface of the LNG pool. This tactic can only be considered on contained LNG pool releases; however, with the correct application, the concentration of vapour above the pool could be reduced by as much as 50% [6].

Note: the foam application may initially have a negative effect on efforts to control the LNG vapour due to the aggregate vaporization in the initial stage of foam application. This is the result of an initial rapid decrease in vapour temperature followed by excessive vaporization.

Therefore, caution should be taken not to allow fresh water into the LNG before initiating foam application.

Expansion foam is effective in reducing the methane in downwind concentrations, resulting in decreasing LFL and ½ LFL distances.

Previous experiences have also identified that the minimum effective foam depth is 0,64 m.

For a good application of high expansion foam, the following are required:

- High expansion foam concentrate for cryogenic liquids
- Foam equipment with expansion ratio of 500:1
- Foam application rate of 10 l/m² min (ask foam supplier for the foam application rate for LNG)

Releases of liquid LNG on board a ship can seriously affect the integrity of the ship's construction due the characteristics of cryogenic LNG.

In order to protect the structure, water is often discharged, creating a water film over the elements which could come into contact with the liquid LNG release. LNG essentially floats on water, and therefore a small leak is not only washed away overboard but the liquid is also quickly vaporised.

4.4.4.5 CONTROLLING RAPID PHASE TRANSITION (RPT)

Depending on the amounts, liquid LNG discharging into the water could create a RPT. This phenomenon could also occur when water is introduced into an LNG pool and should be avoided if possible.

The application of water spray in a measured way by trained professionals could be considered an acceptable tactic to accelerate the vaporisation of the liquid LNG. This technique is called agitation.

4.5 LNG FIREFIGHTING

Should an LNG vapour cloud in the open air be subject to a delayed ignition, the result would not lead to an unconfined vapour cloud explosion (UVCE).

The vapour mixture will not burn explosively but burn steadily along the flame front back to the source of the release.

Depending on the source of the release, either a pool fire, jet fire or two phase release fire would be the subsequent result.

However, if an LNG release into a confined space ignites, it could easily result in a confined vapour cloud explosion (CVCE).

4.5.1 BURN TIME

In order to predict the burn time of LNG fires, the following parameters are required:

- The volume of LNG in cubic metres or mass in kilograms
- The surface area of the fire in square meters
- Contained pool fire or uncontained pool fire

The following table gives a comparison of burn rates between LNG and other commonly known fuels.

Comparing several fuel burning rates (contained fire on ship or land).

	Burning rate		Density	Caloric	Radiation
	mm/minute	$kg/m^2/s$	kg/m^3	MJ/kg	KW/m^2
LNG*	14	0,11	430-470	50,2	220
LPG	13	0,13	585	43,4	140
Gasoline	5	0,055	740	-	-
Kerosene	3	0,06	790	-	-
Fuel Oil	2	0,05	900	-	-

Table 14 Comparison of burning rates for different fuels

*) average of several test results

There are other burn rates applicable for unconfined pool fires on water, which differ from those indicated in the above table for confined situations on land.

In the table below, the values are extrapolated from the Sandia reports (2004 [7] and 2008 [8]) and the report "Large LNG Fire Thermal Radiation – Modelling Issues & Hazard Criteria Revisited" from Phani K. Raj [9].

	Burning rate		Density	Caloric	Radiation
	mm/minute	kg/m²/s	kg/m³	MJ/kg	KW/m²
LNG (D=<100 m)	18	0,135	430-470	50,2	220
LNG (Large pool)	21	0,15	430-470	50,2	280

Table 15 Burning rates of LNG on water

*) all numbers are the average at several test results.

4.5.2 LNG UNCONFINED POOL FIREFIGHTING

Extinguishing LNG pool fires on water is not practicable and the emergency response must be deployed defensively to control the effects from the incident, prioritising as follows:

- Prevent escalation
- Contain the fire
- Control the fire

The heat flux from an LNG pool on water will be at its most intense, for example, following an LNG compartment discharge from an LNG transport tanker with a delayed ignition.

The pool will be extremely large but the duration of the burn will be very short. In such cases, fixed fire protection systems and passive heat resisting coating provided as part of the integral design specification would help to prevent further escalation.

The initial fire would probably already have burnt out before the arrival of the first responders.

In the event that it is still burning, the high levels of heat radiation would prevent the emergency responders from approaching the ship in a position where monitors from a fire boat could reach it and be effective. A BLEVE should not be discounted if the other exposed LNG tanks are not sufficiently cooled.

For smaller LNG pool fires, the emergency response services shall concentrate on cooling the remaining LNG compartment tanks and the ship construction. The cooling can be applied using an up-wind approach, for example from a firefighting vessel with water sprays directed toward the length of the ship.

Although water spray in the pool cannot be avoided, do not discharge a full water beam into the LNG pool.

4.5.3 LNG CONFINED POOL FIREFIGHTING

A confined LNG pool fire occurs when product cannot flow away and is contained (for example in a bund, for small fires <10 m² of surface area). Class BC dry chemical powder should be considered to actively extinguish the fire. For fire with a surface area greater than 10 m², consider a defensive strategy.

Extinguishing an LNG pool fire with foam is not possible, although high ex foam can reduce the intensity of the fire and radiant heat but demands a regular "top up" of foam to be successful. Note: during the initial application of foam, an increase in the intensity of fire will be experienced before any reduction is seen. Foam with an expansion ratio of 500:1 and an application rate of 10 l/m²/min is recommended.

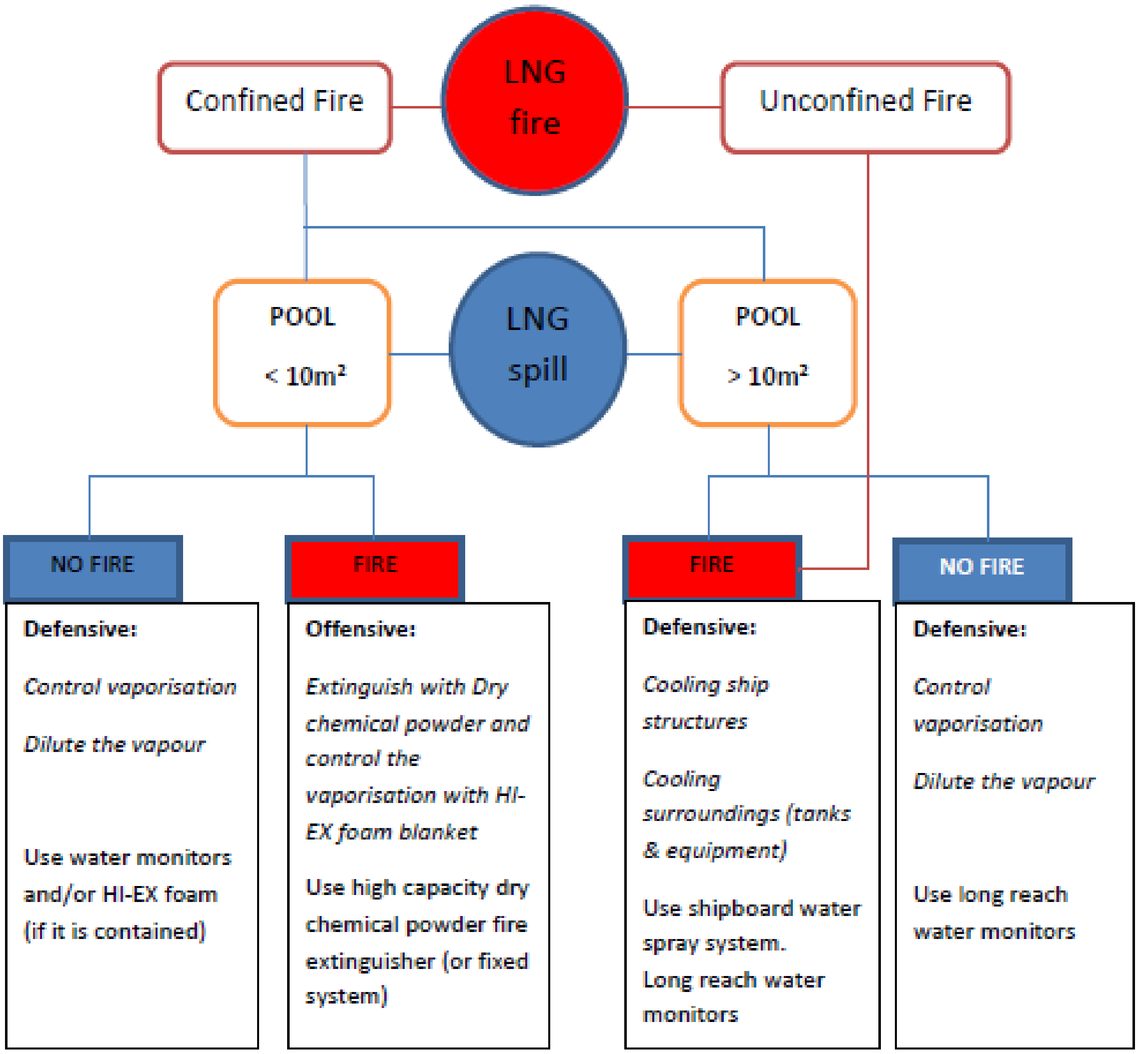


Figure 44 Firefighting strategy summary

4.5.4 JETFIRE-FIGHTING

For a gas fire there are two priorities:

- Stop the LNG (gas) flow via the Emergency Shut Down
- Take care that all other tanks, pipe work and ship construction are cooled with water spray systems. (Regardless whether it is a pressure fire, jet fire or pool fire).

Using a thermal imaging camera to check whether the cooling effect can be achieved is recommended. Adjust cooling strategy as required.

4.5.5 BLEVE

A boiling liquid expanding vapour explosion (BLEVE) is an explosion caused by the rupture of a vessel containing a pressurized liquid above its boiling point at atmospheric pressure.

A BLEVE on a type A of B or membrane tank should not be possible; however, for a Class-C tank, a BLEVE should not be ruled out. A BLEVE should not develop during short term exposure to an event on a class-C tank if the insulation material is not damaged and the vacuum remains intact.

Damaged insulation and extreme temperatures could cause in a failure of the tank shells and result in a BLEVE. Therefore, the priority must be to cool other LNG tanks to prevent escalation and the risk of a BLEVE.

4.6 COOLING

4.6.1 STRATEGY

The use of a defensive strategy is preferable for industrial incidents and the same strategy is also applicable for maritime incidents.

Should the initial firefighting action fail, the risk of escalation is very high due the presence of large quantities of fuel in tanks and lines. The risks increase if the above elements are exposed to the heat from the fire. Therefore, in most cases the first actions are to cool the tanks, lines, equipment and the ship's construction, before extinguishing is considered.

There are situations where the fire cannot be extinguished and the preferred course of action is to let the fire burn itself out. LNG is a product that should be left to let itself burn out under controlled conditions. During the controlled burning, the surrounding areas are cooled.

4.6.2 CAPACITIES

For an indication of the water quantity required for cooling, the guideline IP-19 (Energy Institute, formerly Institute of Petroleum) "Model code of safe practice: Fire precautions at refineries and bulk storage terminals" can be used. In accordance with this code, at least 10 l/m²/min cooling water should be used to protect a vessel's hull from flames.

In the 46CFR154 (Safety standards for self-propelled vessels carrying bulk liquefied gases) the design criteria for water spray systems is documented:

1. 10 l/m²/min. over each horizontal surface; and
2. 4 l/m²/min. against vertical surface, including the water rundown.

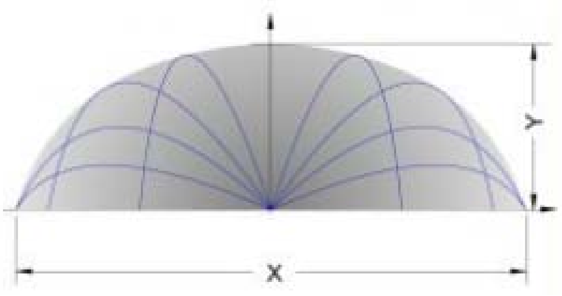


Figure 45 Hydro-shield flat fan pattern

In practice, the flow capacity monitors and/or hydro-shields together with their optimum operating pressure will determine the throw and height of the water screens.

4.7 WATER SHIELDING

4.7.1 CONTROL OF HEAT EXPOSURE AND GAS / VAPOUR CLOUD

The following firefighting boats, which operate along the Rhine corridor, are equipped with water monitors of sufficient capacity and reach, in order to control heat exposure and to control reduction in gas/vapour concentrations.

Figure 46 Firefighting boats along the Rhine

4.7.2 FIFI BOAT CAPACITIES

There are different types of firefighting boats:

FIFI 1 : water capacity 2,400 m^3/ hour
FIFI ½ : water capacity 1,200 m^3/ hour
FIFI : water capacity 500 m^3/ hour

4.8 FIRST AID

4.8.1 EXPOSURE

Cryogenic liquefied gases are condensed into a liquid at atmospheric pressure by cooling them. In the case of LNG, it is cooled to approximately -162°C.

The ambient temperature surrounding the LNG-tanks on (or in) ships results in the boiling off of the cryogenic liquid into a gas the moment it leaves the tank due to a loss of containment.

One litre of cryogenic liquefied gas generates considerable quantities of gas (approximately 600 times its volume).

The areas where the tanks are installed require adequate ventilation which can remove at least the amount of gas generated. Ventilation should prevent substantial changes in the oxygen concentration of the air. When large quantities released, such as in impact collisions, ventilation should not be considered as a sufficient measure for the responders since the likelihood of a system malfunction is high.

LNG is not toxic, but it might displace atmospheric oxygen when it is released, which may cause asphyxiation when the oxygen concentration drops below 15%.

Exposure to LNG may also lead to hypothermia of the body and/or frostbite. If a cryogenic gas is inhaled it may result in freezing of the respiratory tract including the lungs.

LNG (dispersion) clouds may occur when the cold cryogenic gas is mixed with warm air, because the moisture in the air will condense when it is cooled down. In the event of major leaks of cooled LNG (methane), formation of these condensation clouds may result in obscured visibility. Attention should be given to the fact that even outside these clouds a significant change in atmosphere composition must be expected.

4.8.2 ACTIONS

Always follow the ABC-strategy: Airway – Breathing – Circulation – Disability – Exposure.

For first and second responders with adequate PPE who rescue exposed victims, it is important to keep the following aspects in mind:

- Move the exposed victims to a warm place (about 22°C) but don't apply direct heat;
- Gently remove (don't pull) any clothing that may restrict blood circulation to the affected (injuries) areas;
- Flush the affected areas of the skin with large quantities of lukewarm water;
- Continue cooling the affected areas until the pain decreases.

If necessary, protect the injuries with bulky dry sterile dressings. Caution: do not apply the dressings too tightly since this will restrict blood circulation. Avoid moving the affected skin.

5. GUIDELINES FOR EDUCATION AND TRAINING ON INCIDENT RESPONSE LNG

5.1 INTRODUCTION

Incident preparedness and emergency response planning are based on credible incident scenarios and lead to identification of education and training elements needed for this purpose.

This main plot follows a seven-stage structure – as illustrated in figure 47 – starting with technological descriptions and ending with final outcome of education and training needs.

It is important to realize that these education and training needs of any emergency and incident responders are about complementary professional competence (LNG-specific).

Basic professional competence (non-LNG-specific) of any emergency and incident responders is assumed to be already obtained and maintained.

Although basic professional competence may differ per region along the Rhine Corridor due to local conditions, additional LNG-specific competency profiles can be used widely.

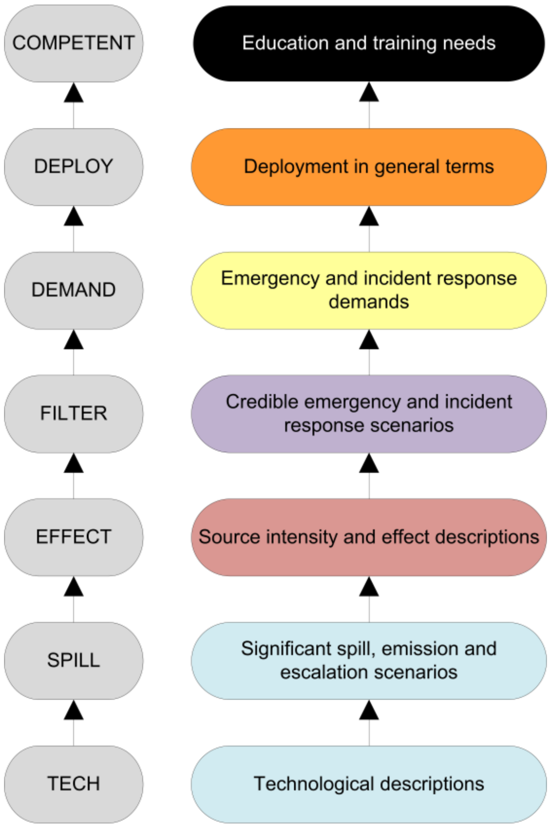


Figure 47 Seven stage structure for education and training needs.

5.2 SCENARIOS

5.2.1 SIGNIFICANT SPILL, EMISSION AND ESCALATION SCENARIOS

The appointed types of containment (vessels), causes and effects in part 1 (see basic matrix) resulted, by expert judgment, in the following significant spill, emission and escalation scenario references:

Type of containment system		Cause	Effect	scenario ref.
1. LNG propelled vessel	1. Fuel tank(s) on deck	3. collision with bridge	B. Flash fire	1.1.3.B
			C. Jet fire	1.1.3.C
			D. Pool fire	1.1.3.D
			E. Cryo damage	1.1.3.E
		5. failure of tank connections	B. Flash fire	1.1.5.B
			C. Jet fire	1.1.5.C
			E. Cryo damage	1.1.5.E
		6. vaporisation leakage	B. Flash fire	1.1.6.B
			C. Jet fire	1.1.6.C
		7. overpressure release	C. Jet fire	1.1.7.C
		8. transfer system failure	B. Flash fire	1.1.8.B
			C. Jet fire	1.1.8.C
			D. Pool fire	1.1.8.D
			E. Cryo damage	1.1.8.E
		11. secondary fire (e.g. cargo)	F. Blast damage	1.1.11.F
			G. Domino	1.1.11.G

Type of containment system		Cause	Effect	scenario ref.
1. LNG propelled vessel	2. Fuel tank(s) below deck	1. collision with another vessel	A. Structural damage	1.2.1.A
			B. Flash fire	1.2.1.B
			C. Jet fire	1.2.1.C
			D. Pool fire	1.2.1.D
			E. Cryo damage	1.2.1.E
		4. grounding	A. Structural damage	1.2.4.A
		5. failure of tank connections	B. Flash fire	1.2.5.B
			C. Jet fire	1.2.5.C
			D. Pool fire	1.2.5.D
			E. Cryo damage	1.2.5.E
		6. vaporisation leakage	B. Flash fire	1.2.6.B
			C. Jet fire	1.2.6.C
		7. overpressure release	C. Jet fire	1.2.7.C
		8. transfer system failure	B. Flash fire	1.2.8.B
			C. Jet fire	1.2.8.C
			D. Pool fire	1.2.8.D
			E. Cryo damage	1.2.8.E
2. LNG carriers / bunker ships	1. Type C tank(s)	1. collision with another vessel	A. Structural damage	2.1.1.A
			B. Flash fire	2.1.1.B
			C. Jet fire	2.1.1.C
			D. Pool fire	2.1.1.D
			E. Cryo damage	2.1.1.E
		4. grounding	A. Structural damage	2.1.4.A
		5. failure of tank connections	B. Flash fire	2.1.5.B
			C. Jet fire	2.1.5.C
			D. Pool fire	2.1.5.D
			E. Cryo damage	2.1.5.E
		6. vaporisation leakage	B. Flash fire	2.1.6.B
			C. Jet fire	2.1.6.C
		7. overpressure release	C. Jet fire	2.1.6.C
		8. transfer system failure	B. Flash fire	2.1.8.B
			C. Jet fire	2.1.8.C
			D. Pool fire	2.1.8.D
			E. Cryo damage	2.1.8.E
	2. Membrane tank(s)	1. collision with another vessel	A. Structural damage	2.2.1.A
			B. Flash fire	2.2.1.B
			C. Jet fire	2.2.1.C
			D. Pool fire	2.2.1.D
			E. Cryo damage	2.2.1.E
		2. collision with quayside	B. Flash fire	2.2.2.B
		4. grounding	A. Structural damage	2.2.4.A
		5. failure of tank connections	B. Flash fire	2.2.5.B
			C. Jet fire	2.2.5.C
			D. Pool fire	2.2.5.D
			E. Cryo damage	2.2.5.E
		6. vaporisation leakage	B. Flash fire	2.2.6.B
			C. Jet fire	2.2.6.C
		7. overpressure release	C. Jet fire	2.2.7.C
		8. transfer system failure	B. Flash fire	2.2.8.B
			C. Jet fire	2.2.8.C
			D. Pool fire	2.2.8.D
			E. Cryo damage	2.2.8.E

Table 16 Credible scenario analysis regarding emergency and incident response

These scenarios (ref. 1.1.3.B to 2.2.8.E) are input for the next step: 'credibility analysis regarding emergency and incident response'.

5.2.2 CREDIBLE EMERGENCY AND INCIDENT RESPONSE SCENARIOS

The significant spill, emission and escalation scenarios (ref. 1.1.3.B to 2.2.8.E) are filtered on credibility regarding emergency and incident response by answering the following three questions:

1. Is the scenario realistic and typical?
2. Can the scenario cause relevant damage to assets or people in the vicinity?
3. Can intervention of the scenario lead to obvious effect, in order to prevent escalation?

Only the scenarios that meet all of these three criteria are selected (by expert judgement) as credible emergency and incident response scenarios.

Source intensity and effects are important parameters. Implausible catastrophic scenarios (such as a plane crash on a vessel) or scenarios whose likelihood of emergence is virtually nil are not taken into account.

This credibility analysis by expert judgement resulted in a selection of 4 credible emergency and incident response scenario types.

Spill, emission and escalation scenario	filter criteria [1]			Credible emergency response scenario	Sorted by emergency response scenario type [2]
	1	2	3		
1.1.3.D	Yes	Yes	Yes	Yes	SCEN-1 (IWT-LNG-SSERP-1)
1.1.11.G	Yes	Yes	Yes	Yes	SCEN-4 (IWT-LNG-SSERP-4)
1.2.8.E	Yes	Yes	Yes	Yes	SCEN-2 (IWT-LNG-SSERP-2)
1.2.5.D	Yes	Yes	Yes	Yes	SCEN-3 (IWT-LNG-SSERP-3)

Table 17 Credible scenario incident response analysis

1) The filter criteria for emergency and incident response are:
   1. *The scenario is realistic and typical,*
   2. *The scenario can cause relevant damage to assets or people in the vicinity,*
   3. *Intervention of scenario will lead to obvious effect, in order to prevent escalation.*

2) *Filtered and sorted emergency and incident response scenario types are:*

SCEN-1: *Inland LNG propelled cargo vessel, **LNG fuel tank on deck**, collision with bridge, failure of pipe work, continuous release LNG, vapour cloud dispersion, **no ignition LNG**, escalation with prolonged gas/vapour concentrations, direct elimination on any ignition sources and water shielding required.*

SCEN-2: *Tank truck to ship bunkering, **LNG fuel tank below deck**, severed hose line, limited release of LNG, unconfined spill on water, RPT, cryogenic damage to ship **no ignition LNG.***

SCEN-3: *Inland LNG tanker/bunker ship, **LNG cargo tanks**, container falls from bunkered ship onto bunkering ship, short continuous release LNG, unconfined spill on water, RPT, **delayed ignition LNG.***

SCEN-4: *Inland LNG propelled cargo vessel, **LNG fuel tank on deck**, collision with another vessel, **direct ignition cargo** (gasoline), heat exposure to LNG fuel tanks, escalation with prolonged exposure, cooling required within 15 minutes.*

These scenarios SCEN-1, SCEN-2, SCEN-3 and SCEN-4 are input for next step: ‘consequence modelling’.

5.3 CONSEQUENCE MODELLING

5.3.1 NECESSITY

Before developing emergency response strategies, scenario-specific insight into thermal, vapour and gas levels and their effects needs to be gained.

5.3.2 BENEFITS

Using consequence modelling with Phast DNV software, visual indications of potential thermal and gas concentration levels around scenarios SCEN-1, SCEN-2, SCEN-3 and SCEN-4 are given.

5.3.3 METEOROLOGICAL INPUT DATA

Data	Input
Ambient air temperature	15 °C
Relative humidity	60 %
Wind speed	9 m/s

Table 18 Meteorological data

5.3.4 GENERAL PRINCIPLES EXTENT OF HEAT CONTOURS AND CLOUD DISPERSION LIMITS

5.3.4.1 EFFECTS ON PEOPLE - FIRES

- Personnel exposed to a jet flame or areas of flame drag in the case of pool fires are assumed to be fatalities;
- People exposed to > 32 kW/m^2 are assumed to be fatalities;
- People exposed to < 12 kW/m^2 but > 6,3 kW/m^2 are assumed to sustain immediate 3rd degree burns;
- People exposed to < 6,3 kW/m^2 are assumed to sustain 2nd degree burns rapidly, and 3rd degree burns within minutes;
- Emergency responders may be able to access the 6,3 kW/m^2 zone to carry out manual intervention but only if dressed in full fire resistant PPE (“Bunker Gear”) and only for periods of < 1 minute.

5.3.4.2 EFFECTS ON STRUCTURES - FIRES

The following are assumed for consequences of fire on structures without protection:

- Lightweight structures could fail in 5 min if exposed to fires with high heat fluxes. High heat fluxes are in the range of 200 kW/m^2 to 300 kW/m^2;
- Heavyweight large structures could fail in 10 min if exposed to fires with lower heat fluxes. Lower heat fluxes are less than 200 kW/m^2;
- Failure of any equipment or structure if located within 100 kW/m^2 envelope for 30 minutes;
- Structures exposed to lower levels of heat flux over a long period of time are prone to collapse. A heat flux of 25 kW/m^2 for an exposure time of 30 minutes or more is liable to cause significant weakening and could lead to collapse.

5.3.5 SCEN-1

Credible emergency and incident response scenario

Inland LNG propelled cargo vessel, LNG fuel tank on deck, collision with bridge, failure of pipe work, continuous release of LNG, vapour cloud dispersion, no ignition of LNG, escalation with prolonged gas/vapour concentrations, direct elimination of any ignition sources and water shielding required.

Case study

Argonon inland LNG vessel.

Input

The LNG propelled vessel has a fixed LNG fuel tank located on deck (double wall type C) with a capacity of 40 m^3. The scenario assumes a collision with a bridge, creating a pipe work failure and unignited vapour release. The criteria used in the scenario are tabulated below.

Data	Input
Tank size	40 m^3
Release	Continuous
Release rate	48,3 kg/sec
Spill duration	360 sec
LNG temperature	-138 °C
LNG tank pressure	4 barg

Concentration of Interest	Downwind Distance
25.000 PPM (50% LFL)	203 m
50.000 PPM (LFL)	136 m
150.000 PPM (UEL)	34 m

Table 19 Phast Input and result data Scenario 1

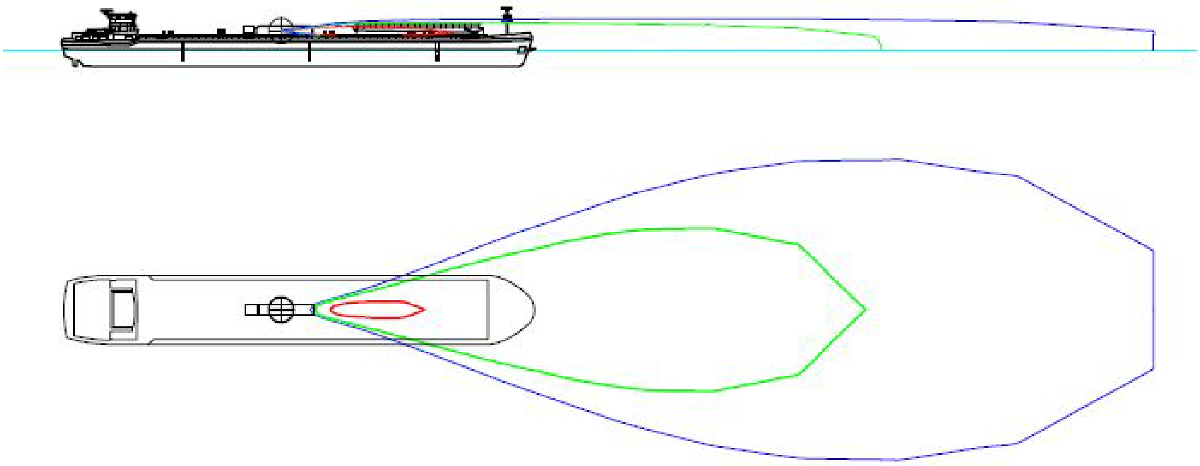


Figure 48 Phast modelling schematics Scenario 1

The calculations show that in this scenario only a small part of the vessel would be within the UFL, but the majority of the vessel would fall within the LFL in a downwind direction. Please refer to appendix 2.1A for further details.

5.3.6 SCEN-2

<u>Credible emergency and incident response scenario</u>
Inland LNG propelled cargo vessel, LNG fuel tank below deck, tank truck to ship bunkering, severed LNG transfer hose, failure of emergency spot button on truck, limited continuous release of LNG, unconfined spill on water, RPT, cryogenic damage to ship's structure.

<u>Case study</u>
Bunkering of ship from a tank truck is a realistic scenario as is any transfer operation. In this case, movement of the ship could lead to the rupture of a hose line. The amount of LNG released depends on the efficiency of the ESD systems and attentiveness of the operators performing the bunkering.

Figure 49 Truck to ship transfer

<u>Input</u>
The ship has a fixed LNG fuel tank (double-walled type C) located below deck with a capacity of 50m^3. The scenario assumes a failure of a number of barriers during the bunkering of a ship from a tank truck, whereby the supply hose fails and releases LNG into the water against the ship's structure.

The criteria used in the scenario are tabulated below.

Data	Input
Tank size	50 m^3
Hole size	75 mm ø
Release	Continuous
Release rate	3000 kg/hour
Spill duration	60 sec
LNG temperature	-162 °C
LNG tank pressure	150 mbarg

Concentration of Interest	Downwind distance
25.000 PPM (50% LFL)	71,25 m
50.000 PPM (LFL)	47,98 m
150.000 PPM (UEL)	22,78 m

Table 20 Phast Input data and results data Scenario 2

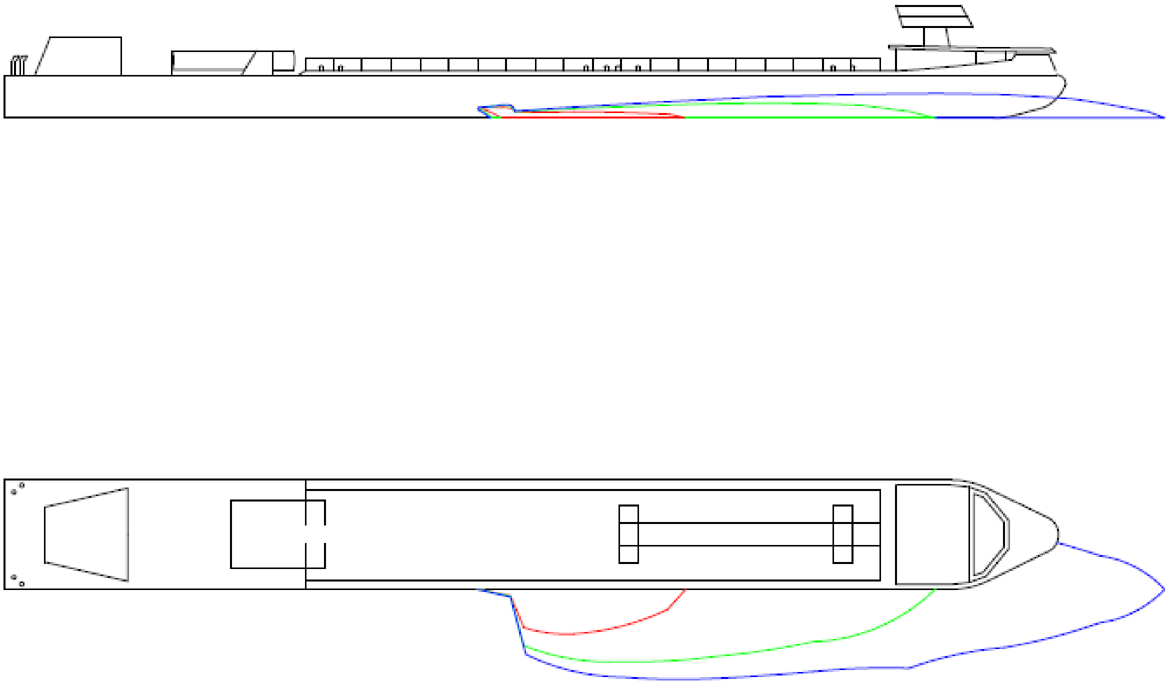


Figure 50 Phast modelling schematic Scenario 2

The calculations show that in this scenario only a small area would be within the UFL, The LFL would extend along the waterline for the majority of the vessel in a downwind direction. Please refer to appendix 2-2A for further details.

5.3.7 SCEN-3

<u>Credible emergency and incident response scenario</u>
Inland LNG tanker/bunker ship, LNG cargo tanks, container falls from bunkered ship onto bunkering ship, short continuous release LNG, unconfined spill on water, RPT, delayed ignition LNG.

<u>Case study</u>
The future bunkering of seagoing ships whilst the receiving ship is itself being loaded with containers has an heightened risk of a rupture of the transfer lines due to falling containers or lashing.

Containers falling overboard is a regular occurrence. The case study looks at the Argos bunker ship transferring LNG to a containership when the incident occurs.

Figure 51 Argos inland LNG bunkering vessel.

Figure 53 Images of incidents where containers have fallen overboard onto a vessel below.

Input

The LNG (ship to ship) transfer was already started minutes before with a flow rate of 0,18 m^3 LNG per second (at this moment, the range of flow rates for STS bunkering is 1.000 – 10.000 m^3 per hour). A container falls overboard onto a moored LNG bunker barge (see vessel above) alongside a receiving container vessel where the cargo is stowed 30 meters high.

The result is a rupture of pipe work on deck (also possible to describe this for a failure of the loading arm). The vessel has an overflow valve, but this doesn't function properly due to the impact. It takes the crew 90 seconds to stop the process manually. Almost 16 m^3 LNG flows from the deck into the water over the other side of the ship. The vapours are ignited after a delay of six minutes.

The criteria used in the scenario are tabulated below.

Data	Input
Tank size	300 m3
Hole size	150 mm ø
Release	Continuous
Release rate	kg/sec
Spill duration	90 sec
Time to ignition	360 sec
Release mass	16m^3
LNG temperature	-160 °C

Heat Flux Rate	Downwind Distance
6,3 KW/m2	2,5 m at an elevation of 0,25 m
12,5 KW/m2	2,29 m at an elevation of 0,52 m
32 KW/m2	Not calculated this means it is contained within the pool fires flame

Table 21 Phast Input and results data scenario 3

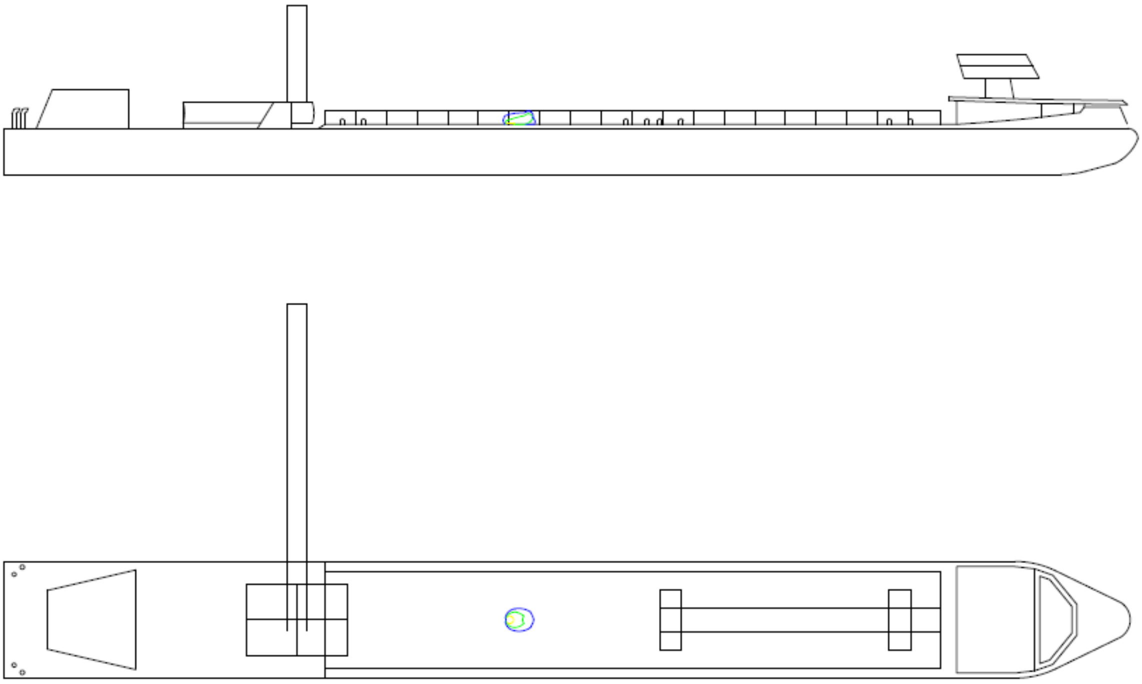


Figure 53 PHAST modelling schematic Scenario 3

The calculated heat flux from the resulting 16 m³ pool fire is limited to the deck and flow into the water. 32 kw/m² is within the flame area; however, the fire could be expected to spread to the services on deck. Please refer to appendix 2.3A for further details.

5.3.8 SCEN-4

<u>Credible emergency and incident response scenario</u>
Inland LNG propelled cargo vessel, LNG fuel tank on deck, collision with another vessel, direct ignition cargo (gasoline), heat exposure to LNG fuel tanks, escalation with prolonged exposure, cooling required within 15 minutes.

<u>Case study</u>
Greenstream inland LNG vessel.

<u>Input</u>
The Greenstream tanker is an LNG propelled vessel for cargo. The tanker has 6 tanks (approximately 500 m^3 each) which transport cargo ranging from mineral oils to chemicals.

Figure 54 Greenstream vessel

The scenario assumes a collision with another vessel, creating a hole in the tank. This creates a spill pool on the water with a delayed ignition pool fire.

The criteria used in the scenario are tabulated below.

Data	Input
Tank size	500m^3
Hole size	1.000 mm ø
Release	Continuous
Release rate	8,592 kg/sec
Spill duration	42 sec
Pool diameter	160,68 m

Heat Flux Rate	Downwind Distance
6,3 KW/m2	204 m
12,5 KW/m2	107 m
32 KW/m2	N/A

Table 22 Phast Input and result data Scenario 4

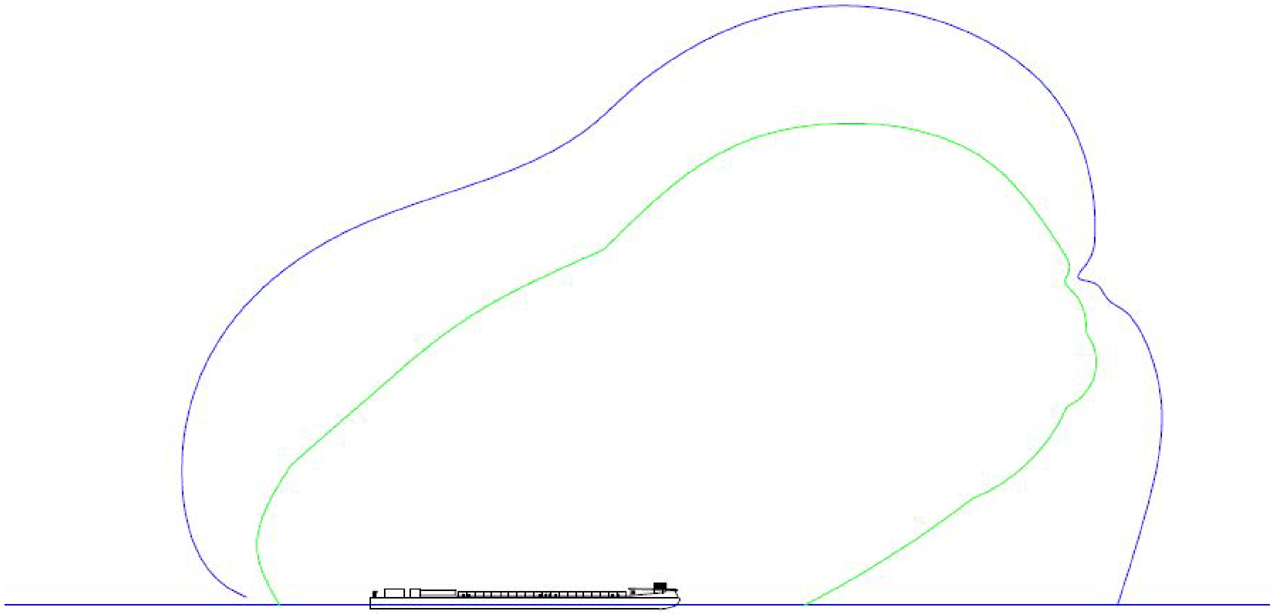


Figure 55 PHAST modelling schematic – side elevation - Scenario 4

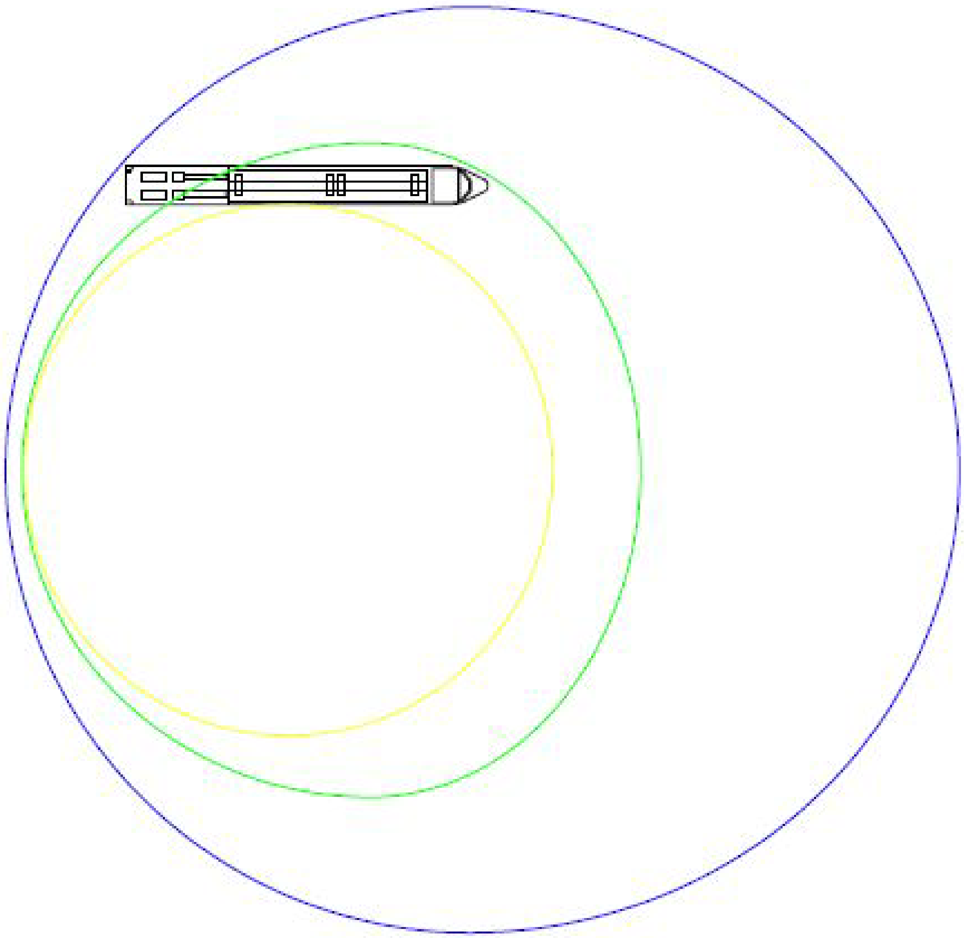


Figure 56 PHAST modelling schematic- Plan view – Scenario 4

The calculations show that in this scenario the majority of the vessel would be within the 12,5 KW/m^2 area. In particular, LNG fuel tanks are a major point of concern.

The 32 KW/m^2 contour has not been calculated in this case. This normally means that this level of thermal radiation would be contained with the flame from the fire.

Please refer to appendix 2.4A for further details.

These newly acquired scenario specific insights – into thermal, vapour and gas levels and effects – are input for the next step: 'emergency response planning'.

5.4 EMERGENCY RESPONSE PLANNING

5.4.1 NECESSITY

Before the necessary education and training elements are identified, scenario-specific emergency response needs to be planned.

5.4.2 BENEFITS

By developing scenario-specific emergency response plans (SSERP's), emergency response actions emerge. All the scenario specific actions together are basic input for complementary education and training needs for emergency and incident responders.

5.4.3 SCEN-1

Considered emergency and incident response scenario: Inland LNG propelled cargo vessel, LNG fuel tank on deck, collision with bridge, failure of pipe work, continuous release of LNG, vapour cloud dispersion, no ignition LNG, escalation with prolonged gas/vapour concentrations, direct elimination on any ignition sources and water shielding required.

5.4.3.1 STRATEGY

- Confirm LNG release event
- Notify emergency services
- Isolation of the LNG release source, if safe and practical to do so
- Avoid entering the gas hazard area
- Put vessel into shore if possible
- Evacuation of persons on board and crew
- Start up fire pumps on board
- Use of water spray in the form of water screens/curtains that may minimize gas migration
- Earliest assessment of gas "cloud" extent and areas that may be affected
- Earliest identification of potential ignition sources and elimination/minimization
- Arrangements for meeting incoming external response groups at forward control point (FCP)
- Eliminate ignition sources in affected area
- Restrict or stop navigational traffic to prevent vessels straying into hazard area
- Use of portable gas monitoring equipment to monitor gas cloud extent
- Local authority fire services assess incident conditions for ongoing safety
- Water spray control support
- Continual monitoring of wind/weather conditions
- Responders stand by at safe distance until area is declared safe.

5.4.3.2 1ST RESPONDERS (SHIP'S CREW)

Actions

- Confirm LNG release
- Notify emergency services
- Try to isolate leakage (activate ESD)
- Shut down ventilation to ship to prevent gas being drawn into ship
- Start up fire pump and water protection systems (if fitted)
- Consider putting ship into shore at a safe location (if possible)
- Evacuate all unessential persons (passengers and crew)
- Prepare to receive emergency services

Equipment/resources

- Detection system(s) and/or visual observation
- Fire pump controls
- Water spray system
- ESD systems
- Ventilation system
- Backup power

Information/comments

Eliminate any ignition sources on board. If water curtains are fitted, activation of these may help protect migration of gas over a navigational bridge.

If leak cannot be stopped, evacuate all persons to a safe location upwind. Evacuation to shore is preferential. However, if leak is substantial, avoid putting vessel into areas of high population density or have high potential for sources of ignition.

Reposition the vessel only when it is safe to do:

- engine room and bridge at the upwind side of the leakage
- vessel 100% free from collision item (bridge)
- backup power for propulsion is available (after ESD)
- water spray systems are activated.

Inform local fire authorities that all listed actions have been carried out up to this point.

5.4.3.3 2ND RESPONDERS (EMERGENCY SERVICES AND RIVER/PORT AUTHORITIES)

Actions

- Approach upwind of incident
- Make contact with master of vessel/port authorities
- Assess extent of gas cloud
- Eliminate ignition sources in path of gas migration
- Set up water spray to disperse gas cloud
- Fire boat to set up water spray to mitigate / disperse gas cloud
- Monitor extent of gas cloud with gas detection equipment. Track gas cloud visually with thermal imaging camera.
- Continually assess incident conditions for ongoing safety and provide water spray control support. Advise if any further evacuation requirements are necessary.
- Prepare for fire
- Aftercare: control for ‘gas pocketing’ in all buildings and enclosed spaces in vicinity of vapour cloud area
- Cordon off incident area and evacuate surrounding area lying in path of gas cloud
- Restrict or control navigation traffic around incident area

Equipment/resources

- Forward control point (FCP) located upwind of incident
- Fire water pump/trucks complete
- Mobile water monitors
- Mobile water screens
- Gas detectors
- (high resolution) thermal image camera
- Rescue boat
- Fire boat with water monitor(s)
- All responders have the proper PPE to prevent burns if ignition takes place.

Information/comments

The wind direction & weather conditions are important for the vapour cloud projection at the local geographic area and for the decision making priorities. For LNG releases, water spray devices and/or portable water monitors may be used to contain, barrier or direct the liberated gas and prevent this from reaching a source of ignition.

Where downwind gas migration is toward an area that clearly has no ignition source, the opportunity may be taken to set up water screens or curtains upwind if ignition sources are present in this direction. Note: it should never be assumed that wind direction and wind speed will be constant.

Migration of gas cloud may be influenced by the surrounding area. Take into account that high river banks and buildings could funnel gas cloud formation. Gas clouds can be directed away from sensitive areas. However, warming up of the gas cloud with water spray will encourage gas to disperse safely into the atmosphere.

'Gas pocketing' means that cold LNG vapour evaporates as gas into congested areas without ventilation. It could be a source for an explosion.

5.4.3.4 UNIFIED COMMAND CONSIDERATIONS

- Meteorological information
- Analyse surrounding area and environmental considerations
- Communication
- Salvage
- Navigational traffic on inland waterways

5.4.3.5 POTENTIAL HAZARDS AND OTHER CONCERNS

It is always prudent to assume that a gas cloud could be ignited at any time.
Any intervention, after proper initial and ongoing risk assessment, should consider setting up water curtains or sprays to reduce the cloud, to contain it in place or to disperse the gas to below its LFL.
Use of water spray streams to assist gas dispersion at or near the release source is only practical if the release is not of significant size or scale. In most cases, such deployment will need to be supported by hose-handling teams using water curtains to protect the deployment teams.

Contact with cryogenic LNG may result in burn injuries. Protective clothing may also be compromised when in contact with LNG.

Ignition of an unconfined gas cloud may result in gas burning back to the source resulting in a jet flame. Gas accumulating in a confined or congested environment may result in an CVCE (confined gas cloud explosion) if ignited, resulting in significant blast damage and secondary fires.

A warm BLEVE should not be ruled out should there be direct flame impingement on unprotected/damaged tanks or pipe work.

Please refer to appendix 2.1B for further details.

5.4.4 SCEN-2

Inland LNG propelled cargo vessel, LNG fuel tank below deck, tank truck to ship bunkering, severed LNG transfer hose, failure of emergency spot button on truck, limited continuous release of LNG, unconfined spill on water, RPT, cryogenic damage to ship's structure

5.4.4.1 STRATEGY

- Confirm LNG release event
- Activate ESD
- Alarm authorities
- Avoid entering the gas hazard area
- Evacuate personnel from affected area
- Prevent ignition of vapours
- Stop vessel movement in area
- Continuous monitoring of wind/weather conditions

5.4.4.2 1ST RESPONDERS (SHIP'S CREW)

Actions

- Confirm LNG release
- Activate ESD on LNG transfer system
- Shut down ventilation systems
- Notify emergency services
- Assess the risk of vapour cloud ignition
- Evacuate ship before vapour cloud reaches the ship bridge / accommodations.
- Go to the authorities and give all relevant technical LNG and vessel data.
- In case of fire: abandon vessel.

Equipment/resources

- Detection system(s) and/or visual observation
- ESD systems
- Ventilation systems
- Backup power
- Lifesaving equipment

Information/comments

The wind direction & weather conditions are important for the vapour cloud projection at the local geographic area and for the decision making priorities.

Assess the risk of ignition at vapour cloud and abandon the vessel immediately when visible vapour cloud could reach:

- Other vessel(s)
- Traffic / highway
- Other source of ignition.

If not safe, abandon the vessel in upwind direction. When everyone is safe, give priority to informing the incident responders.

5.4.4.3 2ND RESPONDERS (EMERGENCY SERVICES AND RIVER/PORT AUTHORITIES)

Actions

- Rescue ship crew if it is necessary/ possible.
- Use defensive strategy.
- Support water curtain/ shield or spray to disperse vapour cloud.
- Investigate vessel integrity for cryogenic damage.
- Control navigation traffic around incident area.

Equipment/resources

- Fire water pump/trucks complete.
- Mobile water monitors.
- Mobile water screens.
- Gas detectors.
- (high resolution) thermal image camera.
- Rescue boat.
- Firefighting vessel with water monitor(s).
- All responders have the proper PPE to prevent burns if ignition takes place.

Information/comments

Use water spray or hydro shields to disperse vapour cloud. Contact the operator to determine the LNG quantities; confirm the actions and findings of the operator. Be aware of flammable and dangerous cargo. Prevent firefighting water from entering into the LNG pool and increasing evaporation.

5.4.4.4 UNIFIED COMMAND CONSIDERATIONS

- Meteorological information
- Analyse surrounding area and environmental considerations
- Communication
- Vessel integrity
- Navigational traffic on inland waterways

5.4.4.5 POTENTIAL HAZARDS AND OTHER CONCERNS

For LNG releases, the application of water 'raining out' onto the pool may initially result in a higher rate of evaporation.

Please refer to appendix 2.2B for further details.

5.4.5 SCEN-3

Inland LNG tanker/bunker ship, LNG cargo tanks, container falls from bunkered ship onto bunkering ship, short continuous release of LNG, unconfined spill on water, RPT, delayed ignition LNG.

5.4.5.1 STRATEGY

Initial:

- Confirm LNG release event
- Activate ESD
- Alarm authorities
- Avoid entering the gas cloud
- Prevent Ignition
- Move, upwind shore side for safe rescue/evacuation operation.

After delayed ignition:

- Use for the start scenario
- Extinguish with Dry Chemical powder
- Cooling the vessel structure
- Prevent for secondary fire (surroundings)
- Protect the cargo (containers)
- Stop vessel traffic in immediate area
- Evacuate occupants for heat radiation (if near - water spray control support)
- Continual wind/weather conditions monitoring.

5.4.5.2 1ST RESPONDERS (SHIP'S CREW)

Actions

- Confirm LNG release from the vessels due to the impact of a container falling onto deck
- Activate ESD at the LNG system
- Notify Emergency Services
- Activate water spray systems if available/possible
- Shutdown ventilation systems
- Assess the risk of vapour cloud ignition reaching accommodate.
- Give to the authority's and give all relevant technical LNG and vessel data.
- Try to extinguish fire with Dry chemical Powder

- By escalation Abandon Ship

Equipment/resources

- Detection system(s) and/or visual observation
- Fire pump controls
- Water spray system
- ESD systems
- Ventilation system
- Backup power
- Emergency anchoring system
- Lifesaving equipment
- Dry Chemical powder

Information/comments

- The wind direction & weather condition are important for the vapour cloud projection at the local geographic situation and the decision making priorities.
- Assess the risk of igniting at vapour cloud and abandoned the vessel immediately when visible vapour cloud possible reach;
  - Inhabited and/or industrial area
  - Other vessel(s)
  - Traffic / highway
  - Other source of ignition.
- If not safe; abandon the vessel in upwind direction.
- If anchoring not possible: beach the vessel!
- Evacuation:
  - In Upwind or crosswind direction
  - From other side than collision impact
  - Be aware of the possible RPT's
- Give priority to inform the incident responders when everyone is safe.

5.4.5.3 2ND RESPONDERS (EMERGENCY SERVICES AND RIVER/PORT AUTHORITIES)

Actions

- Rescue shipboard crew if it is necessary/ possible.
- If Fire is still burning upon arrival extinguish with Dry Chemical powder.
- Setup a Fire boat for cooling the vessel structure. (or from shore side)
- Deploy water spray cooling for the other fuel tanks, cargo and dangerous goods affected by the heat of the fire.
- Starting to prepare the salvage operation for the casualty.
- Control navigation traffic around incident area.

Equipment/resources

- Dry Chemical Powder
- Fire water pump/trucks complete.
- Mobile water monitors.
- Mobile water screens.
- Gas detectors.
- (High Resolution) Thermal Image Camera
- Rescue boat.
- Fire Boat with water monitor(s).
- All Responders have the proper PPE to prevent burns an igniting.

Information/comments

- Several objects in the affected area could have secondary fires.
- Because of the relatively small extent of the fire, an offensive strategy is likely to succeed so should be considered.
- Use water spray or hydro shields to protect the victims for heat radiation.
- Contact the skipper to determine the LNG quantities, pressure his undertaken actions and findings.
- Be aware of the flammable and dangerous cargo.
- Avoid firefighting water into the LNG pool to prevent the size of fire.
- LNG Firefighting is only possible with class BC dry chemical powder.

5.4.5.4 UNIFIED COMMAND CONSIDERATIONS

- It should never be assumed that wind direction and speed or current of the water will be constant.
- Cryogenic damage to the ship's structure could compromise its integrity.
- Burning of the cold methane is rather less pollutant to the environment than a dispersion that's not ignited. Form of pool depends on weather conditions.

5.4.5.5 POTENTIAL HAZARDS AND OTHER CONCERNS

- Although a small spill fire scenario, all efforts are to prevent escalation.
- For LNG releases the application of water 'raining out' onto the pool may initially result in a higher rate of evaporation and fire of the LNG.

Please refer to appendix 2.3B for further details.

5.4.6 SCEN-4

Considered emergency and incident response scenario: Inland LNG propelled cargo vessel (e.g. Greenstream), LNG fuel tank on deck, collision with another vessel, direct ignition cargo (gasoline), heat exposure to LNG fuel tanks, escalation with prolonged exposure, cooling required within 15 minutes.

5.4.6.1 STRATEGY

- Confirm gasoline release event
- Notify emergency services
- Isolation of the gasoline release source, if safe and practical to do so
- Avoid entering the hazard area
- Put into shore if possible
- Evacuation of persons on board and crew
- Start up fire pumps on board
- Use of deluge sprinkler system to cool LNG fuel tanks and areas that may be affected
- Arrangements for meeting incoming external response groups at FCP
- Restrict or stop navigational traffic to prevent vessels straying into hazard area
- Local fire authorities assess incident conditions for ongoing safety
- Use foam to extinguish pool fire
- Water spray control support for cooling surroundings
- Continual monitoring of wind/weather conditions

- Responders stand by at a safe distance until area is declared safe.

5.4.6.2 1ST RESPONDERS (SHIP'S CREW)

Actions

- Confirm gasoline release
- Notify emergency services
- Try to isolate leakage
- Start up fire pump and water protection systems (if fitted)
- Consider putting ship into shore at a safe location (if possible)
- Evacuate all unessential persons (passenger and crew)
- Prepare to receive emergency services

Equipment/resources

- Fire pump and fixed water protection installation

Information/comments

- If leak cannot be stopped evacuate all persons to a safe location upwind. Evacuation to shore is preferential. However, if leak is substantial, avoid putting vessel into areas of a high population density.
- Inform local fire authority that all listed actions have been carried out up to this point.

5.4.6.3 2ND RESPONDERS (EMERGENCY SERVICES AND RIVER/PORT AUTHORITIES)

Actions

- Approach upwind of incident
- Make contact with master of vessel
- Set up water spray to cool LNG fuel tanks
- Set up foam water to extinguish pool fire
- Continually assess incident conditions for ongoing safety and provide water spray control support. Advise if any further evacuation requirements necessary.
- Prepare for fire
- Cordon off incident area and evacuate surrounding area lying in path
- Restrict or control navigation traffic around incident area
- Fire boat to set up foam water / water spray to extinguish fire and to cool surroundings

Equipment/resources

- Forward control point located upwind of incident.

5.4.6.4 UNIFIED COMMAND CONSIDERATIONS

- Meteorological information
- Analyse surrounding area and environmental considerations
- Communication
- Salvage
- Navigational traffic on inland waterways

5.4.3.5 INCIDENT POTENTIAL HAZARDS AND OTHER CONCERNS

Any intervention, after proper initial and ongoing risk assessment, should consider extinguishing with foam and setting up water curtains or sprays to cool surroundings / LNG fuel tanks.
A BLEVE should not be ruled out should there be direct flame impingement on unprotected/damaged tanks or pipe work.

Be aware: When the ship is drifting, the incident will also move.

Please refer to appendix 2.4B for further details.

These newly acquired scenario-specific insights into strategy, actions, equipment and resources, as well as unified command considerations are input for the final step: 'complementary education and training for emergency and incident responders'.

5.5 EDUCATION AND TRAINING

5.5.1 DEMARCATION

Within scenario-specific emergency response planning we distinguish the roles of 1^{st} and 2^{nd} responders.

1^{st} responders : ship's crew (such as deck personnel, machinist, coxswain, boatman, captain)
2^{nd} responders : emergency services (such as fire, police and medical services, port and river authorities)

Initial <u>emergency response</u> for a spill, emission and/or release can only be carried out by the ship's crew within first minutes of the event, up to the moment that 2^{nd} responders arrive and take over the incident.

<u>Incident response</u> should only be carried out by 2^{nd} responders with complementary professional competence for this specific purpose (LNG incident response in inland navigation along the Rhine corridor).

Within the work breakdown structure of the LNG Master Plan for Rhine-Main-Danube, development of training and education for a ship's crew (in emergency situation: 1st responder) is situated under activity column 4: Regulatory Framework & Master Plan, sub activity 2: education and training requirements (as illustrated to the right by red circle). Tender SuAc 4.2: Education & training requirements.

Development of training and education of emergency services is situated under activity column 2: Technologies and operational concepts, sub activity 4: Technical evidence & safety and risk assessment (as illustrated to the right by yellow circle). Tender SuAc 2.4: LNG: emergency and incident response.

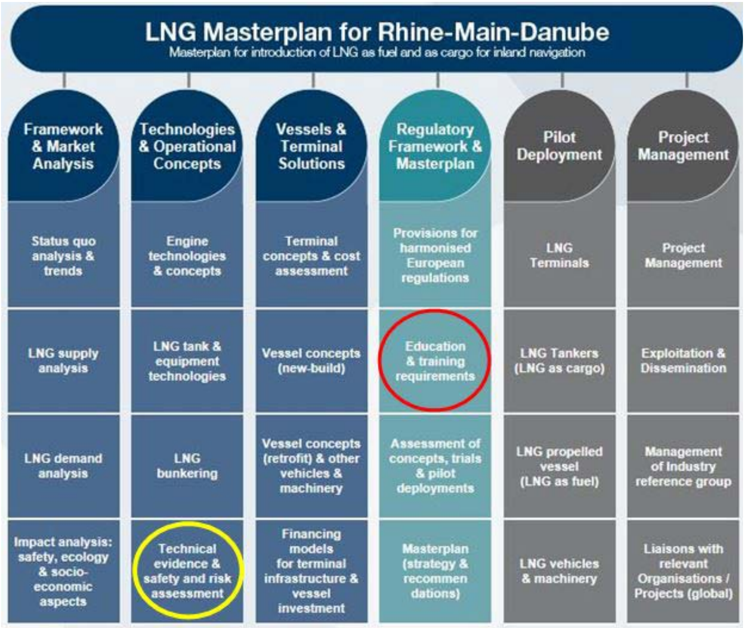


Figure 57 LNG Masterplan for the Rhine – Main- Danube

Therefore, development of training and education for a ship's crew (SuAc 4.2) is not part of this project (SuAc 2.4). Paragraph 3.5 'education and training' only focuses on the needs of emergency services.

5.5.2 STRUCTURE

An elementary education and training program will assist delegates to meet the learning outcomes.

To make efficient use of time and ensure effective learning, there should be an integration of the three phases of knowledge, understanding and skills.

<u>Phase 1 Knowledge</u>

The assimilation of information, facts, descriptions or skills, through theoretical education and learning in order to improve awareness of the subject matter.

Phase 2 Understanding

Understanding requires developing meaningful relationships between different types of knowledge and skills, and taking the basic knowledge and applying it to different situations and settings. Understanding represents a deeper level than ‘knowledge’.

Phase 3 Skills

The application of knowledge in a practical sense; how to do something and being able demonstrate and practice that “skill set’.

The initial education and training course consists of 10 elements related to preparedness (phases 1 and 2) and response (phase 3) of emergency response organisations.

5.5.3 ELEMENTS

The following training elements aim to develop professional competence of incident response organisations along the Rhine Corridor, including how to deal with LNG incidents that could emerge in inland waterways navigation and how to respond to them.

Element	**Object**	**Subject**	**Knowledge**	**Understanding**	**Skills**
01	Properties and behaviour of LNG	Origin and production of LNG;		X	
		The method and the characteristics of the different storage media containing methane;	X		
		Differences in physical properties and their names BOG, CNG, BOG, LCNG, LNG and LPG;	X		
		The differences in transport labelling and regulations, the UN numbers, IMO and ADN;	X		
		The differences in values for LPG and methane;		X	
		Reading and interpreting a Chemistry Card or MSDS of LNG;			X
		The effects of temperature on the behaviour and properties of gases;		X	
02	Descriptions and hazards of LNG	Intrinsic safety and explosions;		X	
		The cryogenic effects on skin, clothing and materials;		X	
		LNG phase transition process;	X		
		The phenomenon and consequences of an RPT (Rapid Phase Transition);	X	X	
		Recognizing the dangers in response to visual perception;	X		
		The danger of vapour clouds and deploying disperse models;	X		
		The phenomenon and consequences of BLEVE;	X		
		Detect hazards using gas detection tools and temperature measuring equipment;	X		X
		Heat radiation from an LNG fire:		X	
		- Codes for heat radiation circles		X	
		- Effects of heat radiation	X		

03	LNG inland vessels; design and safety engineering	Recognizing LNG storage, pipelines and installations of on-board vessels including:			X
		- LNG fuel system and layout;	X		
		- LNG bunkering system;		X	
		- LNG fuel / storage tanks;		X	
		- LNG cargo tank types.		X	
		Recognize the different types of cryogenic insulation and the dangers of insulation damage;		X	
		Engine room safety;	X		
		The ADN and inland shipping regulations for LNG;	X		
		EN-1473, installation and equipment for liquefied natural gas – design of onshore installations;		X	
		Powered Emergency Release Couplers (PERCs);		X	
		Emergency shutdown systems (ESD).		X	
04	The LNG handling and processes	Knowledge of production and handling operations in which LNG is involved: - Transport - Bunkering	X		
		LNG Handling operations: - Truck to ship - Ship to ship - Ship to shore & shore to ship		X	
		Recognizing LNG transportation: - LNG propelled vessels - LNG tankers	X		X
05	Processes that may lead to a flammable vapour cloud	Jets (liquid and two-phase)		X	
		Pool formation: - catastrophic vessel failure - liquid jet impingement		X	
		Vaporisation from within the containment: - Roll-over - Water ingress		X	
		Rapid Phase Transitions (RPT's)		X	
		Pool spread		X	
		Pool vaporisation		X	
06	Control of a vapour cloud	The behaviours of a vapour cloud	X		
		The geographic effects of a vapour cloud		X	
		Functioning and effects of:	X		
		- Water on LNG vapour			X
		- Use of water screens and curtains			X
		- Use of water monitors			X
		- HI-Ex foam			X
07	Controlling fire and firefighting	Controlling a LNG pool fire with expansion foam	X		X
		Controlling a jet-fire	X		X
		Handheld dry powder extinguishers	X		X
		Application rates	X		
		Kick-back effect		X	
		Re-ignition risk		X	
08	Measuring a gas cloud - temperature	Basics of gas measurements: - Ex-Ox-Tox	X		X
		Relation vapour pressure / temperature		X	
		Use of thermal imaging camera's:	X		X
		- heat detection		X	X
		- cold detection		X	X
		- vapour cloud detection		X	X

09	Firefighting strategies	Stopping gas flow:	X		
		- ESD		X	
		- Manual		X	
		Use of water spray:	X		
		- To protect firefighters and those assisting the rescue of trapped personnel from spaces;		X	X
		- To cool surfaces exposed to heat;		X	X
		- To prevent heat radiation through steel bulkheads e.g.		X	X
		Applying dry chemical powder:			
		- Type of powder	X		
		- Minimum rate calculation		X	
		- Sweeping techniques	X		X
		- Preventing direct impact		X	X
10	Incident Management LNG	Exposure limits for residents and emergency response services		X	X
		The marine environment and emergency response		X	
		The incidents and decisive parameters	X		X
		The strategy development for incidents:	X		X
		- LNG release by technical failure on a vessel		X	
		- LNG gas fire on board		X	
		- LNG release on water surface		X	X
		- LNG pool fire		X	
		- Sunken LNG ship		X	
		The additional resources, functionality and (un)possibilities:	X		
		- Fire boat		X	X
		- Fast rescue boat		X	X
		- Marine/inland navigation (LNG) specialist	X		
		- Marine/inland navigation salvage specialist	X		
		- Marine/inland navigation chemist	X		

Table 23 Training elements.

5.6 SUPPLEMENT OF BASIC MATRIX

The education and training for incident response that should be applied for small-scale LNG in inland navigation, is supplement of the basic matrix (see paragraph 3.6). For each of the significant scenarios, education and training is necessary.

5.7 TRAINING FOR VARIOUS RESPONSE ORGANISATIONS

It is clear that a higher awareness of LNG emergencies and incidents is required for all responders, whether it is the ship’s crew, fire brigade, harbour authorities or medical services. The elements described in 3.5.3 may be used to describe what knowledge, understanding and skills each responder has to meet in order to safely and effectively deal with the response. For example, the ship’s crew will already understand how LNG is stored on board, but does not have the knowledge regarding the properties of LNG, may not have an understanding of the consequences of small leaks or the skills required to deal with the emergency.

The matrix below indicates the type of education and training required per responder class and level of operation within that class, i.e. operational, tactical or strategic.

Level	Response class	Knowledge elements *	Understanding elements *	Skill requirements *	Estimated Training duration
1st Response +	Terminal operators	1, 2, 9	2, 9	9	1 day
	Tank truck Drivers	1, 2, 9	2, 9	9	
	Ship's crew	1, 2, 9	2, 9	9	
2nd Response ±	Operational Fire Fighters	1-9	1-9	1-9	2 days
	Operational Harbour and inland waterway response personnel	1-9	1-9	3, 5, 6, 9,	1 day
	Medical services	1	2		½ day
	Tactical command functions	1-10	1-10	10	2 days
	Strategic command functions	1-10	1-10	10	2 days

Table 24 Training requirements for emergency and incident responder training

*Elements 1-10 are referred to Table 5.5.3.

+1st (Emergency) responders training should include 50% theoretical awareness and 50% practical procedural training regarding emergency response to LNG releases.

± 2nd (Incident) responders should have product awareness training which includes operational techniques for controlling LNG incidents and scenario training where the techniques can be applied. Tactical and strategic command functions can be simulated with virtual reality computer training and/or desktop training.

5.8 MULTIDISCIPLINARY EXERCISES

Once the response organisations have received the relevant additional training in order to improve their knowledge, understanding and response skills, then the various agencies should combine their roles in a multidisciplinary exercise in order to determine the level of coordination and interoperability between the services in managing the incident.

Performing an exercise within the first year is recommended and thereafter at a frequency of every 3 years.

6. RECOMMENDATIONS

Several conditions are crucial to filling in the gaps in operational preparedness. The following recommendations to the stakeholders within the scope of influence on the Rhine corridor are made.

6.1 SURROUNDINGS

Along the Rhine-Main-Danube, the geographical areas considered are locally different in height.

The Netherlands (Rotterdam 3,4 meters above European Vertical Reference System, Arnhem 15,4m) and parts of Belgium (Antwerp 7,5m, Gent 8m) are mainly flat areas, with almost only lowlands surrounding the delta, while Germany (Coblenz 64m, Mannheim 112m, Nuremberg 302m), France (Strasbourg 132m), Switzerland (260m) and Romania (Constanta 25m) have mainly hilly surroundings.

In these areas, there are several constructions such as bridges, dykes and floodgates which can affect a loss of containment (LNG spill).

It is important for all the port authorities to make an inventory on the hotspots in the regions they are responsible for in case of an emergency. After the inventory, it is necessary to assess the risks of accumulation of cold LNG in these areas.

Apart from the constructions mentioned above, the authorities should explore natural barriers like hills and forests (row of trees) which can contain the dispersed LNG. Sewers and drains near the river should also be taken into account.

Authorities should perform an inventory of the objects near river(s) that can be affected by a (un)ignited spill of LNG, particularly vulnerable objects (hospitals, hotels, schools) and vital constructions (e.g. vital infrastructures) along the corridor, but also local hazardous zones which can cause escalation of the incidents.

6.2 PEOPLE

Public and private parties should have the ability to deal with the scenarios described in this report. Sharing knowledge and skills can strengthen the measures to cope with these types of incidents.

Pre-planning and coordinating with all emergency (local) responders both on land and on the waterways responses is recommended, so that these incidents are managed in professional and efficient manner.

6.3 MEASURING EQUIPMENT

Accurate assessment of the extent of the incident is essential in forming tactical and strategic plans. Authorities should have the capability to detect vapour releases with compatible gas detectors in order to support the assessment process with reliable information.

It is recommended that response authorities have appropriate gas detection equipment to detect LNG vapour releases and have personnel competent to use the equipment and interpret the measurements.

6.4 SUFFICIENT WATER CAPACITY

Because of the impact the scenarios have shown, it is important that the authorities along the Rhine corridor have sufficient pumps available on shore (by fire trucks) and on water (by fire boats) to minimize the effects of an escalation.

In practice, the quantity of water (capacity) of monitors and hydro-shields together with their optimum operating pressure will determine the monitor range for the height of the water screens.

6.5 TOOLS FOR PREPAREDNESS

All authorities responsible for operational preparedness should arrange deployment to scenarios in their own regions by using the described contours for heat and explosion levels as a template and project this on the inland activities in the sphere of influence of the Rhine-Main-Danube project.

With this template it is possible to make a quick scan of the hotspots in the ports as well as to make a quick scan of the measures needed to be organised by the competent authorities in partnership with private partners in the LNG small-scale (and mid-scale) chain.

PART 3 ADVICE AND STRATEGIC APPROACH

HOW TO COMMUNICATE FINDINGS TO STAKEHOLDERS

IN NEED OF THIS INFORMATION

7 ADVICE AND STRATEGIC APPROACH IN KNOWLEDGE DISSEMINATION

7.1. INTRODUCTION

7.1.1 SCOPE

Finally, there is a third part in which the project team gives advice and a strategic approach on how the findings from part 1 and 2 should be provided to the stakeholders.

7.1.2 DELIVERABLES

This one pager includes a single column describing the disseminating options, the relevant parties and contact details for small-scale LNG handling along the Rhine.

7.2. DISSEMINATION OPTIONS

Promoting these ‘emergency and incident response guidelines’ to national and international stakeholders is an important objective of sub-activity 2.4 (and 6.2. “Exploitation and Dissemination”) as well as an important task of the LNG Master Plan Consortium.

Upcoming LNG events represent good opportunities for the project beneficiaries to promote the most notable aspects of this research project (SuAc 2.4). Targets must be:

- Good retrieving of given presentation(s)
- Audiences showing great interest in the project activities
- Increasing awareness of the project and of LNG as a fuel in general.

Falck can contribute with its own online news, press releases, leaflets and brochures and setting up an SharePoint for Registered members. Organisation of internal and external events as well as active participation in many events:

- Development of an online photo & video archive
- Production of promotional giveaways
- Permanent updating of the Falck LNG website
- Publication of newsletters and leaflets
- Preparation and dissemination of press releases
- Monitoring of press articles.
- Falck LNG twitter account

A lot can be set out for promotional purposes, but the bottom line – for now – is that people who are in need of this knowledge and these insights get mobilized and are enabled to get professional LNG upgrade instruction lessons and practical training.

7.3. RELEVANT PARTIES

The LNG supply chain along the Rhine Corridor is subject of consideration:

- Sea ports & inland ports
- Port authorities
- Barge operations
- Technology suppliers & energy suppliers
- Emergency response authorities

Within the EU LNG Masterplan Rhine-Main-Danube Consortium all partners. More specific the members of the Industry Reference Group and also the members of the Advisory Group. See appendix 3 for contact persons of the Rhine Port Group.

List of appendices

Ref.	*Sub.*	*Description*
1		**References**
2	**0**	**Index scenario specific emergency response plans**
	1A	Emergency map case study SCEN-1
	1B	Incident response plan SCEN-1
	2A	Emergency map case study SCEN-2
	2B	Incident response plan SCEN-2
	3A	Emergency map case study SCEN-3
	3B	Incident response plan SCEN-3
	4A	Emergency map case study SCEN-4
	4B	Incident response plan SCEN-4
3		**Overview relevant parties**
4		**Overview project participants**

APPENDIX 1 | REFERENCES

[1] Melhem, Ozog, Kaleikar (2006). Understand LNG Fire Hazards. ioMosaic white paper.

[2] Luketa, Hanlin (2006). A review of large-scale LNG spills: Experiments and modeling. Journal of Hazardous Materials 2006;May 20;132 (2-3):119-40.

[3] Fluxys (2012).Chain analysis: Supplying Flemish ports with LNG as a marine fuel.

[4] Pitblado, DNV Houston (2006). DNV 'LNG decision making approaches compared. Journal of Hazardous Materials. 2006 Mar 17;130 (1-2):148-54.

[5] ABS Consulting (2004). Consequence Assessment Methods for Incidents Involving Releases from Liquefied Natural Gas Carriers. Table 2.1

[6] Gean Woong Yun (2010). Control of Vapor Dispersion and Pool Fire of Liquefied Natural Gas (LNG) with Expansion Foam.

[7] Sandia (2004). Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water.

[8] Sandia (2008). Breach and Safety Analysis of Spills Over Water from Large Liquefied Natural Gas Carriers

[9] Phani K. Raj (2005). Large LNG Fire Thermal Radiation – Modelling Issues & Hazard Criteria Revisited.

[10] Sandia(2011). Recommendations on the Prediction of Thermal Hazard Distances from Large Liquefied Natural Gas Pool Fires on Water for Solid Flame Models.

APPENDIX 2

SUAC 2.4

SCENARIO SPECIFIC EMERGENCY RESPONSE PLANS (SSERPs)

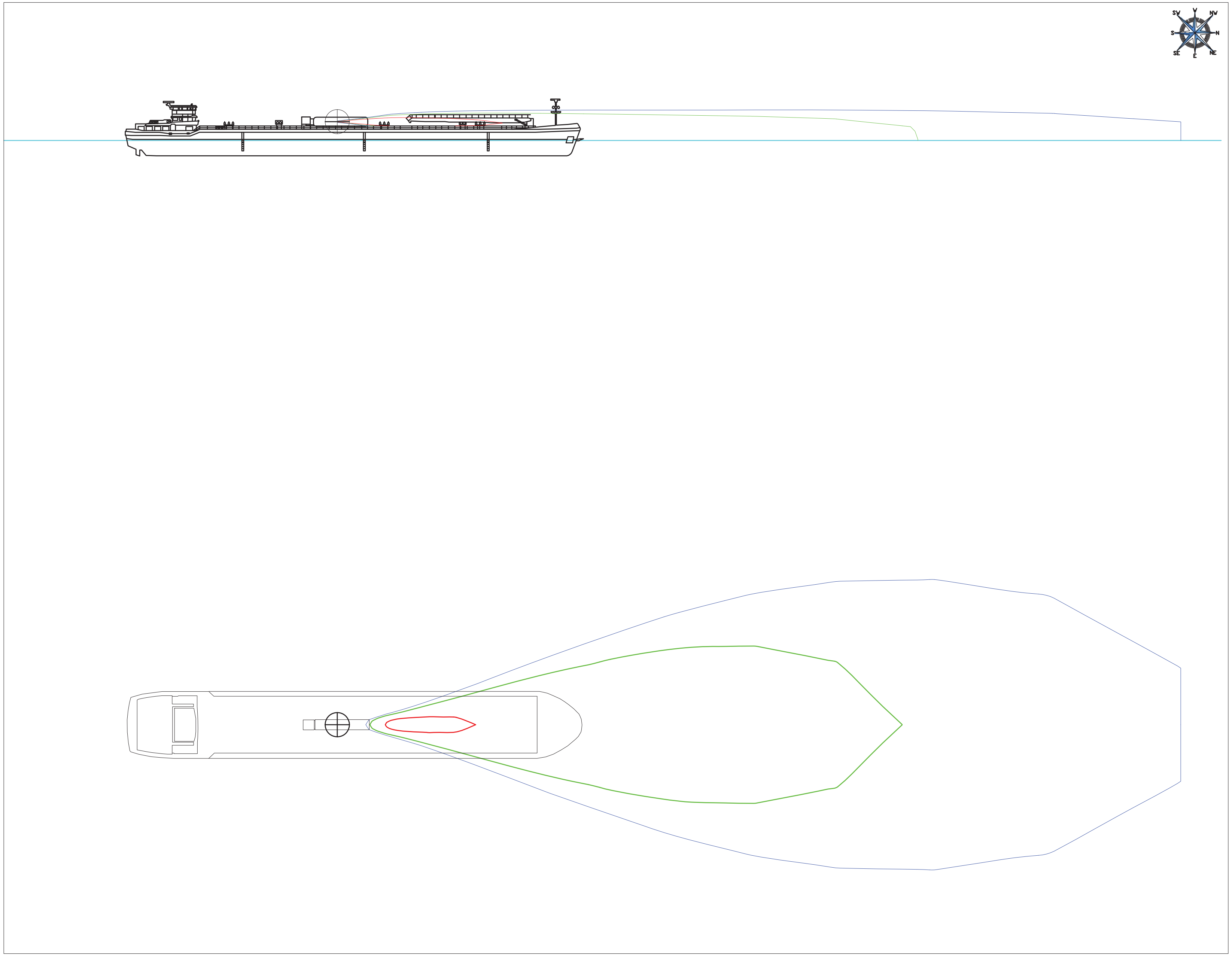
INDEX

REF.	ERP	VESSEL	SCENARIO (TYPE)	SCENARIO (EVENT)	SCALE (LOC)
SCEN-1	IWT-LNG-SSERP-1	Inland LNG propelled cargo vessel, 40m3 LNG fuel tank on deck	LNG vapour cloud	*Collision with bridge, failure of pipework, continuous release LNG, vapour cloud dispertion, **no ignition***	Medium Spill duration: 360 sec. Release rate: 48,3 kg/sec.
SCEN-2	IWT-LNG-SSERP-2	Inland LNG propelled cargo vessel, 50m3 LNG fuel tank below deck	LNG vapour cloud	*Tank truck to ship bunkering, **LNG fuel tank below deck**, severed hose line, limited release of LNG, unconfined spill on water, RPT, cryogenic damage to ship **no ignition LNG***	Small Spill duration: 60 sec. Release rate: 3.000 kg/hour (0,83 kg/sec.)
SCEN-3	IWT-LNG-SSERP-3	Inland LNG tanker/bunker ship, 2x 1870 m3 LNG cargo tank	LNG poolfire	*Inland LNG tanker/bunker ship, **LNG cargo tanks**, container falls from bunkered ship onto bunkering ship, short continuous release LNG, unconfined spill on water, RPT, **delayed ignition LNG**.*	Medium Spill duration: 90 sec. Release mass: $16 m^3$ Pool area: $0{,}75\ m^2$ Time to ignition: 360 sec
SCEN-4	IWT-LNG-SSERP-4	Inland LNG propelled cargo vessel, 2x40m3 LNG fuel tanks 6x cargo tanks (gasoline) $500 m^3$ each	Secondary hydrocarbon fire (cargo fire other than LNG)	*Collision with another vessel, **direct ignition** (cargo), secondary fire (gasoline cargo), heat exposure to LNG fuel tanks, escalation with prolonged exposure, **cooling required within 15 minutes.***	Large Spill duration: 42 sec. Pool diameter: 160,7 meters Cooling within: 15 minutes

SUAC 2.4
SCENARIO SPECIFIC EMERGENCY RESPONSE PLANS (SSERPs)
ERP GLOSSARY

ABBREVIATION	MEANING
DM (Manager)	Duty inland waterway manager
(SS)ERP	(Scenario Specific) Emergency Response Plan
ESD	Emergency Shut Down
FCP	Forward Control Point
FRS	Fire and Rescue Services
LFL	Lower Flammable Limit
LNG	Liquefied Natural Gas
NG	Natural Gas (vapour)
LPM	Litres Per Minute
RPT	Rapid Phase Transition

APPENDIX 2.1A



SHIP INFORMATION

LENGTH: 110 M

WIDTH: 16.2 M

PRODUCT STORED: LNG MODELED AS METHANE

STORAGE CAPACITY: 1 x 40 M3 DOUBLE WALLED STORAGE TANK

EXTENT OF CLOUD DISPERSION DOWNWIND FROM RELEASE CENTER:

25,000 PPM: 203 M

50,000 PPM: 136 M

150,000 PPM: 34 M

EXTENT OF CLOUD DISPERSION CROSSWIND FROM RELEASE CENTER:

25,000 PPM: 18 M

50,000 PPM: 10 M

150,000 PPM: 1 M

EXTENT OF CLOUD DISPERSION HEIGHT FROM RELEASE CENTER:

25,000 PPM: 3.8 M

50,000 PPM: 3.1 M

150,000 PPM: 2.0 M

CONSEQUENCE MODELING PARAMETERS DATA:

TANK SIZE: 40 M³ AMBIENT TEMPERATURE: 15 DEG C

RELEASE RATE: 48.3 KG/SEC RELATIVE HUMIDITY: 60%

SPILL DURATION: 360 SEC WIND SPEED: 9 M/S

REV	DATE	DESCRIPTION	BY	CHK	APP
1	10/11/14	DRAFT FOR APPROVAL	RP		
0	02/10/14	ISSUED FOR COMMENT	SK	PW	

Falck

UPPER FLAMMABLE LIMIT

150,000 PPM

LOWER FLAMMABLE LIMIT

50,000 PPM

50% LOWER FLAMMABLE LIMIT

25,000 PPM

CLIENT NAME: RHINE PORT GROUP

FALCK RPI PROJECT NO: P1336

DRAWING NO: P1336-FR-02

DESCRIPTION: LNG LEAK DISPERSION FROM A RELEASE FROM ARGONON INLAND BARGE

APPENDIX 2.1B

IWT-LNG-SSERP-1 EMERGENCY RESPONSE PLAN FOR:	COLLISION WITH BRIDGE, FAILURE OF PIPEWORK, CONTINUOUS RELEASE LNG, VAPOUR CLOUD DISPERTION, NO IGNITION	Doc: Approved: Rev:2	PAGE 1 OF 2

STRATEGY

Confirm LNG release event – Notify emergency services - Isolation of the LNG release source, if possible, safe and practical to do so - Avoid entering the gas hazard area – Put into shore if possible - evacuation of persons on board and crew - start up fire pumps on board - Use of water spray in the form of water screens/curtains that may minimize gas migration - Earliest assessment of gas "cloud" extent and areas that may be affected – Earliest identification of potential ignition sources and elimination/minimization - Arrangements for meeting incoming external response groups at FCP –- Eliminate ignition sources in effect area – restrict or stop navigational traffic to prevent vessels straying into hazard area - Use of portable gas monitoring equipment to monitor gas cloud extent – Local authority fire service assess incident conditions for ongoing safety – Water spray control support - Continual wind/weather conditions monitoring – Responders stand-by at safe distance until area is declared safe.

1st RESPONDERS	ACTIONS	EQUIPMENT / RESOURCES	INFO / COMMENTS
crew	Confirm LNG release Notify emergency services Try to isolate leakage (activate ESD) Shut down ventilation to ship to prevent gas being drawn into ship Start up fire pump and water protection systems (If fitted) Consider putting ship in to shore at a safe location (if possible) Evacuate all unessential persons (passenger and crew) Prepare to receive emergency services	Detection system(s) and/or visual observation Fire pump controls Water spray system ESD systems Ventilation system Backup power	Eliminate any ignition sources on board. If water curtains are fitted activation of these may help protect migration of gas over navigational bridge. If leak cannot be stopped evacuate all persons to a safe location up wind. Evacuation to shore is preferential, however if leak is substantial avoid putting vessel into areas of a high population density or have high potential sources of ignition. Reposition at the vessel only when it's safe to do; • engine room and bridge at the upwind side at the leakage • vessel 100% free from collision item (bridge) • backup power for propulsion is available (after ESD) • Water spray systems are activated. Inform Local authority Fire Officer that all listed actions have been carried out up to this point.

2nd RESPONDERS	ACTIONS	EQUIPMENT / RESOURCES	INFO / COMMENTS
Local authority Fire Service River / Harbour Authorities	Approach up wind of incident Make contact with master of vessel/port authorities Assess extent of gas cloud Eliminate ignition sources in path of gas migration Set up water spray to disperse gas cloud Fire boat to set up water spray to mitigate / disperse gas cloud Monitor with gas detection equipment extent of gas cloud. Track gas cloud visually with Thermal Imaging Camera. Continually assess incident conditions for ongoing safety and provide water spray control support. Advise if any further evacuation requirements necessary. Prepare for fire Aftercare: Control for 'gas pocketing' into all building and enclosed spaces at vapour cloud area Cordon off incident area and evacuate surrounding area lying in path of gas cloud Restrict or control navigation traffic around incident area	Forward Control Point located up wind of incident Fire water pump/trucks complete. Mobile water monitors. Mobile water screens. Gas detectors. (High Resolution) Thermal Image Camera Rescue boat. Fire Boat with water monitor(s). All Responders have the proper PPE to prevent burns if ignition takes place	The wind direction & weather condition are important for the vapour cloud projection at the local geographic situation and the decision making priorities. For LNG releases water spray, portable water monitors may be used to contain, barrier or direct the liberated gas and prevent this from reaching a source of ignition Where downwind gas migration is toward an area that clearly has no ignition source, the opportunity may be taken to set up water screens or curtains upwind if ignition sources are present in this direction. NB: It should never be assumed that wind direction and speed will be constant Migration of gas cloud may be influenced by surrounding area. Take into account that high river banks and building could funnel gas cloud formation Gas cloud can be directed away from sensitive areas, however warming up of the gas cloud with water spray will encourage gas to disperse safely to atmosphere 'Gas pocketing' means that cold LNG vapour evaporates at gas into congested area without ventilation. It could be a source of an explosion.

IWT-LNG-SSERP-1 EMERGENCY RESPONSE PLAN FOR:	COLLISION WITH BRIDGE, FAILURE OF PIPEWORK, CONTINUOUS RELEASE LNG, VAPOUR CLOUD DISPERTION, NO IGNITION	Doc: Approved: Rev:2	

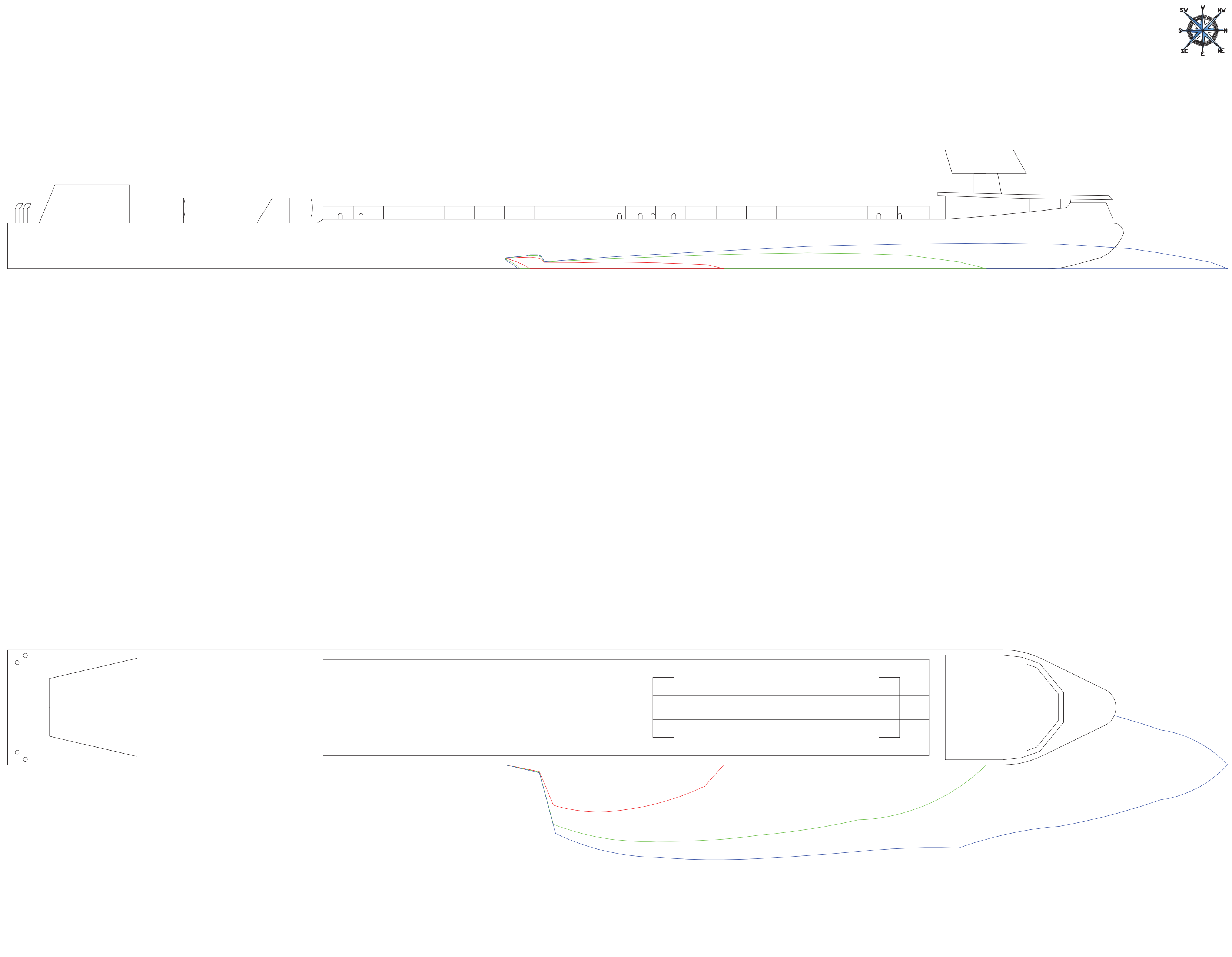
INCIDENT POTENTIAL HAZARDS & OTHER CONCERNS

It is always prudent to assume that a gas cloud could be ignited at any time.
Any intervention, after proper initial and ongoing risk assessment, should consider setting up water curtains or sprays to reduce the cloud; to contain it in place; or to disperse the gas to its LFL.
Use of water spray streams to assist gas dispersion at or near to the release source is only practical if the release is not of significant size or scale. In most cases such deployment will need to be supported by hose-handling teams using water curtains to protect the deployment teams.
Contact with cryogenic LNG may result in burn injuries. Protective clothing may also be compromised when in contact with LNG.
Ignition of an unconfined gas cloud may result in a gas burning back to the source resulting in a jet flame. Gas accumulating in a confined or congested environment may result in an CVCE (confined gas cloud explosion) if ignited resulting in significant blast damage and secondary fires.
A warm BLEVE should not be discounted should there be direct flame impingement on unprotected/damaged tanks or pipe work. .

Unified Command Considerations

Metrological information
Analyse surrounding area and Environmental considerations
Communication
Salvage
Navigational traffic on inland waterways

APPENDIX 2.2A



SHIP INFORMATION

LENGTH: 110 M

WIDTH: 13.5 M

PRODUCT STORED: LNG

EXTENT OF CLOUD DISPERSION DOWNWIND :

25,000 PPM: 71.25 M

50,000 PPM: 47.98 M

150,000 PPM: 22.78 M

EXTENT OF CLOUD DISPERSION CROSSWIND :

25,000 PPM: 9.4 M

50,000 PPM: 7.58 M

150,000 PPM: 4.73 M

EXTENT OF CLOUD DISPERSION HEIGHT :

25,000 PPM: 1.38 M

50,000 PPM: 1.26 M

150,000 PPM: 1.12 M

CONSEQUENCE MODELING PARAMETERS DATA:

TANK SIZE: 50 M^3

RELEASE RATE: 3000 KG/HR

SPILL DURATION: 60 SEC

AMBIENT TEMPERATURE: 15 DEG C

RELATIVE HUMIDITY: 60%

WIND SPEED: 9 M/S

REV	DATE	DESCRIPTION	BY	CHK	APP
0	10/12/14	ISSUED FOR COMMENT	SK	PW	

Falck

UPPER FLAMMABLE LIMIT

150,000 PPM

LOWER FLAMMABLE LIMIT

50,000 PPM

50% LOWER FLAMMABLE LIMIT

25,000 PPM

CLIENT NAME: Rhine Port Group

FALCK RPI PROJECT NO: P1336

DRAWING NO: P1336-FR-06

DESCRIPTION: LNG POOL FIRE - UNIGNITED RELEASE FROM A TRUCK TO SHIP TRANSFER

APPENDIX 2.2B

IWT-LNG-SSERP-2 **EMERGENCY RESPONSE PLAN FOR:**	**RUPTURE OF BUNKERING TRANSFER HOSE (TTS), UNCONFINED SPILL ON WATER, VAPOUR CLOUD FORMATION, NO IGNITION**	**Doc:** **Approved:** **Rev: 2**	

STRATEGY

Initial:
Confirm LNG release event – activate ESD – Alarming authority's - Avoid entering the gas hazard area – Prevent ignition of vapours,, Evacuate personnel from affect area-Stop vessel traffic – Continual wind/weather conditions monitoring

1st RESPONDERS	ACTIONS	EQUIPMENT / RESOURCES	INFO / COMMENTS
Shipboard crew	Confirm LNG release after the collision Activate ESD at the LNG system Notify Emergency Services Activate water spray systems if available/possible Shutdown ventilation systems Assess the risk of vapour cloud ignition Evacuate ship before vapour cloud reach the ship bridge/ accommodate. Goes to the authority's and give all relevant technical LNG and vessel data.	Detection system(s) and/or visual observation ESD systems Ventilation system Backup power Lifesaving equipment	The wind direction & weather condition are important for the vapour cloud projection at the local geographic situation and the decision making priorities. Assess the risk of igniting at vapour cloud and abandoned the vessel immediately when visible vapour cloud possible reach; • Inhabited and/or industrial area • Other vessel(s) • Traffic / highway • Other source of ignition. If not safe; abandon the vessel in upwind direction. Evacuation: • In Upwind or crosswind direction • Be aware of the possible RPT's Give priority to inform the incident responders when everyone is safe.

2nd RESPONDERS	ACTIONS (after vapour cloud ignition)	EQUIPMENT / RESOURCES	INFO / COMMENTS
Local Fire Services	Rescue shipboard crew if it is necessary/ possible. Use gas dispersion strategy from shore side. Setup fire fighting vessel for dispersion of gas cloud. (or from shore side)	Fire water pump/trucks complete. Mobile water monitors. Mobile water screens. Gas detectors. (High Resolution) Thermal Image Camera Rescue boat. Fire fighting vessel with water monitor(s). All Responders have the proper PPE to prevent burns if ignited.	Use water spray or hydro shields to disperse gas cloud Contact the operator to determine the LNG quantities and undertaken actions and findings. Be aware of possible ignition sources Be aware of the flammable and dangerous cargo. Avoid firefighting water into the LNG pool to prevent further evaporation.
Owner	Starting to prepare the salvage operation for the casualty. Check for structural damage from cryogenic release		
River/port authority	Control navigation traffic around incident area.		

IWT-LNG-SSERP-2 EMERGENCY RESPONSE PLAN FOR:	RUPTURE OF BUNKERING TRANSFER HOSE (TTS), UNCONFINED SPILL ON WATER, VAPOUR CLOUD FORMATION, NO IGNITION	Doc: Approved: Rev: 2	

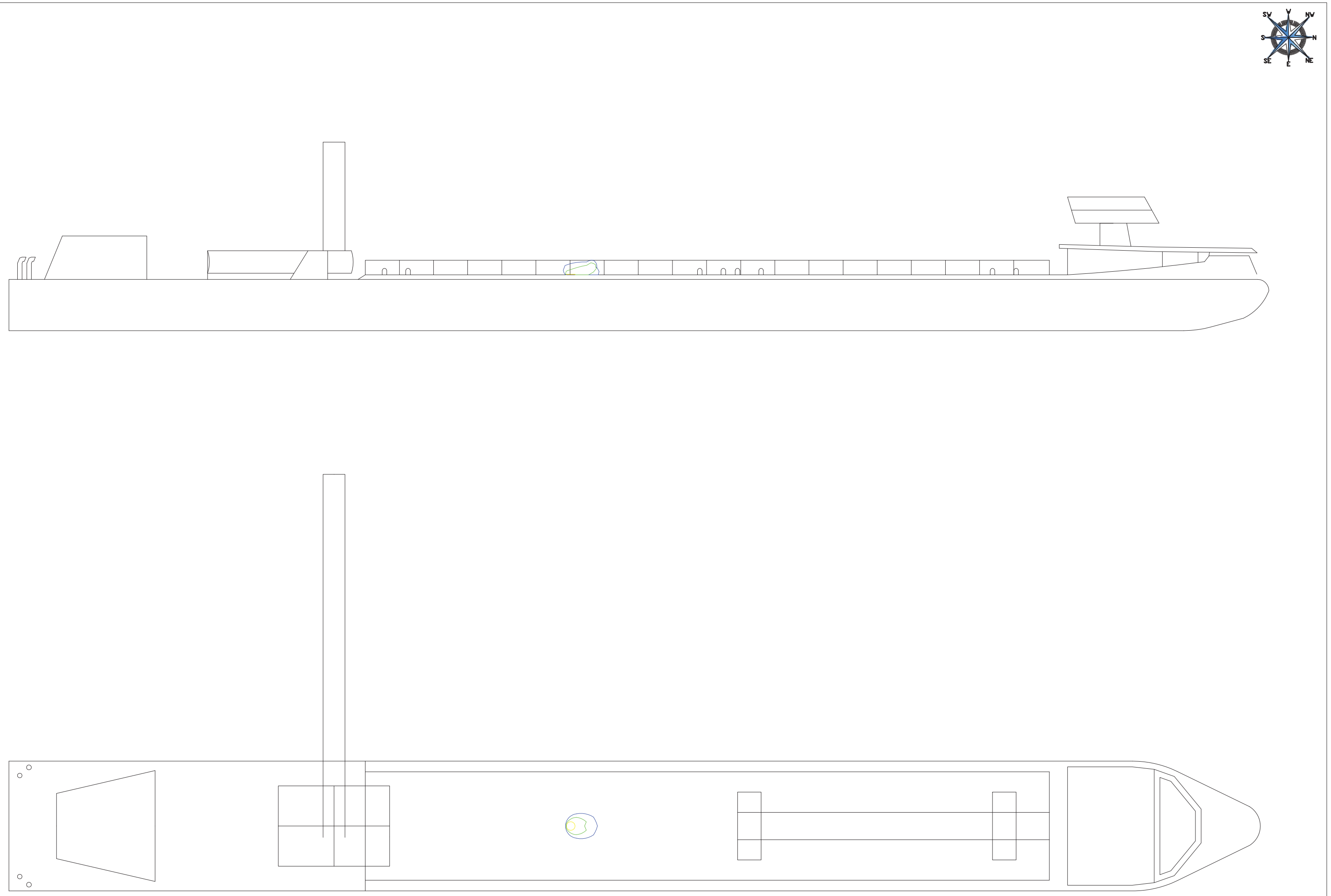
INCIDENT POTENTIAL HAZARDS & OTHER CONCERNS

For LNG releases the application of water ‘raining out’ onto the pool may initially result in a higher rate of evaporation and fire of the LNG.

Unified Command Considerations

Metrological information
Analyse surrounding area and Environmental considerations
Communication
Salvage – cryogenic damage to vessel
Navigational traffic on inland waterways

APPENDIX 2.3A



SHIP INFORMATION

LENGTH: 110 M

WIDTH: 13.5 M

PRODUCT STORED: LNG

EXTENT OF HEAT CONTOURS DOWNWIND FROM POOL CENTER:

32.0 kW/M2: Within Pool Fire Flame

12.5 kW/M2: 1.23 M

6.3 kW/M2: 2.42 M

EXTENT OF HEAT CONTOURS UPWIND FROM POOL CENTER:

32.0 kW/M2: Within Pool Fire Flame

12.5 kW/M2: 0.4 M

6.3 kW/M2: 0.44 M

EXTENT OF HEAT CONTOURS CROSSWIND FROM POOL CENTER:

32.0 kW/M2: Within Pool Fire Flame

12.5 kW/M2: 0.6 M

6.3 kW/M2: 0.88 M

CONSEQUENCE MODELING PARAMETERS DATA:

SOURCE DIAMETER: 75 MM — AMBIENT TEMPERATURE: 15 DEG C

RELEASE RATE: 0.1 KG/SEC — RELATIVE HUMIDITY: 60%

SPILL DURATION: 90 SEC — WIND SPEED: 9 M/S

POOL DIAMETER: 0.75 M

REV	DATE	DESCRIPTION	BY	CHK	APP
1	16/12/14	REVISED FOLLOWING CLIENT COMMENT	SK	RP	
0	10/12/14	ISSUED FOR COMMENT	SK	RP	

Falck

±32kW/M2
PERSONNEL
FATALITY ZONE
EQUIPMENT/ESCALATION
RAPID ESCALATION LIKELY WITHOUT RAPID COOLING <10 MINS.

<12.5kW/M2
PERSONNEL
IMMEDIATE 3RD DEGREE BURNS.
EQUIPMENT/ESCALATION
ESCALATION WITH PROLONGED EXPOSURE, COOLING REQUIRED <15MINS.

<6.3kW/M2
PERSONNEL
IMMEDIATE 3RD DEGREE BURNS.
EQUIPMENT/ESCALATION
ESCALATION WITH PROLONGED EXPOSURE, COOLING REQUIRED <15MINS.

CLIENT NAME: Rhine Port Group

FALCK RPI PROJECT NO: P1336

DRAWING NO: P1336-FR-05-REV 1

DESCRIPTION: LNG POOL FIRE – UNCONFINED SPILL ON DECK/WATER FROM A RELEASE FROM THE ARGOS BUNKERING VESSEL

APPENDIX 2.3B

IWT-LNG-SSERP-3 EMERGENCY RESPONSE PLAN FOR:	BUNKERING VESSELS ALONG SIDE SEAGOING CONTAINERSHIP CONATINER RUPTURE TRANSFER ARM, LNG RELEASE, DELAYED IGNITION	Doc: Approved: Rev: 2	

STRATEGY

Initial:
Confirm LNG release event – activate ESD – Alarming authority's - Avoid entering the gas cloud – Prevent Ignition - Move, upwind shore side for safe rescue/evacuation operation

After a delayed igniting:
Use for the start scenario; Extinguish with Dry Chemical powder - Cooling the vessel structure – Prevent for secondary fire (surroundings)– Protect the cargo (containers) – Stop vessel traffic in immediate area – Evacuate occupants for heat radiation (if near - Water spray control support - Continual wind/weather conditions monitoring

1st RESPONDERS	ACTIONS	EQUIPMENT / RESOURCES	INFO / COMMENTS
Shipboard crew	Confirm LNG release after the collision Activate ESD at the LNG system Notify Emergency Services Activate water spray systems if available/possible Shutdown ventilation systems Assess the risk of vapour cloud ignition reaching accommodate. Give to the authority's and give all relevant technical LNG and vessel data. Try to extinguish fire with Dry chemical Powder By escalation Abandon Ship	Detection system(s) and/or visual observation Fire pump controls Water spray system ESD systems Ventilation system Backup power Emergency anchoring system Lifesaving equipment Dry Chemical powder	The wind direction & weather condition are important for the vapour cloud projection at the local geographic situation and the decision making priorities. Assess the risk of igniting at vapour cloud and abandoned the vessel immediately when visible vapour cloud possible reach; • Inhabited and/or industrial area • Other vessel(s) • Traffic / highway • Other source of ignition. If not safe; abandon the vessel in upwind direction. If anchoring not possible: beach the vessel! Evacuation: • In Upwind or crosswind direction • From other side than collision impact • Be aware of the possible RPT's Give priority to inform the incident responders when everyone is safe.
2nd RESPONDERS	**ACTIONS (after vapour cloud ignition)**	**EQUIPMENT / RESOURCES**	**INFO / COMMENTS**
Local Fire Services Owner River/port authority	Rescue shipboard crew if it is necessary/ possible. If Fire is still burning upon arrival extinguish with Dry Chemical powder. Setup a Fire boat for cooling the vessel structure. (or from shore side) Deploy water spray cooling for the other fuel tanks, cargo and dangerous goods affected by the heat of the fire. Starting to prepare the salvage operation for the casualty. Control navigation traffic around incident area.	Dry Chemical Powder Fire water pump/trucks complete. Mobile water monitors. Mobile water screens. Gas detectors. (High Resolution) Thermal Image Camera Rescue boat. Fire Boat with water monitor(s). All Responders have the proper PPE to prevent burns an igniting.	Use water spray or hydro shields to protect the victims for heat radiation. Contact the skipper to determine the LNG quantities, pressure his undertaken actions and findings. Be aware of the flammable and dangerous cargo. Avoid firefighting water into the LNG pool to prevent the size of fire. A defensive strategy needs to be considered in the spheres of influence: cooling the vital parts effected by the source IP-19 (INSTITUTE of PETROL - model code of safe practice in the petroleum industry) advises: 1. To protect the vessel's hull from flames at least 10 LPM/min water should be used to cool 2. To protect the vessel's hull from heat (10 kW/m2) at least 2 LPM/min water should be used to cool LNG Firefighting is only possible with class BC dry chemical powder.

IWT-LNG-SSERP-3 **EMERGENCY RESPONSE PLAN FOR:**	**BUNKERING VESSELS ALONG SIDE SEAGOING CONTAINERSHIP CONATINER RUPTURE TRANSFER ARM, LNG RELEASE, DELAYED IGNITION**	Doc: Approved: Rev: 2	

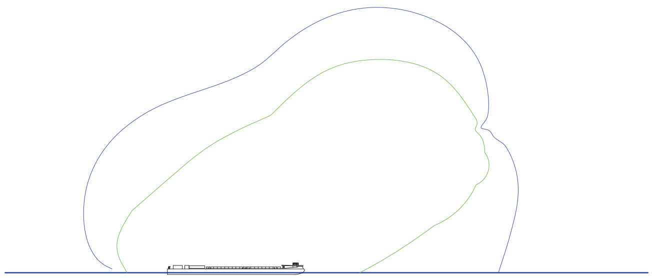
INCIDENT POTENTIAL HAZARDS & OTHER CONCERNS

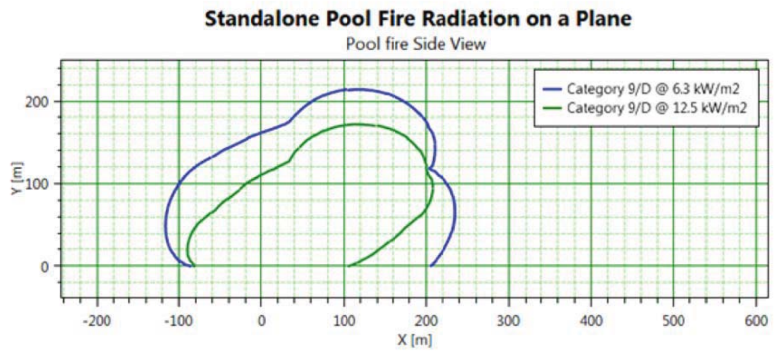
Although a small spill fire scenario, all efforts are to prevent escalation .
For LNG releases the application of water ‘raining out’ onto the pool may initially result in a higher rate of evaporation and fire of the LNG.

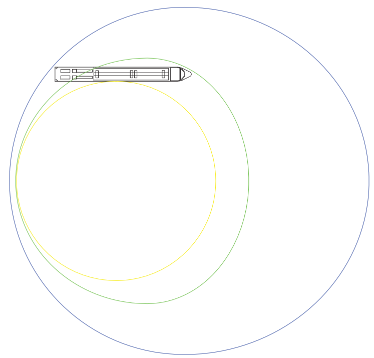
Unified Command Considerations

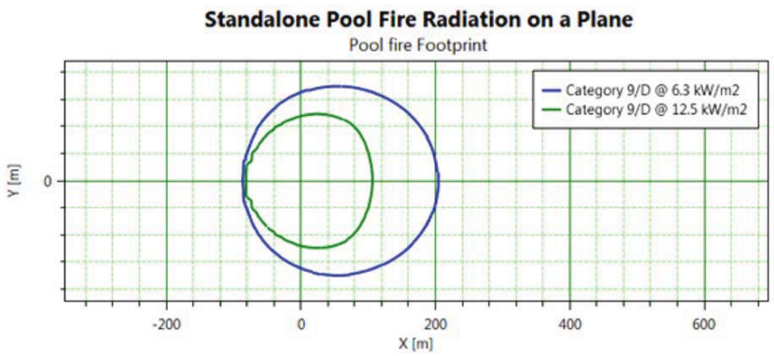
Metrological information
Analyse surrounding area and Environmental considerations
Communication
Salvage
Navigational traffic on inland waterways

APPENDIX 2.4A









SHIP INFORMATION

LENGTH: 110 M

WIDTH: 11.45 M

PRODUCT STORED: GASOLINE

STORAGE CAPACITY: 6 x 500 m^3 STORAGE TANKS

EXTENT OF HEAT CONTOURS DOWNWIND FROM POOL CENTER:

32.0 kW/M2: N/A

12.5 kW/M2: 107 M

6.3 kW/M2: 204 M

EXTENT OF HEAT CONTOURS UPWIND FROM POOL CENTER:

32.0 kW/M2: N/A

12.5 kW/M2: 81 M

6.3 kW/M2: 86 M

EXTENT OF HEAT CONTOURS CROSSWIND FROM POOL CENTER:

32.0 kW/M2: N/A

12.5 kW/M2: 99 M

6.3 kW/M2: 140 M

CONSEQUENCE MODELING PARAMETERS DATA:

SOURCE DIAMETER:	1000 MM	AMBIENT TEMPERATURE:	15 DEG C
RELEASE RATE:	8592 KG/SEC	RELATIVE HUMIDITY:	60%
SPILL DURATION:	42 SEC	WIND SPEED:	9 M/S
POOL DIAMETER:	160.68 M		

REV	DATE	DESCRIPTION	BY	CHK	APP
1	10/11/14	DRAFT FOR APPROVAL	RP		
0	17/10/14	ISSUED FOR COMMENT	JG	SK	

Falck

±32kW/M2
PERSONNEL
FATALITY ZONE
EQUIPMENT/ESCALATION
RAPID ESCALATION LIKELY WITHOUT RAPID COOLING <10 MINS.

<12.5kW/M2
PERSONNEL
IMMEDIATE 3RD DEGREE BURNS.
EQUIPMENT/ESCALATION
ESCALATION WITH PROLONGED EXPOSURE, COOLING REQUIRED <15MINS.

<6.3kW/M2
PERSONNEL
IMMEDIATE 3RD DEGREE BURNS.
EQUIPMENT/ESCALATION
ESCALATION WITH PROLONGED EXPOSURE, COOLING REQUIRED <15MINS.

CLIENT NAME: RHINE PORT GROUP

FALCK RPI PROJECT NO: P1336

DRAWING NO: P1336–FR–04

DESCRIPTION: GASOLINE POOL FIRE – UNCONFINED SPILL ON WATER FROM A RELEASE FROM THE GREENSTREAM VESSEL

APPENDIX 2.4B

IWT-LNG-SSERRP-4 **EMERGENCY RESPONSE PLAN FOR:**	**COLLISION WITH ANOTHER VESSEL, SECONDARY FIRE (GASOLINE CARGO), HEAT EXPOSURE TO LNG FUEL TANKS, ESCALATION WITH PROLONGED EXPOSURE, COOLING REQUIRED WITHIN 15 MINUTES.**	**Doc:** **Approved:** **Rev: 2**	**PAGE 1 OF 1**

STRATEGY

Confirm gasoline release event – Notify emergency services - Isolation of the gasoline release source, if possible, safe and practical to do so - Avoid entering the hazard area – Put into shore if possible - evacuation of persons on board and crew - start up fire pumps on board - Use of deluge sprinkler system to cool LNG fuel tanks and areas that may be affected – Arrangements for meeting incoming external response groups at FCP – restrict or stop navigational traffic to prevent vessels straying into hazard area - Local authority fire service assess incident conditions for ongoing safety – use foam to extinguish poolfire - Water spray control support for cooling surroundings- Continual wind/weather conditions monitoring – Responders stand-by at safe distance until area is declared safe.

1st RESPONDERS	ACTIONS	EQUIPMENT / RESOURCES	INFO / COMMENTS
crew	Confirm gasoline release Notify emergency services Try to isolate leakage Start up fire pump and water protection systems (If fitted) Consider putting ship in to shore at a safe location (if possible) Evacuate all unessential persons (passenger and crew) Prepare to receive emergency services	Fire pump and fixed water protection installation	If leak cannot be stopped evacuate all persons to a safe location up wind. Evacuation to shore is preferential, however if leak is substantial avoid putting vessel into areas of a high population density. Inform Local authority Fire Officer that all listed actions have been carried out up to this point.

2nd RESPONDERS	ACTIONS	EQUIPMENT / RESOURCES	INFO / COMMENTS
Local authority Fire Service	Approach up wind of incident Make contact with master of vessel Set up water spray to cool LNG fuel tanks Set up foam water to extinguish poolfire Continually assess incident conditions for ongoing safety and provide water spray control support. Advise if any further evacuation requirements necessary. Prepare for fire	Forward Control Point located up wind of incident	
Police	Cordon off incident area and evacuate surrounding area lying in path		
River Police /Control	Restrict or control navigation traffic around incident area Fire boat to set up foam water / water spray to extinguish fire and to cool surroundings		

INCIDENT POTENTIAL HAZARDS & OTHER CONCERNS

Any intervention, after proper initial and ongoing risk assessment, should consider extinguishing with foam and setting up water curtains or sprays to cool surroundings / LNG fuel tanks.
A warm BLEVE should not be discounted should there be direct flame impingement on unprotected/damaged tanks or pipe work. .

Unified command

Metrological information
Analyse surrounding area and Environmental considerations
Communication
Salvage
Navigational traffic on inland waterways

APPENDIX 3 | CONTACT PERSONS

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PORT OF MANNHEIM
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GERMANY

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Sector coordinator Harbourmaster Policy Dept
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Direction du développement
Chef de project développement durable
Phone : +33 (0)3 88 21 74 25

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APPENDIX 4 | PROJECT PARTICIPANTS

Project team members	
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Dr. N. Ramsden	Falck (UK)
Mr. R. Roue	Alkane Marine Consultancy (UK)
Mr. R. Peeters	Falck (NL)

Review group members	
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Mr. M. Meijer	Coordinator chemical advisors, EPA Rotterdam-Rijnmond (NL)
Mr. M. van den Berg	Hazmat officer, LIOGS Rotterdam (NL)
Mr. L. Labree	Fire chief, Unified Fire Services Rotterdam / Gezamenlijke Brandweer (NL)
Ms. I. Van de Woude	Policy advisor risk assesment, Safety Region Rotterdam-Rijnmond (NL)
Ms. K. Capello	Chief medical officer at Safety Region Rotterdam-Rijnmond (NL)
Mr. J. van Houwenhove	Consultant, Cryo Advise (BE)

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Mr. R. Van der Veen	Falck (NL)
Ms. S. v.d. Pol – V.d. Hurk	Falck (NL)