European Maritime Safety Agency

SAFETY OF AMMONIA FOR USE IN SHIPS

PART 5 – RISK ASSESSMENT OF A RORO SHIP DESIGN

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EMSA

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Executive Summary

The main goal of this study is to assess the safety of using ammonia as fuel in the maritime industry. To that end, in its first part the feasibility and safety of ammonia as a marine fuel was examined, focusing on its unique hazards such as toxicity, corrosiveness, and solubility in water. While ammonia has an extensive history in land-based applications and as a transported product via liquefied gas carriers, its recent adaptation for marine fuel use highlights regulatory and technological gaps. The first part also emphasised that the existing frameworks by the International Maritime Organization (IMO) and classification societies remain under development.

To address these challenges, the second part of the study employed advanced fault tree analyses (FTA) and reliability modelling for critical systems, such as internal combustion engines, fuel supply systems, and bunkering operations, using insights from similar liquefied gas fuels like LPG. It also highlighted the more stringent safety requirements; proactive and preventive measures to prohibit equipment and component failures to manage ammonia's inherent risks, particularly the loss of containment. The analysis identified weak points across several systems, such as injector valve fatigue, corrosion risks in fuel injectors, and ammonia leakage in components from sources such as rupture of piping and failure of compressors. Reliability models and sensitivity analyses revealed that incorporating redundancy of critical equipment and components, especially in dual-fuel systems, significantly improves operational reliability. For instance, systems with dual-fuel redundancy showed longer mean time to failure (MTTF) than single-system designs. By leveraging data from industry standards and collaboration with equipment vendors, the second part outlined strategies to enhance system reliability, such as improving material properties and addressing operational and human error risks. These insights provided a foundation for further system design refinements and safety protocols, supporting the adoption of ammonia as a sustainable maritime fuel.

The third part of the ammonia safety study complemented earlier findings by conducting i) a HAZOP study for an Ammonia Fuel Supply System, ii) port-related risk assessments approaches (including SIMOPS), and consequence modelling of ammonia leaks through CFD simulation.

The study highlights the importance of understanding ammonia's unique characteristics - particularly its toxicity - to inform effective risk assessments and safety measures. At the early stage of the study the IGF Code was used as baseline regulatory framework, as it is the mandatory instrument applicable to ships using gaseous fuels. However, it was recognised that the existing IGF Code, which is primarily based on natural gas, requires significant adaptation to adequately address ammonia's specific risks. Indeed, the IGF did not adequately address fuel toxicity, suggesting the need for revised and additional safety barriers, both for normal operations and emergency situations. Nevertheless, this was addressed, during the W/S, through the IMO's Interim Guidelines for the safety of ships using ammonia as fuel (MSC.1/Circ.1687), issued on February 26th, 2025. These guidelines take into consideration the different safety characteristics (especially toxicity, not just flammability) of ammonia. Section 12bis, was introduced to specifically address ammonia-specific requirements that go beyond the generic gas fuel safety provisions in Section 12 of the IGF Code.

Parts four (4) and five (5) of the study constitute the continuation of the efforts mentioned above, and they revolve around applying a HAZID methodology for two different ship designs:

- a Newcastlemax Dry Bulk Carrier (in Part 4), and
- A mega RORO (in Part 5).

This report pertains to part five (5) of the EMSA-funded study for the safety of ammonia as a maritime fuel and it consists of three main sections:

- The report of a Hazard Identification (HAZID) study of a mega RORO ship design,
- The modelling of potential consequences in an event of an ammonia leak, and
- The probit analysis related to toxic exposure to ammonia, based on the outcomes of the consequence modelling.

RORO HAZID

NTUA was commissioned by EMSA, in the frame of the study awarded to the consortium led by ABS, to carry out a Hazard Identification (HAZID) Study for a Roll On – Roll Off ship design. The HAZID study is a structured review technique to identify all hazards associated with a specific concept, design, operation or activity, including the likely initiating causes, possible consequences and safeguards so that the hazards can be assessed, eliminated at source (if possible), controlled and/or mitigated otherwise.

In total, six hundred and forty-seven (647) scenarios were identified at the HAZID workshop. A hundred and twenty-nine (129) scenarios were purposefully not ranked either because there were no hazards identified, or there was insufficient technical information to carry out the risk ranking. Twenty-four (24) scenarios were categorised as low-risk and a hundred and forty-seven (147) were categorised as moderate-risk. Three hundred and twenty-nine (329) scenarios were categorised as high-risk, while eighteen (18) scenarios were categorised as extreme risk (as shown in the unmitigated risk table below).

Risk Ranking

		Low	Minor	Moderate	Major	Critical
		3	4	5	6	7
Likelihood	Almost Certain **(0):** Occurs 1 or more times a year	**0**	**0**	**0**	**0**	**0**
	Likely **(-1):** Occurs once every 1-10 ship years	**100**	**111**	**104**	**18**	**0**
	Possible **(-2):** Occurs once every 10-100 ship years	**16**	**47**	**46**	**68**	**0**
	Unlikely **(-3):** Occurs once every 100-1000 ship years	**0**	**8**	**0**	**0**	**0**
	Rare **(-4):** Occurs once every 1000-10000 ship years	**0**	**0**	**0**	**0**	**0**

During the HAZID workshop, recommendations were made in two key situations:

1. When current preventive or mitigating measures were deemed insufficient to manage the risk of an identified scenario to an acceptable level.
2. When further assessments were necessary to gain a more comprehensive understanding of the hazard and associated risk.

In case that additional safeguard(s)/measure(s) implemented to the design, as per discussions and conclusions for the recommendations, is/are considered to reduce frequency/severity of the accident scenario, the risk ranking for the relevant accident scenario was re-evaluated. As a result, three hundred and forty-four (344) scenarios were categorised as low-risk and ninety-three (93) were categorised as moderate-risk. Sixteen (16) scenarios were categorised as high-risk, while no scenario was categorised as extreme risk (shown in the table below). Sixty-five (65) scenarios were initially risk ranked, but there was not enough technical information relevant to the existing safeguards to rank their residual risk and thus have been excluded from the Residual (or mitigated) Risk matrix below.

The sixteen (16) high residual risk scenarios are all relevant to the fuel storage tank node. They include recommendations highlighting the importance of:

- Performing stress analysis study considering vibration and fatigue of the tank,
- Including the provision of a manhole in the middle of the tank on top,
- Developing procedures on gas freeing the ammonia storage tanks considering the operational procedures including the deck compartment,
- Verifying that safe means of access for maintenance of equipment and valves in locations beyond man height will be provided in the Tank Connection Space.

Residual Risk

		Low	Minor	Moderate	Major	Critical
		3	4	5	6	7
Likelihood	Almost Certain **(0):** Occurs 1 or more times a ship year	**0**	**0**	**0**	**0**	**0**
	Likely **(-1):** Occurs once every 1-10 ship years	**10**	**0**	**0**	**0**	**0**
	Possible **(-2):** Occurs once every 10-100 ship years	**338**	**79**	**0**	**16**	**0**
	Unlikely **(-3):** Occurs once every 100-1000 ship years	**0**	**6**	**4**	**0**	**0**
	Rare **(-4):** Occurs once every 1000-10000 ship years	**0**	**0**	**0**	**0**	**0**

Two hundred and forty-two (242) recommendations were made by the HAZID team. After the HAZID workshop, the assigned responsible party/parties for each recommendation carried out the follow-up actions.

The HAZID study was conducted based on the arrangement drawings, documents, and philosophies available at the time of the HAZID workshop. It is strongly recommended that any future significant changes to the design which may impact hazards should be reassessed.

Regarding this specific ship design and the AFSS under examination, the following conclusions were drawn:

- Ammonia introduces complex safety challenges. Its toxicity, corrosivity, and flammability require safety measures that go beyond those for conventional or LNG fuels.
- System integrity and leak prevention are critical. Design should prioritize double barriers, short piping runs, and welded connections to minimize leak potential.
- Detection and ventilation systems must be robust and redundant. Early leak detection, oxygen monitoring, and carefully designed ventilation and dispersion control are essential to protect personnel and equipment.
- Emergency response planning must be comprehensive. The vessel must include safe havens, mustering zones, and clearly defined escape routes, especially considering toxic gas release scenarios.
- Bunkering operations demand special focus. The use of dry disconnects, emergency release systems, drainage provisions, and updated procedures (SOPEP, STS plans) is vital for safe ammonia bunkering.
- Fuel storage and PSV venting require toxic zone management. Toxic dispersion analysis, safe integration of PSVs, and appropriate vent mast design are necessary to manage accidental releases.

- SOPs and operational limitations must be clearly defined. Standard procedures should address both routine operations and emergencies, particularly for purging, closed entry, and power loss scenarios.
- Crew protection and lifesaving systems need careful positioning. Lifesaving appliances, firefighting equipment, and escape paths must be located outside potential toxic gas areas.
- Cybersecurity and automation safety must be included. Digital systems controlling safety functions should meet relevant cyber protection standards, such as ISO/IEC 27001 and IEC 62443.
- Lessons from ammonia cargo and related industries are valuable. Existing accident records, standards, and operational practices from cargo ships and industry can guide safer designs and procedures.

Consequence Modelling

CFD Modelling

The gas dispersion modelling was conducted using Computational Fluid Dynamics (CFD) to predict the air quality and to identify the impact of ammonia dispersion for a ferry design. The release of the ammonia was assumed to be in a gaseous state however, two-phase flows including both liquid and gaseous ammonia is typically involved. The assumption of the purely gaseous state was applicable since the implemented CFD modelled provided a more conservative assessment of the release due to the slow evaporation nature of liquid ammonia. This gives the crew time to respond and take measures. This study evaluates the scenario during possible incidental events. The ammonia tank's relief valve activates and ammonia vapour is routed to the rear vent at the stern of the vessel. Two wind conditions were investigated in this study, i.e. one wind is blowing from the starboard side to the port side and the other wind is blowing from the starboard-aft direction. The analysis highlights critical ammonia concentration levels that match the DNV report: 30 ppm, 220 ppm, 550 ppm, 1,100 ppm, and 2,700 ppm. The study shows that the rear vent release has no impact on the vessel and personnel.

ALOHA Modelling

As part of this study, a series of ammonia dispersion simulations were carried out using ALOHA software. These simulations assess potential risk areas in the event of a leak during bunkering operations, supporting the definition of exclusion zones, emergency planning, and the validation of key recommendations in the SIMOPS analysis.

Probit Analysis

A probit analysis was carried out to estimate the probability of fatality resulting from exposure to toxic ammonia vapours under two representative leak scenarios: a small-scale short-duration (1 minute) release, during bunkering operations and a large-scale rupture of a refrigerated fuel tank with sustained release (60 minutes). The results, based on standard ammonia toxicity parameters, indicate that the small leak scenario poses minimal risk beyond 1 km, with fatality probabilities dropping below 1%. In contrast, the tank rupture scenario yields significantly higher risk levels, with probabilities exceeding 70% at distances below 250 metres. The analysis also confirmed that exposure duration is a critical factor and that negative probit values, observed in low-concentration zones, correspond to negligible risk. These findings provide a robust quantitative basis for defining toxic hazard zones and support the design of appropriate safety measures and emergency response strategies.

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List of Abbreviations

ABS	American Bureau of Shipping
ADS	Addressable Detection System
AEGL	Acute Exposure Guideline Levels
ALOHA	Areal Locations of Hazardous Atmospheres
BOG	Boil-Off Gas
BSL	Bunkering-Safety Link
CCC	Carriage of Cargoes and Containers
CCTV	Closed Circuit Television
CFD	Computational Fluid Dynamics
CO2	Carbon Dioxide
DFDS	Det Forenede Dampskibs-Selskab
EBC	Emergency Breakaway Coupling
EMSA	European Maritime Safety Agency
ERPG	Emergency Response Planning Guidelines
ESD	Emergency Shutdown
FAT	Factory Acceptance Test
FTA	Fault Tree Analysis
FV	Fundación Valenciaport
GA	General Arrangement

GVU-ED	Gas Valve Unit of Enclosed Design
HAT	Harbour Acceptance Tests
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HMI	Human-Machine Interface
IACS	International Association of Classification Societies
IAS	Integrated Automation System
IDLH	Immediately Dangerous to Life and Health
IGF Code	International Code of Safety for Ships using Gases or other Low-flashpoint Fuels
IMO	International Maritime Organization
IR	Infrared
KEH	Knud E. Hansen
LNG	Liquified Natural Gas
LoC	Loss of Containment
LPG	Liquefied Petroleum Gas
MARPLOT	Mapping Application for Response, Planning, and Local Operational Tasks
MGO	Marine Gas Oil
MTTF	Mean Time To Failure
MV	Mechanical Ventilation
NA&ME	Naval Architecture and Marine Engineering
N2	Nitrogen
N2O	Nitrous Oxide
NH3	Anhydrous Ammonia used as fuel
NOAA	National Oceanic and Atmospheric Administration
NTUA	National Technical University of Athens
OPTS	Operator Training System
OSCP	Oil Spill Contingency Plan
PFAS	Per- and polyfluoroalkyl substances
PFD	Process Flow Diagram
PHA	Process Hazard Analysis
PMS	Planned Maintenance System
PP	Personnel Protection
PPM	Parts Per Million
PS	Port Side
PSV	Pressure Safety Valve
PPE	Personal Protective Equipment
QCDC	Quick Connect/Disconnect Coupler
RORO	Roll On Roll Off ship
SAT	Sea Acceptance Tests
SCBA	Self-Contained Breathing Apparatus
SCR	Selective Catalytic Reaction system
SIGTTO	Society of International Gas and Tanker Operators
SIMOPS	Simultaneous Operations
SMPEP	Shipboard Marine Pollution Emergency Plan
SMS	Ship Management System
SOLAS	Safety of Life at Sea
SOP	Standard Operator Procedures
SOPEP	Shipboard Oil Pollution Emergency Plan
STBD	Starboard side

STS	Ship-to-Ship
SV	Safety Valve (Pressure or Thermal)
TCS	Tank Connection Space
UR	Unified Requirements

1. Hazard Identification (HAZID) Study

1.1 Introduction

Ammonia is among the most prevalent options of new fuels to be used in commercial shipping for meeting the 2050 targets[2]. However, the maritime sector has significant experience with ammonia only as cargo, and research is still ongoing for the safe use of ammonia as fuel. Although there is proven experience in handling ammonia in the maritime sector, knowledge is limited to ships carrying ammonia. Its potential wide use as a bunker fuel implies a shift from one-off operations with ammonia to extensive use, which significantly increases the risks considerably and may have a direct impact on the risk of ammonia loss of containment (LoC). Other industries, such as the Oil and Gas and Fertilizer industries, have an already proven track record of safe production and use of ammonia as chemical, and technologies and relevant methodologies have already reached a high maturity level, including the respective regulatory and normative framework applicable to these industries.

Considering the above, in Spring 2023, the European Maritime Safety Agency (EMSA) awarded a framework contract for the provision of a study investigating the safety of ammonia as fuels on ships (EMSA/OP/6/2023)[3] to a Consortium led by the American Bureau of Shipping (ABS) that also included the School of Naval Architecture and Marine Engineering (NA&ME) from the National Technical University of Athens (NTUA), and Fundación Valenciaport (FV). The NTUA research team, is responsible for carrying out the risk assessment procedures and is led by Prof. Nikolaos P. Ventikos.

As part of the above study, NTUA was commissioned to carry out a Hazard Identification (HAZID) study for the function and operation of using ammonia as an alternative fuel of a RORO ship design.

The objectives of the HAZID study were to:

- Identify hazards & hazardous events that may give rise to risks
- Identify potential causes and consequences of the hazardous events identified
- Identify preventive measures and mitigating measures
- Assess risks semi-quantitatively by using a risk matrix
- Recommend additional measures to eliminate/reduce the risks

The HAZID study for the mega RORO ship design was carried out as a brainstorming exercise in the HAZID workshop attended by a multidisciplinary team (i.e., HAZID team) from the project stakeholders that included the National Technical university of Athens (**NTUA** - facilitating), the American Bureau of Shipping (**ABS** - scribing), Fundación Valencia port (**FV**), European Maritime Safety Agency (**EMSA**), Knud E. Hansen (**KEH**), **Wärtsilä**, and Det Forenede Dampskibs-Selskab (**DFDS**).

The risk assessment activities carried out under Task 5 - namely the HAZID workshop focusing on a RORO vessel using ammonia as fuel - are designed to complement the work undertaken in Tasks 3 and 4. While Task 3 involved a HAZOP study based on a generic ammonia-fuelled ship design, and Task 4 combined HAZID and SIMOPS assessments for a bulk carrier case study, Task 5 adds further depth by addressing vessel-specific hazards and operational considerations unique to RORO ship configurations. Together, these three assessments provide a comprehensive understanding of the safety challenges and mitigation strategies across different ship types and operational scenarios, thereby supporting the broader objective of developing robust safety frameworks for the use of ammonia as a marine fuel.

This report concerns Task 5 and constitutes the fourth report under Specific Contract 2 (SC2).

[2] https://www.imo.org/en/MediaCentre/HotTopics/Pages/Cutting-GHG-emissions.aspx
[3] https://etendering.ted.europa.eu/cft/cft-display.html?cftId=13603

1.2 Background

The ship designer Knud E. Hansen (KEH) has been commissioned by Det Forenede Dampskibs-Selskab (DFDS) to outline the design of an ammonia-fuelled RORO vessel equipped with two electrically driven propulsion lines. The section below, offer a high-level overview of key components for the vessel, including ammonia storage, machinery configuration, and redundancy considerations. It also serves as a basis for this HAZID report's initial assessments.

The primary gensets being considered are Wartsila 31DF, which can operate on Marine Gas Oil (MGO) and ammonia, requiring MGO as pilot fuel. Each engine's exhaust will include a selective catalytic reduction (SCR) system to ensure IMO Tier 3 compliance[4]. The descriptions in this document are not final and will be subject to risk assessment by Class and flag state authorities, thus further assisting the regulations development process. Furthermore, DFDS's intentions include to replace MGO as pilot fuel with renewable biodiesel and retrofit ammonia fuel cells for low-power demand scenarios (i.e., where normally the engine would shift from ammonia to diesel mode). Batteries are also intended to be used for load sharing and peak shaving.

1.3 System Description

1.3.1 Vessel General Information

The general arrangement of the DFDS energy efficient Mega RORO is presented in Figure 1.

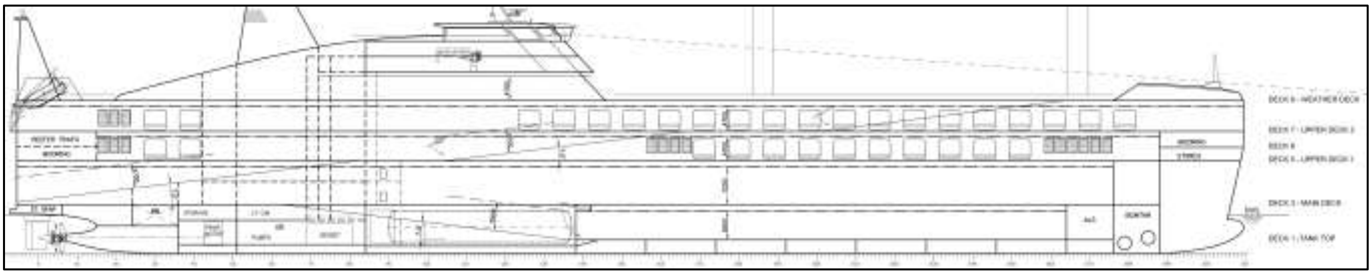


Figure 1: Side view of Mega RORO

The principal dimensions of the RORO are listed in Table 1.

Table 1: Principal dimensions of generic RORO

Particular	Description
Length (Overall)	237 m
Length (Between Perpendiculars)	229.20 m
Breadth (MLD)	33.50 m
Draught (Design)	7.00 m
Draught (Summer)	7.30 m
Draught (Scantling)	7.50 m
Deadweight at Summer Draught	abt. 18.100 tons
Service Speed	21.0 kn
Lane metres	abt. 6.700 m

1.3.2 General

The intended NH3-related systems are designed to bunker, store, control fuel temperature and supply NH3 at a rate corresponding to full load on all main gensets. The system design is based on available knowledge, technology,

[4] https://www.imo.org/en/OurWork/Environment/Pages/Nitrogen-oxides-(NOx)-%E2%80%93-Regulation-13.aspx

current applicable standards, guidelines and codes. The system is designed to handle the vapours, temperatures, and maximum pressure built up in the NH3 tank by cooling down per the tank maker's recommendation.

The overall process flow schematic of the AFSS (developed by Wärtsilä) is presented in Figure 2.

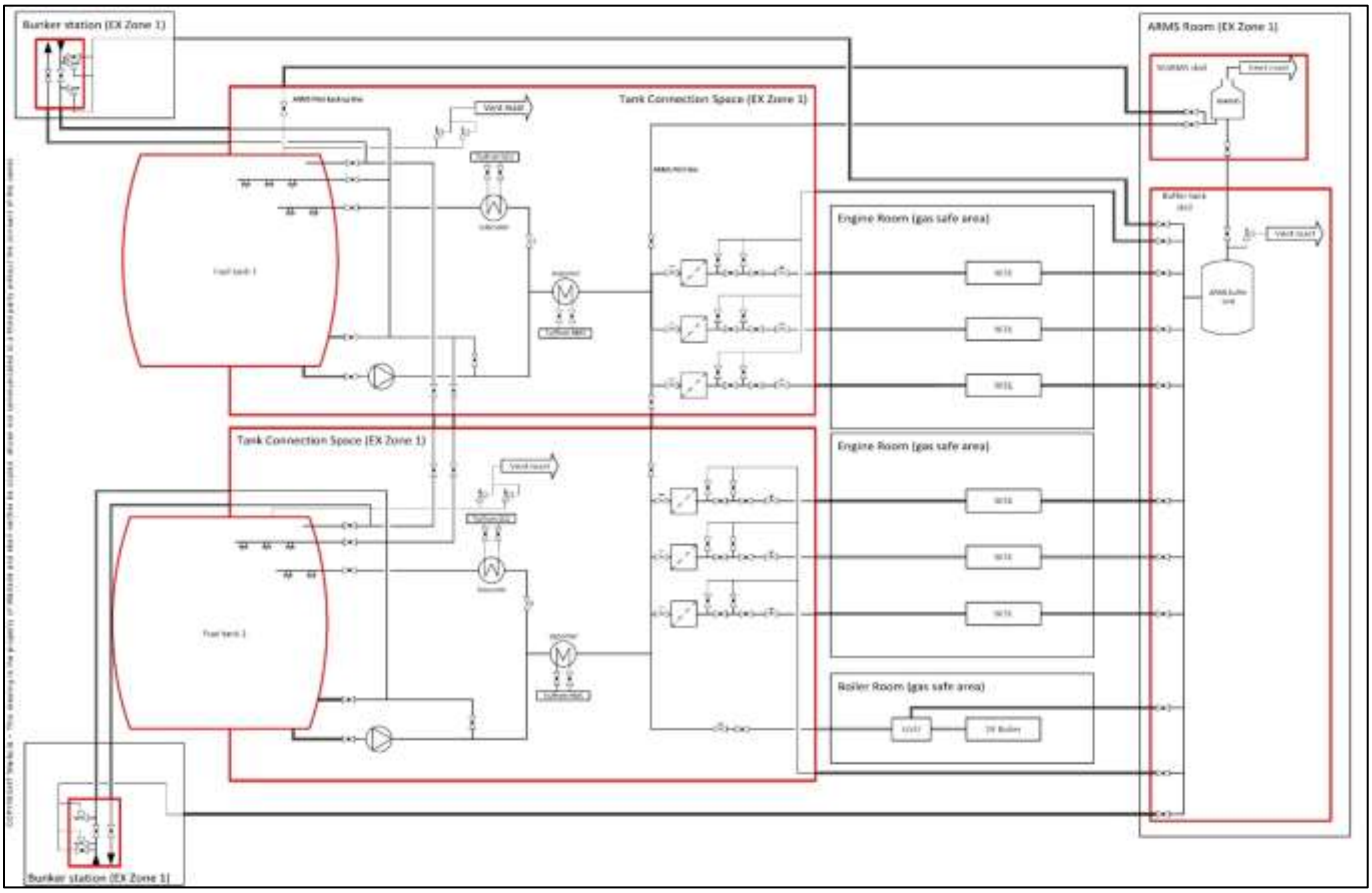


Figure 2: Overall Process Flow Schematic

1.3.3 Bunkering Stations

For the current project, two dedicated NH3 bunkering stations will be installed: one on the port side (PS) and one on the starboard side (STBD) of the vessel, located on the main deck level or above. Each bunkering station will, at minimum, be equipped with the following:

- One (1) emergency shutdown (ESD) valve
- Coamings
- Toxic vapour/gas detection system
- Closed-circuit television (CCTV) system
- Water curtain system
- Fire detection system
- Fixed firefighting system, and
- Portable firefighting extinguishers in accordance with relevant rules and regulations.

Only explosion-proof electrical equipment will be allowed for installation in the bunkering stations. Air locks will be arranged between the bunkering stations and hazardous non-gas areas, such as cargo areas and staircases. If the NH3 bunkering station is located near the MGO bunkering station, an air lock will also be provided for the MGO bunkering station to maintain segregation in case the MGO bunker door is opened during NH3 bunkering. NH3 will be transferred from the bunkering stations to the storage tanks through a double-walled pipe in a dedicated NH3 pipe tunnel or trunk. The dimensions of the liquid filling lines are DN200, and those of the vapour return line are DN150.

The bunkering pipes will be designed to drain towards the storage tanks. Class A60 insulation will separate the bunkering stations from the engine rooms, cargo areas, accommodation, and high-fire-risk spaces; otherwise, A0 bulkheads shall be used. The bunkering system will ensure that no gas or vapours are discharged into the atmosphere when the storage tanks are filled.

MSC.1/Circ.1687 Relevant Provisions

According to IMO's interim GLs, the provisions relevant to the bunkering stations are the following:

- **Section 5.7.3.1**: The location and arrangement of the bunkering station, whether open, enclosed, or semi-enclosed, should be subject to special consideration within the risk assessment. This includes factors such as segregation from other areas, hazardous and toxic area plans, requirements for forced ventilation, leakage detection, safety actions related to leakage detection, access through airlocks, and monitoring via direct line of sight or CCTV.
- **Section 5.7.3.2**: Mechanical spray shielding should be arranged around potential leakage sources from the ammonia system in the bunkering station.
- **Section 5.7.3.3**: The bunkering station should be located in an area where sufficient space for efficient work and access is ensured for personnel involved in bunkering and their equipment while wearing self-contained breathing apparatus (SCBA) and PPE, and to ensure that, in an emergency, they have a clear escape route.
- **Section 8.5.4**: A bunkering-safety link (BSL), or an equivalent means for automatic and manual ESD communication to the bunkering source, should be fitted.
- **Section 8.5.5**: Means should be provided for draining any fuel from the bunkering pipes upon completion of bunkering operations.
- **Section 8.5.9**: Sampling valves, if fitted, should be arranged at suitable locations in the bunkering line to allow verification procedures to confirm that the bunkering line is safe before opening any flanges. A double shut-off, blank flange, or plug should be installed on sampling valves in the bunkering line.

1.3.4 Ammonia Fuel Storage Tanks (PS&STBD)

For this specific design, two (2) dedicated NH3 fuel (i.e., storage) tanks are arranged - one on each side of the vessel. They are designed for pressure and temperature control by subcooling and/or reliquefication. The bunker tanks are horizontal type, single wall, polyurethane-insulated, IMO Type C, Tank Connection Spaces (TCS) is built-in, and is considered a gastight enclosed unit. The tanks have a design pressure of 6 barg to allow bunkering and storage of both fully refrigerated and semi-refrigerated ammonia and provides additional flexibility and safety in operations with possibility for pressure accumulation in the tanks.

A brief description of known bunker process when having fuel tanks designed for pressure and temperature control is provided below:

- Cooldown NH3 tank 1 before starting bunkering. The cooldown of tank 1 could be done by gradually spraying liquid from NH3 fuel tank 2, this will then create NH3 vapours and cool tank 1 due evaporation. The evaporated NH3 vapour will then be handled by the sub cooler/reliquefication plant and return to tank 1. This process will be continued until the required tank temperature has been reached and liquid begins to accumulate in tank 1. The same process can be used for maintaining the low temperature in the tanks when operating the vessel.
- Liquid ammonia must only be sprayed into a fully inert tank. Spraying and splashing can create a static charge, which, with air present, could ignite the liquid.
- Ammonia from the bunker vessel shall be made available in the temperature, pressure, and flow range that the receiving ship's bunker tank can handle. The bunker vessel shall be able to handle the vapour return.
- A pressure relief valve and burst disk shall be arranged to minimise the risk of ammonia release to the atmosphere.

1.3.5 Tank Connection Space and Fuel Supply

Each bunker tank will have one (1) TCS that is equipped with a "low flashpoint" fuel supply system, including the following components:

- One (1) NH3 pump
- Flowmeter
- One (1) fuel conditioner heat exchanger (evaporator)
- Integrated Gas Valve Units (GVU)
- Manual, remotely operated, and emergency shutdown (ESD) valves
- Necessary venting valves
- Toxic vapour gas/liquid detection system (ref. to Table 1 of IMO’s MSC.1-Circ.1687)
- CCTV
- Fire detection system
- Fixed firefighting system
- Portable firefighting extinguisher
- Adequate Ventilation

According to IMO’s MSC.1/Circ.1687 (12bis. 4.2), the TCS along with the interior of the fuel tanks are considered a toxic area.

The two (2) storage tanks will be interconnected via a fuel supply pipe. Additional components, such as valves and instrumentation, will follow the manufacturer's recommendations.

Each NH3 TCS will have individual supply lines for each consumer valve unit. An air lock will be installed in each tank connection space, which is classified as EX Zone 1 hazardous area. .

MSC.1/Circ.1687 Relevant Provisions

According to IMO’s interim GLs, the provisions relevant to the storage tanks and TCS are the following:

- **Section 5.7.2.1**: Fuel tank connections, flanges, and tank valves should be located in a tank connection space arranged in accordance with the provisions in these Interim Guidelines. Apart from fuel process equipment allowed in tank connection spaces as defined in 5.7.1.1, tank connection spaces and fuel preparation rooms should not be combined.
- **Section 5.7.2.2**: Tank connection spaces should be designed to safely contain fuel leakages. The tank connection space boundaries should be gastight towards other spaces in the ship.
- **Section 5.7.2.3**: The material of the bulkheads of the tank connection space should have a design temperature corresponding with the lowest temperature it can be subject to in a probable maximum leakage scenario.
- **Section 5.7.2.4**: The probable maximum leakage into the tank connection space should be determined based on detailed design, detection, and shutdown systems.
- **Section 5.7.2.5**: Tank connection spaces should be fitted with ventilation arrangements ensuring that the spaces can withstand any pressure build-up caused by vapourisation of the liquefied fuel.
- **Section 5.7.2.6**: Tank connection space entrances should be arranged with a sill height exceeding the liquid level resulting from a calculated maximum leakage, but should in no case be lower than 300 mm.
- **Section 5.7.2.7**: Tank connection space entrances should be arranged with water screens having constantly available water supply. The water screen should be possible to activate from a safe location outside the tank connection space toxic zone if an ammonia leak occurs. The water screens should be arranged on the outside of the tank connection spaces. The arrangement should include the means to safely manage any ammonia effluent produced in their operation.
- **Section 5.7.2.8**: Unless the access to the tank connection space is independent and direct from the open deck, it should be provided through a bolted hatch. The bolted hatch should be located in a protective entry space of

gastight construction with a self-closing gastight door. The access should be arranged to facilitate the evacuation of an injured person from the tank connection space by personnel wearing breathing apparatus and PPE.

- **Section 5.7.2.9**: A leakage in the tank connection space should not render necessary safety functions out of order due to low temperatures caused by the evaporation of leaking fuel.
- **Section 5.7.1.1**: Fuel process equipment should be arranged in a fuel preparation room arranged in accordance with provisions in these Interim Guidelines. As an exemption to this provision, vapourisers, heat exchangers, and motors for pumps submerged in tanks may also be located in tank connection spaces.
- **Section 5.7.1.2**: When fuel preparation rooms cannot be located on open deck, or accessed from open deck, access should be provided through an airlock in compliance with 5.11.
- **Section 5.7.1.3**: Fuel preparation rooms should be designed to safely contain fuel leakages. The fuel preparation room boundaries should be gastight towards other spaces in the ship.
- **Section 5.7.1.4**: The probable maximum leakage into the fuel preparation room should be determined based on detailed design, detection, and shutdown systems.
- **Section 5.7.1.5**: The material of the boundaries of the fuel preparation room should have a design temperature corresponding with the lowest temperature it can be subjected to in a probable maximum leakage scenario, unless the boundaries of the space, i.e., bulkheads and decks, are provided with suitable thermal protection.
- **Section 5.7.1.6**: The fuel preparation room should be fitted with ventilation arrangements ensuring that the space can withstand any pressure build-up caused by vapourisation of the liquefied fuel.
- **Section 5.7.1.7**: The fuel preparation room entrance should be arranged with a sill height exceeding the liquid level resulting from a calculated maximum leakage, but should in no case be lower than 300 mm.
- **Section 5.7.1.8**: Fuel preparation room entrances should be arranged with water screens having constantly available water supply. The water screen should be possible to activate from a safe location outside the fuel preparation room toxic zone if an ammonia leak occurs. The water screens should be arranged on the outside of the fuel preparation room. The arrangement should include the means to safely manage any ammonia effluent produced in their operation.
- **Section 5.7.1.9**: A leakage in the fuel preparation room should not render necessary safety functions out of order due to low temperatures caused by the evaporation of leaking fuel.
- **Section 5.7.1.10**: Fuel preparation rooms should be designed to manage any ammonia release for personnel to enter safely.
- **Section 5.6.1**: Fuel pipes and fuel supply systems should not be located less than 800 mm from the ship's side.
- **Section 5.6.2**: Fuel piping should not be led directly through accommodation spaces, service spaces, electrical equipment rooms, or control stations as defined in the SOLAS Convention, even though the piping is protected by secondary enclosures.
- **Section 5.6.3**: Fuel pipes led through RORO spaces, special category spaces, and on open decks should be protected against mechanical damage.
- **Section 5.8.1**: Bilge systems installed in areas where fuel covered by these Interim Guidelines can be present should be segregated from the bilge system of spaces where fuel cannot be present.
- **Section 5.8.2**: Where fuel is carried in a fuel containment system requiring a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure should be provided. The bilge system should not lead to pumps in spaces having no risks of ammonia. Means of detecting such leakage should be provided.
- **Section 5.8.3**: The hold or interbarrier spaces of type A independent tanks for liquid gas should be provided with a drainage system suitable for handling liquid fuel in the event of fuel tank leakage or rupture.
- **Section 5.9.1**: Drip trays should be fitted where leakage may occur which can cause damage to the ship structure or where limitation of the area which is affected from a spill is necessary.
- **Section 5.9.2**: Drip trays should be made of suitable material.
- **Section 5.9.3**: The drip tray should be thermally insulated from the ship's structure so that the surrounding hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquid fuel.

1.3.6 Boil-off Gas (BOG) Handling

The fuel supply, storage, bunker systems and main gensets/boiler consumers shall be designed to prevent venting during normal operations, allowing it only for safety emergencies. The primary method for handling boil-off gas (BOG) during bunkering involves a sub cooler/reliquefication plant system with a dual-fuel boiler as secondary support, operating on oil and ammonia. Each bunker tank will have a dedicated BOG feed line, remaining functional during an emergency shutdown (ESD). The boiler system will automatically switch to ESD mode when activated.

1.3.7 Engine Room

The engine room is designed using the gas-safe machinery space concept according to the IGF Code 5.4. This means that there are no special electrical requirements for fans and auxiliary equipment in the engine room, except for equipment connected to the gas system via the required double-wall pipe between the gas phase and the engine room. To fulfil this, gas engines, gas valve units, and boiler burners shall have enclosed gas systems designed and approved by the equipment maker for the gas-safe concept.

The engine room is adjacent to the two (2) NH3 tank rooms. It houses the boiler and main gensets. Fuel is transferred from the tank connection space to the engine room consumers through individual double-wall pipes. The engine room is equipped with a toxic vapour/gas detection system, CCTV, fire detection system, fixed firefighting system, and portable firefighting system. Bulkheads between the NH3 tank room and engine room shall be separated by an A60+900mm cofferdam or A60+H120 insulation.

1.3.8 Gas Valve Unit

For each engine and boiler burner, a gas valve unit shall be installed. The gas valve units for the engines are integrated into the Engine rooms. The GVU regulates the pressure to the consumer and provide required block and bleed function. In addition, the unit ensures safe maintenance on the engine and performs a leakage test of the automatic shut-off valves before the engine starts operating on gas. In case of hazardous events, the unit will automatically inert the gas line with nitrogen. The main components of the unit are:

- Manual shut off valve
- Gas filter
- Block and bleed valve arrangement
- Flowmeter (optional)
- Pressure control valve
- Nitrogen valves
- Ventilation valves

1.3.9 Heating for Fuel Supply

A dedicated water glycol system is installed as a fuel heating/vapourisation system. It includes a minimum of two (2) 100% circulation pumps, four (4) 50% heater exchangers and expansion tanks with N2 blanket. For vaporisation; cold recovery as heating source shall be used together with HT cooling water system (electrical backup if necessary) and steam system backup.

1.3.10 Exhaust Gas Treatment

Each engine exhaust gas pipe shall be fitted with SCR for Tier 3 compliance in both MGO operation mode and ammonia/MGO pilot fuel operation mode. It is foreseen for such capacity and thus the dimension of the SCR must be increased due to ammonia/MGO pilot fuel operation mode, while N2O/NO emissions from ammonia combustion must be eliminated.

1.3.11 Instrumentation

In general, the operator control panel for bunkering, BOG/vapour management, and fuel supply to consumers shall be fully automated and controlled with a human-machine interface (HMI) software application and hardware. HMIs shall, at minimum, allow operators to start and stop cycles, adjust operational set points, and perform functions required to adjust and interact with the monitored/control process and with necessary interfaces for the control systems.

The main fuel supply line to each consumer is to be equipped with an automatically and manually operated stop valve. The stop valves are to be arranged outside the engine room. Instrumentation and electrical apparatus installed within a specific hazardous space shall be of a type suitable for the specific hazardous zone classification.

1.3.12 Gas Detection System

Due to the toxicity of ammonia, leaks from the NH3 system are high-risk incidents as small concentrations can be fatal to humans. Fire risk shall not be neglected, but from published studies, there seems to be a common understanding that when comparing diesel or LNG fire, ammonia is less critical[5].

One (1) dedicated toxic vapour / gas detection system covering relevant/required areas must be installed for detection of leakage of NH3 and others as recommended by makers. Tank rooms and other non-gas safe rooms should be fitted with O2 content measuring units and alarms. All detectors shall be designed for easy frequent testing. A system philosophy considering the following should be further evaluated:

- Early warning alarm: Vapour concentration alarm with 150 ppm setpoint to be installed. This could activate the max speed on ventilation system. If alarm doesn’t disappear then further actions need to be taken.
- Safe change over mode alarm: Vapour concentration alarm with 350 ppm setpoint to be installed, this could activate change over to dual MGO fuel and close relevant isolating valves.

1.3.13 Fire Detection System

One (1) dedicated fixed fire detection and alarm system complying with the class, flag and fire safety systems code shall be provided for the; engine room, fuel storage spaces and the ventilation trunk(s) to the TCS, TCS and fuel gas system room and other rooms of the vessel where fire cannot be neglected.

1.3.14 Fire Fighting System and Water Spray

In the event of a fire, it shall be considered that when having an ammonia fire and high temperatures, ammonia decomposes into H2, toxic NO and toxic NO2 gasses. Each TCS is to be equipped with water mist for firefighting or fluorine-free foam (not containing PFAS) or sprinkler or CO2 (using CO2 to be investigated as there may be a risk of ammonium carbamate formation by chemical reaction between NH3+CO2).

Manual water spray system to be arranged inside bunkering station and water curtains at the airlock entrance, ventilation outlet, and covering the ship side to bind NH3 gas in case of leakage and prevent spreading of toxic cloud inside and outside of bunker stations.

1.3.15 Nitrogen

A nitrogen generator and buffer tank are installed onboard to supply inert gas with an acceptably low dew point for purging NH3 equipment, providing nitrogen to the annulus of double-wall pipes, gas valve units, maintaining a nitrogen blanket in tanks, and inerting bunker lines on the bunker vessel. The nitrogen is stored in a pressurised buffer tank for immediate use. Where the inert gas supply line connects to the fuel system, it shall be fitted with a double block-and-bleed valve arrangement to prevent the return of flammable gas to any non-hazardous spaces.

[5] [1] H. Fan, X. Xu, N. Abdussamie, P. S.-L. Chen, and A. Harris, ‘Comparative study of LNG, liquid hydrogen, and liquid ammonia post-release evaporation and dispersion during bunkering’, International Journal of Hydrogen Energy, vol. 65, pp. 526–539, May 2024, doi: 10.1016/j.ijhydene.2024.04.039.

1.3.16 Venting and Ammonia Release Mitigation System (ARMS)

As not to exceed any 110-ppm of ammonia released to air (ref. to Table 1 of MSC.1-Circ.1687) during normal operation a gas combustion system is installed. The ammonia release mitigation system (ARMS) will consist of gas combustion unit, air blowers, buffer tank and others as per maker standard. During normal operation the ARMS will be handling liquid and gaseous ammonia from systems such as fuel system, bunker system and vent system. ARMS shall also be used during gas-freeing.

Discharges from the ARMS shall be led to a vent mast arranged at least 25 m away from the nearest air intake, air outlet, bunkering stations, life-saving appliances, or other openings to enclosed spaces on the vessel. Venting of double-wall pipes, gas valve units, engines, and burners shall be carried out by nitrogen inerting.

1.3.17 Hazardous Area Definition of Explosive Gas Atmosphere

The following zones are in general identified as hazardous zone 0 area in which an explosive gas atmosphere is present continuously or is present for long periods:

- NH3 storage tank(s)
- Pipe(s) containing or connected to fuel and used for venting to e.g. pressure relief valve

The following zones are in general identified as hazardous zone 1 area in which an explosive gas atmosphere is likely to occur in normal operations:

- Bunkering stations
- Tank Connection Space
- Reliquification/subcooling equipment
- Ammonia release mitigating system

It should also be noted that fuel storage hold spaces for type C tanks are normally not considered as zone 1.

The following zones are in general identified as hazardous zone 2 area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only:

- Fuel storage hold
- Air lock

1.3.18 Hazardous Area Definition of Toxic Gas Atmosphere

Toxic areas and spaces refer to locations where ammonia concentrations may reach hazardous levels due to potential leaks, venting, or accidental releases. Identifying and assessing these areas is critical to ensuring crew safety, regulatory compliance, and the implementation of effective mitigation measures. The toxic areas are defined based on normal operational conditions, maintenance activities, and potential failure scenarios. According to MSC.1-Circ.1687 (12bis. 4.2), toxic areas include but are not limited to:

- Areas on open deck within 10 m of any flanges, valves, and other potential leakage sources in ammonia fuel systems
- Areas on open deck within B or 25 m, whichever is less, from outlets from the pressure relief valves installed on a liquefied fuel gas tank and all other fuel gas vent outlets
- Areas on open deck within B or 25 m, whichever is less, from outlets from interbarrier spaces for tanks of IMO type A
- Areas on open deck within 10 m from outlets from interbarrier spaces for tanks of IMO type B areas on open deck within 10 m from outlets from secondary enclosures around ammonia piping, ventilation outlets from tank connection spaces and fuel preparation rooms and other spaces containing ammonia leakage sources
- Areas on open deck within 5 m from inlets to secondary enclosures around ammonia piping, ventilation inlets to tank connection spaces and fuel preparation rooms and other spaces containing ammonia leakage sources, and
- Areas on open deck within 5 m from entrance openings to spaces containing ammonia leakage sources.

This classification of toxic areas serves as a foundation for conducting a structured and comprehensive HAZID risk assessment, ensuring that all potential hazards associated with ammonia fuel use on RORO vessels are identified and mitigated effectively.

Furthermore, according to 12bis.4.2, toxic spaces include:

- The interiors of fuel tanks, any pipework for pressure-relief or other venting systems for fuel tanks, pipes and equipment containing fuel
- Tank connection spaces
- Fuel preparation rooms,
- Annular space of secondary enclosure around fuel pipes, and
- Enclosed and semi-enclosed spaces in which potential sources of release.

1.3.19 Ventilation

In general, ammonia gas is lighter than air and will therefore concentrate in the spaces at the top. However, in the presence of moisture, such as during high relative humidity, liquefied anhydrous ammonia gas forms heavier vapours than air. These vapours may spread along the ground or into low-lying areas with poor airflow, where people may become exposed.

Ventilation ducts must share the same hazardous zone classification as the ventilated space. Due to the toxicity of ammonia, all ventilation outlets from areas designed to handle potential ammonia leakages must generally be discharged at least 10 metres away from the nearest air intake, air outlet, bunkering stations, or other openings to enclosed spaces on the vessel. Air intakes, outlets, bunkering stations, or other openings to enclosed spaces on the vessel should be positioned at least 25 metres from the vent mast. A dispersion analysis needs to be performed to simulate the maximum probable leakage scenario that does not result in harmful ammonia concentrations in the relevant spaces and areas. The dispersion analysis must meet the IGF Code's functional requirements in Part A (3.2), the pertinent IACS guidelines, including Confined Space Safe Practice No. 72, as well as IMO’s interim guidelines for the safety of ships using ammonia as fuel (MSC.1-Circ.1687, 12bis. 4.3).

All hazardous areas shall be ventilated. The actual air change required depends on the design philosophy and is subject to the authorities' acceptance. A water spray system will be arranged outside the ventilation outlet from relevant NH3 spaces.

1.4 Scope of Work

1.4.1 Boundary Limits

The HAZID study mainly focuses on potential hazards associated with the normal operation phases of the System to be installed in the RORO ship design. It is assumed that hazards and operability problems related to manufacturing, installation, construction, commissioning, or decommissioning phases of the System would be covered and controlled by the shipyard’s safety management system, vendors’ procedures, etc.

1.4.2 Documents and Drawings

The basis for the HAZID study is the confidential documents and drawings provided by DFDS, Wartsila, and Knud E. Hansen. Those are presented in Table 2.

Table 2: Reviewed Documents & Drawings

Title	Document/Drawing No.	Rev. No.
General Arrangement	22058.23.0110.01	0
High level description of NH3 design philosophy	22058.23.0511.01	0
Standard symbols	22058.22.0775.30	A

Title	Document/Drawing No.	Rev. No.
Principle N2 Inert Gas system	22058.22.1570.01	B
NH3 Rooms Ventilation Principal Routing	22058.22.5112.01	B
Ventilation - Double Walled Piping	22058.22.5114.01	B
NH3 Air Lock Ventilation Principles	22058.22.5115.01	B
Principle Vent. Flow & Duct size Calc	22058.22.5116.01	B
Principle Hazardous Area Bilge System	22058.22.5410.01	B
Principle NH3 gas and leak detection system	22058.22.5721.01	B
For DNV clarification draft boundary conditions for dispersion analysis (002)	22058.01.6015.01	B
Principle NH3 Fuel Pipe Routing	22058.22.7404.01	B
Principle NH3 Fuel temperature Condition System	22058.22.7420.01	B
Principle Hazardous Plan-GAS	22058.23.7250.01	0
Principle Hazardous Plan-HAZARDOUS	22058.23.7250.01	0
Principle Hazardous Plan-TOXIC	22058.23.7250.01	0
Principle Electrical Diagram	22058.23.8020.01	0
Ammonia Pac PFD	-	-

1.5 HAZID Workshop

Hazard Identification (HAZID) is a technique used to identify all significant hazards associated with a particular activity. The typical process begins with identifying all possible undesirable consequences that could arise, followed by the identification of hazards that, if realised, would lead to those consequences.

1.5.1 Objective

The HAZID study is a systematic review technique aimed at identifying all hazards linked to a particular concept, design, operation, or activity. This includes examining potential initiating causes, possible consequences, and existing safeguards. The goal is to assess these hazards and, if feasible, eliminate them at their source, or otherwise implement controls and mitigations. The objectives of the HAZID study in relation to the comprehensive function and operation of using ammonia as an alternative fuel (in the context of dual fuel conceptual design and operation) are to:

- Identify hazards & hazardous events that may give rise to risks
- Identify potential causes and consequences of the hazardous events identified
- Identify preventive measures and mitigating measures
- Assess risks semi-quantitatively by using a risk matrix
- Recommend additional measures to eliminate/reduce the risks and to ensure that Ammonia as fuel is safe according to the IMO CCC 10 Interim Guidelines (2024)

The HAZID study was not intended to resolve all issues arising during the study but intended to flag action to appropriate personnel or party for detailed follow-up after the HAZID.

1.5.2 Procedure

The HAZID study for the System of the RORO was conducted as a brainstorming exercise in the HAZID workshop (virtually), attended by a multidisciplinary team (i.e., the HAZID team) from the project stakeholders including ABS, NTUA, DFDS, Knud E. Hansen, Wartsila and EMSA as observer.

The detailed procedure applied in the workshop follows the steps outlined below:

1. Identification of HAZID Nodes: To assess the specifics of each individual area or operation, the areas and operations were divided into the series of nodes listed in Table 3. The following steps were performed for each node.
2. Node Briefing: To ensure that all HAZID team members have a shared understanding of the design and intended operation of the node, the discipline lead offered a succinct introduction to the node in question.
3. Identification of Hazards and Hazardous Events: The HAZID team identified hazards and hazardous events. Drawing upon the documents and drawings provided, along with previous experience, the team considered each node in sequence.
4. Identification of Causes: For each hazardous event identified, all potential causes of the hazard being realised were identified and discussed where relevant. However, double jeopardy, which refers to a combination of multiple independent events occurring simultaneously, was not considered during the HAZID workshop.
5. Identification of Consequences: For each hazardous event and cause identified, all potential consequences concerning people, assets, the environment, and reputation were assessed, without crediting any preventive or mitigating measures in place. The evaluation of consequences was not constrained by the HAZID node definitions or scope boundaries regarding a given event.
6. Identification of Preventive and Mitigating Measures (Safeguards): For each accident scenario, existing measures expected to prevent a hazardous event from occurring (i.e., preventive measures), as well as those intended to control its development or mitigate its consequences (i.e., mitigating measures), were identified.
7. Risk Ranking: Risk ranking categorizes the identified accident scenarios.
8. Identification of Recommendations: During the HAZID workshop, recommendations were raised if the current provision of preventive or mitigating measures was considered insufficient to manage risks or if further

assessments were required to better understand the hazard or hazardous event. These recommendations were assigned to responsible parties.

1.5.3 Nodes

A structured approach is applied to ensure that all relevant hazards are revealed. The basis for this approach lies in dividing the ammonia FSS into nodes that would be manageable enough to do a systematic review of each node. Then, the systematic review of each node is performed to identify the relevant hazards which these nodes could be subjected.

In total, eleven (11) HAZID nodes were selected and reviewed during the workshop. The nodes are listed in Table 3: HAZID Nodes where the column 'No.' and 'Node' are for the serial number and title of the nodes.

Table 3: HAZID Nodes

No.	Node
1	General
2	Bunkering Stations
3	Fuel Storage Tanks
4	Fuel preparation (TCS)
5	Fuel Supply System
6	Engine Room
7	Venting
8	Ventilation
9	Purging System
10	Bilge System
11	Detection & Alarm systems

1.5.4 Hazards, Sources and Effects

The set of guidewords of ISO Standard 17776:2016(E)[6] was applied for the HAZID study. ISO 17776:2016(E) offers general guidance on tools and techniques for hazard identification and risk assessment in the petroleum and natural gas sectors, specifically for offshore production installations. This document includes a comprehensive hazard checklist designed to identify risks associated with offshore oil and gas production activities. The original checklist within the standard encompasses all types of hazards, including major accidents, flammable materials, and workplace security risks. It is important to note that this checklist provides broad, high-level guidance on the types of hazards that may be encountered. Therefore, the workshop will need to delve into the specifics, such as:

- The presence of this hazard category at a particular node,
- The potential harmful impacts of that hazard,
- The possible causes of any hazardous events,
- The existence of any known prevention or mitigation measures in place for this hazard.

The groups of hazards in ISO 17776:2016(E) applied to the vessel's System are listed in Table 4.

Table 4: Hazard Groups

Hazard Groups	
H–01 Hydrocarbons	H–17 Ionizing radiation, open source
H–02 Refined hydrocarbons	H–18 Ionizing radiation, closed source
H–03 Other flammable materials	H–19 Asphyxiates
H–04 Explosives	H–20 Toxic gas
H–05 Pressure hazards	H–21 Toxic fluid
H–06 Hazards associated with differences in height	H–22 Toxic solid

[6] https://www.iso.org/standard/63062.html

Hazard Groups	
H–07 Objects under induced stress	H–23 Corrosive substances
H–08 Dynamic situation hazards	H–24 Biological hazards
H–09 Environmental hazards	H-25 Ergonomic (human factors) hazards
H–10 Hot surfaces	H–26 Psychological hazards
H–11 Hot fluids	H–27 Security-related hazards
H–12 Cold surfaces	H–28 Use of natural resources
H-13 Cold fluids	H–29 Medical
H–14 Open flame	H-30 Noise
H–15 Electricity	H-31 Entrapment
H–16 Electromagnetic radiation	H–17 Ionizing radiation, open source

1.5.5 Causes

A cause refers to the circumstances or mechanisms that can lead to deviations. It is possible to identify multiple causes for a single deviation. During the HAZID workshop, potential independent causes for each deviation will be identified. The approach for the HAZID study of the System in the RORO involved considering causes that arise within the examined node while also acknowledging that consequences may reach or become evident in other nodes and the node being analysed. Causes may be linked to human factors or hardware issues, and some can arise from a combination of events occurring either simultaneously or sequentially. This situation is known as double jeopardy. However, no instances of double jeopardy will be considered during the workshop.

1.5.6 Consequences

A consequence refers to the outcome of a cause, considering factors such as safety, asset loss, environmental impact, and reputation. It can involve both process hazards and operability issues. Notably, a single cause can lead to multiple consequences, while one consequence may arise from several causes. All credible consequences for each identified cause will be thoroughly analysed to determine if they pushed the system beyond its intended operational range and evaluated without factoring in the effectiveness of safeguards. The implications within the node and any potential upstream or downstream effects stemming from the cause will be examined during the HAZID workshop. To that extent, the workshop will comprehensively identify all outcomes, considering both immediate and delayed effects, as well as those occurring within and outside the section under study. Additionally, participants will examine how these consequences will evolve over time, paying particular attention to when alarms and trips are activated, as well as how and when operators will be notified.

1.5.7 Safeguards

A safeguard is defined as any design feature at a specific system level or other provisions that can prevent deviations (or reduce their frequency) or mitigate the severity or likelihood of their consequences. The safeguards for each consequence were reviewed and discussed during the HAZID workshop for the system of the RORO design, including the following elements:

- Redundant items that ensure the continued operation of the system,
- Alternative means of operation,
- Monitoring and alarm devices or shutdown logic, and
- Any other measures aimed at limiting consequences.

1.5.8 Risk Ranking

Risk ranking was performed for each identified scenario, using the risk matrix presented in Table 5 and it was a collective effort of the HAZID team.

Table 5: HAZID Risk Matrix

Category		Consequence Severity				
Asset		No shutdown, costs less than $10,000 to repair	No shutdown, costs less than $100,000 to repair	Operations shutdown, loss of day rate for 1-7 days and/or repair costs of up to $1,000,000	Operations shutdown, loss of day rate for 7-28 days and/or repair costs of up to $10,000,000	Operations shutdown, loss of day rate for more than 28 days and/or repair more than $10,000,000
Environmental Effects		No lasting effect. Low level impacts on biological or physical environment. Limited damage to minimal area of low significance.	Minor effects on biological or physical environment. Minor short-term damage to small area of limited significance.	Moderate effects on biological or physical environment but not affecting ecosystem function. Moderate short-medium term widespread impacts e.g. oil spill causing impacts on shoreline.	Serious environmental effects with some impairment of ecosystem function e.g. displacement of species. Relatively widespread medium-long term impacts.	Very serious effects with impairment of ecosystem function. Long term widespread effects on significant environment e.g. unique habitat, national park.
Community/ Government/ Media/ Reputation		Public concern restricted to local complaints. Ongoing scrutiny/ attention from regulator.	Minor, adverse local public or media attention and complaints. Significant hardship from regulator. Reputation is adversely affected with a small number of site focused people.	Attention from media and/or heightened concern by local community. Criticism by NGO's. Significant difficulties in gaining approvals. Environmental credentials moderately affected.	Significant adverse national media/public/ NGO attention. May lose license to operate or not gain approval. Environment/ management credentials are significantly tarnished.	Serious public or media outcry (international coverage). Damaging NGO campaign. License to operate threatened. Reputation severely tarnished. Share price may be affected.
Injury and Disease		Low level short-term subjective inconvenience or symptoms. No measurable physical effects. No medical treatment required.	Objective but reversible disability/impairment and/or medical treatment, injuries requiring hospitalisation.	Moderate irreversible disability or impairment (<30%) to one or more persons.	Single fatality and/or severe irreversible disability or impairment (>30%) to one or more persons.	Short- or long-term health effects leading to multiple fatalities, or significant irreversible health effects to >50 persons.
		Low	**Minor**	**Moderate**	**Major**	**Critical**
		3	**4**	**5**	**6**	**7**
Likelihood	Almost Certain **(0)** Occurs 1 or more times a ship year	**High**	**High**	**Extreme**	**Extreme**	**Extreme**
	Likely **(-1)** Occurs once every 1-10 ship years	**Moderate**	**High**	**High**	**Extreme**	**Extreme**
	Possible **(-2)** Occurs once every 10-100 ship years	**Low**	**Moderate**	**High**	**High**	**Extreme**
	Unlikely **(-3)** Occurs once every 100-1000 ship years	**Low**	**Low**	**Moderate**	**High**	**Extreme**
	Rare **(-4)** Occurs once every 1000-10000 ship years	**Low**	**Low**	**Low**	**Moderate**	**High**
Action Key	Low		No action is required, unless change in circumstances			
	Moderate		No additional controls are required, monitoring is required to ensure no changes in circumstances			
	High		Risk is high and additional control is required to manage risk			
	Extreme		Intolerable risk, mitigation is required			

1.6 HAZID Result

1.6.1 HAZID Worksheet

All the results of the HAZID study were documented in the HAZID worksheet using the Process Hazard Analysis (PHA) Software LEADER[7]. The detailed HAZID worksheet produced is included in Appendix A of this report. All the contents documented in the HAZID worksheet were reviewed and agreed upon by the HAZID team.

1.6.2 Recommendations

Where existing safeguards were deemed insufficient to control a hazard or operability issue within acceptable levels, or where further assessment was required to obtain a better understanding of the associated risks, recommendations were raised. A total of seventy-two (72) recommendations were made during the HAZID workshop. A detailed overview of these recommendations is provided in the Action Items List, included in Appendix B. The most significant recommendations are summarised below:

1. General

- Adopt established procedures for mixed fuel operations.
- Conduct analysis of non-conformities, near-misses, and accidents in the ammonia industry, including those on ammonia cargo vessels and in fisheries, to enhance safety measures and practices.
- Integrate applicable rules, codes, standards, and best practices from other sectors related to ammonia, including fishing vessels and cargo ships transporting ammonia.
- Risk assessments should evaluate the adequacy of the safety concepts outlined in the existing regulations and guidelines within the IGF Code, particularly addressing ammonia's toxicity and corrosivity.
- Implement safeguards to segregate ammonia fuel installations from potential external hazards.
- Ensure the integrity of ammonia fuel systems to minimise the risk of leaks.
- Optimize engine and machinery placement to reduce the length of ammonia fuel piping.
- Employ double barriers to safeguard the ship and crew against potential leaks.
- Utilize advanced leak detection systems that provide early warnings and enable rapid automatic safety responses.
- Integrate automatic leak isolation capabilities to mitigate the toxic and hazardous effects of potential releases.
- Developing ship layout designs that:
  - Ensure clear, accessible escape routes from all compartments.
  - Allow gas freeing and gassing operations of ammonia storage tanks without affecting adjacent spaces.
- Develop operational procedures specifically tailored to ammonia's risks and onboard emergency scenarios.
- Given ammonia's corrosive nature, consider implementing material requirements for ammonia fuel tanks and associated systems.
- Ensure electrical system design complies with International Standard IEC 60092-502 Electrical installations in ships - Part 502: Tankers - Special features must be considered. Hazardous electrical equipment selection and installation design areas are divided into Zones 0, 1, and 2.
- Provide a designated safe haven, possibly combined with a mustering function, to ensure the safety of the crew and passengers in the event of an ammonia release.
- Cofferdams beneath the ammonia fuel storage tanks and NH3 equipment room must be considered.
- Power loss scenarios must take into account the handling of residual ammonia in fuel piping.
- The risk assessment for each vessel must consider the power needed for valve fail-safe positions and backup power requirements in the event of a power loss.
- Standard Operating Procedures (SOPs) must clearly outline any operational limitations of the ammonia fuel mode/system.
- Ensure comprehensive cybersecurity by taking into account the relevant IMO Resolution and Guidelines, national regulations and flag state requirements, IACS Unified Requirements (URs), standards such as ISO/IEC 27001 and IEC 62443, as well as industry recommendations and best practices. Additional cybersecurity measures may be necessary for the use of ammonia as marine fuel.
- Develop a drop object protection program to safeguard critical ammonia-related components.

[7] https://www.abs-group.com/Solutions/Software-Solutions/LEADER-PHA-Software/

- Lifesaving equipment, escape routes, and lifeboats must be located away from potential ammonia gas release zones.
- Conduct special analyses for positioning life-saving appliances and mustering stations; assess evacuation procedures under ammonia leakage scenarios.
- For the scenario involving a full-capacity emergency discharge from the PSVs of ammonia storage tanks, the definition of toxic zones and the integration of mustering stations should be evaluated.
- Establish toxic zones around ammonia vapour sources on the open deck to prevent ingress into enclosed spaces via air intakes, outlets or other openings.
- The requirements for venting cargo tanks and ventilating cargo handling spaces are outlined in the IBC Code, which should be considered for such vessels.
- Key topics for SIMOPS (Simultaneous Operations) studies must include:
  - Overlapping or interfering gas hazardous areas.
  - Consequences of a gas release from either vessel onto the other.

2. Bunkering Station

- The vessel's SOPEP/SMPEP must be updated to incorporate the use of ammonia as fuel.
- A Ship-to-Ship (STS) Operations Plan must be developed and approved, referencing updated best practices from IMO guidelines, including the ICS/OCIMF STS Transfer Guide, ISGOTT, and the applicable port Oil Spill Contingency Plan (OSCP), incorporating specific considerations for ammonia.
- The application of SIGTTO recommendations for Emergency Shutdown and Related Safety Systems should be considered.
- Evaluate the need for gas/liquid leak detection in the ammonia piping between the cargo manifold and fuel tank.
- Ensure consistent monitoring of the bunkering area or implement an equivalent detection and safety method.
- Arrangements should be made to install an emergency release system that prevents damage and spark generation, minimizes ammonia release when activated, and includes safeguards against accidental activation.
- The system should be designed as a fail-release system.
- Bunkering connections must use dry-disconnect couplings with additional safety measures such as dry break-away or self-sealing quick-release couplings.
- Consider applying the provisions of the Society of International Gas and Tanker Operators (SIGTTO) publication "A Justification into the Use of Insulation Flanges (and Electrically Discontinuous Hoses) at the Ship/Shore and Ship/Ship Interface", as appropriate.
- Drainage system is to be designed with either inclination or a parallel stripping line. Decision to be made upon final vessel design.
- Drip tray sizing must be based on worst-case discharge scenario.

3. Fuel Storage Tanks

- Evaluate the need for a redundant level transmitter for the fuel tank to ensure the same level of safety with LNG fuel systems.
- Ensure level transmitters are replaceable without requiring gas freeing or man entry into the tank.
- Pressure Safety Valves (PSVs) of ammonia storage tanks must be designed to handle a full-capacity emergency discharge.
- In this type of configuration, all inlet and outlet piping connections for the fuel storage tanks must be located on the outer head (lobe) of the tank.
- For the scenario involving a full-capacity emergency discharge from the PSVs of ammonia storage tanks, the definition of toxic zones and the integration of a safe haven should be assessed.

4. Fuel Preparation (TCS)

- The TCS must provide safe means of access for maintenance of equipment and valves in locations beyond man height.
- Flanged piping in TCS should be used sparingly. Welded connections are highly recommended instead.
- Effective mechanical shielding at all potential leakage points must be implemented to minimize direct personnel exposure to ammonia.
- Appropriate procedures for safe entry into TCS must be developed.

5. Fuel Supply System

- Optimize engine and machinery layout to ensure the shortest possible piping length from the fuel storage system to the ammonia inlet manifold.

6. Engine Room

- The “gas safe machinery” concept must be applied to all machinery spaces containing ammonia consumers.
- The gas dispersion study for the engine room should account for the suction of the ICE turbochargers.
- The dew point for the air used for ventilation in the annular space of the double wall piping must be considered.
- The coaming height for the air intake of the annular space in the double-wall piping must be considered.

7. Ventilation

- An assessment must be conducted to evaluate a potential leakage scenario, considering the following factors:
  - The potential impact it would have on the effectiveness of the ventilation system, and
  - The maximum distance between the safe haven and potential sources of ammonia release, such as vent masts and ventilation outlets.
- The optimal positioning of ventilation inlets to prevent ammonia ingress must be considered.
- Evaluate the ventilation system's importance across all compartments, including the WARMS room.
- The installation of demister filters in ventilation lines serving rooms housing critical components must be considered.

8. Venting

- Assess whether the vent mast height prevents the formation of flammable gas clouds at normal working levels, based on hazardous area classification.
- An ammonia dispersion analysis from the vent must be conducted, considering not only normal operation but also upsetting and emergency scenarios.
- A study on ammonia alarm thresholds and automatic shutdown setpoints is needed, incorporating lessons learned and best practices from industry experience.
- SOPs must include clear procedures/instructions and warning protocols for personnel on deck in the event of ammonia release through venting, exhaust, or accidental discharge.
- Consider installing a gas detection sensor at the vent mast in combination with a water spray system to mitigate vapour dispersion.
- The need for a permanent purging arrangement for the vent mast must be evaluated.

9. Fire-fighting appliances

- A study must be conducted to assess the capacity of the water-based fire-fighting system.
- A dispersion study should be carried out to evaluate the effectiveness of the water mist system. This analysis should include the locations of ventilation inlets, potential ammonia release points, areas at risk of fire, placement of water sprinklers and the results of interactions between water and ammonia in various thermodynamic states.
- In RORO, Ro-Pax and Vehicle Carrier vessels, the potential for electric vehicle batteries (EVBs) to overheat must be taken into account. The following measures should be considered:
  - Installing multiple EX-rated CCTV systems equipped with built-in AI and video analytics, and infrared (IR) night vision capabilities must be considered.
  - Implementing a hydrocarbon or hydrogen gas detection system as an additional safety measure.
  - The overall ventilation strategy could be revised to ensure continuous air supply and exhaust, even prior to detection.
  - Applying fire protection systems, such as water spray or water curtain systems, along all escape routes, lifeboats, and life rafts.
  - Incorporating manual firefighting techniques, including the use of thermal imagers, water mist lances, and water fog nozzle applicators.

10. Bilge System

- The placement of suction valves needs to allow remote operation, considering that the bilge system area is regarded as hazardous.
- The bilge ventilation system should be independent, with a preference for venting to open air.
- The quantity of fluid expected during firefighting operations must be taken into account in bilge system capacity and design.

11. Detection & Alarm Systems

- Gas detection alarms should be set up to alert personnel about leaks and prevent entry into affected spaces.

- The necessity of a continuous oxygen monitoring system in nitrogen-supported compartments must be assessed to mitigate the risk of asphyxiation from nitrogen leakage.
- A formal policy regarding the availability, quantity and use of personal oxygen detectors onboard must be established, taking into account the toxicity of ammonia and the risk of asphyxiation from nitrogen.
- Special attention must be given to the selection of chemical types used in gas detectors.

12. Purging system

- Total ammonia volume within the piping must be calculated, and a Reliability, Availability, and Maintainability (RAM) analysis conducted.
- Required nitrogen quantities must be carefully determined and prioritised to ensure complete and effective purging is consistently available.
- Friction losses within the purging system must be considered, aiming to maximise straight piping runs and minimise bends to reduce resistance.
- The design of the nitrogen purging system, particularly the fuel piping, must fully account for the physical properties of ammonia.

13. Detection & Alarm Systems

- Gas detection alarms must be arranged to alert personnel of any ammonia leakage and to prevent entry into the affected spaces.
- The necessity for a continuous oxygen monitoring system in nitrogen-supported compartments must be considered, to mitigate asphyxiation risks due to potential nitrogen leakage.
- A formal policy on the availability, quantity, and use of personal oxygen detectors onboard, taking into account the toxicity of ammonia and the asphyxiation risks associated with nitrogen, must be established.
- Measurement and sampling points at the compartment boundaries must be provided to enable the use of portable detection devices for remotely measuring ammonia concentrations, especially when fixed double chemical sensors become non-functional.
- Procedures for closed-entry, similar to those implemented on chemical tankers, must be developed specifically for ammonia-fuelled vessels.

1.7 Conclusions

The Ammonia FSS designed by Wartsila according to their 31DF engine specifications was reviewed by the multidisciplinary HAZID team at the HAZID workshop based on the scope of work and methodology described in this report.

In total, six hundred and forty-seven (647) scenarios were identified at the HAZID workshop. A hundred and twenty-nine (129) scenarios were purposefully not ranked either because there were no hazards identified, or there was insufficient technical information to carry out the risk ranking. Twenty-four (24) scenarios were categorised as low-risk and a hundred and forty-seven (147) were categorised as moderate-risk. Three hundred and twenty-nine (329) scenarios were categorised as high-risk, while eighteen (18) scenarios were categorised as extreme risk (shown in Table 6).

Table 6: Risk Ranking (Current Risk)

		Low	Minor	Moderate	Major	Critical
		3	4	5	6	7
Likelihood	Almost Certain **(0):** Occurs 1 or more times a ship year	**0**	**0**	**0**	**0**	**0**
	Likely **(-1):** Occurs once every 1-10 ship years	**100**	**111**	**104**	**18**	**0**
	Possible **(-2):** Occurs once every 10-100 ship years	**16**	**47**	**46**	**68**	**0**
	Unlikely **(-3):** Occurs once every 100-1000 ship years	**0**	**8**	**0**	**0**	**0**
	Rare **(-4):** Occurs once every 1000-10000 ship years	**0**	**0**	**0**	**0**	**0**

In case that additional safeguard(s)/measure(s) implemented to the design, as per discussions and conclusions for the recommendations, is/are considered to reduce frequency/severity of the accident scenario, the risk ranking for the relevant accident scenario was re-evaluated. As a result, three hundred and forty-four (344) scenarios were categorised as low-risk and ninety-three (93) were categorised as moderate-risk. Sixteen (16) scenarios were categorised as high-risk, while no scenario was categorised as extreme risk (shown in Table 7). Sixty-five (65) scenarios included in the General node were initially risk ranked, but since this node only includes general comments/remarks, estimating the residual risk is not applicable. Thus, they have been excluded from the Residual Risk matrix below.

The sixteen (16) high residual risk scenarios are all relevant to the fuel storage tank node. Those include recommendations highlighting the importance of:

- Performing stress analysis study considering vibration and fatigue of the tank,

- Including the provision of a manhole in the middle of the thank on top,

- Developing procedures on gas freeing the ammonia storage tanks considering the operational procedures including the deck compartment,

- Verifying that safe means of access for maintenance of equipment and valves in locations beyond man height will be provided in the Tank Connection Space.

Table 7: Re-evaluated Risk Ranking (Residual Risk)

		Low 3	Minor 4	Moderate 5	Major 6	Critical 7
Likelihood	Almost Certain **(0):** Occurs 1 or more times a ship year	**0**	**0**	**0**	**0**	**0**
	Likely **(-1):** Occurs once every 1-10 ship years	**10**	**0**	**0**	**0**	**0**
	Possible **(-2):** Occurs once every 10-100 ship years	**338**	**79**	**0**	**16**	**0**
	Unlikely **(-3):** Occurs once every 100-1000 ship years	**0**	**6**	**4**	**0**	**0**
	Rare **(-4):** Occurs once every 1000-10000 ship years	**0**	**0**	**0**	**0**	**0**

Two hundred and forty-two (242) recommendations were made from the HAZID team, and the full results of the HAZID workshop were documented in the HAZID Worksheet (see Appendix B). A summary of the main HAZID findings is as follows:

- Ammonia introduces complex safety challenges. Its toxicity, corrosivity, and flammability require safety measures that go beyond those for conventional or LNG fuels.
- System integrity and leak prevention are critical. Design should prioritize double barriers, short piping runs, and welded connections to minimize leak potential.
- Detection and ventilation systems must be robust and redundant. Early leak detection, oxygen monitoring, and carefully designed ventilation and dispersion control are essential to protect personnel and equipment.
- Emergency response planning must be comprehensive. The vessel must include safe havens, mustering zones, and clearly defined escape routes, especially considering toxic gas scenarios.
- Bunkering operations demand special focus. The use of dry disconnects, emergency release systems, drainage provisions, and updated procedures (SOPEP, STS plans) is vital for safe ammonia bunkering.
- Fuel storage and PSV venting require toxic zone management. Toxic dispersion analysis, safe integration of PSVs, and appropriate vent mast design are necessary to manage accidental releases.
- SOPs and operational limitations must be clearly defined. Standard procedures should address both routine operations and emergencies, particularly for purging, closed entry, and power loss scenarios.
- Crew protection and lifesaving systems need careful positioning. Lifesaving appliances, firefighting equipment, and escape paths must be located outside potential toxic gas areas.
- Cybersecurity and automation safety must be included. Digital systems controlling safety functions should meet relevant cyber protection standards, such as ISO/IEC 27001 and IEC 62443.
- Lessons from ammonia cargo and related industries are valuable. Existing accident records, standards, and operational practices from cargo ships and industry can guide safer designs and procedures.

2. Consequence Modelling

2.1 CFD Modelling

DFDS A/S Ferry is investigating a ferry design that uses ammonia as a potential green fuel. Though, there is a potential for the dispersed ammonia vapour to reach locations on the vessel where personnel can be present. Exposure to certain concentration levels of ammonia can cause serious health damage to personnel. Therefore, the purpose of this study is to investigate the ammonia dispersion on the vessel.

CFD has the great capability to accurately predict and display ammonia plume evolution over time. The ammonia plume pattern can be displayed for any specified concentration levels. The impact of various ammonia concentration levels can be inspected from different perspectives. As CFD modelling for multiphase (i.e., gaseous and liquid) release of ammonia has not been mature, the released ammonia is assumed to be purely gaseous for all cases included herein.

For study cases presented in this section, the ammonia releases concerned start in a steady ambient air flow. That means the CFD model with ambient air only and no ammonia should be run for a period of time to establish such a steady-state flow. The time duration required for this pre-release phase varies from case to case and is influenced by the wind speed, direction, and any structures surrounding the release point.

2.1.1 Case Conditions and CFD Model Setup

Two wind conditions were investigated in this section: one with wind blowing from the starboard side to the port side and the other with wind blowing from the starboard-aft direction. The wind speed was 3.1 m/s. Water vapour contents were considered in the CFD model to reflect the relative humidity of the environment. In this study, the ambient air would consist of dry air and water vapour. The relative humidities were set to 70%. The corresponding air temperatures were 15 °C. The release location was the emergency vent at the stern of the vessel. The release direction was assumed to be in the vertical direction. The release rate was estimated to be 2.5 kg/s from a circular hole of 400 mm.

Figure 3 shows the setting of the boundary condition types for the CFD model. The ambient air entered the computational domain from the inlet boundary (red colour) and exit the domain at the outlet boundary (brown colour). The remaining two vertical sides and the top side of the computational domain were symmetry-plane boundaries. The solid surfaces, such as those of the vessels and the water surface, were set as the solid-wall type of boundaries. A coordinate system was set to have its X axis pointing towards the vessel starboard, its Y axis pointing towards the bow and its Z axis pointing upwards. The domain had dimensions of 1500m × 830m × 300m in the X, Y, and Z directions, respectively. The total number of finite volume cells generated for the computational domain was about 21 million.

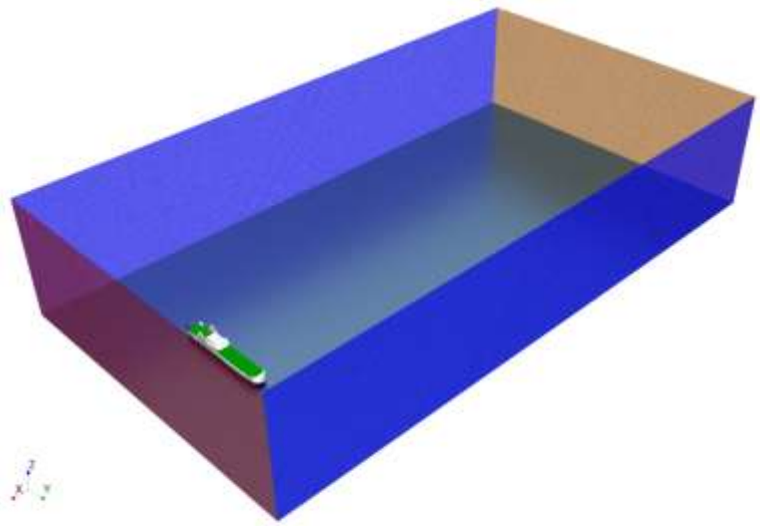


Figure 3 CFD computational domain for the ammonia dispersion study cases for DFDS A/S Ferry.

Figure 4 shows the computational mesh of the CFD domain. The spatial resolution of the mesh was made fine enough to capture physical phenomena of interest. Due to the small size of the leakage hole and the high speed of the ammonia jet out of it, the mesh dimensions in the near field were refined to attain a reasonable Courant number. As the plume was anticipated to slow down significantly in the far field, the mesh there was coarsened accordingly.

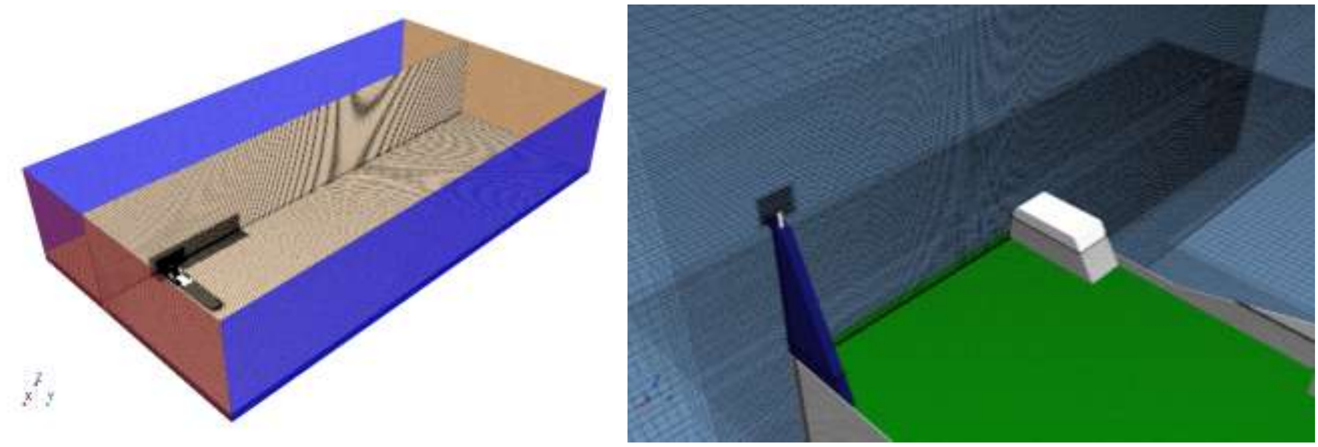


Figure 4 CFD computational mesh for the ammonia dispersion study cases for the DFDS A/S Ferry.

A total of 8 numerical probes were placed above the vessel decks to capture the ammonia concentrations in the working area over time. The probe positions are shown in Figure 5. The detailed locations are listed in Table 8. The origin is located at sea level, the centreline, and the stern of the vessel.

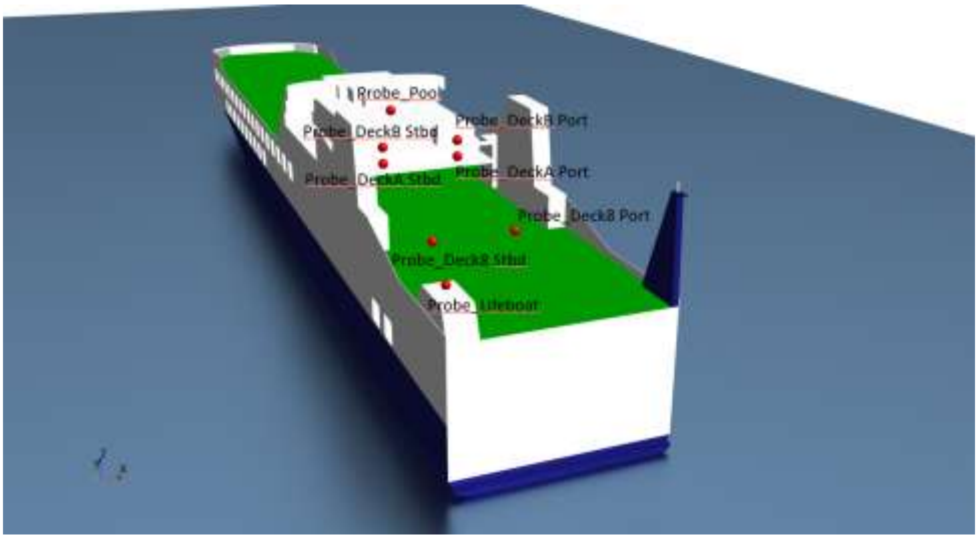


Figure 5 The probe locations on the decks. The probes were used to monitor the ammonia concentrations during the dispersion procedure.

Table 8 Probe locations in a cartesian coordinate system

	Lifeboat	DeckA Stbd	DeckA Port	DeckB Stbd	DeckB Port	Pool	Deck8 Stbd	Deck8 Port
$X\ (m)$	2	57	57	57	57	72	30	30
$Y\ (m)$	14.5	7	-7	7	-7	1	7	-7
$Z\ (m)$	27.5	28.6	28.6	31.6	31.6	34.6	23	23

2.1.2 Simulation Results for the Case with a STB Wind

Figure 6 shows the steady-state air flow field around the vessel when the wind was blowing from the starboard side to the port side. The top pictures show the streamlines at a height of 15 metres above sea level. Due to the blunt obstruction of the vessel, the air flow was displaced around the vessel, causing some vortices and turbulence downwind of the obstructions. The bottom pictures are the streamlines at a height of 40 metres above sea level which is also the height of the rear vent. It clearly demonstrates the streamlines are smoother than the top pictures.

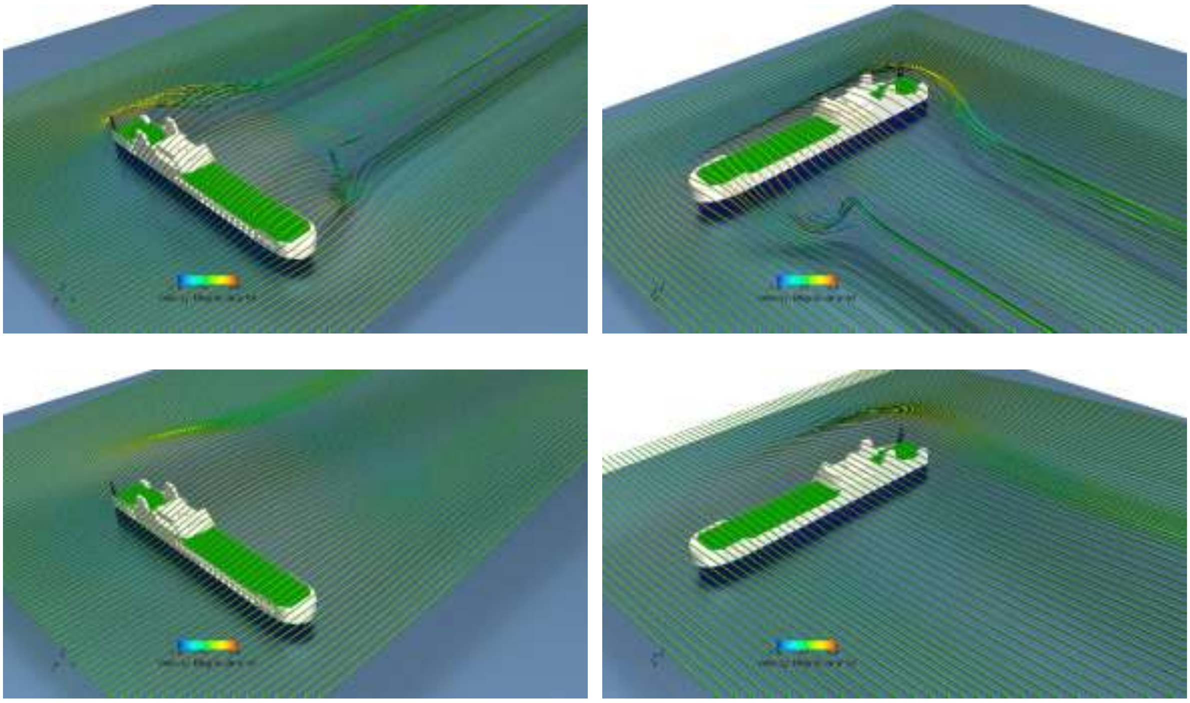
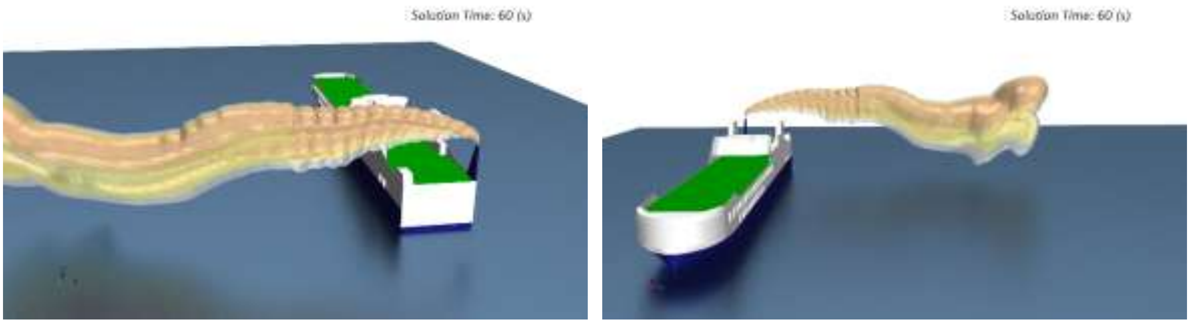
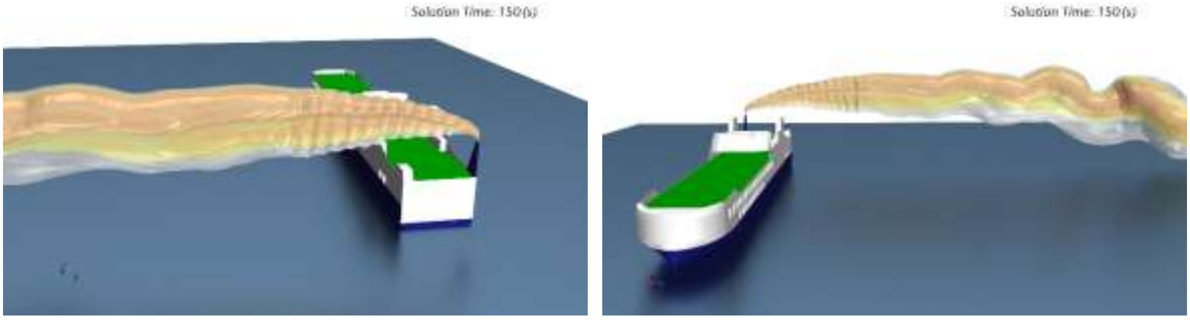


Figure 6 The steady-state air flow field around the vessel for the STB wind. The top and bottom subfigures show the streamlines at 15 metres and 40 metres above the sea level, respectively. The colours along the streamlines represent the velocity magnitude.

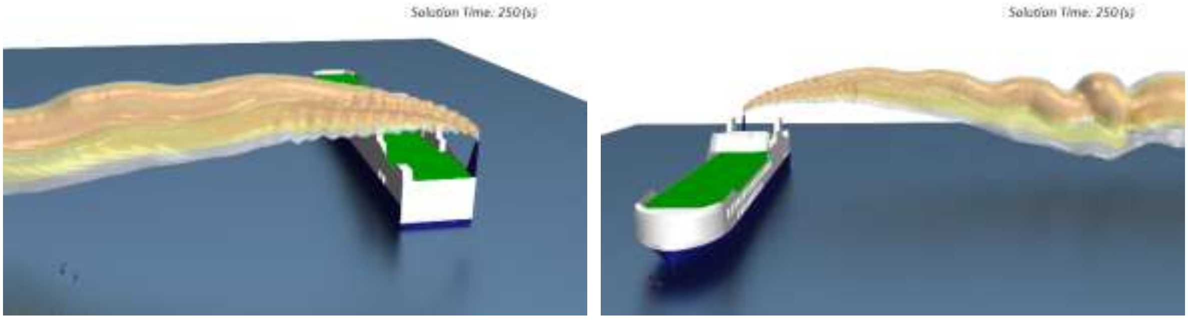
The evolution history of the ammonia plume is shown in Figure 7. Because the released ammonia had an upward momentum, the gas plume had a clear tendency of rising vertically. And it was pushed by the ambient air flow downstream. Because of the release height, the plume barely touched the deck. Overall, the ammonia plume remained clear of the lifeboat, the pool, the decks and the accommodations throughout the entire duration of the release. As a result, the release from the rear vent did not pose a safety risk for personnel onboard.



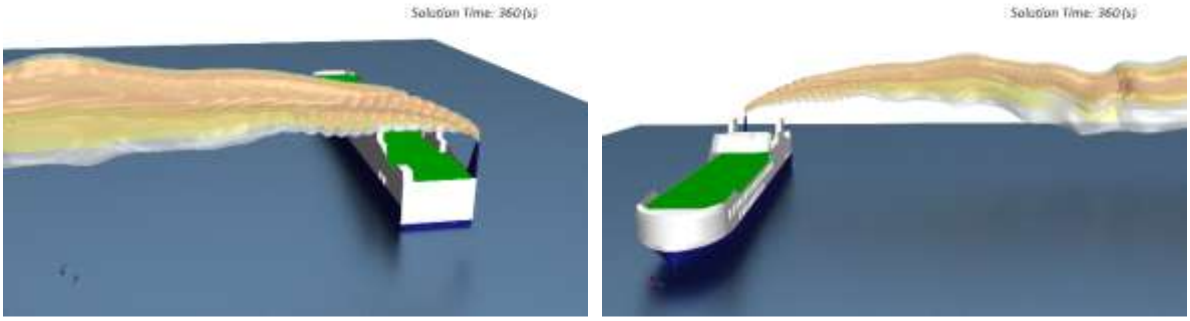
(a) time = 60 s



(b) time = 150 s



(c) time = 250 s



(d) time = 360 s

Figure 7 Evolution of the ammonia plume for the case of STB wind. The contour colours: grey for 30 ppm, yellow for 220 ppm, orange for 550 ppm, red for 1,100 ppm and magenta for 2,700 ppm. Left and right columns show the same flow field and time from two different angles.

Figure 8 shows the ammonia concentration time histories as captured at probes. The plot indicates that ammonia concentrations are lower than 0.1 ppm throughout the entire duration of the release.

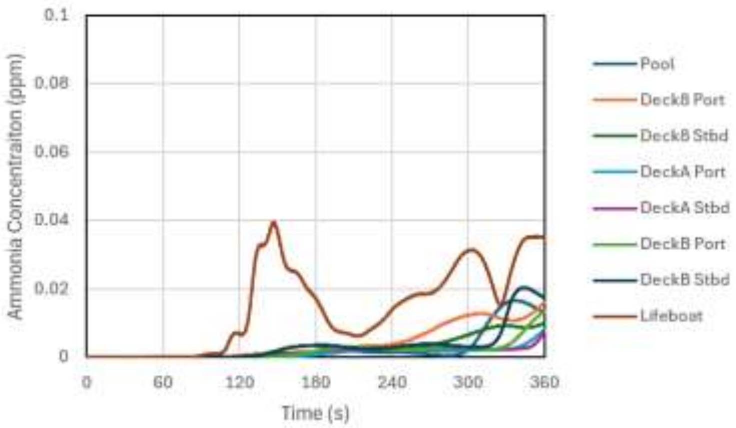


Figure 8 The ammonia concentration time histories as captured at probes, the STB wind.

2.1.3 Simulation Results for the Case with a STB-AFT Wind

Figure 9 shows the steady-state air flow field around the vessel when the wind was blowing from the STB-AFT direction. The top and bottom pictures show the streamlines at a height of 15 metres and 40 metres above sea level respectively. Due to the vessel heading and the wind direction, the air flow behind the vessel produced larger vortices and turbulence at the lower level compared to the previous case. Though, the streamlines of 40-metre height stayed smooth.

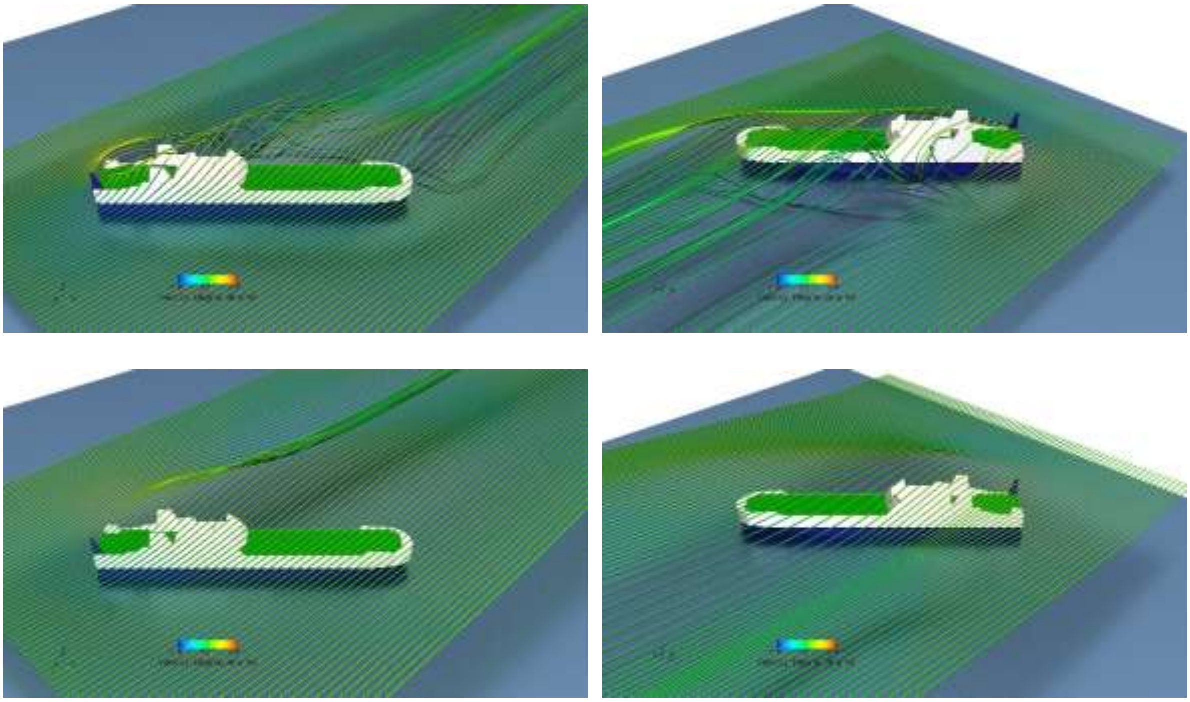
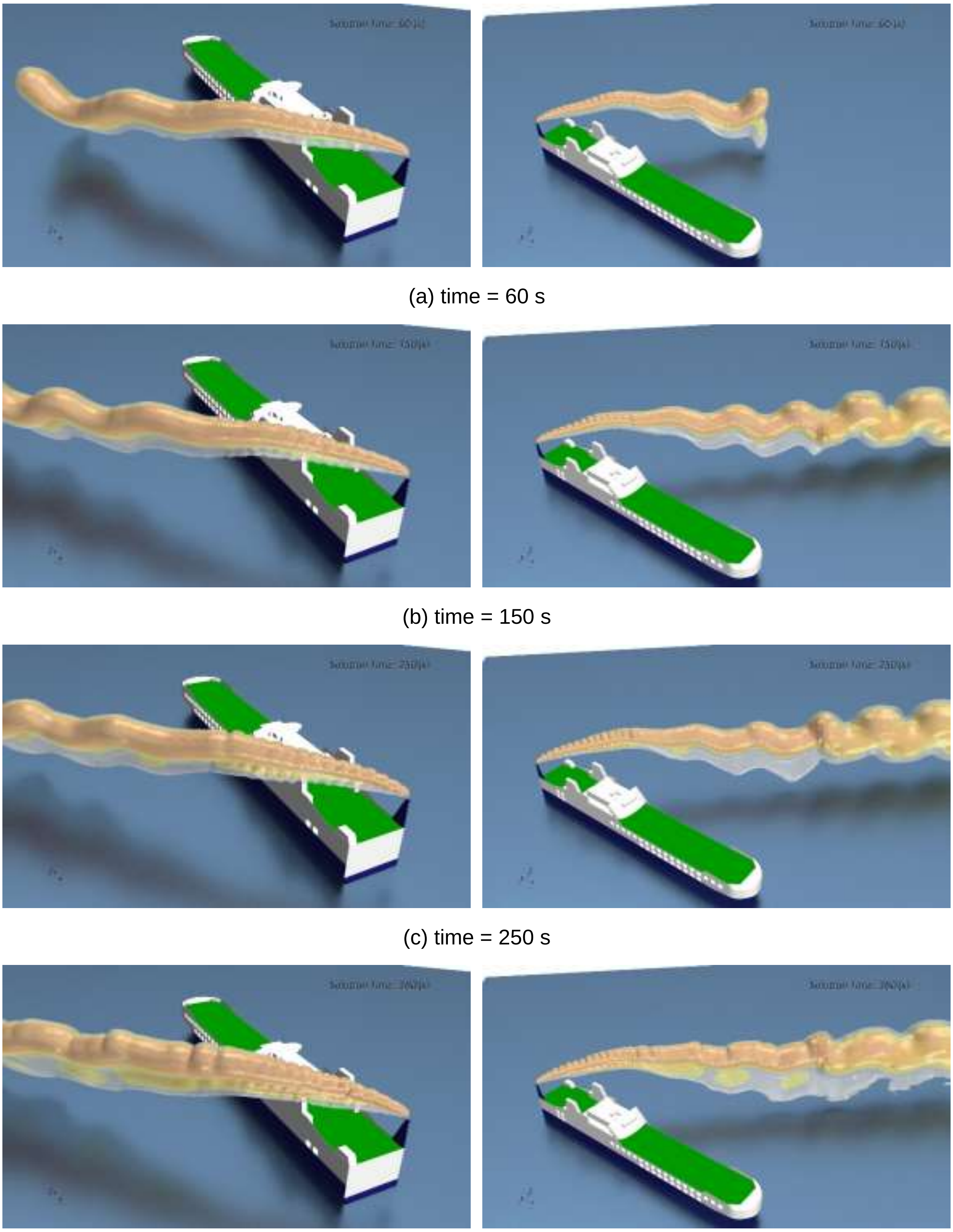


Figure 9 The steady-state air flow field around the vessel for the wind blowing from the std-aft side. The top and bottom subfigures show the streamlines at 15 metres and 40 metres above the sea level, respectively. The colours along the streamlines represent the velocity magnitude.

The snapshots of the ammonia plume are shown in Figure 10. The plume pattern indicates the wind pushed the plumes downstream quickly and the plumes barely touched the deck. Throughout the entire duration of the release, the ammonia plume remained clear of the lifeboat, the pool, the decks and the accommodations.



(a) time = 60 s

(b) time = 150 s

(c) time = 250 s

(d) time = 360 s

Figure 10 Evolution of the ammonia plume for the case of STB-AFT wind. The contour colours: grey for 30 ppm, yellow for 220 ppm, orange for 550 ppm, red for 1,100 ppm and magenta for 2,700 ppm. Left and right columns show the same flow field and time from two different angles.

Figure 11 shows the ammonia concentration time histories as captured at probes. The plot indicates that ammonia concentrations are even lower than the previous case.

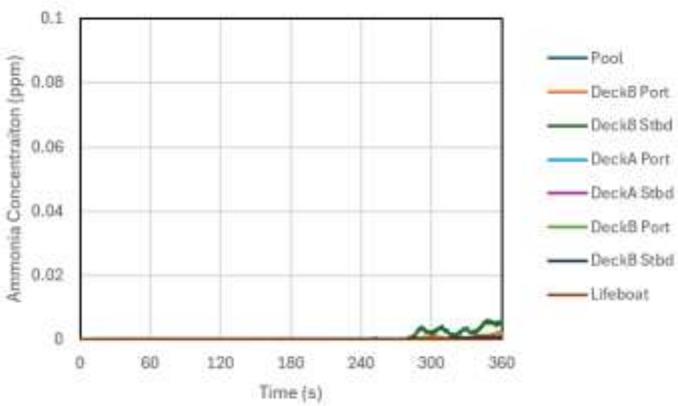


Figure 11 The ammonia concentration time histories as captured at probes, the STB-AFT wind.

2.1.4 Conclusions

The CFD results show that the rear vent release scenario has no impact on the vessel and personnel under both STB and STB-AFT winds.

2.2 ALOHA Modelling

2.2.1 ALOHA software

ALOHA (Areal Locations of Hazardous Atmospheres) is a software developed by the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the United States. It is designed to simulate the dispersion of hazardous chemicals into the atmosphere as a result of accidental releases or leaks. ALOHA allows for the modelling of various emergency scenarios, including refrigerated liquids, pressurised gases, and toxic or flammable materials. It provides key information on the extent of threat zones (AEGL, ERPG, IDLH) under specific meteorological conditions.

ALOHA integrates with mapping tools such as MARPLOT, allowing users to visualize the areas affected by chemical dispersion on geo-referenced maps. This facilitates decision-making processes related to risk analysis, emergency planning, and operational compatibility studies, such as SIMOPS.

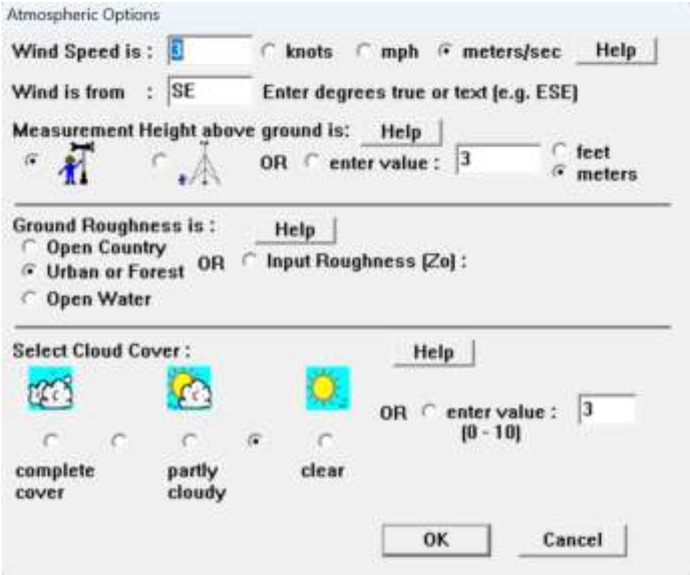


Figure 12 - ALOHA Input Data example – Atmospheric Options

2.2.2 Scenarios Definition

The following table provides a comparison of the three ALOHA simulation scenarios used in this study: Gas Pipeline Leak, Direct Source, and Refrigerated Liquid from a Tank. Each scenario reflects different types of potential ammonia release events, with specific assumptions regarding the physical state of the chemical, the release mechanism, and the environmental conditions.

- Gas Pipeline Leak: Represents a leak from a pressurised pipeline, such as a rupture or puncture in a fuel transfer line.
- Conditions: Chemical is in a **pressurised state** (liquid or gas); pressure and temperature must be physically consistent. Wind speed and direction significantly affect spread.
  - Product temperature: 25ºC, which corresponds to an operating condition of anhydrous ammonia in liquid phase, not refrigerated, stored or transferred under pressure at ambient temperature.
  - Pipeline pressure: 9 atm, to reflect realistic conditions of a pressurised line for bunkering, where the product is contained in liquid form but could be released in two-phase form (liquid + gas).
  - Leak area: 2.5 cm diameter, which represents a moderate failure scenario, such as a partial hose rupture or a significantly leaking valve.

- Direct Source: Simulates the evaporation of a chemical from a spill or surface pool directly into the atmosphere. This scenario is simulated as ALOHA is unable to simulate an ammonia leak scenario using the conditions that we want to simulate (-20ºC) using the source mode "Gas Pipeline Leak" due to software's physical consistency checks.
  - Conditions: Typically used for open-air evaporation. Surface area and ambient temperature influence the release rate. No pressure input is required.
  - Ambient conditions: o Ambient temperature: 20 °C
    - Relative humidity: 70
    - Wind speed: 2 m/s
    - Atmospheric stability class: B
    - Terrain: Urban (industrial port)
  - Leakage data:
    - Type of release: Direct Source
    - Source temperature: -20 °C
    - Source Height: 12m (2.6m + 9.4m) – Bunkering Station
    - Release duration: 1 minute

- Refrigerated Liquid from a Tank: Models the release of a cryogenic liquid stored at low temperature and low pressure, typical of refrigerated ammonia systems.
  - Conditions: ALOHA calculates pressure based on the chemical's **boiling point**. The scenario reflects a **low-pressure, low-temperature** release (e.g., –33.4 °C for NH_3)
  - Ambient conditions: o Ambient temperature: 15 °C
    - Relative humidity: 70
    - Wind speed: 3 m/s
    - Atmospheric stability class: D (neutral)
    - Terrain: Urban (industrial port)
  - Leakage data: o Type of leak: rupture at connection point during bunkering.
    - Type of release: refrigerated liquid from tank
    - Tank temperature: -33.4 °C (boiling point of ammonia at atmospheric pressure)
    - Tank pressure: 1 atm (atmospheric refrigerated tank)
    - Diameter of the leak hole: 2.5 cm
    - Height of leakage point: 4 metres above dock level
    - Leak duration: 60 minutes (The software automatically calculates the duration based on the size of the orifice, the total amount of liquid available in the tank and the physical conditions of the liquid)

2.2.3 Results

- Results for Scenario 1 – Gas Pipeline Leak

Figure 13 below shows the text summary that ALOHA outputs once all the input features have been specified:

```
SITE DATA:
  Location: VALENCIA, SPAIN, SPAIN
  Building Air Exchanges Per Hour: 0.47 (unsheltered single storied)
  Time: May 6, 2025  1034 hours ST (using computer's clock)

CHEMICAL DATA:
  Chemical Name: AMMONIA
  CAS Number: 7664-41-7                    Molecular Weight: 17.03 g/mol
  AEGL-1 (60 min): 30 ppm   AEGL-2 (60 min): 160 ppm   AEGL-3 (60 min): 1100
ppm
  IDLH: 300 ppm      LEL: 150000 ppm      UEL: 280000 ppm
  Ambient Boiling Point: -33.4° C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 2 meters/second from E at 3 meters
  Ground Roughness: open country           Cloud Cover: 5 tenths
  Air Temperature: 15° C                   Stability Class: B
  No Inversion Height                      Relative Humidity: 70%

SOURCE STRENGTH:
  Flammable gas escaping from pipe (not burning)
  Pipe Diameter: 5 centimeters             Pipe Length: 20 meters
  Unbroken end of the pipe is closed off
  Pipe Roughness: smooth                   Hole Area: 19.6 sq cm
  Pipe Press: 9 atmospheres                Pipe Temperature: 25° C
  Release Duration: 1 minute
  Max Average Sustained Release Rate: 3.65 grams/sec
     (averaged over a minute or more)
  Total Amount Released: 219 grams
```

Figure 13 - Text summary for ALOHA Scenario 1

In this particular instance, and given the imputed values, ALOHA has been unable to calculate threat zones. This is due to the fact that the program does not delineate threat zones in instances where the concentration of the chemical is determined to be insufficient to surpass the established AEGL/ERPG thresholds. This phenomenon occurs in instances where the quantity of gas released, the pressure, or the orifice are insufficient. Alternatively, it may result from the rapid dispersion of gas due to weather conditions.

Given the above, figure 14 shows the output of ALOHA when trying to preview the threat zones:

```
THREAT ZONE:
  Model Run: Gaussian
  Red   : less than 10 meters(10.9 yards) --- (1500 ppm = ERPG-3)
  Note: Threat zone was not drawn because effects of near-field patchiness
     make dispersion predictions less reliable for short distances.
  Orange: 17 meters --- (150 ppm = ERPG-2)
  Note: Threat zone was not drawn because effects of near-field patchiness
     make dispersion predictions less reliable for short distances.
  Yellow: 41 meters --- (25 ppm = ERPG-1)
  Note: Threat zone was not drawn because effects of near-field patchiness
     make dispersion predictions less reliable for short distances.
```

Figure 14 - Threat Zone definition for ALOHA scenario 1

- Results for Scenario 2 – Direct Source

  Figure 15 shows the text summary displayed by ALOHA after all features have been specified, while Figure 16 presents the toxic threat zones for Scenario 2:

```
SITE DATA:
  Location: VALENCIA, SPAIN, SPAIN
  Building Air Exchanges Per Hour: 0.40 (unsheltered single storied)
  Time: May 6, 2025  1034 hours ST (user specified)

CHEMICAL DATA:
  Chemical Name: AMMONIA
  CAS Number: 7664-41-7                  Molecular Weight: 17.03 g/mol
  AEGL-1 (60 min): 30 ppm   AEGL-2 (60 min): 160 ppm   AEGL-3 (60 min): 1100 ppm
  IDLH: 300 ppm      LEL: 150000 ppm     UEL: 280000 ppm
  Ambient Boiling Point: -33.4° C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 2 meters/second from E at 3 meters
  Ground Roughness: urban or forest      Cloud Cover: 3 tenths
  Air Temperature: 20° C                 Stability Class: B
  No Inversion Height                    Relative Humidity: 70%

SOURCE STRENGTH:
  Direct Source: 10 cubic meters         Source Height: 12 meters
  Source State: Liquid
  Source Temperature: -20° C
  Release Duration: 1 minute
  Release Rate: 111 kilograms/sec
  Total Amount Released: 6,646 kilograms
  Note: This chemical may flash boil and/or result in two phase flow.
     Use both dispersion modules to investigate its potential behavior.

THREAT ZONE:
  Model Run: Gaussian
  Red    : 1.0 kilometers --- (200 ppm)
  Orange: 1.3 kilometers --- (100 ppm)
  Yellow: 1.6 kilometers --- (50 ppm)
```

Figure 15 - Text Summary for ALOHA Scenario 2

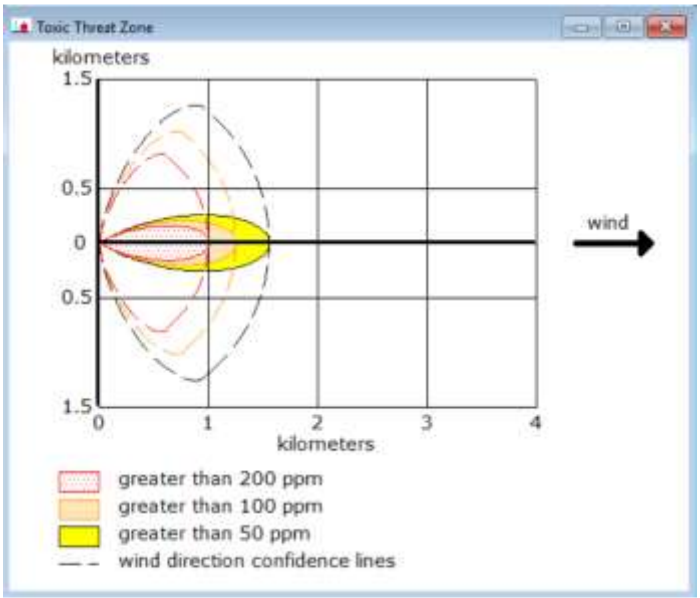


Figure 16 - Toxic Threat Zones for ALOHA Scenario 2

If the AEGL zones are utilised, which are the default Toxic Threat Zones in ALOHA, the result is shown below in figure 17:

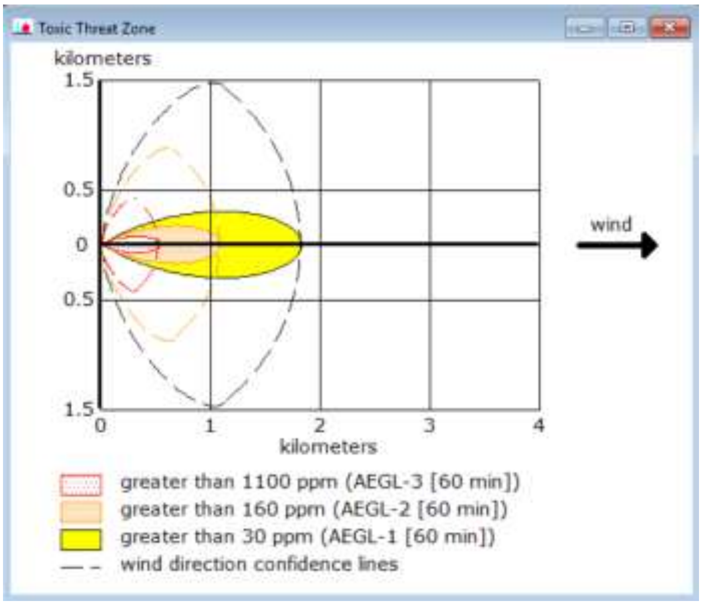


Figure 17 - AEGL Toxic Threat Zones for ALOHA Scenario 2

In order to visually and intuitively represent the potential extent of a toxic cloud generated by an ammonia leak during a bunkering operation, the MARPLOT (Mapping Application for Response, Planning, and Local Operational Tasks) software was used in integration with the ALOHA dispersion model.

Figure 18 shows the affected area in the Port of Valencia, selecting the threat point in the same place as the source point:

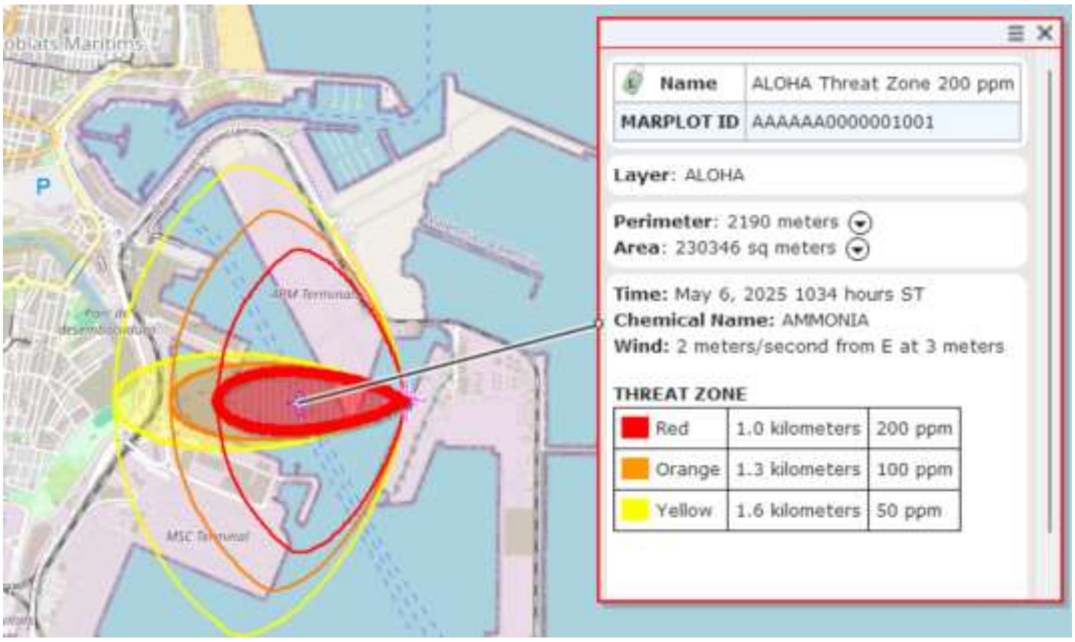


Figure 18 - Toxic Threat Zones represented with MARPLOT at Port of Valencia for Scenario 2

- Results for Scenario 3 – Refrigerated Liquid from a Tank

The following text is a summary that ALOHA outputs once all the input features have been specified:

SITE DATA:
Location: VALENCIA, SPAIN, SPAIN
Building Air Exchanges Per Hour: 0.49 (sheltered single storied)
Time: May 6, 2025 1134 hours ST (using computer's clock)

CHEMICAL DATA:
Chemical Name: AMMONIA
CAS Number: 7664-41-7 Molecular Weight: 17.03 g/mol
AEGL-1 (60 min): 30 ppm AEGL-2 (60 min): 160 ppm AEGL-3 (60 min): 1100 ppm
IDLH: 300 ppm LEL: 150000 ppm UEL: 280000 ppm
Ambient Boiling Point: -33.4° C
Vapor Pressure at Ambient Temperature: greater than 1 atm
Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 3 metres/second from SSW at 3 metres
Ground Roughness: urban or forest Cloud Cover: 3 tenths
Air Temperature: 15° C Stability Class: D
No Inversion Height **Relative Humidity: 70%**

SOURCE STRENGTH:
Leak from hole in horizontal cylindrical tank
Flammable chemical escaping from tank (not burning)
Tank Diameter: 4.71 metres Tank Length: 33 metres
Tank Volume: **576 cubic metres**
Tank contains liquid Internal Temperature: -33.4° C
Chemical Mass in Tank: 346 tons Tank is 80% full
Circular Opening Diameter: 2.5 centimetres
Opening is 3 metres from tank bottom
Release Duration: ALOHA limited the duration to 1 hour
Max Average Sustained Release Rate: 38.9 kilograms/min
(averaged over a minute or more)
Total Amount Released: 2,330 kilograms
Note: The chemical escaped as a mixture of gas and aerosol (two phase flow).

Figure 19 presents the toxic threat zones for Scenario 3

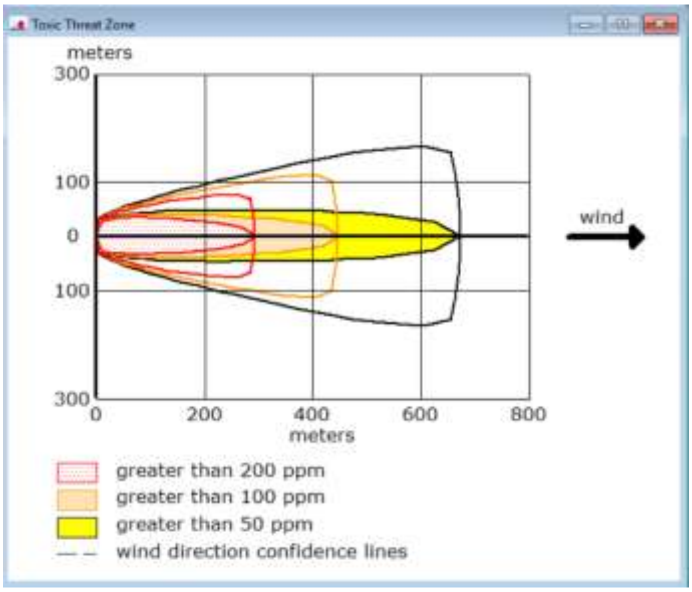


Figure 19 - ALOHA Toxic Threat Zones for Scenario 3

Figure 20 shows the affected area in the Port of Valencia, selecting the threat point in the same place as the source point, using MARPLOT:

Figure 20 - Toxic Threat Zones represented with MARPLOT at Port of Valencia for Scenario 3

3. Probit Analysis

3.1 Introduction

Probit analysis is a quantitative statistical method used to model the relationship between a stimulus (or dose) and a binary outcome - typically survival or death. In risk assessments involving toxic substances (like ammonia), probit analysis is used to estimate the probability of fatality (or other health effects) as a function of exposure concentration and duration. It's especially useful when analysing:

- Toxic gas leaks
- Chemical releases
- Explosion overpressures or thermal radiation exposure

The key assumption is that the response to a toxic dose (e.g., ammonia exposure) follows a normal (Gaussian) distribution in the affected population (i.e., not everyone responds the same way to the same dose). This dose-response relationship is transformed using the probit function to estimate the probability of fatality, according to the following equation[8]:

$$Y = a + b \cdot ln(C^n \cdot t)$$

Where:

- Y = Probit value (dimensionless)
- C = Concentration of the toxic substance (ppm or mg/m³)
- t = Exposure duration (e.g., minutes)
- a, b, and n = substance-specific constants derived from toxicological studies

Once the probit value Y is computed, it is mapped to a probability of death using standard probit-to-probability tables or the cumulative distribution function of a normal distribution.

Considering that ammonia is toxic at low concentrations, corrosive and irritating to the respiratory system, commonly transported and now used as fuel, introducing new exposure scenarios in marine environments, and that ammonia leaks can form toxic vapour clouds, particularly under low wind or confined conditions, it becomes evident that probit analysis can be a potent tool for ensuring safety operations.

For ammonia, literature[9] suggests the following probit constants:

$$Y = -16.5 + 0.99 \cdot ln(C^{2.02} \cdot t)$$

C must be in ppm, and t in minutes. The table below provides an overview of the correlation between the probit value and the probability of death.

Table 9: Correlation between probit value and probability of death

Probit Value (Y)	Interpretation	Approximate Probability of Death
2	Minor effects only	~1%
5	Threshold of serious concern	~50%
8	Extreme hazard	~99%

[8] RIVM, CPR, and VROM, Guidelines for quantitative risk assessment, vol. 3, 4 vols. in Publication Series on Dangerous Substances, vol. 3. PublicatiereeksU Gevaarlijke Stoffen, 2005. [Online]. Available: https://publicatiereeksgevaarlijkestoffen.nl/publicaties/PGS3.html
[9] I.M. Ruijten (Commissioned by RIVM), Probit function technical support document, 201706060ammonia-INTERIM, https://www.rivm.nl/sites/default/files/2018-11/20170606-Ammonia%20INTERIM.pdf

3.2 Scenarios

In the context of these report, the scenarios that were considered are summarised below.

CFD Modelling

Two CFD simulation scenarios were examined: one with wind blowing from the starboard side to the port side, and another with wind blowing from the starboard side toward the aft of the vessel. For both scenarios, eight numerical probes were positioned above the vessel decks to monitor ammonia concentrations within the working areas over time. The simulations concluded that rear vent release scenarios do not pose a hazard to the vessel or personnel under either wind condition (starboard-to-port and starboard-to-aft). A detailed overview of the simulation parameters is provided in Section 2.1.

ALOHA Modelling

The ALOHA simulation scenarios outlined in Section 2.2 include:

- a Gas Pipeline Leak,
- a Direct Source Leak, and
- a Refrigerated Liquid Leak from a Tank.

The Gas Pipeline Leak simulates a release from a pressurised pipeline, such as a rupture or puncture in a fuel transfer line. The Direct Source Leak represents the evaporation of a chemical from a surface pool directly into the atmosphere. The Refrigerated Liquid Leak models the release of a cryogenic liquid stored at low temperature and pressure, as typically found in refrigerated ammonia systems.

Based on the simulation results, ALOHA was unable to calculate threat zones for the pipeline leak scenario, as the predicted concentrations did not exceed the defined AEGL/ERPG thresholds. Consequently, no threat zones were delineated. However, for the other two scenarios — the Direct Source Leak and the Refrigerated Tank Leak - relevant toxic threat zones were successfully calculated.

Taking the above into account, the two scenarios selected for use in the probit analysis are:

- the Direct Source Leak, which effectively simulates a small leak during bunkering operations, and
- the Refrigerated Tank Leak, which represents a fuel tank rupture scenario.

It should be noted that the accuracy of these results may be constrained by ALOHA's modelling limitations. Nevertheless, the outputs are considered sufficiently informative for estimating toxic hazard zones in the event of an ammonia release.

3.3 Results

Considering all parameters outlined in Section 2.2 and applying the probit equation described above, the corresponding probabilities of fatality have been calculated. Table 10 presents the results for the Direct Source Leak scenario, while Table 11 shows the results for the Refrigerated Tank Leak scenario.

Table 10: Probit analysis results for the Direct Source Leak scenario, showing estimated probability of fatality at various distances from the ammonia release point based on a 1-minute exposure duration.

Distance (km)	Concentration (ppm)	Exposure Duration (min)	Probit	Probability of Fatality (%)
1	200	1	-4.32	0.00
1.3	100	1	-5.71	0.00
1.6	50	1	-7.10	0.00

Table 11: Probit analysis results for the Refrigerated Tank Leak scenario, showing estimated probability of fatality at various distances from the ammonia release point based on a 10-minute exposure duration.

Distance (km)	Concentration (ppm)	Exposure Duration (min)	Probit	Probability of Fatality (%)
0.24	200	10	-6.6	0.00
0.42	100	10	-7.99	0.00
0.62	50	10	-9.38	0.00

Figure 21 presents a comparative figure showing the probability of fatality versus distance for both ammonia leak scenarios: the Direct Source Leak (1-minute exposure) and the Refrigerated Tank Leak (10-minute exposure).

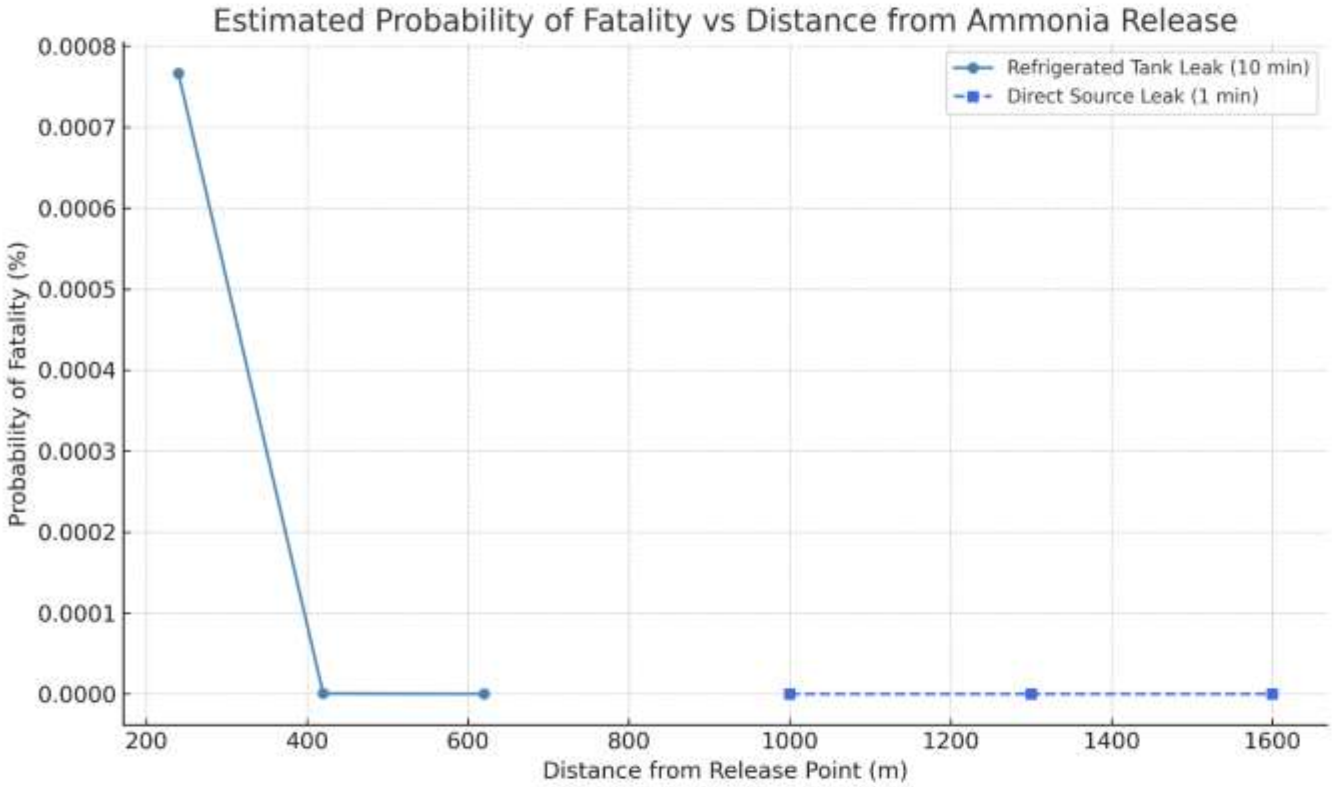


Figure 21: Estimated probability of fatality as a function of distance from the ammonia release point for two simulated scenarios: a Direct Source Leak with a 1-minute exposure duration and a Refrigerated Tank Leak with a 60-minute exposure duration.

3.4 Conclusions

Probit analysis was used to estimate the probability of fatality resulting from exposure to ammonia vapour, based on two representative release scenarios: a *Direct Source Leak* (1-minute duration) and a *Refrigerated Tank Leak* (60-minute duration).

- Zero fatality risk in both scenarios at given distances**:** Using the probit formula with concentrations in mg/m³, the calculated probability of fatality is effectively **0% at all evaluated distances** for both scenarios.
- Exposure duration plays a critical role**:** Despite the higher exposure time (10 minutes) in the refrigerated tank scenario, the resulting ammonia concentrations at the evaluated distances are still too low to result in a significant fatality risk.
- Lower concentration levels dominate the outcome: Even at 200 ppm (which corresponds to 141 mg/m³), the probit values remain well below zero, confirming that lethality requires either much higher concentrations or significantly longer exposures.
- Direct Source Leak presents lower hazard due to shorter duration: The 1-minute exposure in the direct source scenario (e.g. a small leak during bunkering) results in even lower probit values than the refrigerated tank leak, confirming that short-term, small-scale leaks are unlikely to be fatal at distances >1 km.
- Ammonia's acute toxicity is highly dependent on close-range, high-dose exposure: These results suggest that fatality risks are only significant very close to the source of a high-pressure or large-scale ammonia release—something not covered in the selected distances.

Appendix A HAZID Worksheet

This section presents the condensed HAZID Worksheet report (or log) developed during the HAZID workshop. To ensure the log remains concise and manageable for the reader or reviewer, the following assumptions and simplifications were applied:

- Generic hazards related to technological maturity, regulatory framework, training, automation, etc., are addressed in the Recommendations (Subsection **Error! Reference source not found.**).
- Generic Individual Protection Layers (IPLs) or safeguards have been omitted.
- Repetitive hazardous events appearing across multiple nodes (e.g., storage tank and vents) have been consolidated or removed.
- Hazardous events that were not ranked either because there was insufficient technical information or there were no consequences identified have been removed.

Company: EMSA, Wartsila, DFDS, Knud E. Hansen		
Title: EMSA NH3, Ro-Pax Study		
Description:		
Method: HAZID	**Type:**	General Ro-Pax Arrangement
Design Intent:		
Comment: System allowed to run in ammonia while ammonia is being bunkered. for as long as NPSH is fulfilled the pump should be capable of supplying ammonia to the engine.		

No.: 1	**Description:** General Ro-Pax Arrangement

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
1.9	Loss of electrical power	Blackout		1.9.1. Generator Sets failure	1.9.1. Pressure build up in ammonia system	General	5	-1	High (4)	1.9.1. Back up alarm/monitoring system 1.9.2. One (1) Emergency generator for system not covered by battery.	4	-2	Moderate (2)	10. Further study is required for power loss scenarios and residual ammonia fuel handling in piping per vessel. 11. Further study is required on the loss of power for valve fail-safe positions and backup power requirements during the appropriate risk assessment for each vessel.

No.: 1							**Description:** General Ro-Pax Arrangement							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										1.9.3. 1.7.1. Back up alarm/monitoring system 1.7.2. One (1) Emergency generator for the supply of essential/ critical machinery equipment,. 1.7.3. Intrinsically safe flashlights and torch lights are provided.				

No.: 1							**Description:** General Ro-Pax Arrangement							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				1.9.2. Power Distribution System failure	1.9.1. Pressure build up in ammonia system	General	5	-1	High (4)	1.9.1. Back up alarm/monitoring system 1.9.2. One (1) Emergency generator for system not covered by battery.	4	-2	Moderate (2)	10. Further study is required for power loss scenarios and residual ammonia fuel handling in piping per vessel. 11. Further study is required on the loss of power for valve fail-safe positions and backup power requirements during the appropriate risk assessment for each vessel.

No.: 1							**Description:** General Ro-Pax Arrangement							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										1.9.3. 1.7.1. Back up alarm/monitoring system 1.7.2. One (1) Emergency generator for the supply of essential/ critical machinery equipment,. 1.7.3. Intrinsically safe flashlights and torch lights are provided.				

No.: 1							**Description:** General Ro-Pax Arrangement							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				1.9.3. Short Circuit	1.9.1. Pressure build up in ammonia system	General	5	-1	High (4)	1.9.1. Back up alarm/monitoring system 1.9.2. One (1) Emergency generator for system not covered by battery.	4	-2	Moderate (2)	10. Further study is required for power loss scenarios and residual ammonia fuel handling in piping per vessel. 11. Further study is required on the loss of power for valve fail-safe positions and backup power requirements during the appropriate risk assessment for each vessel.

No.: 1							**Description:** General Ro-Pax Arrangement							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										1.9.3. 1.7.1. Back up alarm/monitoring system 1.7.2. One (1) Emergency generator for the supply of essential/ critical machinery equipment,. 1.7.3. Intrinsically safe flashlights and torch lights are provided.				

No.: 1	**Description:** General Ro-Pax Arrangement

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
				1.9.4. Operator error.	1.9.1. Pressure build up in ammonia system	General	5	-1	High (4)	1.9.1. Back up alarm/monitoring system 1.9.2. One (1) Emergency generator for system not covered by battery.	4	-2	Moderate (2)	10. Further study is required for power loss scenarios and residual ammonia fuel handling in piping per vessel. 11. Further study is required on the loss of power for valve fail-safe positions and backup power requirements during the appropriate risk assessment for each vessel.

No.: 1								**Description:** General Ro-Pax Arrangement						
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										1.9.3. 1.7.1. Back up alarm/monitoring system 1.7.2. One (1) Emergency generator for the supply of essential/ critical machinery equipment,. 1.7.3. Intrinsically safe flashlights and torch lights are provided.				

No.: 1							**Description:** General Ro-Pax Arrangement							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				1.9.5. 1.7.2. Power Distribution System failure 1.7.3. Short Circuit or electrical fire 1.7.4. Operator error or load management failure	1.9.1. Pressure build up in ammonia system	General	5	-1	High (4)	1.9.1. Back up alarm/monitoring system 1.9.2. One (1) Emergency generator for system not covered by battery.	4	-2	Moderate (2)	10. Further study is required for power loss scenarios and residual ammonia fuel handling in piping per vessel. 11. Further study is required on the loss of power for valve fail-safe positions and backup power requirements during the appropriate risk assessment for each vessel.

No.: 1							**Description:** General Ro-Pax Arrangement							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										1.9.3. 1.7.1. Back up alarm/monitoring system 1.7.2. One (1) Emergency generator for the supply of essential/ critical machinery equipment,. 1.7.3. Intrinsically safe flashlights and torch lights are provided.				
1.11	External Threat (Attack, Piracy.)	Direct attack (terrorism, piracy, etc.)		1.11.1. Security breach	1.11.1. Crew and passenger injuries and/or fatalities because of ammonia intentional release or fire/explosion	General	6	-2	High (4)	1.11.1. Security measures as per SSP	4	-2	Moderate (2)	13. Additional security measures may be necessary for ammonia usage as marine fuel.

No.: 1							**Description:** General Ro-Pax Arrangement							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				1.11.2. Sabotage	1.11.1. Crew and passenger injuries and/or fatalities because of ammonia intentional release or fire/explosion	General	6	-2	High (4)	1.11.1. Security measures as per SSP	4	-2	Moderate (2)	13. Additional security measures may be necessary for ammonia usage as marine fuel.
				1.11.3. Piracy	1.11.1. Crew and passenger injuries and/or fatalities because of ammonia intentional release or fire/explosion	General	6	-2	High (4)	1.11.1. Security measures as per SSP	4	-2	Moderate (2)	13. Additional security measures may be necessary for ammonia usage as marine fuel.

No.: 1							**Description:** General Ro-Pax Arrangement							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				1.11.4. Armed Robbery	1.11.1. Crew and passenger injuries and/or fatalities because of ammonia intentional release or fire/explosion	General	6	-2	High (4)	1.11.1. Security measures as per SSP	4	-2	Moderate (2)	13. Additional security measures may be necessary for ammonia usage as marine fuel.
1.12	Cyber Attack	Security breach		1.12.1. Targeted attack on navigation systems, ammonia fuel systems, power systems, communications systems, etc..	1.12.1. Loss of ammonia fuel system control, potential for unauthorised release of ammonia 1.12.2. System cannot be controlled remotely	General	6	-1	Extreme (5)	1.12.1. Certified for cyber security **Comment:** IACS URE 27 1.12.2. Protective measures as per cyber security management plan	4	-2	Moderate (2)	14. Further study to be done on the possibility of cutting on line communication and overriding the system so that it can be controlled manually.

														15. Ensure comprehensive cyber security by considering the relevant IMO Resolution and Guidelines, national regulations and flag state requirements, IACS Unified Requirements (URs), standards such as ISO/IEC 27001 and IEC 62443, industry recommendations and best practices, etc. Additional cyber security measures may be necessary for ammonia usage as marine fuel.
1.18	Fire, Explosion	Hot Works in Proximity		1.18.1. Sparks, hot	1.18.1. Fire, human	Injury	6	-2	High (4)	1.18.1. SOPs 1.18.2.	4	-2	Moderate (2)	21. Tank purging process to

No.: 1 | **Description:** General Ro-Pax Arrangement

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
				sources, ignition sources	injury					OPTS 1.18.3. FFS 1.18.4. PP				create safe environment for inspection procedures is to be further studied. 22. Further study to be done on the operating procedures of the purging process. Ammonia will require safer environment as compared to LNG purging processes.

No.: 1	**Description:** General Ro-Pax Arrangement

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
														23. Further study to be done on the hot operations to be allowed during periods the vessel will be bunkering, in preparation status or at berth.

														24. IGF Code 18.7 Regulations for hot work on or near fuel systems Minimize the risk of exposure to toxic ammonia vapours by preventing toxic fuel vapours from accumulating in areas where people might be exposed. Establish toxic zones around ammonia vapour sources on the open deck to prevent spreading to enclosed spaces through air intakes, outlets, or other openings. The requirements for

No.: 1							**Description:** General Ro-Pax Arrangement							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														venting cargo tanks and ventilating cargo handling spaces should be taken into consideration for such vessels.
					1.18.2. Toxic ammonia gas release, human injury or fatality.	Injury	6	-2	High (4)	Same as above	4	-2	Moderate (2)	
					1.18.3. Ammonia ignition or explosion, causing severe structural damage or damage to critical systems.	General	6	-2	High (4)	Same as above	4	-2	Moderate (2)	

No.: 1							**Description:** General Ro-Pax Arrangement							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					1.18.4. Environmental contamination, leading to regulatory violations and legal consequences.	Environmental	6	-2	High (4)	Same as above	4	-2	Moderate (2)	
				1.18.2. Inadequate purging.	1.18.1. Fire, human injury	Injury	6	-2	High (4)	1.18.1. SOPs 1.18.2. OPTS 1.18.3. FFS 1.18.4. PP	4	-2	Moderate (2)	21. Tank purging process to create safe environment for inspection procedures is to be further studied.

No.: 1	**Description:** General Ro-Pax Arrangement

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
														22. Further study to be done on the operating procedures of the purging process. Ammonia will require safer environment as compared to LNG purging processes. 23. Further study to be done on the hot operations to be allowed during periods the vessel will be bunkering, in preparation status or at berth.

														24. IGF Code 18.7 Regulations for hot work on or near fuel systems Minimize the risk of exposure to toxic ammonia vapours by preventing toxic fuel vapours from accumulating in areas where people might be exposed. Establish toxic zones around ammonia vapour sources on the open deck to prevent spreading to enclosed spaces through air intakes, outlets, or other openings. The requirements for

No.: 1	**Description:** General Ro-Pax Arrangement

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
														venting cargo tanks and ventilating cargo handling spaces should be taken into consideration for such vessels.
					1.18.2. Toxic ammonia gas release, human injury or fatality.	Injury	6	-2	High (4)	Same as above	4	-2	Moderate (2)	
					1.18.3. Ammonia ignition or explosion, causing severe structural damage or damage to critical systems.	General	6	-2	High (4)	Same as above	4	-2	Moderate (2)	

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Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					1.18.4. Environmental contamination, leading to regulatory violations and legal consequences.	Environmental	6	-2	High (4)	Same as above	4	-2	Moderate (2)	
				1.18.3. Insufficient ventilation	1.18.1. human injury	Injury	6	-2	High (4)	1.18.1. SOPs 1.18.2. OPTS 1.18.3. FFS 1.18.4. PP	4	-2	Moderate (2)	21. Tank purging process to create safe environment for inspection procedures is to be further studied.

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Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														22. Further study to be done on the operating procedures of the purging process. Ammonia will require safer environment as compared to LNG purging processes. 23. Further study to be done on the hot operations to be allowed during periods the vessel will be bunkering, in preparation status or at berth.

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														venting cargo tanks and ventilating cargo handling spaces should be taken into consideration for such vessels.
					1.18.2. Toxic ammonia gas release, human injury or fatality.	Injury	6	-2	High (4)	Same as above	4	-2	Moderate (2)	
					1.18.3. Explosion, causing severe structural damage or damage to critical systems.	General	6	-2	High (4)	Same as above	4	-2	Moderate (2)	

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Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					1.18.4. Environmental contamination, leading to regulatory violations and legal consequences.	Environmental	6	-2	High (4)	Same as above	4	-2	Moderate (2)	
				1.18.4. Ammonia leakage	1.18.1. Fire, human injury	Injury	6	-2	High (4)	1.18.1. SOPs 1.18.2. OPTS 1.18.3. FFS 1.18.4. PP	4	-2	Moderate (2)	21. Tank purging process to create safe environment for inspection procedures is to be further studied.

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														24. IGF Code 18.7 Regulations for hot work on or near fuel systems Minimize the risk of exposure to toxic ammonia vapours by preventing toxic fuel vapours from accumulating in areas where people might be exposed. Establish toxic zones around ammonia vapour sources on the open deck to prevent spreading to enclosed spaces through air intakes, outlets, or other openings. The requirements for

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														venting cargo tanks and ventilating cargo handling spaces should be taken into consideration for such vessels.
					1.18.2. Toxic ammonia gas release, human injury or fatality.	Injury	6	-2	High (4)	Same as above	4	-2	Moderate (2)	
					1.18.3. Ammonia ignition or explosion, causing severe structural damage or damage to critical systems.	General	6	-2	High (4)	Same as above	4	-2	Moderate (2)	

No.: 1							**Description:** General Ro-Pax Arrangement							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					1.18.4. Environmental contamination, leading to regulatory violations and legal consequences.	Environmental	6	-2	High (4)	Same as above	4	-2	Moderate (2)	
1.19	Electric Cars	EVBs that experience overheating		1.19.1. Explosion of Battery.	1.19.1. Fire, Human Injury	Injury	6	-2	High (4)	1.19.1. Audible and visual alarm from EV Itself CCTV 1.17.1. FFS IECEx MV (2x100%) Ventilation Control Plan	4	-2	Moderate (2)	25. Further study to be done on a cooling system of electric car's batteries.

														26. Consider installing multiple EX-CCTV systems equipped with built-in AI and video analytics, IR cameras capable of night vision. Implementation of a hydrocarbon or hydrogen gas detection system as an additional feature. Potential revision of the overall ventilation strategy to ensure continuous supply and exhaust prior to detection. Use a fire blanket to cover the vehicle that is on fire. Consider implementing a fixed boundary

														cooling system or deploying portable boundary cooling devices. Consider the application of a higher rate of fire integrity to adjacent compartments. Consider the application of fire protection, water spray system or water curtain system for all escape routes, lifeboats and life rafts. Consider the use of manual firefighting techniques, thus implementing a thermal imager, water mist lances

No.: 1	**Description:** General Ro-Pax Arrangement

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
														and water fog nozzle applicators.

Company: EMSA, Wartsila, DFDS, Knud E. Hansen		
Title: EMSA NH3, Ro-Pax Study		
Description:		
Method: HAZID	**Type:**	Bunkering Stations
Design Intent:		
Comment: NTUA: Is QRQC (Power Emergency Release Coupling perk) connection system used? Hansen: Yes. Hansen: Intention to carry out bunkering in parallel with embarkation Always manned bunker station. Semi enclosed station. Wartsila: Bunkering pipe temperature will have a minimal effect on bunkering process, no cooling down needed. Hansen: Further study to be done on the closing time of the bunkering valve		

No.: 2 **Description:** Bunkering Stations

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
2.2	Toxicity (Ammonia Release)	Loss of Containment		2.2.1. Design, Fabrication or Installation error.	2.2.2. Ammonia spill in the sea.	Environmental	5	-1	High (4)	2.2.2. FAT/HAT/SAT spec 2.2.3. Material specs	4	-2	Moderate (2)	37. Evaluate the need of detection measures for liquid/gas leakage from the ammonia piping between the cargo manifold and fuel tank. 38. Consistent monitoring of the bunkering area or use of an equivalent method.

No.: 2	**Description:** Bunkering Stations													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														39. Ships' fuel hoses are to comply with the requirements in Part 5C, Chapter 13, Section 8-3.2 of the ABS Rules for Building and Classing Marine Vessels. Bunker hoses are also to comply with ISO 5771:2024 "Rubber Hoses and Hoses Assemblies AMMONIA BUNKERING: TECHNICAL AND OPERATIONAL ADVISORY for Transferring Anhydrous Ammonia - Specification." 40. Excessive cooling should not adversely affect hull or deck structures in the event of a fuel leak.
					2.2.3. Ammonia spill on deck, human injury.	Injury	3	-1	Moderate (2)	2.2.2. FAT/HAT/SAT spec 2.2.3. Material specs	3	-2	Low (1)	
				2.2.2. Failure of application of procedures. Human error.	2.2.2. Ammonia spill in the sea.	Environmental	5	-1	High (4)	2.2.4. FFS 2.2.5. PP 2.2.7. ADS 2.2.8. CCTV 2.2.9. ESD 2.2.10. SOPs	4	-2	Moderate (2)	41. A person in charge must be appointed to coordinate and oversee the bunkering operation.

No.: 2 | **Description:** Bunkering Stations

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										2.2.11. SSL 2.2.13. OPTS 2.2.15. ERC/BAC-QCDC 2.2.16. SVS				42. The bunkering team should use the loading plan and checklist throughout the process and ensure that all crew members know the standard operating procedures (SOPs), alarm systems, and loading sequence. 43. Clear and detailed drawings of the vessel's bunkering system should be readily accessible to the ship's bunkering team during operations. 44. A piping diagram should be posted in a convenient location for easy reference by the team. 45. Respective valves and piping should be tagged for easy identification.
				2.2.3. Operational weather limits.	2.2.1. Ammonia spill on deck. Chemical corrosion.	Asset	3	-1	Moderate (2)	2.2.5. PP 2.2.7. ADS 2.2.8. CCTV 2.2.9. ESD 2.2.10. SOPs 2.2.11. SSL 2.2.13. OPTS	3	-2	Low (1)	12. Standard Operating Procedures (SOPs) must clearly outline any operational limitations of the ammonia fuel mode/system 33. Drip tray schematic showing positions in bunker stations areas are to be provided.

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Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										2.2.14. SMS				34. SIMOPS **Priority:** A **Comment:** Matters to be discussed during a SIMOPS study: 1. Interaction with bunker vessel. 2. Types of bunker vessels to be used for this design. 3. Operational procedures and required time for each process. 4. Action in case of a fire. Possible presence of tugboat(s). 5. Embarkation/Disembarkation procedures during bunkering 6. Bunkering temperature range. 35. Final design of the bunkering station arrangement, including the presence of an air lock, is to be provided. 36. Considering early stages of design, location of washing stations are to be provided in the updated drawings.

No.: 2	**Description:** Bunkering Stations													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
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														41. A person in charge must be appointed to coordinate and oversee the bunkering operation. 42. The bunkering team should use the loading plan and checklist throughout the process and ensure that all crew members know the standard operating procedures (SOPs), alarm systems, and loading sequence. 43. Clear and detailed drawings of the vessel's bunkering system should be readily accessible to the ship's bunkering team during operations. 44. A piping diagram should be posted in a convenient location for easy reference by the team. 45. Respective valves and piping should be tagged for easy identification.
					2.2.2. Ammonia spill in the sea.	Environmental	5	-1	High (4)	2.2.7. ADS 2.2.8. CCTV 2.2.9. ESD	4	-2	Moderate (2)	

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Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										2.2.10. SOPs 2.2.11. SSL 2.2.13. OPTS 2.2.14. SMS				
					2.2.3. Ammonia spill on deck, human injury.	Injury	4	-1	High (3)	2.2.5. PP 2.2.7. ADS 2.2.8. CCTV 2.2.9. ESD 2.2.10. SOPs 2.2.11. SSL 2.2.13. OPTS 2.2.14. SMS	3	-2	Low (1)	
				2.2.4. Materials defect.	2.2.1. Ammonia spill on deck. Chemical corrosion.	Asset	3	-1	Moderate (2)	2.2.6. Materials spec 2.2.7. ADS 2.2.8. CCTV 2.2.9. ESD 2.2.10. SOPs 2.2.11. SSL 2.2.12.PMS 2.2.13. OPTS	3	-2	Low (1)	33. Drip tray schematic showing positions in bunker stations areas are to be provided.

No.: 2	**Description:** Bunkering Stations													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														34. SIMOPS **Priority:** A **Comment:** Matters to be discussed during a SIMOPS study: 1. Interaction with bunker vessel. 2. Types of bunker vessels to be used for this design. 3. Operational procedures and required time for each process. 4. Action in case of a fire. Possible presence of tugboat(s). 5. Embarkation/Disembarkation procedures during bunkering 6. Bunkering temperature range. 35. Final design of the bunkering station arrangement, including the presence of an air lock, is to be provided. 36. Considering early stages of design, location of washing stations are to be provided in the updated drawings.

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														41. A person in charge must be appointed to coordinate and oversee the bunkering operation. 42. The bunkering team should use the loading plan and checklist throughout the process and ensure that all crew members know the standard operating procedures (SOPs), alarm systems, and loading sequence. 43. Clear and detailed drawings of the vessel's bunkering system should be readily accessible to the ship's bunkering team during operations. 44. A piping diagram should be posted in a convenient location for easy reference by the team. 45. Respective valves and piping should be tagged for easy identification.
					2.2.2. Ammonia spill in the sea.	Environmental	5	-1	High (4)	Same as above	4	-2	Moderate (2)	

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Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					2.2.3. Ammonia spill on deck, human injury.	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	
				2.2.5. Hose failure.	2.2.2. Ammonia spill in the sea.	Environmental	5	-1	High (4)	2.2.3. Material specs 2.2.7. ADS 2.2.8. CCTV 2.2.9. ESD 2.2.10. SOPs 2.2.11. SSL 2.2.12.PMS 2.2.13. OPTS	4	-2	Moderate (2)	33. Drip tray schematic showing positions in bunker stations areas are to be provided. 34. SIMOPS **Priority:** A **Comment:** Matters to be discussed during a SIMOPS study: 1. Interaction with bunker vessel. 2. Types of bunker vessels to be used for this design. 3. Operational procedures and required time for each process. 4. Action in case of a fire. Possible presence of tugboat(s). 5. Embarkation/Disembarkation procedures during bunkering 6. Bunkering temperature range. 35. Final design of the bunkering station arrangement, including the presence of an air lock, is to be provided.

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														36. Considering early stages of design, location of washing stations are to be provided in the updated drawings. 37. Evaluate the need of detection measures for liquid/gas leakage from the ammonia piping between the cargo manifold and fuel tank. 38. Consistent monitoring of the bunkering area or use of an equivalent method. 39. Ships' fuel hoses are to comply with the requirements in Part 5C, Chapter 13, Section 8-3.2 of the ABS Rules for Building and Classing Marine Vessels. Bunker hoses are also to comply with ISO 5771:2024 "Rubber Hoses and Hoses Assemblies AMMONIA BUNKERING: TECHNICAL AND OPERATIONAL ADVISORY for Transferring Anhydrous Ammonia - Specification."

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														46. Hoses used for fuel transfer must be compatible with the type of fuel and suitable for the specific fuel temperature. Hoses must possess a bursting pressure that is at least five times greater than the maximum pressure experienced during bunkering.
				2.2.6. QCDC failure	2.2.1. Ammonia spill on deck. Chemical corrosion.	Asset	3	-1	Moderate (2)	2.2.3. Material specs 2.2.7. ADS 2.2.8. CCTV 2.2.9. ESD 2.2.10. SOPs 2.2.11. SSL 2.2.12.PMS	3	-2	Low (1)	33. Drip tray schematic showing positions in bunker stations areas are to be provided.

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No.: 2	**Description:** Bunkering Stations													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														47. Arrangements should be made to install an emergency release system that prevents damage and spark generation, minimizes ammonia release when activated, and includes measures to prevent accidental activation. 48. The system should be designed as a fail-release system. 49. The connections at the bunkering station must utilize dry-disconnect types, equipped with additional safety features like dry breakaway couplings or self-sealing quick-release couplings.
2.3	Toxicity (Ammonia Release)	QCDC Failure		2.3.1. Design, Fabrication or Installation error.	2.3.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	2.3.5. FAT/HAT/SAT spec 2.3.10. Materials spec	6	-2	High (4)	12. Standard Operating Procedures (SOPs) must clearly outline any operational limitations of the ammonia fuel mode/system 36. Considering early stages of design, location of washing stations are to be provided in the updated drawings.

No.: 2 | **Description:** Bunkering Stations

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
														48. The system should be designed as a fail-release system. 49. The connections at the bunkering station must utilize dry-disconnect types, equipped with additional safety features like dry breakaway couplings or self-sealing quick-release couplings. 50. Arrangements should be made to install an emergency release system that prevents damage and spark generation, minimizes ammonia release when activated, and includes measures to prevent accidental activation.
					2.3.2. Ammonia spill in the sea.	Environmental	5	-1	High (4)	Same as above	4	-2	Moderate (2)	
					2.3.3. Ammonia spill on deck. Chemical corrosion.	Asset	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 2	**Description:** Bunkering Stations													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					2.3.4. Ammonia spill on deck, human injury.	Injury	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
				2.3.2. Failure of application of procedures. Human error.	2.3.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	2.3.1. ADS 2.3.2. CCTV 2.3.3. ESD 2.3.4. OPTS 2.3.9. PP 2.3.11. SMS 2.3.12. SOPs 2.3.13. SSL 2.3.17. MV 2x100%	6	-2	High (4)	12. Standard Operating Procedures (SOPs) must clearly outline any operational limitations of the ammonia fuel mode/system 36. Considering early stages of design, location of washing stations are to be provided in the updated drawings.
					2.3.2. Ammonia spill in the sea.	Environmental	5	-1	High (4)	Same as above	4	-2	Moderate (2)	
					2.3.3. Ammonia spill on deck. Chemical corrosion.	Asset	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					2.3.4. Ammonia spill on deck, human injury.	Injury	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 2	**Description:** Bunkering Stations													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				2.3.3. Operational weather limits.	2.3.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	2.3.1. ADS 2.3.2. CCTV 2.3.3. ESD 2.3.4. OPTS 2.3.9. PP 2.3.12. SOPs 2.3.13. SSL 2.3.17. MV 2x100%	6	-2	High (4)	12. Standard Operating Procedures (SOPs) must clearly outline any operational limitations of the ammonia fuel mode/system 36. Considering early stages of design, location of washing stations are to be provided in the updated drawings.
					2.3.2. Ammonia spill in the sea.	Environmental	5	-1	High (4)	Same as above	4	-2	Moderate (2)	
					2.3.3. Ammonia spill on deck. Chemical corrosion.	Asset	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					2.3.4. Ammonia spill on deck, human injury.	Injury	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
				2.3.4. Materials defect.	2.3.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	2.3.1. ADS 2.3.2. CCTV 2.3.4. OPTS 2.3.9. PP	6	-2	High (4)	12. Standard Operating Procedures (SOPs) must clearly outline any operational limitations of the ammonia fuel mode/system

No.: 2	**Description:** Bunkering Stations													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										2.3.12. SOPs 2.3.13. SSL 2.3.14.PMS 2.3.17. MV 2x100% 2.3.18. BOG				36. Considering early stages of design, location of washing stations are to be provided in the updated drawings.
					2.3.2. Ammonia spill in the sea.	Environmental	5	-1	High (4)	Same as above	4	-2	Moderate (2)	
					2.3.3. Ammonia spill on deck. Chemical corrosion.	Asset	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					2.3.4. Ammonia spill on deck, human injury.	Injury	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
				2.3.5. Hose failure.	2.3.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	2.3.1. ADS 2.3.2. CCTV 2.3.3. ESD 2.3.12. SOPs 2.3.13. SSL 2.3.14.PMS	6	-2	High (4)	12. Standard Operating Procedures (SOPs) must clearly outline any operational limitations of the ammonia fuel mode/system 36. Considering early stages of design, location of washing stations are to be provided in the updated drawings.

No.: 2 | **Description:** Bunkering Stations

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
														46. Hoses used for fuel transfer must be compatible with the type of fuel and suitable for the specific fuel temperature. Hoses must possess a bursting pressure that is at least five times greater than the maximum pressure experienced during bunkering. 51. Hoses must possess a bursting pressure that is at least five times greater than the maximum pressure experienced during bunkering.
					2.3.2. Ammonia spill in the sea.	Environmental	5	-1	High (4)	Same as above	4	-2	Moderate (2)	
					2.3.3. Ammonia spill on deck. Chemical corrosion.	Asset	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					2.3.4. Ammonia spill on deck, human injury.	Injury	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 2 | **Description:** Bunkering Stations

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
2.4	Toxicity (Ammonia Release)	Collision		2.4.1. Collision	2.4.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	2.4.1. ESD 2.4.2. ERC/BAC-QCDC 2.4.3. OPTS 2.4.4. MV 2x100% 2.4.5. SMS 2.4.6. Standard operating procedure 2.4.7. SSL	6	-2	High (4)	
					2.4.2. Ammonia spill in the sea.	Environmental	5	-1	High (4)	Same as above	4	-2	Moderate (2)	
					2.4.3. Ammonia spill on deck. Chemical corrosion.	Asset	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					2.4.4. Ammonia spill on deck, human injury.	Injury	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
2.5	Toxicity	Dropped object		2.5.1. Dropped Object	2.5.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	2.5.1. ADS 2.5.2. CCTV 2.5.3. ESD 2.5.4. OPTS	6	-2	High (4)	16. Development of a drop object protection program (ABS Guide dropped Object Prevention on Offshore Units and Installations)

No.: 2 | **Description:** Bunkering Stations

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										2.5.5. PP 2.5.6. SOPs 2.5.7. SSL 2.5.8. ERC/BAC-QCDC 2.5.9. MV 2x100%				52. Identify the section of the fuel piping which needs to be protected from a dropped object
					2.5.2. Ammonia spill in the sea.	Environmental	5	-1	High (4)	Same as above	4	-2	Moderate (2)	
					2.5.3. Ammonia spill on deck. Chemical corrosion.	Asset	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					2.5.4. Ammonia spill on deck, human injury.	Injury	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

Company: EMSA, Wartsila, DFDS, Knud E. Hansen		
Title: EMSA NH3, Ro-Pax Study		
Description:		
Method: HAZID	**Type:**	Fuel Storage Tank
Design Intent:		
Comment:		

No.: 3 **Description:** Fuel Storage Tank

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
3.2	Toxicity	Pipe/Connection Leakage		3.2.1. Vibration	3.2.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	3.2.1. ADS 3.2.2. ESD 3.2.3. IAS 3.2.4. IECEx 3.2.5. Material specs 3.2.6. MV (2x100%) 3.2.7.PMS 3.2.8. OPTS 3.2.9. PP 3.2.11. SOPs	6	-2	High (4)	74. Stress analysis considering vibration and fatigue
				3.2.2. Fatigue	3.2.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	3.2.1. ADS 3.2.2. ESD 3.2.3. IAS 3.2.4. IECEx 3.2.5. Material specs 3.2.6. MV (2x100%)	6	-2	High (4)	74. Stress analysis considering vibration and fatigue

No.: 3	**Description:** Fuel Storage Tank													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										3.2.7.PMS 3.2.8. OPTS 3.2.9. PP 3.2.11. SOPs				
				3.2.3. Bad Design	3.2.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	3.2.1. ADS 3.2.2. ESD 3.2.5. Material specs	6	-2	High (4)	75. All inlet and outlet piping connections for the fuel storage tanks must be situated on the outer head of the tank.
				3.2.4. Hull deformation	3.2.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	3.2.1. ADS 3.2.2. ESD 3.2.3. IAS 3.2.4. IECEx 3.2.5. Material specs 3.2.6. MV (2x100%) 3.2.7.PMS 3.2.8. OPTS 3.2.9. PP 3.2.11. SOPs 3.2.12. BOG 3.2.13. CCTV 3.2.14. DF ICE	6	-2	High (4)	74. Stress analysis considering vibration and fatigue 75. All inlet and outlet piping connections for the fuel storage tanks must be situated on the outer head of the tank.

No.: 3 **Description:** Fuel Storage Tank

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										3.2.15. Redundancy 3.2.16. CCTV 3.2.17. FFS 3.2.18. SMS 3.2.19. SSL 3.2.20. SVs				
				3.2.5. Corrosion	3.2.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	3.2.1. ADS 3.2.2. ESD 3.2.5. Material specs	6	-2	High (4)	
				3.2.6. Gasket failure	3.2.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	3.2.1. ADS 3.2.2. ESD 3.2.3. IAS 3.2.4. IECEx 3.2.5. Material specs 3.2.6. MV (2x100%) 3.2.7.PMS 3.2.8. OPTS 3.2.9. PP 3.2.11. SOPs 3.2.12. BOG 3.2.13. CCTV	6	-2	High (4)	

No.: 3	**Description:** Fuel Storage Tank													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										3.2.14. DF ICE 3.2.15. Redundancy				
				3.2.7. Piping expansion	3.2.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	3.2.1. ADS 3.2.2. ESD 3.2.3. IAS 3.2.4. IECEx 3.2.5. Material specs 3.2.7.PMS 3.2.8. OPTS 3.2.9. PP 3.2.12. BOG 3.2.14. DF ICE 3.2.15. Redundancy 3.2.16. CCTV 3.2.17. FFS 3.2.18. SMS 3.2.19. SSL 3.2.20. SVs	6	-2	High (4)	

No.: 3 | **Description:** Fuel Storage Tank

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
3.3	Pressure	Overfilling		3.3.1. Control failure	3.3.2. Over Pressurisation, Boiling Liquid Expanding Vapour Explosion (BLEVE), Tank rupture. Fire. Asset damage.	Asset	5	-1	High (4)	3.3.1. ESD 3.3.8. DF ICE 3.3.12. IAS 3.3.15. OPTS 3.3.18. SOPs 3.3.21. BOG 3.3.22.PMS 3.3.23. SVs	3	-2	Low (1)	78. Evaluate the need of a redundant level transmitter for the fuel tank to ensure the same level of safety with LNG fuel systems. 79. The level transmitter must be able to be replaced without gas freeing the tank and man entry
				3.3.2. Pressure, temperature management.	3.3.2. Over Pressurisation, Boiling Liquid Expanding Vapour Explosion (BLEVE), Tank rupture. Fire. Asset damage.	Asset	5	-1	High (4)	3.3.1. ESD 3.3.8. DF ICE 3.3.12. IAS 3.3.15. OPTS 3.3.21. BOG 3.3.22.PMS 3.3.23. SVs	3	-2	Low (1)	80. Further study is needed to address a full-capacity emergency discharge from the PSVs of ammonia storage tanks. 81. Further study is needed to address a full-capacity emergency discharge from the PSVs of ammonia storage tanks.

No.: 3	**Description:** Fuel Storage Tank													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					3.3.2. Over Pressurisation, Boiling Liquid Expanding Vapour Explosion (BLEVE), Tank rupture. Fire. Asset damage.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
					3.3.2. Over Pressurisation, Boiling Liquid Expanding Vapour Explosion (BLEVE), Tank rupture. Fire. Asset damage.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
3.4	Explosion			3.4.1. Air inside storage tank.	3.4.1. Formation of a combustible atmosphere Presence of air and residual stress causes the formation of SCC	Asset	5	-2	High (3)	3.4.1. OPTS 3.4.3. OPs	4	-2	Moderate (2)	21. Tank purging process to create safe environment for inspection procedures is to be further studied. 82. Pipe routing of pilot fuel is to be provided.

No.: 3	**Description:** Fuel Storage Tank													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														83. Verify that atmospheric control within the ammonia fuel tanks and fuel storage hold spaces are to be arranged in compliance with the requirements in Part 5C, Chapter 13, Section 6/10 of the ABS Rules for Building and Classing Marine Vessels. 84. Consider use of warm ammonia after purging with nitrogen before loading occurs.
				3.4.2. Surrounding area.	3.4.1. Formation of a combustible atmosphere Presence of air and residual stress causes the formation of SCC	Asset	5	-2	High (3)	3.4.4. BOG 3.4.5. DF ICE 3.4.6. ESD 3.4.7. FFS 3.4.8. IAS 3.4.9. IECEx 3.4.10. OPTS 3.4.11. PP 3.4.12. SMS 3.4.13. SOPs	4	-2	Moderate (2)	21. Tank purging process to create safe environment for inspection procedures is to be further studied. 82. Pipe routing of pilot fuel is to be provided. 85. Sampling the bunker line for air existence

No.: 3 **Description:** Fuel Storage Tank

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										3.4.14. SVs				
3.5	Explosion	Overpressurisation		3.5.1. High fuel temperature.	3.5.1. Pressure build up. Tank Rupture	Asset	5	-2	High (3)	3.5.1. BOG 3.5.2. DF ICE 3.5.3. ESD 3.5.5. OPTS 3.5.6. PP 3.5.7. Redundancy 3.5.8. SMS 3.5.9. SOPs 3.5.10. SSL 3.5.11. SVs	4	-2	Moderate (2)	86. Fuel will be used from one tank at a time, and liquefaction will regulate the tank pressure.
				3.5.2. Fill flash	3.5.1. Pressure build up. Tank Rupture	Asset	5	-2	High (3)	3.5.1. BOG 3.5.2. DF ICE 3.5.3. ESD 3.5.4. IAS 3.5.5. OPTS 3.5.6. PP 3.5.7. Redundancy 3.5.8. SMS 3.5.9. SOPs 3.5.10. SSL 3.5.11. SVs	4	-2	Moderate (2)	86. Fuel will be used from one tank at a time, and liquefaction will regulate the tank pressure.

No.: 3 | **Description:** Fuel Storage Tank

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
				3.5.3. Vapour displacement	3.5.1. Pressure build up. Tank Rupture	Asset	5	-2	High (3)	3.5.1. BOG 3.5.2. DF ICE 3.5.3. ESD 3.5.4. IAS 3.5.5. OPTS 3.5.6. PP 3.5.7. Redundancy 3.5.8. SMS 3.5.9. SOPs 3.5.10. SSL 3.5.11. SVs	4	-2	Moderate (2)	86. Fuel will be used from one tank at a time, and liquefaction will regulate the tank pressure.
				3.5.4. Barometric pressure change	3.5.1. Pressure build up. Tank Rupture	Asset	5	-2	High (3)	3.5.1. BOG 3.5.2. DF ICE 3.5.3. ESD 3.5.4. IAS 3.5.5. OPTS 3.5.6. PP 3.5.7. Redundancy 3.5.8. SMS 3.5.9. SOPs 3.5.10. SSL 3.5.11. SVs	4	-2	Moderate (2)	86. Fuel will be used from one tank at a time, and liquefaction will regulate the tank pressure.

No.: 3 **Description:** Fuel Storage Tank

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
				3.5.5. Fire Exposure	3.5.1. Pressure build up. Tank Rupture	Asset	5	-2	High (3)	3.5.1. BOG 3.5.2. DF ICE 3.5.3. ESD 3.5.4. IAS 3.5.5. OPTS 3.5.6. PP 3.5.7. Redundancy 3.5.8. SMS 3.5.9. SOPs 3.5.10. SSL 3.5.11. SVs	4	-2	Moderate (2)	86. Fuel will be used from one tank at a time, and liquefaction will regulate the tank pressure.
				3.5.6. Reliquefaction Plant Failure	3.5.1. Pressure build up. Tank Rupture	Asset	5	-2	High (3)	3.5.1. BOG 3.5.3. ESD 3.5.4. IAS 3.5.9. SOPs 3.5.11. SVs 3.5.12.PMS	4	-2	Moderate (2)	
				3.5.7. Vapour Management Failure	3.5.1. Pressure build up. Tank Rupture	Asset	5	-2	High (3)	3.5.1. BOG 3.5.3. ESD 3.5.4. IAS 3.5.9. SOPs 3.5.11. SVs 3.5.12.PMS	4	-2	Moderate (2)	
				3.5.8. Water Ingress in Vent Mast	3.5.1. Pressure build up. Tank Rupture	Asset	5	-2	High (3)	3.5.4. IAS 3.5.5. OPTS 3.5.9. SOPs 3.5.11. SVs 3.5.12.PMS	4	-2	Moderate (2)	87. Drain is to be provided

No.: 3 **Description:** Fuel Storage Tank

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
3.7	Pressure	Insulation Damage		3.7.1. Insulation damage	3.7.1. Tank heat gain increasing internal pressure	Asset	5	-2	High (3)	3.7.1. Preventive maintenance schedule as provider by the supplier.	3	-2	Low (1)	88. The maintenance plan should include a procedure for periodic inspection of insulation. 89. Develop material handling procedures for machinery and equipment repair and overhaul. 90. Verify that safe means of access for maintenance of equipment and valves in locations beyond man height will be provided in the TCS.
3.8	Fire	External Fire		3.8.1. Impingement from external fire.	3.8.1. Damage to the Tank	Asset	5	-2	High (3)	3.8.1. BOG 3.8.2. DF ICE 3.8.3. ESD 3.8.4. FFS 3.8.5. IAS 3.8.6. OPTS 3.8.7. SMS 3.8.8. SOPs 3.8.9. SVs	3	-2	Low (1)	

No.: 3	**Description:** Fuel Storage Tank													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
3.9	Explosion	External		3.9.1. Explosion in the Tank Connection Space (TCS).	3.9.1. Damage to the Tank	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	91. IGF 4.3: Limitation of explosion consequences "An explosion in any space containing any potential sources of release and potential ignition sources shall not: .1 cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs"

No.: 3	**Description:** Fuel Storage Tank													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
3.10	Maintenance	Error during Maintenance		3.10.1. Ammonia Release.	3.10.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	Same as above	6	-2	High (4)	92. Clarification on the existence of a hatch on the deck above the tank; Manhole in the middle of the thank on top. Clearances are to be further studied . All other connections inside the Tank Connection Space (TCS). 93. Further study to be done on the location of the tank and the surrounding structures. 94. Procedures on gas freeing the ammonia storage tanks are to be developed considering the operational procedures including the deck compartment.

No.: 3	**Description:** Fuel Storage Tank													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														95. Develop material handling procedures for machinery and equipment repair and overhaul. 96. Verify that safe means of access for maintenance of equipment and valves in locations beyond man height will be provided in the TCS.
3.11	Damage	Object dropped upon		3.11.1. Dropped object **Comment:** Any type of object, vehicle or other.	3.11.1. Ammonia release, fire, human injury.	Injury	6	-1	Extreme (5)	Same as above	6	-2	High (4)	97. Identify the section of the fuel piping which needs to be protected from a dropped object 98. Development of a drop object protection program (ABS Guide dropped Object Prevention on Offshore Units and Installations)

No.: 3	**Description:** Fuel Storage Tank													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
3.12	Adverse weather	Unintentional ESD activation due to high-high level alarm in the fuel storage tank		3.12.1. Unintentional ESD activation due to high-high level alarm in the fuel storage tank	3.12.1. AFGSS shutdown Loss of pressure management Loss of ammonia fuel mode Pressure increase inside the storage tank	Asset	4	-2	Moderate (2)	3.12.1. DF ICE 3.12.2. IAS 3.12.3. OPTS 3.12.4. Proven design 3.12.5. SOPs	3	-2	Low (1)	99. Verify the time delay (e.g. to 60 sec) for high-high level alarm for the fuel storage tank (for Seagoing Condition Only).

No.: 3	**Description:** Fuel Storage Tank													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
Company: EMSA, Wartsila, DFDS, Knud E. Hansen														
Title: EMSA NH3, Ro-Pax Study														
Description:														
Method: HAZID	**Type:**	Tank Connection Space												
Design Intent:														
Comment: shell and plate type Ammonia at higher pressure than cooling medium.														

No.: 4	**Description:** Tank Connection Space													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
4.2	Ammonia leakage or accidental release	Loss of containment		4.2.1. Design, fabrication or installation error	4.2.1. Ammonia Release, toxic environment inside Tank Connection Space (TCS), human injury	Injury	4	-3	Low (1)	4.2.1. FAT/HAT/Sat spec 4.2.2. Material specs	3	-2	Low (1)	107. Flanged piping in TCS should be used sparingly. Weld piping is highly recommended instead.

No.: 4							**Description:** Tank Connection Space							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				4.2.2. Abnormal operating condition (exceeding design limits) due to equipment/valve malfunction or operator error	4.2.1. Ammonia Release, toxic environment inside Tank Connection Space (TCS), human injury	Injury	4	-3	Low (1)	4.2.4. ADS 4.2.5. BOG 4.2.6. DF ICE 4.2.7. ESD 4.2.8. IAS 4.2.9. IECEx 4.2.10. OPTS 4.2.11.PMS 4.2.12. PP 4.2.13. Redundancy x% 4.2.14. SOPs 4.2.15. SVs	3	-2	Low (1)	
				4.2.3. Material defect on equipment, pipe, fitting, valve or flange connection	4.2.1. Ammonia Release, toxic environment inside Tank Connection Space (TCS), human injury	Injury	4	-3	Low (1)	4.2.4. ADS 4.2.5. BOG 4.2.6. DF ICE 4.2.7. ESD 4.2.8. IAS 4.2.9. IECEx	3	-2	Low (1)	

No.: 4						**Description:** Tank Connection Space								
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										4.2.10. OPTS 4.2.11.PMS 4.2.12. PP 4.2.13. Redundancy x% 4.2.14. SOPs 4.2.15. SVs				
				4.2.4. Joint failure	4.2.1. Ammonia Release, toxic environment inside Tank Connection Space (TCS), human injury	Injury	4	-3	Low (1)	4.2.4. ADS 4.2.5. BOG 4.2.6. DF ICE 4.2.7. ESD 4.2.8. IAS 4.2.9. IECEx 4.2.10. OPTS 4.2.11.PMS 4.2.12. PP 4.2.13. Redundancy x% 4.2.14. SOPs 4.2.15. SVs	3	-2	Low (1)	107. Flanged piping in TCS should be used sparingly. Weld piping is highly recommended instead.

No.: 4							**Description:** Tank Connection Space							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				4.2.5. Operator error	4.2.1. Ammonia Release, toxic environment inside Tank Connection Space (TCS), human injury	Injury	4	-3	Low (1)	4.2.4. ADS 4.2.5. BOG 4.2.6. DF ICE 4.2.7. ESD 4.2.8. IAS 4.2.9. IECEx 4.2.10. OPTS 4.2.11.PMS 4.2.12. PP 4.2.13. Redundancy x% 4.2.14. SOPs 4.2.15. SVs	3	-2	Low (1)	
				4.2.6. External impact	4.2.1. Ammonia Release, toxic environment inside Tank Connection Space (TCS), human injury	Injury	4	-3	Low (1)	4.2.4. ADS 4.2.5. BOG 4.2.6. DF ICE 4.2.7. ESD 4.2.8. IAS 4.2.9. IECEx	3	-2	Low (1)	112. SOP on entrance to Tank Connection Space (TCS) are to be developed.

No.: 4							**Description:** Tank Connection Space							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										4.2.10. OPTS 4.2.11.PMS 4.2.12. PP 4.2.13. Redundancy x% 4.2.14. SOPs 4.2.15. SVs				113. Development of a drop object protection program (ABS Guide dropped Object Prevention on Offshore Units and Installations)
				4.2.7. Thermal fatigue	4.2.1. Ammonia Release, toxic environment inside Tank Connection Space (TCS), human injury	Injury	4	-3	Low (1)	4.2.4. ADS 4.2.5. BOG 4.2.6. DF ICE 4.2.7. ESD 4.2.8. IAS 4.2.9. IECEx 4.2.10. OPTS 4.2.11.PMS 4.2.12. PP 4.2.13. Redundancy x%	3	-2	Low (1)	114. Procedures on entrance to Tank Connection Space (TCS) are to be developed. 115. The building specifications must define a plan for stress analysis for the ammonia fuel piping.

No.: 4 | **Description:** Tank Connection Space

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										4.2.14. SOPs 4.2.15. SVs				
4.6	Fire	Fire adjacent to Tank Connection Space (TCS)		4.6.1. Leakage from surrounding installations.	4.6.1. Ammonia Release, toxic environment inside Tank Connection Space (TCS), human injury	Injury	5	-2	High (3)	Same as above	3	-2	Low (1)	
					4.6.2. Ammonia Release, flammable environment inside Tank Connection Space (TCS), fire, human injury.	Injury	5	-2	High (3)	Same as above	3	-2	Low (1)	

No.: 4						**Description:** Tank Connection Space								
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					4.6.3. Ammonia Release, flammable environment inside Tank Connection Space (TCS), fire, damage to the hull.	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					4.6.4. Ammonia fuel mode failure	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
4.7	Explosion	Explosion adjacent to Tank Connection Space (TCS)		4.7.1. Fire (see 4.6)	4.7.1. Ammonia Release, toxic environment inside Tank Connection Space (TCS), human injury	Injury	5	-2	High (3)	4.7.1. ADS 4.7.2. BOG 4.7.3. DF ICE 4.7.4. ESD 4.7.5. IAS 4.7.6. IECEx 4.7.7. OPTS 4.7.8.PMS 4.7.9. PP 4.7.10. Redundancy x%	3	-2	Low (1)	

No.: 4	**Description:** Tank Connection Space

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										4.7.11. SOPs 4.7.12. SVs				
					4.7.2. Ammonia Release, flammable environment inside Tank Connection Space (TCS), fire, human injury.	Injury	5	-2	High (3)	Same as above	3	-2	Low (1)	
					4.7.3. Ammonia Release, flammable environment inside Tank Connection Space (TCS), fire, damage to the hull.	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					4.7.4. Ammonia fuel mode failure	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	

No.: 4 | **Description:** Tank Connection Space

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
4.8	Ammonia in liquid form entering fuel lines for gas-phase ammonia	Ammonia Liquid Trap Failure		4.8.1. Mechanical failure	4.8.1. Hydraulic shock, potential for pipe rupture, valve failures, engine damage, etc.	Asset	4	-2	Moderate (2)	4.8.1. BOG 4.8.2. DF ICE 4.8.3. ESD 4.8.4. IAS 4.8.5. IECEx 4.8.6. OPTS 4.8.7.PMS 4.8.8. PP 4.8.9. Redundancy x% 4.8.10. SOPs 4.8.11. SVs	3	-2	Low (1)	
					4.8.2. Fuel system instability, ammonia fuel mode failure.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					4.8.3. Ammonia leakage, toxic environment, human injury	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 4							**Description:** Tank Connection Space							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				4.8.2. Contaminated ammonia.	4.8.1. Hydraulic shock, potential for pipe rupture, valve failures, engine damage, etc.	Asset	4	-2	Moderate (2)	4.8.1. BOG 4.8.2. DF ICE 4.8.3. ESD 4.8.4. IAS 4.8.5. IECEx 4.8.6. OPTS 4.8.7.PMS 4.8.8. PP 4.8.9. Redundancy x% 4.8.10. SOPs 4.8.11. SVs	3	-2	Low (1)	
					4.8.2. Fuel system instability, ammonia fuel mode failure.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					4.8.3. Ammonia leakage, toxic environment, human injury	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 4							**Description:** Tank Connection Space							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				4.8.3. Ammonia Quality - Bunkering Stations (see 2.18)	4.8.1. Hydraulic shock, potential for pipe rupture, valve failures, engine damage, etc.	Asset	4	-2	Moderate (2)	4.8.1. BOG 4.8.2. DF ICE 4.8.3. ESD 4.8.4. IAS 4.8.5. IECEx 4.8.6. OPTS 4.8.7.PMS 4.8.8. PP 4.8.9. Redundancy x% 4.8.10. SOPs 4.8.11. SVs	3	-2	Low (1)	
				4.8.4. Capacity - Bilge System (see 10.2)	4.8.1. Hydraulic shock, potential for pipe rupture, valve failures, engine damage, etc.	Asset	4	-2	Moderate (2)	4.8.1. BOG 4.8.2. DF ICE 4.8.3. ESD 4.8.4. IAS 4.8.5. IECEx 4.8.6. OPTS 4.8.7.PMS 4.8.8. PP	3	-2	Low (1)	

No.: 4 | **Description:** Tank Connection Space

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										4.8.9. Redundancy x% 4.8.10. SOPs 4.8.11. SVs				
4.10	Ammonia	Master Valve failure		4.10.1. Mechanical Failure.	4.10.1. Ammonia fuel mode failure	Asset	4	-1	High (3)	4.10.1. ESD 4.10.2. IAS 4.10.3.PMS 4.10.4. SOPs	3	-2	Low (1)	
				4.10.2. Operator error.	4.10.1. Ammonia fuel mode failure	Asset	4	-1	High (3)	4.10.1. ESD 4.10.2. IAS 4.10.3.PMS 4.10.4. SOPs	3	-2	Low (1)	
				4.10.3. Electrical, Control failure.	4.10.1. Ammonia fuel mode failure	Asset	4	-1	High (3)	4.10.1. ESD 4.10.2. IAS 4.10.3.PMS 4.10.4. SOPs	3	-2	Low (1)	

No.: 4							**Description:** Tank Connection Space							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
4.11	Nitrogen	Trapped nitrogen in the piping		4.11.1. Operator error.	4.11.1. Hazard	Asset	4	-1	High (3)	4.11.1. OPTS 4.11.2.PMS	3	-1	Moderate (2)	124. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
				4.11.2. System control logic failure	4.11.1. Hazard	Asset	4	-1	High (3)	4.11.1. OPTS 4.11.2.PMS	3	-1	Moderate (2)	124. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.

No.: 4	**Description:** Tank Connection Space

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
				4.11.3. Inadequate piping design.	4.11.1. Hazard	Asset	4	-1	High (3)	4.11.1. OPTS 4.11.2.PMS	3	-1	Moderate (2)	124. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
4.12	Cold surface	Exposure to cold surface		4.12.1. Operator error.	4.12.1. Human injury (cryogenic burn)	Injury	4	-1	High (3)	4.12.1. SOPs 4.12.2. CCTV 4.12.3. OPTS 4.12.4. PP	4	-2	Moderate (2)	
				4.12.2. Heat trace system failure.	4.12.1. Human injury (cryogenic burn)	Injury	4	-1	High (3)	4.12.1. SOPs 4.12.5.PMS 4.12.6. IAS	4	-2	Moderate (2)	
4.13	Adverse Weather	Environmental conditions outside operational limits		4.13.1. Extreme (high or low) temperatures.	4.13.1. Ammonia fuel mode loss	Asset	3	-1	Moderate (2)	4.13.2. DF ICE 4.13.3. IAS 4.13.4. OPTS	3	-1	Moderate (2)	

No.: 4						**Description:** Tank Connection Space								
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										4.13.5. SOPs				
4.14	Adverse Weather	Adverse weather interrupting access to the TCS due to vessels extreme responses (pitching, rolling)		4.14.1. Unable to access the TCS due to adverse weather	4.14.1. Delay in emergency response (e.g. fire in the TCS)	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
4.15	Inability to diagnose and resolve system failures	Troubleshooting inability		4.15.1. Lack of training	4.15.1. Ammonia fuel mode loss. Hazardous environment, potential for escalation	General	4	-2	Moderate (2)	4.15.1. IAS 4.15.2. OPTS 4.15.3. SOPs	4	-3	Low (1)	125. Verify the remote access and support for makers (WARTSILA's system has the capability for remote access and support according to the operator's security policy)

No.: 4							**Description:** Tank Connection Space							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														126. According to DFDS's security policy, consider details about access and speed for remote access and support for the AFGSS with WARTSILA. 127. Critical spare parts on board according to OEM recommendations

No.: 4	**Description:** Tank Connection Space

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
				4.15.2. Novel design - system complexity	4.15.1. Ammonia fuel mode loss. Hazardous environment, potential for escalation	General	4	-2	Moderate (2)	4.15.1. IAS 4.15.2. OPTS 4.15.3. SOPs	4	-3	Low (1)	125. Verify the remote access and support for makers (WARTSILA's system has the capability for remote access and support according to the operator's security policy) 126. According to DFDS's security policy, consider details about access and speed for remote access and support for the AFGSS with WARTSILA.

No.: 4	**Description:** Tank Connection Space

Item	Hazard/ Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
														127. Critical spare parts on board according to OEM recommendations
				4.15.3. Poor documentation or instrumentation	4.15.1. Ammonia fuel mode loss. Hazardous environment, potential for escalation	General	4	-2	Moderate (2)	4.15.1. IAS 4.15.2. OPTS 4.15.3. SOPs	4	-3	Low (1)	125. Verify the remote access and support for makers (WARTSILA's system has the capability for remote access and support according to the operator's security policy)

No.: 4							**Description:** Tank Connection Space							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														126. According to DFDS's security policy, consider details about access and speed for remote access and support for the AFGSS with WARTSILA. 127. Critical spare parts on board according to OEM recommendations
4.16	Fire/Explosion	Hot Works with ammonia present		4.16.1. Operators error	4.16.1. Ammonia Release, fire, human injury.	Injury	5	-2	High (3)	4.16.1. CCtv 4.16.2. FFS 4.16.3. OPTS 4.16.4. SOPs 4.16.5. PPE	5	-3	Moderate (2)	

No.: 4							**Description:** Tank Connection Space							
Item	**Hazard/ Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					4.16.2. Ammonia Release, fire, damage to the vessel.	Asset	5	-2	High (3)	Same as above	5	-3	Moderate (2)	

Company: EMSA, Wartsila, DFDS, Knud E. Hansen		
Title: EMSA NH3, Ro-Pax Study		
Description:		
Method: HAZID	**Type:**	Fuel Supply to the Consumers
Design Intent:		
Comment:		

No.: 5 **Description:** Fuel Supply to the Consumers

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
5.2	Loss of containment			5.2.1. Design, fabrication or installation error	5.2.1. General	Asset	4	-2	Moderate (2)	5.2.1. FAT/HAT/SAT Spec 5.2.2. Material spec 5.2.3. Proven design 5.2.4. Heat-traced ammonia gas supply line. 5.2.5. Gas vent lines leading to WARMS. 5.2.6. Drain pot fitted with level switch on fuel supply line before GVU.	3	-2	Low (1)	134. Clarify if additional measures for preventing the ammonia fuel supply piping from being damaged by vibration from the TCS to Engine Room. Or consider carrying out gas dispersion study to ensure that flammable gas will not reach to safe areas (e.g. accommodation), in case of ammonia leakage between the aforementioned compartments.

No.: 5	**Description:** Fuel Supply to the Consumers													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										5.2.7. Monitoring of fuel pipe wall temperature. Monitoring of fuel pressure. ESD and automatic purging in case of abnormal operating conditions.				

Company: EMSA, Wartsila, DFDS, Knud E. Hansen		
Title: EMSA NH3, Ro-Pax Study		
Description:		
Method: HAZID	**Type:**	Engine Rooms
Design Intent:		
Comment:		

No.: 6 | **Description:** Engine Rooms

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
6.25	Exhaust gas leakage from expansion below			6.25.1. General	6.25.1. Potential for ammonia leakage in the engine room as exhaust gas content.	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	159. Further studies to performed to define the position of gas detectors in the exhaust gas piping casing.
6.26	Inability to diagnose and resolve system failures	Troubleshooting inability		6.26.1. Novel design - system complexity	6.26.1. Ammonia fuel mode loss, Hazardous environment, potential for escalation	General	4	-2	Moderate (2)	Same as above	4	-3	Low (1)	160. Verify the remote access and support for makers (WARTSILA's system has the capability for remote access and support according to the operator's security policy)

No.: 6	**Description:** Engine Rooms													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														161. According to DFDS's security policy, consider details about access and speed for remote access and support for the AFGSS with WARTSILA. 162. Critical spare parts on board according to OEM recommendations
				6.26.2. Lack of training	6.26.1. Ammonia fuel mode loss, Hazardous environment, potential for escalation	General	4	-2	Moderate (2)	Same as above	4	-3	Low (1)	160. Verify the remote access and support for makers (WARTSILA's system has the capability for remote access and support according to the operator's security policy)

No.: 6	**Description:** Engine Rooms													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														161. According to DFDS's security policy, consider details about access and speed for remote access and support for the AFGSS with WARTSILA. 162. Critical spare parts on board according to OEM recommendations
				6.26.3. Poor documentation on or instrumentation	6.26.1. Ammonia fuel mode loss, Hazardous environment, potential for escalation	General	4	-2	Moderate (2)	Same as above	4	-3	Low (1)	160. Verify the remote access and support for makers (WARTSILA's system has the capability for remote access and support according to the operator's security policy)

No.: 6 | **Description:** Engine Rooms

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
														161. According to DFDS's security policy, consider details about access and speed for remote access and support for the AFGSS with WARTSILA. 162. Critical spare parts on board according to OEM recommendations

Company: EMSA, Wartsila, DFDS, Knud E. Hansen		
Title: EMSA NH3, Ro-Pax Study		
Description:		
Method: HAZID	**Type:**	Venting
Design Intent:		
Comment:		

No.: 7 | **Description:** Venting

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
7.3	Ammonia Release	Vent Mast Release			7.3.1. Toxic environment, human injury	Injury	4	-1	High (3)	7.3.1. ADS 7.3.2. BOG 7.3.3. ESD 7.3.4. IAS 7.3.5. OPTS 7.3.6.PMS 7.3.7. PP 7.3.8. SOPs	3	-2	Low (1)	172. Further study to be done on the (adequate) volume sizing of the buffer tank. The tank must be capable of receiving ammonia in the case of an ESD - this represents the worst-case scenario in terms of trapped liquid ammonia in the piping. 173. To mitigate the dispersion of ammonia vapours from the vent mast, the installation of a gas detection alarm sensor together with a water spray system should be considered.

No.: 7 | **Description:** Venting

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
7.4	Ammonia Release (Port)	Vent Mast Release		7.4.1. ARMS tank overpressurisation	7.4.1. Toxic environment, human injury	Injury	4	-1	High (3)	7.4.1. Redundancy x% 7.4.2. BOG 7.4.3. ESD 7.4.4. IAS 7.4.5. OPTS 7.4.6.PMS 7.4.7. PP 7.4.8. SOPs	3	-2	Low (1)	174. Further study to be done on the possible release of ammonia through the vent system. Study should consider port related matters (legislation, restrictions etc. 175. SOPs must include clear procedures for the pilot to board the vessel, considering the dispersion analysis and the risks associated with ammonia.
				7.4.2. Fuel Tank overpressurszation	7.4.1. Toxic environment, human injury	Injury	4	-1	High (3)	7.4.1. Redundancy x% 7.4.2. BOG 7.4.3. ESD 7.4.4. IAS 7.4.5. OPTS 7.4.6.PMS 7.4.7. PP 7.4.8. SOPs	3	-2	Low (1)	174. Further study to be done on the possible release of ammonia through the vent system. Study should consider port related matters (legislation, restrictions etc. 175. SOPs must include clear procedures for the pilot to board the vessel, considering the dispersion analysis and the risks associated with ammonia.

No.: 7	**Description:** Venting													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				7.4.3. Pressure Safety Valve (PSV) malfunction	7.4.1. Toxic environment, human injury	Injury	4	-1	High (3)	7.4.1. Redundancy x% 7.4.2. BOG 7.4.3. ESD 7.4.4. IAS 7.4.5. OPTS 7.4.6.PMS 7.4.7. PP 7.4.8. SOPs	3	-2	Low (1)	174. Further study to be done on the possible release of ammonia through the vent system. Study should consider port related matters (legislation, restrictions etc. 175. SOPs must include clear procedures for the pilot to board the vessel, considering the dispersion analysis and the risks associated with ammonia.
				7.4.4. WARMS malfunction	7.4.1. Toxic environment, human injury	Injury	4	-1	High (3)	7.4.1. Redundancy x% 7.4.2. BOG 7.4.3. ESD 7.4.4. IAS 7.4.5. OPTS 7.4.6.PMS 7.4.7. PP 7.4.8. SOPs	3	-2	Low (1)	174. Further study to be done on the possible release of ammonia through the vent system. Study should consider port related matters (legislation, restrictions etc. 175. SOPs must include clear procedures for the pilot to board the vessel, considering the dispersion analysis and the risks associated with ammonia.

No.: 7 **Description:** Venting

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
7.5	Ammonia Release (Port)	Vent mast release during embarkation, disembarkation			7.5.1. Toxic environment, human injury	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	176. SIMOPS **Comment:** Comment: Matters to be discussed during a SIMOPS study: 1. Interaction with bunker vessel. 2. Types of bunker vessels to be used for this design. 3. Operational procedures and required time for each process. 4. Action in case of a fire. Possible presence of tugboat(s). 5. Embarkation/Disembarkation procedures during bunkering 6. Bunkering temperature range. 177. Dispersion analysis is to be taken into account in the design of the vessel and the embarkation/disembarkation procedures.
7.6	Ammonia Release (Bunkering)	Vent mast release during bunkering		7.6.1. ARMS tank overpressurisation	7.6.1. Toxic environment, human injury	Injury	4	-1	High (3)	7.6.1. Redundancy x% 7.6.2. BOG 7.6.3. ESD 7.6.4. IAS 7.6.5. OPTS	3	-2	Low (1)	

No.: 7	**Description:** Venting													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										7.6.6.PMS 7.6.7. PP 7.6.8. SOPs 7.6.9. SSL				
				7.6.2. Fuel Tank overpressurisation	7.6.1. Toxic environment, human injury	Injury	4	-1	High (3)	7.6.1. Redundancy x% 7.6.2. BOG 7.6.3. ESD 7.6.4. IAS 7.6.5. OPTS 7.6.6.PMS 7.6.7. PP 7.6.8. SOPs 7.6.9. SSL	3	-2	Low (1)	
				7.6.3. Pressure Safety Valve (PSV) malfunction	7.6.1. Toxic environment, human injury	Injury	4	-1	High (3)	7.6.1. Redundancy x% 7.6.2. BOG 7.6.3. ESD 7.6.4. IAS 7.6.5. OPTS 7.6.6.PMS 7.6.7. PP 7.6.8. SOPs 7.6.9. SSL	3	-2	Low (1)	

No.: 7 | **Description:** Venting

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
				7.6.4. WARMS malfunction	7.6.1. Toxic environment, human injury	Injury	4	-1	High (3)	7.6.1. Redundancy x% 7.6.2. BOG 7.6.3. ESD 7.6.4. IAS 7.6.5. OPTS 7.6.6.PMS 7.6.7. PP 7.6.8. SOPs 7.6.9. SSL	3	-2	Low (1)	
7.8	Ammonia Release	WARMS Leakage		7.8.1. Manufacturing or installation defect	7.8.1. Failure to neutralize ammonia. Toxic environment, human exposure. Potential for fire or explosion	Asset	5	-1	High (4)	7.8.1. BOG 7.8.2. ESD 7.8.3. IAS 7.8.4. OPTS 7.8.5.PMS 7.8.6. Redundancy x% 7.8.7. SOPs	3	-2	Low (1)	17. Maintenance procedures are to be provided in the operational manual 178. Further study to be done on the available option to vent trapped ammonia in the system in case of a WARMS malfunction. Possibility to have a controlled manual venting directly to the vent mast. 179. Further study to be done on the gas detection in the WARMS room and the subsequent action including the operational status of the burner.

No.: 7	**Description:** Venting													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				7.8.2. Material degradation/corrosion	7.8.1. Failure to neutralize ammonia. Toxic environment, human exposure. Potential for fire or explosion	Asset	5	-1	High (4)	7.8.1. BOG 7.8.2. ESD 7.8.3. IAS 7.8.4. OPTS 7.8.5.PMS 7.8.6. Redundancy x% 7.8.7. SOPs	3	-2	Low (1)	17. Maintenance procedures are to be provided in the operational manual 178. Further study to be done on the available option to vent trapped ammonia in the system in case of a WARMS malfunction. Possibility to have a controlled manual venting directly to the vent mast. 179. Further study to be done on the gas detection in the WARMS room and the subsequent action including the operational status of the burner.
				7.8.3. Weld or structural failure	7.8.1. Failure to neutralize ammonia. Toxic environment, human exposure. Potential for fire or explosion	Asset	5	-1	High (4)	7.8.1. BOG 7.8.2. ESD 7.8.3. IAS 7.8.4. OPTS 7.8.5.PMS 7.8.6. Redundancy x% 7.8.7. SOPs	3	-2	Low (1)	17. Maintenance procedures are to be provided in the operational manual 178. Further study to be done on the available option to vent trapped ammonia in the system in case of a WARMS malfunction. Possibility to have a controlled manual venting directly to the vent mast.

No.: 7	**Description:** Venting													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														179. Further study to be done on the gas detection in the WARMS room and the subsequent action including the operational status of the burner.
				7.8.4. Seal/Gasket failure	7.8.1. Failure to neutralize ammonia. Toxic environment, human exposure. Potential for fire or explosion	Asset	5	-1	High (4)	7.8.1. BOG 7.8.2. ESD 7.8.3. IAS 7.8.4. OPTS 7.8.5.PMS 7.8.6. Redundancy x% 7.8.7. SOPs	3	-2	Low (1)	17. Maintenance procedures are to be provided in the operational manual 178. Further study to be done on the available option to vent trapped ammonia in the system in case of a WARMS malfunction. Possibility to have a controlled manual venting directly to the vent mast. 179. Further study to be done on the gas detection in the WARMS room and the subsequent action including the operational status of the burner.

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Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				7.8.5. Valve or connection failure	7.8.1. Failure to neutralize ammonia. Toxic environment, human exposure. Potential for fire or explosion	Asset	5	-1	High (4)	7.8.1. BOG 7.8.2. ESD 7.8.3. IAS 7.8.4. OPTS 7.8.5.PMS 7.8.6. Redundancy x% 7.8.7. SOPs	3	-2	Low (1)	17. Maintenance procedures are to be provided in the operational manual 178. Further study to be done on the available option to vent trapped ammonia in the system in case of a WARMS malfunction. Possibility to have a controlled manual venting directly to the vent mast. 179. Further study to be done on the gas detection in the WARMS room and the subsequent action including the operational status of the burner.
				7.8.6. Impact damage	7.8.1. Failure to neutralize ammonia. Toxic environment, human exposure. Potential for fire or explosion	Asset	5	-1	High (4)	7.8.1. BOG 7.8.2. ESD 7.8.3. IAS 7.8.4. OPTS 7.8.5.PMS 7.8.6. Redundancy x% 7.8.7. SOPs	3	-2	Low (1)	17. Maintenance procedures are to be provided in the operational manual 178. Further study to be done on the available option to vent trapped ammonia in the system in case of a WARMS malfunction. Possibility to have a controlled manual venting directly to the vent mast.

No.: 7 | **Description:** Venting

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
														179. Further study to be done on the gas detection in the WARMS room and the subsequent action including the operational status of the burner. 180. Identify the section of the fuel piping which needs to be protected from a dropped object 181. Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)
7.9	Ammonia Release	WARMS Malfunction (other than leakage)		7.9.1. Combustion air fan failure	7.9.1. Failure to neutralize ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	182. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
					7.9.2. Ammonia discharge	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.3. Trapped ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.4. Human injury	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 7 | **Description:** Venting

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
					7.9.5. Ammonia in car deck.	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.6. Ammonia in accommodation area. Potential for fire or explosion. Ammonia fuel mode failure	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
				7.9.2. WARMS fan module failure	7.9.1. Failure to neutralize ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	182. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
					7.9.2. Ammonia discharge	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.3. Trapped ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.4. Human injury	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.5. Ammonia in car deck.	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 7	**Description:** Venting													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					7.9.6. Ammonia in accommodation area. Potential for fire or explosion. Ammonia fuel mode failure	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
				7.9.3. Mechanical failure	7.9.1. Failure to neutralize ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	182. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
					7.9.2. Ammonia discharge	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.3. Trapped ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.4. Human injury	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.5. Ammonia in car deck.	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 7	**Description:** Venting													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					7.9.6. Ammonia in accommodation area. Potential for fire or explosion. Ammonia fuel mode failure	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
				7.9.4. Electrical failure	7.9.1. Failure to neutralize ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	182. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
					7.9.2. Ammonia discharge	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.3. Trapped ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.4. Human injury	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.5. Ammonia in car deck.	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 7 **Description:** Venting

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
					7.9.6. Ammonia in accommodation area. Potential for fire or explosion. Ammonia fuel mode failure	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
				7.9.5. Control System failure	7.9.1. Failure to neutralize ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	182. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
					7.9.2. Ammonia discharge	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.3. Trapped ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.4. Human injury	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.5. Ammonia in car deck.	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 7	**Description:** Venting													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					7.9.6. Ammonia in accommodation area. Potential for fire or explosion. Ammonia fuel mode failure	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
				7.9.6. Sensors malfunction	7.9.1. Failure to neutralize ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	182. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
					7.9.2. Ammonia discharge	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.3. Trapped ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.4. Human injury	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.5. Ammonia in car deck.	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 7 **Description:** Venting

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
					7.9.6. Ammonia in accommodation area. Potential for fire or explosion. Ammonia fuel mode failure	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
				7.9.7. Blocked/restricted flow	7.9.1. Failure to neutralize ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	182. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
					7.9.2. Ammonia discharge	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.3. Trapped ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.4. Human injury	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.5. Ammonia in car deck.	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

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Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					7.9.6. Ammonia in accommodation area. Potential for fire or explosion. Ammonia fuel mode failure	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
				7.9.8. Extreme environmental conditions	7.9.1. Failure to neutralize ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	182. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
					7.9.2. Ammonia discharge	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.3. Trapped ammonia	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.4. Human injury	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.5. Ammonia in car deck.	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 7	**Description:** Venting													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					7.9.6. Ammonia in accommodation area. Potential for fire or explosion. Ammonia fuel mode failure	General	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
7.11	Water Ingress	Vent Mast		7.11.1. Weather	7.11.1. Blockage of vent mast	Asset	3	-2	Low (1)	7.11.1. BOG 7.11.2. OPTS 7.11.3. SOPs	3	-2	Low (1)	184. Identify the section of the fuel piping which needs to be protected from a dropped object 185. Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)

Company: EMSA, Wartsila, DFDS, Knud E. Hansen		
Title: EMSA NH3, Ro-Pax Study		
Description:		
Method: HAZID	**Type:**	Ventilation
Design Intent:		
Comment:		

No.: 8 **Description:** Ventilation

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
8.1	Design			8.1.1. Inadequate ventilation system design/operation.	8.1.1. Toxic environment	Asset	4	-2	Moderate (2)	8.1.1. Redundancy x%	3	-2	Low (1)	189. Further study to be done on ventilation inlets and outlets locations.

No.: 8 | **Description:** Ventilation

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
														190. An assessment will be conducted to evaluate a potential leakage scenario, taking the following factors into consideration: -The potential impact it would have on the effectiveness of the ventilation system. -The maximum distance between the safe haven and ammonia release sources, such as vent masts and ventilation outlets, should be clearly defined. -The optimal placement of ventilation inlets to prevent the entry of ammonia.

No.: 8	**Description:** Ventilation													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														191. Further study to be done on the necessity of having mechanical ventilation in combination with gas measurement. 192. Ventilation system analysis should examine the importance for all rooms. In particular the criticality with the WARMS room is to be assessed. 193. For ventilation of critical components room use of demister filters is to be further studied. **Comment:** Not obligatory by the rules

No.: 8	**Description:** Ventilation													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														194. Install a water spray system to cover the area around ventilation openings, reducing the spread of ammonia vapours on the deck. 195. Allow for manual closure of ventilation inlets from within the safe haven. 196. Install gas detectors at the ventilation inlets.

No.: 8	**Description:** Ventilation													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														197. For ventilation outlets, the IBC Code Chapter 17 column "o" specifies that ventilation openings from pump rooms containing toxic cargoes must comply with Section 15.17 regarding toxic cargoes, as outlined in Section 10 [2.3.1].

No.: 8	**Description:** Ventilation													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														198. Conduct dispersion analyses for worst-case scenarios, such as full venting from tank safety valves and the ventilation of large volumes of gas due to maximum probable leakage from the ventilation system openings to maintain minimum safe distances. 199. Revise the gas dispersion study for the engine room using suitable assumptions, such as fuel composition, and illustrate the ventilation strategy and placement of gas detectors according to the gas dispersion study results.

No.: 8	**Description:** Ventilation													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
8.5	Accumulation of ammonia vapours	Ventilation failure for Tank Connection Space (TCS)		8.5.1. Mechanical failure	8.5.1. Toxic environment, human injury. Potential for fire or explosion. Ammonia fuel mode failure	Asset	4	-1	High (3)	8.5.1. Material specs 8.5.2. ADS 8.5.3. BOG 8.5.4. DF ICE 8.5.5. ESD 8.5.6. IAS 8.5.7. OPTS 8.5.8. PP 8.5.9.PMS 8.5.11. Redundancy x% 8.5.12. SOPs 8.5.13. Material specs	3	-2	Low (1)	
				8.5.2. Electrical failure	8.5.1. Toxic environment, human injury. Potential for fire or explosion. Ammonia fuel mode failure	Asset	4	-1	High (3)	8.5.1. Material specs 8.5.2. ADS 8.5.3. BOG 8.5.4. DF ICE 8.5.5. ESD 8.5.6. IAS 8.5.7. OPTS 8.5.8. PP 8.5.9.PMS 8.5.11. Redundancy x%	3	-2	Low (1)	

No.: 8	**Description:** Ventilation													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										8.5.12. SOPs 8.5.13. Material specs				
				8.5.3. Power failure	8.5.1. Toxic environment, human injury. Potential for fire or explosion. Ammonia fuel mode failure	Asset	4	-1	High (3)	8.5.1. Material specs 8.5.2. ADS 8.5.3. BOG 8.5.4. DF ICE 8.5.5. ESD 8.5.6. IAS 8.5.7. OPTS 8.5.8. PP 8.5.9.PMS 8.5.11. Redundancy x% 8.5.12. SOPs 8.5.13. Material specs	3	-2	Low (1)	
				8.5.4. Blocked inlet	8.5.1. Toxic environment, human injury. Potential for fire or explosion. Ammonia fuel mode failure	Asset	4	-1	High (3)	8.5.1. Material specs 8.5.2. ADS 8.5.3. BOG 8.5.4. DF ICE 8.5.5. ESD 8.5.6. IAS 8.5.7. OPTS	3	-2	Low (1)	

No.: 8	**Description:** Ventilation													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										8.5.8. PP 8.5.9.PMS 8.5.11. Redundancy x% 8.5.12. SOPs 8.5.13. Material specs				
				8.5.5. Blocked outlet	8.5.1. Toxic environment, human injury. Potential for fire or explosion. Ammonia fuel mode failure	Asset	4	-1	High (3)	8.5.1. Material specs 8.5.2. ADS 8.5.3. BOG 8.5.4. DF ICE 8.5.5. ESD 8.5.6. IAS 8.5.7. OPTS 8.5.8. PP 8.5.9.PMS 8.5.11. Redundancy x% 8.5.12. SOPs 8.5.13. Material specs	3	-2	Low (1)	

No.: 8	**Description:** Ventilation													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
8.7	Accumulation of ammonia vapours	Ventilation failure for NH3 equipment room		8.7.1. Mechanical failure	8.7.1. Toxic environment, human injury. Potential for fire or explosion	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	202. Further study to be done on the classification of the nitrogen room as gas tight. **Comment:** Nitrogen not ammonia
					8.7.2. Restricted operation	General	4	-1	High (3)	Same as above	3	-2	Low (1)	
					8.7.3. Purging system loss, trip to diesel.	General	4	-1	High (3)	Same as above	3	-2	Low (1)	
				8.7.2. Electrical failure	8.7.1. Toxic environment, human injury. Potential for fire or explosion	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	202. Further study to be done on the classification of the nitrogen room as gas tight. **Comment:** Nitrogen not ammonia
				8.7.3. Power failure	8.7.1. Toxic environment, human injury. Potential for fire or explosion	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	202. Further study to be done on the classification of the nitrogen room as gas tight. **Comment:** Nitrogen not ammonia

No.: 8	**Description:** Ventilation													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				8.7.4. Blocked inlet	8.7.1. Toxic environment, human injury. Potential for fire or explosion	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	202. Further study to be done on the classification of the nitrogen room as gas tight. **Comment:** Nitrogen not ammonia
				8.7.5. Blocked outlet	8.7.1. Toxic environment, human injury. Potential for fire or explosion	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	202. Further study to be done on the classification of the nitrogen room as gas tight. **Comment:** Nitrogen not ammonia

Company: EMSA, Wartsila, DFDS, Knud E. Hansen		
Title: EMSA NH3, Ro-Pax Study		
Description:		
Method: HAZID	**Type:**	Purging System
Design Intent:		
Comment: Nitrogen only for purging and controlling annular space in double wall pipes. Also, from the burner in the WARMS room. Not for hydraulic (valve control) use.		

No.: 9 | **Description:** Purging System

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
9.3	Nitrogen Release	Loss of Containment		9.3.1. Mechanical failure	9.3.1. No/Inadequate nitrogen supply.	General	4	-1	High (3)	9.3.1. ADS 9.3.2. DF ICE 9.3.3. ESD 9.3.4. IAS 9.3.5. MV (2x100%) 9.3.6. OPTS 9.3.7.PMS 9.3.9. Redundancy x% 9.3.10. SOPs	3	-2	Low (1)	207. Further study to be done on the avoidance of having nitrogen spreading to adjacent compartments 209. Assess the necessity of a continuous oxygen monitoring system for nitrogen-supported compartments to mitigate risks related to asphyxiation from

No.: 9	**Description:** Purging System

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
					9.3.2. Hazardous atmosphere, potential for injury or death.	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	
				9.3.2. Abnormal operation	9.3.1. No/Inadequate nitrogen supply.	General	4	-1	High (3)	9.3.1. ADS 9.3.2. DF ICE 9.3.3. ESD 9.3.4. IAS 9.3.5. MV (2x100%) 9.3.6. OPTS 9.3.7.PMS 9.3.9. Redundancy x% 9.3.10. SOPs	3	-2	Low (1)	207. Further study to be done on the avoidance of having nitrogen spreading to adjacent compartments
					9.3.2. Hazardous atmosphere, potential for injury or death.	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	
				9.3.3. Material defect	9.3.1. No/Inadequate nitrogen supply.	General	4	-1	High (3)	9.3.1. ADS 9.3.2. DF ICE 9.3.3. ESD 9.3.4. IAS 9.3.5. MV (2x100%) 9.3.6. OPTS 9.3.7.PMS	3	-2	Low (1)	207. Further study to be done on the avoidance of having nitrogen spreading to adjacent compartments

No.: 9 | **Description:** Purging System

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										9.3.9. Redundancy x% 9.3.10. SOPs				
					9.3.2. Hazardous atmosphere, potential for injury or death.	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	
				9.3.4. Operator error	9.3.1. No/Inadequate nitrogen supply.	General	4	-1	High (3)	9.3.1. ADS 9.3.2. DF ICE 9.3.3. ESD 9.3.4. IAS 9.3.5. MV (2x100%) 9.3.6. OPTS 9.3.7.PMS 9.3.9. Redundancy x% 9.3.10. SOPs	3	-2	Low (1)	207. Further study to be done on the avoidance of having nitrogen spreading to adjacent compartments
					9.3.2. Hazardous atmosphere, potential for injury or death.	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	

No.: 9	**Description:** Purging System													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				9.3.5. External impact	9.3.1. No/Inadequate nitrogen supply.	General	4	-1	High (3)	9.3.1. ADS 9.3.2. DF ICE 9.3.3. ESD 9.3.4. IAS 9.3.5. MV (2x100%) 9.3.6. OPTS 9.3.7.PMS 9.3.9. Redundancy x% 9.3.10. SOPs	3	-2	Low (1)	207. Further study to be done on the avoidance of having nitrogen spreading to adjacent compartments
					9.3.2. Hazardous atmosphere, potential for injury or death.	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	
				9.3.6. Thermal stress	9.3.1. No/Inadequate nitrogen supply.	General	4	-1	High (3)	9.3.1. ADS 9.3.2. DF ICE 9.3.3. ESD 9.3.4. IAS 9.3.5. MV (2x100%) 9.3.6. OPTS 9.3.7.PMS 9.3.9. Redundancy x% 9.3.10. SOPs	3	-2	Low (1)	207. Further study to be done on the avoidance of having nitrogen spreading to adjacent compartments

No.: 9 | **Description:** Purging System

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
				9.3.7. Design, fabrication or installation error	9.3.1. No/Inadequate nitrogen supply.	General	4	-1	High (3)	9.3.11. FAT/HAT/SAT spec	3	-2	Low (1)	207. Further study to be done on the avoidance of having nitrogen spreading to adjacent compartments
9.5	High-pressure nitrogen	Overpressure in Nitrogen Generator		9.5.1. Equipment malfunction	9.5.1. Damage of nitrogen generator. Damage to piping or buffer tank. Purging capacity lost.	Asset	4	-1	High (3)	9.5.1. ADS 9.5.2. DF ICE 9.5.3. ESD 9.5.4. IAS 9.5.5. Material specs 9.5.6. MV (2x100%) 9.5.7. OPTS 9.5.8.PMS 9.5.9. PP 9.5.11. Redundancy x% 9.5.12. SOPs 9.5.13. SVs	3	-2	Low (1)	

No.: 9	**Description:** Purging System													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
9.6	High-pressure nitrogen	Buffer Tank Overpressure		9.6.1. Blocked, malfunctioned Pressure Relief Valve (PRV). 9.6.2. Failed nitrogen supply regulation	9.6.1. Malfunction of pressure regulation system. Excessive nitrogen supply. Thermal expansion due to external heat sources	Asset	4	-1	High (3)	9.6.1. ADS 9.6.2. DF ICE 9.6.3. ESD 9.6.4. IAS 9.6.5. Material specs 9.6.6. MV (2x100%) 9.6.7. OPTS 9.6.8.PMS 9.6.9. PP 9.6.11. Redundancy x% 9.6.12. SOPs 9.6.13. SVs	3	-2	Low (1)	
9.7	Low-pressure nitrogen	Buffer Tank Underpressure		9.7.1. Rapid nitrogen consumption exceeding supply.	9.7.1. Loss of buffer tank pressure, back flow from other system components.	Asset	4	-1	High (3)	9.7.1. ADS 9.7.2. DF ICE 9.7.3. ESD 9.7.4. IAS 9.7.5. Material specs 9.7.6. MV (2x100%) 9.7.7. OPTS 9.7.8.PMS 9.7.9. PP 9.7.11. Redundancy x%	3	-2	Low (1)	211. The building specifications must define a plan for stress analysis for the buffer tank.

No.: 9	**Description:** Purging System													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										9.7.12. SOPs 9.7.13. SVs				212. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
				9.7.2. Pressure Relief Valve (PRV) malfunction.	9.7.1. Loss of buffer tank pressure, back flow from other system components.	Asset	4	-1	High (3)	9.7.1. ADS 9.7.2. DF ICE 9.7.3. ESD 9.7.4. IAS 9.7.5. Material specs 9.7.6. MV (2x100%) 9.7.7. OPTS 9.7.8.PMS 9.7.9. PP 9.7.11. Redundancy x% 9.7.12. SOPs 9.7.13. SVs	3	-2	Low (1)	211. The building specifications must define a plan for stress analysis for the buffer tank. 212. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.

No.: 9	**Description:** Purging System													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				9.7.3. Operator error.	9.7.1. Loss of buffer tank pressure, back flow from other system components.	Asset	4	-1	High (3)	9.7.1. ADS 9.7.2. DF ICE 9.7.3. ESD 9.7.4. IAS 9.7.5. Material specs 9.7.6. MV (2x100%) 9.7.7. OPTS 9.7.8.PMS 9.7.9. PP 9.7.11. Redundancy x% 9.7.12. SOPs 9.7.13. SVs	3	-2	Low (1)	211. The building specifications must define a plan for stress analysis for the buffer tank. 212. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
				9.7.4. Drainage valve malfunction.	9.7.1. Loss of buffer tank pressure, back flow from other system components.	Asset	4	-1	High (3)	9.7.1. ADS 9.7.2. DF ICE 9.7.3. ESD 9.7.4. IAS 9.7.5. Material specs 9.7.6. MV (2x100%) 9.7.7. OPTS 9.7.8.PMS 9.7.9. PP 9.7.11. Redundancy x%	3	-2	Low (1)	211. The building specifications must define a plan for stress analysis for the buffer tank.

No.: 9	**Description:** Purging System

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										9.7.12. SOPs 9.7.13. SVs				212. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.

Company: EMSA, Wartsila, DFDS, Knud E. Hansen		
Title: EMSA NH3, Ro-Pax Study		
Description:		
Method: HAZID	**Type:**	Bilge System
Design Intent:		
Comment: System is expected to have minimum operation.		

No.: 10	**Description:** Bilge System

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
10.1	Design			10.1.1. General	10.1.1. General	Asset	4	-1	High (3)	10.1.1. FAT/HAT/SAT spec 10.1.2. Material spec	3	-2	Low (1)	216. Capacity and routing of the bilge system is to be provided. 217. Further study to be done on the position of the suction valves to allow for remote operation, taking into consideration that the bilge system area is considered a hazardous area.

No.: 10 | **Description:** Bilge System

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
														218. Venting of the bilge tank to ARMS is to be reconsidered due to potential pressure levels in the buffer tank. Consider double isolation between the two systems. 219. Bilge ventilation system is to be designed independently, with a preferred venting to open air. Also. isolation from any ammonia components is to be preferred.

No.: 10	**Description:** Bilge System													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														220. ABS Ammonia Fueled Vessels, Sep 2023 Sec 5-8.4 The drainage system is to be sized to remove not less than 125% of the capacity of either the water screen, deluge or water spray system, whichever has the greater capacity.

No.: 10	**Description:** Bilge System													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														221. According to GHS, ammonia is classified as toxic to aquatic life with long-lasting environmental effects. Therefore: - Discharging ammonia spills into the sea or allowing ammonia vapour to escape underwater must be strictly avoided. Containment on board is preferred. - Releasing ammonia into the sea has severe environmental consequences and must be prevented.

No.: 10	**Description:** Bilge System													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														222. ABS Ammonia Fueled Vessels, Sep 2023 Sec 5-8.5 Dissolved ammonia (i.e. aqueous ammonia with concentration 28% or less) collected in the drain tank(s) may be discharged at sea complying with the standards and operational procedures required in MARPOL 73/78, Annex II.
10.2	Capacity			10.2.1. General	10.2.1. Ammonia Liquid Trap Failure - Tank Connection Space (see 4.7)	Injury	4	-1	High (3)	10.2.1. IAS 10.2.2. OPTS 10.2.3.PMS 10.2.4. Material specs 10.2.5. Redundancy x% 10.2.6. SOPs 10.2.7. DF ICE	3	-2	Low (1)	223. Study is to be conducted on the capacity and capabilities of the bilge system. The amount of fluid during a firefighting process is to be considered.

No.: 10 **Description:** Bilge System

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										10.2.8. ESD				224. Study on a dedicated bilge system for contaminated quantities is to be provided.
10.3	Inability to manage bilge	Bilge Pump Failure		10.3.1. Electrical failure or power loss	10.3.1. Flooding in ammonia spaces, leading to equipment damage. Delayed ammonia leak containment. Toxic environment, human injury	Injury	5	-1	High (4)	10.3.1. IAS 10.3.2. OPTS 10.3.3.PMS 10.3.4. Material specs 10.3.5. Redundancy x% 10.3.6. SOPs 10.3.7. DF ICE 10.3.8. ESD 10.3.10. ADS	3	-2	Low (1)	223. Study is to be conducted on the capacity and capabilities of the bilge system. The amount of fluid during a firefighting process is to be considered.

No.: 10	**Description:** Bilge System													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				10.3.2. Mechanical failure	10.3.1. Flooding in ammonia spaces, leading to equipment damage. Delayed ammonia leak containment. Toxic environment, human injury	Injury	5	-1	High (4)	10.3.1. IAS 10.3.2. OPTS 10.3.3.PMS 10.3.4. Material specs 10.3.5. Redundancy x% 10.3.6. SOPs 10.3.7. DF ICE 10.3.8. ESD 10.3.10. ADS	3	-2	Low (1)	223. Study is to be conducted on the capacity and capabilities of the bilge system. The amount of fluid during a firefighting process is to be considered.
10.4	Inability to manage bilge	Failure of bilge sensors/alarms		10.4.1. Sensor malfunction or incorrect calibration.	10.4.1. Flooding in ammonia spaces, leading to equipment damage. Delayed ammonia leak containment. Toxic environment, human injury	Injury	5	-1	High (4)	10.4.1. IAS 10.4.2. OPTS 10.4.3.PMS 10.4.4. Material specs 10.4.5. Redundancy x% 10.4.6. SOPs 10.4.7. DF ICE 10.4.8. ESD 10.4.10. ADS	3	-2	Low (1)	

No.: 10	**Description:** Bilge System													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				10.4.2. Sensor blockage due to sediment buildup.	10.4.1. Flooding in ammonia spaces, leading to equipment damage. Delayed ammonia leak containment. Toxic environment, human injury	Injury	5	-1	High (4)	10.4.1. IAS 10.4.2. OPTS 10.4.3.PMS 10.4.4. Material specs 10.4.5. Redundancy x% 10.4.6. SOPs 10.4.7. DF ICE 10.4.8. ESD 10.4.10. ADS	3	-2	Low (1)	
10.6	Ammonia or contaminated bilge water release	Unintended ammonia or contaminated bilge water release from bunker stations or overboard discharge below waterline		10.6.1. Operator error	10.6.1. Environmental contamination. Ammonia or contaminated bilge water exposure, human injury. Reputation damage. Fines or legal action	General	5	-2	High (3)	10.6.1. IAS 10.6.2. OPTS 10.6.3. SOPs 10.6.4. ESD 10.6.5. SMS	5	-3	Moderate (2)	

No.: 10	**Description:** Bilge System													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
10.8	Spillage or leakage of ammonia or contaminated bilge water	Overfill of bilge tank		10.8.1. General	10.8.1. Operator error. Excessive accumulation of leaked ammonia and water	Injury	5	-1	High (4)	Same as above	3	-2	Low (1)	

Company: EMSA, Wartsila, DFDS, Knud E. Hansen		
Title: EMSA NH3, Ro-Pax Study		
Description:		
Method: HAZID	**Type:**	Detection & Alarm Systems
Design Intent:		
Comment:		

No.: 11 **Description:** Detection & Alarm Systems

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
11.1	General			11.1.1. General	11.1.1. Scenario	Asset	5	-1	High (4)	11.1.2. Materials Spec 11.1.3. FAT/HAT/SAT spec	3	-1	Moderate (2)	226. ABS Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries. 2020, pg 38 Gas dispersion 227. Automatic closing of isolation valves after detecting ammonia leakage.

No.: 11	**Description:** Detection & Alarm Systems													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
														228. Gas detection alarms must be arranged to alert personnel about leakages and prevent entering the space 229. Assess the necessity of a continuous oxygen monitoring system for nitrogen-supported compartments to mitigate risks related to asphyxiation from nitrogen leakage.

No.: 11 **Description:** Detection & Alarm Systems

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
														230. Establish a policy regarding the quantity and utilisation of personal oxygen detectors on board, considering the toxicity of ammonia and the risk of asphyxiation from nitrogen.
11.2	Undetected ammonia leak	Failure of ammonia detectors		11.2.1. Incorrect calibration	11.2.1. Failure to detect leakage, toxic environment human injury	Injury	5	-1	High (4)	11.2.1. ESD 11.2.2. FFS	3	-2	Low (1)	
					11.2.2. Failure to trigger alarm and ESD	Injury	5	-1	High (4)	Same as above	3	-2	Low (1)	
				11.2.2. Chemical detector malfunction	11.2.1. Failure to detect leakage, toxic environment human injury	Injury	5	-1	High (4)	11.2.1. ESD 11.2.2. FFS	3	-2	Low (1)	

No.: 11	**Description:** Detection & Alarm Systems													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					11.2.2. Failure to trigger alarm and ESD	Injury	5	-1	High (4)	Same as above	3	-2	Low (1)	
				11.2.3. Sensor degradation/contamination	11.2.1. Failure to detect leakage, toxic environment human injury	Injury	5	-1	High (4)	11.2.1. ESD 11.2.2. FFS	3	-2	Low (1)	
					11.2.2. Failure to trigger alarm and ESD	Injury	5	-1	High (4)	Same as above	3	-2	Low (1)	
				11.2.4. Electric failure	11.2.1. Failure to detect leakage, toxic environment human injury	Injury	5	-1	High (4)	11.2.1. ESD 11.2.2. FFS	3	-2	Low (1)	
					11.2.2. Failure to trigger alarm and ESD	Injury	5	-1	High (4)	Same as above	3	-2	Low (1)	
				11.2.5. Failure of sampling point	11.2.1. Failure to detect leakage, toxic environment human injury	Injury	5	-1	High (4)	11.2.1. ESD 11.2.2. FFS	3	-2	Low (1)	

No.: 11	**Description:** Detection & Alarm Systems													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					11.2.2. Failure to trigger alarm and ESD	Injury	5	-1	High (4)	Same as above	3	-2	Low (1)	
11.3	Unnecessary emergency response and operational disruption	False Alarm		11.3.1. Incorrect calibration	11.3.1. Unnecessary emergency response (ESD, evacuation)	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
				11.3.2. Sensor Degradation/Contamination	11.3.1. Unnecessary emergency response (ESD, evacuation)	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
				11.3.3. Environmental conditions	11.3.1. Unnecessary emergency response (ESD, evacuation)	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
11.4	Undetected ammonia leak	Failure of Alarm Activation		11.4.1. Electrical failure	11.4.1. Crew members unable to detect leaks. Toxic environment. Human injury	Injury	5	-1	High (4)	11.4.1. ADS 11.4.2. IAS 11.4.3. OPTS 11.4.4.PMS 11.4.5. Material specs 11.4.6. MV 2x100% 11.4.7. Redundancy x%	4	-2	Moderate (2)	

No.: 11 | **Description:** Detection & Alarm Systems

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										11.4.8. SOPs 11.4.9. DF ICE 11.4.10. ESD 11.4.11. FFS				
				11.4.2. Power supply failure	11.4.1. Crew members unable to detect leaks. Toxic environment. Human injury	Injury	5	-1	High (4)	11.4.1. ADS 11.4.2. IAS 11.4.3. OPTS 11.4.4.PMS 11.4.5. Material specs 11.4.6. MV 2x100% 11.4.7. Redundancy x% 11.4.8. SOPs 11.4.9. DF ICE 11.4.10. ESD 11.4.11. FFS	4	-2	Moderate (2)	

No.: 11 | **Description:** Detection & Alarm Systems

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
				11.4.3. Wrong alarm settings	11.4.1. Crew members unable to detect leaks. Toxic environment. Human injury	Injury	5	-1	High (4)	11.4.1. ADS 11.4.2. IAS 11.4.3. OPTS 11.4.4.PMS 11.4.5. Material specs 11.4.6. MV 2x100% 11.4.7. Redundancy x% 11.4.8. SOPs 11.4.9. DF ICE 11.4.10. ESD 11.4.11. FFS	4	-2	Moderate (2)	
				11.4.4. Control/Monitoring system failure	11.4.1. Crew members unable to detect leaks. Toxic environment. Human injury	Injury	5	-1	High (4)	11.4.1. ADS 11.4.2. IAS 11.4.3. OPTS 11.4.4.PMS 11.4.5. Material specs 11.4.6. MV 2x100% 11.4.7. Redundancy x%	4	-2	Moderate (2)	

No.: 11 | **Description:** Detection & Alarm Systems

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										11.4.8. SOPs 11.4.9. DF ICE 11.4.10. ESD 11.4.11. FFS				
11.5	Undetected ammonia leak	Failure of Portable Detectors		11.5.1. Battery depletion.	11.5.1. Crew members unable to detect leaks. Toxic environment. Human injury	Injury	5	-1	High (4)	11.5.1. ADS 11.5.2. IAS 11.5.3. OPTS 11.5.4.PMS 11.5.5. Material specs 11.5.6. MV 2x100% 11.5.7. Redundancy x% 11.5.8. SOPs 11.5.9. DF ICE 11.5.10. ESD 11.5.11. FFS 11.5.13. PP	4	-2	Moderate (2)	

No.: 11	**Description:** Detection & Alarm Systems													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				11.5.2. Improper maintenance.	11.5.1. Crew members unable to detect leaks. Toxic environment. Human injury	Injury	5	-1	High (4)	11.5.1. ADS 11.5.2. IAS 11.5.3. OPTS 11.5.4.PMS 11.5.5. Material specs 11.5.6. MV 2x100% 11.5.7. Redundancy x% 11.5.8. SOPs 11.5.9. DF ICE 11.5.10. ESD 11.5.11. FFS 11.5.13. PP	4	-2	Moderate (2)	
				11.5.3. Butadiene calibration.	11.5.1. Crew members unable to detect leaks. Toxic environment. Human injury	Injury	5	-1	High (4)	11.5.1. ADS 11.5.2. IAS 11.5.3. OPTS 11.5.4.PMS 11.5.5. Material specs 11.5.6. MV 2x100%	4	-2	Moderate (2)	

No.: 11	**Description:** Detection & Alarm Systems													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										11.5.7. Redundancy x% 11.5.8. SOPs 11.5.9. DF ICE 11.5.10. ESD 11.5.11. FFS 11.5.13. PP				
				11.5.4. Rough equipment handling.	11.5.1. Crew members unable to detect leaks. Toxic environment. Human injury	Injury	5	-1	High (4)	11.5.1. ADS 11.5.2. IAS 11.5.3. OPTS 11.5.4.PMS 11.5.5. Material specs 11.5.6. MV 2x100% 11.5.7. Redundancy x% 11.5.8. SOPs 11.5.9. DF ICE 11.5.10. ESD 11.5.11. FFS 11.5.13. PP	4	-2	Moderate (2)	

No.: 11	**Description:** Detection & Alarm Systems													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				11.5.5. Equipment malfunction.	11.5.1. Crew members unable to detect leaks. Toxic environment. Human injury	Injury	5	-1	High (4)	11.5.1. ADS 11.5.2. IAS 11.5.3. OPTS 11.5.4.PMS 11.5.5. Material specs 11.5.6. MV 2x100% 11.5.7. Redundancy x% 11.5.8. SOPs 11.5.9. DF ICE 11.5.10. ESD 11.5.11. FFS 11.5.13. PP	4	-2	Moderate (2)	
11.6	Undetected ammonia leak	Complete Detection system power loss		11.6.1. Vessel blackout	11.6.1. Loss of ammonia monitoring, potential for undetected ammonia.	General	5	-2	High (3)	11.6.1. ADS 11.6.2. IAS 11.6.3. OPTS 11.6.4.PMS 11.6.5. Material specs 11.6.6. MV 2x100%	5	-3	Moderate (2)	

No.: 11 **Description:** Detection & Alarm Systems

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
										11.6.7. Redundancy x% 11.6.8. SOPs 11.6.9. DF ICE 11.6.10. ESD 11.6.11. FFS				

Company: EMSA, Wartsila, DFDS, Knud E. Hansen		
Title: EMSA NH3, Ro-Pax Study		
Description:		
Method: HAZID	**Type:**	firefighting Appliances
Design Intent:		
Comment:		

No.: 12 **Description:** firefighting Appliances

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
12.2	Uncontrolled fire incident	FFS failure		12.2.1. Power loss	12.2.1. Inability to control ammonia-related fires or hot surfaces.	Asset	5	-1	High (4)	12.2.1. Emergency power supply. 12.2.2. Material spec 12.2.4. Redundancy x% 12.2.5. OPTS 12.2.6.PMS 12.2.7. SOPs	3	-2	Low (1)	225. Develop material handling procedures for machinery and equipment repair and overhaul.
					12.2.2. Potential for ammonia fuel tank rupture due to excessive heat exposure.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
					12.2.3. Potential escalation to ammonia release	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	

No.: 12 | **Description:** firefighting Appliances

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
					12.2.4. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					12.2.5. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					12.2.6. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					12.2.7. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
				12.2.2. Nozzle, piping damage	12.2.1. Inability to control ammonia-related fires or hot surfaces.	Asset	5	-1	High (4)	12.2.2. Material spec 12.2.4. Redundancy x% 12.2.5. OPTS 12.2.6.PMS 12.2.7. SOPs	3	-2	Low (1)	225. Develop material handling procedures for machinery and equipment repair and overhaul.
					12.2.2. Potential for ammonia fuel tank rupture due to excessive heat exposure.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
					12.2.3. Potential escalation to ammonia release	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	

No.: 12 **Description:** firefighting Appliances

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
					12.2.4. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					12.2.5. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					12.2.6. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					12.2.7. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
				12.2.3. Low pressure	12.2.1. Inability to control ammonia-related fires or hot surfaces.	Asset	5	-1	High (4)	12.2.2. Material spec 12.2.4. Redundancy x% 12.2.5. OPTS 12.2.6.PMS 12.2.7. SOPs	3	-2	Low (1)	225. Develop material handling procedures for machinery and equipment repair and overhaul.
					12.2.2. Potential for ammonia fuel tank rupture due to excessive heat exposure.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
					12.2.3. Potential escalation to ammonia release	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	

No.: 12	**Description:** firefighting Appliances													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
					12.2.4. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					12.2.5. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					12.2.6. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					12.2.7. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
				12.2.4. Poor Maintenance	12.2.1. Inability to control ammonia-related fires or hot surfaces.	Asset	5	-1	High (4)	12.2.2. Material spec 12.2.4. Redundancy x% 12.2.5. OPTS 12.2.6.PMS 12.2.7. SOPs 12.2.8. Ventilation	3	-2	Low (1)	225. Develop material handling procedures for machinery and equipment repair and overhaul.
					12.2.2. Potential for ammonia fuel tank rupture due to excessive heat exposure.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	

No.: 12 **Description:** firefighting Appliances

Item	Hazard/Top Event	Initiating Event	Comment	Cause	Consequences & Loss Events Scenario	Matrix	Severity	Unmitigated Likelihood	Unmitigated Risk	Existing IPLs (Safeguards)	Mitigated Severity	Mitigated Likelihood	Mitigated Risk	Recommended IPLs (Action Items)
12.3	Uncontrolled incident or escalation in case of fire	Failure of ESD		12.3.1. Electrical of software failure	12.3.1. Damage to the vessel	Asset	5	-2	High (3)	12.3.1. Material spec 12.3.3. Redundancy x% 12.3.4. OPTS 12.3.5.PMS 12.3.6. SOPs	3	-2	Low (1)	
				12.3.2. Valve, actuator failure	12.3.1. Damage to the vessel	Asset	5	-2	High (3)	12.3.1. Material spec 12.3.3. Redundancy x% 12.3.4. OPTS 12.3.5.PMS 12.3.6. SOPs	3	-2	Low (1)	
				12.3.3. Human error	12.3.2. Fire, human injury.	Injury	5	-1	High (4)	12.3.1. Material spec 12.3.3. Redundancy x% 12.3.4. OPTS 12.3.5.PMS 12.3.6. SOPs 12.3.7. Ventilation	3	-2	Low (1)	

No.: 12	**Description:** firefighting Appliances													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
12.4	Water, ammonia Reaction	Water contact with ammonia during firefighting		12.4.1. Use of water on ammonia leaks	12.4.1. Formation of corrosive solution, Toxic environment, human injury	Injury	5	-2	High (3)	12.4.1. Material spec 12.4.3. OPTS 12.4.4. SOPs 12.4.5. PP	3	-2	Low (1)	
12.6	Fire incident escalation	Inability to Shut Down Ventilation		12.6.1. Operator error	12.6.1. Accumulation of ammonia vapours, toxic environment, human injury.	Asset	5	-1	High (4)	12.6.2. Redundancy x% 12.6.3. OPTS 12.6.4.PMS 12.6.5. SOPs 12.6.6. Ventilation 12.6.7. MV 2x100% 12.6.8. ADS 12.6.9. IAS 12.6.10. PP 12.6.11. FAT/HAT/SAT spec	3	-2	Low (1)	
					12.6.2. Ineffective FFS due to high ammonia concentration.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	

No.: 12	**Description:** firefighting Appliances													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
				12.6.2. Electrical or control system failure	12.6.1. Accumulation of ammonia vapours, toxic environment, human injury.	Asset	5	-1	High (4)	12.6.2. Redundancy x% 12.6.3. OPTS 12.6.4.PMS 12.6.5. SOPs 12.6.6. Ventilation 12.6.7. MV 2x100% 12.6.8. ADS 12.6.9. IAS 12.6.10. PP 12.6.11. FAT/HAT/SAT spec	3	-2	Low (1)	
					12.6.2. Ineffective FFS due to high ammonia concentration.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
				12.6.3. Mechanical failure	12.6.1. Accumulation of ammonia vapours, toxic environment, human injury.	Asset	5	-1	High (4)	12.6.2. Redundancy x% 12.6.3. OPTS 12.6.4.PMS 12.6.5. SOPs 12.6.6. Ventilation 12.6.7. MV 2x100% 12.6.8. ADS	3	-2	Low (1)	

No.: 12	**Description:** firefighting Appliances													
Item	**Hazard/Top Event**	**Initiating Event**	**Comment**	**Cause**	**Consequences & Loss Events Scenario**	**Matrix**	**Severity**	**Unmitigated Likelihood**	**Unmitigated Risk**	**Existing IPLs (Safeguards)**	**Mitigated Severity**	**Mitigated Likelihood**	**Mitigated Risk**	**Recommended IPLs (Action Items)**
										12.6.9. IAS 12.6.10. PP 12.6.11. FAT/HAT/SAT spec				
					12.6.2. Ineffective FFS due to high ammonia concentration.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	

Appendix B HAZID Action Items List

Table 12 HAZID Action Items List

No.	References	Action	Comment	Responsibility
1	1.1 Major Ship Casualty (Maritime Disaster). Losing streak in Ship design and production(going awry) – General Ro-Pax Arrangement	Risk assessment should evaluate the suitability of the safety concepts outlined in the current regulations and guidelines within the IGF Code, particularly in light of ammonia fuel's toxicity and corrosivity. Results may recommend modifications to existing safety barriers, designed for LNG installations onboard ships, and the introduction of new safety barriers to safeguard against ammonia exposure during normal operations and in emergency situations. Key safety measures include: Segregation measures to protect ammonia fuel installations from potential external hazards. System integrity assurance to minimize leaks from ammonia fuel systems. Optimised engine and machinery positioning to ensure the shortest possible piping length to the ammonia inlet manifold. Implementation of double barriers to protect the ship and crew from potential leaks. Advanced leak detection systems providing early warnings and enabling rapid automatic safety responses. Automatic leak isolation to minimize the toxic and hazardous consequences of potential releases. Ship layout design that ensures clear and accessible escape routes from all compartments. Ship layout design that ensures gas freeing and gasing of ammonia storage tanks without intraction of adjacent compartments.		

No.	References	Action	Comment	Responsibility
2	1.2 Major Ship Casualty (Maritime Disaster). Insufficient Safety Management System (SMS) for ammonia-fuelled ships. – General Ro-Pax Arrangement	Incorporate detailed procedures tailored to the unique risks and hazards associated with ammonia, as well as potential shipboard emergency situations, such as: -Risk Management life cycle/MOC -Emergency preparedness/SEP/ ERP/ SOPEP/ SMPEP/ -HSSE/ SMS/ SOPs/ SIMOPS -PMS according to OEM guidelines -Critical equipment/machinery and spare parts identification -HSE/ TRA/ PTW/ Toolbox talks/ PP Ship's personnel Training/ Familiarisation/ Certification/ Qualification -Emergency Drills/Scenarios -Compliance with all ammonia related updated resolutions, rules, guidelines, circulars and requirements.		
3	1.3 Major Ship Casualty (Maritime Disaster). Materials – General Ro-Pax Arrangement	Consider the implementation of specific material requirements for ammonia storage tanks and associated systems because of ammonia's corrosive nature.		
4	1.4 Toxic Exposure. Accident Machinery/piping failure – General Ro-Pax Arrangement	ABS Requirements for Ammonia Fueled Vessels Subsection 5/11 Personnel Safety and PP		
5	1.5 Electrical – General Ro-Pax Arrangement	Consider design compliance with International Standard IEC 60092-502 Electrical installations in ships - Part 502: Tankers - Special features. Hazardous areas for electrical equipment selection and installation design are divided into Zones 0, 1, and 2.		
6	1.6 Alternative Power Sources – General Ro-Pax Arrangement	Study to be conducted on a possible battery module that would support the vessel while at berth.		
7	1.6 Alternative Power Sources – General Ro-Pax Arrangement	Further study to be done on the possibility the vessel will have to connect to onshore power (cold ironing) while at birth.		
8	1.7 Maintenance – General Ro-Pax Arrangement	Arrangements should be made for the safe maintenance of ammonia equipment in machinery spaces, including manual isolation valves and fuel line purging. Crew must wear proper PP when working in ammonia related compartments, and procedures for safe entry and maintenance work must be developed.		

No.	References	Action	Comment	Responsibility
9	1.8 Ammonia. Large scale ammonia release – General Ro-Pax Arrangement	Ensure the safety of the crew and passengers in the event of an ammonia release by providing a safe haven, possibly combined with a mustering function. Consider a Cofferdam underneath the ammonia fuel storage tanks and NH3 equipment room		
10	1.9 Loss of electrical power. Blackout – General Ro-Pax Arrangement	Further study is required for power loss scenarios and residual ammonia fuel handling in piping per vessel.		
11	1.9 Loss of electrical power. Blackout – General Ro-Pax Arrangement	Further study is required on the loss of power for valve fail-safe positions and backup power requirements during the appropriate risk assessment for each vessel.		
12	1.10 Extreme Weather – General Ro-Pax Arrangement 2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations 2.3 Toxicity (Ammonia Release). QCDC Failure – Bunkering Stations	Standard Operating Procedures (SOPs) must clearly outline any operational limitations of the ammonia fuel mode/system		
13	1.11 External Threat (Attack, Piracy.). Direct attack (terrorism, piracy, etc.) – General Ro-Pax Arrangement	Additional security measures may be necessary for ammonia usage as marine fuel.		
14	1.12 Cyber Attack. Security breach – General Ro-Pax Arrangement	Further study to be done on the possibility of cutting on line communication and overriding the system so that it can be controlled manually.		
15	1.12 Cyber Attack. Security breach – General Ro-Pax Arrangement	Ensure comprehensive cyber security by considering the relevant IMO Resolution and Guidelines, national regulations and flag state requirements, IACS Unified Requirements (URs), standards such as ISO/IEC 27001 and IEC 62443, industry recommendations and best practices, etc. Additional cyber security measures may be necessary for ammonia usage as marine fuel.		
16	1.13 Dropped Object – General Ro-Pax Arrangement 2.5 Toxicity . Dropped object – Bunkering Stations	Development of a drop object protection program (ABS Guide dropped Object Prevention on Offshore Units and Installations)		
17	1.15 Human Factors – General Ro-Pax Arrangement 7.8 Ammonia Release. WARMS Leakage – Venting	Maintenance procedures are to be provided in the operational manual		
18	1.15 Human Factors – General Ro-Pax Arrangement 6.5 Pipe Failure. Outer Pipe – Engine Rooms	Stress analysis considering vibration and fatigue		

No.	References	Action	Comment	Responsibility
19	1.16 Abandon Vessel, RORO – General Ro-Pax Arrangement	The location of lifesaving equipment, escape routes, and lifeboats should be selected with consideration to keep them away from potential ammonia gas releases. Special analyses of the location of lifesaving equipment and mustering stations need to be conducted, and evacuation scenarios involving ammonia leakages must be properly evaluated. For the scenario involving a full-capacity emergency discharge from the PSVs of ammonia storage tanks, the definition of toxic zones and the integration of mustering stations should be evaluated.		
20	1.17 Abandon Vessel, ROPAX – General Ro-Pax Arrangement	The location of lifesaving equipment, escape routes, and lifeboats should be selected with consideration to keep them away from potential ammonia gas releases. Special analyses of the location of lifesaving equipment and mustering stations need to be conducted, and evacuation scenarios involving ammonia leakages must be properly evaluated. For the scenario involving a full-capacity emergency discharge from the PSVs of ammonia storage tanks, the definition of toxic zones and the integration of mustering stations should be evaluated.		
21	1.18 Fire, Explosion. Hot Works in Proximity – General Ro-Pax Arrangement 3.4 Explosion – Fuel Storage Tank	Tank purging process to create safe environment for inspection procedures is to be further studied.		Knud E. Hansen
22	1.18 Fire, Explosion. Hot Works in Proximity – General Ro-Pax Arrangement 9.8 Contaminated Nitrogen . Contamination of nitrogen supply – Purging System	Further study to be done on the operating procedures of the purging process. Ammonia will require safer environment as compared to LNG purging processes.		
23	1.18 Fire, Explosion. Hot Works in Proximity – General Ro-Pax Arrangement	Further study to be done on the hot operations to be allowed during periods the vessel will be bunkering, in preparation status or at berth.		
24	1.18 Fire, Explosion. Hot Works in Proximity – General Ro-Pax Arrangement	IGF Code 18.7 Regulations for hot work on or near fuel systems Minimize the risk of exposure to toxic ammonia vapours by preventing toxic fuel vapours from accumulating in areas where people might be exposed. Establish toxic zones around ammonia vapour sources on the open deck to prevent spreading to enclosed spaces through air intakes, outlets, or other openings. The requirements for venting cargo tanks and ventilating cargo handling spaces should be taken into consideration for such vessels.		

No.	References	Action	Comment	Responsibility
25	1.19 Electric Cars. EVBs that experience overheating – General Ro-Pax Arrangement	Further study to be done on a cooling system of electric car's batteries.		
26	1.19 Electric Cars. EVBs that experience overheating – General Ro-Pax Arrangement	Consider installing multiple EX-CCTV systems equipped with built-in AI and video analytics, IR cameras capable of night vision. Implementation of a hydrocarbon or hydrogen gas detection system as an additional feature. Potential revision of the overall ventilation strategy to ensure continuous supply and exhaust prior to detection. Use a fire blanket to cover the vehicle that is on fire. Consider implementing a fixed boundary cooling system or deploying portable boundary cooling devices. Consider the application of a higher rate of fire integrity to adjacent compartments. Consider the application of fire protection, water spray system or water curtain system for all escape routes, lifeboats and life rafts. Consider the use of manual firefighting techniques, thus implementing a thermal imager, water mist lances and water fog nozzle applicators.		
27	2.1 General – Bunkering Stations	IGF Code 18.2.4: "the ship shall be provided with suitable emergency procedures". Procedures to follow during bunkering operations must be outlined in a vessel's Safety Management System.		
28	2.1 General – Bunkering Stations	The vessel's SOPEP/SMPEP must be updated to incorporate the use of ammonia as fuel.		
29	2.1 General – Bunkering Stations	An STS Operations Plan must be developed and approved with careful consideration of information outlined in various best STS practice guidelines, which are periodically updated by the International Maritime Organisation (IMO). This includes the ICS/OCIMF STS Transfer Guide, ISGOTT, and the applicable port Oil Spill Contingency Plan (OSCP), incorporating specific cons applicable.		
30	2.1 General – Bunkering Stations	Consider the application of SIGTTO Recommendations for Emergency Shutdown and Related Safety Systems		
31	2.1 General – Bunkering Stations	Consider the application of a Spill tank for the manifold area, designed according to OCIMF Recommendations for Oil and Chemical Tanker Manifolds and Associated Equipment		

No.	References	Action	Comment	Responsibility
32	2.1 General – Bunkering Stations	Consider performing RA according to the provisions of ISO/TS 18683:2021 "Guidelines for Safety and Risk Assessment of LNG Fuel Bunkering Operations taking into account the unique properties of ammonia."		
33	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	Drip tray schematic showing positions in bunker stations areas are to be provided.		
34	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations 2.6 Toxicity. Interaction with Bunker Vessel – Bunkering Stations 2.13 Fire. Vehicle on deck – Bunkering Stations 2.15 Fire. Bunker Vessel Accident – Bunkering Stations	SIMOPS	Matters to be discussed during a SIMOPS study: 1. Interaction with bunker vessel. 2. Types of bunker vessels to be used for this design. 3. Operational procedures and required time for each process. 4. Action in case of a fire. Possible presence of tugboat(s). 5. Embarkation/Disembarkation procedures during bunkering 6. Bunkering temperature range.	All
35	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	Final design of the bunkering station arrangement, including the presence of an air lock, is to be provided.		Knud E. Hansen
36	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations 2.3 Toxicity (Ammonia Release). QCDC Failure – Bunkering Stations 2.6 Toxicity. Interaction with Bunker Vessel – Bunkering Stations 2.12 Fire (Ammonia Release). Fire explosion in the manifold area – Bunkering Stations	Considering early stages of design, location of washing stations are to be provided in the updated drawings.		
37	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	Evaluate the need of detection measures for liquid/gas leakage from the ammonia piping between the cargo manifold and fuel tank		
38	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	Consistent monitoring of the bunkering area or use of an equivalent method.		
39	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	Ships' fuel hoses are to comply with the requirements in Part 5C, Chapter 13, Section 8-3.2 of the ABS Rules for Building and Classing Marine Vessels. Bunker hoses are also to comply with ISO 5771:2024 "Rubber Hoses and Hoses Assemblies AMMONIA BUNKERING: TECHNICAL AND OPERATIONAL ADVISORY for Transferring Anhydrous Ammonia - Specification."		
40	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	Excessive cooling should not adversely affect hull or deck structures in the event of a fuel leak.		

No.	References	Action	Comment	Responsibility
41	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	A person in charge must be appointed to coordinate and oversee the bunkering operation.		
42	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	The bunkering team should use the loading plan and checklist throughout the process and ensure that all crew members know the standard operating procedures (SOPs), alarm systems, and loading sequence.		
43	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	Clear and detailed drawings of the vessel's bunkering system should be readily accessible to the ship's bunkering team during operations.		
44	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	A piping diagram should be posted in a convenient location for easy reference by the team.		
45	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	Respective valves and piping should be tagged for easy identification.		
46	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations 2.3 Toxicity (Ammonia Release). QCDC Failure – Bunkering Stations	Hoses used for fuel transfer must be compatible with the type of fuel and suitable for the specific fuel temperature. Hoses must possess a bursting pressure that is at least five times greater than the maximum pressure experienced during bunkering.		
47	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	Arrangements should be made to install an emergency release system that prevents damage and spark generation, minimizes ammonia release when activated, and includes measures to prevent accidental activation.		
48	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations 2.3 Toxicity (Ammonia Release). QCDC Failure – Bunkering Stations	The system should be designed as a fail-release system.		
49	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations 2.3 Toxicity (Ammonia Release). QCDC Failure – Bunkering Stations	The connections at the bunkering station must utilize dry-disconnect types, equipped with additional safety features like dry breakaway couplings or self-sealing quick-release couplings.		
50	2.3 Toxicity (Ammonia Release). QCDC Failure – Bunkering Stations	Arrangements should be made to install an emergency release system that prevents damage and spark generation, minimizes ammonia release when activated, and includes measures to prevent accidental activation.		
51	2.3 Toxicity (Ammonia Release). QCDC Failure – Bunkering Stations	Hoses must possess a bursting pressure that is at least five times greater than the maximum pressure experienced during bunkering.		

No.	References	Action	Comment	Responsibility
52	2.5 Toxicity . Dropped object – Bunkering Stations	Identify the section of the fuel piping which needs to be protected from a dropped object		
53	2.6 Toxicity. Interaction with Bunker Vessel – Bunkering Stations	SOPs/ERP should account for performance during significant movements of bunker, vessel, or hoses, considering the effects of wind and waves. The difference in freeboard between vessels should be taken into account when mooring.		
54	2.6 Toxicity. Interaction with Bunker Vessel – Bunkering Stations	Vents of the bunkering vessel must not affecting/interfering with toxic / hazardous areas of other vessel		
55	2.6 Toxicity. Interaction with Bunker Vessel – Bunkering Stations	Develop material handling procedures for machinery and equipment repair and overhaul.		
56	2.7 Fire (Ammonia Release). Absence of Electrical Isolation – Bunkering Stations	Consider applying the provisions of Society of International Gas and Tanker Operators (SIGTTO) publication "A Justification into the Use of Insulation Flanges (and Electrically Discontinuous Hoses) at the Ship/Shore and Ship/Ship Interface", as appropriate.		
57	2.8 Overfilling – Bunkering Stations	SOPs must include a system for measuring and controlling liquid levels, for example: Regular soundings of the tanks. When the tank level exceeds 70%, the measurement intervals must be decreased accordingly. Multiple tank bunkering is not recommended		
58	2.9 Toxicity (Ammonia Release). Failure of Purging Lines – Bunkering Stations 9.4 Ammonia Release – Purging System	Considering early stages of design, drawings are to be updated to include the purging piping diagram. Investigate the possibility of purging the system with water or start the purging process with heated ammonia.		
59	2.10 Toxicity (Ammonia Release). Drip Trays – Bunkering Stations	Drainage system is to be designed wether with inclination or with a parallel stripping line. Decision to be made upon final vessel design.	Bunker station on top of tank	Wartsila, Hansen
60	2.11 Toxicity (Ammonia Release). Trapped liquid between the bunker valve and the tank valve – Bunkering Stations	Provide tag numbers for safety valves		
61	2.13 Fire. Vehicle on deck – Bunkering Stations	Study on tolerance of structure to high temperatures in case of tank fire		
62	2.15 Fire. Bunker Vessel Accident – Bunkering Stations	Develop procedures for crew training on how to handle a fire situation.		

No.	References	Action	Comment	Responsibility
63	2.15 Fire. Bunker Vessel Accident – Bunkering Stations	Investigate the possibility of both vessels should have coordinated NH3 fire suppression plans in place.		
64	2.16 General Accident – Bunkering Stations	Study to be conducted on the communication protocol with port authorities in case of an incident for coordinated actions.		
65	2.17 Environmental Pollution. Incident during Bunkering – Bunkering Stations	Study to be conducted on the ammonia that would be vented in case of emergency. Scenario to be investigated on the possibility of (in case of ultimate safe scenario) it can be disposed in the water. Study should take into consideration the safety advantage of discharging the fuel below the fire line into the water.		
66	3.1 General – Fuel Storage Tank	IGF: 6.7.2.2: "Liquefied gas fuel tanks shall be fitted with a minimum of 2 pressure relief valves (PRVs) allowing for disconnection of one PRV in case of malfunction or leakage".		
67	3.1 General – Fuel Storage Tank	IGF 6.7.2.6: "In the event of a failure of a fuel tank PRV a safe means of emergency isolation shall be available".		
68	3.1 General – Fuel Storage Tank	IGF 6.7.2.6.2: "The procedures shall allow only one of the installed PRVs for the liquefied gas fuel tanks to be isolated, physical interlocks shall be included to this effect"		
69	3.1 General – Fuel Storage Tank	ABS GUIDANCE NOTES ON STRENGTH ASSESSMENT OF INDEPENDENT TYPE C TANKS 2022 5 Section 1 Introduction 1 -Type C cargo/fuel tanks must be designed and built to meet the requirements of recognised pressure vessel standards or codes, which are supplemented by additional Class Society requirements and statutory regulations. -The liquefied gas cargo/fuel tank itself must be designed to sustain all static and dynamic loads (e.g., weight, wave-induced loads, sloshing loads, etc.) during its service life. Valves that are connected to fuel storage tanks should be equipped with fail-safe mechanisms that automatically close during a power outage.		
70	3.1 General – Fuel Storage Tank	Pressure relief valves that are connected to fuel storage tanks must be fire-rated, while all other valves do not have this requirement.		

No.	References	Action	Comment	Responsibility
71	3.1 General – Fuel Storage Tank	To estimate the volume of ammonia that will be transferred to the fuel storage tank in case of ESD, it is important to consider the closing time of the ammonia filling valves and the cargo loading rate. Additionally, the air space above the 98.5% fill level must also be taken into account.		
72	3.1 General – Fuel Storage Tank	Arrangements must be made to avoid nitrogen in the re-liquification plant e.g. re-liquification plant to be separate and only to be used for fuel tank pressure/temperature management		
73	3.1 General – Fuel Storage Tank	All inlet and outlet piping connections for the fuel storage tanks must be situated on the outer head of the tank.		
74	3.2 Toxicity. Pipe/Connection Leakage – Fuel Storage Tank	Stress analysis considering vibration and fatigue		
75	3.2 Toxicity. Pipe/Connection Leakage – Fuel Storage Tank	All inlet and outlet piping connections for the fuel storage tanks must be situated on the outer head of the tank.		
76	3.3 Pressure. Overfilling – Fuel Storage Tank	Study is to be conducted on the possibility of transferring ammonia between tanks in the case of pressure build up.		
77	3.3 Pressure. Overfilling – Fuel Storage Tank	Study to be conducted on the BoG system in case ammonia is transferred from one tank to the other either for cooling or for overfilling purposes.		
78	3.3 Pressure. Overfilling – Fuel Storage Tank	Evaluate the need of a redundant level transmitter for the fuel tank to ensure the same level of safety with LNG fuel systems		
79	3.3 Pressure. Overfilling – Fuel Storage Tank	The level transmitter must be able to be replaced without gas freeing the tank and man entry		
80	3.3 Pressure. Overfilling – Fuel Storage Tank	Further study is needed to address a full-capacity emergency discharge from the PSVs of ammonia storage tanks.		
81	3.3 Pressure. Overfilling – Fuel Storage Tank	Further study is needed to address a full-capacity emergency discharge from the PSVs of ammonia storage tanks.		
82	3.4 Explosion – Fuel Storage Tank	Pipe routing of pilot fuel is to be provided.		

No.	References	Action	Comment	Responsibility
83	3.4 Explosion – Fuel Storage Tank	Verify that atmospheric control within the ammonia fuel tanks and fuel storage hold spaces are to be arranged in compliance with the requirements in Part 5C, Chapter 13, Section 6/10 of the ABS Rules for Building and Classing Marine Vessels.		
84	3.4 Explosion – Fuel Storage Tank	Consider use of warm ammonia after purging with nitrogen before loading occurs.		
85	3.4 Explosion – Fuel Storage Tank	Sampling the bunker line for air existence		
86	3.5 Explosion. Overpressurisation – Fuel Storage Tank	Fuel will be used from one tank at a time, and liquefaction will regulate the tank pressure.		
87	3.5 Explosion. Overpressurisation – Fuel Storage Tank	Drain is to be provided		
88	3.7 Pressure. Insulation Damage – Fuel Storage Tank	The maintenance plan should include a procedure for periodic inspection of insulation.		
89	3.7 Pressure. Insulation Damage – Fuel Storage Tank	Develop material handling procedures for machinery and equipment repair and overhaul.		
90	3.7 Pressure. Insulation Damage – Fuel Storage Tank	Verify that safe means of access for maintenance of equipment and valves in locations beyond man height will be provided in the TCS.		
91	3.9 Explosion. External – Fuel Storage Tank	IGF 4.3: Limitation of explosion consequences "An explosion in any space containing any potential sources of release and potential ignition sources shall not: .1 cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs"		
92	3.10 Maintenance. Error during Maintenance – Fuel Storage Tank 3.11 Damage. Object dropped upon – Fuel Storage Tank 4.17 Design Failure. Bad Design – Tank Connection Space	Clarification on the existence of a hatch on the deck above the tank; Manhole in the middle of the thank on top. Clearances are to be further studied . All other connections inside the Tank Connection Space (TCS).		
93	3.10 Maintenance. Error during Maintenance – Fuel Storage Tank 3.11 Damage. Object dropped upon – Fuel Storage Tank	Further study to be done on the location of the tank and the surrounding structures.		
94	3.10 Maintenance. Error during Maintenance – Fuel Storage Tank	Procedures on gas freeing the ammonia storage tanks are to be developed considering the operational procedures including the deck compartment.		

No.	References	Action	Comment	Responsibility
	4.17 Design Failure. Bad Design – Tank Connection Space			
95	3.10 Maintenance. Error during Maintenance – Fuel Storage Tank	Develop material handling procedures for machinery and equipment repair and overhaul.		
96	3.10 Maintenance. Error during Maintenance – Fuel Storage Tank	Verify that safe means of access for maintenance of equipment and valves in locations beyond man height will be provided in the TCS.		
97	3.11 Damage. Object dropped upon – Fuel Storage Tank	Identify the section of the fuel piping which needs to be protected from a dropped object		
98	3.11 Damage. Object dropped upon – Fuel Storage Tank	Development of a drop object protection program (ABS Guide dropped Object Prevention on Offshore Units and Installations)		
99	3.12 Adverse weather. Unintentional ESD activation due to high-high level alarm in the fuel storage tank – Fuel Storage Tank	Verify the time delay (e.g. to 60 sec) for high-high level alarm for the fuel storage tank (for Seagoing Condition Only).		
100	4.1 General – Tank Connection Space	IGF: 7.4.1.2 Materials having a melting point below 925°C shall not be used for piping outside the fuel tanks.		
101	4.1 General – Tank Connection Space	IGF Code Supplement 2024 Part A-1 9.5 Regulations for distribution of fuel outside of machinery space, paragraphs 9.5.3, 9.5.4, 9.5.5 and 9.5.6		
102	4.1 General – Tank Connection Space	TCS boundaries connecting to other compartments must be completely gas-tight.		
103	4.1 General – Tank Connection Space	TCS should be arranged to prevent the spread of ammonia leaks in areas where double-pipe protection of the ammonia system is impractical.		
104	4.1 General – Tank Connection Space	Tank valves in the TCS should be located mounted at the outer head of the tank,		
105	4.1 General – Tank Connection Space	TCS is to be designated as Zone 1 by IEC 60092-502.		
106	4.1 General – Tank Connection Space	TCS is to be subjected to negative pressure by IEC 60092-502.		
107	4.2 Ammonia leakage or accidental release. Loss of containment – Tank Connection Space	Flanged piping in TCS should be used sparingly. Weld piping is highly recommended instead.		
108	4.2 Ammonia leakage or accidental release. Loss of containment – Tank Connection Space	Effective mechanical shielding at all leakage points to minimize direct exposure to ammonia.		
109	4.2 Ammonia leakage or accidental release. Loss of containment – Tank Connection Space	Piping in TCS must be stainless steel.		

No.	References	Action	Comment	Responsibility
110	4.2 Ammonia leakage or accidental release. Loss of containment – Tank Connection Space	The refrigeration and fishing industry requirements should be studied and potentially adopted during system design.		
111	4.2 Ammonia leakage or accidental release. Loss of containment – Tank Connection Space	Shell and plate type (Ammonia at higher pressure than cooling medium.)		
112	4.2 Ammonia leakage or accidental release. Loss of containment – Tank Connection Space	SOP on entrance to Tank Connection Space (TCS) are to be developed.		
113	4.2 Ammonia leakage or accidental release. Loss of containment – Tank Connection Space	Development of a drop object protection program (ABS Guide dropped Object Prevention on Offshore Units and Installations)		
114	4.2 Ammonia leakage or accidental release. Loss of containment – Tank Connection Space	Procedures on entrance to Tank Connection Space (TCS) are to be developed.		
115	4.2 Ammonia leakage or accidental release. Loss of containment – Tank Connection Space	The building specifications must define a plan for stress analysis for the ammonia fuel piping.		
116	4.3 Loss of ammonia fuel supply. Ammonia Pump Failure – Tank Connection Space	Consider monitoring the vibrations of the AFGSS pump.		
117	4.3 Loss of ammonia fuel supply. Ammonia Pump Failure – Tank Connection Space	Consider a permanent vibration monitoring tool and additional measurements for the monitoring of critical machinery		
118	4.4 Loss of ammonia fuel supply. Evaporator failure – Tank Connection Space	Further study to be done on an ammonia indicator inside the Glycol/Water tank		
119	4.4 Loss of ammonia fuel supply. Evaporator failure – Tank Connection Space	IGF Code Part A-1 10.3 Regulations for internal combustion engines of piston type 10.3.1 General, paragraph 10.3.1.4 "Where gas can leak directly into the auxiliary system medium (lubricating oil, cooling water), an appropriate means shall be fitted after the engine outlet to extract gas in order to prevent gas dispersion. The gas extracted from auxiliary systems media shall be vented to a safe location in the atmosphere".		

No.	References	Action	Comment	Responsibility
120	4.4 Loss of ammonia fuel supply. Evaporator failure – Tank Connection Space	ABS RULES FOR BUILDING AND CLASSING MARINE VESSELS o 2025 PART 5C CHAPTER 1 3 Vessels Using Gases or other Low-Flashpoint Fuels SECTION 9 Fuel Supply to Consumers (2024), 4.14 (ABS) "Where the auxiliary heat exchange circuits are likely to contain gas in abnormal conditions as a result of a component failure (refer to FMEA), they are to be arranged with gas detection in the header tank. Alarm is to be given when the presence of gas is detected. Vent pipes are to be independent and to be led to a non- hazardous area and are to be fitted with a flame screen or flame arrester.		
121	4.5 Loss of cooling power. Subcooler failure – Tank Connection Space	IGF Code Part A-1 10.3 Regulations for internal combustion engines of piston type 10.3.1 General, paragraph 10.3.1.4 "Where gas can leak directly into the auxiliary system medium (lubricating oil, cooling water), an appropriate means shall be fitted after the engine outlet to extract gas in order to prevent gas dispersion. The gas extracted from auxiliary systems media shall be vented to a safe location in the atmosphere".		
122	4.5 Loss of cooling power. Subcooler failure – Tank Connection Space	ABS RULES FOR BUILDING AND CLASSING MARINE VESSELS o 2025 PART 5C CHAPTER 1 3 Vessels Using Gases or other Low-Flashpoint Fuels SECTION 9 Fuel Supply to Consumers (2024), 4.14 (ABS) "Where the auxiliary heat exchange circuits are likely to contain gas in abnormal conditions as a result of a component failure (refer to FMEA), they are to be arranged with gas detection in the header tank. Alarm is to be given when the presence of gas is detected. Vent pipes are to be independent and to be led to a non- hazardous area and are to be fitted with a flame screen or flame arrester.		
123	4.6 Fire. Fire adjacent to Tank Connection Space (TCS) – Tank Connection Space	Routing of all fuel supplies on vessel is to be provided		
124	4.11 Nitrogen. Trapped nitrogen in the piping – Tank Connection Space	Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.		
125	4.15 Inability to diagnose and resolve system failures. Troubleshooting inability – Tank Connection Space	Verify the remote access and support for makers (WARTSILA's system has the capability for remote access and support according to the operator's security policy)		

No.	References	Action	Comment	Responsibility
126	4.15 Inability to diagnose and resolve system failures. Troubleshooting inability – Tank Connection Space	According to DFDS's security policy, consider details about access and speed for remote access and support for the AFGSS with WARTSILA.		
127	4.15 Inability to diagnose and resolve system failures. Troubleshooting inability – Tank Connection Space	Critical spare parts on board according to OEM recommendations		
128	4.16 Fire/Explosion. Hot Works with ammonia present – Tank Connection Space	Hot works are to be restricted when ammonia is present in the Tank Connection Space (TCS).		
129	4.19 FFS Leakage. Equipment Leakage – Tank Connection Space	Further study to be done on the medium of the FFS. Final choice will be conducted with shipyard. Compatibility of the water as a medium and whether it will, under special conditions, react with ammonia and produce a corrosive fluid;	Knud E. Hansen: Initial design is with fresh water high pressure mist. Powder/foam/water for the portable ones. Wartsila: If water droplets are big upon reaction with ammonia can dissipate heat. Foam second best option (after fine mist). Foam not recommended in rooms with piping, it will stay on top of them.	
130	5.1 General – Fuel Supply to the Consumers	IGF: PART A-1 7.3.6 Piping fabrication and joining details		
131	5.1 General – Fuel Supply to the Consumers	IGF: PART A-1 7.4.1.2 Materials having a melting point below 925°C shall not be used for piping outside the fuel tanks.		
132	5.1 General – Fuel Supply to the Consumers	IGF PART A-1 9.4 Regulations on safety functions of gas supply system paragraph 9.4.9: "For single-engine installations and multiengine installations, where a separate master valve is provided for each engine, the master gas fuel valve and the double block and bleed valve functions can be combined".		
133	5.1 General – Fuel Supply to the Consumers	IGF Code Supplement 2024 Part A-1 9.5 Regulations for fuel distribution outside of machinery space, paragraphs 9.5.3, 9.5.4, 9.5.5 and 9.5.6		
134	5.2 Loss of containment – Fuel Supply to the Consumers	Clarify if additional measures for preventing the ammonia fuel supply piping from being damaged by vibration from the TCS to Engine Room. Or consider carrying out gas dispersion study to ensure that flammable gas will not reach to safe areas (e.g. accommodation), in case of ammonia leakage between the aforementioned compartments.		
135	6.1 General – Engine Rooms	ABS Ammonia Fueled Vessels Sep 2023, 5-4.1 A single failure within the fuel system is not to lead to a release of fuel into the machinery space. Therefore, the gas safe machinery concept of 5C-13-5/4.1.1 of the Marine Vessel Rules is to be applied to all machinery spaces containing ammonia consumers.		

No.	References	Action	Comment	Responsibility
136	6.1 General – Engine Rooms	KR Guidelines for Ships Using Ammonia as Fuel 2021/ Chapter 3 General Requirements/ Section 6 ESD-Protected Machinery Spaces: ESD protected machinery space concept is not be permitted.		
137	6.1 General – Engine Rooms	Verify that the vessel satisfies ABS Ammonia Fueled Vessels Sec 5-4.3 Machinery spaces containing ammonia as fuel consumers are to be arranged for remote monitoring in accordance with the ACC, ACCU or ABCU requirements of the Marine Vessel Rules.		
138	6.1 General – Engine Rooms	IGF Code Part A-1 9.6 Regulations for fuel supply to consumers in gas-safe machinery spaces, paragraph 9.6.1.1		
139	6.1 General – Engine Rooms	The engine has been tested and approved by the Class. To this end, a Risk Assessment was conducted as part of the Design Approval process.		
140	6.1 General – Engine Rooms	The engine manufacturer addressed exhaust emissions after conducting tests on pollutants such as NOx, N2O, and NH3.		
141	6.1 General – Engine Rooms	Regulations related to exhaust emissions were examined and implemented, such as maintaining an ammonia (NH3) slip limit of 10 parts per million (ppm).		
142	6.1 General – Engine Rooms	Consider whether the gas dispersion study for the engine room should account for the suction of the ICEs turbochargers.		
143	6.1 General – Engine Rooms	Confirm if remote access and support for the DF ICE can be applied, provided that the Integrated Automation System is not supplied by WARTSILA.		
144	6.2 Loss of Containment – Engine Rooms	ABS Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries. 2020, pg 38 "Gas dispersion analysis to Determine if the toxic gas will reach concentrations that could cause sickness or fatalities".		
145	6.2 Loss of Containment – Engine Rooms	Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)		
146	6.2 Loss of Containment – Engine Rooms	The building specifications must define a plan for stress analysis for the ammonia fuel piping.		
147	6.2 Loss of Containment – Engine Rooms	Identify the section of the fuel piping which needs to be protected from a dropped object		

No.	References	Action	Comment	Responsibility
148	6.2 Loss of Containment – Engine Rooms	Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)		
149	6.4 Pipe Failure. Inner Pipe – Engine Rooms 6.5 Pipe Failure. Outer Pipe – Engine Rooms	IGF Code PART A-1 7.3 Regulations for general pipe design 7.3.4 "Allowable Stress" paragraph 7.3.4.4		
150	6.4 Pipe Failure. Inner Pipe – Engine Rooms	Stress analysis considering vibration and fatigue		
151	6.4 Pipe Failure. Inner Pipe – Engine Rooms 6.5 Pipe Failure. Outer Pipe – Engine Rooms	IGF Code PART A-1 7.3 Regulations for general pipe design 7.3.5 "Flexibility of piping"		
152	6.5 Pipe Failure. Outer Pipe – Engine Rooms	IGF Code PART A-1 9.8 Regulations for the design of ventilated duct, outer pipe against inner pipe gas leakage.		
153	6.5 Pipe Failure. Outer Pipe – Engine Rooms	The outer pipe must be designed to withstand the maximum expected pressure.		
154	6.6 Pipe Failure. Annular Space Blockage – Engine Rooms	Verify the dew point for the starting air used for ventilation in the annular space of the double wall piping.		
155	6.6 Pipe Failure. Annular Space Blockage – Engine Rooms	Check the coaming height for the air intake of the annular space in the double-wall piping.		
156	6.8 Fire – Engine Rooms	ABS Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries. 2020, pg 40 Fire Hazard Analysis to assess the risk to assets or humans as a result of exposure to various fire scenarios.		
157	6.11 Trip to Diesel Mode Failure – Engine Rooms	Further study to be done on the ESD operational procedures. Scenarios to include inability of switching to diesel mode		
158	6.24 Leakage of ammonia in the glycol water system – Engine Rooms	Verify the installation of a Gas detection system for the vent nozzle of the AFGSS glycol tank		
159	6.25 Exhaust gas leakage from expansion below – Engine Rooms	Further studies to performed to define the position of gas detectors in the exhaust gas piping casing.		
160	6.26 Inability to diagnose and resolve system failures . Troubleshooting inability – Engine Rooms	Verify the remote access and support for makers (WARTSILA's system has the capability for remote access and support according to the operator's security policy)		
161	6.26 Inability to diagnose and resolve system failures . Troubleshooting inability – Engine Rooms	According to DFDS's security policy, consider details about access and speed for remote access and support for the AFGSS with WARTSILA.		

No.	References	Action	Comment	Responsibility
162	6.26 Inability to diagnose and resolve system failures . Troubleshooting inability – Engine Rooms	Critical spare parts on board according to OEM recommendations		
163	7.1 General – Venting	ABS Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries. 2020, pg 38 Gas dispersion analysis to Determine if the toxic gas will reach concentrations that could cause sickness or fatalities		
164	7.1 General – Venting	Assess whether the vent mast height prevents the formation of flammable gas clouds at normal working levels, based on hazardous area classification.		
165	7.1 General – Venting	Further analysis of ammonia dispersion from the vent mast will be conducted, considering not only normal conditions but also upset and emergency situations.		
166	7.1 General – Venting	Further study on ammonia alarm and shutdown levels is needed, incorporating industry experience.		
167	7.1 General – Venting	SOPs must include clear procedures and warning systems for personnel on deck in case of ammonia release through venting, exhaust, or any other accidental scenario. This should consider dispersion analysis and the associated risks of ammonia.		
168	7.1 General – Venting	To mitigate the dispersion of ammonia vapours from the vent mast, the installation of a gas detection alarm sensor together with a water spray system should be considered.		
169	7.1 General – Venting	Evaluate the need of permanent purging arrangement for the vent mast.		
170	7.1 General – Venting	Further study on the potential use of explosion vents can prevent pressure buildup if ammonia is released into ammonia handling compartments.		
171	7.2 Number of Vent Masts. System overpressure or ammonia release requiring venting – Venting	The number of vent masts is to be further studied. It should be noted that the vent mast is used also and for ammonia related operations, not only when the Pressure Relief Valve (PRV) directs ammonia to the venting system.		
172	7.3 Ammonia Release. Vent Mast Release – Venting	Further study to be done on the (adequate) volume sizing of the buffer tank. The tank must be capable of receiving ammonia in the case of an ESD - this represents the worst-case scenario in terms of trapped liquid ammonia in the piping.		

No.	References	Action	Comment	Responsibility
173	7.3 Ammonia Release. Vent Mast Release – Venting	To mitigate the dispersion of ammonia vapours from the vent mast, the installation of a gas detection alarm sensor together with a water spray system should be considered.		
174	7.4 Ammonia Release (Port). Vent Mast Release – Venting	Further study to be done on the possible release of ammonia through the vent system. Study should consider port related matters (legislation, restrictions etc.		
175	7.4 Ammonia Release (Port). Vent Mast Release – Venting	SOPs must include clear procedures for the pilot to board the vessel, considering the dispersion analysis and the risks associated with ammonia.		
176	7.5 Ammonia Release (Port). Vent mast release during embarkation, disembarkation – Venting	SIMOPS	Comment: Matters to be discussed during a SIMOPS study: 1. Interaction with bunker vessel. 2. Types of bunker vessels to be used for this design. 3. Operational procedures and required time for each process. 4. Action in case of a fire. Possible presence of tugboat(s). 5. Embarkation/Disembarkation procedures during bunkering 6. Bunkering temperature range.	
177	7.5 Ammonia Release (Port). Vent mast release during embarkation, disembarkation – Venting	Dispersion analysis is to be taken into account in the design of the vessel and the embarkation/disembarkation procedures.		
178	7.8 Ammonia Release. WARMS Leakage – Venting	Further study to be done on the available option to vent trapped ammonia in the system in case of a WARMS malfunction. Possibility to have a controlled manual venting directly to the vent mast.		
179	7.8 Ammonia Release. WARMS Leakage – Venting	Further study to be done on the gas detection in the WARMS room and the subsequent action including the operational status of the burner.		
180	7.8 Ammonia Release. WARMS Leakage – Venting	Identify the section of the fuel piping which needs to be protected from a dropped object		
181	7.8 Ammonia Release. WARMS Leakage – Venting	Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)		
182	7.9 Ammonia Release. WARMS Malfunction (other than leakage) – Venting	Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.		

No.	References	Action	Comment	Responsibility
183	7.10 Fire. Vent Mast Ignition – Venting	IGC-Code Int. Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (MSC.177(79)) 17.10 Flame screens on vent outlets		
184	7.11 Water Ingress. Vent Mast – Venting	Identify the section of the fuel piping which needs to be protected from a dropped object		
185	7.11 Water Ingress. Vent Mast – Venting	Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)		
186	7.11 Water Ingress. Vent Mast – Venting	Further study to be done on constant purging of the vent lines to keep them constantly dry.		
187	7.12 Ammonia Release. Leakage from WARMS buffer tank – Venting	Identify the section of the fuel piping which needs to be protected from a dropped object		
188	7.12 Ammonia Release. Leakage from WARMS buffer tank – Venting	Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)		
189	8.1 Design – Ventilation	Further study to be done on ventilation inlets and outlets locations.		
190	8.1 Design – Ventilation	An assessment will be conducted to evaluate a potential leakage scenario, taking the following factors into consideration: -The potential impact it would have on the effectiveness of the ventilation system. -The maximum distance between the safe haven and ammonia release sources, such as vent masts and ventilation outlets, should be clearly defined. -The optimal placement of ventilation inlets to prevent the entry of ammonia.		
191	8.1 Design – Ventilation	Further study to be done on the necessity of having mechanical ventilation in combination with gas measurement.		
192	8.1 Design – Ventilation	Ventilation system analysis should examine the importance for all rooms. In particular the criticality with the WARMS room is to be assessed.		
193	8.1 Design – Ventilation	For ventilation of critical components room use of demister filters is to be further studied.	Not obligatory by the rules	
194	8.1 Design – Ventilation	Install a water spray system to cover the area around ventilation openings, reducing the spread of ammonia vapours on the deck.		

No.	References	Action	Comment	Responsibility
195	8.1 Design – Ventilation	Allow for manual closure of ventilation inlets from within the safe haven.		
196	8.1 Design – Ventilation	Install gas detectors at the ventilation inlets.		
197	8.1 Design – Ventilation	For ventilation outlets, the IBC Code Chapter 17 column "o" specifies that ventilation openings from pump rooms containing toxic cargoes must comply with Section 15.17 regarding toxic cargoes, as outlined in Section 10 [2.3.1].		
198	8.1 Design – Ventilation	Conduct dispersion analyses for worst-case scenarios, such as full venting from tank safety valves and the ventilation of large volumes of gas due to maximum probable leakage from the ventilation system openings to maintain minimum safe distances.		
199	8.1 Design – Ventilation	Revise the gas dispersion study for the engine room using suitable assumptions, such as fuel composition, and illustrate the ventilation strategy and placement of gas detectors according to the gas dispersion study results.		
200	8.2 Accumulation of leaked ammonia. Ventilation failure of double wall piping – Ventilation	Ducting for double-walled piping ventilation should be properly sized to prevent excessive backpressure.		
201	8.4 Accumulation of ammonia vapours. Ventilation failure for Ammonia Bunker Station – Ventilation	ABS Ammonia Fueled Vessels 13-3.1. ABS MRV 5C-13-13.7 Regulations for Bunkering Stations "Bunkering stations that are not located on open deck shall be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed outside. If the natural ventilation is not sufficient, mechanical ventilation shall be provided in accordance with the risk assessment required by 5C-13-8/3.1.1"		
202	8.7 Accumulation of ammonia vapours. Ventilation failure for NH3 equipment room – Ventilation	Further study to be done on the classification of the nitrogen room as gas tight.	Nitrogen not ammonia	
203	9.1 Design – Purging System 9.2 Nitrogen System Efficiency – Purging System	Further study to be done on the capacity of the purging system. The total amount of ammonia in the pipes is to be computed. A RAM analysis is to be conducted.	Knud E. Hansen: Prioritize nitrogen quantities. Make sure complete purging is available at all times.	
204	9.1 Design – Purging System	Further study to be done on the piping routing of the venting system. Aim is to have as many straight lines as possible and avoid bends.		

No.	References	Action	Comment	Responsibility
205	9.1 Design – Purging System	The design of the nitrogen purging system (specifically the fuel pipes) must take into consideration the ammonia physical properties.		
206	9.2 Nitrogen System Efficiency – Purging System	Further study to be done on the nitrogen requirements from Wartsila's system.		
207	9.3 Nitrogen Release. Loss of Containment – Purging System	Further study to be done on the avoidance of having nitrogen spreading to adjacent compartments		
208	9.3 Nitrogen Release. Loss of Containment – Purging System	The building specifications must define a plan for stress analysis for the ammonia fuel piping.		
209	9.3 Nitrogen Release. Loss of Containment – Purging System	Assess the necessity of a continuous oxygen monitoring system for nitrogen-supported compartments to mitigate risks related to asphyxiation from		
210	9.4 Ammonia Release – Purging System	Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.		
211	9.7 Low-pressure nitrogen. Buffer Tank Underpressure – Purging System	The building specifications must define a plan for stress analysis for the buffer tank.		
212	9.7 Low-pressure nitrogen. Buffer Tank Underpressure – Purging System	Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.		
213	9.8 Contaminated Nitrogen . Contamination of nitrogen supply – Purging System	Nitrogen generator is to be equipped with a Carbon Dioxide ($CO2$) measurement device.		
214	9.8 Contaminated Nitrogen . Contamination of nitrogen supply – Purging System	Detailed piping		
215	9.9 Contamination of nitrogen with ammonia. Ammonia backflow – Purging System	Verify the installation of non-return valves		
216	10.1 Design – Bilge System	Capacity and routing of the bilge system is to be provided.		
217	10.1 Design – Bilge System	Further study to be done on the position of the suction valves to allow for remote operation, taking into consideration that the bilge system area is considered a hazardous area.		
218	10.1 Design – Bilge System	Venting of the bilge tank to ARMS is to be reconsidered due to potential pressure levels in the buffer tank. Consider double isolation between the two systems.		

No.	References	Action	Comment	Responsibility
219	10.1 Design – Bilge System	Bilge ventilation system is to be designed independently, with a preferred venting to open air. Also. isolation from any ammonia components is to be preferred.		
220	10.1 Design – Bilge System	ABS Ammonia Fueled Vessels, Sep 2023 Sec 5-8.4 The drainage system is to be sized to remove not less than 125% of the capacity of either the water screen, deluge or water spray system, whichever has the greater capacity.		
221	10.1 Design – Bilge System	According to GHS, ammonia is classified as toxic to aquatic life with long-lasting environmental effects. Therefore: - Discharging ammonia spills into the sea or allowing ammonia vapour to escape underwater must be strictly avoided. Containment on board is preferred. - Releasing ammonia into the sea has severe environmental consequences and must be prevented.		
222	10.1 Design – Bilge System	ABS Ammonia Fueled Vessels, Sep 2023 Sec 5-8.5 Dissolved ammonia (i.e. aqueous ammonia with concentration 28% or less) collected in the drain tank(s) may be discharged at sea complying with the standards and operational procedures required in MARPOL 73/78, Annex II.		
223	10.2 Capacity – Bilge System 10.3 Inability to manage bilge. Bilge Pump Failure – Bilge System	Study is to be conducted on the capacity and capabilities of the bilge system. The amount of fluid during a firefighting process is to be considered.		
224	10.2 Capacity – Bilge System	Study on a dedicated bilge system for contaminated quantities is to be provided.		
225	10.5 Inability to manage bilges . Bilge Lines Clogging – Bilge System 12.2 Uncontrolled fire incident . FFS failure – Firefighting Appliances	Develop material handling procedures for machinery and equipment repair and overhaul.		
226	11.1 General – Detection & Alarm Systems	ABS Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries. 2020, pg 38 Gas dispersion		
227	11.1 General – Detection & Alarm Systems	Automatic closing of isolation valves after detecting ammonia leakage.		
228	11.1 General – Detection & Alarm Systems	Gas detection alarms must be arranged to alert personnel about leakages and prevent entering the space		

No.	References	Action	Comment	Responsibility
229	11.1 General – Detection & Alarm Systems	Assess the necessity of a continuous oxygen monitoring system for nitrogen-supported compartments to mitigate risks related to asphyxiation from nitrogen leakage.		
230	11.1 General – Detection & Alarm Systems	Establish a policy regarding the quantity and utilisation of personal oxygen detectors on board, considering the toxicity of ammonia and the risk of asphyxiation from nitrogen.		
231	11.5 Undetected ammonia leak. Failure of Portable Detectors – Detection & Alarm Systems	Develop material handling procedures for machinery and equipment repair and overhaul.		
232	11.6 Undetected ammonia leak. Complete Detection system power loss – Detection & Alarm Systems	Further study to be done on the installation of two independent detection and alarm systems.		
233	11.7 Design – Detection & Alarm Systems	Further study to be done on the choice of detectors, chemical type will require special attention.		
234	11.7 Design – Detection & Alarm Systems	Portable sampling devices are to be available.		
235	11.7 Design – Detection & Alarm Systems	Further study to be done on portable measuring devices that would measure ammonia levels in an area from the outside, once the double chemical sensors that will have trigger an alarm will no longer be able to measure.		
236	11.7 Design – Detection & Alarm Systems	Closed entry procedures similar to chemical tanker vessels are to be drawn for the ammonia fuelled vessel.		
237	12.1 Design – Firefighting Appliances	Further study to be done on the choice of medium for the FFS. Final selection will be made in collaboration with the shipyard. The study should assess the compatibility of water as a firefighting medium and whether, under specific conditions, it may react with ammonia to form a corrosive fluid.	Knud E. Hansen: The initial design includes a freshwater high-pressure mist system, with powder, foam, and water used for portable extinguishers. Wärtsilä: If water droplets are large, they can dissipate heat when reacting with ammonia. Foam is the second-best option after fine mist. However, foam is not recommended in rooms with piping since it would accumulate on top of them.	
238	12.1 Design – Firefighting Appliances	Study is to be conducted on the capacity of the water-based firefighting system.		
239	12.1 Design – Firefighting Appliances	Dispersion study to be conducted on the effectiveness of the water mist system. Analysis should include locations of ventilation inlets, locations of possible ammonia release and/or occurrence of fire, location of water sprinklers and results of interaction of water with ammonia being in various thermodynamic states.		

No.	References	Action	Comment	Responsibility
240	12.1 Design – Firefighting Appliances	Ammonia system supplier is to design the FFS/ESD system.		
241	12.1 Design – Firefighting Appliances	Further studies on the N2 system need to be conducted for firefighting for the TCS and vent masts (ref. International Chamber of Shipping Chapter 3.7.3).		
242		Review the positioning of the engines. Review the position of the inlet manifold. Provided drawing showing engine arrangements are to be updated. Examine the possibility of reducing the length of the double wall pipes	Wartsila: Only possible if engines are rotated.	
243		Bunkering according to applicable standards. Manual according to IGF code.		
244		Study is to be conducted on the capacity of the water firefighting system.		
245		Dispersion study to be conducted on the effectiveness of the water mist system. Analysis should include locations of ventilation inlets, locations of possible ammonia release and/or occurrence of fire, location of water sprinklers and results of interaction of water with ammonia being in various thermodynamic states.		
246		Ammonia system supplier is to design the FFS/ESD system.		

Appendix C HAZID Workshop Attendance Sheets

The multi-disciplined HAZID team from ABS, Fundación FV, EMSA, Wartsila, KEH, DFDS, and NTUA attended the workshop (virtually). NTUA facilitated the workshop, which was scribed by ABS. The table below presents the HAZID team.

Table 13: HAZID Team

S/N	Affiliation	Position
1	NTUA	Professor
2	NTUA	PhD(c)
3	NTUA	PhD(c)
4	NTUA	Research Engineer
5	NTUA	Project Manager
6	NTUA	General Manager
7	NTUA	Research Engineer
8	NTUA	Research Engineer
9	ABS	Director of Global Sustainability Centre
10	ABS	Global Sustainability Centre
11	ABS	Global Ships Systems Centre
12	ABS	Global Ships Systems Centre
13	ABS	Global Ships Systems Centre
14	ABS	Global Ships Systems Centre
15	FV	Innovation project Manager
16	DFDS A/S	Project Manager – Naval Architect
17	DFDS A/S	Senior Project Manager – Naval Architect
18	KEH	Marine Engineer and Naval Architect
19	Wartsila	Engineer
20	Wartsila	Engineer

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