European Maritime Safety Agency

SAFETY OF AMMONIA FOR USE IN SHIPS

PART 4 – RISK ASSESSMENT OF A BULK CARRIER SHIP DESIGN

Date: 16/07/2025

EMSA

About this study:

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Document History

Version	Date	Changes	Prepared	Approved
0.5	23/05/2025	First Version	NTUA, ABS, FVP	-
1.0	30/05/2025	▪ Miscellaneous updates	NTUA, ABS, FVP	-
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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 Organisation (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 four (4) of the EMSA-funded study for the safety of ammonia as a maritime fuel and it consists of the Hazard Identification (HAZID) study of a Newcastlemax Bulk Carrier ship design (including SIMOPS).

Bulk Carrier 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 Bulk Carrier 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.

All the results of the HAZID study were documented in the HAZID worksheet during the HAZID workshop. In total, four hundred and fifty-two (452) scenarios were identified at the HAZID workshop. Thirty-four (34) scenarios were purposefully not ranked either because there were no hazards identified, or there was insufficient technical information to carry out the risk ranking. No scenarios were categorised as low-risk, and one hundred and twenty-two (122) scenarios were categorised as moderate-risk. Two hundred and ninety-seven (297) scenarios were categorised as high-risk, while no scenarios were categorised as extreme risk. The results are presented in the Risk Ranking (or unmitigated risks) table below.

Risk Ranking

		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	**12**	**178**	**23**	**0**	**0**
	Possible **(-2):** Occurs once every 10-100 ship years	**0**	**110**	**80**	**16**	**0**
	Unlikely **(-3):** Occurs once every 100-1000 ship years	**0**	**0**	**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 sixty-eight (368) scenarios were categorised as low-risk and forty-eight (48) were categorised as moderate-risk. No scenarios were categorised as high-risk, while no scenarios were categorised as extreme risk. The results are presented in the Residual Risk (or mitigated risk) table below.

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	**8**	**0**	**0**	**0**	**0**
	Possible **(-2):** Occurs once every 10-100 ship years	**368**	**40**	**0**	**0**	**0**
	Unlikely **(-3):** Occurs once every 100-1000 years	**0**	**0**	**0**	**0**	**0**
	Rare **(-4):** Occurs once every 1000-10000 years	**0**	**0**	**0**	**0**	**0**

Two hundred and forty-six (246) 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:

- Operational complexity during bunkering is a key safety concern, particularly when combined with other concurrent activities. As such, SIMOPS involving ammonia bunkering and cargo operations should be carefully restricted or phased in gradually, especially during the early adoption phase of ammonia-fuelled vessels.
- Conservative operational strategies are recommended during the initial deployment phase, including running ICE generators on Marine Gas Oil (MGO) while at port or anchorage, even if ammonia is technically available. This reflects a risk-averse approach prioritizing safety over fuel switching flexibility.
- The interaction between ammonia and cargo environments requires further scrutiny, particularly regarding chemical compatibility and dust interference. These factors can compromise bunkering safety, gas detection reliability, and overall equipment performance.
- Ship layout and emergency preparedness must be adapted to ammonia-specific hazards.
- Multiple safe havens may be needed based on vessel size and crew distribution.
- Muster stations and escape routes should be positioned away from ammonia systems.
- A comprehensive review must be conducted regarding the requirements (type and use) and the availability (quantity and storage onboard) of personal protective equipment (PPE) that is lightweight and does not hinder physical movement. Additionally, the PPE should not restrict the duration of tasks based on environmental conditions, such as humidity and ambient temperature.
- Design implications emerged as critical themes:
  - Flexible piping arrangements are needed to accommodate hull deformation (hogging/sagging).
  - Tank Connection Spaces (TCS) must allow for safe maintenance and emergency access.
  - Segregation and compartmentalisation of ammonia systems are vital to prevent escalation during leak scenarios, promote system maintenance and availability of subsystems, such as the tank pressure management system.
- Training and human factors are essential, especially for port personnel who may be less familiar with ammonia-specific hazards. Tailored programs should focus on emergency response, first aid, and safe handling practices.

- The increased bunkering frequency due to ammonia's lower energy density introduces new logistical and safety challenges. These should be mitigated through tank sizing, optimised scheduling, and bunkering safeguards.
- Security risks, including potential targeted attacks on vulnerable ammonia-related equipment, must be formally assessed and mitigated through both physical protection and procedural controls.
- A risk-based design philosophy is strongly recommended, going beyond baseline compliance with the IGF Code and MSC1-Circ. 1687. This includes material selection, corrosion resistance, and long-term reliability in ammonia environments.

SIMOPS

The goal of the SIMOPS (Simultaneous Operations) assessment was to identify and evaluate potential hazards arising from overlapping operations during ammonia bunkering on board a Newcastlemax bulk carrier. The scope of the study covered various bunkering scenarios — including operations in port (from barge, truck, or terminal), at anchor, and while underway — and examined how these may interact with concurrent activities such as cargo handling, maintenance, crew transfer, and fuel provisioning. The assessment aimed to propose practical safeguards and procedural measures to ensure the safe and effective implementation of ammonia bunkering under real operational conditions.

The key takeaways from the SIMOPS assessment session are summarised below.

General Observations

- The primary hazard across all SIMOPS scenarios is ammonia release due to loss of containment, potentially caused by equipment failure, operator error, or external damage (e.g., dropped objects).
- Secondary hazards include fire/explosion risks, especially in the presence of flammable cargoes, substances, or fuels (e.g., MGO).
- Human injury is the dominant consequence, with occasional mention of environmental impacts (e.g., ammonia spill at sea).
- Activities assessed span port, terminal, at anchor, and underway bunkering operations.

Main Hazardous SIMOPS

The main hazardous SIMOPS identified are outlined in the table below.

Main Hazardous SIMOPS

Operation Category	Typical SIMOPS Risks with Ammonia Bunkering	Notable Recommendations
Cargo Handling	Crane/grab ops, conveyor systems interfering with ammonia infrastructure	Avoid cargo operations during ammonia bunkering, especially coal
Provision Loading	Forklifts/cranes potentially entering hazardous zone	Define safety zones based on wind direction & dispersion modelling
Hazmat Loading	Risk of reaction between ammonia and chemicals (e.g., solvents, oils)	Prohibit simultaneous handling of hazardous materials
MGO Bunkering	Flammability of MGO in proximity to toxic ammonia	Avoid simultaneous ammonia and MGO bunkering
Embarkation/Disembarkation	Exposure of personnel in access ways to ammonia	Restrict access; use stern ladder; schedule outside bunkering
Ship Operations & Drills	Hot work, drills, inspections during bunkering create risk	Conduct these outside bunkering hours; risk assessment required
Man Overboard Response	Conflicting priorities between life-saving operations and bunkering	Immediate halt of bunkering and initiation of SAR procedures

Key mitigating measures

The key mitigating measures proposed are the following:

- Training of port personnel on ammonia-specific risks.
- Clear zoning policies and restricted access during bunkering operations.
- Dedicated procedural planning to schedule high-risk operations at non-overlapping times.
- Emergency response coordination (e.g., with Firefighting tugs, Search & Rescue units).
- Technical upgrades such as leak detection, inerting systems, or anti-spill hoses.
- Infrastructure improvements like increasing ammonia tank size to reduce bunkering frequency.

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List of Abbreviations

ABS	American Bureau of Shipping
ADS	Addressable Detection System
ARMS	Ammonia Release Mitigation System
BOG	Boil-Off Gas Management
CAMS	Control Alarm & Monitoring System
CBM	Cubic Meters
CCTV	Closed Circuit Television
CFD	Computational Fluid Dynamics
DWT	Deadweight Tonnage
EBC	Emergency Breakaway Coupling
EMSA	European Maritime Safety Agency
ESD	Emergency Shutdown
ESDSS	Emergency Shutdown and Safety System
FAT	Factory Acceptance Test
FFS	Fire Fighting System
FiFi tug	Notation for tugboat equipped with a Fire Fighting System for combating fires at sea
FMEA	Fail Modes Effects Analysis
FPR	Fuel Preparation Room
FSS	Fuel Supply System
FTA	Fault Tree Analysis
FV	Fundación Valenciaport
FVU	Fuel Valve Unit
GA	General Arrangement
GCU	Gas Combustion Unit
GVU	Gas Valve Unit
GVU-ED	Gas Valve Unit of Enclosed Design
HAT	Harbour Acceptance Test
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HFO	Heavy Fuel Oil
HMI	Human Machine Interface
HP	High Pressure

IAS	Integrated Automation System
ICE	Internal Combustion Engine
IGF Code	International Code of Safety for Ships using Gases or other Low-flashpoint Fuels
IMO	International Maritime Organization
LAHH	High-High L Alarm
LEL	Lower Explosive Limit
LNG	Liquefied Natural Gas
LoC	Loss of Containment
LP	Low Pressure
LPG	Liquefied Petroleum Gas
MARIC	Marine Design and Research Institute of China
M/E	Main Engine
MGO	Marine Gas Oil
MTTF	Mean Time To Failure
MV	Mechanical Ventilation
NH_3	Anhydrous Ammonia used as fuel
NRV	Non-Return Valve
NTUA	National Technical University of Athens
OPTS	Operator Training System
PFAS	Per- and Polyfluoroalkyl Substances
PFD	Process Flow Diagram
PMS	Planned Maintenance System
PP	Personnel Protection
PPE	Personal Protective Equipment
PRV	Pressure Relief Valve
PS	Port Side
QCDC	Quick Connect/Disconnect Coupler
RORO	Roll On Roll Off
SAR	Maritime Search and Rescue operation
SAT	Sea Acceptance Tests
SC	Specific Contract
SCR	Selective Catalytic Reduction System
SGMF	Society for Gas as a Marine Fuel
SIGTTO	Society of International Gas Tanker and Terminal Operators

SIMOPS	Simultaneous Operations
SMS	Ship Management System
SOP	Standard Operator Procedures
SSL	Secure Sockets Layer
STBD	Starboard Side
SV	Safety Valve (Pressure or Thermal)
TCS	Tank Connection Space
VFD	Variable Frequency Drive
WG	Water Glycol
WINGD	Winterthur Gas & Diesel
W/S	Workshop

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, where it falls under the jurisdiction of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases (IGC Code). The handling of ammonia is fraught with challenges due to its toxicity at low concentrations, which raises notable health and safety concerns for the crew members aboard vessels. Therefore, s potential wide use as a bunker fuel implies a shift from one-off operations with ammonia to extensive use, which significantly increases the risks 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 Bulk Carrier 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 Newcastlemax Bulk Carrier 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**), Marine Design and Research Institute of China (**MARIC**), **TGE** Marine, Winterthur Gas & Diesel (**WINGD**), **Cargill**, **Færder Tankers**, and **Oldendorff** Carriers.

This report concerns Task 4 and constitutes the third 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 technology providers for the purposes of this risk assessment workshop are MARIC (bulk carrier general GA design), TGE (fuel supply system design), and WINGD (main engine specifications).

The 210,000DWT Newcastlemax Bulk Carrier design provided by **MARIC** is equipped with Type C ammonia storage tanks with a total capacity of 6,600 m³, providing an endurance of approximately 18,000 nautical miles at mixed loading conditions (50% at 12 knots, 50% at 13 knots). The vessel also includes heavy fuel oil (HFO) and marine gas oil (MGO) tanks with capacities of 4,500 m³ and 700 m³, respectively, enabling an endurance exceeding 30,000 nautical miles at design speed. A reliquefication system will also need to be installed to manage boil-off gas (BOG), with the expected BOG rate being less than 0.1% per day. Ammonia venting will be designed only for emergency scenarios, such as in the event of overpressure due to fire or system malfunction. Releases during normal operations are to be strictly controlled to maintain ammonia concentrations within acceptable safety thresholds. An ammonia catching system will also be installed. Storage tanks do not require inerting as per existing rules, although a nitrogen-based inerting system will be provided, primarily to facilitate purging operations and safe isolation of the engine system during shutdown or maintenance. To mitigate sloshing risks, internal tank structures are designed accordingly, and tank strength calculations account for dynamic loads. The engine room will be designed to be gas safe, allowing standard maintenance activities without special protective measures, although personal protective equipment (PPE) will be kept readily accessible. In terms of emergency response, the deckhouse will be considered the primary haven in the event of a significant ammonia leak. The ventilation inlet will be located outside toxic areas. While not required by regulations, maintaining overpressure in the deckhouse is considered a potential safety enhancement. An airlock system is not required for the deckhouse but will be installed for the fuel preparation room, which will also be fitted with continuous mechanical ventilation under negative pressure. All equipment installations will comply with hazardous area classification requirements. The bunker station, located within the cargo hold area, will be protected by gratings to prevent mechanical damage to pipes. Details regarding bunkering procedures, crew protection, and simultaneous operations are to be further discussed and finalised at a later stage.

The Fuel Supply System (FSS) was designed by **TGE** and is intended for MARIC's Newcastlemax bulk carrier design. The FSS is designed to supply a dual-fuel, two-stroke main engine, according to WINGD specifications. Redundancy for both propulsion and power generation will be ensured by fuel oil in the event of a fuel gas supply shutdown. The system will be developed in accordance with the alternative design provisions outlined in Chapter 2.3 of the IGF Code and will comply with the relevant ABS rules for the use of ammonia as fuel, taking into consideration the interim IMO guideline MSC.1/Circ.1687, where applicable. TGE's ammonia Fuel Supply System (NH_3 FSS) will be developed in compliance with all applicable rules and regulations currently in force. The system will be designed to meet WinGD interface requirements and reflects the current stage of technical development. The design remains subject to modification at a later stage.

For the purposes of the HAZID, **WinGD** provided the specifications of their X-DF-A dual-fuel engine, which is capable of operating on both liquid ammonia and conventional fuel oils. Key features include electronically controlled ammonia injection, a safety system that detects hazards early and responds with alarms or shutdowns, and full compliance with IGF and IGC codes. A dedicated FMEA for this engine design has been performed but is not publicly available.

1.3 System Description

1.3.1 Vessel General Information

The general arrangement of the Newcastlemax Bulk Carrier (developed by MARIC) is presented in Figure 1.

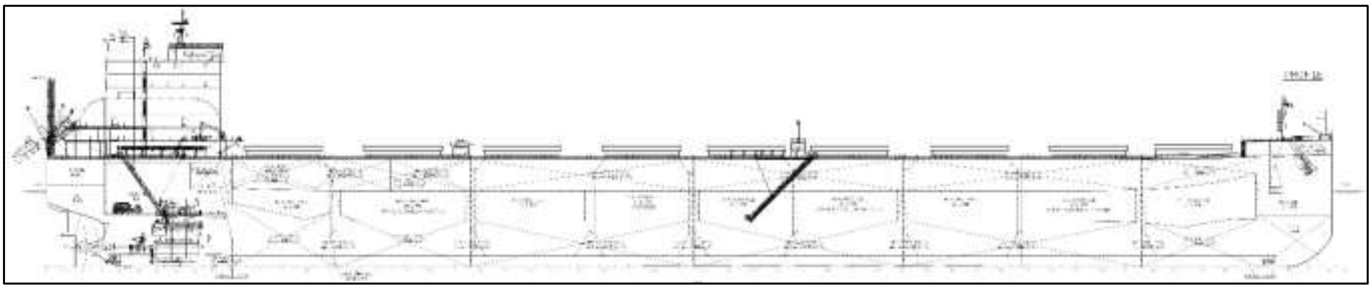

Figure 1: Side view of Newcastlemax Bulk Carrier

The principal dimensions of the Bulk Carrier are listed in Table 1.

Table 1: Principal dimensions of Newcastlemax Bulk Carrier

Particular	Description
Length (Overall - m)	299.95
Length (Between Perpendiculars - m)	295.90
Breadth (MLD - m)	50.00
Depth (m)	25.20
Draught (Design - m)	16.10
Draught (Scantling - m)	18.55
Deadweight at Ts (ton)	210,500
Design speed at Td (kn)	14.5
Cargo hold (cbm)	228,000
Ammonia tanks (cbm)	6,600
HFO tanks (cbm)	4,000
MGO tanks (cbm)	700

1.3.2 Ammonia Fuel Supply System General Information

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

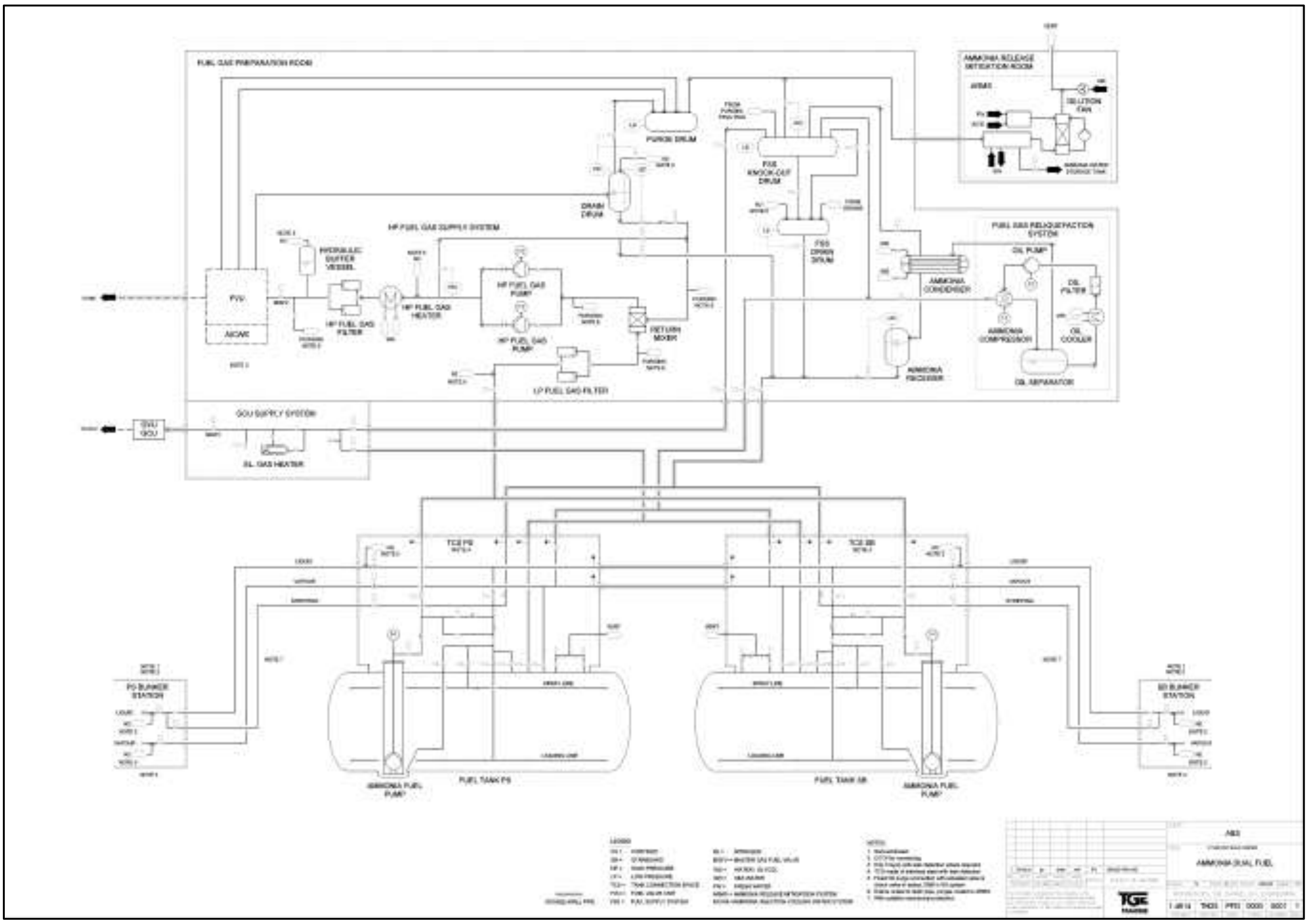

Figure 2: Overall Process Flow Schematic

The fuel supply system (FSS) specified hereinafter is provided for the new building of a 210,000 dwt Bulk Carrier. The FSS shall supply the dual fuel two stroke main engine. Redundancy of propulsion and power supply is ensured by fuel oil in case of fuel gas supply shutdown. The FSS will be designed following the alternative design as per IGF code chapter 2.3 and is based on applicable ABS rules for ammonia as fuel considering interim IMO guideline MSC.1/Circ. 1687 if required.

The design of TGE´s NH3 fuel supply system will comply with rules and regulations which are in place at this point in time. TGE will supply its own NH3 FSS Design which will supply the fuel according to WinGD interface requirements. The NH3 FSS design reflects the current status of development and is subject to change at a later stage.

1.3.2.1 Rules and Regulations

Dimensioning and material, the fuel gas system and its components mentioned in this specification outline will comply with the following rules, regulations and recommendations:

- ABS Rules
- Code of Safety for Ships using Gases or other Low flashpoint Fuels (IGF Code) as far as applicable
- MSC.1/Circ. 1687 - Interim guidelines for the safety of ships using ammonia as fuel
- SOLAS
- IEC 60092 Electrical installations in ships

1.3.2.2 Design Parameters

The vessel will be equipped with the following gas consumers:

- **Main Engine**: 1 x WinGD 6X72DF-A-1.0, Supplier: WinGD, Total power: about 13,460 kW (CMCR)
- **GCU**: Provisions based on estimated flow below, Type: tba, Supplier: tba, Estimated flow: Abt. 70 kg/h (tba)

Basic Layout concept of FSS

- Fuel gas storage tanks will be installed horizontally on deck with sufficient natural ventilation around the tanks to prevent accumulation of ammonia.
- Tank Connection Space(s) will be located on top of the tanks for the containment of tank equipment. The TCS will be classified as hazardous and toxic area and will be ventilated. It must be equipped with an airlock system and a hatch room.
- The fuel gas preparation room will be located on deck next to the storage tanks. This room will be classified as hazardous and toxic area and ventilated. It must be equipped with an airlock system.
- Separate compartment incl. separate access of the FGPR to accommodate equipment for GCU supply to be arranged.
- Auxiliary equipment (instrument air system, nitrogen generator, LT water-glycol cooler, LT water-glycol pumping and cooling system) will be installed in appropriate location, e. g. in engine room.
- The gas valve unit for the GCU and gas conditioning equipment will be in a dedicated GCU room.
- The FVU (by others) for the M/E will be located inside FGPR. If located inside the engine room the GVUs and FVU are of an enclosed design and the internal space will be classified as hazardous area and ventilated accordingly.
- The engine room is considered as a gas-safe machinery space in accordance with IGF code chapter 9.6.
- All fuel gas supply lines outside the fuel gas preparation room passing through ship enclosed spaces as well as through the engine room are double walled.
- Bunkering lines are routed on deck and are single walled with suitable mechanical protection subject to confirmation by risk assessment.
- Fuel gas bunkering connections will be arranged on open deck at both sides of the ship below the tank connections located in a semi-enclosed shelter subject to confirmation by risk assessment.
- Manifold filters in accordance with SGMF requirements.
- TGE's filter concept are intended for equipment protection only.
- The FSS switchboard will be in an electrical room.
- The control, alarm and monitoring system and the emergency shutdown and safety system will be located in the engine control room.
- The CAMS operator stations will be in the engine control room and on the navigation bridge.
- Ammonia Release Mitigation System (ARMS) to be installed in dedicated room on upper deck.
- Ammonia water storage tank(s) (by others) to be installed in a dedicated area/room.

Fuel Storage Tanks

The design parameters of the fuel storage tanks are presented in Table 2 below:

Table 2: Design parameters of fuel storage tanks

Parameter	Value
Number of tanks	2
Total geometric volume	6,600m^3
Max. allowable relief valve setting (Tank Design)	4.0 barg
Max. allowable working pressure	3.6 barg
Min. allowable tank pressure	-0.3barg
Min. temperature	-35 ^{o}C
Max. fuel density	682 kg/m^3
Max. loading limit (IGF-Code Ch. 6.8)	As per IMO guideline 6.8.2

1.3.2.3 Plant Description

The main subsystems of the AFSS are the following:

- Fuel gas storage tanks
- High pressure fuel gas supply system to main engine
- Low pressure boil-off supply system to GCU
- Boil-off gas reliquefaction system
- ARMS, incl. dilution air fan
- Fuel valve unit (by others)
- Vent and drain system
- Water/glycol system
- Bunkering System
- GCU

The auxiliary systems consist of the following:

- Instrument air distribution system
- Water/glycol system
- Nitrogen generation and distribution system
- Connection to ship system for heating/cooling water supply

The safety systems are the following:

- Gas detection system
- Fire detection system
- Leakage detection system
- Emergency shutdown system
- Water spray systems (to be supplied by others)
- Safety showers and eye washers (to be supplied by others)

The control systems include the control, alarm, and monitoring system.

1.3.3 Basic Processes

1.3.3.1 General

The FSS will be designed to operate in the following process modes:

- Bunkering ammonia with vapour return
- Fuel supply to main engine
- BOG supply to GCU (free flow)
- Fuel tank cooling (BOG reliquefication)

1.3.3.2 Inerting, Gas-freeing, Drying

When not in use the fuel gas piping inside the bunkering stations is inerted. The required nitrogen will be provided by the nitrogen system. Neither inerting nor gas-freeing of the complete system including the fuel gas storage tank are considered as standard operations. This will only be necessary for preparing for repair, maintenance work or dry docking. In this case nitrogen needs to be provided by an external source. For maintenance purposes and purging of fuel supply lines, nitrogen can be provided from on-board systems.

1.3.3.3 Purging with Ammonia and Cooling Down

Purging with ammonia and cooling down of fuel gas storage tanks and fuel gas system are not considered as standard operations. Purging with ammonia must be carried out during commissioning and after maintenance work (gas free ship). Required vapour could be taken from shore. Cooling down will take place afterwards with liquid ammonia from shore. All vapours produced by purging and cooling down will be handled by shore facility.

1.3.3.4 Bunkering

The system is designed to transfer ammonia with vapour return. While one bunkering station is in operation, the station on the other side of the ship stays inerted and segregated.

1.3.3.5 Low Pressure Liquid Supply

Low pressure liquid supply from the fuel gas storage tanks by LP fuel gas pumps and to the HP Fuel Gas Supply System.

1.3.3.6 Fuel Gas Supply to Consumers

Fuel gas is supplied through pressurisation of ammonia by HP fuel gas pump and fuel gas heating by HP fuel gas heater for main engine.

1.3.3.7 BOG Treatment System

Since ammonia is stored in the tanks at low temperatures, heat leaks from the environment cause the ammonia to produce boil-off gas. To prevent the resulting tank pressure from rising above acceptable limits, the Fuel Gas Cooling System reliquefies the BOG by employing a direct reliquefication system. The BOG is compressed, condensed against water-Glycol (WG) and routed back to the fuel gas tank.

The GCU will be used as back-up for the BOG reliquefaction plant. In that case the GCU will be operated in free-flow directly fed via a separate line from the Fuel Gas Tank vapour space.

1.3.3.8 Unloading

Unloading NH3 from the Fuel Gas Storage Tanks without providing the fuel gas to the engine is a non-standard/emergency operation. Emergency unloading can be carried out by tank pressurisation using hot ammonia or nitrogen.

1.3.3.9 Warming up and Gas Freeing

Warming up and gas freeing of the system will only be required during repair or maintenance activities. Under normal operating conditions, these procedures will not be necessary for the fuel gas system, including the fuel gas storage tank.

Only the bunkering system (when disconnected) and the fuel gas supply lines between the GVU/FVT and the consumers (when not in operation) must be inerted (to be carried out by others).

1.3.4 Fuel Gas Storage System

1.3.4.1 Fuel Gas Storage Tank

The Fuel Gas Storage Tanks will be delivered by TGE completely prepared for installation below deck of the ship. Calculation of the temperature distribution at the tank saddles will also be supplied by TGE. The tank specifications are presented in the Table 3 below.

Table 3: Fuel storage tanks specifications

Parameter	Value
Number of tanks	2
Tank shape	Cylindrical with hemispherical heads, installed horizontally
Tank volume	Abt. 3,300m^3 (each)
Tank dimensions	Abt 12.2m x 33m (steel dimensions, insulation excluded
Internal piping	Stainless steel: AISI 304L or equivalent
Design lifetime	25 years

The Fuel Gas Storage Tanks will be made from P355 or other equivalent material with charpy V-notch impact values as per Code and Class requirements.

The fuel gas storage tank equipment includes the following:

- Liquid and vapour connections as per PFD
- Remote operated pneumatically actuated valves with ESD function for liquid loading lines, pump discharge line, spray line, stripping line and vapour line.
- Separate direct connection of tank vapour space to GCU-preparation equipment including a normally closed remote operated valve which is not connected to the ESD-system
- Manually operated valves
- Manhole
- Two tank safety relief valves
- Spray line for fuel gas storage tank cool-down and to prepare the system for bunkering
- Foundations for installation of LP fuel gas pumps in the fuel gas storage tank
- Sloshing protection chamber for LP fuel gas pumps
- Caisson pipe for installation of LP fuel gas pumps

1.3.4.2 Fuel Gas Storage Tank Shipside foundations

The tank is supported by two bearings to the deck. To ensure free movement of tank as a statically determined system, one support is designed as a fixed and the other as a sliding bearing. Interface information to foundation will be provided. Anti-floating and anti-rotation devices will be provided to keep the tank down on its foundations in case the cargo hold is flooded.

Interface information to foundation, including provisions for anti-floating and anti-rotation will be provided by TGE. The Fuel Gas Storage Tank will be completely welded, 100% x-rayed, as well as tested for tightness and hydrostatic pressure, according to code requirements.

The outside surface of NH3 fuel gas tank will be insulated with an insulation system with the characteristics presented in Table 4 below.

Table 4: Fuel storage tanks additional characteristics

Parameter	Value
Min. tank temperature	-35 ^{o}C
Insulation material	PU spray foam with polymeric surface protection coating
Insulation thickness	Min. 200 mm (depending on final selected insulation)
Mechanical Protection	GRP cover or similar
Average K-value	0.124 W/m² K at min. temperature
Fire resistance class of insulation system	According to IGF code

Fuel Gas storage Tank will be delivered to shipyard with cleanness certificate by third party.

1.3.4.3 Fuel Storage Gas Tanks Connection Space

The tank connection space (TCS) is mounted on the top of the NH3 Fuel Gas Storage Tank. It houses the tank equipment. Bunkering connections and fixed fuel gas storage tank nozzles are penetrating the TCS and are then connected to the fuel gas preparation room. The TCS is a hazardous and toxic area and is designed as a liquid and gas tight room with sufficient ventilation as per rules (by the Yard). Explosive proof equipment is mandatory to be installed inside the TCS. The fuel gas storage tank and the TCS are joined and supplied as one unit ready for installation on the ship side tank foundation. Connections are located at the boundary of the tank connection space ready for shipside connections. Double-walled pipes (if applied) need to be connected inside of the TCS. Adjacent platforms, as well as stairways/ladders to access the TCS (by Yard) is also required. An airlock system for the access is provided at the TCS as per class requirements. Further ventilation of the tank connection space as per rules needs to be provided (by the Yard). A water curtain to be installed at the entrance of the TCS (by others).

The TCS is supported on the fuel gas storage tank and is structurally independent. Its material is stainless steel (304/304L), whereas its maximum design pressure is 100mbarg. Externally the TCS is equipped with an interface for spillage collection and potential passive or active fire-protection measures.

1.3.4.4 Low-pressure (LP) Fuel Gas Pumps

Two (2 x 100 %, one per tank) fuel gas pumps are installed in each of the tanks. The pumps feed the HP fuel gas pumps. The pumps are of vertical, deep well, centrifugal multistage design. For retraction, the pumps are equipped with foot valves. The motor is installed in the TCS outside of the tank. The pumps are installed in a caisson pipe fitted with a closable foot valve allowing removal of the equipment without gas-freeing the tank. The pumps are equipped with a magnetic coupling without mechanical seal. The pumps are designed for remote start and stop and are shut down automatically upon emergency or malfunction (low or high power). The fuel gas pumps will be frequency controlled, and minimum flow is controlled by return to the tank and equipped with cavitation protection. An overview of their characteristics is provided in Table 5 below.

Table 5: LP fuel gas pumps design characteristics

Design Data	
Quantity	2
Capacity	8.6 m^3/h at 200 mlc (acc. to WinGD spec.)
Discharge pressure	13 barg
Speed	Frequency controlled
Shaft power	Abt. 15 kW
Min. cargo temperature	-35 ^oC

1.3.5 Fuel Gas System

1.3.5.1 Return Mixer

The return mixer (made from stainless steel) is fitted in the fuel supply stream upstream the HP fuel gas pumps. It mixes the stream from the fuel tank with the liquid ammonia catch tank/drain drum).

1.3.5.2 High-pressure (HP) Fuel Gas Pumps

Two (2 x 100%) HP fuel gas pumps are installed in the fuel gas preparation room. The HP fuel gas pump pressurizes the liquid fuel gas to the pressure required by the main engine. The HP fuel gas pumps are of the membrane piston type. The pump is designed for remote and local start and stop and is shut down automatically upon emergency or malfunction. The speed of the fuel gas pump will be frequency controlled. An overview of their characteristics is provided in Table 6 below.

Table 6: HP fuel gas pumps design characteristics

Design Data	
Quantity	2 (2x100%)
Type	Membrane piston
Capacity	Max. 9.8 m^3/h
Supply pressure	90 barg

1.3.5.1 High-pressure (HP) Gas Heater

One (1x100%) HP fuel gas heater will heat the supercritical fuel gas coming from the HP fuel gas pump unit to a suitable temperature for the main engine. An overview of its characteristics is provided in Table 7 below.

Table 7: HP fuel gas heater design characteristics

Design Data	
Quantity	1 (1x100%)
Type	Shell and tube Tube side: fuel gas Shell side: GW
Capacity	9.8 m^3/h
Operating pressure	85 barg
Material	Tube side: Stainless steel Shell side: TBD during project execution by TGE
Heating medium	Glycol/Water (GW)
Thermal Duty	Abt. 550kW (acc. To WinGD Spec.)

The fuel supply line to the HP pumps is equipped with duplex type filters with changeover function. For maintenance and repair works the filter will be equipped with suitable drain and purge connections. The fuel supply line to the FVU is equipped with duplex type filters. The HP filter has a design pressure of 110 barg and an absolute fineness of 10 µm. A mass flow metres installed in supply line will be provided.

1.3.5.2 Fuel Gas Return System

The fuel gas return system is designed to allow the supply system to be emptied and purged after engine stop and enables system filling prior to engine start. It consists of an ammonia drain drum (WinGD: catch tank) and purge drum. The system is connected to the FVU. The specifications of these drums are presented in Table 8 below.

Table 8: HP fuel gas heater design characteristics

Drain Drum	
Quantity	1
Type	Pressure Vessel
Capacity	To be confirmed during design
Design pressure	30 barg
Operating pressure	Abt. 22 barg
Medium	Liquid ammonia and nitrogen
Purge Drum	
Quantity	1
Type	Pressure Vessel
Capacity	To be defined by simulation studies during project execution
Design pressure	10 barg
Operating pressure	Abt. 0-5 barg
Medium	Gaseous ammonia and nitrogen

1.3.5.3 Fuel Gas Reliquefication System

The purpose of the fuel gas reliquefication system is to maintain the fuel gas storage tank pressure within the design and required operational limits of the containment system. It is designed as a direct system where evaporated gas (BOG) is compressed, condensed and returned to the storage tank. Its main components include a suction strainer, a boil-off gas compressor, an oil separator (<0.5 ppm w), an ammonia condenser, and an ammonia receiver. The BOG compressor along with the motor and the oil system are forming a skid-mounted compressor package. The availability of the cooling function as required by the rules is ensured by the GCU.

Boil-off Gas (BOG) Compressor

One (1) oil injected screw compressor is equipped with the following:

- forced oil lubrication and sealing system
- suction filter
- hydraulically operated slide valve for automatic capacity control
- suction pressure controller, and a
- pressure retention valve

The BOG compressor will be driven by an electric motor. The motor will be of squirrel cage induction type and equipped with anti-condensation heating.

1.3.5.4 Gas Combustion Unit (GCU) System

The GCU will be employed for thermal oxidation of purge gas or as back-up for the fuel gas cooling system. The GCU supply system conditions the temperature of the ammonia boil-off gas/purge gas the conditions which can be accepted by the GCU, as well as isolation towards the GCU.

Its main equipment includes the following:

- One electrical gas heater
- Automated valves

All components to be arranged in a separate GCU supply system room. This room needs to be separated from the FGPR by create his own hazardous zone.

1.3.5.5 Gas Combustion Unit

A Gas Combustion Unit will be provided for burning of mixtures of Ammonia and Nitrogen from 0 – 100 % Ammonia. The unit is designed as a back-up method for tank pressure control in case the reliquefication system is not available. The system is designed for installation inside a gas safe machinery space and it has a capacity of 70 kg/h. It can be fed in free flow from the tank and it consists of the:

- GVU
- GCU
- Combustion Fan
- Cooling Air Fan
- Pilot burner combustion air fan
- Pilot burner liquid fuel supply system
- Control panel

1.3.6 Ammonia Bunkering System

1.3.6.1 Bunkering Connection (skid mounted)

Two (2) ammonia bunkering stations, both provided as separate skid units, will be arranged. One with connection to starboard and one with connection to portside. The bunkering skids have been designed for installation on open deck within a shelter. Each skid will be equipped with:

- One liquid connection with a manually operated valve and a remote operated shutdown valve in series, or a combined manually and remote operated valve as indicated in PFD
- One vapour return connection with a manually operated valve and a remote operated shutdown valve in series, or a combined manually and remote operated valve as indicated in PFD

- Provisions for the ESD
- Fixed nitrogen connection with globe check valve
- Draining liquid from bunker manifold and bunker line to fuel gas tank by dedicated stripping line / Nitrogen connection for stripping the lines
- One (1) manifold filter with mesh size 250 µm in acc. with SGMF requirements
- Water spray system for bunkering station as per class requirement by Yard
- Reducers and spool pieces according to SGMF requirements by TGE

The bunkering stations are equipped with thermal relief valves as per Class requirements. Drip trays will be located below the skids, which may extend over the ship's side to protect the ship's side from possible leakage in combination with a water curtain (water curtain to be supplied by the yard). The piping, valves and instrumentation will be mounted on the skid, so only the connection at the respective interfaces to the skid must be made. All remote indicating instruments will be connected to common junction box. Electronic components, e.g. transmitters, digital indications (if any) will be protected by a respective protection box. A water curtain at the entrance to the bunker station must be installed (by other manufacturers). Monitoring of the bunker station will be performed by CCTV (provided by other manufacturers).

1.3.7 Piping

1.3.7.1 Fuel Gas Piping

Liquid fuel gas piping shall be of stainless steel and shall consist of pipes, flanges, fittings, bolts and nuts, gaskets, pipe supports etc. to ASME standard and in accordance with the classification rules. Liquid fuel gas piping shall be single walled in the TCS, at the bunkering stations, inside the FGPR and on open deck. Liquid fuel gas piping below deck outside of hazardous areas are double wall vacuum piping. The bunkering line connecting the bunkering station are routed on deck and may be fully welded single-walled, subject to confirmation by risk assessment. Adequate mechanical protection shall be provided. Welded connections will be preferred wherever feasible. The pipe diameters will be designed to the max. flow velocities (except manifold). The liquid fuel gas lines will be arranged to allow free drainage avoiding liquid traps as far as practical. The piping system will be designed to allow thermal expansion and contraction without excessive stress to the material. Pipe rooting of cryogenic lines shall be designed with expansion and contraction loops. Pipe ducts (by the Yard) shall be designed to provide sufficient space for pipe loops.

1.3.7.2 Vapour Fuel Gas Piping

Vapour fuel gas piping shall be of stainless steel and shall consist of pipes, flanges, fittings, bolts and nuts, gaskets, pipe supports etc. to ASME standard and in accordance with the classification rules. For fuel gas, single walled piping is applied in the TCS, at the fuel gas bunkering stations, inside the FGPR and on open deck. For cold fuel gas piping below deck outside of hazardous areas are double wall vacuum. The pipe diameters will be designed to the max. flow velocities (except vent lines and manifold).

1.3.7.3 Vent and Drain System

The vent system will have a separate vent line for the tank safety relief valves. Other relief and vent lines of the FSS are connected to the FSS knock out drum from where the vapour is sent to the ARMS. The vapour can manually be rooted to the GCU. Gaseous N2/ammonia mixtures from the main engine purging/release are collected in the purge drum and routed to the ARMS. The vent heads will be provided with rainwater deflector heads and protection screens while the vent headers will be fitted with level alarm switches and drain or purge connections on low points. A water spray system must be fitted on the vent head of the tank safety valves (by other manufacturers). One vent head for both tank safety valves and one vent head for FGPR will be provided.

The Ammonia Release Mitigation System (ARMS) ensures that the vent stream released into the atmosphere contains less than 110 ppm ammonia. The ARMS mainly consists of a scrubber device which utilizes freshwater and sulfuric acid to absorb the ammonia entering the scrubber as gas. A dilution air fan at the gas outlet to the vent supports the adjustment of the required ammonia concentration to 110 ppm. Ammonia sulfuric water generated as effluent from ARMS needs to be stored in a dedicated tank (by others). Measures must be taken to avoid freezing of the whole system. (by other manufacturers).

1.3.7.4 Auxiliary Piping Systems

Water-Glycol piping will be carbon steel. The arrangement inside in the fuel gas preparation room will be provided by TGE. Piping will be single walled with flanged connections. The piping will be equipped with vent and drain connections.

Nitrogen piping to be stainless steel and to be installed on deck as well as in the fuel gas preparation room. Instrument Air will be provided for control and actuated valves. Stainless steel piping and tubing to be installed. Piping material including all pipes, flanges, bends, reducers, T-pieces, bolts, screws, nuts, gaskets, pipe supports. The auxiliary piping will be generally equipped with split body flanged ball valves, butterfly valves or globe type valves. The design will be in accordance with class Rules. Water-Glycol piping will be warm insulated. Warm insulation is to be provided by rock wool covered with aluminium foil cloth. Nitrogen and Pressure Air piping will not be insulated.

1.3.8 Safety Systems

1.3.8.1 Gas Detection Equipment

One separated gas detection system with fixed mounted detectors will be provided for all spaces of the vessel as per class requirements. The system serves for checking possible gas concentrations within the fuel gas system area. The number of detectors is limited to the following definition: The system is designed to detect the toxic levels. LEL is higher and will not be detected. Two portable gas detectors suitable for ammonia which include different alarm values.

1.3.8.2 Emergency Shutdown and Safety System (ESDSS)

The ESDSS system is designed according to IGF Code and class requirements to bring the fuel gas supply system in a safe condition in case of emergency, the safety shut off will bring the related system/equipment into safe condition.

Emergency shut down will:

- Initiate emergency position (failsafe) of respective ESD – valves
- Interrupt electrical power supply to all electrical consumers in the fuel gas area / fuel gas preparation room
- Safety Shutdown of fuel gas supply to M/E

Safety - / unit - shut down will close the related valves and stop the related electrical consumers. A free flow connection to the GCU shall be installed. This connection will be normally closed and can be operated manually in ESD case.

Emergency shutdown push buttons will be installed at strategic locations and within the fuel gas system area. The number and location of the ESD-push buttons will be in accordance with the classification requirements. For the safety of bunker operations, a ship shore link as per IGF Code 18.4.4.4 between fuel gas supplier and fuel gas receiver will be provided, consisting of a standard SIGTTO type ESD connection box (five pin) for electrical ESD signal. Fire detection for the fuel gas system is covered by the “vessel fire detection system” (by Yard). Pneumatic actuators will be fitted on remote operated fuel gas valves as required by the IGF-Code:

- Tank connections
- Bunker connections
- Master gas fuel valve

The pneumatic actuators will be generally spring loaded and switch to a safe position in case of ESD or failure. All actuators will be equipped with local and remote position indicators.

Monitoring of ventilation within the FGPR and other compartments/rooms shall be provided by Yard. A water spray system shall be installed at the ventilation outlets and automatically activated when the ammonia concentration exceeds 220 ppm. Drip trays must be placed at the bunkering stations and at strategic locations in the FGPR (flanged connections etc.). Each drip tray will be equipped with at least one temperature indicator. One sensor is in TCS compartment. The fire detection system shall be installed in the rooms, areas and compartments of the vessel (including the fuel gas system) to alert the crew in due time for the proper extinguishing process and evacuation. The firefighting system shall include compartmentalisation, suppression and investigation of fire and its related emergencies in all the rooms, areas and compartments of the vessel (including the fuel gas system) as well as the application of mitigating systems.

1.3.9 Auxiliary Systems

One (1) nitrogen generator to allow inerting of pipe sections and equipment will be supplied, which is of a membrane type, fed from a dedicated air compressor supplied by TGE.

The water/glycol system provides cooling or heating for the following consumers of the fuel gas supply system, including:

- BOG compressor
- Ammonia condenser
- HP fuel gas heater

The water/glycol system consists of:

- Two (2 x 100%) circulation pumps. The motors are not ex-proof and VFD controlled.
- One heat exchanger for cooling/heating the WG. Cooling/Heating medium will be LT cooling water. The heat exchanger will be placed in the engine room.

One (1) instrument air system to be in the engine room will be provided to distribute compressed dry air for instrumentation and control purposes (mainly control valves with pneumatic actuators). The system will comprise the following items:

- Fine mesh oil filter
- Desiccant air dryer
- Pressure reducing valve
- Distribution piping in fuel gas system area

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 Newcastlemax Bulk Carrier 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 documents and drawings provided by MARIC, TGE, and WINGD. Those are presented in Table 9 below.

Table 9: Reviewed Documents & Drawings

Title	Provider
General Arrangement Plan	MARIC
Toxic Area Plan	MARIC
Hazardous Area Plan	MARIC
2-Stroke Dual-Fuel Ammonia Safety Concept Prod.	WINGD
X72DF - Ammonia Fuel System	WINGD
X72DF – Marine Installation Manual	WINGD
Ammonia Dual Fuel PFD	TGE
Key Equipment and Dimensions for Ammonia FSS	TGE
Outline Specifications of an Ammonia FSS for a 2-Stroke Main Engine	TGE

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 Bulk Carrier 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, MARIC, TGE, WINGD, Cargill, Færder Tankers, Oldendorff and EMSA.

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 10. 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 10 where the column 'No.' and 'Node' are for the serial number and title of the nodes.

Table 10: HAZID Nodes

No.	Node
1	General Arrangement
2	Bunkering Stations
3	Fuel Storage Tanks
4	Tank Connection Space (TCS)
5	Fuel Gas Preparation Room
6	Engine Room
7	Venting
8	Ventilation
9	Fire-fighting appliances
10	Purging system
11	Detection & Alarm systems
12	Bilge System

1.5.4 Hazards, Sources and Effects

The set of guidewords represented in the hazard and effect checklist in Annex F of ISO Standard 17776:2016(E) 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 11.

Table 11: 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
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

Hazard Groups	
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 Bulk Carrier, 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 extend, 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 Bulk Carrier 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 12.

Table 12: 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[4]. The HAZID worksheet produced is included in Appendix B of this report.

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 two hundred and forty-six (246) 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:

- Consider prohibiting simultaneous cargo operations and ammonia bunkering (SIMOPS) during the initial deployment phase of ammonia-fuelled vessels to reduce operational complexity and safety risks.
- Operate internal combustion engine (ICE) generators exclusively on Marine Gas Oil (MGO) while at port or anchorage during the early adoption phase, even if ammonia operation is feasible, to minimize risks.
- Conduct detailed assessments on the compatibility and potential chemical reactivity between ammonia and various cargo types, particularly during bunkering, to prevent hazardous incidents.
- Investigate the impact of dust on ammonia bunkering components (e.g., gas detectors, electronic components of instrumentation, valves and actuators etc.). Establish regular deck cleaning protocols to ensure proper functionality and accurate gas detection.
- Based on vessel size, operational layout, and crew/visitors' distribution, assess the need for multiple safe havens to ensure safe, quick, and unobstructed access during ammonia-related emergencies.
- Consider the effects of hull deformation due to hogging and sagging on ammonia piping systems and apply flexible design solutions to maintain integrity under stress.
- Design the tank connection space (TCS) with adequate size and ergonomics to enable safe maintenance, inspection, and emergency access.
- Analyse the risks of personnel embarkation/disembarkation during ammonia bunkering operations and develop appropriate procedures or scheduling separation.
- Deliver comprehensive training programs for all relevant port personnel, focusing on ammonia properties, safety precautions, emergency handling, and first-response actions.
- Consider equipping the vessel with portable ventilation units to facilitate rapid dispersion of ammonia vapours in the event of a deck spill or leakage[5].
- Due to ammonia's lower energy density and potential limitations of sailing routes operators may anticipate more frequent bunkering operations. Address the associated increased risk through larger fuel tank capacity, optimised bunkering logistics, and enhanced safety measures during bunkering.
- Perform comprehensive security risk assessments considering the potential for threats such as terrorism, piracy, or armed robbery, particularly in relation to externally exposed ammonia storage tanks, piping, and bunkering stations. Implement robust physical and procedural protective measures.
- Adopt a risk-based design approach that extends beyond the IGF Code, identifying and mitigating ammonia-specific hazards during both design and operational phases.
- Select materials based on durability, corrosion resistance, and long-term reliability in ammonia environments.
- Ensure segregation and appropriate layout of ammonia systems. Compartmentalize key components such as GCU and ARMS to prevent leak propagation and facilitate containment,
- Prioritise the protection of critical systems (e.g., boil-off gas systems) that must remain operational during emergencies.
- Locate muster stations, lifeboats, and life rafts well away from potential ammonia release sources. Reevaluate conventional design practices to ensure crew safety during emergencies involving toxic vapour dispersion or fire.
- Proper positioning of muster stations and LSAs should be demonstrated by dispersion simulation availability of 1 escape route to the safe heaven.

[4] https://www.abs-group.com/Solutions/Software-Solutions/LEADER-PHA-Software/
[5] Leaks at manifold should be contained, whereas leaks on the fuel piping are less probable due to welded connections and protection/precautions against dropped objects

- Both available escape route and the lifesaving appliance should not be exposed to a toxic concentration higher than 25 ppm.
- Mustering station / safe heaven should provide protection for the period of the credible worst-case scenario.
- Design all escape routes, ladders, and emergency exits to avoid proximity to ammonia tanks, vents, or piping, ensuring safe evacuation during any emergency, including leak or spill events.

1.7 Conclusions

The Ammonia FSS designed by TGE, for the Newcastlemax ship design of MARIC, according to WINGD's specifications, was reviewed by the multi-disciplined HAZID team at the HAZID workshop based on the scope of work and methodology described in this report.

In total, four hundred and fifty-two (452) scenarios were identified at the HAZID workshop. Thirty-four (34) scenarios were purposefully not ranked either because there were no hazards identified, or there was insufficient technical information to carry out the risk ranking. No scenarios were categorised as low-risk, and one hundred and twenty-two (122) scenarios were categorised as moderate-risk. Two hundred and ninety-seven (297) scenarios were categorised as high-risk, while no scenarios were categorised as extreme risk. The results are presented in the Risk Ranking (or unmitigated risks) Table 13 below.

Table 13: 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	**12**	**178**	**23**	**0**	**0**
	Possible **(-2):** Occurs once every 10-100 ship years	**0**	**110**	**80**	**16**	**0**
	Unlikely **(-3):** Occurs once every 100-1000 ship years	**0**	**0**	**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 sixty-eight (368) scenarios were categorised as low-risk and forty-eight (48) were categorised as moderate-risk. No scenarios were categorised as high-risk, while no scenarios were categorised as extreme risk. The results are presented in the Residual Risk (or mitigated risk) Table 14 below.

Table 14: Re-evaluated Risk Ranking (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	**8**	**0**	**0**	**0**	**0**
	Possible **(-2):** Occurs once every 10-100 ship years	**368**	**40**	**0**	**0**	**0**
	Unlikely **(-3):** Occurs once every 100-1000 ship years	**0**	**0**	**0**	**0**	**0**
	Rare **(-4):** Occurs once every 1000-10000 ship years	**0**	**0**	**0**	**0**	**0**

Two hundred and forty-six (246) recommendations were made from the HAZID team, and the full results of the HAZID workshop were documented in the HAZID Worksheet (see Appendix B).

Nineteen (19) scenarios were purposefully not ranked. These unranked scenarios were general remarks/considerations that were either not node-specific (thus grouped under the 'General' node) or there was not enough technical information to carry out the risk ranking.

A summary of the main HAZID findings is as follows:

- A risk-based design philosophy is strongly recommended, going beyond baseline compliance with the IMO MSC.1/1687*Interim guidelines for the safety of ships using ammonia as fuel*, this includes material selection, corrosion resistance, and long-term reliability in ammonia environments.
- Operational complexity during bunkering is a key safety concern, particularly when combined with other concurrent activities. As such, SIMOPS involving ammonia bunkering and cargo operations should be carefully restricted or phased in gradually, especially during the early adoption phase of ammonia-fuelled vessels.
- Conservative operational strategies are recommended during the initial deployment phase, including running ICE generators on Marine Gas Oil (MGO) while at port or anchorage, even if ammonia is technically available. This reflects a risk-averse approach prioritizing safety over fuel switching flexibility.
- The interaction between ammonia and cargo environments requires further scrutiny, particularly regarding chemical compatibility and dust interference. These factors can compromise bunkering safety, gas detection reliability, and overall equipment performance.
- Ship layout and emergency preparedness must be adapted to ammonia-specific hazards:
  - Multiple safe havens may be needed based on vessel size and crew distribution.
  - Muster stations and escape routes should be positioned away from ammonia potential leakage or toxic area or potential hazards.
  - Portable ventilation equipment may enhance rapid gas dispersion in the event of a leak.
- Design implications emerged as critical themes:
  - Flexible piping arrangements are needed to accommodate hull deformation (hogging/sagging).
  - Tank Connection Spaces (TCS) must allow for safe maintenance and emergency access.
  - Segregation and compartmentalisation of ammonia systems are vital to prevent escalation during leak scenarios.
- Training and human factors are essential, especially for port personnel who may be less familiar with ammonia-specific hazards. Tailored programs should focus on emergency response, first aid, system automation and safe handling practices.

- The increased bunkering frequency due to ammonia's lower energy density introduces new logistical and safety challenges. These should be mitigated through tank sizing, optimised scheduling, and bunkering safeguards.
- Security risks, including potential targeted attacks on vulnerable ammonia-related equipment, must be formally assessed and mitigated through both physical protection and procedural controls.

2. Simultaneous Operations (SIMOPS)

In complex maritime environments, multiple activities often occur concurrently, introducing potential interactions that can compromise safety if not properly managed. Simultaneous Operations (SIMOPS) refer to situations in which two or more independent operations are conducted at the same time and in proximity to one another, with the potential for mutual interference. In the context of the present risk assessment for the ammonia-fuelled Newcastlemax bulk carrier, a dedicated SIMOPS study was conducted to evaluate the risks associated with overlapping activities - such as fuel bunkering, cargo handling, maintenance, and crew transfer - during both port and offshore operations. The objective of the SIMOPS assessment is to identify hazardous interactions between these activities, evaluate their potential consequences, and define operational controls and safeguards necessary to ensure that combined risks remain within acceptable limits. This study forms an integral part of the broader HAZID analysis and supports the development of safe operating procedures and contingency planning for the vessel's ammonia-fuelled operations.

2.1 Scenarios

As part of the risk assessment for the ammonia-fuelled Newcastlemax bulk carrier, a dedicated SIMOPS (Simultaneous Operations) study was conducted to evaluate the risks associated with overlapping operational activities during various bunkering scenarios. Given the novel use of ammonia as a marine fuel and its unique hazard profile—particularly toxicity and potential for vapour dispersion—it is essential to assess how routine shipboard operations may interact with fuel transfer activities.

The following five representative bunkering scenarios were analysed:

- Bunkering in port from a bunkering vessel or barge: This common configuration involves fuel transfer via ship-to-ship connection while the vessel is berthed. The assessment considered potential interactions with cargo handling, mooring operations, and port personnel activity.
- Bunkering in port from a truck: Typically used for smaller-scale or early-stage deployments, this method introduces specific risks associated with shore-side equipment, hose handling, and limited buffer zones between transfer operations and other port activities.
- Bunkering in port from a terminal: Involving fixed infrastructure, this scenario offers a more controlled environment but also requires careful alignment between terminal procedures and vessel operations, particularly regarding shore power use, cargo operations, and emergency coordination.
- Bunkering at anchor from a bunkering vessel or barge: This offshore ship-to-ship transfer scenario introduces additional complexity due to dynamic positioning, limited escape routes, and the absence of port-based emergency support. The SIMOPS study assessed risks related to crew transfer, anchoring operations, and environmental conditions.
- Bunkering while underway: Though rare and typically restricted to specific strategic or military operations, this scenario was evaluated for completeness. It presents unique challenges related to vessel motion, emergency response time, and system stability, and would require exceptional safeguards if ever considered for implementation.
- Each scenario was assessed with respect to the potential for conflicts with other ongoing operations (e.g., cargo handling, personnel movement, maintenance), the likelihood of hazard escalation, and the effectiveness of available mitigation measures. The outcomes of the SIMOPS analysis contribute to the definition of safe operational envelopes and support the development of structured bunkering procedures tailored to the vessel's design and ammonia-specific risks.

2.2 Bunker Vessel

As part of the SIMOPS study, the workshop was supported by the active participation of Færder Tankers, a company currently developing a dedicated ammonia bunker vessel. Their team provided comprehensive technical specifications for their vessel design, as well as detailed insights into the bunkering procedures and operational protocols specific to ammonia. This input was invaluable for ensuring that the risk assessment accurately reflected the real-world conditions and constraints of ship-to-ship ammonia bunkering. Færder Tankers' contributions allowed the workshop participants to assess critical interfaces, technical safeguards, and emergency response capabilities based on an actual vessel concept, thereby enhancing the robustness and relevance of the SIMOPS evaluation.

The side view of Færder Tankers' 50,000cbm Ammonia/LPG Carrier & Bunker vessel, is presented in Figure 3.

Figure 3: Side view of ammonia bunker vessel

The principal dimensions of the ship are listed in Table 15.

Table 15: Principal dimensions of ammonia bunker vessel

Particular	Description
Length (Overall - m)	189
Length (Between Perpendiculars - m)	182.5
Breadth (MLD - m)	32.3
Depth (m)	20.50
Draught (Design - m)	10.50
Draught (Scantling - m)	11.50
Deadweight at Td (ton)	32,500
Design speed at Td (kn)	14.5
Cargo hold (cbm)	50,000

2.3 SIMOPS Workshop

The SIMOPS workshop was conducted over two full days and followed a structured methodology to identify and assess the risks arising from concurrent activities on board or in the vicinity of a vessel. The goal of the workshop was to systematically evaluate how overlapping operations - such as bunkering, cargo handling, crew movements, and maintenance - may interfere with one another and lead to hazardous situations, particularly when involving a high-risk fuel such as ammonia.

The first day of the workshop was dedicated to establishing context and identifying potential hazards. It begun with an opening session where participants were introduced to the objectives, scope, and methodology of the workshop. This was followed by detailed presentations outlining the bunker vessel's design, the ammonia fuel system, and the key operational scenarios under consideration. Each SIMOPS scenario - for example, bunkering from a barge in port, or bunkering at anchor - was described in detail to ensure all participants have a shared understanding. Guided by structured keywords (e.g., "interference," "incompatibility," "delay," or "miscommunication"), the HAZID team then carried out a hazard identification process, systematically examining possible interactions between concurrent operations. Rather than applying a formal risk ranking matrix, the workshop focused on qualitative hazard identification and scenario-based discussion. The aim was to capture expert input across a broad range of operational experiences and technical disciplines, allowing for a pragmatic assessment of what could go wrong and where additional safeguards might be needed.

On the second day, the discussion moved toward identifying practical risk reduction measures and outlining key recommendations. These included considerations such as procedural separation between critical operations, design adjustments to improve access or isolation, and enhanced training or coordination protocols. The workshop concluded with a structured summary of the key findings and agreement on follow-up actions, such as integrating outcomes into the vessel's operational planning and further validating bunkering procedures with stakeholders like Færder Tankers.

All findings, risk rankings, and recommendations are documented in SIMOPS assessment worksheets, which form the basis of the final report. The collaborative and interdisciplinary nature of the workshop ensures that both technical and operational expertise is captured, leading to a robust and practical understanding of the risks associated with simultaneous operations.

2.4 SIMOPS Result

The outcomes of the workshop, including the identified hazards, affected operations, and corresponding mitigation measures, were systematically catalogued in the SIMOPS assessment worksheet, which can serve as a key reference for the development of operational procedures and design validation. The detailed worksheet is provided in Appendix C.

The key takeaways from the SIMOPS assessment session are summarised below.

General Observations

- The primary hazard across all SIMOPS scenarios is ammonia release due to loss of containment, potentially caused by equipment failure, operator error, or external damage (e.g., dropped objects).
- Secondary hazards include fire/explosion risks, especially in the presence of flammable cargoes, substances, or fuels (e.g., MGO).
- Human injury is the dominant consequence, with occasional mention of environmental impacts (e.g., ammonia spill at sea).
- Activities assessed span port, terminal, at anchor, and underway bunkering operations.

Main Hazardous SIMOPS

The main hazardous SIMOPS identified are outlined in Table 16.

Table 16: Main Hazardous SIMOPS

Operation Category	Typical SIMOPS Risks with Ammonia Bunkering	Notable Recommendations
Cargo Handling	Crane/grab ops, conveyor systems interfering with ammonia infrastructure	Avoid cargo ops during ammonia bunkering, especially coal
Provision Loading	Forklifts/cranes potentially entering hazardous zone	Define safety zones based on wind direction & dispersion modelling
Hazmat Loading	Risk of reaction between ammonia and chemicals (e.g., solvents, oils)	Prohibit simultaneous handling of hazardous materials
MGO Bunkering	Flammability of MGO in proximity to toxic ammonia	Avoid simultaneous ammonia and MGO bunkering
Embarkation/Disembarkation	Exposure of personnel in access ways to ammonia	Restrict access; use stern ladder; schedule outside bunkering
Ship Operations & Drills	Hot work, drills, inspections during bunkering create risk	Conduct these outside bunkering hours; risk assessment required
Man Overboard Response	Conflicting priorities between life-saving operations and bunkering	Immediate halt of bunkering and initiation of SAR procedures

Key mitigating measures

The key mitigating measures proposed are the following:

- Training of port personnel on ammonia-specific risks.
- Clear zoning policies and restricted access during bunkering operations.
- Dedicated procedural planning to schedule high-risk operations at non-overlapping times.
- Emergency response coordination (e.g., with FiFi tugs, SAR units).
- Technical upgrades such as leak detection, inerting systems, or anti-spill hoses.
- Infrastructure improvements like increasing ammonia tank size to reduce bunkering frequency.

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 1.6.2).
- 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.

No.: 1 — **Description:** General Vessel 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)
1.2	Maintenance Design	Maintenance Design		1.2.1. Design errors in ship design Unable to perform maintenance	1.2.1. Insufficient technological preparedness.	Asset	6	-2	High (4)	1.2.2. Analysing non-conformities, accidents, and hazardous incidents in the ammonia industry, ammonia cargo vessels and fisheries to improve safety and practices.	4	-2	Moderate (2)	5. Adopt a risk-based design approach that extends beyond the IGF Code, identifying and mitigating ammonia-specific hazards during both design and operational phases.

No.: 1 **Description:** General Vessel 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)
										1.2.3. Integrating rules, codes, standards, best practices, and insights from other ammonia-related industries, fishing vessels, and cargo ships that transport ammonia.)				6. Select materials based on durability, corrosion resistance, and long-term reliability in ammonia environments. Avoid compromising safety or performance in favour of cost savings. 7. Ensure segregation and appropriate layout of ammonia systems. Compartmentalize key components to prevent leak propagation and facilitate containment. **Comment:** Avoid locating the GCU heater inside the engine room.

No.: 1	**Description:** General Vessel 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)**
														8. Prioritize the protection of critical systems (e.g. boil-off gas systems) that must remain operational during emergencies. 9. Further study to be done on the maintenance plan of all ammonia handling equipment.
				1.2.2. Absence of a clear regulatory framework.	1.2.1. Insufficient technological preparedness.	Asset	6	-2	High (4)	1.2.2. Analysing non-conformities, accidents, and hazardous incidents in the ammonia industry, ammonia cargo vessels and fisheries to improve safety and practices.	4	-2	Moderate (2)	5. Adopt a risk-based design approach that extends beyond the IGF Code, identifying and mitigating ammonia-specific hazards during both design and operational phases.

No.: 1	Description: General Vessel 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)**
										1.2.3. Integrating rules, codes, standards, best practices, and insights from other ammonia-related industries, fishing vessels, and cargo ships that transport ammonia.				6. Select materials based on durability, corrosion resistance, and long-term reliability in ammonia environments. Avoid compromising safety or performance in favour of cost savings. 7. Ensure segregation and appropriate layout of ammonia systems. Compartmentalize key components to prevent leak propagation and facilitate containment. **Comment:** Avoid locating the GCU heater inside the engine room.

No.: 1	**Description:** General Vessel 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)**
														8. Prioritize the protection of critical systems (e.g. boil-off gas systems) that must remain operational during emergencies. 9. Further study to be done on the maintenance plan of all ammonia handling equipment.
1.5	Cleaning			1.5.1. General	1.5.1. General	Asset	5	-2	High (3)	1.5.1. SOPs (deck cleaning after loading and unloading process.)	4	-2	Moderate (2)	12. Investigate the impact of dust on ammonia bunkering components (e.g., gas detectors, electronic components of instrumentation, valves and actuators etc.). Establish regular deck cleaning protocols to ensure proper functionality and accurate gas detection.

No.: 1	**Description:** General Vessel 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)**
1.13	Escape Routes			1.13.1. General	1.13.1. Loss of life	Injury	5	-2	High (3)	1.13.1. SOPs	4	-2	Moderate (2)	25. Dispersion analysis is to be carried out for the case of leakage from the Fuel Storage Tanks. Analysis will investigate the case of PRV opening and should include amount of ammonia being released. 26. Dispersion study is to be conducted for potential leakage scenarios during the bunkering process.

No.: 1	**Description:** General Vessel 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)**
														27. Further study to be done on safe haven locations and their access through the escape routes of the vessel in case of a leakage. **Comment:** Based on vessel size, operational layout, and crew/visitors' distribution, assess the need for multiple safe havens to ensure safe, quick, and unobstructed access during ammonia-related emergencies.

No.: 1	**Description:** General Vessel 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)**
														28. Design all escape routes, ladders, and emergency exits to avoid proximity to ammonia tanks, vents, or piping, ensuring safe evacuation during any emergency, including leak or spill events. 29. Dispersion analysis is to be conducted for a potential leakage in the Fuel Preparation Room (FPR).

No.: 1	**Description:** General Vessel 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)**
1.14	Abandon Vessel			1.14.1. Major ship accident	1.14.1. Ship loss	Asset	6	-2	High (4)	1.14.1. OPTS 1.14.3. SMS	4	-2	Moderate (2)	30. Locate muster stations, lifeboats, and life rafts well away from potential ammonia release sources. Reevaluate conventional design practices to ensure crew safety during emergencies involving toxic vapor dispersion or fire.
					1.14.2. Loss of life	Injury	6	-2	High (4)	Same as above	4	-2	Moderate (2)	

No.: 1 **Description:** General Vessel 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)
1.15	Security Threat	Security Threat		1.15.1. Maritime Security Breach	1.15.1. General	General	6	-2	High (4)	1.15.1. OPTS 1.15.3. SMS	4	-2	Moderate (2)	31. Perform comprehensive security risk assessments considering the potential for threats such as terrorism, piracy, or armed robbery, particularly in relation to externally exposed ammonia storage tanks, piping, and bunkering stations. 32. The security risk assessment must pay special attention to the overall security measures across the vessel's deck areas. 33. Implement robust physical and procedural protective measures.

Company:		
Title: EMSA NH3, Bulk Carrier Study		
Description:		
Method: HAZID	**Type:**	Bunkering Stations
Design Intent:		
Comment:		

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	Loss of Containment		2.2.1. Ammonia Release due to mechanical coupling failure.	2.2.1. Ammonia spill in the sea.	Environmental	5	-1	High (4)	2.2.1. Pressure test prior to bunkering/ Documented processes. **Comment:** consider the use water for pressure testing not air. 2.2.2. Operational Sequence for bunkering process 2.2.3. Ammonia detection in the air 2.2.4. Spill detection	3	-2	Low (1)	39. Due to ammonia's lower energy density, anticipate more frequent bunkering operations. Address the associated increased risk through larger fuel tank capacity, optimized bunkering logistics, and enhanced safety measures during bunkering.

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)
										2.2.5. Certified bunkering hoses 2.2.6. Material specifications according to pertinent regulations 2.2.7. Drip tray 2.2.8. PPE)				40. Further study to be done on the type of ammonia bunkering arms (flexible or rigid) **Comment:** Comment: Preference on flexible ones. 41. Further study to be done on the possibility of ship to ship bunkering process while anchored. 42. Further study to be done on the ability to run generator sets with ammonia while in bunkering process 43. Further study to be done on the ability to operate the engine with ammonia at low loads during bunkering

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)
														44. Further study to be done on the specific types and specific applicability of PPE to be used during a specific process (bunkering, transfer operations, works etc) taking into account the toxic characteristics of ammonia and the complexity of the system. **Comment:** ABS: Defined in IGC code EMSA: Levels are defined in the IMO GL / MSC.1/Circ.1687 - Chapter 15 Table 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)
														45. Further study to be done on the inclusion of a spill tank dedicated to the drip trays around the bunkering area.
					2.2.2. Human Injury	Injury	6	-2	High (4)	Same as above				
2.3	Toxicity	Human Error		2.3.1. Ammonia release due to operational mistake	2.3.1. Ammonia spill in the sea.	Environmental	5	-1	High (4)	2.3.1. CCTV 2.3.2. ESD 2.3.3. OPTS 2.3.4. PPE	3	-2	Low (1)	46. Further study to be done on the necessary crew training to handle ammonia as a fuel.
					2.3.2. Human Injury	Injury	6	-2	High (4)					
2.4	Toxicity	Dropped object, Cargo		2.4.1. Dropped Object	2.4.1. Human Injury	Injury	6	-2	High (4)	2.4.1. CCTV 2.4.2. ESD 2.4.3. PPE	3	-2	Low (1)	47. Dropped object study is to be conducted for the vessel. Study should consider initial and operational cost of bunkering station.

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	Toxicity	Dropped Object, Machinery		2.5.1. Dropped Object, Machinery	2.5.1. Human Injury	Injury	6	-2	High (4)	2.5.1. CCTV 2.5.2. ESD 2.5.3. PPE	3	-2	Low (1)	47. Dropped object study is to be conducted for the vessel. Study should consider initial and operational cost of bunkering station.
2.6	Toxicity	Component Defect		2.6.1. Failure of a system mechanical component.	2.6.1. Human Injury	Injury	6	-2	High (4)	2.6.1. ADS 2.6.2. Drip Trays 2.6.3. CCTV 2.6.4. ESD 2.6.5. PPE	3	-2	Low (1)	45. Further study to be done on the inclusion of a spill tank dedicated to the drip trays around the bunkering area. 48. Consider the effects of hull deformation due to hogging and sagging on ammonia piping systems and apply flexible design solutions to maintain integrity under stress.

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)**
														49. Further study to be done on the use of dry disconnect couplings equipped with additional safe features.
				2.6.2. QCDC failure.	2.6.1. Human Injury	Injury	6	-2	High (4)	2.6.1. ADS 2.6.2. Drip Trays 2.6.3. CCTV 2.6.4. ESD 2.6.5. PPE	3	-2	Low (1)	45. Further study to be done on the inclusion of a spill tank dedicated to the drip trays around the bunkering area. 49. Further study to be done on the use of dry disconnect couplings equipped with additional safe features.

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)
2.7	Toxicity	Tank Overfilling		2.7.1. Tank overfilling	2.7.1. Ammonia to vent mast, release to the environment.	Environmental	4	-1	High (3)	2.7.1. Proper determination of loading limit 2.7.2. Bunkering procedures (max quantity defined before bunkering process) 2.7.3. Detection system 2.7.4. BoG management 2.7.5. ESD 2.7.6. Non-Return Valve (NRV) as per design 2.7.7. Access to electronic parts of tank instrumentation located inside the storage tank. 2.7.8. PRV	4	-2	Moderate (2)	50. Further study to be done on the identification of critical spare parts of the ammonia handling system to maintain autonomy without secondary fuel.

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)
					2.7.2. Overpressurisation	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
2.8	Toxicity	Failure of Purging Lines		2.8.1. Failure in the purging line.	2.8.1. Ammonia to vent mast, release to the environment	Environmental	4	-1	High (3)	2.8.1. Personal Gas Detectors 2.8.2. Sampling points 2.8.3. Procedures 2.8.4. Hand pumps for sampling purposes. 2.8.5. Pressure monitoring.	3	-2	Low (1)	51. Further study to be done to identify the lowest point of the bunkering system depending on the actual arrangement to allow effective drain operation utilising the stripping line. Study should identify geometrical location of all bunkering station components.

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)
														52. Further study to be done on the operational procedure of the bunkering process and the possibility of warming up the ammonia fuel supply line (with a hot ammonia gas or another manner).
					2.8.2. Human Injury	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	
				2.8.2. Efficiency of purging lines due to friction losses.	2.8.1. Ammonia to vent mast, release to the environment.	Environmental	4	-1	High (3)	2.8.1. Personal Gas Detectors 2.8.2. Sampling points 2.8.3. Procedures 2.8.4. Hand pumps for sampling purposes. 2.8.5. Pressure monitoring.	3	-2	Low (1)	51. Further study to be done to ensure the bunkering tank will be the lowest point in the system. Study should identify geometrical location of all bunkering station components.

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)
														52. Further study to be done on the operational procedure of the bunkering process and the possibility of warming up the return line (with a hot gas or another manner).
					2.8.2. Human Injury	Injury	4	-1	High (3)	Same as above	3	-2	Low (1)	
2.10	Toxicity	Entrapped Liquid		2.10.1. Trapped liquid between bunker valve and tank valve	2.10.1. Human Injury	Injury	4	-1	High (3)	2.10.1. Two pressure safety valves **Comment:** Directed to ARMS buffer tank. 2.10.2. ESD 2.10.3. Leakage detection in the annular space of the double wall pipping **Comment:** Nitrogen in annular space at all times	3	-2	Low (1)	54. Provide tag numbers for safety valves

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)**
2.11	Toxicity	Ammonia Release in Manifold Area		2.11.1. Ammonia Release	2.11.1. Human Injury	Injury	4	-1	High (3)	2.11.1. Standard operating procedures of deck cleaning after loading and unloading process.	3	-2	Low (1)	
2.13	Fire	Absence of Electrical Isolation		2.13.1. General	2.13.1. Human Injury	Injury	4	-1	High (3)	2.13.1. Operational Sequence for bunkering process 2.13.2. Ammonia detection in the air 2.13.3. Spill detection 2.13.4. Certified bunkering hoses 2.13.5. Material specifications according to pertinent regulations 2.13.6. Drip tray 2.13.7. PPE 2.13.8. CCTV	3	-2	Low (1)	55. 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.

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)**
										2.13.9. ESD 2.13.10. SSL communication line 2.13.11. Maintenance				
2.15	Contaminated Fuel			2.15.1. Impurities in the fuel.	2.15.1. Damage to the equipment	Asset	4	-2	Moderate (2)	2.15.1. Quality control 2.15.2. Staged filters from wider to finer mesh	3	-2	Low (1)	57. Bunkering fuel quality is to be included in the operations manual 58. Further study to be done on the required mesh of the filters upstream of the low-pressure pumps.
				2.15.2. Filter clogging	2.15.1. Damage to the equipment	Asset	4	-2	Moderate (2)	2.15.1. Quality control 2.15.2. Staged filters from wider to finer mesh	3	-2	Low (1)	58. Further study to be done on the required mesh of the filters upstream of the low-pressure pumps.

Company:		
Title: EMSA NH3, Bulk Carrier 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)
3.1	Pressure	Overfilling		3.1.1. Overfilling **Comment:** Manifold closes to 5 sec	3.1.1. Pressure Build up.	Asset	4	-1	High (3)	3.1.1. CAMS 3.1.2. ESD	3	-2	Low (1)	59. Loading limits are to be calculated /determined for each bunkering operation.
3.3	Pressure Rise	Equipment Malfunction		3.3.1. Pressure transmitter malfunction	3.3.1. Pressure build up.	Asset	4	-1	High (3)	3.3.1. CAMS	3	-2	Low (1)	
3.4	Pressure Rise	Operator Fault		3.4.1. Operator Fault	3.4.1. Pressure build up.	Asset	4	-1	High (3)	3.4.1. PRV	3	-2	Low (1)	
3.6	Toxicity			3.6.1. Ammonia Release	3.6.1. Pressure build up.	Asset	4	-1	High (3)	3.6.1. CAMS 3.6.2. PRV **Comment:** TGE: 4 bar for the PRV is the absolute minimum setting value	3	-2	Low (1)	62. Stress analysis study is to be conducted on the dynamic loads of the 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)**
				3.6.2. Failure of Structural Integrity	3.6.1. Pressure build up.	Asset	4	-1	High (3)	3.6.1. CAMS 3.6.2. PRV	3	-2	Low (1)	62. Stress analysis study is to be conducted on the dynamic loads of the storage tanks **Comment:** TGE: 4 bar for the PRV is the absolute minimum setting value
3.11	Toxicity	Bad Weather		3.11.1. Triggering of High-High L Alarm (LAHH) due to bad weather	3.11.1. Unintended activation of ESD.	Asset	4	-2	Moderate (2)	3.11.1. CAMS 3.11.2. DF ICE 3.11.3. ESD 3.11.4. Second tank	3	-2	Low (1)	65. Further study to be done on High-High L Alarm (LAHH) settings to avoid unnecessary activation of ESD. Designer to provide time delay for seagoing conditions

3.12	Loss of Ammonia Supply	Low Pressure Pump		3.12.1. Material defect	3.12.1. Loss of DF ICE ammonia mode	Asset	4	-2	Moderate (2)	3.12.1. CAMS 3.12.2. DF ICE 3.12.3. ESD 3.12.4. Second tank 3.12.5. Vibration Alarm	3	-2	Low (1)	66. Proposal is to create a separate manual for all operations where ammonia is involved. Manual will include operational processes, maintenance procedures, general safety matters, worst case scenarios, emergency actions in case of accidents and necessary crew training. Manual should include Safety Data Sheets for all components and for (compatible) cargoes to be loaded on the vessel. Tag out procedures are also to be included. **Comment:** TGE: Emphasis on the tank maintenance in the case of a pump removal. The pumps have power/current

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)**
														monitoring and alarm/shutdown.

				3.12.2. Mechanical failure	3.12.1. Loss of DF ICE ammonia mode	Asset	4	-2	Moderate (2)	3.12.1. CAMS 3.12.2. DF ICE 3.12.3. ESD 3.12.4. Second tank 3.12.5. Vibration Alarm	3	-2	Low (1)	66. Proposal is to create a separate manual for all operations where ammonia is involved. Manual will include operational processes, maintenance procedures, general safety matters, worst case scenarios, emergency actions in case of accidents and necessary crew training. Manual should include Safety Data Sheets for all components and for (compatible) cargoes to be loaded on the vessel. Tag out procedures are also to be included. **Comment:** TGE: Emphasis on the tank maintenance in the case of a pump removal.
				3.12.3. Electrical	3.12.1. Loss of DF ICE	Asset	4	-2	Moderate	3.12.1.	3	-2	Low (1)	66. Proposal is to create a

failure	ammonia mode				(2)	CAMS 3.12.2. DF ICE 3.12.3. ESD 3.12.4. Second tank 3.12.5. Vibration Alarm				separate manual for all operations where ammonia is involved. Manual will include operational processes, maintenance procedures, general safety matters, worst case scenarios, emergency actions in case of accidents and necessary crew training. Manual should include Safety Data Sheets for all components and for (compatible) cargoes to be loaded on the vessel. Tag out procedures are also to be included. **Comment:** TGE: Emphasis on the tank maintenance in the case of a pump removal.
3.12.4. Corrosion, erosion	3.12.1. Loss of DF ICE ammonia mode	Asset	4	-2	Moderate (2)	3.12.1. CAMS 3.12.2. DF ICE 3.12.3. ESD	3	-2	Low (1)	66. Proposal is to create a separate manual for all operations where

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)**
										3.12.4. Second tank 3.12.5. Vibration Alarm				ammonia is involved. Manual will include operational processes, maintenance procedures, general safety matters, worst case scenarios, emergency actions in case of accidents and necessary crew training. Manual should include Safety Data Sheets for all components and for (compatible) cargoes to be loaded on the vessel. Tag out procedures are also to be included. **Comment:** TGE: Emphasis on the tank maintenance in the case of a pump removal.

				3.12.5. Operational matters	3.12.1. Loss of DF ICE ammonia mode	Asset	4	-2	Moderate (2)	3.12.1. CAMS 3.12.2. DF ICE 3.12.3. ESD 3.12.4. Second tank 3.12.5. Vibration Alarm	3	-2	Low (1)	66. Proposal is to create a separate manual for all operations where ammonia is involved. Manual will include operational processes, maintenance procedures, general safety matters, worst case scenarios, emergency actions in case of accidents and necessary crew training. Manual should include Safety Data Sheets for all components and for (compatible) cargoes to be loaded on the vessel. Tag out procedures are also to be included. **Comment:** TGE: Emphasis on the tank maintenance in the case of a pump removal.
				3.12.6. Vibrations	3.12.1. Loss of DF ICE ammonia	Asset	4	-2	Moderate (2)	3.12.1. CAMS 3.12.2. DF	3	-2	Low (1)	66. Proposal is to create a separate manual for all

					mode					ICE 3.12.3. ESD 3.12.4. Second tank 3.12.5. Vibration Alarm				operations where ammonia is involved. Manual will include operational processes, maintenance procedures, general safety matters, worst case scenarios, emergency actions in case of accidents and necessary crew training. Manual should include Safety Data Sheets for all components and for (compatible) cargoes to be loaded on the vessel. Tag out procedures are also to be included. **Comment:** TGE: Emphasis on the tank maintenance in the case of a pump removal.
				3.12.7. Filter clogging	3.12.1. Loss of DF ICE ammonia mode	Asset	4	-2	Moderate (2)	3.12.1. CAMS 3.12.2. DF ICE 3.12.3. ESD	3	-2	Low (1)	66. Proposal is to create a separate manual for all operations where

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)
										3.12.4. Second tank				ammonia is involved. Manual will include operational processes, maintenance procedures, general safety matters, worst case scenarios, emergency actions in case of accidents and necessary crew training. Manual should include Safety Data Sheets for all components and for (compatible) cargoes to be loaded on the vessel. Tag out procedures are also to be included. **Comment:** TGE: Emphasis on the tank maintenance in the case of a pump removal.

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)**
3.13	Contaminated Flow	Chemical Corrosion of the Tank		3.13.1. Suction of impurities from the bottom of the tank **Comment:** Bad cleaning, debris from connecting equipment	3.13.1. Loss of DF ICE ammonia mode	Asset	4	-2	Moderate (2)	3.13.1. CAMS 3.13.2. DF ICE 3.13.3. ESD 3.13.4. Second tank 3.13.5. Strainers and filters	3	-2	Low (1)	

Company:		
Title: EMSA NH3, Bulk Carrier Study		
Description:		
Method: HAZID	**Type:**	Tank Connection Space
Design Intent:		
Comment:		

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)
4.1	Toxicity			4.1.1. Design	4.1.1. Toxic environment inside Tank Connection Space (TCS)	Injury	5	-2	High (3)	4.1.1. ADS 4.1.2. BOG 4.1.3. CAMS 4.1.4. DF ICE 4.1.5. ESD 4.1.6. IECEx 4.1.7. OPTS 4.1.8. PMS 4.1.9. PP 4.1.11. Redundancy 4.1.12. SOPs	4	-2	Moderate (2)	67. Design the tank connection space (TCS) with adequate size and ergonomics to enable safe maintenance, inspection, and emergency access.
					4.1.2. Flammable environment inside Tank Connection Space (TCS)	Asset	5	-2	High (3)		4	-2	Moderate (2)	
					4.1.3. Loss of ammonia	Injury	5	-2	High (3)		4	-2	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)**
				4.1.2. Fabrication	4.1.1. Toxic environment inside Tank Connection Space (TCS)	Injury	5	-2	High (3)	4.1.1. ADS 4.1.2. BOG 4.1.3. CAMS 4.1.4. DF ICE 4.1.5. ESD 4.1.6. IECEx 4.1.7. OPTS 4.1.8. PMS 4.1.9. PP 4.1.11. Redundancy 4.1.12. SOPs	4	-2	Moderate (2)	TGE: Proven design stems also from quality procedures, control and workmanship addressed in the fabrication errors too.
					4.1.2. Flammable environment inside Tank Connection Space (TCS)	Asset	5	-2	High (3)	Same as above	4	-2	Moderate (2)	
					4.1.3. Loss of ammonia	Injury	5	-2	High (3)	Same as above	4	-2	Moderate (2)	
				4.1.3. Installation error	4.1.1. Toxic environment inside Tank Connection Space (TCS)	Injury	5	-2	High (3)	4.1.1. ADS 4.1.2. BOG 4.1.3. CAMS 4.1.4. DF ICE 4.1.5. ESD 4.1.6. IECEx 4.1.7. OPTS 4.1.8. PMS	4	-2	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)**
										4.1.9. PP 4.1.11. Redundancy 4.1.12. SOPs				
					4.1.2. Flammable environment inside Tank Connection Space (TCS)	Asset	5	-2	High (3)	Same as above	4	-2	Moderate (2)	
					4.1.3. Loss of ammonia	Injury	5	-2	High (3)	Same as above	4	-2	Moderate (2)	
				4.1.4. Operator error	4.1.1. Toxic environment inside Tank Connection Space (TCS)	Injury	5	-2	High (3)	4.1.1. ADS 4.1.2. BOG 4.1.3. CAMS 4.1.4. DF ICE 4.1.5. ESD 4.1.6. IECEx 4.1.7. OPTS 4.1.8. PMS 4.1.9. PP 4.1.11. Redundancy 4.1.12. SOPs	4	-2	Moderate (2)	
					4.1.2. Flammable environment inside Tank Connection Space (TCS)	Asset	5	-2	High (3)	Same as above	4	-2	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)
					4.1.3. Loss of ammonia	Injury	5	-2	High (3)	Same as above	4	-2	Moderate (2)	
				4.1.5. Connection failures	4.1.1. Toxic environment inside Tank Connection Space (TCS)	Injury	5	-2	High (3)	4.1.1. ADS 4.1.2. BOG 4.1.3. CAMS 4.1.4. DF ICE 4.1.5. ESD 4.1.6. IECEx 4.1.7. OPTS 4.1.8. PMS 4.1.9. PP 4.1.11. Redundancy 4.1.12. SOPs	4	-2	Moderate (2)	68. Consider installing warning signs on the entrance of the Tank Connection Space (TCS).
					4.1.2. Flammable environment inside Tank Connection Space (TCS)	Asset	5	-2	High (3)	Same as above	4	-2	Moderate (2)	
					4.1.3. Loss of ammonia	Injury	5	-2	High (3)	Same as above	4	-2	Moderate (2)	
				4.1.6. Fatigue stress	4.1.1. Toxic environment inside Tank Connection Space (TCS)	Injury	5	-2	High (3)	4.1.1. ADS 4.1.2. BOG 4.1.3. CAMS 4.1.4. DF ICE 4.1.5. ESD 4.1.6. IECEx	4	-2	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)
										4.1.7. OPTS 4.1.8. PMS 4.1.9. PP 4.1.11. Redundancy 4.1.12. SOPs				
					4.1.2. Flammable environment inside Tank Connection Space (TCS)	Asset	5	-2	High (3)	Same as above	4	-2	Moderate (2)	
					4.1.3. Loss of ammonia	Injury	5	-2	High (3)	Same as above	4	-2	Moderate (2)	
4.2	Toxicity	Collision		4.2.1. Collision	4.2.1. Toxic environment inside Tank Connection Space (TCS)	Injury	5	-2	High (3)	4.2.1. ADS 4.2.2. BOG 4.2.3. CAMS 4.2.4. DF ICE 4.2.5. ESD 4.2.6. IECEx 4.2.7. OPTS 4.2.8. PMS 4.2.9. PP 4.2.11. Redundancy 4.2.12. SOPs	4	-2	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)**
4.3	Fire			4.3.1. New - Firefighting Appliances	4.3.1. Flammable environment inside Tank Connection Space (TCS)	Asset	4	-2	Moderate (2)	4.3.1. IECEx 4.3.2. Fire Detection 4.3.3. ESD 4.3.4 ADS 4.3.5. Firefighting equipment 4.3.6. Ventilation	3	-2	Low (1)	
4.4	Inability to Diagnose/Resolve System Failures	Bad Design		4.4.1. Design failure	4.4.1. Toxic environment inside Tank Connection Space (TCS)	Injury	5	-2	High (3)	4.4.1. Second Tank Connection Space (TCS) acts as a redundancy	4	-2	Moderate (2)	
					4.4.2. Flammable environment inside Tank Connection Space (TCS)	Asset	5	-2	High (3)	Same as above	4	-2	Moderate (2)	

Company:		
Title: EMSA NH3, Bulk Carrier Study		
Description:		
Method: HAZID	**Type:**	Fuel Gas Preparation Room
Design Intent:		
Comment:		

No.: 5 **Description:** Fuel Gas Preparation Room

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)
5.1	Design related failure	Inadequate design		5.1.1. Inability to maintain equipment due to stringent/inaccessible locations	5.1.1. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	5.2.2. FAT/HAT/SAT 5.2.3. Materials spec	3	-2	Low (1)	29. Dispersion analysis is to be conducted for a potential leakage in the Fuel Preparation Room (FPR). 69. IGF: 7.4.1.2 Materials having a melting point below 925°C shall not be used for piping outside the fuel tanks. TGE comment: Compartment segregation (e.g., for the BOF management).

No.: 5	**Description:** Fuel Gas Preparation Room													
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)**
					5.1.2. Ammonia Release, flammable environment inside FGPR, fire, human injury.	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
				5.1.3. Improper material selection	5.1.1. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	5.2.2. FAT/HAT/SAT 5.2.3. Materials spec	3	-2	Low (1)	69. IGF: 7.4.1.2 Materials having a melting point below 925°C shall not be used for piping outside the fuel tanks.
					5.1.2. Ammonia Release, flammable environment inside FGPR, fire, human injury.	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 5 **Description:** Fuel Gas Preparation Room

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	Ammonia leakage or accidental release	Loss of containment		5.2.1. Design, fabrication or installation error	5.2.1. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	5.2.2. FAT/HAT/SAT 5.2.3. Materials spec. 5.2.4. Shut off valves at the Fuel Preparation Room (FPR) entrance. 5.2.5. Quality procedure, control, and workmanship	3	-2	Low (1)	70. Further study to be done on later design stages for routing optimization in large-scale evacuation planning, according to possible leakage position. 71. Flanged piping in FGPR should be used sparingly. 72. Weld piping is highly recommended instead. 73. Effective mechanical shielding at all leakage points to minimize direct exposure to ammonia. 74. Piping (containing ammonia) in FGPR must be stainless steel.

No.: 5	**Description:** Fuel Gas Preparation Room													
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)**
														75. The refrigeration and fishing industry requirements should be studied and potentially adopted during system design
					5.2.2. Ammonia Release, flammable environment inside FGPR, fire, human injury.	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
				5.2.2. Abnormal operating condition (exceeding design limits) due to equipment/valve malfunction or operator error	5.2.1. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	5.2.5. ADS 5.2.6. BOG 5.2.7. CAMS 5.2.8. DF ICE 5.2.9. ESD 5.2.10. IECEx 5.2.11. OPTS 5.2.12. PMS 5.2.13. PP 5.2.14. Redundancy	3	-2	Low (1)	

No.: 5 | **Description:** Fuel Gas Preparation Room

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)
										5.2.15. SOPs 5.2.16. SVs				
					5.2.2. Ammonia Release, flammable environment inside FGPR, fire, human injury.	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.2.3. Ammonia Release, flammable environment inside FGPR, fire, damage to the ship structure.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.2.4. Ammonia fuel mode failure	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
				5.2.3. Material defect on equipment, pipe, fitting, valve or flange connection	5.2.1. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	5.2.5. ADS 5.2.6. BOG 5.2.7. CAMS 5.2.8. DF ICE 5.2.9. ESD 5.2.10. IECEx 5.2.11. OPTS 5.2.12. PMS	3	-2	Low (1)	

No.: 5	**Description:** Fuel Gas Preparation Room													
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)**
										5.2.13. PP 5.2.14. Redundancy 5.2.15. SOPs 5.2.16. SVs				
					5.2.2. Ammonia Release, flammable environment inside FGPR, fire, human injury.	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.2.3. Ammonia Release, flammable environment inside FGPR, fire, damage to the ship structure.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.2.4. Ammonia fuel mode failure	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
				5.2.4. Joint failure	5.2.1. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	5.2.5. ADS 5.2.6. BOG 5.2.7. CAMS 5.2.8. DF ICE 5.2.9. ESD	3	-2	Low (1)	

No.: 5 | **Description:** Fuel Gas Preparation Room

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)
										5.2.10. IECEx 5.2.11. OPTS 5.2.12. PMS 5.2.13. PP 5.2.14. Redundancy 5.2.15. SOPs 5.2.16. SVs				
					5.2.2. Ammonia Release, flammable environment inside FGPR, fire, human injury.	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.2.3. Ammonia Release, flammable environment inside FGPR, fire, damage to the ship structure.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.2.4. Ammonia fuel mode failure	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 5	**Description:** Fuel Gas Preparation Room													
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)**
				5.2.5. Operator error	5.2.1. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	5.2.5. ADS 5.2.6. BOG 5.2.7. CAMS 5.2.8. DF ICE 5.2.9. ESD 5.2.10. IECEx 5.2.11. OPTS 5.2.12. PMS 5.2.13. PP 5.2.14. Redundancy 5.2.15. SOPs 5.2.16. SVs	3	-2	Low (1)	
					5.2.2. Ammonia Release, flammable environment inside FGPR, fire, human injury.	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 5 **Description:** Fuel Gas Preparation Room

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)
					5.2.3. Ammonia Release, flammable environment inside FGPR, fire, damage to the ship structure.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.2.4. Ammonia fuel mode failure	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
				5.2.6. External impact	5.2.1. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	5.2.5. ADS 5.2.6. BOG 5.2.7. CAMS 5.2.8. DF ICE 5.2.9. ESD 5.2.10. IECEx 5.2.11. OPTS 5.2.12. PMS 5.2.13. PP 5.2.14. Redundancy 5.2.15. SOPs 5.2.16. SVs	3	-2	Low (1)	

No.: 5 | **Description:** Fuel Gas Preparation Room

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)
					5.2.2. Ammonia Release, flammable environment inside FGPR, fire, human injury.	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.2.3. Ammonia Release, flammable environment inside FGPR, fire, damage to the ship structure.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.2.4. Ammonia fuel mode failure	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
				5.2.7. Fatigue - Stresses	5.2.1. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	5.2.5. ADS 5.2.6. BOG 5.2.7. CAMS 5.2.8. DF ICE 5.2.9. ESD 5.2.10. IECEx 5.2.11. OPTS 5.2.12. PMS 5.2.13. PP	3	-2	Low (1)	

No.: 5 **Description:** Fuel Gas Preparation Room

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)
										5.2.14. Redundancy 5.2.15. SOPs 5.2.16. SVs				
					5.2.2. Ammonia Release, flammable environment inside FGPR, fire, human injury.	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.2.3. Ammonia Release, flammable environment inside FGPR, fire, damage to the ship structure.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.2.4. Ammonia fuel mode failure	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 5	**Description:** Fuel Gas Preparation Room													
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)**
5.3	Fire/Explosion	Hot work with ammonia present		5.3.1. Operator's error	5.3.1. Potential for human injury or fatality	Injury	4	-2	Moderate (2)	5.3.1. DF ICE 5.3.2. CAMS 5.3.3. OPTS 5.3.5. Gas-free FGPR	3	-2	Low (1)	TGE comment: To address hot work in the FGPR, there should be a permit procedure, risk assessment etc., which needs to address the conditions for the works to be executed.
					5.3.2. Potential for asset damage	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
5.4	Fire	Fire adjacent to FGPR		5.4.1. Leakage from surrounding installations.	5.4.1. Ammonia Release, flammable environment inside FGPR, fire, damage to the ship (structural, electrical, control, etc.).	Asset	4	-2	Moderate (2)	5.4.1. DF ICE 5.4.2. CAMS 5.4.3. OPTS 5.4.5. SOPs	3	-2	Low (1)	

No.: 5	**Description:** Fuel Gas Preparation Room													
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)**
					5.4.2. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.4.3. Ammonia fuel mode failure	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
5.5	Explosion	Explosion adjacent to FGPR		5.5.1. Fire	5.5.1. Ammonia Release, flammable environment inside FGPR, fire, damage to the ship (structural, electrical, control, etc.).	Asset	4	-2	Moderate (2)	5.5.1. DF ICE 5.5.2. CAMS 5.5.3. OPTS 5.5.5. SOPs	3	-2	Low (1)	
					5.5.2. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.5.3. Ammonia fuel mode failure	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 5	**Description:** Fuel Gas Preparation Room													
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)**
5.6	Ammonia in liquid form entering fuel lines for gas-phase ammonia	Ammonia Liquid Trap Failure		5.6.1. Mechanical failure	5.6.1. Hydraulic shock, potential for pipe rupture, valve failures, engine damage, etc.	Asset	4	-2	Moderate (2)	5.6.2. DF ICE 5.6.3. CAMS 5.6.4. OPTS 5.6.6. SOPs	3	-2	Low (1)	
					5.6.2. Fuel system instability, ammonia fuel mode failure.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.6.3. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
				5.6.2. Contaminated ammonia.	5.6.1. Hydraulic shock, potential for pipe rupture, valve failures, engine damage, etc.	Asset	4	-2	Moderate (2)	5.6.1. Filters and strainers. 5.6.2. DF ICE 5.6.3. CAMS 5.6.4. OPTS 5.6.6. SOPs	3	-2	Low (1)	TGE comment:

No.: 5 | **Description:** Fuel Gas Preparation Room

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)
										5.6.7. Bunkering Delivery Note from bunkering facility. 5.6.8. Quality procedures, control, and workmanship.				1.Residuals from the fabrication phase are crucial. To that end, thorough and meticulous system cleaning during fabrication and installation at the yard is required. 2. A Bunker Delivery Note (BDN) from a bunkering facility is required to confirm the delivery of fuel oil to a ship, as mandated by MARPOL Annex VI regulations, and to detail the quantity and quality of the fuel delivered.
					5.6.2. Fuel system instability, ammonia fuel mode failure.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 5 | **Description:** Fuel Gas Preparation Room

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)
					5.6.3. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
				5.6.3. Ammonia Quality - Bunkering Stations	5.6.1. Hydraulic shock, potential for pipe rupture, valve failures, engine damage, etc.	Asset	4	-2	Moderate (2)	5.6.1. Filters and strainers are installed. 5.6.2. DF ICE 5.6.3. CAMS 5.6.4. OPTS 5.6.6. SOPs 5.6.7. Bunkering Delivery Note from bunkering facility. 5.6.8. Quality procedures, control, and workmanship.	3	-2	Low (1)	TGE comment: 1.Residuals from the fabrication phase are crucial. To that end, thorough and meticulous system cleaning during fabrication and installation at the yard is required.

No.: 5	**Description:** Fuel Gas Preparation Room													
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. A Bunker Delivery Note (BDN) from a bunkering facility is required to confirm the delivery of fuel oil to a ship, as mandated by MARPOL Annex VI regulations, and to detail the quantity and quality of the fuel delivered.
					5.6.2. Fuel system instability, ammonia fuel mode failure.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					5.6.3. Ammonia Release, toxic environment inside FGPR, human injury	Injury	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 5 **Description:** Fuel Gas Preparation Room

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)
5.7	(Trapped) Ammonia	Trapped ammonia in the piping		5.7.1. Inadequate design	5.7.1. Pressure increase in the ammonia piping, potential for triggering pressure safety valves, potential for damage and ammonia leakage.	Asset	4	-2	Moderate (2)	5.7.1. DF ICE 5.7.2. CAMS 5.7.3. OPTS 5.7.5. SOPs	3	-2	Low (1)	
				5.7.2. Inadequate system purging.	5.7.1. Pressure increase in the ammonia piping, potential for triggering pressure safety valves, potential for damage and ammonia leakage.	Asset	4	-2	Moderate (2)	5.7.1. DF ICE 5.7.2. CAMS 5.7.3. OPTS 5.7.5. SOPs	3	-2	Low (1)	

No.: 5 **Description:** Fuel Gas Preparation Room

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)
5.11	Adverse Weather	Adverse weather interrupting access to the FGPR due to vessels extreme responses (pitching, rolling)		5.11.1. Unable to access the FGPR due to adverse weather.	5.11.1. Delay in emergency response (e.g. fire in the FGPR).	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
5.12	Inability to diagnose and resolve system failures	Troubleshooting inability		5.12.1. Novel design - system complexity	5.12.1. Ammonia fuel mode failure	Asset	4	-2	Moderate (2)	5.12.1. CAMS 5.12.2. OPTS 5.12.3. SOPs	3	-2	Low (1)	76. Verify the remote access and support for makers 77. Consider details about access and speed for remote access and support. 78. Critical spare parts on board according to OEM recommendations
					5.12.2. Hazardous environment, potential for escalation	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	

No.: 5 **Description:** Fuel Gas Preparation Room

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)
				5.12.2. Lack of training	5.12.1. Ammonia fuel mode failure	Asset	4	-2	Moderate (2)	5.12.1. CAMS 5.12.2. OPTS 5.12.3. SOPs	3	-2	Low (1)	76. Verify the remote access and support for makers 77. Consider details about access and speed for remote access and support. TGE comment: Consider training schemes for operators
					5.12.2. Hazardous environment, potential for escalation	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
				5.12.3. Poor documentation or instrumentation	5.12.1. Ammonia fuel mode failure	Asset	4	-2	Moderate (2)	5.12.1. CAMS 5.12.2. OPTS 5.12.3. SOPs	3	-2	Low (1)	76. Verify the remote access and support for makers 78. Critical spare parts on board according to OEM recommendations

No.: 5 | **Description:** Fuel Gas Preparation Room

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)
					5.12.2. Hazardous environment, potential for escalation	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	

5.15	Loss of HP ammonia fuel supply	HP fuel pump failure		5.15.1. Material defect.	5.15.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.15.1. BOG 5.15.2. CAMS 5.15.3. DF ICE 5.15.4. ESD 5.15.5. OPTS 5.15.6. PMS 5.15.7. Redundancy	3	-2	Low (1)	
				5.15.2. Mechanical failure.	5.15.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.15.1. BOG 5.15.2. CAMS 5.15.3. DF ICE 5.15.4. ESD 5.15.5. OPTS 5.15.6. PMS 5.15.7. Redundancy	3	-2	Low (1)	
				5.15.3. Electrical failure	5.15.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.15.1. BOG 5.15.2. CAMS 5.15.3. DF ICE 5.15.4. ESD 5.15.5. OPTS 5.15.6. PMS 5.15.7. Redundancy	3	-2	Low (1)	
				5.15.4. Abnormal operating conditions (vibration, exceeding design limits, etc.)	5.15.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.15.1. BOG 5.15.2. CAMS 5.15.3. DF ICE 5.15.4. ESD 5.15.5. OPTS 5.15.6. PMS 5.15.7. Redundancy	3	-2	Low (1)	

				5.15.5. Operator's error	5.15.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.15.1. BOG 5.15.2. CAMS 5.15.3. DF ICE 5.15.4. ESD 5.15.5. OPTS 5.15.6. PMS 5.15.7. Redundancy	3	-2	Low (1)	
5.16	Loss of HP ammonia fuel supply	LP fuel gas filter clogging		5.16.1. Clogging due to contamination/corrosion	5.16.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.16.1. BOG 5.16.2. CAMS 5.16.3. DF ICE 5.16.4. ESD 5.16.5. OPTS 5.16.6. 5.16.7. Redundancy	3	-2	Low (1)	
					5.16.2. Damage of HP fuel pump	Asset	4	-1	High (3)		3	-2	Low (1)	
				5.16.2. Inadequate maintenance	5.16.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.16.1. BOG 5.16.2. CAMS 5.16.3. DF ICE 5.16.4. ESD 5.16.5. OPTS 5.16.6. PMS 5.16.7. Redundancy	3	-2	Low (1)	
					5.16.2. Damage of HP fuel pump	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
5.17	Loss of HP ammonia fuel supply	Return mixer failure		5.17.1. Mechanical failure	5.17.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.17.1. BOG 5.17.2. CAMS 5.17.3. DF ICE 5.17.4. ESD 5.17.5. OPTS	3	-2	Low (1)	

										5.17.6. PMS 5.17.7. Redundancy				
					5.17.2. Damage of HP fuel pump	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.17.2. Other failure/error (?)	5.17.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.17.1. BOG 5.17.2. CAMS 5.17.3. DF ICE 5.17.4. ESD 5.17.5. OPTS 5.17.6. PMS 5.17.7. Redundancy	3	-2	Low (1)	
					5.17.2. Damage of HP fuel pump	Asset	4	-1	High (3)		3	-2	Low (1)	
5.18	Loss of HP ammonia fuel supply	HP fuel gas heater failure		5.18.1. Electrical failure	5.18.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.18.1. BOG 5.18.2. CAMS 5.18.3. DF ICE 5.18.4. ESD 5.18.5. OPTS 5.18.6. PMS 5.18.7. Redundancy	3	-2	Low (1)	
					5.18.2. Damage of HP fuel pump	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.18.2. Instrument failure	5.18.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.18.1. BOG 5.18.2. CAMS 5.18.3. DF ICE 5.18.4. ESD 5.18.5. OPTS 5.18.6. PMS	3	-2	Low (1)	

										5.18.7. Redundancy				
					5.18.2. Damage of HP fuel pump	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.18.3. Heater control error	5.18.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.18.1. BOG 5.18.2. CAMS 5.18.3. DF ICE 5.18.4. ESD 5.18.5. OPTS 5.18.6. PMS 5.18.7. Redundancy	3	-2	Low (1)	
					5.18.2. Damage of HP fuel pump	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
5.19	Loss of HP ammonia fuel supply	HP Duplex filter fuel gas heater failure		5.19.1. Clogging due to contamination/corrosion	5.19.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.19.1. BOG 5.19.2. CAMS 5.19.3. DF ICE 5.19.4. ESD 5.19.5. OPTS 5.19.6. PMS 5.19.7. Redundancy	3	-2	Low (1)	
					5.19.2. Damage of HP fuel pump	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
5.20	Loss of HP ammonia fuel supply	FVU (Fuel Valve Unit) failure		5.20.1. Material defect	5.20.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.20.1. BOG 5.20.2. CAMS 5.20.3. DF ICE 5.20.4. ESD 5.20.5. OPTS 5.20.6. PMS	3	-2	Low (1)	
					5.20.2. Damage of HP fuel pump	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	

				5.20.2. Mechanical failure	5.20.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.20.1. BOG 5.20.2. CAMS 5.20.3. DF ICE 5.20.4. ESD 5.20.5. OPTS 5.20.6. PMS	3	-2	Low (1)	
					5.20.2. Damage of HP fuel pump	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.20.3. Electrical failure (electronic?)	5.20.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.20.1. BOG 5.20.2. CAMS 5.20.3. DF ICE 5.20.4. ESD 5.20.5. OPTS 5.20.6. PMS	3	-2	Low (1)	
					5.20.2. Damage of HP fuel pump	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.20.4. Abnormal operating conditions (vibration, exceeding design limits, etc.)	5.20.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.20.1. BOG 5.20.2. CAMS 5.20.3. DF ICE 5.20.4. ESD 5.20.5. OPTS 5.20.6. PMS	3	-2	Low (1)	
					5.20.2. Damage of HP fuel pump	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.20.5. Operator error	5.20.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.20.1. BOG 5.20.2. CAMS 5.20.3. DF ICE 5.20.4. ESD 5.20.5. OPTS 5.20.6. PMS	3	-2	Low (1)	

					5.20.2. Damage of HP fuel pump	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.20.6. Signal failure	5.20.1. Shutdown of engine fuel supply, ammonia mode failure	Asset	4	-1	High (3)	5.20.1. BOG 5.20.2. CAMS 5.20.3. DF ICE 5.20.4. ESD 5.20.5. OPTS 5.20.6. PMS	3	-2	Low (1)	
					5.20.2. Damage of HP fuel pump	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
5.21	High pressure in HP fuel system	Blocked line or valve stuck		5.21.1. Valve failure	5.21.1. Line rupture, ammonia release, human injury + potential for fire/explosion	Asset	4	-1	High (3)	5.21.1. BOG 5.21.2. CAMS 5.21.3. DF ICE 5.21.4. ESD 5.21.5. OPTS 5.21.6. PMS	3	-2	Low (1)	
					5.21.2. Fuel mode trip	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.21.2. Valve control failure	5.21.1. Line rupture, ammonia release, human injury + potential for fire/explosion	Asset	4	-1	High (3)	5.21.1. BOG 5.21.2. CAMS 5.21.3. DF ICE 5.21.4. ESD 5.21.5. OPTS 5.21.6. PMS	3	-2	Low (1)	
					5.21.2. Fuel mode trip	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.21.3. Operator error	5.21.1. Line rupture, ammonia release, human injury + potential for fire/explosion	Asset	4	-1	High (3)	5.20.1. BOG 5.21.2. CAMS 5.21.3. DF ICE 5.21.4. ESD 5.21.5. OPTS 5.21.6. PMS	3	-2	Low (1)	

					5.21.2. Fuel mode trip	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.21.4. Corrosion, erosion	5.21.1. Line rupture, ammonia release, human injury + potential for fire/explosion	Asset	4	-1	High (3)	5.20.1. BOG 5.21.2. CAMS 5.21.3. DF ICE 5.21.4. ESD 5.21.5. OPTS 5.21.6. PMS	3	-2	Low (1)	
					5.21.2. Fuel mode trip	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
5.22	Low pressure of HP fuel system	Flow restriction or HP pump fault		5.22.1. Blocked line/valve	5.22.1. Shutdown of engine fuel supply, ammonia mode failure, transition to backup fuel	Asset	4	-1	High (3)	5.20.1. BOG 5.22.2. CAMS 5.22.3. DF ICE 5.22.4. ESD 5.22.5. OPTS 5.22.6. PMS	3	-2	Low (1)	
				5.22.2. Pump failure	5.22.1. Shutdown of engine fuel supply, ammonia mode failure, transition to backup fuel	Asset	4	-1	High (3)	5.22.1. BOG 5.22.2. CAMS 5.22.3. DF ICE 5.22.4. ESD 5.22.5. OPTS 5.22.6. PMS	3	-2	Low (1)	
				5.22.3. Improper suction conditions	5.22.1. Shutdown of engine fuel supply, ammonia mode failure, transition to backup fuel	Asset	4	-1	High (3)	5.22.1. BOG 5.22.2. CAMS 5.22.3. DF ICE 5.22.4. ESD 5.22.5. OPTS 5.22.6. PMS	3	-2	Low (1)	

5.23	Overheating of HP ammonia	Heater failure		5.23.1. Control failure	5.23.1. Shutdown of engine fuel supply, ammonia mode failure, transition to backup fuel	Asset	4	-1	High (3)	5.23.1. BOG 5.23.2. CAMS 5.23.3. DF ICE 5.23.4. ESD 5.23.5. OPTS 5.23.6. PMS	3	-2	Low (1)	
					5.23.2. Risk of overpressure and equipment damage?	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
5.24	Low temperature of HP ammonia	Heater failure (under performance)		5.24.1. Control failure	5.24.1. Shutdown of engine fuel supply, ammonia mode failure, transition to backup fuel	Asset	4	-1	High (3)	5.20.1. BOG 5.20.2. CAMS 5.20.3. DF ICE 5.20.4. ESD 5.20.5. OPTS 5.20.6. PMS	3	-2	Low (1)	
				5.24.2. Blocked heater	5.24.1. Shutdown of engine fuel supply, ammonia mode failure, transition to backup fuel	Asset	4	-1	High (3)	5.20.1. BOG 5.20.2. CAMS 5.20.3. DF ICE 5.20.4. ESD 5.20.5. OPTS 5.20.6. PMS	3	-2	Low (1)	
5.25	Loss of pressure damping	Malfunction of hydraulic buffer vessel		5.25.1. Mechanical failure	5.25.1. Excessive pressure fluctuations, equipment damage(?), ammonia release(?)	Asset	4	-1	High (3)	5.25.1. BOG 5.25.2. CAMS 5.25.3. DF ICE 5.25.4. ESD 5.25.5. OPTS 5.25.6. PMS	3	-2	Low (1)	

				5.25.2. Corrosion	5.25.1. Excessive pressure fluctuations, equipment damage(?), ammonia release(?)	Asset	4	-1	High (3)	5.25.1. BOG 5.25.2. CAMS 5.25.3. DF ICE 5.25.4. ESD 5.25.5. OPTS 5.25.6. PMS	3	-2	Low (1)	
				5.25.3. Nitrogen leakage	5.25.1. Excessive pressure fluctuations, equipment damage(?), ammonia release(?)	Asset	4	-1	High (3)	5.25.1. BOG 5.25.2. CAMS 5.25.3. DF ICE 5.25.4. ESD 5.25.5. OPTS 5.25.6. PMS	3	-2	Low (1)	
				5.25.4. Control failure - pressure regulation failure	5.25.1. Excessive pressure fluctuations, equipment damage(?), ammonia release(?)	Asset	4	-1	High (3)	5.25.1. BOG 5.25.2. CAMS 5.25.3. DF ICE 5.25.4. ESD 5.25.5. OPTS 5.25.6. PMS	3	-2	Low (1)	
				5.25.5. Valve failure	5.25.1. Excessive pressure fluctuations, equipment damage(?), ammonia release(?)	Asset	4	-1	High (3)	5.25.1. BOG 5.25.2. CAMS 5.25.3. DF ICE 5.25.4. ESD 5.25.5. OPTS 5.25.6. PMS	3	-2	Low (1)	
				5.25.6. Operator error	5.25.1. Excessive pressure fluctuations, equipment damage(?), ammonia release(?)	Asset	4	-1	High (3)	5.25.1. BOG 5.25.2. CAMS 5.25.3. DF ICE 5.25.4. ESD 5.25.5. OPTS 5.25.6. PMS	3	-2	Low (1)	

5.26	Loss of liquid fuel return (liquid ammonia and nitrogen)	Drain drum (catch tank) failure		5.26.1. Drum rupture or leakage	5.26.1. Inability to empty and purge fuel gas supply system	Asset	4	-1	High (3)	5.26.1. BOG 5.26.2. CAMS 5.26.3. DF ICE 5.26.4. ESD 5.26.5. OPTS 5.26.6. PMS	3	-2	Low (1)	
					5.26.2. Inability to fill system before engine start	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.26.2. Instrumentation and control failure (level sensor, pressure transmitter, etc.)	5.26.1. Inability to empty and purge fuel gas supply system	Asset	4	-1	High (3)	5.26.1. BOG 5.26.2. CAMS 5.26.3. DF ICE 5.26.4. ESD 5.26.5. OPTS 5.26.6. PMS	3	-2	Low (1)	
					5.26.2. Inability to fill system before engine start	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.26.3. Operator error	5.26.1. Inability to empty and purge fuel gas supply system	Asset	4	-1	High (3)	5.26.1. BOG 5.26.2. CAMS 5.26.3. DF ICE 5.26.4. ESD 5.26.5. OPTS 5.26.6. PMS	3	-2	Low (1)	
					5.26.2. Inability to fill system before engine start	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				5.26.4. Valve failure	5.26.1. Inability to empty and purge fuel gas supply system	Asset	4	-1	High (3)	5.26.1. BOG 5.26.2. CAMS 5.26.3. DF ICE 5.26.4. ESD 5.26.5. OPTS 5.26.6. PMS	3	-2	Low (1)	

					5.26.2. Inability to fill system before engine start	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
5.27	Loss of gas fuel return (gaseous ammonia and nitrogen)	Purge drum failure		5.27.1. Drum rupture or leakage	5.27.1. Inability to empty and purge fuel gas supply system	Asset	4	-1	High (3)	5.27.1. BOG 5.27.2. CAMS 5.27.3. DF ICE 5.27.4. ESD 5.27.5. OPTS 5.27.6. PMS	3	-2	Low (1)	
					5.27.2. Inability to fill system before engine start	Asset	4	-1	High (3)		3	-2	Low (1)	
				5.27.2. Instrumentation and control failure (level sensor, pressure transmitter, etc.)	5.27.1. Inability to empty and purge fuel gas supply system	Asset	4	-1	High (3)		3	-2	Low (1)	
					5.27.2. Inability to fill system before engine start	Asset	4	-1	High (3)		3	-2	Low (1)	
				5.27.3. Operator error	5.27.1. Inability to empty and purge fuel gas supply system	Asset	4	-1	High (3)		3	-2	Low (1)	
					5.27.2. Inability to fill system before engine start	Asset	4	-1	High (3)		3	-2	Low (1)	
				5.27.4. Valve failure	5.27.1. Inability to empty and purge fuel gas supply system	Asset	4	-1	High (3)		3	-2	Low (1)	

					5.27.2. Inability to fill system before engine start	Asset	4	-1	High (3)		3	-2	Low (1)	
5.28	Loss of Knockout Drum	FSS Knockout Drum failure		5.28.1. Drum rupture or leakage	5.28.1. Loss of vapor stream collection	Asset	4	-1	High (3)	5.28.1. BOG 5.28.2. CAMS 5.28.3. DF ICE 5.28.4. ESD 5.28.5. OPTS 5.28.6. PMS	3	-2	Low (1)	
					5.28.2. Loss of liquid ammonia collection from PSVs, TSVs, etc.	Asset	4	-1	High (3)		3	-2	Low (1)	
					5.28.3. No liquid ammonia removal from vapor stream	Asset	4	-1	High (3)		3	-2	Low (1)	
				5.28.2. Instrumentation and control failure (level sensor, pressure transmitter, etc.)	5.28.1. Loss of vapor stream collection	Asset	4	-1	High (3)		3	-2	Low (1)	
					5.28.2. Loss of liquid ammonia collection form PSVs, TSVs, etc.	Asset	4	-1	High (3)		3	-2	Low (1)	
					5.28.3. No liquid ammonia removal from vapor stream	Asset	4	-1	High (3)		3	-2	Low (1)	
				5.28.3. Valve failure	5.28.1. Loss of vapor stream collection	Asset	4	-1	High (3)		3	-2	Low (1)	
					5.28.2. Loss of liquid ammonia collection form PSVs, TSVs, etc.	Asset	4	-1	High (3)		3	-2	Low (1)	

					5.28.3. No liquid ammonia removal from vapor stream	Asset	4	-1	High (3)		3	-2	Low (1)	
5.29	Loss of Drain Drum	SS Drain Drum failure		5.29.1. Drum rupture or leakage	5.29.1. Loss of liquid ammonia collection from drains, system purges, etc.	Asset	4	-1	High (3)	5.29.1. BOG 5.29.2. CAMS 5.29.3. DF ICE 5.29.4. ESD 5.29.5. OPTS 5.29.6. PMS	3	-2	Low (1)	
				5.29.2. Instrumentation and control failure (level sensor, pressure transmitter, etc.)	5.29.1. Loss of liquid ammonia collection from drains, system purges, etc.	Asset	4	-1	High (3)		3	-2	Low (1)	
				5.29.3. Valve failure	5.29.1. Loss of liquid ammonia collection from drains, system purges, etc.	Asset	4	-1	High (3)		3	-2	Low (1)	
5.30	Reliquefaction failure	Compressor failure		5.30.1. Mechanical failure	5.30.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.30.1. BOG 5.30.2. CAMS 5.30.3. DF ICE 5.30.4. ESD 5.30.5. OPTS 5.30.6. PMS 5.30.7. Redundancy (GCU)	3	-2	Low (1)	289. Increased frequency of Inspection of compressor for liquid ammonia leakage.

				5.30.2. Electrical failure	5.30.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.30.1. BOG 5.30.2. CAMS 5.30.3. DF ICE 5.30.4. ESD 5.30.5. OPTS 5.30.6. PMS	3	-2	Low (1)	289. Increased frequency of Inspection of compressor for liquid ammonia leakage.
				5.30.3. Abnormal operating conditions (vibration, exceeding design limits, etc.)	5.30.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.30.1. BOG 5.30.2. CAMS 5.30.3. DF ICE 5.30.4. ESD 5.30.5. OPTS 5.30.6. PMS	3	-2	Low (1)	289. Increased frequency of Inspection of compressor for liquid ammonia leakage.
				5.30.4. Control failure	5.30.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.30.1. BOG 5.30.2. CAMS 5.30.3. DF ICE 5.30.4. ESD 5.30.5. OPTS 5.30.6. PMS	3	-2	Low (1)	289. Increased frequency of Inspection of compressor for liquid ammonia leakage.
5.31	Reliquefaction failure	Ammonia condenser failure		5.31.1. Blocked condenser (ammonia side)	5.31.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.31.1. BOG 5.31.2. CAMS 5.31.3. DF ICE 5.31.4. ESD 5.31.5. OPTS 5.31.6. PMS	3	-2	Low (1)	
				5.31.2. Blocked condenser (WG side)	5.31.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.31.1. BOG 5.31.2. CAMS 5.31.3. DF ICE 5.31.4. ESD 5.31.5. OPTS 5.31.6. PMS	3	-2	Low (1)	

				5.31.3. Control failure	5.31.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.31.1. BOG 5.31.2. CAMS 5.31.3. DF ICE 5.31.4. ESD 5.31.5. OPTS 5.31.6. PMS	3	-2	Low (1)	
				5.31.4. Mechanical failure	5.31.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.31.1. BOG 5.31.2. CAMS 5.31.3. DF ICE 5.31.4. ESD 5.31.5. OPTS 5.31.6. PMS	3	-2	Low (1)	
				5.31.5. Electrical failure	5.31.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.31.1. BOG 5.31.2. CAMS 5.31.3. DF ICE 5.31.4. ESD 5.31.5. OPTS 5.31.6. PMS	3	-2	Low (1)	
				5.31.6. Abnormal operating conditions (vibration, exceeding design limits, etc.)	5.31.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.31.1. BOG 5.31.2. CAMS 5.31.3. DF ICE 5.31.4. ESD 5.31.5. OPTS 5.31.6. PMS	3	-2	Low (1)	
				5.31.7. Control failure	5.31.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.31.1. BOG 5.31.2. CAMS 5.31.3. DF ICE 5.31.4. ESD 5.31.5. OPTS 5.31.6. PMS	3	-2	Low (1)	

5.32	Reliquefaction failure	Blocked line or valve stuck		5.32.1. Valve failure	5.32.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.32.1. BOG 5.32.2. CAMS 5.32.3. DF ICE 5.32.4. ESD 5.32.5. OPTS 5.32.6. PMS	3	-2	Low (1)	
				5.32.2. Valve control failure	5.32.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.32.1. BOG 5.32.2. CAMS 5.32.3. DF ICE 5.32.4. ESD 5.32.5. OPTS 5.32.6. PMS	3	-2	Low (1)	
				5.32.3. Operator error	5.32.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.32.1. BOG 5.32.2. CAMS 5.32.3. DF ICE 5.32.4. ESD 5.32.5. OPTS 5.32.6. PMS	3	-2	Low (1)	
				5.32.4. Corrosion, erosion	5.32.1. Loss of reliquefaction, pressure buildup, potential ammonia release	Asset	4	-1	High (3)	5.32.1. BOG 5.32.2. CAMS 5.32.3. DF ICE 5.32.4. ESD 5.32.5. OPTS 5.32.6. PMS	3	-2	Low (1)	
5.33	Oil in ammonia	Oil carryover into the ammonia system		5.33.1. Malfunction of oil separator	5.33.1. Reduced equipment performance	Asset	3	-1	Moderate (2)	5.33.1. BOG 5.33.2. CAMS 5.33.3. DF ICE 5.33.4. ESD 5.33.5. OPTS 5.33.6. PMS	3	-2	Low (1)	290. Define handling procedure and oil type specification; ensure use of appropriate chemical facility.
					5.33.2. Fire risk (if hot surface present)	Asset	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	

				5.33.2. Compressor failure/wear	5.33.1. Reduced equipment performance	Asset	3	-1	Moderate (2)	5.33.1. BOG 5.33.2. CAMS 5.33.3. DF ICE 5.33.4. ESD 5.33.5. OPTS 5.33.6. PMS	3	-2	Low (1)	290. Define handling procedure and oil type specification; ensure use of appropriate chemical facility.
					5.33.2. Fire risk (if hot surface present)	Asset	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
5.34	High temperature oil in compressor and oil separator	Failure of oil cooling system		5.34.1. Oil cooler malfunction	5.34.1. Equipment overheating, system shutdown	Asset	3	-1	Moderate (2)	5.34.1. BOG 5.34.2. CAMS 5.34.3. DF ICE 5.34.4. ESD 5.34.5. OPTS 5.34.6. PMS	3	-2	Low (1)	
					5.34.2. Potential fire from hot surfaces	Asset	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
				5.34.2. Control failure	5.34.1. Equipment overheating, system shutdown	Asset	3	-1	Moderate (2)	5.34.1. BOG 5.34.2. CAMS 5.34.3. DF ICE 5.34.4. ESD 5.34.5. OPTS 5.34.6. PMS	3	-2	Low (1)	
					5.34.2. Potential fire from hot surfaces	Asset	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
				5.34.3. Oil filter clogged	5.34.1. Equipment overheating, system shutdown	Asset	3	-1	Moderate (2)	5.34.1. BOG 5.34.2. CAMS 5.34.3. DF ICE 5.34.4. ESD	3	-2	Low (1)	

										5.34.5. OPTS 5.34.6. PMS				
					5.34.2. Potential fire from hot surfaces	Asset	3	-1	Moderate (2)	Same as above	3	-2	Low (1)	
5.35	Hot ammonia gas	Ammonia receiver malfunction		5.35.1. Automatic level control malfunction	5.35.1. Hot ammonia gas being passed to the storage tanks	Asset	3	-1	Moderate (2)	5.35.1. BOG 5.35.2. CAMS 5.35.3. DF ICE 5.35.4. ESD 5.35.5. OPTS 5.35.6. PMS	3	-2	Low (1)	
				5.35.2. Automatic venting to incondensable malfunction	5.35.1. Hot ammonia gas being passed to the storage tanks	Asset	3	-1	Moderate (2)	5.35.1. BOG 5.35.2. CAMS 5.35.3. DF ICE 5.35.4. ESD 5.35.5. OPTS 5.35.6. PMS	3	-2	Low (1)	

Company:		
Title: EMSA NH3, Bulk Carrier Study		
Description:		
Method: HAZID	**Type:**	Engine Room
Design Intent:		
Comment:		

No.: 6 **Description:** Engine Room

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. .	6.25.1. Potential for ammonia leakage in the engine room as exhaust gas content.	Asset	5	-2	High (3)	6.25.1. CAM 6.26.2. OPTS 6.25.3. PMS 6.25.5. Redundancy 6.25.6. SOPs	3	-2	Low (1)	100. 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.	General	5	-2	High (3)	6.26.1. CAM 6.26.2. OPTS 6.26.3. PMS 6.26.5. Redundancy 6.26.6. SOPs	3	-2	Low (1)	101. Verify the remote access and support from equipment manufacturers for troubleshooting

No.: 6 **Description:** Engine Room

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)
														281. Consider details about access and speed for remote access and support for the AFGSS. 282. Critical spare parts on board according to OEM recommendations
					6.26.2. Hazardous environment, potential for escalation	General	5	-2	High (3)	Same as above	3	-2	Low (1)	
				6.26.2. Lack of training	6.26.1. Ammonia fuel mode loss.	General	5	-2	High (3)	6.26.1. CAM 6.26.2. OPTS 6.26.3. PMS 6.26.5. Redundancy 6.26.6. SOPs	3	-2	Low (1)	101. Verify the remote access and support from equipment manufacturers for troubleshooting 281. Consider details about access and speed for remote access and support for the AFGSS.

No.: 6	**Description:** Engine Room													
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)**
														282. Critical spare parts on board according to OEM recommendations
					6.26.2. Hazardous environment, potential for escalation	General	5	-2	High (3)	Same as above	3	-2	Low (1)	
				6.26.3. Poor documentation or instrumentation	6.26.1. Ammonia fuel mode loss.	General	5	-2	High (3)	6.26.1. CAM 6.26.2. OPTS 6.26.3. PMS 6.26.5. Redundancy 6.26.6. SOPs	3	-2	Low (1)	101. Verify the remote access and support from equipment manufacturers for troubleshooting 281. Consider details about access and speed for remote access and support for the AFGSS. 282. Critical spare parts on board according to OEM recommendations

No.: 6 **Description:** Engine Room

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)
					6.26.2. Hazardous environment, potential for escalation	General	5	-2	High (3)	Same as above	3	-2	Low (1)	

Company:		
Title: EMSA NH3, Bulk Carrier 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)**
7.2	Ammonia Release (underway)	Vent Mast Release		7.2.1. ARMS tank overpressurisation	7.2.1. Toxic environment, human injury	Injury	5	-1	High (4)	7.2.1. BOG 7.2.2. ESD 7.2.3. CAMS 7.2.4. OPTS 7.2.5. PMS 7.2.6. PP 7.2.7. Redundancy 7.2.8. SOPs	3	-1	Moderate (2)	113. Further study to be done on the (adequate) volume sizing of the buffer tank. The buffer 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.: 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)
														114. 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. 283. SOPs must include clear procedures for the pilot to board the vessel, considering the dispersion analysis and the risks associated with ammonia. 284. The scenario of leakage in the vent mast must 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)
				7.2.2. Fuel Tank overpressurisation	7.2.1. Toxic environment, human injury	Injury	5	-1	High (4)	7.2.1. BOG 7.2.2. ESD 7.2.3. CAMS 7.2.4. OPTS 7.2.5. PMS 7.2.6. PP 7.2.7. Redundancy 7.2.8. SOPs	3	-1	Moderate (2)	113. 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.

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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)**
														114. 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. 283. SOPs must include clear procedures for the pilot to board the vessel, considering the dispersion analysis and the risks associated with ammonia. 284. The scenario of leakage in the vent mast must be considered.

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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)**
				7.2.3. Pressure Safety Valve (PSI) malfunction	7.2.1. Toxic environment, human injury	Injury	5	-1	High (4)	7.2.1. BOG 7.2.2. ESD 7.2.3. CAMS 7.2.4. OPTS 7.2.5. PMS 7.2.6. PP 7.2.7. Redundancy 7.2.8. SOPs	3	-1	Moderate (2)	113. 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.: 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)**
														114. 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. 283. SOPs must include clear procedures for the pilot to board the vessel, considering the dispersion analysis and the risks associated with ammonia. 284. The scenario of leakage in the vent mast must 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)**
				7.2.4. ARMS malfunction	7.2.1. Toxic environment, human injury	Injury	5	-1	High (4)	7.2.1. BOG 7.2.2. ESD 7.2.3. CAMS 7.2.4. OPTS 7.2.5. PMS 7.2.6. PP 7.2.7. Redundancy 7.2.8. SOPs	3	-1	Moderate (2)	113. 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.: 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)
														114. 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. 283. SOPs must include clear procedures for the pilot to board the vessel, considering the dispersion analysis and the risks associated with ammonia. 284. The scenario of leakage in the vent mast must 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)
7.3	Ammonia Release (Port)	Vent Mast Release		7.3.1. ARMS tank overpressurisation	7.3.1. Toxic environment, human injury	Injury	5	-1	High (4)	7.3.1. BOG 7.3.2. ESD 7.3.3. Redundancy x% 7.3.4. IAS 7.3.5. OPTS 7.3.6. PMS 7.3.7. PP 7.3.8. SOPs 7.3.9. CAMS	3	-1	Moderate (2)	115. Further study to be done on the possible release of ammonia through the vent system. Study should consider port related matters (legislation, restrictions etc. 116. 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)**
				7.3.2. Fuel Tank overpressurisation	7.3.1. Toxic environment, human injury	Injury	5	-1	High (4)	7.3.1. BOG 7.3.2. ESD 7.3.3. Redundancy x% 7.3.4. IAS 7.3.5. OPTS 7.3.6. PMS 7.3.7. PP 7.3.8. SOPs 7.3.9. CAMS	3	-1	Moderate (2)	115. Further study to be done on the possible release of ammonia through the vent system. Study should consider port related matters (legislation, restrictions etc. 116. 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)**
				7.3.3. Pressure Safety Valve (PSV) malfunction	7.3.1. Toxic environment, human injury	Injury	5	-1	High (4)	7.3.1. BOG 7.3.2. ESD 7.3.3. Redundancy x% 7.3.4. IAS 7.3.5. OPTS 7.3.6. PMS 7.3.7. PP 7.3.8. SOPs 7.3.9. CAMS	3	-1	Moderate (2)	115. Further study to be done on the possible release of ammonia through the vent system. Study should consider port related matters (legislation, restrictions etc. 116. 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)
				7.3.4. ARMS malfunction	7.3.1. Toxic environment, human injury	Injury	5	-1	High (4)	7.3.1. BOG 7.3.2. ESD 7.3.3. Redundancy x% 7.3.4. IAS 7.3.5. OPTS 7.3.6. PMS 7.3.7. PP 7.3.8. SOPs 7.3.9. CAMS	3	-1	Moderate (2)	115. Further study to be done on the possible release of ammonia through the vent system. Study should consider port related matters (legislation, restrictions etc. 116. SOPs must include clear procedures for the pilot to board the vessel, considering the dispersion analysis and the risks associated with ammonia.
7.7	Ammonia Release	ARMS Leakage		7.7.1. Manufacturing or installation defect	7.7.1. Failure to neutralize ammonia. Toxic environment, human exposure. Potential for fire or explosion	Asset	4	-1	High (3)	7.7.2. FAT/HAT/SAT 7.7.3. Materials spec	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)**
					7.7.2. Toxic environment, human exposure	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.7.3. Potential for fire or explosion	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				7.7.2. Material degradation/corrosion	7.7.1. Failure to neutralize ammonia. Toxic environment, human exposure. Potential for fire or explosion	Asset	4	-1	High (3)	7.7.2. FAT/HAT/SAT 7.7.3. Materials spec	3	-2	Low (1)	
					7.7.2. Toxic environment, human exposure	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.7.3. Potential for fire or explosion	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				7.7.3. Weld or structural failure	7.7.1. Failure to neutralize ammonia. Toxic environment, human exposure. Potential for fire or explosion	Asset	4	-1	High (3)	7.7.2. FAT/HAT/SAT 7.7.3. Materials spec	3	-2	Low (1)	
					7.7.2. Toxic environment, human exposure	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.7.3. Potential for fire or explosion	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				7.7.4. Seal/Gasket failure	7.7.1. Failure to neutralize ammonia. Toxic environment, human exposure. Potential for fire or explosion	Asset	4	-1	High (3)	7.7.2. FAT/HAT/SAT 7.7.3. Materials spec	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)
					7.7.2. Toxic environment, human exposure	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.7.3. Potential for fire or explosion	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				7.7.5. Valve or connection failure	7.7.1. Failure to neutralize ammonia. Toxic environment, human exposure. Potential for fire or explosion	Asset	4	-1	High (3)	7.7.2. FAT/HAT/SAT 7.7.3. Materials spec	3	-2	Low (1)	
					7.7.2. Toxic environment, human exposure	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.7.3. Potential for fire or explosion	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				7.7.6. Impact damage	7.7.1. Failure to neutralize ammonia. Toxic environment, human exposure. Potential for fire or explosion	Asset	4	-1	High (3)	7.7.2. FAT/HAT/SAT 7.7.3. Materials spec	3	-2	Low (1)	285. Identify the section of the fuel piping which needs to be protected from a dropped object

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)**
														286. Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)
					7.7.2. Toxic environment, human exposure	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.7.3. Potential for fire or explosion	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
7.8	Ammonia Release	ARMS Malfunction (other than leakage)		7.8.1. Dilution fan failure	7.8.1. Failure to neutralize ammonia	Asset	4	-1	High (3)	7.8.1. BOG 7.8.2. ESD 7.8.3. CAMS 7.8.4. OPTS 7.8.5. PMS 7.8.6. Redundancy 7.8.7. SOPs	3	-2	Low (1)	124. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.

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)**
														287. Design drain system with automatic pump-out capability in piping. Also, a e level switch should be included.
					7.8.2. Ammonia discharge	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.3. Trapped ammonia	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.4. Human injury	General	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.5. Ammonia in accommodation area.	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.6. Potential for fire or explosion	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.7. Ammonia fuel mode failure	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				7.8.2. Mechanical failure	7.8.1. Failure to neutralize ammonia	Asset	4	-1	High (3)	7.8.1. BOG 7.8.2. ESD 7.8.3. CAMS 7.8.4. OPTS 7.8.5. PMS 7.8.6. Redundancy	3	-2	Low (1)	124. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.

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)**
										7.8.7. SOPs				287. Design drain system with automatic pump-out capability in piping. Also, a e level switch should be included.
					7.8.2. Ammonia discharge	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.3. Trapped ammonia	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.4. Human injury	General	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.5. Ammonia in accommodation area.	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.6. Potential for fire or explosion	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.7. Ammonia fuel mode failure	Asset	4	-1	High (3)	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)**
				7.8.3. Electrical failure	7.8.1. Failure to neutralize ammonia	Asset	4	-1	High (3)	7.8.1. BOG 7.8.2. ESD 7.8.3. CAMS 7.8.4. OPTS 7.8.5. PMS 7.8.6. Redundancy 7.8.7. SOPs	3	-2	Low (1)	124. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided. 287. Design drain system with automatic pump-out capability in piping. Also, a e level switch should be included.
					7.8.2. Ammonia discharge	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.3. Trapped ammonia	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.4. Human injury	General	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.5. Ammonia in accommodation area.	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.6. Potential for fire or explosion	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.7. Ammonia fuel mode failure	Asset	4	-1	High (3)	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)**
				7.8.4. Control System failure	7.8.1. Failure to neutralize ammonia	Asset	4	-1	High (3)	7.8.1. BOG 7.8.2. ESD 7.8.3. CAMS 7.8.4. OPTS 7.8.5. PMS 7.8.6. Redundancy 7.8.7. SOPs	3	-2	Low (1)	124. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided. 287. Design drain system with automatic pump-out capability in piping. Also, a e level switch should be included.
					7.8.2. Ammonia discharge	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.3. Trapped ammonia	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.4. Human injury	General	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.5. Ammonia in accommodation area.	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.6. Potential for fire or explosion	Asset	4	-1	High (3)	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)
					7.8.7. Ammonia fuel mode failure	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				7.8.5. Sensors malfunction	7.8.1. Failure to neutralize ammonia	Asset	4	-1	High (3)	7.8.1. BOG 7.8.2. ESD 7.8.3. CAMS 7.8.4. OPTS 7.8.5. PMS 7.8.6. Redundancy 7.8.7. SOPs	3	-2	Low (1)	124. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided.
					7.8.2. Ammonia discharge	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.3. Trapped ammonia	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.4. Human injury	General	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.5. Ammonia in accommodation area.	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.6. Potential for fire or explosion	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.7. Ammonia fuel mode failure	Asset	4	-1	High (3)	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)**
				7.8.6. Blocked/restricted flow	7.8.1. Failure to neutralize ammonia	Asset	4	-1	High (3)	7.8.1. BOG 7.8.2. ESD 7.8.3. CAMS 7.8.4. OPTS 7.8.5. PMS 7.8.6. Redundancy 7.8.7. SOPs	3	-2	Low (1)	124. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided. 287. Design drain system with automatic pump-out capability in piping. Also, a e level switch should be included.
					7.8.2. Ammonia discharge	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.3. Trapped ammonia	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.4. Human injury	General	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.5. Ammonia in accommodation area.	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.6. Potential for fire or explosion	Asset	4	-1	High (3)	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)
					7.8.7. Ammonia fuel mode failure	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
				7.8.7. Extreme environmental conditions	7.8.1. Failure to neutralize ammonia	Asset	4	-1	High (3)	7.8.1. BOG 7.8.2. ESD 7.8.3. CAMS 7.8.4. OPTS 7.8.5. PMS 7.8.6. Redundancy 7.8.7. SOPs	3	-2	Low (1)	124. Ensure that drain and isolation procedures are established, and that the facilities required for purging and gas-freeing are provided. 287. Design drain system with automatic pump-out capability in piping. Also, a e level switch should be included.
					7.8.2. Ammonia discharge	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.3. Trapped ammonia	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.4. Human injury	General	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.5. Ammonia in accommodation area.	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
					7.8.6. Potential for fire or explosion	Asset	4	-1	High (3)	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)
					7.8.7. Ammonia fuel mode failure	Asset	4	-1	High (3)	Same as above	3	-2	Low (1)	
7.9	Fire	Vent Mast Ignition		7.9.1. Accumulation of ammonia in the vent mast.	7.9.1. Fire and explosion. Damage to ship and equipment.	Asset	4	-2	Moderate (2)	7.9.1. ESD 7.9.2. IAS 7.9.3. PMS 7.9.4. Redundancy	3	-2	Low (1)	125. 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
					7.9.2. Collateral damage (spreading of the fire).	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.3. Health impact	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.4. Environmental contamination	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.5. Disruption of port operations	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.6. Regulatory and legal consequences/fines/insurance claims	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.9.7. Reputation damage. Business damage	Reputation	4	-2	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)
7.10	Water Ingress	Vent Mast		7.10.1. Weather	7.10.1. Blockage of vent mast	Asset	4	-2	Moderate (2)	7.10.1. BOG 7.10.2. OPTS 7.10.3. SOPs 7.10.4. OPTS	3	-2	Low (1)	126. Identify the section of the fuel piping which needs to be protected from a dropped object
					7.10.2. Ammonia pressure build up	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.10.3. Water ingress	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.10.4. Corrosion	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
				7.10.2. Incorrect vent mast design	7.10.1. Blockage of vent mast	Asset	4	-2	Moderate (2)	7.10.1. BOG 7.10.2. OPTS 7.10.3. SOPs	3	-2	Low (1)	126. Identify the section of the fuel piping which needs to be protected from a dropped object 128. Further study to be done on constant purging of the vent lines to keep them constantly dry.
					7.10.2. Ammonia pressure build up	Asset	4	-2	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)**
					7.10.3. Water ingress	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.10.4. Corrosion	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
				7.10.3. Firefighting close to vent mast	7.10.1. Blockage of vent mast	Asset	4	-2	Moderate (2)	7.10.1. BOG 7.10.2. OPTS 7.10.3. SOPs	3	-2	Low (1)	128. Further study to be done on constant purging of the vent lines to keep them constantly dry.
					7.10.2. Ammonia pressure build up	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.10.3. Water ingress	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.10.4. Corrosion	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
				7.10.4. Drain blockage/failure	7.10.1. Blockage of vent mast	Asset	4	-2	Moderate (2)	7.10.1. BOG 7.10.2. OPTS 7.10.3. SOPs	3	-2	Low (1)	128. Further study to be done on constant purging of the vent lines to keep them constantly dry.
					7.10.2. Ammonia pressure build up	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.10.3. Water ingress	Asset	4	-2	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)
					7.10.4. Corrosion	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
7.11	Ammonia Release	Gas Combustion Unit (GCU) Supply Leakage		7.11.1. Manufacturing or installation defect	7.11.1. Failure to neutralize ammonia	Asset	4	-2	Moderate (2)	7.11.2. FAT/HAT/SAT 7.11.3. materials spec	3	-2	Low (1)	129. Identify the section of the fuel piping which needs to be protected from a dropped object 130. Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)
					7.11.2. Toxic environment, human exposure. Potential for fire or explosion.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.11.3. Potential for fire or explosion	Asset	4	-2	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)**
				7.11.2. Material degradation/corrosion	7.11.1. Failure to neutralize ammonia	Asset	4	-2	Moderate (2)	7.11.2. FAT/HAT/SAT 7.11.3. materials spec	3	-2	Low (1)	129. Identify the section of the fuel piping which needs to be protected from a dropped object 130. Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)
					7.11.2. Toxic environment, human exposure. Potential for fire or explosion.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.11.3. Potential for fire or explosion	Asset	4	-2	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)
				7.11.3. Weld or structural failure	7.11.1. Failure to neutralize ammonia	Asset	4	-2	Moderate (2)	7.11.2. FAT/HAT/SAT 7.11.3. materials spec	3	-2	Low (1)	129. Identify the section of the fuel piping which needs to be protected from a dropped object 130. Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)
					7.11.2. Toxic environment, human exposure. Potential for fire or explosion.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.11.3. Potential for fire or explosion	Asset	4	-2	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)**
				7.11.4. Seal/Gasket failure	7.11.1. Combustion of ammonia	Asset	4	-2	Moderate (2)	7.11.2. FAT/HAT/SAT 7.11.3. materials spec	3	-2	Low (1)	129. Identify the section of the fuel piping which needs to be protected from a dropped object 130. Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)
					7.11.2. Toxic environment, human exposure. Potential for fire or explosion.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.11.3. Potential for fire or explosion	Asset	4	-2	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)
				7.11.5. Valve or connection failure	7.11.1. Failure to neutralize ammonia	Asset	4	-2	Moderate (2)	7.11.2. FAT/HAT/SAT 7.11.3. materials spec	3	-2	Low (1)	129. Identify the section of the fuel piping which needs to be protected from a dropped object 130. Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)
					7.11.2. Toxic environment, human exposure. Potential for fire or explosion.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.11.3. Potential for fire or explosion	Asset	4	-2	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)**
				7.11.6. Impact damage (dropped object)	7.11.1. Combustion of ammonia	Asset	4	-2	Moderate (2)	7.11.2. FAT/HAT/SAT 7.11.3. materials spec. 7.11.4. CAMS 7.11.5. ESD 7.11.6. OPTS 7.11.7. PMS 7.11.8. Redundancy 7.11.9. SOPs	3	-2	Low (1)	129. Identify the section of the fuel piping which needs to be protected from a dropped object 130. Development of a drop object protection program (ABS Guide Dropped Object Prevention on Offshore Units and Installations)
					7.11.2. Toxic environment, human exposure. Potential for fire or explosion.	Asset	4	-2	Moderate (2)	Same as above	3	-2	Low (1)	
					7.11.3. Potential for fire or explosion	Asset	4	-2	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)
7.12	Fire	Fire inside GCU Supply System space		7.12.1. Leakage, ignition source	7.12.1. Explosion	Asset	5	-1	High (4)	7.11.2. FAT/HAT/SAT 7.11.3. materials spec. 7.11.4. CAMS 7.11.5. ESD 7.11.6. OPTS 7.11.7. Power Management System (PMS) PMS 7.11.8. Redundancy 7.11.9. SOPs	4			288. 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
7.13	Water Ingress	Water ingress through the exhaust pipe of GSU		7.13.1. Weather	7.13.1. Blockage of exhaust	Asset	5	-2	High (3)	7.13.1. OPTS 7.13.2. SOPs	3	-2	Low (1)	128. Further study to be done on constant purging of the vent lines to keep them constantly dry.
					7.13.2. Ammonia pressure build up	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					7.13.3. Corrosion	Asset	5	-2	High (3)	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)**
				7.13.2. Incorrect vent mast design	7.13.1. Blockage of exhaust	Asset	5	-2	High (3)	7.13.1. OPTS 7.13.2. SOPs	3	-2	Low (1)	128. Further study to be done on constant purging of the vent lines to keep them constantly dry.
					7.13.2. Ammonia pressure build up	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					7.13.3. Corrosion	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
				7.13.3. Firefighting close to vent mast	7.13.1. Blockage of exhaust	Asset	5	-2	High (3)	7.13.1. OPTS 7.13.2. SOPs	3	-2	Low (1)	128. Further study to be done on constant purging of the vent lines to keep them constantly dry.
					7.13.2. Ammonia pressure build up	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					7.13.3. Corrosion	Asset	5	-2	High (3)	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)**
				7.13.4. Firefighting close to exhaust	7.13.1. Blockage of exhaust	Asset	5	-2	High (3)	7.13.1. OPTS 7.13.2. SOPs	3	-2	Low (1)	128. Further study to be done on constant purging of the vent lines to keep them constantly dry.
					7.13.2. Ammonia pressure build up	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					7.13.3. Corrosion	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
				7.13.5. Drain blockage/failure	7.13.1. Blockage of exhaust	Asset	5	-2	High (3)	7.13.1. OPTS 7.13.2. SOPs	3	-2	Low (1)	128. Further study to be done on constant purging of the vent lines to keep them constantly dry.
					7.13.2. Ammonia pressure build up	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					7.13.3. Corrosion	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	

Company:		
Title: EMSA NH3, Bulk Carrier 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)	8.1.2. MV 2x100%	3	-2	Low (1)	131. 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)**
														132. Further study to be done on the interaction of the ventilation system in relation to the dust arising from the cargo holds. Inclusion of filters is to be examined in the updated design. 133. Consider equipping the vessel with portable ventilation units to facilitate rapid dispersion of ammonia vapours in the event of a deck spill or leakage.

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)**
														134. 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. 135. 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)**
														136. 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)**
														137. Allow for manual closure of ventilation inlets from within the safe haven. 138. Install gas detectors at the ventilation inlets. 139. Design the ventilation of the engine room with capability to shut down in case of ammonia release. 140. Implement engine slowdown function in case of detected malfunction. 141. Ducting for double-walled piping ventilation should be properly sized to prevent excessive backpressure.

Company:		
Title: EMSA NH3, Bulk Carrier Study		
Description:		
Method: HAZID	**Type:**	firefighting Appliances
Design Intent:		
Comment:		

No.: 9	**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)**
9.1	Inability to perform task	Design Failure		9.1.1. Incompatibility with ammonia.	9.1.1. Fire, human injury.	Injury	5	-2	High (3)	9.1.1. Material spec 9.1.3. Redundancy	3	-2	Low (1)	142. Further study to be done on the choice of medium for the Fire Fighting System (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. **Comment:** The initial design could include a freshwater high-pressure mist system, with powder, foam, and water used for portable extinguishers.

No.: 9	**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)**
														144. 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. 145. Ammonia system supplier is to design the Fire Fighting System (FFS)/ESD system.

No.: 9	**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)**
														146. 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). 147. 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.

No.: 9 | **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)
				9.1.2. Limited capacity of water.	9.1.2. Damage to the vessel	Asset	5	-2	High (3)	9.1.1. Material spec 9.1.3. Redundancy x%	3	-2	Low (1)	142. Further study to be done on the choice of medium for the Fire Fighting System (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. **Comment:** The initial design could include a freshwater high-pressure mist system, with powder, foam, and water used for portable extinguishers.

No.: 9	**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)**
														143. Study is to be conducted on the capacity of the water-based firefighting system. 144. 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.: 9	**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)**
														145. Ammonia system supplier is to design the Fire Fighting System (FFS)/ESD system.
9.2	Uncontrolled fire incident	Fire Fighting System (FFS) failure		9.2.1. Power loss	9.2.1. Inability to control ammonia-related fires or hot surfaces.	Asset	5	-1	High (4)	9.2.1. Emergency power supply. 9.2.2. Material spec 9.2.4. Redundancy x% 9.2.5. OPTS 9.2.6. PMS 9.2.7. SOPs	3	-2	Low (1)	148. Develop material handling procedures for machinery and equipment repair and overhaul.
					9.2.2. Potential for ammonia fuel tank rupture due to excessive heat exposure.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
					9.2.3. Potential escalation to ammonia release	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
					9.2.4. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	

No.: 9	**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)**
					9.2.5. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					9.2.6. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					9.2.7. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
				9.2.2. Nozzle, piping damage	9.2.1. Inability to control ammonia-related fires or hot surfaces.	Asset	5	-1	High (4)	9.2.2. Material spec 9.2.4. Redundancy x% 9.2.5. OPTS 9.2.6. PMS 9.2.7. SOPs	3	-2	Low (1)	148. Develop material handling procedures for machinery and equipment repair and overhaul.
					9.2.2. Potential for ammonia fuel tank rupture due to excessive heat exposure.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
					9.2.3. Potential escalation to ammonia release	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
					9.2.4. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	

No.: 9	**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)**
					9.2.5. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					9.2.6. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					9.2.7. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
				9.2.3. Low pressure	9.2.1. Inability to control ammonia-related fires or hot surfaces.	Asset	5	-1	High (4)	9.2.2. Material spec 9.2.4. Redundancy x% 9.2.5. OPTS 9.2.6. PMS 9.2.7. SOPs	3	-2	Low (1)	148. Develop material handling procedures for machinery and equipment repair and overhaul.
					9.2.2. Potential for ammonia fuel tank rupture due to excessive heat exposure.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
					9.2.3. Potential escalation to ammonia release	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
					9.2.4. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	

No.: 9	**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)**
					9.2.5. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					9.2.6. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					9.2.7. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
				9.2.4. Poor Maintenance	9.2.1. Inability to control ammonia-related fires or hot surfaces.	Asset	5	-1	High (4)	9.2.2. Material spec 9.2.4. Redundancy x% 9.2.5. OPTS 9.2.6. PMS 9.2.7. SOPs 9.2.8. Ventilation	3	-2	Low (1)	148. Develop material handling procedures for machinery and equipment repair and overhaul.
					9.2.2. Potential for ammonia fuel tank rupture due to excessive heat exposure.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
					9.2.3. Potential escalation to ammonia release	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	

No.: 9	**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)**
					9.2.4. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					9.2.5. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					9.2.6. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
					9.2.7. Damage to the vessel	Asset	5	-2	High (3)	Same as above	3	-2	Low (1)	
9.3	Uncontrolled incident or escalation in case of fire	Failure of ESD		9.3.1. Electrical of software failure	9.3.1. Damage to the vessel	Asset	5	-2	High (3)	9.3.1. Material spec 9.3.3. Redundancy x% 9.3.4. OPTS 9.3.5. PMS 9.3.6. SOPs	3	-2	Low (1)	
				9.3.2. Valve, actuator failure	9.3.1. Damage to the vessel	Asset	5	-2	High (3)	9.3.1. Material spec 9.3.3. Redundancy x% 9.3.4. OPTS 9.3.5. PMS 9.3.6. SOPs	3	-2	Low (1)	
				9.3.3. Human error	9.3.2. Fire, human injury.	Injury	5	-1	High (4)	9.3.1. Material spec	3	-2	Low (1)	

No.: 9	**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)**
										9.3.3. Redundancy x% 9.3.4. OPTS 9.3.5. PMS 9.3.6. SOPs 9.3.7. Ventilation				
					9.3.3. Ammonia release, fire	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
9.4	Water, ammonia Reaction	Water contact with ammonia during firefighting		9.4.1. Use of water on ammonia leaks	9.4.1. Formation of corrosive solution, Toxic environment, human injury	Injury	5	-2	High (3)	9.4.1. Material spec 9.4.3. OPTS 9.4.4. SOPs 9.4.5. PP	3	-2	Low (1)	
9.6	Fire incident escalation	Inability to Shut Down Ventilation		9.6.1. Operator error	9.6.1. Accumulation of ammonia vapours, toxic environment, human injury.	Asset	5	-1	High (4)	9.6.2. Redundancy x% 9.6.3. OPTS 9.6.4. PMS 9.6.5. SOPs 9.6.6. Ventilation 9.6.7. MV 2x100% 9.6.8. ADS 9.6.9. IAS 9.6.10. PP	3	-2	Low (1)	

No.: 9	**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)**
										9.6.11. FAT/HAT/SAT spec				
					9.6.2. Ineffective Fire Fighting System (FFS) due to high ammonia concentration.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	
				9.6.2. Electrical or control system failure	9.6.1. Accumulation of ammonia vapours, toxic environment, human injury.	Asset	5	-1	High (4)	9.6.2. Redundancy x% 9.6.3. OPTS 9.6.4. PMS 9.6.5. SOPs 9.6.6. Ventilation 9.6.7. MV 2x100% 9.6.8. ADS 9.6.9. IAS 9.6.10. PP 9.6.11. FAT/HAT/SAT spec	3	-2	Low (1)	
					9.6.2. Ineffective Fire Fighting System (FFS) due to high ammonia concentration.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	

No.: 9 | **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)
				9.6.3. Mechanical failure	9.6.1. Accumulation of ammonia vapours, toxic environment, human injury.	Asset	5	-1	High (4)	9.6.2. Redundancy x% 9.6.3. OPTS 9.6.4. PMS 9.6.5. SOPs 9.6.6. Ventilation 9.6.7. MV 2x100% 9.6.8. ADS 9.6.9. IAS 9.6.10. PP 9.6.11. FAT/HAT/SAT spec	3	-2	Low (1)	
					9.6.2. Ineffective Fire Fighting System (FFS) due to high ammonia concentration.	Asset	5	-1	High (4)	Same as above	3	-2	Low (1)	

Company:		
Title: EMSA NH3, Bulk Carrier Study		
Description:		
Method: HAZID	**Type:**	Purging System
Design Intent:		
Comment:		

No.: 10	**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)

Company:		
Title: EMSA NH3, Bulk Carrier 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)

Company:		
Title: EMSA NH3, Bulk Carrier Study		
Description:		
Method: HAZID	**Type:**	Bilge System
Design Intent:		
Comment:		

No.: 12	**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)**

Appendix B 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. Optimized 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 gassing of ammonia storage tanks without interaction 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/ Familiarization/ 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 in the IGC Code 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	IGC Code Chapter 14-Personnel Protection (PP) 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.		
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 vapor 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 are outlined in the IGC Code and the IBC Code, which 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 Organization (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 as per the requirements of the IGC Code, as appropriate.		

No.	References	Action	Comment	Responsibility
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		
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.	TGE comment: N/A as bunkering station is located on open deck	
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 (Analogous detection measures are not required by IGC code).		
38	2.2 Toxicity (Ammonia Release). Loss of Containment – Bunkering Stations	Consistent monitoring of the bunkering area or use of an equivalent method.		

No.	References	Action	Comment	Responsibility
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.		
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.		

No.	References	Action	Comment	Responsibility
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.		
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	TGE Comment: Simultaneous tank filling is the intended operating setup for this design.	
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.		

No.	References	Action	Comment	Responsibility
59	2.10 Toxicity (Ammonia Release). Drip Trays – Bunkering Stations	Drainage system is to be designed with inclination or with a parallel stripping line. Decision to be made upon final vessel design.		
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.		
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"		

No.	References	Action	Comment	Responsibility
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.		
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 vapour space above the 98% 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 overfilled tank.		
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.		

No.	References	Action	Comment	Responsibility
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 in accordance with the IGC code 16.9.		
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.		
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.		

No.	References	Action	Comment	Responsibility
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 tank 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 4.17 Design Failure. Bad Design – Tank Connection Space	Procedures on gas freeing the ammonia storage tanks are to be developed considering the operational procedures including the deck compartment.		
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.		

No.	References	Action	Comment	Responsibility
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.		
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.		

No.	References	Action	Comment	Responsibility
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".		
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".		

No.	References	Action	Comment	Responsibility
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		
126	4.15 Inability to diagnose and resolve system failures. Troubleshooting inability – Tank Connection Space	Consider details about access and speed for remote access and support for the AFGSS.		
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 Fire Fighting System (FFS) Leakage. Equipment Leakage – Tank Connection Space	Further study to be done on the medium of the Fire Fighting System (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;		
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.		

No.	References	Action	Comment	Responsibility
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.		
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.		

No.	References	Action	Comment	Responsibility
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.		
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		
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.		

No.	References	Action	Comment	Responsibility
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		
161	6.26 Inability to diagnose and resolve system failures . Troubleshooting inability – Engine Rooms	Consider details about access and speed for remote access and support for the AFGSS.		
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 needs to comply with IGC code requirements to prevent 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.		

No.	References	Action	Comment	Responsibility
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 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.		
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 tug boat(s). 5. Embarkation/Disembarkation procedures during bunkering 6. Bunkering temperature range.	

No.	References	Action	Comment	Responsibility
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 ARMS 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.		
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.		

No.	References	Action	Comment	Responsibility
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.		
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.		

No.	References	Action	Comment	Responsibility
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 vapor 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.		
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.		
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.		

No.	References	Action	Comment	Responsibility
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.		
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 vapor 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.	References	Action	Comment	Responsibility
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 . Fire Fighting System (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		
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 utilization 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.		

No.	References	Action	Comment	Responsibility
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 Fire Fighting System (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.		
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.		
240	12.1 Design – Firefighting Appliances	Ammonia system supplier is to design the Fire Fighting System (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		
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.		

No.	References	Action	Comment	Responsibility
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 Fire Fighting System (FFS)/ESD system.		

Appendix C SIMOPS Worksheet

Node 1. Bunkering in Port (from Bunkering Vessel/Barge)

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
1.1	Ammonia Release	Loss of containment	Loading / Unloading cargo	Cargo operations: cargo cranes / grabs or conveyor systems, ballast water system, cargo hatch cover and coamings opening/closing systems, lighting, communication systems. Ammonia bunkering: Bunkering lines, fuel transfer pumps (bunkering vessel/barge), fuel storage tanks, tank connection spaces, reliquefaction system, ARMS, GCU, ammonia leak detection system, ventilation system, purging system	1.1.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.1.1. Ammonia release, toxicity, human injury.	Injury		The port personnel will need to be trained. Port needs to create some clear regulation on safe areas in case of an ammonia leak (Mar: something that the port needs to determine. Even if there is some vessel doing some) FSTBD especially for coal where you have a lot of dust in combination with the loading of the cargo, and if you have a dust in combination with a risk of fire, it makes the condition worst – there must be an arrangement that prevents dust from spreading While you connect the hoses in the vapour returns you cannot risk having contaminated hoses (that is another risk of SIMOPS) Certain cargo operations (e.g., coal (un)loading) should be considered as impossible to take place/avoided due to the excessive risk (e.g., coal (un)loading)
						1.1.2 Ammonia spill in the sea.	Environmental		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
1.2	Fire/Explosion	Loss of containment	Loading / Unloading of cargo		1.2.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.2.1. Ammonia release, toxic exposure	Injury		
1.3	Ammonia Release	Loss of containment	Loading stores / provisions	Loading stores: Truck, forklift, crane, hoist, elevator	1.3.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.3.1. Human injury.	Injury		When bunkering there is no loading of provisions In case the toxic cloud moves towards the cranes, the motors of the cranes can ignite the cloud. Safety zone should be defined based on dispersion analysis and wind direction that will determine which part of the ship can safely operate and which not – that way safety zones can be determined
1.4	Ammonia Release	Loss of containment	Loading of hazardous substances (paints and solvents, cleaning agents, lubricants / oils, compressed gas cylinders, etc.)	Loading hazardous substances: Truck, forklift, crane, hoist, elevator	1.4.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.4.1. Human injury.	Injury		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
1.5	Fire/Explosion	Loss of containment	Loading of hazardous substances (paints and solvents, cleaning agents, lubricants / oils, compressed gas cylinders, etc.)	Loading hazardous substances: Truck, forklift, crane, hoist, elevator	1.5.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.5.1. Ammonia release, reaction with hazardous substances, flammable / explosive atmosphere, potential for fire/explosion	Injury		
1.6	Ammonia Release	Loss of containment	Embarkation / Disembarkation of personnel	Embarkation / Disembarkation: Portable metal detector	1.6.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.6.1. Human injury.	Injury		Have controlled access from the embarkation ladders all the way to the accommodation (special attention should be given on the procedures relevant to embarking/disembarking personnel) Bunkering should be done in the opposite side from the embarkation side/ladder – Maybe the rec. should be to always use the stern ladder for (dis)embarkation. Written in the company policy to avoid work or visit to the deck when ammonia is bunkered – to be scheduled outside bunkering operations.
1.7	Ammonia Release	Loss of containment	Provision of services by port personnel (waste collection, fresh water connection, sewage/sludge discharge, etc.)	Provision of services: Trucks, forklifts, cranes, portable tanks, garbage skips, hoses, manifolds, etc.	1.7.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.7.1. Human injury.	Injury		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
1.8	Ammonia Release	Loss of containment	Ballast / De-Ballast	Ballast / De-ballast: Pumps, valves	1.8.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.8.1. Human injury	Injury		
1.9	Ammonia Release	Loss of containment	MGO fuel bunkering	MGO bunkering: transfer pumps, bunkering manifold and pipelines, tanks, ventilation and overflow lines, communication system	1.9.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.9.1. Human injury	Injury		Simultaneous MGO and NH3 bunkering should be avoided to limit the risk of spreading MGO which is highly flammable and then heat ammonia facilities – this should be prohibited because there are many reasons why this should be avoided -Note to double check what is happening to LNG (Rene will try to find something and share it with us)
1.11	Ammonia Release	Loss of containment	Ship activity / operation (repair work / maintenance incl. hot work, work at height, cargo hold cleaning, deck cleaning, diving activities, etc.) or drill (e.g. abandon ship/ lifeboat drill, security drill), flag/class/vetting audit/inspection		1.11.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.11.1. Human injury	Injury		As a rule, you should avoid having too many things simultaneously. It takes quite a lot of manpower to lower a lifeboat. However, if you need to do small things (e.g., paint), we shouldn't overcomplicate this work with many crew members on deck. Plan maintenance should be done according to best practices. You should do so as soon as you schedule outside of bunkering hours. Nevertheless, a proper risk assessment should be done. A recommendation could be to perform a risk assessment before engaging in such work.

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
1.12	Fire/Explosion	Loss of containment	Ship activity / operation (repair work / maintenance incl. hot work, work at height, cargo hold cleaning, deck cleaning, diving activities, etc.) or drill (e.g. abandon ship/ lifeboat drill, security drill), flag/class/vetting audit/inspection		1.12.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.12.1. Ammonia release, flammable / explosive atmosphere, potential for fire/explosion	Injury		
1.13	Ammonia Release	Loss of containment	Man overboard	Man overboard: Davit/Crane, Rescue boat, lighting/searchlights, public address system	1.13.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.13.1. Human injury	Injury		

2. Bunkering in Port (from Truck)

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
2.1	Ammonia Release	Loss of containment	Loading / Unloading cargo	Cargo operations: cargo cranes / grabs or conveyor systems, ballast water system, cargo hatch cover and coamings opening/closing systems, lighting, communication systems. Ammonia bunkering: Bunkering lines, fuel transfer pumps truck), fuel storage tanks, tank connection spaces, reliquefaction system, ARMS, GCU, ammonia leak detection system, ventilation system, purging system	2.1.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	2.1.1. Ammonia release, toxicity, human injury.	Injury		
						1.1.2 Ammonia spill in the sea.	Environmental		
2.2	Fire/Explosion	Loss of containment	Loading / Unloading of cargo		1.2.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.2.1. Ammonia release, reaction with cargo, flammable / explosive atmosphere, potential for fire/explosion	Injury		
2.3	Ammonia Release	Loss of containment	Loading stores / provisions	Loading stores: Truck, forklift, crane, hoist, elevator	1.3.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.3.1. Human injury.	Injury		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
2.4	Ammonia Release	Loss of containment	Loading of hazardous substances (paints and solvents, cleaning agents, lubricants / oils, compressed gas cylinders, etc.)	Loading hazardous substances: Truck, forklift, crane, hoist, elevator	1.4.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.4.1. Human injury.	Injury		General Rec. Consider the increase the amount of bunker tanks onboard the ammonia-power vessels – this will decrease the number of bunkering operations, increase the endurance, and lower the risk. Every single bunkering operation will need to be as efficient as possible, the more bunkering operations you make, the greater the risk
2.5	Fire/Explosion	Loss of containment	Loading of hazardous substances (paints and solvents, cleaning agents, lubricants / oils, compressed gas cylinders, etc.)	Loading hazardous substances: Truck, forklift, crane, hoist, elevator	1.5.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.5.1. Ammonia release, reaction with hazardous substances, flammable / explosive atmosphere, potential for fire/explosion	Injury		
2.6	Ammonia Release	Loss of containment	Embarkation / Disembarkation of personnel	Embarkation / Disembarkation: Portable metal detector	1.6.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.6.1. Human injury.	Injury		(Dis)embarkation must be controlled and limited to the absolutely necessary
2.7	Ammonia Release	Loss of containment	Provision of services by port personnel (waste collection, fresh water connection, sewage/sludge discharge, etc.)	Provision of services: Trucks, forklifts, cranes, portable tanks, garbage skips, hoses, manifolds, etc.	1.7.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.7.1. Human injury.	Injury		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
2.8	Ammonia Release	Loss of containment	Ballast / De-Ballast	Ballast / De-ballast: Pumps, valves	1.8.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.8.1. Human injury (?)	Injury		
2.9	Ammonia Release	Loss of containment	MGO fuel bunkering	MGO bunkering: transfer pumps, bunkering manifold and pipelines, tanks, ventilation and overflow lines, communication system	1.9.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.9.1. Human injury	Injury		
2.10	Fire / Explosion	Loss of containment	MGO fuel bunkering		1.10.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.10.1. Ammonia release, reaction with MGO, flammable / explosive atmosphere, potential for fire/explosion (?)			
2.11	Ammonia Release	Loss of containment	Ship activity / operation (repair work / maintenance incl. hot work, work at height, cargo hold cleaning, deck cleaning, diving activities, etc.) or drill (e.g. abandon ship/ lifeboat drill, security drill), flag/class/vetting audit/inspection		1.11.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.11.1. Human injury	Injury		Rec for port: Do a risk assessment from the port side in order to determine the best course of action (e.g., need for a FiFi tug to be standby, or have a spray system installed in the quay side

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
2.12	Fire/Explosion	Loss of containment	Ship activity / operation (repair work / maintenance incl. hot work, work at height, cargo hold cleaning, deck cleaning, diving activities, etc.) or drill (e.g. abandon ship/ lifeboat drill, security drill), flag/class/vetting audit/inspection		1.12.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.12.1. Ammonia release, flammable / explosive atmosphere, potential for fire/explosion	Injury		
2.13	Ammonia Release	Loss of containment	Man overboard	Man overboard: Davit/Crane, Rescue boat, lighting/searchlights, public address system	1.13.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.13.1. Human injury	Injury		Stop bunkering immediately and engage in SAR operations – This is an emergency situation where human life is at stake

3. Bunkering in Port (from Terminal)

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
3.1	Ammonia Release	Loss of containment	Loading / Unloading cargo	Cargo operations: cargo cranes / grabs or conveyor systems, ballast water system, cargo hatch cover and coamings opening/closing systems, lighting, communication systems. Ammonia bunkering: Bunkering lines, fuel transfer pumps (terminal), fuel storage tanks, tank connection spaces, reliquefaction system, ARMS, GCU, ammonia leak detection system, ventilation system, purging system	1.1.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.1.1. Ammonia release, toxicity, human injury.	Injury		
						1.1.2 Ammonia spill in the sea.	Environmental		
3.2	Fire/Explosion	Loss of containment	Loading / Unloading of cargo		1.2.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.2.1. Ammonia release, reaction with cargo, flammable / explosive atmosphere, potential for fire/explosion	Injury		
3.3	Ammonia Release	Loss of containment	Loading stores / provisions	Loading stores: Truck, forklift, crane, hoist, elevator	1.3.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.3.1. Human injury.	Injury		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
3.4	Ammonia Release	Loss of containment	Loading of hazardous substances (paints and solvents, cleaning agents, lubricants / oils, compressed gas cylinders, etc.)	Loading hazardous substances: Truck, forklift, crane, hoist, elevator	1.4.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.4.1. Human injury.	Injury		
3.5	Fire/Explosion	Loss of containment	Loading of hazardous substances (paints and solvents, cleaning agents, lubricants / oils, compressed gas cylinders, etc.)	Loading hazardous substances: Truck, forklift, crane, hoist, elevator	1.2.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.2.1. Ammonia release, reaction with hazardous substance, flammable / explosive atmosphere, potential for fire/explosion	Injury		
3.6	Ammonia Release	Loss of containment	Embarkation / Disembarkation of personnel (pilot, crew, visitors)	Embarkation / Disembarkation: Portable metal detector	1.6.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.6.1. Human injury.	Injury		
3.7	Ammonia Release	Loss of containment	Provision of services by port personnel (waste collection, fresh water connection, sewage/sludge discharge, etc.)	Provision of services: Trucks, forklifts, cranes, portable tanks, garbage skips, hoses, manifolds, etc.	1.7.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.7.1. Human injury.	Injury		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
3.8	Ammonia Release	Loss of containment	Ballast / De-Ballast	Ballast / De-ballast: Pumps, valves	1.8.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.8.1. Human injury	Injury		
3.9	Ammonia Release	Loss of containment	MGO fuel bunkering	MGO bunkering: transfer pumps, bunkering manifold and pipelines, tanks, ventilation and overflow lines, communication system	1.9.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.9.1. Human injury	Injury		
3.10	Fire / Explosion	Loss of containment	MGO fuel bunkering		1.10.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.10.1. Ammonia release, reaction with MGO, flammable / explosive atmosphere, potential for fire/explosion (?)			
3.11	Ammonia Release	Loss of containment	Ship activity / operation (repair work / maintenance incl. hot work, work at height, cargo hold cleaning, deck cleaning, diving activities, etc.) or drill (e.g. abandon ship/ lifeboat drill, security drill), flag/class/vetting audit/inspection		1.11.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.11.1. Human injury	Injury		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
3.12	Fire/Explosion	Loss of containment	Ship activity / operation (repair work / maintenance incl. hot work, work at height, cargo hold cleaning, deck cleaning, diving activities, etc.) or drill (e.g. abandon ship/ lifeboat drill, security drill), flag/class/vetting audit/inspection		1.12.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.12.1. Ammonia release, flammable / explosive atmosphere, potential for fire/explosion	Injury		
3.13	Ammonia Release	Loss of containment	Man overboard	Man overboard: Davit/Crane, Rescue boat, lighting/searchlights, public address system	1.13.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.13.1. Human injury	Injury		

4. Bunkering at Anchor (from Bunkering Vessel/barge)

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
4.1	Ammonia Release	Loss of containment	Tugboat operations	Tugboat	1.1.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.1.1. Ammonia release, toxicity, human injury.	Injury		
						1.1.2 Ammonia spill in the sea.	Environmental		
4.2	Fire/Explosion	Loss of containment	Tugboat operations		1.2.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.2.1. Ammonia release, reaction with tugboat operations, flammable / explosive atmosphere, potential for fire/explosion	Injury		
4.3	Ammonia Release	Loss of containment	Loading stores / provisions	Loading stores: Barge/Workboat, crane, hoist, elevator	1.3.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.3.1. Human injury.	Injury		
4.4	Ammonia Release	Loss of containment	Loading of hazardous substances (paints and solvents, cleaning agents, lubricants / oils, compressed gas cylinders, etc.)	Loading hazardous substances: Barge/Workboat, crane, hoist, elevator	1.4.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.4.1. Human injury.	Injury		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
4.5	Fire/Explosion	Loss of containment	Loading of hazardous substances (paints and solvents, cleaning agents, lubricants / oils, compressed gas cylinders, etc.)		1.5.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.5.1. Ammonia release, flammable / explosive atmosphere, potential for fire/explosion	Injury		
4.6	Ammonia Release	Loss of containment	Embarkation / Disembarkation of personnel	Embarkation / Disembarkation: Barge/Workboat, Portable metal detector	1.6.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.6.1. Human injury.	Injury		
4.7	Ammonia Release	Loss of containment	Provision of services (waste collection, sewage/sludge discharge, etc.)	Provision of services: Barge/Workboat, hoses, manifolds, etc.	1.7.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.7.1. Human injury.	Injury		
4.8	Ammonia Release	Loss of containment	Ballast / De-Ballast	Ballast / De-ballast: Pumps, valves	1.8.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.8.1. Human injury	Injury		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
4.9	Ammonia Release	Loss of containment	MGO fuel bunkering	MGO bunkering: transfer pumps, bunkering manifold and pipelines, tanks, ventilation and overflow lines, communication system	1.9.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.9.1. Human injury	Injury		
4.10	Fire / Explosion	Loss of containment	MGO fuel bunkering		1.10.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.10.1. Ammonia release, reaction with MGO, flammable / explosive atmosphere, potential for fire/explosion (?)			
4.11	Ammonia Release	Loss of containment	Ship activity / operation (repair work / maintenance incl. hot work, work at height, cargo hold cleaning, deck cleaning, diving activities, etc.) or drill (e.g. abandon ship/ lifeboat drill, security drill), flag/class/vetting audit/inspection		1.11.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.11.1. Human injury	Injury		
4.12	Fire/Explosion	Loss of containment	Ship activity / operation (repair work / maintenance incl. hot work, work at height, cargo hold cleaning, deck cleaning, diving activities, etc.) or drill (e.g. abandon ship/ lifeboat drill, security drill), flag/class/vetting audit/inspection		1.12.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.12.1. Ammonia release, flammable / explosive atmosphere, potential for fire/explosion	Injury		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
4.13	Ammonia Release	Loss of containment	Man overboard	Man overboard: Davit/Crane, Rescue boat, lighting/searchlights, public address system	1.13.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.13.1. Human injury	Injury		

5. Bunkering when underway (from bunkering vessel)

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
5.1	Ammonia Release	Loss of containment	Vessel manoeuvring	Vessel manoeuvring: Main engine(s), generators, steering gear, thruster(s), navigation equipment, communication systems, control/ monitoring systems, etc.	1.1.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.1.1. Ammonia release, toxicity, human injury.	Injury		
						1.1.2 Ammonia spill in the sea.	Environmental		
5.2	Ammonia Release	Loss of containment	Tugboat operations		1.1.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.1.1. Ammonia release, toxicity, human injury.	Injury		
5.3	Fire/Explosion	Loss of containment	Tugboat operations		1.2.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.2.1. Ammonia release, reaction with tugboat operations, flammable / explosive atmosphere, potential for fire/explosion	Injury		
~~5.3~~	~~Ammonia Release~~	~~Loss of containment~~	~~Loading stores / provisions~~	~~Loading stores:~~ ~~Barge/Workboat, crane, hoist, elevator~~	~~1.3.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.~~	~~1.3.1. Human injury.~~	~~Injury~~		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
5.8	Ammonia Release	Loss of containment	Ballast / De-Ballast	Ballast / De-ballast: Pumps, valves	1.8.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.8.1. Human injury	Injury		
5.9	Ammonia Release	Loss of containment	MGO fuel bunkering	MGO bunkering: transfer pumps, bunkering manifold and pipelines, tanks, ventilation and overflow lines, communication system	1.9.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.9.1. Human injury	Injury		
5.10	Fire / Explosion	Loss of containment	MGO fuel bunkering		1.10.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.10.1. Ammonia release, reaction with MGO, flammable / explosive atmosphere, potential for fire/explosion (?)			
5.11	Ammonia Release	Loss of containment	Ship activity / operation (repair work / maintenance incl. hot work, work at height, cargo hold cleaning, deck cleaning, diving activities, etc.) or drill (e.g. abandon ship/ lifeboat drill, security drill), flag/class/vetting audit/inspection		1.11.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.11.1. Human injury	Injury		

Item	Hazard/Top Event	Initiating Event	SIMOP	Active Equipment	Cause	Consequences & Loss Events Scenario	Matrix	Existing IPLs (Safeguards)	Recommended IPLs (Action Items)
5.12	Fire/Explosion	Loss of containment	Ship activity / operation (repair work / maintenance incl. hot work, work at height, cargo hold cleaning, deck cleaning, diving activities, etc.) or drill (e.g. abandon ship/ lifeboat drill, security drill), flag/class/vetting audit/inspection		1.12.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.12.1. Ammonia release, flammable / explosive atmosphere, potential for fire/explosion	Injury		
5.13	Ammonia Release	Loss of containment	Man overboard	Man overboard: Davit/Crane, Rescue boat, lighting/searchlights, public address system	1.13.1. Ammonia leakage due to operator error/mistake, material defect, equipment (hose, QCDC or ERC/BAC, pipe, valve, etc.) failure, equipment damage by e.g. dropped object, excessive movement/vibration, etc.	1.13.1. Human injury	Injury		

Appendix D HAZID Workshop Attendance Sheets

The multi-disciplined HAZID team from ABS, Fundación FV, EMSA, and NTUA attended the workshop (virtually). NTUA facilitated the workshop, which was scribed by ABS. Table 17 below presents the HAZID team.

Table 17: 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	TGE	Engineer
17	TGE	Engineer
18	MARIC	Ship Type Expert
19	MARIC	Senior Engineer in Machinery
20	WINGD	Engineer
21	WINGD	Engineer

S/N	Affiliation	Position
22	Færder Tankers	Manager
23	Cargill	Safety Expert
24	Oldendorff	Naval Architect & Marine Engineer

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