Documentation providing safeguards solutions for the system as identified in the HAZID analysis

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Glossary, abbreviations and acronyms

ABL	Above Base Line
ABS	American Bureau of Shipping (Ship Class Society)
CCTV	Closed-Circuit TV surveillance system
CNG	Compressed Natural Gas
DF	Dual Fuel
ESD	Emergency Shutdown
FSU	Floating Storage Unit
HAZID	Hazard Identification
OCIMF	Oil Companies International Marine Forum
W/H	Wheelhouse

1. Introduction

1.1 Introduction

As part of its HORIZON 2020 initiative European Commission formed a consortium to develop a CNG transportation vessel for gas delivery on medium-short leg routes where offshore pipelines or LNG Ships are un-economic or impracticable.

CNG ship will be fitted with pressure cylinders of composite construction of the CNG transportations. The total quantity of the cylinder arranged on board will ensure the capacity (NG @ 300 bar, 20°C) of abt. 15 x 10^6 Nm^3. The Ship is designed to carry natural gas (min. methane number 70) in the compressed gaseous form @ 300 bar and 20° C temperature.

The ship will receive the natural gas previously dehydrated and desulfurized by the production facility or CNG FSU. No provision on board the Ship is provided for preliminary treatments of the natural gas. The production facility or CNG FSU will supply the gas to the ship at abt. 240 bar. The ship is fitted with cargo compressors and relevant systems as necessary to rise the pressure from 240 to 300 bar inside the cylinders to increase the cargo carrying capacity.

Typical ship's machinery, systems and components designed, constructed, supplied and installed to the manufacturer and/or Builder standard in compliance with the requirements of the ABS CNG guide and other regulatory bodies, as applicable. The ship power generation will be performed by four (4) dual fuel engines type Wartsila 8V31DF (4240 kW at 720 RPM each).

To ensure the hazards associated with the operation of vessel is adequately identified and mitigated, a Hazard Identification (HAZID) workshop was conducted from 27th February to 28th February 2019. This document provides the results of the study.

This study was be performed in accordance with the requirements set forth in ABS Guide for Vessels Intended to Carry Compressed Natural Gases in Bulk/Section 2.

1.2 Objectives

The objective of the assessment was to:

- Identify hazards associated with the design and operations of the CNG transportation vessel operation.
- Develop hazard scenarios and identify potential causes, assess the related consequences, and identify the existing protection, detection, and indicating mechanisms.
- Suggesting opportunities of alternative options towards an inherently safer design or identify risk mitigation measures to reduce the estimated risk.

2. Design overview

The Ship is designed to carry natural gas (min. methane number 70) in the compressed gaseous form @ 300 bar and 20° C temperature. The Ship will receive the natural gas previously dehydrated and desulfurized by the production facility or CNG FSU. No provision is provided on board the Ship for systems to perform said preliminary treatments of the natural gas.

Basically, it was assumed that the production facility or CNG FSU will supply the gas to the Ship at abt. 240 bar. The Ship is fitted with cargo compressors and relevant systems as necessary to rise the pressure from 240 to 300 bar inside the cylinders to increase the cargo carrying capacity.

Compressors will also be used during Ship unloading operations as scavenging compressors when the differential pressure between gas in the cargo cylinders and receiving shore net is so low to affect the scheduled discharging time.

The CNG ship is divided as follows:

- **Aft ship**: which includes power generators and propulsive systems
- **Mid ship**: which consist of an eight (8) cargo holds, each one divided in two sections by one longitudinal bulkhead, designed to contain the CNG pressure cylinders foreseen for the cargo containment. Loading and unloading cargo station is located on the Deck at 28.000 ABL according to OCIMF rules. The loading and unloading operations will be carried out with ship berthed or with single mooring. Double bottom and double sides in way of cargo holds is provided. These spaces to be used for ballast water and to form a complete segregation of cargo.
- **Fore ship**: which includes accommodation for 30 people and various technical spaces for ship systems and electrical management.

Following section provides brief overview of CNG containment and associated systems. Detailed overview of all ship system is provided in a ship outline specification (Doc# WP5-D5.1-RV0-833-001-A01).

CNG Cargo containment

In the present configuration and size, the Ship is fitted with the following pressure cylinders of composite construction for the CNG transportation:

Cylinder @ 300 bar	Length (m)	External Dia (m)	Quantity (pcs)
Type A	22.5	3.4	256
Type B	20.5	3.4	12
Type C	18.5	3.4	4

The total quantity of the cylinder arranged on board will ensure the capacity (NG @ 300 bar, 20°C) of abt. 15 x 10^6 Nm^3. Cylinders are of the composite type 3, with internal stainless-steel liner wrapped with resins and carbon fibers. Cargo cylinders, tested, approved, certified and installed on board the Ship according with Chapter 5 Cargo Containment of the ABS Rules for CNG Vessels and under ABS survey.

Each cargo hold contains a set number of cargo tanks (each tank is comprised of four pressure cylinders interconnected via common header). Cargo holds are inerted with nitrogen at a positive 50 mbar pressure.

CNG Piping systems

Cargo tanks are connected to loading/unloading manifold via cargo deck piping. All the cargo deck piping is routed via a segregated pipe tunnel that runs above the cargo holds dome, in a central position. Cargo pipe tunnel is also inerted with nitrogen. All the CNG piping is butt-welded without flange connection to prevent any leakage during operation.

CNG loading and unloading operation

Gas will be taken on board via the loading facilities and transferred via the deck piping to the cargo containment system. Compressors will be used to increase the gas pressure from the site delivery pressure to the storage pressure cylinders. Once loading is complete, all the remote-controlled stop valves between deck piping and cargo containment systems will be closed in order to segregate the cargo tanks from each other. The deck piping will remain pressurized after loading operation.

Unloading follows the reverse of the above operations. All tanks valves will be opened simultaneously to start the unloading. Once the tank pressure drops below or equalized the destination pressure, flow will be diverted via compressors to deliver the remaining gas in CNG tanks. A residual gas inside of vessels at the end of the unloading is expected to be abt. 30 bar.

The process facilities are not yet designed, but a concept P&ID is shown in Figure 2.

Cargo compressors and Cargo Control Room

Cargo compressor (2x centrifugal compressor type) with relevant auxiliary services and cargo heat exchangers is provided above Deck at 27,500 ABL. Compressor room is designated as a gas-dangerous area and built, outfitted and installed in the respect of the relevant rules, including the safety, monitoring and alarm appliances.

Cargo Control Room will be located and arranged as per General Arrangement Plan, outfitted and protected as a gas-safe area. Instrumentation shall be, as far as practicable, of indirect reading system to prevent accidental escape of gas in the atmosphere of the Control Room.

Propulsion System

The ship power generation will be performed by four (4) dual fuel engines type Wartsila 8V31DF (4240 kW at 720 RPM each), installed on Deck at 9 000 ABL.

Four GVU (one for each engine) will be installed in Engine Room for engine gas operation mode.

GVU will be connected to loading/unloading gas cargo manifold. Installation of GVU and associated piping will be in accordance to Chapter 15 Section 1 of ABS Rules for CNG Vessels and ABS Guide for Propulsion Systems for LNG Carriers.

Safety and Supervision System

Emergency Shut-down systems: Two emergency shut-down systems are provided: 1) Ship ESD and 2) Cargo ESD. Ship ESD system will shut down ventilation and fuel systems, while the cargo ESD is dedicated to emergency shutdown of the cargo loading/unloading operations. The cargo ESD system will also interfaced with the loading/unloading terminals ESD systems.

Fire detection system:

Fire Detection Plant, comprising a central panel installed in W/H and a number of addressable detectors and manual call points according to the Rules will be installed. The type of detector will be chosen according to the place of installation. The detectors in hazardous areas will be of certified safe (intrinsically safe) type. A dedicated UPS is provided for fire detection system.

Gas detection system:

Natural gas detection system will be installed. The addressable detectors will be located in cargo area, engine room, cargo compressor room and on the inlets of the ventilation system. The central unit located in W/H will collect all the data from the detectors.

CCTV:

A Closed-Circuit TV surveillance system will be installed. The cameras will cover the cargo manifold zones, cargo compressor room and the engine rooms.

Detail information regarding ESD and gas detection system can be found in ESD system philosophy (doc# WP5-D5.3-RV0-833-7-003-A01) and Gas Detection system philosophy (doc# WP5-D5.3-RV0-833-7-004-A01), respectively.

Figure 2-1 and 2-2 provides the general overview of the CNG system.

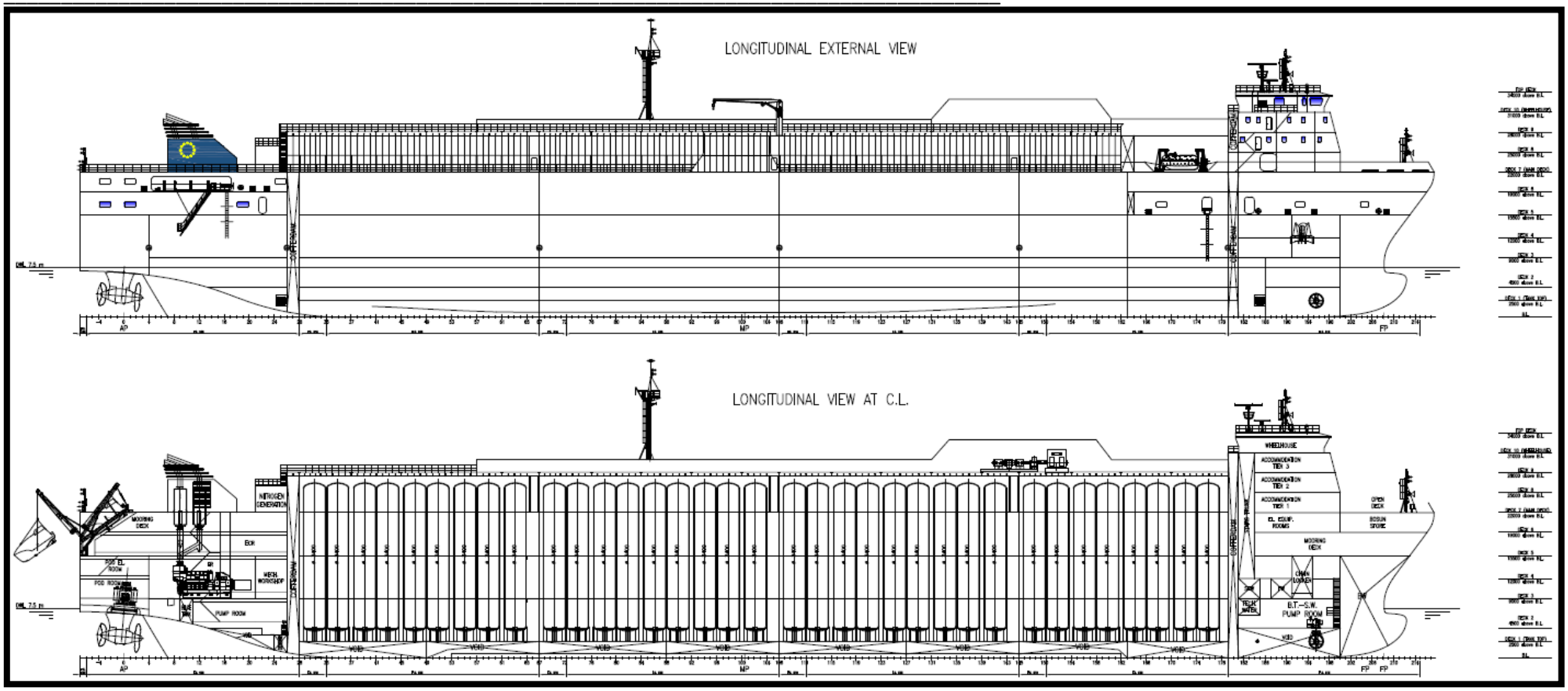


Figure 2-1 General Arrangement – Longitudinal view

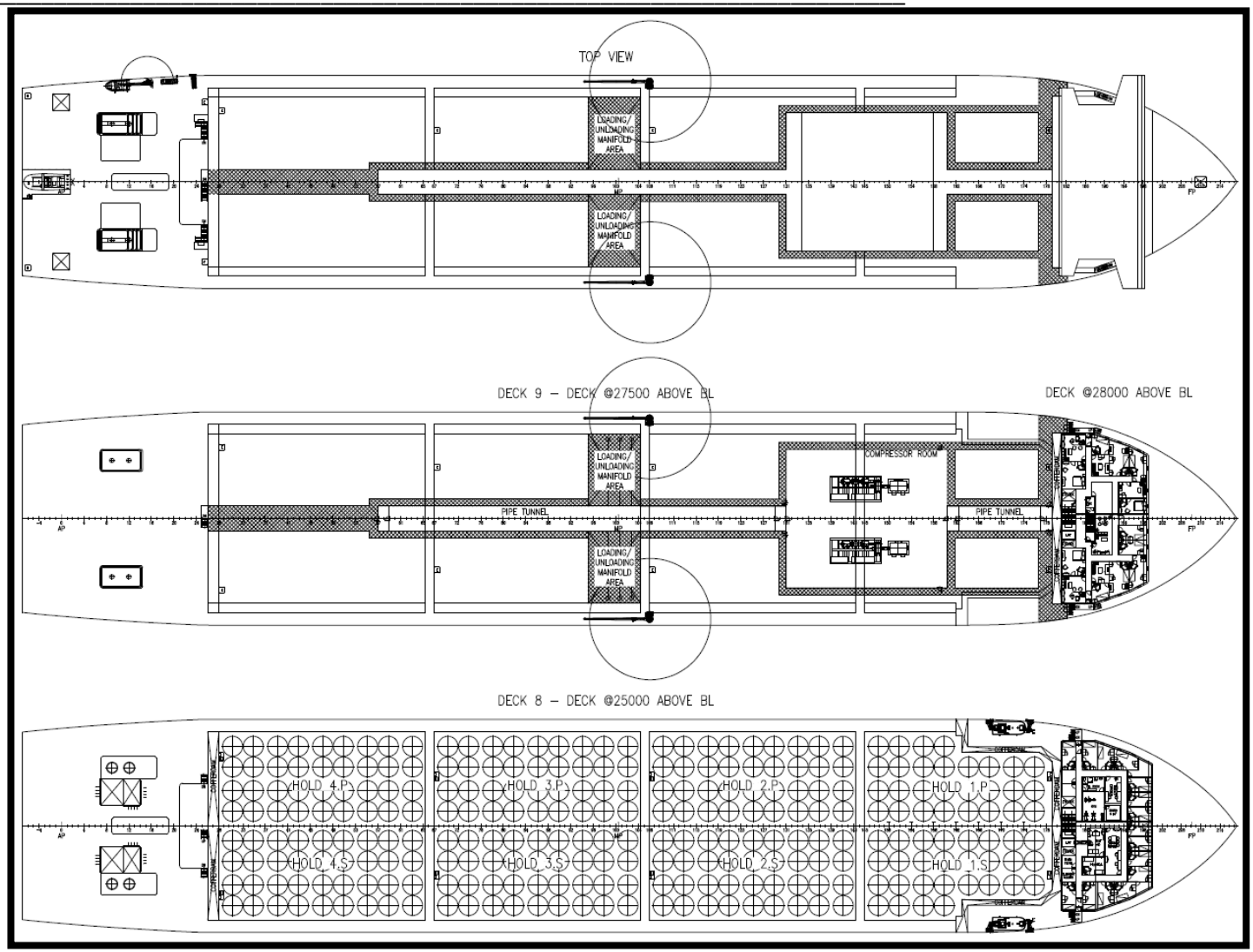


Figure 2-2 General Arrangement – Top view

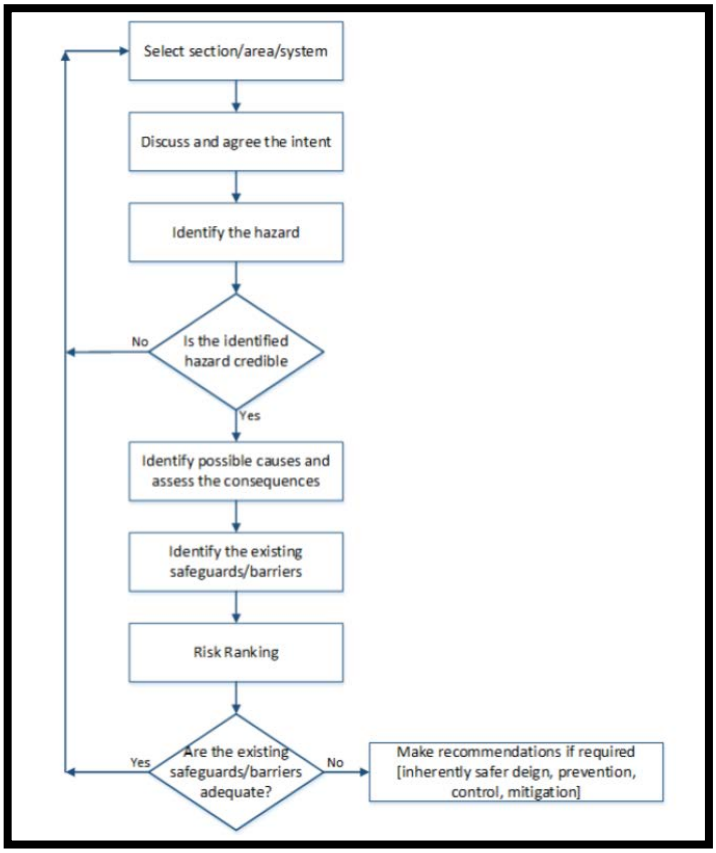
3. Methodology

The Hazard Identification (HAZID) study is a systematic review of the possible causes and consequences of hazardous events. It can be applied to all or part of the vessel or it can be applied to analyse the operational procedures. It can be used for identification and assessment of potential hazards and their causes and consequences

The basic HAZID study involves following tasks:

- The assembly of an appropriate team of experienced personnel, including representatives of all disciplines involved in the area being reviewed and (as needed) interfaces with adjacent systems.
- Completion of the HAZID workshop, the methodology of which is detailed in Figure 2-1

Figure 3-1: The HAZID Study Process



During the HAZID workshop, the following activities will be performed:

- Application of the relevant guidewords to identify hazards and other HSE concerns.
- Use the list of HAZID guidewords provided and if required identify any further guidewords (or Issues of Concern) that require coverage or consideration;
- Brainstorm to identify all potential causes that could result in a “hazard scenario” developing related to that guideword/Issue of concern;

- Identify the worst credible consequence associated with realization of the hazard scenario; for this study primary focus will be on scenarios that can lead to safety and environmental consequences.
- Identify the safeguards and controls in place to help to prevent the scenario from starting and those that mitigate the ultimate consequences should it occur;
- Perform a risk ranking for each of the identified scenarios;
- Use the risk ranking to help to assess whether the current controls and safeguards are considered adequate, if not then look to identify additional safeguards/controls to help reduce the risk (or identify areas where further review or analysis is required to better understand the risk and potential mitigating measures) and record these as Actions;
- Repeat for all review areas until complete scope of the HAZID has been studied.
- Risk ranking was performed as per the risk matrix provided in Table 3-1
- HAZID workshop was recorded in the worksheet template as provided in Table 3-2.

Table 3-1 Risk Matrix

		Likelihood of Occurrence			
		Low	Low to Med	Med to High	High
Consequences	Minor injuries/ Slight Damages	1	2	3	4
	Major injuries/ Localized Damages	2	4	6	8
	Single fatality/ Major Damage	3	6	9	12
	Multiple fatalities/ Extensive Damage	4	8	12	16

RISK RATING

Negligible or Low
Low to Medium
Medium to high
High

Table 3-2 Worksheet Template

Node:								
Hazards	**Causes**	**Consequences**	**Effective Safeguards**	**CAT**	**S**	**L**	**RR**	**Recommendations**

4. Scope

The physical scope of the HAZID included the design and operations of the vessel, and loading/unloading operations. To perform the thorough review of the design and its associated effect on the vessel operation, the design was divided in to nodes as following:

1. Cargo containment system (cylinders)
2. Cargo loading and unloading header and fuel gas piping arrangement
3. Compressor room and fuel gas system
4. Gas combustion unit
5. Nitrogen system
6. Main engine and engine room
7. Ship interface and marine systems

Following operating modes/scenario will be considered for each of the above nodes, where applicable:

- Inerting
- Loading
- Depressurization
- Cool down
- Filling
- Normal operation
- Startup/shutdown
- Dry dock
- Emergency shutdown
- Extended shutdown

Guide words were selected to stimulate discussion within a node and identify hazard scenarios that articulate how the hazard is realized and the potential consequence that might arise. Following list provides the list of general guidewords used during the workshop, but not limited to:

Table 4-1 Guidewords

CNG Carriers - HAZARD IDENTIFICATION - Categories		
NATURAL DISASTERS	**EQUIPMENT/INSTRUMENTATION MALFUNCTION**	**LOSS OF CONTAINMENT/FIRE/EXPLOSION**
High winds - Typhoons	Scavenging compressor failure	Leak from CNG pressure cylinders
Squalls, swells	Safety systems failure	Leak from piping/flange
Hurricane	Communication failure	Leak from process area
Tornado	Common cause failures	Leak from loading line
Extreme wave	**PROCESS UPSETS**	Leak from turret
Extreme current	Pressure deviations	Leak from export system
Tsunami	Temperature deviations	Leak from import system
Extreme heat	Flow deviations	Leak from fuel gas

High humidity	Level deviations	Leak into ballast tank
Lightning	Corrosion/erosion	Drains
Earthquake	Startup/shutdown	Bunker oil fire
EXTERNAL EFFECTS	Simultaneous operations	Engine room fire
Dropped object	**COMPOSITION PROBLEMS**	Generator room fire
Marine collision	Moisture	Accommodation fire
Grounding	H2S concentrations	Explosive hazard
Helicopter impact	CO2	
Reduced visibility	**UTILITY FAILURES**	**ENVIRONMENTAL IMPACT**
Sabotage/Terrorism	Blackout	Flaring/venting during normal operations
Mooring line failure	Cooling Water	Flaring/venting during emergency
Structural failure	Instrument air	CNG leak
Loading line failure	Inert gas/nitrogen	Waste water treatment
CNG Carrier listing	Fire water	Ballast water disposal
Loss of station keeping	HVAC System	Oily water treatment/disposal
Loss of buoyancy	Ballast system	**CREW TRANSPORTATION**
Fatigue/cracking	Thrusters	Crew boat accident
HUMAN FACTORS	**EMERGENCY OPERATIONS**	Accident during transfer of personnel
Occupational accidents	Escape/egress/rescue	Helicopter accident
Improper/inadequate training	Disconnect during loading	**INSPECTION/MAINTENANCE ISSUES**
Weather monitoring	Disconnect during unloading	Confined spaces
Shipping traffic monitoring	Turning bow against intruder	Machinery instrument accessibility
Material handling	Release from vent	Reduced visibility
Man overboard		
Dynamic situations hazards		Training of inhabitants surrounding the plants

5. Assumptions

In order for a successful HAZID to be conducted there are some key assumptions that made during the workshop. Those assumptions are noted below:

- Gas detection will be provided in areas where gas may accumulate
- Ventilation fans that may handle gas vapors are to be of the non-sparking type.
- No gas containing piping will be routed through an accommodation or service spaces.
- Vessel is designed and constructed according to all applicable standards and regulations. HAZID scope does not include the review of codes and standard against design in consideration.
- Onshore loading systems and equipment were not part of the HAZID scope

6. Lists of References

The following drawings and documents were made available during the workshop. Below requested document will be made available upon request.

- WP5-D5.1-RV0-833-0-001-A02 Ship technical specification – updated;
- WP5-D5.1-RV0-833-0-002-A04 General arrangement – updated;
- WP5-D5.1-RV0-833-0-003-A02 Capacity plan;
- WP5-D5.1-RV0-833-0-004-A04 Lines and Body plan;
- WP5-D5.1-RV0-833-0-005-A01 Freeboard calculations;
- WP5-D5.1-RV0-833-0-006-A01 Equipment number calculations;
- WP5-D5.1-RV0-833-0-007-A01 Intact stability calculations;
- WP5-D5.1-RV0-833-0-008-A01 Damage stability calculations;
- WP5-D5.1-RV0-833-0-009-A01 Lightship and CoG;
- WP5-D5.1-RV0-833-0-010-A01 Preliminary resistance and propulsion calculations;
- WP5-D5.1-RV0-833-0-011-A01 International tonnage calculations;
- WP5-D5.1-RV0-833-0-012-A01 Escape route plan;
- WP5-D5.1-RV0-833-0-013-A01 Hazardous areas and gas dangerous spaces plan:
- WP5-D5.2-RV0-833-0-017-A01 Model tests input data;
- WP5-D5.1-RV0-833-2-001-A01 Bilge keels schematic layout;
- WP5-D5.1-RV0-833-1-001-A01 Midship section;
- WP5-D5.3-RV0-833-3-004-A01 Lifesaving appliances plan;
- WP5-D5.3-RV0-833-5-001-A01 Structural fire protection plan – insulation plans;
- WP5-D5.3-RV0-833-5-002-A01 Thermal insulation scheme of cargo area;
- WP5-D5.3-RV0-833-5-003-A01 HVAC Schematic layout;
- WP5-D5.3-RV0-833-5-004-A01 AHU Systems pressure drop calculation;
- WP5-D5.3-RV0-833-5-005-A01 HVAC System fwd frame 179 P&ID;
- WP5-D5.3-RV0-833-5-006-A01 HVAC System fwd frame 179 Report;
- WP5-D5.3-RV0-833-5-007-A01 HVAC System between frame 28 and frame 179 P&ID;
- WP5-D5.3-RV0-833-5-008-A01 HVAC System between frame 28 and frame 179 Report;
- WP5-D5.3-RV0-833-5-009-A01 HVAC System aft frame 28 P&ID;
- WP5-D5.3-RV0-833-5-010-A01 HVAC System aft frame 28 Report;
- WP5-D5.3-RV0-833-6-001-A01 Active fire protection systems and deck washing - philosophy;

- WP5-D5.1-RV0-833-7-001-A01 Preliminary electric balance;
- WP5-D5.1-RV0-833-7-002-A01 Electric distribution one-line diagram;
- WP5-D5.3-RV0-833-7-010-A01 Emergency shutdown system – philosophy;
- WP5-D5.3-RV0-833-7-013-A01 Gas detection system – philosophy.

7. Workshop Participation details

The HAZID workshop was conducted from 27th February through 28th February 2019 in Trieste Italy at ESTECO SpA premises.

HAZID workshop team included participant from various discipline. This team included personnel from Navalprogetti S.r.l., ESTECO, Cenergy, and ABS, who were familiar with the intended design, operation, and maintenance of the system. In addition, the team included personnel from ABS AS, an engineering firm that specializes in process safety and reliability analysis. Per our agreement, ABS AS provided the risk engineer to facilitate the meetings, document the HAZID analysis, and provide knowledge of the hazard evaluation techniques used. The team members who performed this HAZID review are listed in Table 5-1

Table 5-1 List of Attendees

Name	Title	Company
Loris Cok	President	Navalprogetti Srl
Spartaco Angelini	Project Manager	Navalprogetti Srl
Oscar Perosa	Naval Architect	Navalprogetti Srl
Silvia Dorigo	Naval Architect	Navalprogetti Srl
Stavros Niotis	Pincipal Engineer	ABS Global Gas Solutions
Darshan Lakhani	Facilitator/Engineering Manager, Risk and Integrity	ABS Advanced Solution
Alberto Clarich	Head of Engineering Services and Support	Esteco SpA
Rosario Russo	Engineering Services & Support	Esteco SpA
Luca Battaglia	Engineering Services & Support	Esteco SpA
Giovanni Fratti	CEO	CNGV
Michele Capobianco	Managing Director	Cenergy
Tancredi Chinese	Project Engineer	Cenergy
Rodolfo Taccani	Partner	Cenergy

8. Results

Based on the review and insight gained from performing this HAZID analysis, the HAZID team made 27 recommendations as listed in Table 8-1. The table also includes reference(s) to the HAZID worksheet provided in Appendix A, where the recommendation was developed, and where a complete description of the scenario can be found. A system shall be established to address the HAZID analysis team's recommendations and ensure that the recommendations are incorporated into the design or otherwise resolved early in the next design phase. This table is the basis for the Hazard Register. It is anticipated that additional hazards may be identified as more details are available during further development of the project phases and accordingly this register should be kept up to date, with items closed out and added, as appropriate.

Table 8-1 List of Recommendations

No.	Recommendations	Place(s) Used
1.	Review ship structural protection against the brittle fracture from low temperature exposure during manifold area leak. Low temperature exposure can lead to long term damage to steel due to brittle fracture. CNG temperature is not expected to be low enough to cause an immediate brittle fracture of structural steel.	Consequences: 2.1.1.1
2.	Consider use of quick connect/disconnect coupling for hose connection. Inability to isolate the flow during emergency or leakage scenario can lead to escalation of event.	Consequences: 2.1.1.1
3.	Define flexible hose management and accordingly evaluate venting arrangements of flexible line during emergency scenario to minimize loss of containment.	Consequences: 2.1.1.1
4.	Review need for relief valve for the loading manifold. During the workshop team raised a concerned that upstream process upsets can lead to overpressure of manifold piping resulting in loss of containment and fire hazard.	Consequences: 2.2.1.1
5.	Review class requirement for helicopter operations for emergency evacuation of personnel and provide adequate safeguards to avoid any helicopter accident during evacuation.	Consequences: 2.17.1.1
6.	Review hose connection design to ensure ship movement stresses are accounted in the connection design to avoid damage to hose connection during ship movement. Hose connection damage can lead to loss of containment and fire hazard during loading/unloading	Consequences: 2.28.1.1

No.	Recommendations	Place(s) Used
7.	Ensure operating manual considers loading and unloading as a special operation and provides adequate operational safeguards as applicable considering 1) station keeping, 2) fatigue 3) operator training and 4) ship traffic during loading to prevent hose damage. Hose damage can lead to loss of containment and fire hazard during loading/unloading.	Consequences: 2.29.1.1, 2.31.1.1, 2.33.1.1, 2.35.1.1
8.	Perform study to analyse low temperature exposure to hold area and pressure profile within cargo hold during cylinder leakage scenario and provide adequate safeguards accordingly.	Consequences: 1.1.1.3
9.	Review gas combustion unit operating philosophy/capacity in regard to 1) release via cylinder rupture disk 2) release via cargo hold rupture disk 3) control venting from leaking cylinders via GCU gas inlet header to ensure GCU is sized adequately to handle anticipated flow rate.	Consequences: 1.1.1.1
10.	Confirm use of rupture disk in lieu of relief valves and routing to GCU instead to vent mast in terms of Class requirement.	Consequences: 1.1.1.1
11.	Review cylinder design against external conditions (e.g. extreme weather conditions) in accordance with class requirements and provide adequate safeguards as applicable.	Consequences: 1.18.1.1
12.	Review structural design in terms of class grounding requirement and provide adequate safeguards as applicable.	Consequences: 1.26.1.1
13.	Define survey plan requirements for tanks considering the tank internals/surface and external coating to ensure survey can be performed adequately to identify any fatigue defects occurred during ship operation.	Consequences: 1.30.1.1
14.	Review if gas detection system is required for bilge system. Cargo hold are connected to pump room via bilge system and team raised a concerned that during gas leak in cargo hold there is a potential for gas migration to pump room leading to fire hazard in pump room.	Consequences: 1.45.1.1
15.	Review tank inlet valve arrangement to ensure adequate arrangement is provide for isolation of individual cargo tank during emergency scenario.	Consequences: 2.1.1.1
16.	Review if valve (#32) across remotely controlled valve can be removed. Removal of valve will improve operability of CNG loading and unloading operation.	Consequences: 2.1.1.1

No.	Recommendations	Place(s) Used
17.	Review rupture disc location to ensure it is in compliance with class requirement. Currently rupture disc is routed to gas combustion unit which may pose a restriction in rupture disc relief path and lead to ineffective pressure relief during overpressure scenario.	Consequences: 2.1.1.1
18.	Review if remotely controlled valve (VM2) can be used as an emergency shutdown valve. Concerned was raised during the workshop that remotely controlled valve is currently planned to regulate the flow to cargo tank during loading and unloading operation and may not be able to meet requirements for emergency shutdown valve.	Consequences: 2.1.1.1
19.	Review if manual valve (#V36) at cargo tank inlet can be moved in to pipe tunnel. Currently subject valve is located in the cargo hold area and will required entrance into cargo hold area for valve maintenance or to operate the valve. as per the class requirement this valve is supposed to as close as possible to tank. Team wanted to confirm if the design will be able to meet class requirements with valve being moved to pipe tunnel for improved operability efficiency.	Consequences: 2.1.1.1
20.	Review need to perform and fire explosion analysis to understand effect on the adjacent area in case of a gas leak in compressor room and provide adequate safeguards as applicable.	Consequences: 3.1.1.1, 3.14.1.1
21.	Review emergency shutdown philosophy for the ship in regard to IGC and IGF code and update as required.	Consequences: 3.4.1.1, 3.5.1.1
22.	Review compressor inlet separator drain arrangement and ensure it is routed to safe location. If drain valve is left open inadvertently it can lead to gas blow-by resulting in a fire/explosion.	Consequences: 3.6.1.1
23.	Perform gas dispersion analysis to optimized vent mast location and height to ensure gas release from vent mast will not lead to migration of gas to hazardous zone or accommodation area which can result in a fire hazard.	Consequences: 3.17.1.1
24.	Consider providing multiple N2 header such that single failure in the line cannot lead to complete loss of N2 supply to cargo holds. Loss of inert atmosphere in a cargo hold can lead to potential fire hazard if ignition source is present during leak.	Consequences: 5.1.1.1

No.	Recommendations	Place(s) Used
25.	Review nitrogen system arrangement for purging operation to ensure cylinders can be effectively and safely made gas free for maintenance purpose. Currently only one inlet port is shown for CNG cylinders and it will be difficult to inert the cylinder completely if separate outlet port is not provided. Ineffective purging can lead to fire hazard.	Consequences: 5.7.1.1
26.	Consider making life raft area open to avoid any gas pockets during gas release scenario. Gas accumulation in life raft can lead to fire hazard and inaccessibility to life raft during evacuation.	Consequences: 7.1.1.1
27.	Consider increasing cofferdam till wheel house to protect wheel house from fire incident in compressor room. Also, ensure cofferdam height increase till wheel house is in compliance with class requirement for visibility from wheel house.	Consequences: 7.1.1.1

Appendix A – HAZID Worksheets

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
1. Leak from CNG pressure cylinders	1. Mechanical damage; material quality; corrosion; fatigue; vibration; defective welds; process upsets	1. Potential for jet fire within the hold if ignition source present; overpressure of cargo holds; damage to ship structure	1. All cargo holds during normal operation in port and at sea are inserted with nitrogen	AST	3	1	3	9. Review gas combustion unit operating philosophy/capacity in regard to 1) release via cylinder rupture disk 2) release via cargo hold rupture disk 3) control venting from leaking cylinders via GCU gas inlet header to ensure GCU is sized adequately to handle anticipated flow rate.

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			2. Pressure monitoring of cargo tank (group of four cylinders) 3. Ability to isolate individual cargo tank via remotely operated valve 4. Cargo tanks and piping is provided with overpressure protection as applicable 5. Ability to isolate individual cargo tank 6. Cargo hold pressure monitoring 7. Ability to divert gas to gas combustion unit 8. Cargo hold is provided with thief hatch for protection against overpressure	PER	2	1	2	10. Confirm use of rupture disk in lieu of relief valves and routing to GCU instead to vent mast in terms of Class requirement.

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			9. A60 bulkhead provided where applicable and required					
			10. Insulations of cargo holds side walls and ceiling will be fireproof					
			11. Active fire protection					
			12. Gas detectors within the hold area with alarm and emergency shutdown					
			13. Oxygen detectors provided in cargo hold with alarm					
			14. Ability to vent cylinders via vent mast, if required					
			15. Cylinder material is protected against the corrosion					

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			16. Cylinders are of the composite type 3, with internal stainless-steel liner wrapped with resins and carbon fibers.					
			17. Cargo cylinders, tested, approved, certified and installed on board the Ship according with Chapter 5 Cargo Containment of the ABS Rules for CNG Vessels and under ABS survey.					
			18. Hazardous area classification					
			19. QA/QC during fabrication					
		2. Potential for jet fire within the hold, damage to adjacent cylinders;	1. All cargo holds during normal operation in port and at sea are inserted with nitrogen	AST	3	1	3	

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
		overpressure; loss of containment; fire hazard if ignition source present; ship structure damage	2. Pressure monitoring of cargo tank (group of four cylinders)	PER	2	1	2	
			3. Ability to isolate individual cargo tank via remotely operated valve					
			4. Cargo tanks and piping is provided with overpressure protection as applicable					
			5. Ability to isolate individual cargo tank					
			6. Cargo hold pressure monitoring					
			7. Ability to divert gas to gas combustion unit					
			8. Cargo hold is provided with thief hatch for protection against overpressure					

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			9. A60 bulkhead provided where applicable and required					
			10. Insulations of cargo holds side walls and ceiling will be fireproof					
			11. Active fire protection provided as per class requirements					
			12. Gas detectors within the hold area with alarm and emergency shutdown					
			13. Oxygen detectors provided in cargo hold with alarm					
			14. Ability to vent cylinders via vent mast, if required					

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			15. Cylinder material is protected against the corrosion					
			16. Cylinders are of the composite type 3, with internal stainless-steel liner wrapped with resins and carbon fibers.					
			17. Cargo cylinders, tested, approved, certified and installed on board the Ship according with Chapter 5 Cargo Containment of the ABS Rules for CNG Vessels and under ABS survey.					
			18. Hazardous area classification					
			19. QA/QC during fabrication					

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
		3. Low temperature exposure (~ -60 C) of ship structure; asset damage	1. Ceramic tile flooring at bottom 2. Cargo hold sides are covered with cryogenic coating	AST	3	1	3	8. Perform study to analyze low temperature exposure to hold area and pressure profile within cargo hold during cylinder leakage scenario and provide adequate safeguards accordingly.
2. Leak from piping/flange	1. Mechanical damage	1. Potential explosive atmosphere in cargo hold	1. The pipe tunnel, as the cargo holds, will be inserted with nitrogen 2. Pressure monitoring of cargo tank (group of four cylinders) 3. Cargo tanks and piping is provided with overpressure protection as applicable 4. Ability to isolate individual cargo tank	AST	3	1	3	

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			5. Cargo hold pressure monitoring					
			6. Ability to divert gas to gas combustion unit					
			7. Cargo hold is provided with thief hatch for protection against overpressure					
			8. A60 bulkhead provided where applicable					
			9. Fully insulated piping					
			10. Insulations of cargo holds side walls and ceiling will be fireproof					
			11. Active fire protection provided as per class requirements					

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			12. Gas detectors within the hold area with alarm and emergency shutdown					
			13. Oxygen detectors provided in cargo hold with alarm					
			14. Ability to vent cylinders via vent mast, if required					
			15. Hazardous area classification					
			16. All the CNG pipes are butt-welded without flange connections.					
			17. Piping systems common to multiple cargo holds arranged so that release of gas from one hold space shall not leak into other hold spaces.					

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			18. Structure and supports suitably shielded from piping system leakage.					
			19. QA/QC during fabrication					
		2. Potential explosive atmosphere in pipe tunnel	1. Design considered thermal expansion issue that can lead to piping damage	AST	3	1	3	
			2. All cargo hold piping is of butt-welded connection type	PER	2	1	2	
			3. Gas detectors in pipe tunnel					
			4. Oxygen detectors provided as applicable					
			5. Pipe tunnel is provided with burst disk with routing to GCU					

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			6. Design considered thermal expansion issue that can lead to piping damage 7. All the CNG pipes are butt-welded without flange connections. 8. QA/QC during fabrication					
3. Pressure deviations	1. No additional hazards identified							
4. Temperature deviations	1. Use of compressor	1. Increase of the gas temperature leading to high heat dissipation from cylinder into cargo hold (approx. 30 kw/cylinder). No issues of concern identified						

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
5. Flow deviations	1. No additional hazards identified							
6. Level deviations	1. No additional hazards identified							
7. Corrosion/erosion	1. No additional hazards identified							
8. Startup/shutdown	1. Extended shutdown	1. Potential high pressure due to high atmospheric temperature; not expected to lead to any damage to tanks	1. Water curtains available to cool down cylinder temperature 2. Ability to use refrigerator inert gas to lower cargo hold temperature 3. Rupture disk is provided for protection against overpressure	AST	1	1	1	
9. Simultaneous operations	1. No additional hazards identified							

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
10. Moisture	1. Condensation on cylinder surface due to temperature difference between cylinder content and cargo hold temperature	1. No issue of concern identified	1. Cargo hold is provided with drain 2. Dry inert gas					
11. H2S concentrations	1. off spec gas	1. Potential damage to equipment and H2S exposure hazards	1. H2S is not expected in inlet stream	AST	3	1	3	
			2. Gas will be tested before loading	PER	3	1	3	
			3. Ship will not receive gas if H2S is present in the inlet stream					
12. CO_2	1. Not applicable							
13. Drains	1. No additional hazards identified							

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
14. Explosive hazard	1. No additional hazards identified							
15. Flaring/venting during normal operations	1. No additional hazards identified							
16. Flaring/venting during emergency	1. No additional hazards identified							
17. CNG leak	1. No additional hazards identified							
18. High winds - Typhoons	1. extreme weather	1. Cylinder damage	1. Cylinder foundation and supports, fastening devices and piping connections are designed based on worst case weather condition	AST	3	1	3	11. Review cylinder design against external conditions (e.g. extreme weather conditions) in accordance with class requirements and provide adequate safeguards as applicable.

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
19. Confined spaces	1. Confines space entry	1. Asphyxiation hazards	1. Entry into cargo hold area is a controlled activity 2. buddy system 3. Training	PER	3	1	3	
20. Machinery instrument accessibility	1. No issues of concern identified							
21. Reduced visibility	1. Ineffective lighting	1. Operational issues	1. Adequate explosion proof lighting (normal and emergency) is provided for cargo hold area					
22. High humidity	1. No additional hazards identified							
23. Lightning strike	1. No issue of concern identified							
24. Dropped object	1. Lifting activities		1. Cargo hold is covered on top	AST	3	1	3	

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
		1. Dropped object; cylinder damage; asset damage	2. No lifting is performed over the cargo hold area					
25. Marine collision	1. Ship collision	1. potential damage to tank	1. Collision study indicates that cylinder will not be damaged during worst cast collision scenario (10000 tons at 5 knots)	AST	4	1	4	
			2. Voyage planning to avoid any collision risk	PER	4	1	4	
			3. Hull structures designed to avoid penetration to cargo holds					
			4. Radio and navigation aids as per SOLAS requirements					
26. Grounding	1. Ship grounding	1. Potential damage to cylinders	1. Double bottom	AST	4	1	4	12. Review structural design in terms of class grounding requirement and provide adequate

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
								safeguards as applicable.
27. CNG Carrier listing	1. No additional hazards identified							
28. Loss of station keeping	1. No issues of concern identified							
29. Loss of buoyancy	1. Cargo hold flooding	1. In securement of cylinder leading to potential damage; asset damage	1. Cylinder fastening arrangement that prevents cylinder becoming buoyant	AST	3	1	3	
30. Fatigue/cracking	1. Operational cycles	1. Potential cylinder damage	1. Fatigue test will be performed for cylinders 2. Regular maintenance and inspection 3. Cylinder is designed based on expected fatigue loads	AST	3	1	3	13. Define survey plan requirements for tanks considering the tank internals/surface and external coating to ensure survey can be performed adequately to identify any fatigue defects occurred during ship operation.

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
31. Occupational accidents	1. Confines space entry	1. Asphyxiation hazards	1. Entry into cargo hold area is a controlled activity 2. Buddy system 3. Training	PER	4	1	4	
32. Improper/inadequate training	1.	1.	1. Crew will be provided with appropriate training for CNG operations					
33. Shipping traffic monitoring	1. No additional hazards identified							
34. Material handling	1. No issues of concern identified	1.	1. Lifting within cargo hold be a controlled activity					
35. Man overboard	1. No issues of concern identified	1.						
36. Dynamic situations hazards	1. No issues of concern identified	1.						
37. Blackout	1. No issues of concern identified	1.						

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
38. Cooling Water	1. No issues of concern identified	1.						
39. Instrument air	1. No issues of concern identified	1.						
40. Inert gas/nitrogen	1. Loss of N2	1. Loss of inert atmosphere in cargo hold, potential for explosive atmosphere during leak scenario; fire hazard if ignition source present	1. Two N2 generators (2x95%)	AST	3	1	3	
			2. Oxygen sensor in cargo hold with alarm	PER	3	1	3	
41. Fire water	1. No issues of concern identified	1.	1. Active fire water system is provided					
			2. Cargo hold is provided with drains					
42. HVAC System	1. No issues of concern identified	1.						

Node: 1. Cargo containment system (cylinders)

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
43. Escape/egress/rescue	1. Emergency situation	1. Personnel injury if escape routes not available	1. Two means of escape routes provided from each cargo hold	PER	3	1	3	
44. Release from vent	1.	1.	1. cylinders are provided with venting capability					
45. Bilge system	1. Bilge pump room is connected with cargo hold via bilge system	1. Potential ingress of gas in to pump room via bilge system; fire hazard		AST	3	1	3	14. Review if gas detection system is required for bilge system. Cargo hold are connected to pump room via bilge system and team raised a concerned that during gas leak in cargo hold there is a potential for gas migration to pump room leading to fire hazard in pump room.
				PER	3	1	3	

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
1. Leak from piping/flange	1. Mechanical damage, extreme weather, process upsets, dropped object; material quality; corrosion; fatigue; vibration; defective welds	1. Potential leak at manifold; potential fire hazard; structural damage	1. Emergency shutdown valve at loading manifold	AST	3	1	3	1. Review ship structural protection against the brittle fracture from low temperature exposure during manifold area leak. Low temperature exposure can lead to long term damage to steel due to brittle fracture. CNG temperature is not expected to be low enough to cause an immediate brittle fracture of structural steel.
			2. Gas detectors provide in manifold area	PER	3	1	3	2. Consider use of quick connect/disconnect coupling for hose connection. Inability to isolate the flow during emergency or leakage

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
								scenario can lead to escalation of event.
			3. Visual monitoring of manifold and piping area via CCTV					3. Define flexible hose management and accordingly evaluate venting arrangements of flexible line during emergency scenario to minimize loss of containment.
			4. Escape routes					15. Review tank inlet valve arrangement to ensure adequate arrangement is provide for isolation of individual cargo tank during emergency scenario.
			5. Active fire protection					16. Review if valve (#32) across remotely controlled valve can be removed. Removal of

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
								valve will improve operability of CNG loading and unloading operation.
			6. Welded connections, where applicable					17. Review rupture disc location to ensure it is in compliance with class requirement. Currently rupture disc is routed to gas combustion unit which may pose a restriction in rupture disc relief path and lead to ineffective pressure relief during overpressure scenario.
			7. Weather monitoring					18. Review if remotely controlled valve (VM2) can be used as an emergency shutdown valve. Concerned was raised during the

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
								workshop that remotely controlled valve is currently planned to regulate the flow to cargo tank during loading and unloading operation and may not be able to meet requirements for emergency shutdown valve.
			8. Emergency interface protocol will be defined between terminal and ship to isolate flow during emergency situations					19. Review if manual valve (#V36) at cargo tank inlet can be moved in to pipe tunnel. Currently subject valve is located in the cargo hold area and will required entrance into cargo hold area for valve maintenance or to operate the valve. as per the class
			9. Cargo tanks and piping is provided with overpressure protection as applicable					
			10. Ability to divert gas to gas combustion unit					

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			11. Hazardous area classification 12. QA/QC during fabrication 13. All the CNG pipes are butt-welded without flange connections. 14. Structure and supports suitably shielded from piping system leakage.					requirement this valve is supposed to as close as possible to tank. Team wanted to confirm if the design will be able to meet class requirements with valve being moved to pipe tunnel for improved operability efficiency.
2. Pressure deviations	1. Upstream process upsets	1. Potential piping damage; loss of containment; fire hazard	1. Pressure monitoring at manifold	AST	3	1	3	4. Review need for relief valve for the loading manifold. During the workshop team raised a concerned that upstream process upsets can lead to overpressure of manifold piping resulting in loss of containment and fire hazard.
			2. Emergency interface protocol will be defined between terminal and ship to isolate flow during emergency situations	PER	3	1	3	

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
3. Temperature deviations	1. Upstream process upsets	1. Potential piping damage; loss of containment; fire hazard	1. Low temperature monitoring	AST	3	1	3	
			2. Heat tracing	PER	3	1	3	
			3. Onshore temperature monitoring					
			4. Piping material is compatible with low/high temperature operation					
4. Flow deviations	1. No issue of concern identified							
5. Corrosion/erosion	1. No issue of concern identified							
6. Startup/shutdown	1. No issue of concern identified							
7. Simultaneous operations	1. No issue of concern identified							

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
8. Moisture	1. Out of spec gas	1. No issue of concern identified for manifold piping						
9. H2S concentrations	1. off spec gas	1. Potential damage to equipment and H2S exposure hazards	1. H2S is not expected in inlet stream	AST	3	1	3	
			2. Ship will not receive gas if H2S is present in the inlet stream	PER	3	1	3	
			3. Gas will be tested before loading					
10. CO2	1. No issue of concern identified							
11. Drains	1. Not applicable							
12. Explosive/jet fire hazard	1. Leak	1. Potential obstruction of escape routes; personnel	1. Multiple escape routes provided	PER	4	1	4	

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
		injury/fatality during emergency scenario						
13. Flaring/venting during normal operations	1. No additional hazards identified							
14. Flaring/venting during emergency	1. No additional hazards identified							
15. Crew boat accident	1. Pilot error	1. Potential collision with loading hose during transfer; potential fire hazard	1. Crew boat will be embark away from the loading manifold area to avoid any contact with loading hose	AST	3	1	3	
				PER	3	1	3	
16. Accident during transfer of personnel	1. No additional hazards identified							
17. Helicopter accident	1. Emergency evacuation	1. Potential damage to cargo area; loss of containment; fire hazard; asset damage		PER	4	1	4	5. Review class requirement for helicopter operations for emergency evacuation of personnel and provide adequate safeguards to avoid any

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
								helicopter accident during evacuation.
18. Confined spaces	1. No confined space in manifold area							
19. Machinery instrument accessibility	1. No issues of concern identified							
20. Reduced visibility	1. Manifold area is equipped with CCTVs and have a direct line of visibility from wings							
21. Lightning	1. Adverse weather	1. Potential escalation of fire events or fire hazard	1. Ship is provided with adequate lightning protection	AST	2	1	2	
				PER	2	1	2	
22. Marine collision	1. No issues of concern identified							

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
23. Grounding	1. Static electricity	1. Fire hazards	1. Grounding is provided, as applicable	PER	3	1	3	
24. Reduced visibility	1. Obstruction of view from wheel house	1. Operational issues	1. Manifold area is equipped with CCTVs and have a direct line of visibility from wings					
25. Mooring line failure	1. No additional hazards identified							
26. Structural failure	1. No additional hazards identified							
27. Loading line failure	1. No additional hazards identified							
28. CNG Carrier listing	1. Listing	1. Potential damage to hose connections; potential fire hazards	1. Loading is unmanned operation	PER	3	1	3	6. Review hose connection design to ensure ship movement stresses are accounted in the connection design to avoid damage to hose connection during ship

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
								movement. Hose connection damage can lead to loss of containment and fire hazard during loading/unloading.
29. Loss of station keeping	1. Operator/pilot error	1. Potential damage to hose connections; potential fire hazards	1. Operation manual	PER	3	1	3	7. Ensure operating manual considers loading and unloading as a special operation and provides adequate operational safeguards as applicable considering 1) station keeping, 2) fatigue 3) operator training and 4) ship traffic during loading to prevent hose damage. Hose damage can lead to loss of containment and fire hazard during loading/unloading.

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
30. Loss of buoyancy	1. No issues of concern identified							
31. Fatigue/cracking	1. Hose operation	1. Potential damage to hose; potential leak; fire hazards	1. Regular maintenance and inspection	AST	2	1	2	7. Ensure operating manual considers loading and unloading as a special operation and provides adequate operational safeguards as applicable considering 1) station keeping, 2) fatigue 3) operator training and 4) ship traffic during loading to prevent hose damage. Hose damage can lead to loss of containment and fire hazard during loading/unloading.
				PER	3	1	3	
32. Occupational accidents	1. No issues of concern identified							

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
33. Improper/inadequate training	1. Operator error	1. Hose damage; loss of containment; fire hazard; exposure of personnel to CNG; personnel fatality/injury	1. Adequate training will be provided to personnel for loading and unloading operation	PER	3	1	3	7. Ensure operating manual considers loading and unloading as a special operation and provides adequate operational safeguards as applicable considering 1) station keeping, 2) fatigue 3) operator training and 4) ship traffic during loading to prevent hose damage. Hose damage can lead to loss of containment and fire hazard during loading/unloading.
34. Weather monitoring	1. No additional hazards identified							
35. Shipping traffic monitoring	1. Ship traffic around loading area	1. Potential collision leading to loading operation interruption or damage; loss of	1. Voyage planning	AST	3	1	3	7. Ensure operating manual considers loading and unloading as a special operation and provides adequate operational
				PER	3	1	3	

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
		containment; fire hazards						safeguards as applicable considering 1) station keeping, 2) fatigue 3) operator training and 4) ship traffic during loading to prevent hose damage. Hose damage can lead to loss of containment and fire hazard during loading/unloading.
36. Material handling	1. Crane operation; dropped object	1. Potential damage to piping; fire hazard	1. No crane operations will be performed during the loading/unloading operations	PER	3	1	3	
				AST	3	1	3	
37. Man overboard	1. No issues of concern identified							
38. Dynamic situations hazards	1. No additional hazards identified							

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
39. Communication failure	1. No issues of concern identified	1.	1. Communication system is provided as per the rules and industry practices					
40. Common cause failures	1. No issues of concern identified	1.	1. Communication system is provided as per the rules and industry practices					
41. Blackout	1. No issues of concern identified	1.						
42. Cooling Water	1. Not applicable							
43. Instrument air	1. Not applicable							
44. Inert gas/nitrogen	1. No additional hazards identified							
45. Fire water	1. No additional hazards identified							
46. HVAC System	1. NA							
47. Escape/egress/rescue	1. No additional hazards identified							

Node: 2. Cargo loading and unloading header and fuel gas piping arrangement

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
48. Disconnect during loading	1. No additional hazards identified							
49. Disconnect during unloading	1. No additional hazards identified							
50. Release from vent	1. No additional hazards identified							

Node: 3. Compressor room and fuel gas system

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
1. Leak from compressor room piping/flange	1. Mechanical damage	1. Loss of containment; fire hazard	1. Emergency shutdown valve at loading manifold	AST	3	1	3	20. Review need to perform and fire explosion analysis to understand effect on the adjacent area in case of a gas leak in compressor room and provide adequate safeguards as applicable.
			2. Gas detectors	PER	3	1	3	
			3. Cameras					
			4. Two means of escape routes provided from compressor room					
			5. Active fire protection					
			6. Welded connections, where applicable					
			7. Ventilation inlets are explosion proof					
			8. Hazardous area classification					
2. Leak from fuel gas	1. Mechanical damage	1. Fire hazards	1. Emergency shutdown valve will be provided, as required	AST	3	1	3	

Node: 3. Compressor room and fuel gas system

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			2. Fuel gas piping through accommodation or enclosed space will be of double wall arrangement	PER	3	1	3	
			3. Ventilation inlets for engine room provided with gas detectors with ESD activation					
			4. Two means of escape routes provided from engine room					
			5. Gas detectors					
			6. Engine room cameras					
			7. Active fire protection					
			8. Hazardous area classification					
			9. Welded connections, where applicable					

Node: 3. Compressor room and fuel gas system

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
3. Pressure deviations	1. Process upsets	1. Potential overpressure and damage; fire hazards	1. Adequate pressure relief valves are provided as needed	AST	3	1	3	
			2. Thermal relief valve will be provided for all isolated sections	PER	3	1	3	
			3. Emergency shutdown valve provided to isolated process sections during overpressure scenarios					
4. Temperature deviations	1. Process upsets	1. Potential high temperature gas due to compression which can affect cargo cylinder structural integrity	1. Cargo cylinders are provided with high high temperature shutdown to prevent cylinder structural damage due to high temperature of gas content	AST	3	1	3	21. Review emergency shutdown philosophy for the ship in regard to IGC and IGF code and update as required.
				PER	1	1	1	
5. Flow deviations	1. Process upsets	1. If all cylinders are not available to receive the flow rate coming from	1. Cargo cylinders are provided with high high temperature shutdown to prevent cylinder structural damage	AST	3	1	3	21. Review emergency shutdown philosophy for the ship in regard to
				PER	1	1	1	

Node: 3. Compressor room and fuel gas system

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
		compressor, it can lead to temperature increase in other cylinders which can affect cylinder structural integrity	due to high temperature of gas content					IGC and IGF code and update as required.
6. Level deviations	1. Separator drain left open after draining operation	1. Potential for gas blow-by via separator drain; potential fire hazards		AST	3	1	3	22. Review compressor inlet separator drain arrangement and ensure it is routed to safe location. If drain valve is left open inadvertently it can lead to gas blow-by resulting in a fire/explosion.
				PER	3	1	3	
	2. High level in compressor inlet separator	1. Potential liquid carryover to compressor and potential damage to compressor; loss of	1. Compressor package is provided with all adequate safety measures are required	AST	3	1	3	
				PER	3	1	3	

Node: 3. Compressor room and fuel gas system

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
		containment; fire hazards						
7. Corrosion/erosion	1. High flow rate	1. Potential erosion damage to piping	1. Piping are designed to handle maximum anticipated flow rates from compressors	AST	2	1	2	
				PER	1	1	1	
8. Startup/shutdown	1. No issues of concern identified							
9. Simultaneous operations	1. No issues of concern identified							
10. Moisture	1. No additional hazards identified							
11. H_2S concentrations	1. Off spec gas	1. Potential damage to equipment and H_2S exposure hazards	1. H_2S is not expected in inlet stream	AST	3	1	3	
			2. Ship will not receive gas if H_2S is present in the inlet stream	PER	3	1	3	

Node: 3. Compressor room and fuel gas system

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			3. Gas will be tested before loading					
12. CO_2	1. No issues of concern identified							
13. Drains	1. No additional hazards identified							
14. Accommodation fire	1. Compressor room leak	1. Potential fire/explosion in compressor might affect accommodation area; personnel injury/fatality	1. Active fire protection	AST	3	1	3	20. Review need to perform and fire explosion analysis to understand effect on the adjacent area in case of a gas leak in compressor room and provide adequate safeguards as applicable.
				PER	3	1	3	
15. Explosive hazard	1. No additional hazards identified							

Node: 3. Compressor room and fuel gas system

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
16. Flaring/venting during normal operations	1. No additional hazards identified							
17. Flaring/venting during emergency	1. Venting scenario	1. Potential gas release through vent mast; potential fire hazards if ignition source is found	1. Vent mast is provided with required height as per the class requirements	AST	3	1	3	23. Perform gas dispersion analysis to optimized vent mast location and height to ensure gas release from vent mast will not lead to migration of gas to hazardous zone or accommodation area which can result in a fire hazard.
				PER	3	1	3	
18. High winds - Typhoons	1. No issues of concern identified							
19. Confined spaces	1. No issues of concern identified	1.						

Node: 3. Compressor room and fuel gas system

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
20. Machinery instrument accessibility	1. No issues of concern identified	1.						
21. Reduced visibility	1. No issues of concern identified	1.						
22. Lightning	1. No issues of concern identified	1.						
23. Dropped object	1. No issues of concern identified	1.	1. No cranes around compressor room that can lead to dropped object incident					
24. Escape/egress/rescue	1. No issues of concern identified	1.	1. Two means of escape is provided from compressor room					
25. Release from vent	1. No additional hazards identified							

Node: 4. Gas combustion unit

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
1. GCU was not analyzed during meeting as requirements are not finalized and if installed, review will be updated accordingly	1.	1.						

Node: 5. Nitrogen system

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
1. Leak from piping/flange	1. Mechanical damage; corrosion; weld defects	1. Lost/inability to maintain inert atmosphere in cargo hold; potential fire hazard in cargo hold area during leak scenario if ignition source present	1. 2x100% Nitrogen generators	AST	3	1	3	24. Consider providing multiple N2 header such that single failure in the line cannot lead to complete loss of N2 supply to cargo holds. Loss of inert atmosphere in a cargo hold can lead to potential fire hazard if ignition source is present during leak.
			2. Oxygen sensor to detect presence of O2 in N2 system	PER	3	1	3	
2. Pressure deviations	1. No issue of concern identified							
3. Temperature deviations	1. No issue of concern identified							
4. Flow deviations	1. No issue of concern identified							
5. Level deviations	1. No issue of concern identified							

Node: 5. Nitrogen system

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
6. Corrosion/erosion	1. No issue of concern identified							
7. Startup/shutdown	1. Purging operation	1. Potential ineffective purging operation; fire hazard		PER	4	1	4	25. Review nitrogen system arrangement for purging operation to ensure cylinders can be effectively and safely made gas free for maintenance purpose. Currently only one inlet port is shown for CNG cylinders and it will be difficult to inert the cylinder completely if separate outlet port is not provided. Ineffective purging can lead to fire hazard.
8. Simultaneous operations	1. No issues of concern identified							

Node: 5. Nitrogen system

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
9. Moisture	1. No issues of concern identified							
10. H2S concentrations	1. Not applicable							
11. CO2	1. Not applicable							
12. Drains	1. No issues of concern identified							

Node: 6. Main engine and engine room

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
1. Fire in the engine room	1. Potential escalation to cargo area	1. Potential escalation of fire events	1. Cargo containment is separated by cofferdam	AST	3	1	3	
			2. Emergency shutdown and associated operation of fuel gas lines is as per IGC code requirements	PER	3	1	3	
			3. Main engine and associated systems are designed as per IGC code requirements					

Node: 7. Ship interface and marine systems

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
1. Loss of containment in cargo area or compressor room	1. Gas ingress into accommodation area	1. Potential fire hazard in accommodation area	1. Accommodation ventilation are provided with gas detectors with automatic damper closing on gas detection	AST	3	1	3	26. Consider making life raft area open to avoid any gas pockets during gas release scenario. Gas accumulation in life raft can lead to fire hazard and inaccessibility to life raft during evacuation.
			2. Accommodation ventilation inlets are located far away from cargo area and in opposite direction	PER	4	1	4	27. Consider increasing cofferdam till wheel house to protect wheel house from fire incident in compressor room. Also, ensure cofferdam height increase till wheel house is in compliance with class requirement for
			3. Coffer dam between accommodation (up to wheelhouse deck) and cargo area					
			4. Life rafts are protected by cofferdam					

Node: 7. Ship interface and marine systems

Hazards	Causes	Consequences	Effective Safeguards	CAT	S	L	RR	Recommendations
			5. Air lock with gas detectors in access from accommodation to cargo area					visibility from wheel house.
			6. Temporary refuge area entry is protected via air lock					
			7. Active fire protection					
			8. Lifesaving appliances are provided as per the class requirements					