DESIGN REPORT

DESIGN AND SAFETY STATEMENT

Design Description

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Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

C-JOB
DEDICATED NAVAL ARCHITECTS

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1 INTRODUCTION

This document provides the documentation required to obtain an Approval in Principle (AiP) for refitting the inland patrol vessel RWS 88 with a Methanol Propulsion System (MPS). The equivalent level of safety of methanol systems to conventional diesel fuel systems is to be demonstrated by means of risk assessment and engineering analysis. The approval of the design is to be carried out in accordance with SOLAS Reg 55 & MSC Circ. 1455. See also IGF Code Part A and MSC Circ. 1621 Guidelines Methanol.

2 GENERAL INFORMATION

2.1 Ship intro

The RWS 88 is an inland patrol vessel owned by the Dutch Department of Waterways and Public Works (RWS). On an annual basis patrol vessel RWS 88 will operate on inland canals and (small) rivers for about 1.500 hours per year. The current maximum speed is 16,6 knots and the current maximum engine power is 1040 kW. The principal dimensions of the current configuration of the RWS 88 are shown below:

Built:	1998	
Builder:	Damen Shipyards	
Length over all:	18,47	m
Breadth moulded:	5,00	m
Depth to upper deck:	2,49	m
Draught design approximately:	1,35	m
Displacement:	66	ton
Total MGO bunker capacity:	3000	kg
Power:	1040	kW (2x MAN D2840LE401, 520 kW, 2100 RPM)
Speed:	16,6	knots

2.2 Objectives

This document provides the basis of design of the methanol propulsion system of the RWS 88. Furthermore, the document provides the documents required as input for a HAZID. After the HAZID the document can be updated to obtain an AiP for the methanol propulsion system of the RWS 88.

2.3 Scope

The scope is limited to the methanol fuel system, the two main engines, and the supporting systems allowing for the safe operation of the methanol propulsion system.

2.4 Applicable rules and regulations

The risk assessment, safety philosophy, project description plans and diagrams are developed in accordance with the regulations below:

- ES-TRIN Chapter 30 + Annex 8
- IMO Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel (MSC.1/Circ.1621)
- IMO International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels
- NR 670 DT R00 E Bureau Veritas Rules for Methyl/ethyl alcohol Fuelled Ships
- IEC 60079-10-11 Classification of areas – Explosive gas atmospheres

3 SPECIFICATION

In this chapter the functional specification, and a description of the methanol propulsion system is given.

3.1 Functional specification of the methanol propulsion system

The RWS 88 shall have a safe and operatable methanol propulsion system. Furthermore, based on its current operational profile, the RWS 88 shall have sufficient methanol storage capacity to only bunker two times per week.

3.2 Main components and sub systems

The Methanol propulsion system consists of the following sub systems:

- Bunker station
- Methanol storage tanks
- Fuel preparation box
- Main engines (2x Scandinaos DI16 415 kW, 2100 RPM)
- Methanol fuel system
- Nitrogen system
- Methanol ventilation system
- Methanol vent system
- Regulatory alarm and indication systems
- Firefighting system
- Inherent safety features

These will be further clarified in chapter 7. Although the MGO system is not within the scope of description of the methanol system, it does interface with the MPS, and therefore the main components and sub systems of the MGO system are listed below:

- MGO bunker station
- MGO tank
- MGO supply system to auxiliary generator
- Auxiliary generator

4 DESIGN AND SAFETY APPROACH

4.1 Safety objectives

The following objectives have been adopted from the IGF code with gas adjusted to methanol shown in bold:

- 3.2.1 The safety, reliability and dependability of the systems shall be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery.
- 3.2.2 The probability and consequences of fuel-related hazards shall be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions shall be initiated.
- 3.2.3 The design philosophy shall ensure that risk reducing measures and safety actions for the **methanol** fuel installation do not lead to an unacceptable loss of power.
- 3.2.4 Hazardous areas shall be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.
- 3.2.5 Equipment installed in hazardous areas shall be minimized to that required for operational purposes and shall be suitably and appropriately certified.
- 3.2.6 Unintended accumulation of explosive, flammable or toxic gas concentrations shall be prevented.
- 3.2.7 System components shall be protected against external damages.
- 3.2.8 Sources of ignition in hazardous areas shall be minimized to reduce the probability of explosions.
- 3.2.9 It shall be arranged for safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, the system shall be designed to prevent venting under all normal operating conditions including idle periods.
- 3.2.10 Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application shall be provided.
- 3.2.11 Machinery, systems and components shall be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.
- 3.2.12 Fuel containment system and machinery spaces containing source that might release gas into the space shall be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.
- 3.2.13 Suitable control, alarm, monitoring and shutdown systems shall be provided to ensure safe and reliable operation.
- 3.2.14 Fixed **methanol** detection suitable for all spaces and areas concerned shall be arranged.
- 3.2.15 Fire detection, protection and extinction measures appropriate to the hazards concerned shall be provided.
- 3.2.16 Commissioning, trials and maintenance of fuel systems and methanol utilization machinery shall satisfy the goal in terms of safety, availability and reliability.
- 3.2.17 The technical documentation shall permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.

- 3.2.18 A single failure in a technical system or component shall not lead to an unsafe or unreliable situation.

4.2 Safety philosophy

The main safety philosophy is to prevent methanol air (oxygen) mixtures. This is because methanol is very volatile and highly flammable. Furthermore, exposure to humans and non-methanol equipment should be prevented as methanol is toxic and corrosive. Methanol is not considered harmful for the environment.

To mitigate the above mentioned hazards and to comply with the safety objectives, the safety systems applied to the methanol propulsion system shall be arranged to fulfill the following functional requirements:

- The system safety risk shall be As Low As Reasonably Possible (ALARP). Passive safety systems shall be applied whenever reasonably possible.
- The engine room will be gas safe. A single failure within the methanol system will not lead to a leakage of methanol into the engine room.
- Leakage of methanol (vapour) shall be detected and alarmed.

5 INTEGRATION

5.1 Arrangement

The methanol propulsion system is distributed over the following spaces:

- **Fuel tanks**: Holds the methanol.
- **Fuel preparation box**: Holds the methanol fuel pumps.
- **Engine room**: Holds the two methanol engines, the nitrogen system and the FiFi-system.
- **Methanol bunkering station**: Here the bunkering connection is located.
- **Methanol vent point**: Here the overpressure in the methanol tanks is vented into the water.

Although the MGO system is not within the scope of description of the methanol system, it does interface with the MPS, and therefore the location of the main components and sub systems of the MGO system are listed below:

- **MGO tank:** Holds MGO for the auxiliary generator.
- **Engine room**: Holds the auxiliary generator.
- **MGO bunker station:** Here the MGO bunkering equipment is located.

5.2 Access, inspection and replacement

All equipment and components shall be repairable and replaceable through normal access routes or dedicated hatches or manholes.

5.3 Hazardous areas

For the initial study, the hazardous zone plan shall be based upon the Bureau Veritas 670-NR "Methyl/ethyl alcohol Fuelled Ships" rule notes. In a later design stage the hazardous zones could be reduced that follow from calculating the hazardous zones using the IEC code.

In order to select the appropriate electrical equipment and design suitable electrical installations, the hazardous areas are divided into zone 0, 1 and 2. The Bureau Veritas 670-NR "Methyl/ethyl alcohol Fuelled Ships" rule note defines the hazardous area zones as listed below.

Hazardous areas zone 0 are areas in which an explosive gas atmosphere is present continuously or for longer periods. Hazardous areas of zone 0 include, but are not limited to:

- The inside of the methanol fuel tanks, methanol fuel pipes, and equipment containing methanol.
- Any piping for the pressure relief or venting of methanol.

Hazardous areas zone 1 are areas in which as explosive gas atmosphere is likely to occur in normal operation. Hazardous areas of zone 1 include, but are not limited to:

- Cofferdams and other spaces surrounding the methanol fuel tank.
- The fuel preparation spaces.
- Areas on open or semi-enclosed spaces on deck, within 3 meter of any methanol fuel tank outlet, gas or vapour outlet, bunker manifold valve, or other methanol valve, methanol fuel pipe flange, or methanol fuel preparation space outlets.
- Areas on open deck or semi-enclosed spaces on deck in the vicinity of the fuel tank pressure release/vent outlets, within a vertical cylinder of unlimited height and a 6 meter radius centered upon the center of the outlet and within a hemisphere of 6 meter radius below the outlet.
- Areas on open deck or semi-enclosed spaces on deck within 1.5 meter of fuel preparation space entrances, fuel preparation space ventilation inlets and other opening zone 1 spaces.
- Areas on open deck within spillage coamings surrounding methanol fuel bunker manifold valves and 3 meter beyond these, up to a height of 2.4 meter above the deck.
- Enclosed or semi-enclosed spaces in which pipes containing methanol fuel are located, for example ducts around methanol fuel pipes, semi-enclosed bunkering stations.
- A space protected by an airlock is considered as non-hazardous area during normal operation, but will require equipment to operate following loss of differential pressure between the protected space and the hazardous area to be certified as suitable for zone 1
- Air locks not protected by over pressure relative to the surrounding area but artificially ventilated, between hazardous area zone 1 and hazardous area zone 2.

Hazardous areas zone 2 are areas in which an explosive gas atmosphere is unlikely to occur during normal operation, and when an explosive gas atmosphere occurs it will only exist for a short period of time. Hazardous areas of zone 2 include, but are not limited to:

- Areas 4 meter beyond the cylinder and 4 meters beyond the sphere as defined in the section above.
- Areas within 1.5 meter surrounding open spaces of zone 1 as specified in the section above.
- Air locks protected by overpressure relative to the surrounding area, between hazardous areas zone 1 and non-hazardous areas.
- Air locks not protected by over pressure relative to the surrounding area but artificially ventilated, between hazardous area zone 2 and non-hazardous area.

6 DESCRIPTION OF THE METHANOL PROPULSION SYSTEM

6.1 General

The patrol vessel RWS 88 shall be refitted to use methanol as main fuel, after the conversion the vessel will have the following main particulars:

Built:	1998	
Builder:	Damen Shipyards	
Length over all:	18,47	m
Breadth moulded:	5,00	m
Depth to upper deck:	2,49	m
Draught design approximately:	1,35	m
Displacement:	66	ton
Total methanol bunker capacity:	2400	kg
Power:	830	kW (2x Scandinaos DI16 415 kW, 2100 RPM)
Speed:	15.4	Knots (to be confirmed)

6.2 High level description

The methanol storage tanks are filled via the bunker station located on the port side of the vessel next to the deckhouse. The fuel can be pumped into the methanol fuel tanks via the bunker line. To prevent pressure build up in the methanol tanks a vapour return line allows the vapour in the methanol fuel tanks to flow to the bunkering facility. Furthermore, in case of overfilling the methanol tanks the vapour return line allows the excess fuel to flow back to the bunkering facility.

The methanol fuel tanks are actively inerted using nitrogen to prevent the build-up of explosive methanol vapour/air mixtures. Furthermore, the methanol tanks shall be surrounded by cofferdams. The cofferdams are ventilated at a high rate to prevent the build-up of methanol vapour in case of methanol leakage. The cofferdams shall be equipped with sensors to detect any methanol leakage into the cofferdams.

The methanol is pumped from the fuel tanks to the fuel preparation box, which is located in the middle of the engine room. The fuel preparation box contains the fuel pumps required to supply the methanol engines with the specified fuel pressure. All methanol fuel pipes passing through non-hazardous areas shall be double walled.

The two main engines of each 415 kW will be supplied with methanol, these ICE will run on 97% methanol with 3% pre-mixed additives for lubrication and combustion purposes. Each engine drives a propeller shaft via a gearbox. The casings of the methanol engines are mechanically ventilated to prevent methanol air mixtures in case of fuel leakage. The methanol ventilation air outlet is located at the stern of the vessel.

The methanol fuel preparation box is ventilated at a ventilation rate high enough to prevent the build-up of flammable methanol mixture in case of methanol leakages. The fuel preparation box, cofferdam ventilation and engine covers share one methanol ventilation outlet point. The engine room is considered gas safe and therefore, no additional or dedicated methanol ventilation system is required in the engine room.

Methanol that is released from the pressure relief of the methanol fuel tanks will be relieved through a vent point on the bottom of the ship which is under the waterline. It is expected that underwater venting does not create a hazardous zone because methanol dissolves quickly in water.

A nitrogen generation system dedicated to the methanol propulsion system shall be installed in an enclosure on open deck. This system includes a nitrogen generator that uses membrane technology for continuous on-site nitrogen generation from air. The nitrogen separators are passive devices without moving parts, which requires minimum maintenance and operator attention. The separator requires compressed air and electricity to operate. The nitrogen in stored in a pressurised nitrogen storage tank.

6.3 Specific operational parameters

In its current state the RWS 88 has a bunker capacity of approximately 2x 1600 litre. Because the methanol tank is surrounded by cofferdams, the tank capacity is reduced to approximately 2x 1000 litre, a reduction of 38% in terms of volume. Furthermore, MGO has a volumetric energy density of 36.7 MJ/L where methanol has a volumetric energy density of 15.8 MJ/L. Therefore, the autonomy of the RWS 88 is further decreased with 57%. Because of the reduction in available volume and a lower energy density of methanol the energy storage capacity of the RWS 88 is reduced to 26% of the original (MGO) energy storage capacity. Assuming the methanol engines will have a similar efficiency as the current installed engines, the autonomy will be reduced by approximately 74%.

To mitigate the reduction in autonomy, an additional methanol tank is placed behind the aft peak. This tank has a capacity of 1000 litre, when three tanks are used, the autonomy is reduced to 39% of the original autonomy.

The methanol engines have a specific fuel consumption of 195 kg/h at 100% power, with a methanol storage capacity of 2400 kg and two engines the vessel can sail for 6 hours at full speed. It is recommended to perform a thorough operational profile analysis to determine if the vessel has sufficient fuel capacity to meet the desired bunker frequency.

6.4 Special points of attention

Points of special attention for the MPS design are:

- Safe storage of methanol
    - Provisions of inerting the methanol tank
    - Provisions for pressure and vacuum relief of the tank
    - Minimise the risk of loss of containment
    - Mitigating measures in case of loss of containment
- Safe handling of methanol
    - Provisions for suitable ventilation
    - Minimise the risk of loss of containment
    - Mitigating measures in case of loss of containment
- Means of safe bunkering

7 FUNCTIONAL DESCRIPTION

7.1 Modes of operation

The intended area of service is in inland waters of the Netherlands. During the operation of the methanol propulsion system the following operational modes are considered:

- Bunkering of methanol
- Sailing (Both engines deliver power)
- Docked (Methanol propulsion system is not operational, power provided from shore)
- Maintenance (Access to methanol spaces is required)

7.1.1 Bunkering methanol

During the bunkering of methanol the patrol vessel is stationary and moored next to the bunkering vessel or bunker facility onshore. The two methanol engines are disabled during the bunkering, the auxiliary generator provides power for the electrical equipment.

7.1.2 Sailing

The two main engines provide mechanical power to the propellers. The vessel sails at various speeds. The electricity is provided by the auxiliary generator which runs on MGO.

7.1.3 Docked

The patrol vessel is not in use all the time, overnight and sometimes during the day the vessel lays unmanned in a harbour. When the vessel is docked the methanol is still present in the tanks and the safety system should still be active. Shore power is provided by a cable.

7.1.4 Maintenance

When mechanics have to work on the methanol equipment the methanol has to be drained. All the spaces, tanks and pipes that could potentially contain methanol should be purged and cleaned before they can be accessed by personnel.

7.2 Function statement

7.2.1 Bunker station

The bunker station is the interface between the ship and the fuel supply vessel or the bunker supply on land. During the bunkering two external hoses are connected to the methanol storage tanks, one to supply methanol, and one vapour return line. The methanol fuel system does not have an overflow tank, in case of overfilling the methanol tanks, the access methanol will flow back to the bunker facility via the vapour return line. To prevent build-up of methanol vapour, the bunkering station shall be placed in an open, well ventilated space.

7.2.2 Methanol fuel system

The methanol fuel system distributes the methanol from the methanol storage tanks to the methanol engines. The pumps to transfer the methanol are located in the fuel preparation box.

7.2.3 Double walled methanol piping

All the methanol fuel piping going through non-hazardous zones shall be double walled. The double walled piping mitigates the risk of loss of containment when the inner fuel pipe fails. The annular space between the inner and outer pipe will be inerted using nitrogen, which is supplied by the nitrogen system. Pressure sensors shall be installed to monitor the pressure in the annular space, a drop in pressure in the annular space indicates a leakage from the outer pipe to the environment, a pressure rise indicates a leakage from the inner pipe to the outer pipe.

7.2.4 Methanol storage system

The methanol storage tanks are located in the engine room against the hull on both sides. Both tanks start approximately at frame 7.5 and end approximately at frame 9.5. Therefore, the fuel tanks penetrate the bulkhead on frame 8.5. A third tank is located after the peak bulkhead on frame 2.5. To prevent the loss of containment all methanol fuel tanks are surrounded by a secondary boundary. The secondary boundary or cofferdam is equipped with ATEX-certified sensors to detect leakage of methanol into the cofferdam. To reduce the risk of escalation of a fire the outside of the cofferdam is insulated with A60 fire insulation.

7.2.5 Methanol engine

Two methanol engines of 415 kW each provide power for the propulsion of the vessel. Each engine is connected to a propeller via a gearbox and a drive shaft. The engines run on 97% methanol and 3% pre-mixed additives for combustion and lubrication purposes. Both engine covers are mechanically ventilated, therefore the engines do not create hazardous zones and the engine room is “gas safe”.

7.2.6 Methanol ventilation system

The methanol engines require a separate ventilation system. This ventilation system works by means of extraction ventilation. A ventilator sucks the air from the engine hood to the methanol ventilation outlet, which creates an under pressure in the engine hood. Because the engine hood is not gastight, air is extracted from the engine room via the engine hood. To guarantee that the engine hood is properly ventilated, the system is redundant with two ventilators and two flow detectors. The ventilation outlet is located at the stern of the vessel. According to the calculations of the engine supplier Scandinaos, there will be no hazardous zone at the ventilation outlet if a ventilation rate of 340 m^3/h is applied. The cofferdams and fuel preparation box will also have a ventilation system with redundant fans. This ventilation system has both air supply and air extraction ducts.

7.2.7 Nitrogen generation system

The nitrogen generation system will be installed in an enclosure on open deck and will consist of the following main components: A feed air compressor (which is located in the engine room), nitrogen generator, and a nitrogen storage tank (buffer).

7.2.8 Methanol vent system

Methanol that is released from the overpressure valves of the methanol storage tanks, cofferdams or fuel preparation box, will be relieved through the methanol vent system. To avoid large hazardous area zones, and because methanol dissolves in water, the methanol vapour will be released under water at least one meter below the lowest water line. Experiments should be performed to prove that underwater venting of methanol is safe.

7.2.9 Inherent safe features

An inherent safe design relies on chemistry and physics to prevent accidents rather than on control systems, redundancy and special operating procedures to prevent accidents. The majority of the hazards are related to the potential loss of containment of methanol and the effects of fire or an explosion when flammable methanol vapour gets ignited. Furthermore, exposure to humans in terms of toxicity is an important consideration. Methanol is not classified as harmful to the environment. Based on these aspects the following features are implemented in the design:

- Second barrier principle
- Elimination of ignition sources
- Reduction of escalation potential

Second barrier principle

One inherent method to prevent the creation of flammable methanol vapour/air mixtures is to apply second barriers in the following locations:

- All methanol piping going to non-hazardous spaces shall be double walled with an inerted annular space.
- To prevent the leakage of methanol into machinery or accommodation spaces the methanol fuel tanks are surrounded by cofferdams.

Elimination of ignition sources

To minimize the risk of ignition of a potentially explosive atmosphere only ATEX-certified systems are installed near the bunker station and in the fuel preparation box.

Reducing escalation potential

To minimize the risk of escalation of a fire, rooms that have a higher risk for fire are equipped with thermal insulation and adequate firefighting installations.

8 IDENTIFICATION OF INTERFACES BETWEEN THE ALTERNATIVE AND OTHER SYSTEMS

The MPS interfaces with multiple conventional systems of the RWS 88. The following systems are identified as major interfaces between the alternative design and the conventional features.

- Ship geometry
- Bilge system
- Electrical system
- MGO supply system
- Cooling system
- Alarm, Monitoring and Control System (AMCS)
- Fire detection and firefighting system
- Emergency lighting

8.1 Ship geometry

To vent the methanol under water an opening has to be made in the bottom of the vessel. To prevent water flowing into the fuel tanks the methanol vent pipe has to be brought above freeboard height before it connects to the fuel tank. An extra reinforced pipe is used to mitigate the risk of flooding the engine room in case of a pipe rupture.

8.2 Bilge system

The fuel preparation box and cofferdams will be equipped with ejectors to remove any methanol in case of a methanol fuel leakage. The ejectors will be supplied with water from a water supply pump. The need for ejectors in the engine room is to be determined in a later design stage.

8.3 Electrical system

The methanol propulsion system requires electrical power to operate, this power is provided by the onboard electrical system. During normal operation power is provided by the auxiliary generator. When the ship is docked power is provided by a shore connection. In case the regular power supply fails, an emergency battery pack will provide power to the most essential systems.

8.4 Cooling system

The two methanol engines are connected to the conventional engine cooling system.

8.5 Alarm, Monitoring and Control System (AMCS)

The RWS 88 will have an integrated AMCS that monitors and controls the regular and methanol systems. This system is used to start and stop the engines and generator, and to monitor all the supporting systems.

The methanol propulsion system will have an independent alarm system that interacts with the regular alarm system. The methanol alarm system will be designed to achieve and maintain a safe state when an abnormality occurs.

8.6 Fire detection and firefighting system

All rooms will be equipped with fire detectors that will be integrated in the ship's system. The engine room shall be fitted with an alcohol resistant aqueous film forming foam (AR-AFFF) firefighting system. A pump will supply water to the AR-AFFF firefighting system.

9 DESIGN APPROVAL BASIS DOCUMENTS

9.1 Initial requirements

The Dutch Department of Waterways and Public Works (RWS) wants to reduce their carbon emissions. In order to do so the possibility to convert the patrol vessel RWS 88 to run on methanol is investigated. In order to promote the development of sustainable ship design the knowledge and experience gained during this project is shared via the GMM 2.0 consortium.

9.2 Functional performance requirements

The RWS 88 shall have a safe and operatable methanol propulsion system capable of propelling the vessel. The ship will have sufficient methanol storage capacity to bunker maximum two times per week.

9.3 Design parameters

The methanol storage system, the methanol delivery system and the methanol engines are designed to work under the temperatures and pressures shown in Table 9.1. The nitrogen pressure in the annular space shall be approximately 1.8 bar(g), the pressure of the nitrogen supply to the methanol fuel tank shall be approximately 0.05 bar(g). Based on these operational conditions the following design parameters are defined.

Name	Design temperature	Design pressure
Bunkering station	-10 °C - 50 °C	2.0 bar(g)
Methanol storage tank	-10 °C - 50 °C	0.5 - 1.0 bar(g)
Methanol vent system	TBD	5.0 bar(g)
Low pressure CH3OH pump	-10 °C - 50 °C	2.0 bar(g)
High pressure CH3OH pump	TBD	TBD
Main engines	TBD	TBD

Table 9.1: Design parameters.

9.4 Structural basis of design

The following loads should be considered in the methanol propulsion system:

- Vibration loads
- Acceleration loads
- Collision loads

9.5 Principles underlying the design

In order to support a safe and efficient design, construction and operation of the methanol propulsion system, the following safety objectives have been adopted from the IGF code:

- 3.2.1 The safety, reliability and dependability of the systems shall be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery.
- 3.2.2 The probability and consequences of fuel-related hazards shall be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions shall be initiated.
- 3.2.3 The design philosophy shall ensure that risk reducing measures and safety actions for the methanol fuel installation do not lead to an unacceptable loss of power.
- 3.2.4 Hazardous areas shall be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.
- 3.2.5 Equipment installed in hazardous areas shall be minimized to that required for operational purposes and shall be suitably and appropriately certified.
- 3.2.6 Unintended accumulation of explosive, flammable or toxic gas concentrations shall be prevented.
- 3.2.7 System components shall be protected against external damages.
- 3.2.8 Sources of ignition in hazardous areas shall be minimized to reduce the probability of explosions.
- 3.2.9 It shall be arranged for safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, the system shall be designed to prevent venting under all normal operating conditions including idle periods.
- 3.2.10 Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application shall be provided.
- 3.2.11 Machinery, systems and components shall be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.
- 3.2.12 Fuel containment system and machinery spaces containing source that might release gas into the space shall be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.
- 3.2.13 Suitable control, alarm, monitoring and shutdown systems shall be provided to ensure safe and reliable operation.
- 3.2.14 Fixed methanol detection suitable for all spaces and areas concerned shall be arranged.
- 3.2.15 Fire detection, protection and extinction measures appropriate to the hazards concerned shall be provided.
- 3.2.16 Commissioning, trials and maintenance of fuel systems and methanol utilization machinery shall satisfy the goal in terms of safety, availability and reliability.
- 3.2.17 The technical documentation shall permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.
- 3.2.18 A single failure in a technical system or component shall not lead to an unsafe or unreliable situation.

9.6 Calculations and assumptions

The following assumptions haven been made:

- To be determined in a later design stage

The following calculations are to be executed:

- Ventilation shaft calculations
- Concept risk assessment
- Dispersion calculation CH3OH vent mast
- Dispersion calculations CH3OH bunker station

9.7 Preliminary general arrangement drawing

Reference is made to the General Arrangement drawing:
21.516-000-001-REV0-GENERAL_ARRANGEMENT-1-1

9.8 Preliminary fuel system diagram

Reference is made to the fuel system diagram: 21.516-320-100-REVA-CH3OH_FUEL_SYSTEM-SH1-1

9.9 Preliminary hazardous zone plan

Reference is made to the hazardous zone plan:
21.516-570-104-REV0-HAZARDOUS_ZONE_PLAN-SH1-1

9.10 Preliminary fire integrity plan

Reference is made to the fire integrity plan:
21.516-570-106-REV0-STRUCTURAL_FIRE_ INTEGRITY_PLAN-SH1-1

10 LIST OF CODES AND STANDARDS APPLIED

The safety and operability of the methanol propulsion system must be demonstrated to comply with SOLAS regulation II-1/55 for alternative design and arrangement. The following rules and guidelines will be the basis to demonstrate that the methanol propulsion system complies with the SOLAS regulation II-1/55.

- ES-TRIN Chapter 30 + Annex 8
- IMO Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel (MSC.1/Circ.1621)
- IMO International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels
- NR 670 DT R00 E Bureau Veritas Rules for Methyl/ethyl alcohol Fuelled Ships
- IEC 60079-10-11 Classification of areas – Explosive gas atmospheres

11 RISK ASSESSMENT PLANS

11.1 Project category

To estimate the extend of work to be performed and submitted MSC.1/Circ.1455 section 6.2 is used. This paragraph gives an indication of the work to be performed and submitted based on the relation between Project Category and the requirements in the risk assessment and amount of documentation. To determine the project category MSC.1/Circ.1455 section 4.6.4 table 1 is used, which is shown below in Table 11.1.

Application area		**Technology status**		
		Proven	Limited field history	New or unproven
Known	0	1	2	3
New	1	2	3	4

Table 11.1: Project category.

Currently there are multiple ships powered by methanol. The Stena Germanica is a 240 meter long passenger ferry which is refitted with four dual-fuel four-stroke gensets of about 6 MW each. Furthermore, there are already methanol tankers powered by their cargo. These tankers use MAN B&W ME-LGIM two-stroke dual-fuel engines, the tankers can run on methanol or traditional marine fuels allowing for fuel flexibility. Lastly, tests have been performed with smaller four-stoke dual fuel methanol engines on the pilot vessel GREENPILOT. Therefore, the application of methanol engines on ships is known.

The technology status is limited field history, internal combustion engines are a mature and proven technology. However, to the authors knowledge, methanol engines of this scale have only been used in the GREENPILOT vessel. Therefore, methanol engines in small patrol vessels have limited field history.

According to Table 11.1, the project category of the methanol propulsion system is 2. The requirements for the risk analysis are determined with table 2 - “the approval matrix” in section 6.2 of MSC.1/Circ 1455. The matrix has two axes: one with the project category; the other referring to the requirements in the risk assessment and the amount of documentation that has to be submitted. The approval matrix for project category 2 is given in Table 11.2.

Risk assessment subject	Requirements for known application of a technology with a limited field history/new application of proven technology (2)
A) Basic risk assessment	Required (unless rule challenge deemed insignificant or of negligible impact on safety and environment).
B) Further analysis requirements	Depending on basic risk assessment outcome. Hazards medium or high, if any, may be examined further, at least by semi-quantified analysis.
C) Qualifications of analysis	Operational experience general knowledge of risk assessment techniques.
D) Applied rules and guidance	Existing prescriptive rules where no rule challenge prevails (SOLAS, MARPOL, relevant codes, national, regional and international legislation, prescriptive class rules) applicable standards if available from other industrial sectors, class guidance on risk-based approval as applicable.
E) Potential additional tests, surveys and compliance control (after commissioning)	Internal surveying. Additional review at safety related events subject to recording and corrective action.
F) Review by third party	Considered.

Table 11.2: Risk assessment requirements for project category 2.

Plans to compliance with the basic risk assessment (A) is demonstrated in the following sections:

- Equivalent level of safety **(11.2)**
- Risk acceptance criteria **(11.3)**
- Risk assessment **(11.4)**
- Project Health Safety and Environment (HSE) Action List **(11.5)**
- Approval in principle **(11.6)**

11.2 Equivalent level of safety

The MPS design requires a risk-based analysis to demonstrate an equivalent level of safety. An equivalent level of safety means that the safety level of the methanol propulsion system must be comparable to conventional systems. This can be derived from the functional requirements of the IGF-code and the following rule notes from Bureau Veritas: BV– NI 670 – Methyl/ethyl alcohol fueled ships, July 2021.

11.3 Risk acceptance criteria

The following risk acceptance criteria shown in Table 11.3 and Table 11.4 are used during the HAZID workshop. This risk matrix has been adapted from IACS document No. 146 (August 2016) “Risk Assessment as required by the IGF Code”. Table 11.5 shows what actions must be taken for which risk level.

Cat.	Descriptor	Personnel safety	Environmental damage	Asset damage
A	Minor	Single or multiple minor injuries	Limited and reversible damage to sensitive areas/species in the immediate vicinity	Local equipment / structural damage; Limited loss of operation (several hours)
B	Significant	Major injury - long-term disability / health effect	Significant but reversible damage to sensitive areas/species in the immediate vicinity	Non-severe ship damage; Significant loss of operation (several days)
C	Severe	Single fatality or multiple major injuries	Extensive or persistent damage to sensitive areas/species	Severe damage; Severe loss of operation (several months)
D	Catastrophic	Multiple fatalities	Irreversible or chronic damage to sensitive areas/species	Total loss

Table 11.3: Consequence severity.

Risk matrix					
Likelihood (L)		Severity (S)			
Frequency (per ship/year)	Frequency description	A	B	C	D
		Minor	Significant	Severe	Catastrophic
> 10^{-2}	6 Very likely	Medium	High	High	High
10^{-2} - 10^{-3}	5 Likely	Medium	Medium	High	High
10^{-3} - 10^{-4}	4 Unlikely	Low	Medium	Medium	High
10^{-4} - 10^{-5}	3 Very unlikely	Low	Low	Medium	Medium
10^{-5} - 10^{-6}	2 Extremely unlikely	Low	Low	Medium	Medium
<10^{-6}	1 Remote	Low	Low	Low	Medium

Table 11.4: Risk index.

High risk	**Unacceptable risk:** The risk is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.
Medium risk	**Medium risk or ALARP (As Low As Reasonably Practicable) region.** The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.
Low risk	**Acceptable risk:** The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective it is good practice to implement mitigation measures that would further reduce the risk.

Table 11.5: Risk ranking.

11.4 Risk assessment

The Hazard Identification (HAZID) method is used for the risk assessment. A HAZID is a semi-quantitative risk assessment which estimates the frequency and consequences of an activity or operation. In the HAZID study scenarios are described and categorized according to their probability and impact.

The primary objective of the HAZID is to consider the functional requirements of section 3.2 of the IGF-code, and to demonstrate that the MPS has an equivalent level of safety to these.

On the 20th and 21st of April 2022 a HAZID workshop has been executed. The workshop was attended by personnel representing management, design, process and technical experts from RWS, C-Job Naval Architects, the Flag state, Bureau Veritas Marine & Offshore, and Bureau Veritas Solutions Marine & Offshore, who facilitated and reported the workshop.

During the HAZID 200 scenarios where identified of which 48 where risk ranked. The risks where qualitatively ranked based on the workshop attendees judgement according to the process described in section 11.3. The risk ranking during the workshop was done considering the current residual risk, i.e. considering the application of existing safeguards, but did not consider the implementation and effectiveness of the recommendations assigned to each scenario.

The scenarios which were not risk ranked were those assessed as not an issue to the personnel safety, environment or to the ship; those not applicable or not specific; those which were studied in another scenario; or those with no causes identified.

As general outcome of this study, there was no High risk scenarios identified. Nevertheless, a total of 14 out of 48 (29%) risk ranked scenarios were assigned with a Medium Risk. All the HAZID results and recommendations are available in the technical report: “Inland Patrol vessel RWS88 Methanol as fuel - HAZID study” written by Bureau Veritas Solutions Marine & Offshore.

11.5 HSE action list

All recommendations from the HAZID (potential risks or knowledge gaps) are included in the HSE action list. All the actions are categorised into either the initial design scope or the basic/detailed design scope. The actions within the initial design scope have been implemented in the current design. The actions within the basic/detailed design scope will be assessed on a regular basis during later design phases to ensure that they are included in the design, and to ensure that sufficient protection is provided.

11.6 Approval in principle

Based on the document listed below, an Approval in Principle (AiP) can be obtained. Recommendations or requirements resulting from the AiP will be included in the HSE action list.

- 21.516-000-001-REV0-GENERAL_ARRANGEMENT-SH1-1
- 21.516-320-100-REVA-CH3OH_FUEL_SYSTEM-SH1-1
- 21.516-570-104-REV0-HAZARDOUS_ZONE_PLAN-SH1-1
- 21.516-570-106-REV0-STRUCTURAL_FIRE_INTEGRITY_PLAN-SH1-1
- 21.516-000-501-REV0-DESIGN_AND_SAFETY_STATEMENT

12 TESTING AND ANALYSIS PLAN

A testing and analysis plan is to be provided prior to the approval by Class. This plan describes all the test or analysis of materials, structures or systems that require further documentation beyond what is currently available. The tests may be substituted by documentation of a track record of the system or material in another relevant field. A concrete description of the testing and analysis plan is to be provided in a later design stage.

13 HIGH LEVEL CONCLUSION

This report provides the documentation required to obtain an Approval in Principle (AiP). Once an AiP has been obtained this document can be used as a basis for the further development and detailing of the design.

In further development stages of the design the following topics should be taken into special consideration:

- Safe storage of methanol
    - Provisions of inerting the methanol tank
    - Provisions for pressure and vacuum relief of the tank
    - Minimise the risk of loss of containment
    - Mitigating measures in case of loss of containment
- Safe handling of methanol
    - Provisions for suitable ventilation
    - Minimise the risk of loss of containment
    - Mitigating measures in case of loss of containment
- Means of safe bunkering

After having obtained an AiP a complete approval by Class can be obtained by demonstrating an equivalent level of safety. The equivalent level is to be demonstrated my means of a quantitative risk assessment, including a full close-out of all recommendations. During the risk assessment potential risks and knowledge gaps are to be identified and included in the HSE action list. The identified knowledge gaps require additional research, the identified risks should be mitigated to an acceptable risk level.

At the current design stage it is recommended to further investigate the following:

- Operational profile and methanol storage requirements
- Underwater venting of methanol
- Hazardous zones classification based on the IEC code