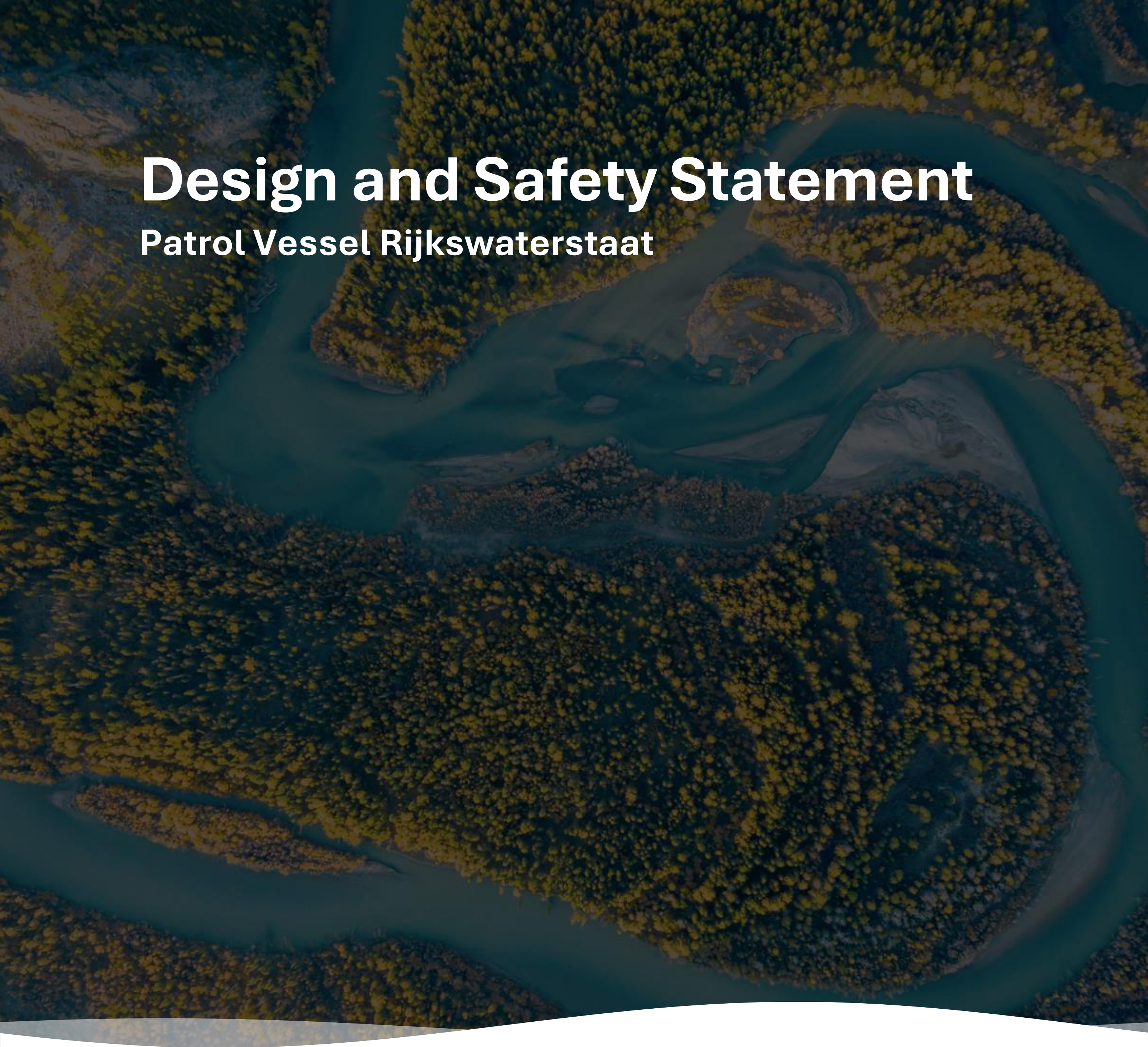

Design and Safety Statement

Patrol Vessel Rijkswaterstaat

Project title	Green Maritime Methanol 3.0 WP-3
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GREEN MARITIME METHANOL

C-JOB DEDICATED NAVAL ARCHITECTS

Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

REVISION HISTORY

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Rev	**Date**	**Description**	**Aut.**	**Chk.**	**App.**

DESCRIPTION OF MODIFICATIONS

Rev	**Description of modifications**
0	First issue

DISCLAIMER

TABLE OF CONTENTS

LIST OF ACRONYMS, UNITS AND CHEMICAL SYMBOLS

°C	Degrees Celsius
AiP	Approval in Principle
ALARP	As Low As Reasonably Possible
B	Breadth
bar(a)	Absolute pressure
bar(g)	Gauge pressure
ESD	Emergency Shut Down
FPR	Fuel Preparation Room (or Space)
HAZID	HAZard IDentification
IEC	International Electrotechnical Commission
IGF	International code of safety for ships using Gases or other low-flashpoint Fuels
IMO	International Maritime Organization
kg	Kilogram
LFL	Lower Flammability Limit
MCR	Maximum Continuous Rating
MSC	Marine Safety Committee
N_2	Nitrogen
ppm	Parts per million
TCS	Tank Connection Space

1. INTRODUCTION

The purpose of this document is to describe the initial design, power generation system, safety philosophy, and safety features of the methanol fuel system onboard of a high speed patrol vessel. This report can be used as input for a HAZID study.

Reference documents

[1] 23.516-999-001-REV0-Design and Comparison Report
[2] 23.516-000-001-REVD-GENERAL ARRANGEMENT CONCEPT 1
[3] 23.516-000-001-REVD-GENERAL ARRANGEMENT CONCEPT 2
[4] 23.516-000-001-REVD-GENERAL ARRANGEMENT CONCEPT 3
[5] 23.516-570-104-REVA-HAZARDOUS ZONE PLAN
[6] 23.516-000-001-REVA-METHANOL_SYSTEM_DIAGRAM

2. DEFINITIONS

The following definitions are used in this report and the general description of the methanol system:

2.1. Hazardous zone identification

The International Electrotechnical Commission IEC 60079-10-1:2021 Explosive atmospheres (which from now on will be referred to as IEC code) and the International Code of Safety for ships using Gases or other low-flashpoint Fuels (which from now on will be referred to as IGF code) can be used to identify areas in which an explosive atmosphere might occur. The IGF code use the following definitions:

2.1.1. Hazardous area

Area in which an explosive gas atmosphere is present or can be expected to be present, in quantities such that special precautions for the construction, installation, and use of equipment are required.

2.1.2. Non-hazardous area

Area in which an explosive gas atmosphere is not expected to be present in quantities such that special precautions for the construction, installation and use of equipment are required.

2.1.3. Zoning of Hazardous areas

Hazardous areas are classified based on the frequency of the occurrence and duration of the explosive atmosphere. The following hazardous area zone classes are defined:

2.1.4. Zone 0

Area in which an explosive gas atmosphere is present continuously, for long periods, or frequently.

2.1.5. Zone 1

Area in which an explosive gas atmosphere is likely to occur occasionally in normal operation.

2.1.6. Zone 2

An area in which an explosive gas atmosphere is not likely to occur in normal operation, but, if it does occur, will exist for a short period only.

In a later design stage, the hazardous zones could be reevaluated following the International Electrotechnical Commission IEC 60079-10-1:2021 Explosive atmospheres (which from now on will be referred to as IEC code) to identify areas in which an explosive atmosphere might occur.

2.2. Fuel characteristics

In Table 2-1 the fuel characteristics of methanol and diesel are listed.

Table 2-1: Fuel characteristics

	Methanol	Diesel	Unit
Lower heating value (LHV)	19.9	42.7	[MJ/kg]
Volumetric energy density (stored in fuel tank space)	15.7	34.2	[GJ/m^3]
Fuel density	791.0	800.0	[kg/m^3]
Lower Flammability Limit (LFL or LEL)	5.5	1.0	[%]
Upper Flammability Limit (UFL or UEL)	44.0	6.0	[%]

3. PRELIMINARY DESIGN DESCRIPTION

This report describes the preliminary design of three concepts for a high speed patrol vessel powered my methanol.. When one of the concepts is selected, and the design is further developed, this document shall be revised.

3.1. General

The system and arrangement will be designed in accordance with the ES-TRIN supplementary provisions applicable to craft equipped with propulsion or auxiliary system operating on fuels with a flashpoint equal to or lower than 55 C, see Table 3-1. Out of eight initial design concepts, three were selected for more detailed concept designs. The main particulars of these three concepts are given in Table 3-2. For the detailed description of the concept designs, see reference [1]. For the general arrangements of these concept designs, see reference [2], [3], [4].

Table 3-1 General information

Vessel Type	Inland patrol vessel
Class	ES-TRIN
Service	Inland waterways
Classification	ES-TRIN ADN ART 7.1.2.19.1 "SMALL ADN"
Flag	Dutch

Table 3-2: Main particulars of the three selected concepts

Parameter	Concept 1 Monohull 2 propeller	Concept 2 Catamaran 2 propellers	Concept 3 Monohull 3 propellers
Length OA [m]	19.95	19.95	19.95
Breadth [m]	5.00	6.80	5.50
Depth [m]	2.35	2.50	2.35
Draught [m]	1.20	1.10	1.20
Lightship weight [ton]	36.2	43.6	40.7
Deadweight [ton]	6.0	6.0	7.5
Displacement [ton]	42.7	49.6	48.2
Number of engines [-]	2	2	3

For a potential methanol fuel system, the following spaces shall be considered to be arranged on board:

- Methanol fuel storage space
- Methanol bunkering station
- Tank connection space combined with the fuel preparation space
- Methanol tank deaeration line, which is lead to a safe space

3.2. Modes of operation

During the operation of the methanol fuel system, the following modes are considered.

- Bunkering of methanol fuel
- Operating while using methanol fuel (sailing)
- Not operating while using methanol (harbor/mooring)
- Maintenance

The effects of these operational modes are listed in the next sections.

3.2.1. Bunkering of methanol

During bunkering, the vessel is moored and methanol fuel is supplied to the bunker station and subsequently to the methanol fuel tanks from the bunker source. During bunkering, the bunkering source has one liquid hose connected for each tank. The deaeration pipe, which is connected to the methanol tank and is led to a safe location prevents overpressure within the tank and releases methanol vapor to a safe place during bunkering. In this state, the cofferdam (fuel preparation space) ventilation is active in order to remove any methanol vapor due to possible leakages in the cofferdam.

3.2.2. Sailing

During sailing, methanol engines are running on methanol fuel. In this state, the methanol fuel is supplied to the methanol engines though double-walled methanol piping from the storage tanks via methanol pumps with dry running protection. A deaeration pipe, which is connected to the methanol tank prevents vacuum formation by providing an open connection to the atmosphere. The deaeration outlet is placed in a safe location to prevent the ignition of any possible methanol fumes. During sailing the cofferdam (fuel preparation space) and engine cover ventilation are active in order to remove any methanol vapor due to, possible leakages.

3.2.3. Harbor

During this mode of operation, the vessel is moored in harbor. The methanol fuel system is not in operation, but still contains methanol. The electricity required for monitoring the methanol storage is provided by a battery or via shore power. The most convenient powering method is to be defined in a later design stage.

3.2.4. Maintenance

During maintenance of the methanol system, access to methanol spaces is required. The methanol fuels system cannot be operational during maintenance activities. However, to create a safe working environment the active ventilation of methanol spaces must be in operation during maintenance activities.

4. FUNCTIONAL DESCRIPTION

In this chapter a functional description of the methanol fuel system is provided. The functional description is divided in the following sub systems: bunker station, methanol fuel storage tank, Tank connection space, double walled piping, ventilation system, and inherent safety features.

4.1. Bunker station

The bunker station is the interface between the bunker supply and the vessel. During bunkering an external hose is connected to one of the two methanol tank filling lines to supply methanol. The bunker station is placed outside on the port side of the main deck in an open, well-ventilated space.

The bunkering hose is to be equipped with a break-away coupling, in case of high external forces the coupling will break away, whereupon the breakaway valve will automatically close to prevent the release of methanol. Wherever bunkering filling line is routed through a non-hazardous space inside the hull it is to be double-walled Each methanol tank has a deaeration line to prevent pressure buildup in the methanol tank during bunkering. The deaeration line releases the methanol vapor to a safe location. Furthermore, the outlet of the deaeration line is equipped with a flame arrestor.

4.2. Methanol fuel storage tank

Concept 1 and 3 (the two monohulls) have two side by side methanol storage tanks located inside the hull structure under the main deck.

Concept 2, the catamaran has two separate methanol storage tanks, each tank is located in its own demi hull under the main deck.

The methanol storage tanks are surrounded by cofferdams except for the parts of the tanks facing the hull below the lowest waterline. The methanol storage tanks must be constructed of suitable materials (e.g., stainless steel) for methanol fuel, which is corrosive. Alternatively, a coating to protect the tank from the corrosive properties of methanol can be applied. Each methanol tank is equipped with level transmitter and a high level alarm to prevent overfilling the tank.

4.3. Tank Connection Space (TCS)

The tank connection space is an enclosed space containing all the tank connections and tank valves. This space is combined with the cofferdam of the tank, and is located aft of the methanol storage tank.

4.4. Double walled piping

All the methanol fuel piping going through non-hazardous zones is double walled. The double walled piping mitigates the risks of loss of containment by providing a secondary barrier. The annular space between the inner and outer pipe will be filled with nitrogen (inerted). The annular space can be manually filled by connecting a compressed nitrogen bottle to one of the nitrogen supply connections on the annular space.

Pressure and temperature sensors are used to monitor the pressure and temperature 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. Any accumulated methanol in the annular space can be drained by gravity to the methanol storage tank.

4.5. Ventilation system

Enclosed spaces that are identified as hazardous areas require a separate ventilation system. Spaces that are identified as hazardous zones are the combined tank connections space and cofferdam.

Furthermore, the ScandiNAOS engine require continuous extraction ventilation of their engine cover.

Therefore, two extraction ventilation systems, each with two fans, are connected to each methanol engine and combined tank connection space and cofferdam. In case one of the ventilators fails the system will automatically switch over to the other fan. In case of fire, the ventilation to the corresponding room should be shut down to limit the available oxygen. If the ventilation system fails an ESD will be initiated. The redundant fans servicing the engine cover and combined tank connection space and cofferdam must automatically switchover every time the engines are started to prevent hidden failure of fans.

Each methanol ventilation inlet is equipped with a non-return damper in order to prevent backflow of methanol vapors to non-hazardous areas.

4.6. Inherent safety 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, the effects of fire or an explosion when flammable methanol vapor gets ignited, and exposure of personnel to toxic methanol fumes. 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 vapor/air mixtures, and to avoid exposure of personnel, is to apply second barriers in the following locations:

- All methanol piping going through non-hazardous spaces shall be double-walled with an inerted annular space.
- The methanol storage tanks are surrounded by a cofferdams, creating a secondary barrier between the engine room, accommodation, and the methanol storage tank.

Elimination of ignition sources

To minimize the risk of ignition, all equipment installed in hazardous zones is ATEX certified. ATEX certified equipment is designed to operate in flammable atmospheres without igniting them.

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.

5. INTEGRATION

5.1. Arrangement

The methanol system is distributed over the following spaces:

- **Methanol fuel storage tank:** located midship on the bottom of the hull.
- **Methanol bunkering station:** located at PS on main deck above the methanol tank.
- **Tank connection space combined with the fuel preparation space:** space within aft cofferdam with methanol tank connections and equipment to filter and supply methanol to the engines.
- **Methanol tank deaeration line:** connection between the methanol tanks and a safe location above the superstructure.
- **Engine room:** contains the engines and is located aft of the methanol tanks.

The locations of the above mentioned spaces are shown in the general arrangement for each concept, see reference [2], [3] and [4].

5.2. Access, inspection and replacement

All the areas listed in the previous section shall provide a repairable and replaceable access route, dedicated hatches, or manholes to the equipment and components. All access routes are to be fitted with sufficient warning signs.

5.3. Hazardous areas

The definition of hazardous areas is described in Chapter 2.1. The hazardous area zoning of the bunker station during bunkering, methanol storage tanks and cofferdams is based on the prescriptive requirements of the IGF code. Hazardous zones determined by these rules and regulations are based on the flammability of gases. The identification of hazardous zones is performed in compliance with the requirements provided by the rules.

For the other hazardous zones the IEC 60079-10-1 code is used. These hazardous zones are defined according to the procedure defined in IEC 60079-10-1 and are based on the methanol (vapor) flow in pipes as well as leakage rates of fittings.

The IGF code defines the following hazardous zones:

Hazardous area of zone 0

Hazardous areas of zone 0 include, but are not limited to:

- The interiors of fuel tanks, pipes and equipment containing fuel, any pipework of pressure-relief or other venting systems for fuel tanks.

Hazardous area of zone 1

Hazardous areas of zone 1 include, but are not limited to:

- Tank connection spaces, cofferdams, fuel preparation rooms, fuel storage hold spaces, inter barrier spaces, enclosed bunkering stations and other enclosed spaces where leakage of methanol may occur.
- Enclosed spaces in which pipes containing fuel are located, e.g. secondary enclosures around fuel pipes.
- Areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet, gas or vapor outlet, bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room outlets and fuel tank openings for pressure release provided to permit the flow of small volumes of gas or vapor mixtures caused by thermal variation.

Hazardous area of zone 2

Hazardous areas of zone 2 include, but are not limited to:

- Areas within 1.5 m surrounding open spaces of zone 1 as specified in the section above.

Furthermore, based on the IEC 60079-10-1 code the following hazardous zones are defined:

Hazardous area of zone 1

Hazardous areas of zone 1 include, but are not limited to:

- Areas in the proximity of the methanol space ventilation outlet. The exact sizes of these hazardous zones are to be calculated using IEC 60079-10-1 once the design is sufficiently mature to determine the methanol leaking rates.

Hazardous area of zone 2

Hazardous areas of zone 2 include, but are not limited to:

- Area within 1.1 m of the methanol tank deaeration pipe outlet during bunkering.
- Areas in the proximity of the methanol tank deaeration pipe outlet during sailing. The exact sizes of these hazardous zones are to be calculated using IEC 60079-10-1 at a later design stage.

6. IDENTIFICATION OF INTERFACES BETWEEN THE ALTERNATIVE AND OTHER SYSTEMS

The methanol system interfaces with multiple conventional systems of the patrol vessel. The following systems are identified as major interfaces between the alternative design and the conventional features.

- Vessel geometry
- Electrical system
- Cooling system
- Alarm, Monitoring and Control system
- Fire detection and firefighting system
- Emergency lighting

6.1. Vessel geometry

The methanol system impacts the outside of the patrol vessel. A methanol tank deaeration pipe is located above the superstructure. Furthermore, the separate methanol ventilation system requires separate air inlets and outlets, which cannot be located near each other or near the inlets and outlets of the conventional ventilation system. Therefore, methanol ventilation outlets are placed at the aft of the vessel. Lastly, a dedicated methanol bunker station is located at the portside on the main deck above the methanol fuel tank.

Furthermore, on the inside of the vessel space is arranged for combined tank connections spaces and cofferdams, and methanol fuel tanks.

6.2. Electrical system

Multiple electrical users of the methanol fuel system (e.g., methanol fuel pumps) are connected to the electrical system of the vessel. The methanol engines are controlled from the bridge. Multiple alarm, monitoring and sensing fittings, installed within the methanol fuel system are connected to the electrical system of the vessel and are controlled from the bridge.

6.3. Cooling system

The main methanol engines will use a conventional engine cooling systems.

6.4. Alarm, Monitoring and Control System (AMCS)

The patrol vessel will have an integrated AMCS that monitors and controls the regular and methanol systems. The system will be used to start or stop the engines and regulate power.

The methanol power 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.

6.5. Fire detection and firefighting system

All rooms will be equipped with fire detection that will be integrated in the vessel's system. The engine room and fuel preparation space (within the cofferdam) shall be fitted with an alcohol resistant aqueous film forming foam (AR-AFFF) firefighting system. The regular Fi-Fi system will supply water to the AR-AFFF firefighting system.

6.6. Emergency lighting system

Emergency lighting systems for the methanol fuel system shall be provided so that escape routes and control or operation stations, which are required in an emergency, remain illuminated in the event of loss of normal lighting. The emergency lighting system shall be integrated with the vessel’s overall emergency lighting system.

7. DESIGN APPROVAL BASIS DOCUMENTS

7.1. Functional performance requirements

The patrol vessel shall have a safe and operatable methanol propulsion.. The methanol propulsion system shall provide enough power to reach the speed of 40 km/h. Furthermore, the methanol propulsion system shall have sufficient fuel storage capacity to sail 40 km/h for 12 hours.

7.2. Principles underlying the design

In order to support a safe and efficient design, construction and operation of the methanol power system, the 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-fueled 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 vessel, 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 overpressure 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 sources 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.

7.3. 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 to the environment. The safety philosophy is based on the safety objectives (listed in 7.2).

As the starting point, the safety philosophy is based on a single point of failure principle. Per failure, a worst-case scenario is determined. The safety philosophy regarding methanol is established to prevent/limit loss of containment and exposure to crew and environment. The safety philosophy is obtained by the application of double-walled piping, methanol detection and ventilation.

Worst case scenario in a single point of failure.

- Worst case determination derived from land-based installation failure consequence analysis.
- Worst case calculation methods set up according to the theoretical solubility of methanol.
- Dos and Don’ts of liquid methanol based on fact sheets and safety data sheets.
- Determine the pros and cons of various mitigation solutions given by ES-TRIN.
- Step-by-step paper study of what happens to methanol liquid and vapor in four overall scenarios.
    - Liquid methanol in water below the waterline.
    - Liquid methanol spills on top of water.
    - Methanol vapor spills on top of the water surface.
    - Methanol vapor sprayed with water mist.
- Mitigation system determined according to liquid and vaporized methanol characteristics.
- Supporting calculations set up to find system requirements.
- Internally peer-reviewed system and calculations.
- Expert opinion of recognized institutes on calculation methods and systems philosophy.
- Design principle for water washing based on removing, vaporizing, and dissolving.

To mitigate the above-mentioned hazards and to comply with the safety objectives, the safety systems applied to the methanol power 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.
- Leakage of methanol shall be detected and alarmed.

- An Emergency Shut Down (ESD) system shall be arranged to automatically isolate the fuel supply and ignition source upon a fault condition in accordance with rules and the installations safety philosophy.
- The control, monitoring and safety systems shall be arranged to minimize the likelihood of unintended shutdowns of the fuel supply system.

To mitigate the risks of potential loss of containment, double walled piping is applied for methanol piping in non-methanol spaces. The annular space of the double walled piping will be filled with nitrogen (inerted). The methanol tanks shall be surrounded by protective cofferdams, except for the surfaces that are below the lowest possible waterline.

7.4. Calculations and assumptions

The following calculations are to be executed:

- Hazardous zone calculation methanol deaeration pipe
- Hazardous zone calculation methanol bunker station

7.5. General arrangement

A general arrangement has been made for each concept; reference is made to the General arrangement drawings:

- **23.516-000-001-REVD-GENERAL ARRANGEMENT CONCEPT 1**
- **23.516-000-001-REVD-GENERAL ARRANGEMENT CONCEPT 2**
- **23.516-000-001-REVD-GENERAL ARRANGEMENT CONCEPT 3**

7.6. Methanol fuel system diagram

A methanol fuel system diagram has been made; reference is made to the methanol fuel system diagram:

- **23.516-327-100-REVA-METHANOL_SYSTEM_DIAGRAM**

7.7. Hazardous zone plan

A hazardous zone plan has been made; reference is made to the Hazardous zone plan:

- **23.516-570-104-REVA-HAZARDOUS ZONE PLAN**

8. LIST OF CODES AND STANDARDS APPLIED

The safety of the methanol 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 system complies with the above-mentioned SOLAS regulations.

- ES-TRIN Chapter 30 + Annex 8
- IMO International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels
- IEC 60079-10-1 Classification of areas – Explosive gas atmospheres (IEC-code)
- SGMF (Society for Gas as a Marine Fuel) guidance on the safe and responsible use of gases as sustainable marine fuels.
- NR 670 DT R02 Bureau Veritas (BV) Rules for Methyl/ethyl alcohol Fuelled Ships.
- European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (AND).

9. RISK ASSESSMENT PLAN

In view of the eventual methanol upgrade, the procedure for HAZID and AiP is presented below.

9.1. Project category

To estimate the extent of work to be performed and submitted, MSC.1/Circ.1455 section 6.2 is used. This paragraph indicates the work to be performed and submitted based on the relation between the Project Category, the requirements in the risk assessment and the amount of documentation. To determine the project category, MSC.1/Circ.1455 section 4.6.4 Table 1 is used as shown in Table 9-1.

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

Table 9-1: Project category.

Currently there are several applications of methanol engines on vessels. For example, Fugro Pioneer is a survey vessel, which is refitted with methanol ScandiNAOS engines to operate on methanol. Furthermore, test have been conducted with methanol engines both in laboratory and on a pilot vessel.

The technology status is “limited field history”, internal combustion engines are a mature and proven technology and methanol engines are being used on vessels. However, more powerful methanol engines availability is still limited with developments ongoing. According to Table 9-1, the project category of the methanol power system is 2. The requirements for the risk analysis are determined following section 6.2 of MSC.1/Circ 1455 as gathered in Table 9-2.

Risk assessment subject	New application of novel or unproven 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 9-2: Risk assessment requirements for project category 2.

Plans to comply with the basic risk assessment (A) are demonstrated in the following sections:

- Equivalent level of safety (9.2)
- Risk acceptance criteria (9.3)
- Risk assessment (9.4)
- Approval in Principle (9.5)
- Project Health Safety and Environment (HSE) action list (9.6)

9.2. Equivalent level of safety

The methanol power system 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 system must be comparable to conventional systems. This can be derived from the functional requirements of the IGF-code and ES-TRIN Chapter 30 + Annex 8.

9.3. Risk Acceptance Criteria

The risk index is provided in Table 9-3 below. The criticality (C) is defined as the product of the frequency (F) of the event and the potential severity (S) of the event.

Risk Index (RI)						
Frequency (F)		Severity (S)				
Frequency (per ship/year)	Frequency description	1 Negligible	2 Minor	3 Severe	4 Critical	5 Catastrophic
10^{-1} or higher	5 Extremely probable	C3	C4	C5	C5	C5
≤ 10^{-1} till 10^{-2}	4 Reasonably probable	C3	C4	C4	C4	C5
≤ 10^{-2} till 10^{-3}	3 Remote	C2	C3	C3	C4	C4
≤ 10^{-3} till 10^{-4}	2 Improbable	C1	C2	C2	C3	C3
≤ 10^{-4}	1 Extremely improbable	C1	C1	C2	C2	C3

Table 9-3: Risk index.

The project risk acceptance criteria are in accordance with the As Low As Reasonably Practicable (ALARP) principle. Hazards in the green area are accepted, and hazards from C2 to C4 will be treated according to a cost-benefit principle to assess whether they should be reduced. As a general guideline, hazards from C3 to C4 shall be reduced if possible. Unacceptable risks C5 are indicated in red, these hazards must be eliminated or reduced.

9.4. Risk assessment

The Hazard Identification (HAZID) method is to be 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 methanol power system has an equivalent level of safety to these.

Potential risks or knowledge gaps will be identified in the risk assessment, these will be included in the Project HSE Action list. A risk is identified in one of the following risk impact categories in Table 9-4.

Risk level	Code	Impact
High	H	High priority. Showstopper. Risk is unacceptable.
Medium	M	Medium priority. Point of attention to be dealt with. The risk is medium. Reasonably practicable mitigation measures should be implemented. Additional or alternative mitigation measures should be identified
Low	L	Low priority. The risk is low. Reasonably practicable mitigation measures are implemented.

Table 9-4: Levels of importance/priority

The HAZID is then performed as a high-level risk assessment which will follow a structured approach, listing different areas and guidewords/hazards. This methodology is a combination of identification, analysis and brainstorming driven by a structured list of potential hazards taking advantage of the experience of workshop participants. An overview of the risk assessment methodology is presented in Figure 9-1.

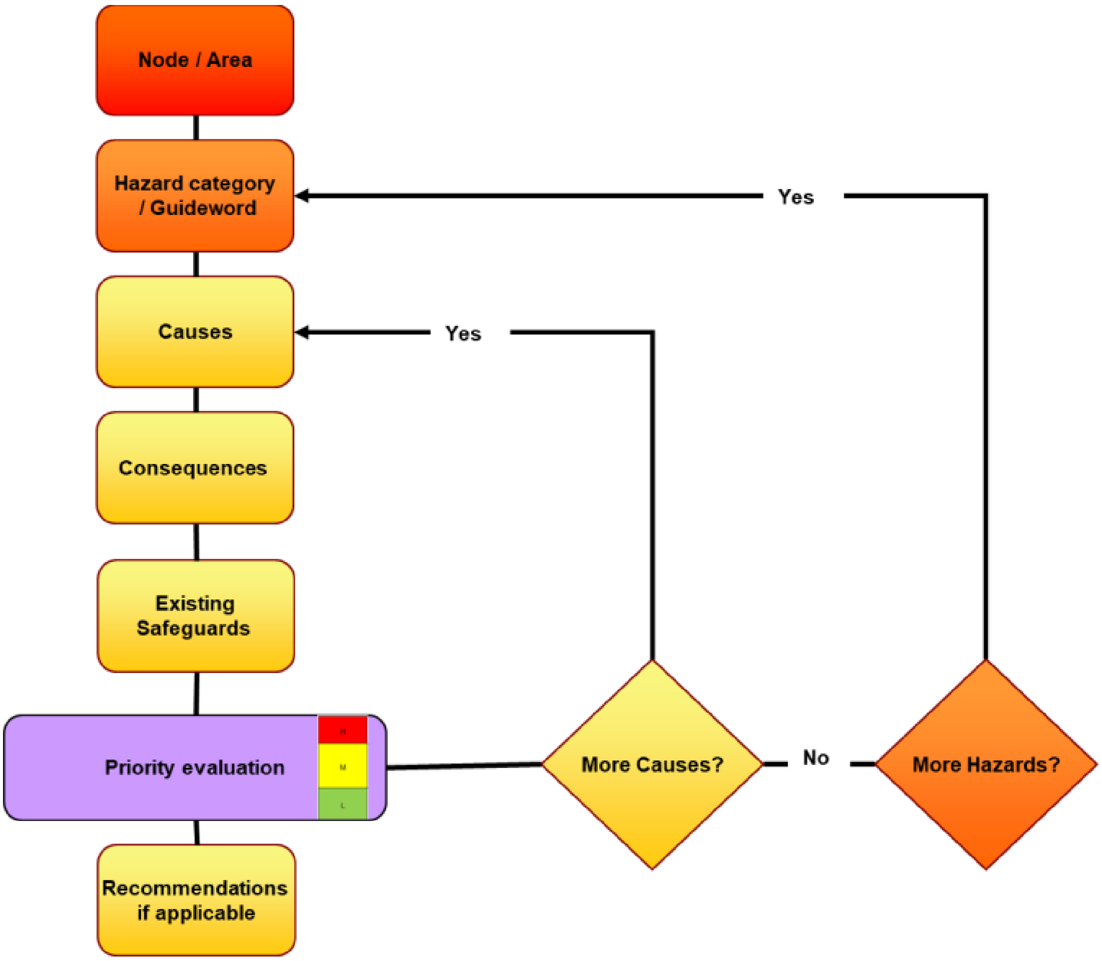

Figure 9-1: Risk Assessment Methodology

According to the defined scope, nodes are defined to structure the workshop. The nodes and hazard categories will be used to give some structure to the workshop. Each hazard category contains a list of guidewords, which are used as prompts during the workshop to develop credible causes and direct and indirect consequences. The categories are:

1. Fuel tanks
2. Combined tank connection space and cofferdam
3. Bunker station
4. Piping
5. Fuel tank deaeration line

Where possible, hazards are mitigated with appropriate existing safeguards to reduce the risks and where the safeguards are deemed insufficient, action opportunities or recommendations are identified. A safeguard is a prevention or mitigation method which, according to its nature, can decrease either the likelihood of the causes or the severity of the consequences of the hazardous event.

9.5. Approval in Principle

Once the HAZID has taken place, the results should be incorporated in the design documentation. After the design documentation is updated it could be used to obtain an Approval in Principle (AiP).

9.6. Project HSE action list

The items of the project HSE action list will be assigned to action parties. The actions on the project HSE action list will be assessed regularly during the design phases to ensure that they are included in the design, and to ensure that sufficient protection is provided.

10. TESTING AND ANALYSIS PLAN

A testing and analysis plan is to be provided before the approval by Class. This plan describes all the tests or analyses 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 in accordance with and based on information required equipment suppliers and class.

11. HIGH LEVEL CONCLUSION

This report provides the documentation for a preliminary methanol design. It may serve as a foundation to be further developed in view of a potential methanol integration. The following aspects are especially considered in the current design stage. Whether a later stage is addressed, they should be taken into account and investigated in more detail.

- Means for the safe installation of a methanol storage tank below deck requires at least:
    - Selection of suitable materials;
    - Accounting for thermal effects on the construction, if any;
    - Provisions for suitable room ventilation;
    - Minimize the risk of loss of containment;
    - Mitigating measures of loss of containment.
- Means for the safe operation of the methanol power generation system requires at least:
    - Provisions for suitable room ventilation;
    - Provisions for suitable combustion exhaust system;
    - Minimize the risk of leaks;
    - Mitigating measures in case of leaks.
- Prevention of blackout in case of an unintended shutdown of the methanol power generation system.
- Means for a safe bunkering of methanol.

In addition, this report covers the necessary documentation for conducting a potential HAZID. To this effect, these inputs shall be accordingly updated based on the subsequent design phase conclusions. The design and safety statement should then incorporate the recommendations and further developments received from the HAZID results. Afterwards, the updated documentation can be used to obtain an Approval in Principle (AiP) for the methanol patrol vessel.

Provided that an AiP is obtained, a full Class approval can subsequently be achieved as a result by demonstrating an equivalent level of safety. The equivalent level is to be demonstrated by 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, and the identified risks should be mitigated to an acceptable risk level.