SUMMETH

SUMMETH – Sustainable Marine Methanol

Hazard Identification Study for the M/S Jupiter Methanol Conversion Design

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PROJECT PARTNERS

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ABSTRACT

This report describes the hazard identification study carried out for the *M/S Jupiter* road ferry methanol conversion design. The study identified hazards through two structured hazard identification meetings and a review of historical accident and incident data for free sailing road ferries. The hazard identification sessions covered the main areas affected by conversion to methanol operation, including methanol bunkering, storage, the pump area, and fuel transfer to the engine. Hazard scenarios identified as part of the work were ranked according to frequency and severity and all were considered to be in the "low risk" or "as low as reasonably practicable" (ALARP) risk area. Safeguards and follow-up areas were identified for the ALARP risks.

SUMMETH PROJECT SUMMARY

SUMMETH, the **Su**stainable **M**arine **Meth**anol project, is focussed on developing clean methanol engine and fuel solutions for smaller ships. The project is advancing the development of methanol engines, fuel system installations, and distribution systems to facilitate the uptake of sustainable methanol as a fuel for coastal and inland waterway vessels through:

- developing, testing and evaluating different methanol combustion concepts for the smaller engine segment
- identifying the total greenhouse gas and emissions reduction potential of sustainable methanol through market investigations
- producing a case design for converting a road ferry to methanol operation
- assessing the requirements for transport and distribution of sustainable methanol.

The SUMMETH project consortium consists of SSPA Sweden (project coordinator), ScandiNAOS (technical coordinator), Lund University, VTT Technical Research Centre of Finland, Scania AB, Marine Benchmark, Swedish Transport Administration Road Ferries, and the Swedish Maritime Technology Forum.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

1 INTRODUCTION

This report describes the hazard identification study done for the *M/S Jupiter* road ferry methanol conversion design developed as part of the Sustainable Marine Methanol (SUMMETH) project, Work Package 4. The methanol conversion design was prepared by project partner ScandiNAOS for the Swedish Transport Administration Road Ferries vessel *M/S Jupiter* and is described in detail in report D4.1 (Bomanson and Ramne, 2018). The general arrangement and vessel specifications served as the basis for the hazard identification study.

2 OBJECTIVES

The objectives of the hazard identification study were to:

- identify relevant and foreseeable hazards associated with the methanol conversion design for the *M/S Jupiter*, focussing on the areas of bunkering, fuel tank room (including pumps), and engine room
- describe cause and effects of hazards where possible
- estimate the frequency and consequence of hazards where possible
- identify any scenarios and hazards that may potentially need more in-depth risk analysis or risk mitigation measures.

3 BACKGROUND

Methanol is a low flashpoint fuel that has been used in only a few marine applications to date, with the first being on the RoPax ferry *Stena Germanica*, which has been operating since 2015. This was followed by seven chemical tanker new builds that were put into service in 2016. These ships have large methanol / diesel dual fuel engines and systems that were developed specifically for the vessels. There are not yet any smaller commercial vessels such as road ferries and inland waterway vessels that have used methanol as a fuel.

The SUMMETH project has the overall goal of developing methanol engine and fuel solutions for smaller ships. Part of the project work includes developing and analyzing a methanol conversion design of a case study vessel, the *M/S Jupiter*. The safety analysis part of the work included a hazard identification study, which is described in this report.

3.1 GUIDELINES AND REGULATIONS

International guidelines and classification society rules are still under development for the use of low-flashpoint liquid fuels, with methanol one of the main fuels in focus. The International Maritime Organization's (IMO) Safety of Life at Sea Convention (SOLAS) states that fuels should have a minimum flashpoint of 60^{o} Celsius, and because methanol's is 12^{o} Celsius, a risk assessment must be carried out for each methanol installation to demonstrate equivalent fire safety to conventional fuels for marine use. This provision for allowing use of a lower flashpoint fuel is specified in SOLAS Chapter II-2 Part F Reg. 17. The International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels (IGF CODE) is under development for methanol and ethanol (which will be covered in "Part A-2") and this should facilitate the use of such fuels. The IGF code part A, covering LNG, came into effect in 2017. Sweden is coordinating the correspondence group that is developing the code further to cover aspects such as methanol / ethanol fuel. The most recent meeting of the correspondence group was in September 2017, where an updated version of the "Draft Technical Provisions for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel" was developed and discussed.

Vessels that do not operate in international waters, such as the Swedish Transport Administration's road ferries, or smaller vessels, such as pilot boats, may be operating on a national certificate and as such national regulations apply. For the *M/S Jupiter* and other Swedish road ferries, the national regulations "Transportstyrelsens föreskrifter" apply. Regulation "TSFS 2014:1 Transportstyrelsens föreskrifter och allmänna råd om maskininstallation, elektrisk installation och periodvis obemannat maskinrum" applies to engine room installations, electrical installations, and periodically unmanned engine rooms, and is applicable to the design for the methanol conversion for the *M/S Jupiter*. Chapter 35 of this regulation allows alternative design of engine and electrical installations if an analysis is done showing equivalent safety to conventional systems. Guidelines for this type of analysis are provided in MSC.1/Circ 1212, "Guidelines on Alternative Design and Arrangements for SOLAS Chapters II-1 and III". These guidelines state that identification of hazards and specifying accident scenarios are key to the alternative design methodology.

3.2 Risk Assessment

Hazard identification and specification of accident scenarios are part of the risk assessment process, which also includes analysis of the probability and consequences of relevant accident scenarios and assessment of the risk level to determine whether additional risk control measures need to be implemented. The main steps in a risk assessment process are shown in Figure 1.

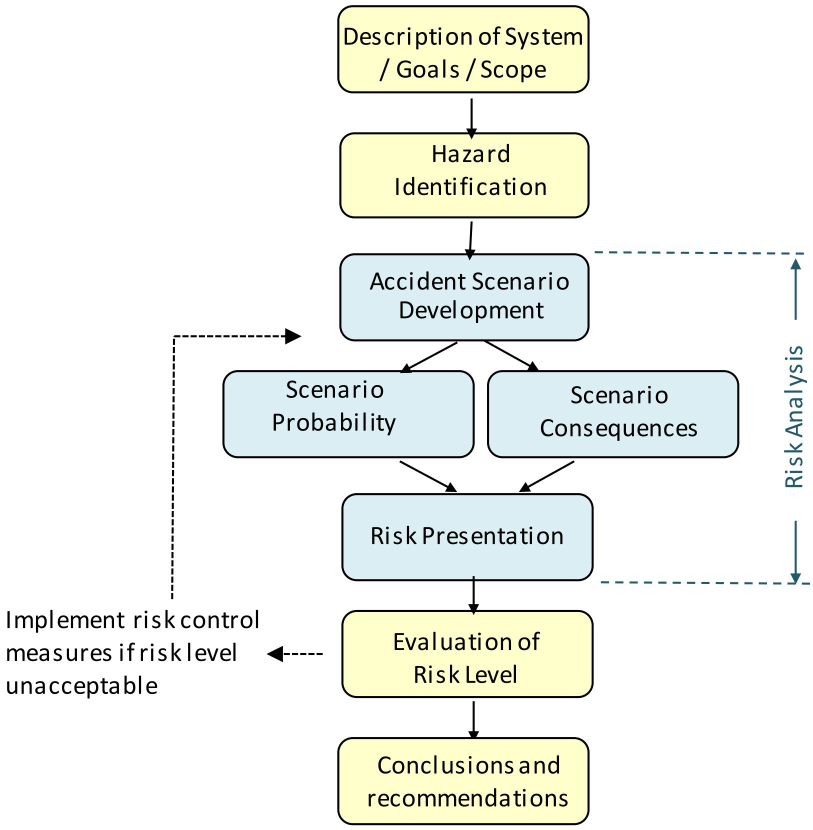

Figure 1. *Risk Assessment Process*

Risk assessment is used in many industries, and there are ISO standards for carrying them out. The International Maritime Organization has developed guidelines for “Formal Safety Assessment” (FSA), which is a risk assessment method to be applied as a tool as part of the IMO decision making process.

The first step of the risk assessment process is describing the system and/or problem to be analysed and setting the boundaries for the study. The hazard identification phase of the study has the purpose of developing a list of hazards and associated accident scenarios. Identified accident scenarios should then be assessed in terms of the expected frequency and consequence of the scenarios. A more detailed risk analysis investigating causes and consequences should then be carried out for the important scenarios identified during the hazard identification phase. If the risk analysis identifies high risk areas that need to be addressed, then risk control options should be generated and assessed in terms of risk reduction effect.

The IMO’s Guidelines for Alternative Design (MSC.1/Circ 1212) state that hazard identification is a crucial step in developing casualty scenarios for comparing alternative designs. Hazards may be identified using historical and statistical data, hazard evaluation techniques, expert opinion, and experience.

4 METHOD AND SCOPE

The hazard identification study carried out for the methanol conversion design for the *M/S Jupiter* included the following:

- Two hazard identification meetings, held 24 March 2017 and 21 September 2017, carried out as a structured group review
- Review of accident and incident data for road ferries from the Swedish Transport Agency's casualty database to identify possible casualties and estimate frequencies.

The hazard identification covered the main areas affected by conversion to methanol operation, as follows: methanol bunkering, storage, the pump area, and fuel transfer to the engine.

4.1 HAZARD IDENTIFICATION MEETINGS

Details of the two hazard identification meetings were as follows:

4.1.1 24 March 2017 Meeting:

The first hazard identification meeting was held 24 March 2017 and included a presentation of the *M/S Jupiter* methanol conversion, an overview of the hazard identification process, and a structured group review to identify hazards. The participants' names, titles, and company affiliation are shown in Table 1.

Table 1. *List of Participants in the Hazard Identification Meeting held 20170324*

Participant Name	Company	Title
Fredrik Almlöv	Swedish Transport Administration Ferry Operations	Technical and Environmental Head
Peter Jansson Peterberg	Swedish Transport Administration Ferry Operations	Environmental Coordinator
Joakim Bomanson	ScandiNAOS AB	Naval Architect
Bengt Ramne	ScandiNAOS AB	Naval Architect
Nelly Forsman	SSPA Sweden AB	Risk Analyst
Joanne Ellis	SSPA Sweden AB	Project manager, risk and environment specialist
Mats Bengtsson	Lund Technical University	Research engineer, combustion engines
Sam Shamun	Lund Technical University	Doctoral student, combustion engines

The hazard identification focused on the functions affected by the methanol conversion design. Four functional areas were used as the basis of the discussion:

- Bunkering
- Fuel Storage
- Pump area
- Engine room

The following guide words were used to help brainstorm hazard scenarios: leakage, rupture, corrosion, fire, mechanical failure, control system failure, human error, impacts, manufacturing defects, and material selection.

Notes from the hazard identification meetings were recorded in an Excel spreadsheet. It was not possible to complete the discussion of all nodes during the first meeting so a second meeting was scheduled.

Prior to the second meeting Joanne Ellis and Joakim Bomanson met on 24 August 2017 and 1 September 2017 to fill in additional information and gaps remaining after the first hazard identification meeting.

4.1.2 21 September 2017 Meeting

The second hazard identification session was held 21 September 2017 and included both a review of the hazard identification Excel spreadsheet and an "open brainstorming" discussion regarding the design and possible incident scenarios. The participants' names, titles, and company affiliation for this meeting are shown in Table 2.

Table 2. *List of Participants in the Hazard Identification Meeting held 20170921*

Participant Name	Company	Title
Fredrik Almlöv	Swedish Transport Administration Ferry Operations	Technical and Environmental Head
Peter Jansson Peterberg	Swedish Transport Administration Ferry Operations	Environmental Coordinator
Tim Flink	Swedish Transport Administration Ferry Operations	Captain M/S Jupiter, worked on Swedish Transport road ferries since 1994, including all "planet" vessels
Joakim Bomanson	ScandiNAOS AB	Naval Architect
Joanne Ellis	SSPA Sweden AB	Project manager, risk and environment specialist

5 System Description

The Swedish Transport Administration road ferry *M/S Jupiter* is a free sailing road ferry that was built in 2007 at the Työvene shipyard in Finland.

Figure 2. *The M/S Jupiter (Photo by Andreas Lundqvist).*

The vessel operates on a route between Östano and Ljusterö in Stockholm's archipelago. The route length is 1100 metres and the crossing time is approximately seven minutes (Trafikverket, 2016). Thus the sailing time to the nearest land point is at most 4 minutes. The vessel operates year round, even in ice conditions. The vessel particulars of the *M/S Jupiter* and the proposed engine and tank details for the methanol conversion design are shown in the Table 3.

Table 3. M/S Jupiter Vessel Particulars and Machinery and Fuel Capacity for the Existing Vessel and the Methanol Conversion Design

M/S Jupiter Vessel Particulars		
Main Dimensions		
Length Overall (LOA)	86 m	
Breadth	14 m	
Depth	3.45 m	
Ramp Length	11 m	
GT	737 tonnes	
Design speed	11.6 knots	
Cargo		
Passengers	397	
Passenger cars	60	
Loading capacity	340 tonnes	
Machinery and Fuel Capacity for the Existing Vessel and the Methanol Conversion Design		
	Existing	**Methanol Conversion Design**
Main Engine	4 x Volvo Penta D12D-C, 331 kW, total installed power is 1324 kW	4x Spark ignited methanol engines
Fuel Tank Size	2 x 28 m^3 (diesel) (total capacity 56 m^3)	1 x 25 m^3 (methanol) 1 x 28 m^3 (diesel)

Ref: Data on M/S Jupiter from Trafikverket: https://www.trafikverket.se/farjerederiet/om-farjerederiet/vara-farjor/Vara-farjor/Jupiter/

Fuel Use and Bunkering: The vessel uses approximately one tonne of diesel fuel per day and is bunkered once every fourteen days. Bunkering is carried out from a tanker truck that parks on the deck when the vessel has a break in its regular operating schedule and there are no other vehicles or passengers on board. A similar procedure is expected to occur for methanol bunkering, except that the vessel will have to be bunkered approximately every eight days. A drip-free coupling would be used for the methanol bunkering, of the same type that is used for the *Stena Germanica*.

Classification / Design / Safety training: The Swedish Transport Agency national regulations apply to the current design and operation of the *M/S Jupiter*, with the following exception noted for the existing design regarding insulation between the deck and the engine room:

- Engine room fire insulation: There is no A60 fire insulation between the engine room and the car deck, as is the case for all of the Swedish road ferries with redundant engine rooms (one in each end of the vessel). This permits heat transfer between the engine room and the car deck and keeps the deck ice-free under winter conditions.

Training of on-board personnel consists of Basic Safety according to STCW Manila (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers) and ADR training according to SRVFS 2006:7 (ADR-S, Regulations for transport of dangerous goods by road) with training in extinguishing vehicle fires. There is no self-contained breathing apparatus equipment on board and in the event of an engine room fire on a ferry the arrangement is for land-based firefighters to carry out the main firefighting activities required. Existing on board firefighting equipment includes two fire pumps, two water canons (one at each end of the deck), a sprinkler system to protect the superstructure, and extinguishers with alcohol resistant foam, which were introduced when vehicles using ethanol fuel became more common on board.

5.1 METHANOL CONVERSION DESIGN

The methanol conversion design is based on the available rules and changes have been done continually in parallel with the risk analysis. This section represents a summary of the design, for more details see report D4.1 “General Arrangement”.

The main work for conversion is to modify Tank Room 1. The existing Tank Room 1 and Tank Room 3 contain one independent diesel tank each and also serve as the main passage way to the machinery rooms aft and forward of the tank rooms. Tank Room 2 in the middle contains auxiliary tanks, switchboard and fire station.

Tank room 1, in the aft, will be divided in two parts with a new watertight and gastight bulkhead along the centre line. Port side of the bulkhead will define the methanol tank room. The existing fuel tank will be modified for methanol either with internal coating or installation of a new tank. Connections on the tank will need to be modified and the tank is also to be equipped with nitrogen inertion and new tank ventilation.

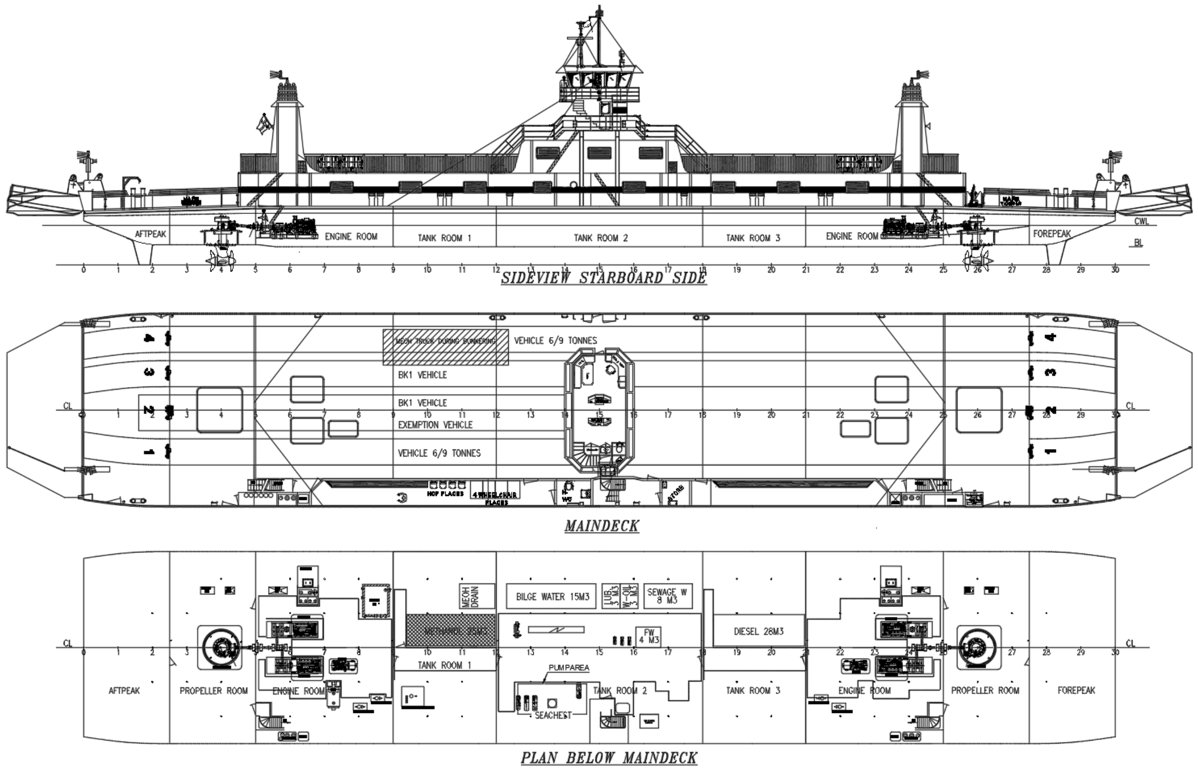

Figure 3. *General overview of Jupiter. Tank room 1 will be converted to a methanol tank and pump room with a new water and gas tight bulkhead along the centre line. Methanol fuel pumps and other equipment on the fuel valve will be located inside the pump room. Individual double walled fuel pipes supply the propulsion engines forward and aft with methanol.*

The room will contain individual fuel pumps for each engine, remotely operated fuel shutoff valves and fuel filters. The methanol tank room is also equipped with independent mechanical ventilation and methanol vapour detection as well as liquid leak detection. From a fire safety point of view the pump room is classified as a hazardous area and all electrical equipment is of EX type.

To prevent methanol leaks in other parts of the ferry all fuel pipes outside of the new tank room are double walled and vapour detectors are placed close to each engine. The fuel system has a working pressure of about 3 bar.

Methanol vapour detection serves as an important part of the safety system as potential leaks can be detected early and appropriate safety measures implemented before a dangerous situation can evolve.

In addition to the vapour detection system fire detection and fire suppression systems are upgraded. IR-detectors are installed to detect methanol fires in the engine rooms and pump room. For suppression of fire the gaseous total flooding system is expanded with a section for the pump room. The capacity is also expanded as the gas concentration for methanol needs to be somewhat higher to obtain the necessary safety margin compared to diesel.

Bunkering of methanol is done through a new bunker connection above the methanol tank room. The bunkering connection is a dry disconnect fast coupling.

5.2 METHANOL PROPERTIES AND CHARACTERISTICS

Selected characteristics of methanol as compared to conventional marine gas oil fuel are shown in Table 4.

Table 4. *Selected chemical and physical properties of methanol as compared to MGO (data from Ellis and Tanneberger, 2015)*

Properties	MGO	Methanol
Physical State	liquid	liquid
Boiling Temperature at 1 bar [°C]	175-650	65
Density at 15°C [kg/m^3]	Max. 900	796
Dynamic Viscosity [cSt]	(at 40°C) 3.5	(at 25°C) 0.6
Lower Heating Value [MJ/kg]	43	20
Lubricity WSD [µm]	280-400	1100
Vapour Density air=1	>5	1.1
Flash Point (TCC) [°C]	>60	12
Auto Ignition Temperature [°C]	250 - 500	464
Flammability Limits [by % Vol of Mixture]	0.3 -10	6 – 36

Other characteristics for methanol relevant from a hazard perspective include:

- burns with a clear flame which is difficult to see in daylight
- corrosive, so care should be taken with material selection (stainless steel is a recommended material for use with methanol (Methanol Institute, 2013), for seals, o-rings, gaskets, etc., material compatibility needs to be checked)
- toxic to humans by ingestion, inhalation, or contact
- in the event of a spill to water it dissolves, is biodegradable and does not bio-accumulate
- completely soluble in water, and water/methanol solutions are non-flammable when methanol concentration is less than 25% in water.

Occupational exposure limit values for methanol and diesel vapours in air are shown in Table 5.

Table 5. *Swedish Occupational Exposure Limit Values for methanol and two types of diesel / fuel oil: diesel values are specified as maximum total hydrocarbons in air*

Swedish Occupational Exposure Limit	Methanol	Diesel
Level Limit Value (LVL) – value for exposure for one working day (8 hours)	200 ppm 250 mg/m^3	Diesel MK1: 350 mg/m^3 Heating oil: 250 mg/m^3
Short Term Value (STV) – time weighted average for a 15 minute reference period	250 ppm 350 mg/m^3	

Reference: Swedish Work Environment Authority, 2005.

6 HAZARD IDENTIFICATION DISCUSSION

A record of the hazards identified during the meetings, comments recorded, and risk ratings is provided in the Excel worksheets included in Appendix I.

6.1 RISK RATINGS

Risk estimation takes into account the likelihood (frequency) and severity of an unwanted event. For the hazards identified during the hazard identification meeting, both the cause of a hazardous event occurring and the possible effects (consequences) were identified and described. For a methanol fuel system evaluation, for example, the hazardous event is the release of methanol, and one example of cause could be damage to the bunker hose. Possible effects of the release could be fire if there is an ignition source present. Severity of this could be judged by the maximum amount of fuel that could be released from the hose before transfer is stopped. The frequency and severity of each identified hazardous event were estimated using either a review of historical accident data where possible and judgement of the persons involved in the study.

6.1.1 Frequency Ratings

For some of the hazardous events identified, the cause could be a ship casualty event such as a collision, grounding, or fire that has an impact on the methanol bunkering, storage, or fuel transfer system. Data from the Swedish Sea Accident (SOS) database (SOS: "SJöOlyckssytem") was used to estimate probability of these ship casualty events that may result in consequences from the methanol fuel. SOS is a national casualty database that contains information on accidents and incidents involving Swedish flagged vessels in all waters, and vessels of all flags in Swedish territorial water. Reportable accidents to this database include events that may have resulted in personal injury or death, ship damage, or escape of harmful substance (spill). Three categories are used to describe the severity of the event: serious accident, minor accident, and incident.

Data on accidents and incidents involving Swedish road ferries over the 20-year period from 1997 to the end of 2016 was obtained from the SOS database to estimate frequency for some of the events. Data from only the free sailing road ferries was used, as cable ferries were considered to be quite different with respect to the probability of specific accident categories, such as groundings and engine room fires. Incidents/accidents occurring while the vessels were at a shipyard for maintenance were also not included. Only the accidental events in the categories "serious accident" and "minor accident" were included in the estimation of frequency. Those classified as "incident" were for the most part "near-misses", such as close proximity to another vessel when passing, that did not result in any consequences to humans or to the ship. Minor and serious accidents involving free sailing road ferries during the 20-year period 19970101 to 20161231 are shown in Figure 4.

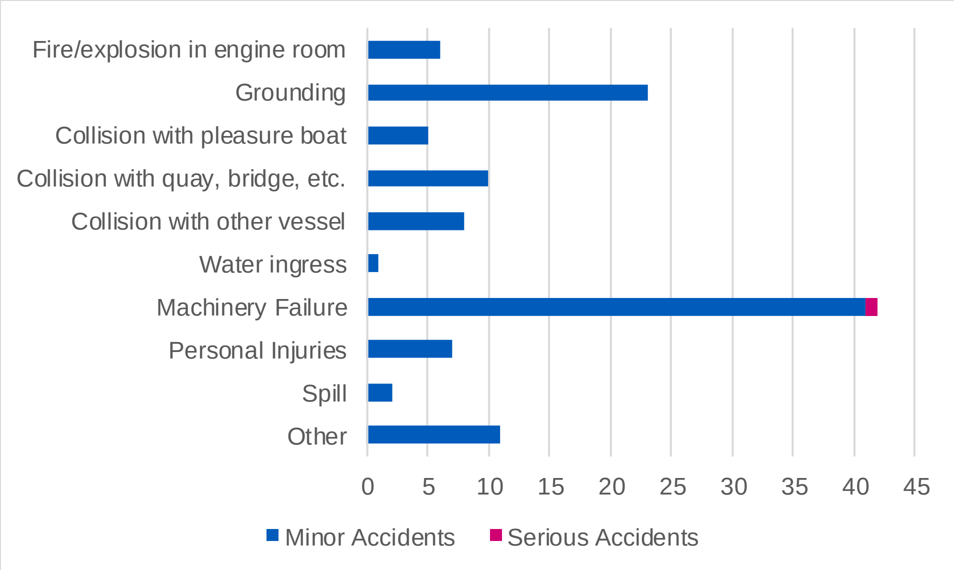

Figure 4. *Accidents involving free sailing Swedish road ferries during the 20-year period 19970101 to 20161231, categorized according to initiating event, as recorded in the Swedish Sea Accident database*

All accidents except one were categorized as minor. The accident categories that were considered possible base causes of some of the scenarios identified in the hazard identification sessions included fire/explosion, grounding, and collisions. No serious accidents were reported in these categories. Further discussion of these main categories were as follows:

- Fire / Explosion: 6 minor accidents were recorded in this category. Two of the six involved smoke development and no firefighting activities were necessary. One was a small fire that self-extinguished when the engine was stopped. The remaining three were quickly extinguished by crew. Localized damage was reported for only one of the six accidents.
- Grounding: 23 minor accidents occurred with the free-sailing vessels over the twenty-year period. For 17 of these, there was minor damage to the vessel – primarily to the propeller or rudder. For the remainder there was no damage noted in the report.
- Collision with pleasure boat: Five reported incidents, all of them were minor. Only one resulted in damage to the road ferry, and it was recorded as minor damage.
- Collision with quay, or similar fixed object: 10 incidents were reported, all described as minor, with minor damage noted for 8 of them, and no damage for the other two.
- Collision with other vessel: There were eight reported incidents, all minor, with some minor damage to the road ferry noted in five cases.

To calculate frequency of the above type of accident events, an annual fleet size of 45 free sailing ferries was used, for the 20 year period, thus giving 900 ship-years of operation. No major accidents were recorded in the fire, collision, and grounding scenarios during the 20-year period, so the frequency for major accidents was estimated as less than 1/900 (approximately 10^{-3}). Minor accidents were more frequent but were not of sufficient magnitude to initiate a methanol release scenario as described in the hazard identification spreadsheet (See Appendix I).

The scale used for estimating the frequency index of each scenario recorded in the spreadsheet was that presented in the International Maritime Organization´s Guidelines for formal safety assessment (FSA) as shown in Table 6.

__Table 6.__ Frequency Index for Accident Scenarios (from IMO's Guidelines for Formal Safety Assessment)

Frequency Index			
FI	FREQUENCY	DEFINITION	F (per ship year)
7	Frequent	Likely to occur once per month on one ship	10
5	Reasonably probable	Likely to occur once per year in a fleet of 10 ships, i.e. likely to occur a few times during the ship's life	0.1
3	Remote	Likely to occur once per year in a fleet of 1000 ships, i.e. likely to occur in the total life of several similar ships	10^{-3}
1	Extremely remote	Likely to occur once in the lifetime (20 years) of a world fleet of 5000 ships.	10^{-5}

6.1.2 Severity Rating

Severity of scenarios was also rated according to the scale presented in the IMO's Guidelines for Formal Safety Assessment, as shown in Table 7.

__Table 7.__ Severity Index for Accident Scenarios (from IMO's Guidelines for Formal Safety Assessment)

Severity Index				
SI	SEVERITY	EFFECTS ON HUMAN SAFETY	EFFECTS ON SHIP	S (Equivalent fatalities)
1	Minor	Single or minor injuries	Local equipment damage	0.01
2	Significant	Multiple or severe injuries	Non-severe ship damage	0.1
3	Severe	Single fatality or multiple severe injuries	Severe damage	1
4	Catastrophic	Multiple fatalities	Total loss	10

The IMO's Guidelines for Alternative design (MSC.1/Circ 1212) state that hazards should be grouped according to whether they are localized, major, or catastrophic. Localized hazards are considered to be those where effects are limited to a localized area. Major incidents are considered to be those that are limited to "a medium effect zone, limited to the boundaries of the ship." Catastrophic incidents are those that would have effects extending beyond the ship.

6.2 Risk Ranking

To evaluate and rank the overall risk in terms of probability and consequence a risk matrix was used, as shown in Figure 5.

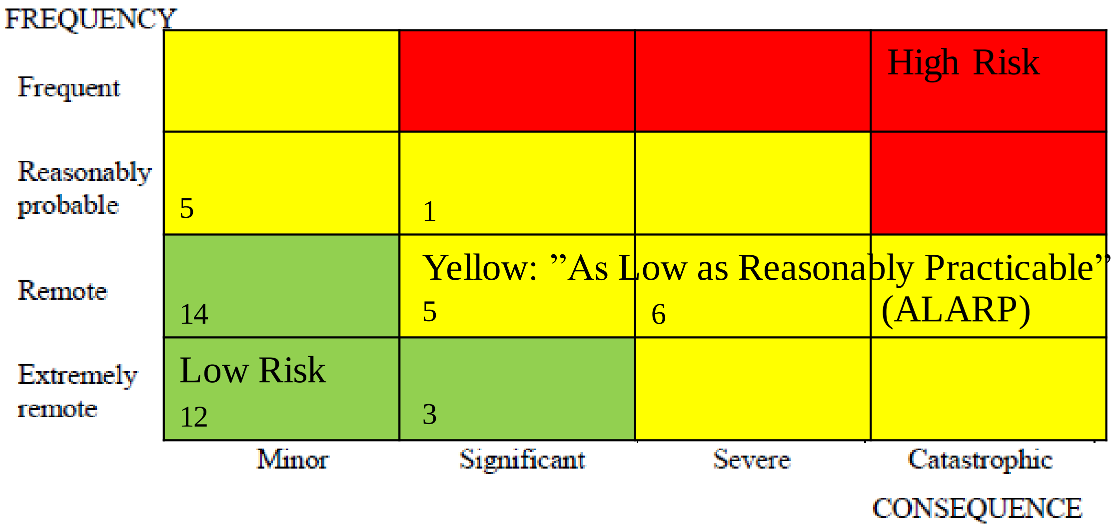

Figure 5. *Risk matrix showing number of scenarios for the case study that were ranked in each category*

The frequency and consequence of each of the scenarios identified during the hazard identification session for the SUMMETH case study were ranked, with results recorded in the Excel spreadsheet in Appendix I. The numbers shown on Figure 4 correspond to the number of scenarios achieving the specific ranking – for example 12 scenarios were estimated to be "extremely remote" with minor consequences. All scenarios were either in the green "low risk" or yellow "as low as reasonably practicable" zones. Accident scenarios that fall into the "red zone" are considered to have an unacceptably high risk level and risk reduction measures should be implemented to reduce the risk to an acceptable level. Scenarios within the yellow zone are tolerable but measures to keep the risk "as low as reasonable practicable" should be taken. Those within the green zone are considered to be acceptable.

7 Main Findings and Recommendations

The hazard scenarios identified in the workshop and sessions were all ranked to be "low risk" or "as low as reasonably practicable". It should be noted that the engine itself was not included in the hazard identification workshop, but should be covered separately by the engine supplier when engine type details are available.

Issues highlighted from the hazard identification are as follows:

- Ensure that a tank entry procedure is in place for any maintenance, and specify procedures should be specified for when the ship goes for repairs and maintenance
- All who enter the tank / pump room should have basic safety training for methanol
- Method for detection of methanol in the annular space of the double-walled pipes should be specified
- Specify procedures for draining possible methanol spills (for example if there is an accumulation under the methanol tank)
- Ensure bunkering procedure and check-list specific to methanol bunkering is developed
- Pump area leakage: consider ways to localize any leaks from connections for the four pumps in this area - perhaps have separate spill trays and detectors to determine which of the four may be leaking.
- Review engine room safety when engine selection has been finalized, considering issues such as spray guard/vent hood, gas detection.

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APPENDIX I HAZARD IDENTIFICATION WORKSHEETS

SUMMETH Project HazID Discussion of the Jupiter Road Ferry Design - Consolidated version with comments from sessions 20170324 and 20170921, with addtional ratings estimated by J. Ellis and J. Bomansor

	ITEM	CAUSE/DESCRIPTION	HAZARD	POTENTIAL EFFECTS / CONSEQUENCES	SAFEGUARDS	COMMENTS	Risk Component Rating	
							Frequency	Severity
	Node 1 Bunkering							
Node 1 Bunkering - Node 1 Bunkering - Node 1 Bunkering - ring	1.1 Leakage							
	1.1.1	Leaking bunker connection	Release of methanol onto the deck during bunkering operation.	Fire/explosion	Drip free coupling between truck and bunker line. No passengers are on board during bunkering. Exclusion/Safety Zone to be established around the bunkering station during bunkering. Establish bunkering procedures to be followed.	Prepare a specific bunkering procedure.	remote	minor
	1.1.2	hose rupture	methanol release	fire if an ignition source is present	1. Flush the spill area with water, using a spill barrier towards other areas of the deck. 2. Cofferdam, spill berm, tank to collect the spill. Inspection of the hose before bunkering, safety procedures for the tanker truck PPE: safety glasses and gloves when handling methanol. Shower and eyewash available in case of exposure. Safety routines and equipment as required by the material safety data sheet.	Determine which procedures would be acceptable from the environmental authorities: either collect the spill or flush the area with water and direct to the receiving water. Check drainage systems on deck, and whether it is possible to have a collection area.	reasonably probable for rupture, remote to have both rupture and ignition source, as bunkering should take place with no ignition sources	minor if no ignition
	1.1.3	Improprer connection of hose	methanol release	fire if an ignition source is present	As for above: 1.1.2		remote	minor
	1.1.4	tanker truck drives away with hose still connected	methanol release	fire if an ignition source is present	Flush the area with water, spill barrier towards the deck. 2. Cofferdam, spill barrier, spill tank. Inspection of the hose prior to bunkering, safety routine for the tanker truck, wheel chocks for the truck.		remote	minor
	1.1.5	Collision (ferry collision)	Tanker truck damaged, hose comes loose, methanol spill	fire if an ignition source is present	Bunkering while the ferry is berthed at the quay.		remote	minor
	1.1.6	Another vehicle collides with the tanker truck during bunkering.	Tanker truck damaged, hose comes loose, methanol spill	fire if an ignition source is present	No other vehicles permitted on deck during bunkering.		extremely remote	minor

Node 1 Bunkering	1.1.7	Leakage of valves or pipe in bunker line within vessel	Leakage of methanol into the vessel's tank room (ex classed area)	Fire/explosion	The tank room has gas / vapour detection, is ex-classed. If methanol is detected, the alarm would be triggered and bunkering would be stopped (written procedure to stop bunkering if the alarm sounds). Active ventilation of the tank room. Inspection and testing of piping, appropriate materials used.		extremely remote	minor given that detection systems and safeguards should prevent ignition if there is a spill
	1.2 Rupture							
Node 1 Bunkering	1.2.1	Bunker pipe damaged by vehicle on car deck	Release of methanol		No vehicles on deck during bunkering	When repairing a damaged bunker pipe, must empty tanks (same procedure as currently happens for diesel). Consider extra protection for bunkering pipe on deck	remote	minor - limited amount of fuel in pipe
Node 1 Bunkering	1.2.2	Hose rupture	as above for 1.1.2	as above for 1.1.2	as above for 1.1.2	as above for 1.1.2	reasonably probable for rupture, remote to have both rupture and ignition source, as bunkering should take place with no ignition sources	minor if no ignition
Node 1 Bunkering	1.2.3	Overpressure of bunker line			Not possible as it is a gravity fed line.		Extremely remote	
Node 1 Bunkering	1.2.4	Bunker pipe damaged by vehicle on car deck (not during bunkering because vehicles will not be on deck during the bunkering procedure)	Leak of N_2 gas (limited amount - only what is existing in the pipe)	Small amounts of N_2 will leak to open air	Pipe inerted after bunkering, valve on pipe at tank is closed when no bunkering is in progress. Therefore only nitrogen will leak to the open air. Protection of the bunker pipe from vehicle traffic.	Recommend that the bunker pipe is protected from vehicle traffic.	Reasonably probable, at least to sustain damage to the protection	Minor
Node 1 Bunkering	1.2.5	Bunker pipe in tank room damaged	Release of methanol	limited release of methanol	Pipe is located in safe area, high up in the room, bunkering pipe enters the top of the tank.		Extremely remote	Minor
Node 1 Bunkering	1.2.6	Side impact collision on bunker connection from another vessel	Release of methanol vapour	N2 will leak out of the bunker line	Bunker line is inerted after bunkering		remote	Minor
	1.3 Corrosion/erosion							
Node 1 Bunkering	1.3.1	Corrosion of pipes and components	Mechanical failure/leakage	Limited release of methanol into tank room.	All materials used in components to be assessed for compatibility with methanol. SS316 to be used for all piping. Tank room is an Ex classed space with gas detection and ventilation.		Remote	Minor
Node 1 Bunkering	1.3.2	Erosion/corrosion at tank filling pipe	Erosion of tank	Release of methanol	Filling pipe is going to the bottom of the tank to prevent too much movement of the fluid, as well as buildup of static electricity. Flow rate is limited. Tank room safeguards as in 1.3.1.		extremely remote	Minor
	1.4 Fire/explosion (External sources)							

Node 1 - Node 1 Bunkering - Node 1 Bunkering	1.4.1	Fire in engine room	High temperatures in the tank room	Fire/explosion	Fire protection. Bulkhead between engine room and methanol tank room to be A-60 or appropriate to limit temperature rise in tank room. Engines are not running during bunkering - connection to land electricity instead.		remote: no fires that spread during 20 years of operation	severe (results from the fire in general, not much added damage expected for methanol as compared to diesel fuel in this case)
	1.4.3	Fire on car deck during bunkering operations	Methanol in pipe could be overheated and potentially rupture the pipe	Fire/explosion	No passengers on ship during bunkering. Car deck is empty, besides bunkering truck. There is a deck wash system to cool the deck.		Remote: none recorded in accident database over 20 years	significant
	1.4.4	Lightning strike during bunkering	Potential fire	Fire/explosion	No bunkering during thunderstorms, no open ventilation to the tank.	Bunkering procedure to specify no bunkering during electrical storms.	extremely remote	minor - should be no methanol to ignite.
	1.7 Control system							
	1.7.1	Control system faliure / power loss	Loss of control during bunkering	Tank overflow/release to environment	Controls are manual - Manual valves on truck. No source of ignition during bunkering, procedures. If there is power loss on the vessel resulting in loss of active ventilation then bunkering would stop automaticallly (valves would close on the bunkering line).		remote	minor
	1.8 Human error							
		Bunkering of the wrong fuel into the tank			Different type of connection for the methanol tank - wouldn't be possible. Bunkering checklist and procedures, crew training regarding methanol handling.			
ystem	**Node 2 : Storage tank and venting system / tank room**							
	2.1 Leakage (methanol)							
	2.1.1	Methanol tank failure	Methanol will fill the tank room	Fire/explosion	Tank room is a hazardous area (Ex class), detection of methanol leaks in air and drain wells. Door to non- hazardous area gas tight. Fixed fire fighting system installed. Tank certification and regular inspection. The tank is a free standing unit and not integral.		Remote	significant
	2.1.2	Leakage from the pipe connection (master fuel pipe from the tank to the four pumps)	Methanol release into the tank/pump room	Fire if there is an ignition source. Shut down of engines, loss of power to the ship if no redundancy	EX classed equipment, non-sparking tools, shut down procedure.	Need to think about redundancy - possibly two master fuel valves or tank connections for redundancy - each one goes to two pumps. Current design has engine rooms in both ends of the vessel, providing redundancy.	Remote	Significant with redundant engine room. Severe (if no redundancy is in place).
	2.1.3	Leakage from the pipe connection (tank to pumps: individual fuel pipes to each of the four pumps. Pipes originate from the T-connection to the master fuel pipe	Methanol release into the tank/pump room	Fire if ignition source. Shut down of affected pump and engine (one out of four).	EX classed equipment, non-sparking tools, shut down procedure.	How to determine which of the pipes are leaking? Think about a way of localising the leak location - such as individual spill trays and detectors for each of the four pipes, and put spill detectors around connectors.	Reasonably probable	Minor - loss of one engine but there is redundancy.

Node 2 : Storage tank and venting system

2.1.4	Nitrogen gas system stops functioning.	Methanol vapours enter the venting system	release of methanol from the vent	Safety zone around the vent, low pressure alarm for the nitrogen system, safety procedures		Remote	Minor
2.1.5 Leaks into space under tank (bottom plating)	Methanol pools in space under tank (this is only expected to happen with a large leak).	Vapour build up under tank	Fire/explosion. Methanol vapour could build up in space under tank. Require stop in service to clean up.	Vapour detection specifically located in lowest area, EX safe space, ventilation , fire insulation on the bulkhead towards the engine room.	Need procedure for safe removal of any spill that accumulates.	Remote	significant
Leakage - N_2 into confined space							
2.1.6	Methanol tank fracture above liquid line	N_2 in tank room	Insufficient breathing atmosphere in tank room	tank inspection, detectors in tank room (for O_2), ventilation	Recommend oxygen sensor in tank/pump room to warn if atmosphere becomes un-breathable	Extremely remote	minor
2.1.7	Failure from methanol bunker line where it enters into tank	N_2 in tank room	Insufficient breathing atmosphere in tank room	detectors in tank room, ventilation	Recommend oxygen sensor in tank/pump room to warn if atmosphere becomes un-breathable	extremely remote	minor
2.1.8	Leakage of N_2 from N_2 storage tanks (stored on deck)	N_2 in nitrogen storage room	Insufficient breathing atmosphere in storage room (room is on deck)	Warning signs, procedure for entering the room, confined space entry procedure	Check current procedures are for entering the rooms today. The rooms are currently used for inert gas so there is the same risk for the rooms today. Similar risk reduction procedure.	extremely remote	minor
2.1.9	Leakage of methanol into N_2 lines - is this possible?	Not possible because there is a check valve (no return valve)					
2.2 Rupture							
2.2.1	Collision	Tank rupture, leakage	Fire/explosion	Design with deformation zone. Tank is independent. If hull is ruptured the compartment will fill with water, diluting the methanol.	Collision is possible, but a collision of the severity that would result in tank damage is extremely remote, as the tank is independent within the hull.	Remote (for a severe collision)	minor
2.2.2	Grounding	Tank rupture, leakage	Fire/explosion	Design with deformation zone. Tank is independent. If hull is ruptured the compartment will fill with water, diluting the methanol.	Grounding is possible, but a grounding of such a severity that would result in tank damage is extremely remote, as the tank is independent within the hull.	Remote (for a severe grounding)	minor
2.3 Corrosion/erosion							
2.3.1	Corrosion of methanol tank. Methanol with some water content is corrosive to steel	Leakage	Small release of methanol.	The methanol tank will be stainless steel and coated with a suitable material. Tank inspection procedures.		Remote	minor
2.4 Fire/explosion (External causes)							
2.4.1	Engine room fire.	Development of heat, fire spreading to the tank/pump room	Fire in the tank room.	Firefighting system in the tank room, increase the concentration of gas. A60 insulation between the engine room and tank room.		Remote	severe
2.4.2	Fire on deck	Development of heat, fire spreading to the tank/pump room	Fire in the tank room.	Water canons on the ship structure, sprinkers on deck, fire insulation or drencher system	Note that insulation between the deck and the tank room / engine room is not A60 (decision related to keeping the car deck "ice free", but time to reach land is less than 7 minutes.	Remote	severe
2.4.3	Fire in pump area (pumps and associated piping)	Pump breaks and causes fire, fire affects the methanol storage tanks	Fire/explosion	Fire and heat detection system. Supply valve will close. Gas fire suppression system.		Remote	severe
2.5 Mechanical failure							

Node 3: Methanol pump chest - Node 3: Methanol pump chest - Node 3: Methanol pump chest - Node 3: M

2.5.1	P/V valve jams/freezes during bunkering	Tank could be over-pressurised		High pressure alarm in the tank. Procedures to stop bunkering before any effects. Regular inspection of valve.	Inspect the valve regularly.	Reasonably probable	minor
2.6 Alongside/maintenance							
2.6.1	Person enters tank with non-breathable atmosphere for inspection/maintenance	Tank contains a hazardous atmosphere. Entry could cause asphyxiation	Asphyxiation	Tank will be emptied before entering and filled up with water to evacuate methanol vapour and N_2 before entering. Confined space entry procedures to be followed before entering: including checking for breathable atmosphere before entry, ventilation of space, personal protective equipment, entry guard. Training in procedures	Tank entry procedure needed. Develop procedures for maintenance work, visiting a shipyard, hot work procedures.	Remote	Severe
Node 3: Methanol pump (located in ex-classed tank room) plus piping to engine (fuel supply)							
3.1 Leakage							
3.1.1 From fuel pump	Leaks from pump equipment (Pump, filter, etc.)	methanol vapours	Explosive atmosphere	gas detection with ESD-function - power turned off, ventilation, fire insulation towards the engine room, pump placed in the methanol tank room (EX classed space). Eye protection to be used. Gloves if contacts with methanol is expected. Spill tray below pump to prevent spread of methanol.	Basic training about methanol safety for all who enter the tank/pump room	Reasonably probable	Minor
3.1.2 From pressure side (8 bar) of pump and connections	Leaks from pipe connections on pressure side of pumps	Release of methanol into tank room (can be spray)	explosive and toxic atmosphere	gas detection with ESD-function - power turned off, ventilation, fire insulation towards the engine room, pump placed in the methanol tank room (EX classed space). Eye protection to be used. Gloves if contacts with methanol is expected. Spill tray will contain most, but there could be spray.	Basic training about methanol safety for all who enter the tank/pump room	Remote	Minor
3.1.3 From suction side of pump	Leaks/drips from suction side of pump	Release of methanol into tank room	explosive and toxic atmosphere	As in 3.1.1	As in 3.1.1	Remote	Minor
3.1.4 From piping leading away from pump	Leaks from pipe leading from pump to engine room bulkhead	Release of methanol into tank room	explosive and toxic atmosphere	No pipe connections after the pump. Vapour detection - ESD-function - triggering power shut down, ventilation, fire insulation towards the engine room. Eye protection to be used. Gloves if contacts with methanol is expected.	As in 3.1.1	extremely remote	Minor
3.2 Rupture							
3.2.1 Rupture of fuel pump	Failure of pump casing	Release of methanol	Fire/explosion	Ex-class pump. Methanol contained in ex-class space.	Pump should fail in a safe way if designed as Ex-class. Need procedure for safe removal of any spill that accumulates.	extremely remote	significant
3.3 Corrosion/erosion							

Node 3: Methanol pump chest	3.3.1 Corrosion of pumps/pipes	Internal corrosion	Failure/leakage	system failure	Material specification, ensuring compatible materials, inspection and maintenance program. Ex-class space.		extremely remote	minor
Node 3: Methanol pump chest	3.3.2 Corrosion of valve	Internal corrosion	Failure/leakage	system failure	Material specification, ensuring compatible materials, inspection and maintenance program. Ex-class space.		extremely remote	minor
Node 3: Methanol pump chest	**3.4 Impact (comment: enclosed space with no possibility for impact from falling objects, etc.)**							
Node 3: Methanol pump chest	**3.5 Fire/explosion (see above for fuel tank)**							
Node 3: Methanol pump chest	**3.6 Mechanical failiure**							
Node 3: Methanol pump chest	**3.6.1**	Mechanical failure of the pump system.	Loss of supply of methanol to the engines	Loss of power	Four pumps - redundancy of the pump system.		Extremely remote (for all 4 pumps to fail)	significant
-	**3.7 Control system**							
Node 3: Methanol pump chest	3.7.1 Control system faliure	Failure in system/blackout	Control system fails	Faults in the system may develop and are not recognised, loss of propulsion power	System should fail to a safe state		Remote	significant
Node 3: Methanol pump chest	**3.8 Human error**							
Node 3: Methanol pump chest	3.8.1 Pumping against a closed valve	Valve left closed after maintenance	Pump damage		Maintenance procedures		Remote	minor
Node 3: Methanol pump chest	**3.9 Manufacturing defects**				Inspection and checks during installation			
Node 3: Methanol pump chest	**3.10 Material selection**				Specifications as part of design			
Node 4: Engine room node (excluding the actual engine as this should be the subject of certification testing)								
	4.1 Leakage							
	4.1.1 Leakage in piping from engine room bulkhead to engine	Failure in inner pipe	Leakage into the annular space	Methanol would accumulate in the annular space, drain to the engine or the tank room	Double walled piping inside the engine room. Vapour detection at either end of double walled pipes.	Need to specify system to detect leakage into the annular space of the piping. Possibilities include level detection and pressure monitoring.	Extremely remote	significant
	4.1.2. Leakage on engine connection point	Seal failure	Leakage of methanol onto the engine	fire, explosive atmosphere	Spray guard/venthood, gas detection, fire suppression system in the engine room		Reasonably probably	significant
	4.1.1. Leakage from the engine into the engine room	Failure on engine	Leakage of methanol onto the engine	fire, explosive atmosphere	Fuel supply will stop automatically if a gas alarm occurs. Spray guard/vent hood, gas detection, fire suppression system in the engine room	Need engine manufacturer input for frequency rating for methanol engine		significant
	4.2 Rupture				Double walled pipe		Extremely remote	minor
	4.3 Corrosion/erosion							
					Double walled pipe		Extremely remote	minor
	4.4 Impact					Not under normal operations, if major maintenance takes place the system should be drained.		
	4.5 Fire/explosion							

4.5.1 Engine room fire	From other equipment in the engine room (boiler, etc.)	Fire spreads to fuel system	Fire / explosion	Fuel supply to be stopped if there is an engine room fire alarm, limited amount of methanol in the pipes. Fixed fire suppression system.	Note that statistics are for diesel engine systems	Remote	Severe
4.6 Manufacturing defects				Inspection and checks during installation			
4.7 Material selection				Specifications as part of design			