SUMMETH

SUMMETH – Sustainable Marine Methanol

Deliverable D4.1

General arrangement, class documentation

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ABSTRACT

This report describes the design developed for converting the road ferry Jupiter to methanol operation. The conversion is based on existing regulations for low flashpoint fuels in combination with experience from other methanol conversions and conclusions from risk analysis and hazard identification studies. The reasoning behind the design choices is described along with the larger deviations from the requirements for SOLAS classed ships.

To convert Jupiter to methanol the aft diesel tank is modified to hold methanol and the surrounding tank room converted to a methanol storage area. The new compartment is equipped with mechanical ventilation, methanol vapour detection and has special procedures for safe operation. The four main engines are exchanged for methanol engines while the electrical generators and diesel boiler are kept on diesel. At a later stage the forward diesel tank can be modified and the remaining diesel consumers changed to methanol counterparts.

SUMMETH PROJECT SUMMARY

SUMMETH, the **Su**stainable **M**arine **Meth**anol project, is focused 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, ScandiNAOS, 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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1 INTRODUCTION

Methanol has a long history of being used as a fuel and during recent years has been identified as a possible future fuel for the marine industry. Development of rules and standards as well as practical experience of how to handle the liquid on board is still ongoing. Methanol is not unknown to the sea transport sector, however, as it is one of the world's most transported commodities and there is much experience with handling methanol both at sea and in port.

For use of conventional diesel fuels on board the requirements are for all intents and purposes pretty clear. Where written regulations don't dictate the design, praxis does. For methanol as a marine fuel experience is scarce and the chemical properties motivate some practical changes. Special considerations are necessary to achieve a corresponding level of safety. Rules partly exist but not for smaller ships such as a road ferry. Based on the existing rules and experience a design for conversion of the road ferry Jupiter to methanol operation has been developed and is presented in this report. While the design was done specifically for the Jupiter, similar solutions are reasonable for other ships of the same type.

1.1 ABBREVIATIONS

IBC Code	International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk
IGF Code	International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels
IMO	International Maritime Organisation
LEL	Lower Explosion Limit
LFL	Low Flashpoint Fuels
SOLAS	International Convention for the Safety of Life at Sea
TS	Swedish Transport Agency

1.2 ABOUT METHANOL

Methanol is the simplest alcohol, having one carbon atom and the chemical formula CH_3OH. It is used as a building block in all sorts of chemical industries and is one of the most transported commodities on earth. Most of the methanol available on the market is produced from natural gas but any carbon source can be used. Methanol can be used as chemical energy storage when it is created as an electro fuel. Hydrogen from electrolysis of water is combined with carbon dioxide to form methanol, which is easier to store and transport and has higher energy density compared to compressed hydrogen or batteries. The large quantity of methanol already available in combination with the relative ease of sustainable production is one major advantage of methanol.

From a safety perspective methanol offers some new challenges. In contrast to diesel fuels the flashpoint is low which means that methanol is easily ignited by a spark or open flame. The low flashpoint is the largest difference in terms of safety and as a result all equipment used where methanol leaks can be expected needs to be of explosion proof type (EX-class).

As methanol is a liquid, conventional fuel tanks are used for storage. As a liquid potential spills will also behave like a liquid and conventional fire suppression methods are used. Methanol is also soluble in water and water can be used to put out methanol fires.

1.2.1 Fire

By using the flashpoint, vapour pressure and flammability range a corresponding temperature where a flammable atmosphere can occur inside a closed tank can be calculated. The table below illustrates that for methanol a combustible mixture can form inside a closed tank in the temperature range between 11 and 41°C. This is a reason why tank inertion is required by the IGF code when using methanol. The image below also shows the heat radiation from pool fires of 50 m^2 and 4 m^2 respectively for pure methanol and a gasoline-methanol mixture. The heat radiation from the pure methanol fire is significantly less which makes a potential fire easier to approach for firefighting.

	Vapor pressure @20°C [kPa]	Flamability range [vol%]	Flashpoint [°C]	Translated temperature range [°C]
Methanol	12.3	6 – 36	11	11 – 41
Diesel	0.05	1 – 6	>56	60 – 150
Gasoline	40 – 100	1.4 – 7.6	<-40	-43 – 10

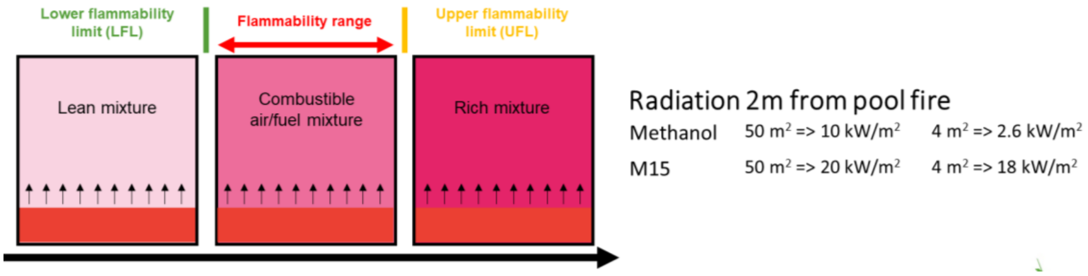


Figure 1: Flammability and fire characteristics summary of methanol compared to diesel and gasoline. Numbers and figures adopted from SP Rapport 2017:22 proFLASH: Methanol fire detection and extinguishment.

1.2.2 Toxicity

As methanol is toxic precautions during handling are necessary. During work with methanol equipment eye protection should be used and exposure to the skin avoided. If ingested, seek immediate medical attention. Compared to diesel and gasoline methanol is more toxic (classified as toxic in contrast to harmful) but is not carcinogenic. It is also classified as highly flammable in contrast to flammable (diesel) and extremely flammable (gasoline).

From an environmental perspective methanol is soluble in water and quickly biodegrades with no lasting effects on the environment. As a result methanol can, in contrast to petroleum products, be stored in double bottom tanks without double barrier towards the sea.

	METHANOL	DIESEL	GASOLINE
Hazard pictograms (CPL)			
Signal word: (CPL)	Danger	Danger	Danger
Hazard statements (CPL)	H225 Highly flammable liquid and vapour. H301 Toxic if swallowed. H311 Toxic in contact with skin. H331 Toxic if inhaled. H370 Causes damage to organs.	H226: Flammable liquid and vapour. H304: May be fatal if swallowed and enters airways. H315: Causes skin irritation. H332: Harmful if inhaled. H351: Suspected of causing cancer. H373: May cause damage to organs through prolonged or repeated exposure. H411: Toxic to aquatic life with long lasting effects	H224: Extremely flammable liquid and vapour. H304: May be fatal if swallowed and enters airways H315: Causes skin irritation H340: May cause genetic defects H350: May cause cancer H361: Suspected of damaging fertility or the unborn child H336: May cause drowsiness or dizziness H411: Toxic to aquatic life with long lasting effects
Precautionary statements (CLP)	P210 · Keep away from heat. · No smoking P280 · Wear protective gloves, protective clothing, eye protection, face protection P304+P340 · IF INHALED: remove victim to fresh air and keep at rest in a position comfortable for breathing P303+P361+P353 · IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower P301+P310 · IF SWALLOWED: Immediately call a POISON CENTRE or doctor P403+P235 · Store in a well ventilated place. Keep cool	P201: Obtain special instructions before use P210: Keep away from heat/sparks/open flames/hot surfaces – No smoking P240: Ground/bond container and receiving equipment P241: Use explosion proof electrical/ventilation/ lightning equipment P242: Use only non sparing tools P243: Take precautionary measures against static discharge P260: Do not breathe dust/fume/gas/vapours/spray P264: Wash hands thoroughly after handling P270: Do not eat, drink or smoke when using this product P273: Avoid release to the environment P280: Wear protective gloves/clothing/eye protection P301+P310: IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician P302+P352: IF ON SKIN: Wash with plenty of soap and water P303+P361+P353: IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower P304+P340: IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing P308+P313: IF exposed or concerned: Get medical advice/attention P312: Call a POISON CENTER or doctor/physician if you feel unwell P331: Do NOT induce vomiting P332+P313: If skin irritation occurs: Get medical advice/attention P370+P378: In case of fire: Use water spray or foam for extinction P391: Collect spillage P403+P233: Store in a well ventilated place. Keep container tightly closed P403+P235: Store in a well ventilated place. Keep cool P405: Store locked up P501: Dispose of contents/container in accordance with local/regional/national/international regulation	P201: Obtain special instructions before use P202: Do not handle until all safety precautions have been read and understood P210: Keep away from heat/sparks/open flames/hot surfaces · No smoking P233: Keep container tightly closed P240: Ground/bond container and receiving equipment P241: Use explosion proof electrical/ventilation/ lightning equipment P242: Use only non sparing tools P243: Take precautionary measures against static discharge P261: Do not breath fume/gas/mist/vapours/spray P264: Wash hands thoroughly after handling P271: Use only outdoors or in a well ventilated area P273: Avoid release to the environment P280: Wear protective gloves/clothing/eye protection P301+P310: IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician P302+P352: IF ON SKIN: Wash with plenty of soap and water P303+P361+P353: IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower P304+P340: IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing P308+P313: IF exposed or concerned: Get medical advice/attention P312: Call a POISON CENTER or doctor/physician if you feel unwell P331: Do NOT induce vomiting P332+P313: If skin irritation occurs: Get medical advice/attention P370+P378: In case of fire: Use water spray or foam for extinction P391: Collect spillage P403+P235: Store in a well ventilated place. Keep cool P405: Store locked up P501: Dispose of contents/container in accordance with local/regional/national/international regulation

Figure 2: Comparison of CPL hazards for methanol, diesel and gasoline according to European Regulation (EC) No 1272/2008. A readable format of the table can be found as appendix 1.

1.2.3 Energy content

In terms of energy density methanol has lower energy density compared to petroleum products, thus requiring larger fuel tanks to achieve the same range. For the road ferry the practical result will be that bunkering will be twice as often at about once every week instead of every other.

Table 1: Energy density comparison between different potential fuels and energy carriers.

	Specific energy [MJ/kg]	Energy density [MJ/l]
Methanol	19.7	15.6
Ethanol	26.4	20.9
Diesel	48	35.8
Gasoline	46.4	26
LNG	53.6	22.2
Natural gas	55.5	0.0364
Hydrogen (700 bar)	142	9.17
Lithium-ion 26650 battery	0.53-0.65	

2 DESIGN PHILOSOPHY AND REGULATORY FRAMEWORK

In terms of regulations for using methanol as fuel IMO is working on the IGF code that will cover the use of gas and low flashpoint liquids (LFL) as fuel for ships covered by the SOLAS convention. The classification societies DNV GL and Lloyd's Register have also published class rules. For vessels in national traffic there are no particular rules for the use of methanol. When the SUMMETH project started the Swedish Transport Agency TSFS 2014:1 statute did not allow for use of fuels with lower flashpoint than 43°C, similar to the requirements in SOLAS of minimum flashpoint of 60°C. Similar to SOLAS, TSFS 2014:1 also had provisions for alternative designs where risk analysis is used to show that the alternative design is as safe or safer than the prescribed design.

From 1 June 2017 new Swedish national statutes entered in to force, TSFS 2017:26[1]. The new statutes are function based and have no formal requirements on the fuel used on board. Instead the rules require an adequately safe design with little guidelines on actual requirements.

As risk assessment is already a big part of the methanol system design the new statutes do not have a major impact other than removing the formal process of having an *alternative* design.

Prescriptive rules are still used in a sense as the class rules are used as reference in the design process together with experience from the conversion design for both Stena Germanica and the pilot boat conversion of the sister project GreenPilot.

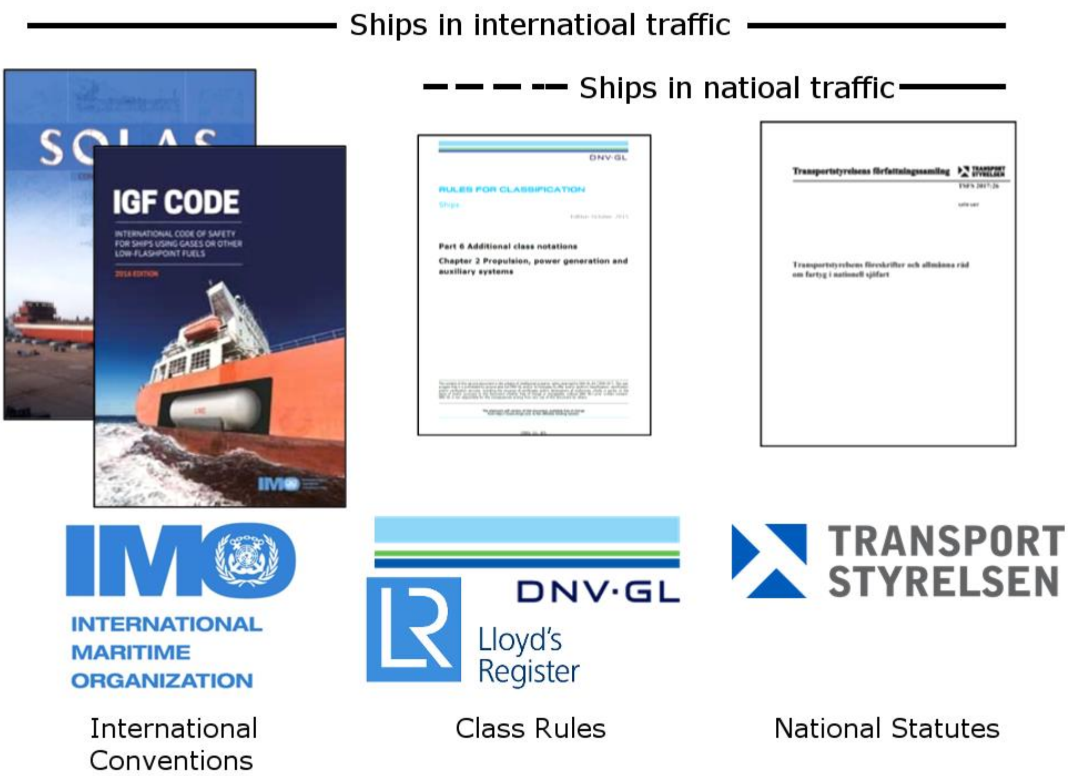


Figure 3: The layers of regulations for installations on ships and boats. The regulations from IMO are not directly applicable but influence the national statutes and class requirements. Class rules are always applicable for ships covered by the international rules and can be for ships in national traffic. Class requirements can also be used in the design and specification of ships in national traffic even though the ship may not have class certificate. The ship can, however, be built with class certificate, as was done for the new Finnish road ferry Elektra.

[1] Transportstyrelsens föreskrifter och allmänna råd om fartyg i nationell sjöfart

3 CONVERSION DETAILS

The methanol conversion design was done for the road ferry Jupiter, which is in traffic between Ljusterö and Östanå northeast of Stockholm. The ferry is equipped with four main engines – two in a forward and two in an aft engine room. The engine couple in each end mechanically drives pods on each side. In addition to the propulsion engines each engine room is equipped with gensets. The aft engine room has a diesel burner for a thermal oil heating system.

Jupiter

Year built:	2007
Yard:	Työvene OY, Nystad, Finland
Call sign:	SFKL

Main particulars

L_{OA}	86.20	m
L_{Hull}	75	m
L_{CWL}	73.27	m
$Breath_{moulded}$	15	m
$Depth_{moulded}$	2.95	m
$Disp_{CWL}$	856	ton
Speed	10.0	kn
Passengers	397	pcs
Cars:	60	pcs

Main engines 4 x Volvo Penta D12D-C MH

The ship is approved for speed area E and has no class certificate.

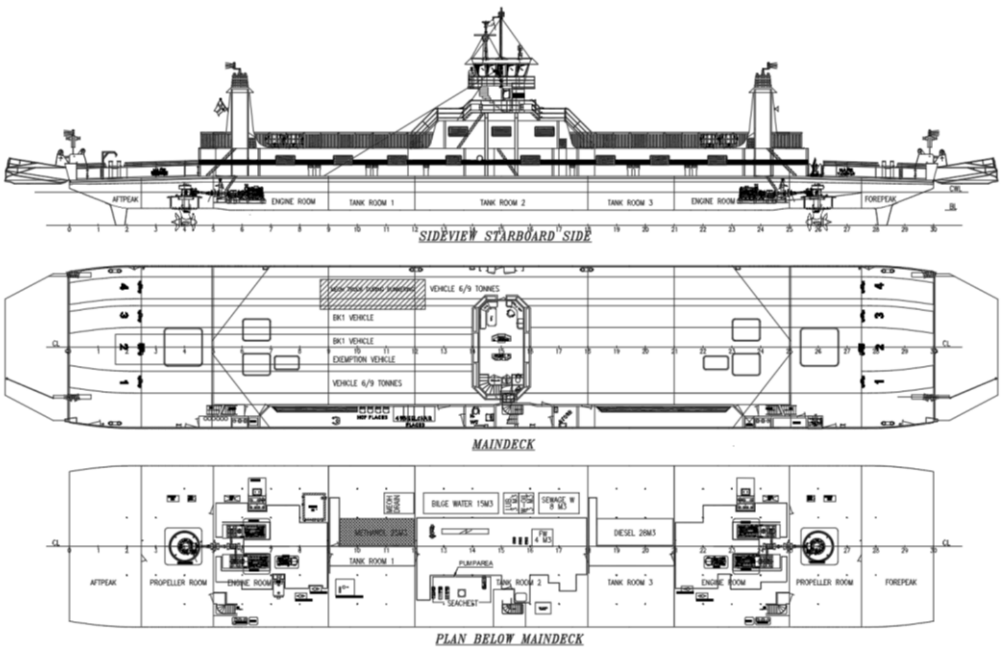


Figure 4: Schematic view of Jupiter below deck. Tank Room 2 in the middle houses water tanks, switchboard and the fire station. The tank rooms on either side (Tank Room 1 to the left and Tank Room 3 to the right) have the diesel tanks and then

the aft and forward engine room are outside of each tank. The hull and propulsion devices are double symmetrical. Each machinery room has emergency exits to deck through the propeller rooms.

Reference documents:

Appendix II SNP15095-100 General Arrangement Methanol Conversion

Appendix III SNP15095-707 Hazardous area plan

Appendix IV SNP15095-780 System Coordination Diagram

3.1 General functionality and principles of the methanol system

The general principle of the methanol fuel system is similar to any conventional fuel system. The special requirements for the fuel piping such as double walled and limitation on joints are aimed at minimizing the possibility of leakage. The double walled piping is used to provide an outer protective barrier to contain any methanol in case of rupture of the inner pipe.

The methanol fuel tank is located in the aft tank room which is modified with a longitudinal bulkhead to create a new compartment. The fuel pumps are separated from the engines and located in a new pump room together with the equipment that is most likely to cause leakage if it fails during operation or during maintenance. All electrical equipment in the new pump room is EX-approved.

The aft tank is modified and a new longitudinal bulkhead is installed in the existing tank room, thus insulating the new methanol tank room from the ordinary passage way to the engine room. The new methanol tank room is also used as the methanol pump room.

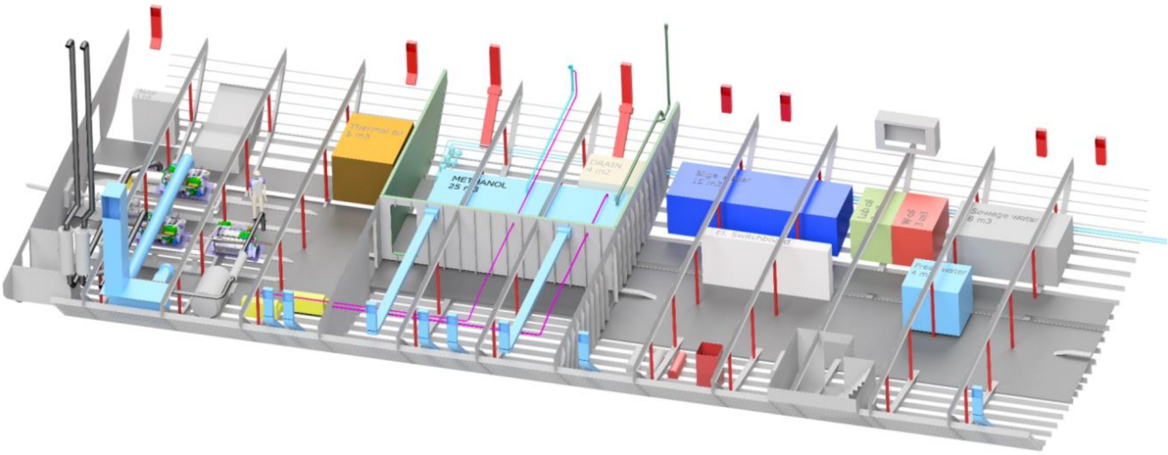


Figure 5: The methanol tank room is directly aft of tank room 2 in the middle of the ferry. Tank room 2 contains the fire station, electrical switchboard and auxiliary tanks. The machinery room is directly aft of the methanol tank room.

In addition to the fuel supply system other modifications include upgrading of the safety systems. Both for early detection in case of any methanol leakage and for reducing dangerous consequences in case any such scenario would develop.

3.2 Methanol tank room

The largest structural modification for the methanol conversion is construction of a new compartment for storage of methanol. The new compartment is part of existing Tank Room 1 where a bulkhead is constructed along the centre line. The new methanol room is to the port side of the bulkhead while starboard side will be a safe passage way to the aft engine room.

The bulkhead along the centre line is watertight and the compartment is equipped with forced ventilation that in case of spillage create an under pressure that will prevent methanol vapours from spreading to other compartments.

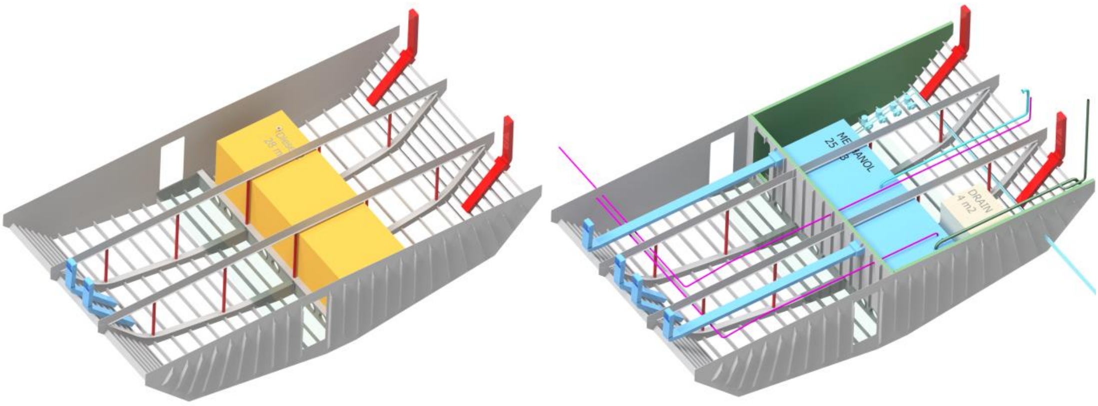


Figure 6: The methanol tank room (tank room 1) before and after conversion. A new watertight bulkhead along the centre line is installed, new ventilation is installed, and the fuel tank is modified for methanol. The compartment is also insulated to ensure fire integrity.

The new compartment is insulated with A60 insulation towards the surrounding spaces. Insulation below the car deck on road ferries is an ongoing discussion. The machinery room has so far been exempted from requirements for insulation towards open deck, the methanol pump room should for fire safety be regarded as machinery room category A and also exempted.

In addition to the tank the new compartment contains fuel pumps, filters and other equipment that is part of the fuel system. The methanol tank room is considered hazardous from a fire safety point of view (Ch. 2.9) and all electrical equipment inside is of EX-type.

Entry to the compartment is through a watertight door aftmost on the new bulkhead. An oxygen meter at the entry alerts persons entering of low oxygen concentration caused by damage to the inertion system. Alarm in case of methanol leaks inside the compartment should also be displayed at the entry.

The forward diesel tank in tank room 3 will remain a diesel tank. The auxiliary engines and the thermal oil heater will not be converted to methanol in a first stage. Keeping the diesel system also allows the main engines to be converted one by one to methanol in order to properly test the systems on board. The forward tank could at a later stage be upgraded to make the ferry fully operational on methanol.

3.3 METHANOL TANK

The methanol tank is located inside the new tank room. The existing tank is either modified or a new independent tank is installed in its place. The tank needs to be somewhat shorter than the existing diesel tank to allow enough space for the new tank room door. The volume of the methanol tank is 25 m^3 while the existing diesel tank is 28 m^3.

The master fuel valves are remotely operated solenoid valves that are closed when methanol engines are not in operation.

Methanol is corrosive, especially if water is present in the fuel. The inside of the tank should be coated for protection; Sigma Silguard 750 is a proven product but other alternatives are available. Alternatively the tank can be built of stainless steel, especially for smaller applications.

Inspection hatches allow for inspection of the tank internals. Remote tank level measurement and a separate high-high alarm are required.

3.3.1 Tank inertion

The rules for use of low flashpoint fuels on SOLAS ships require fuel tanks to be inerted. Inertion is also required for transporting large quantities of some flammable products in bulk as defined in the IBC code; bulk transport of methanol does not require inertion at this time but is being discussed. Inertion is however often used when transporting methanol in large quantities at sea but not for barges and trucks.

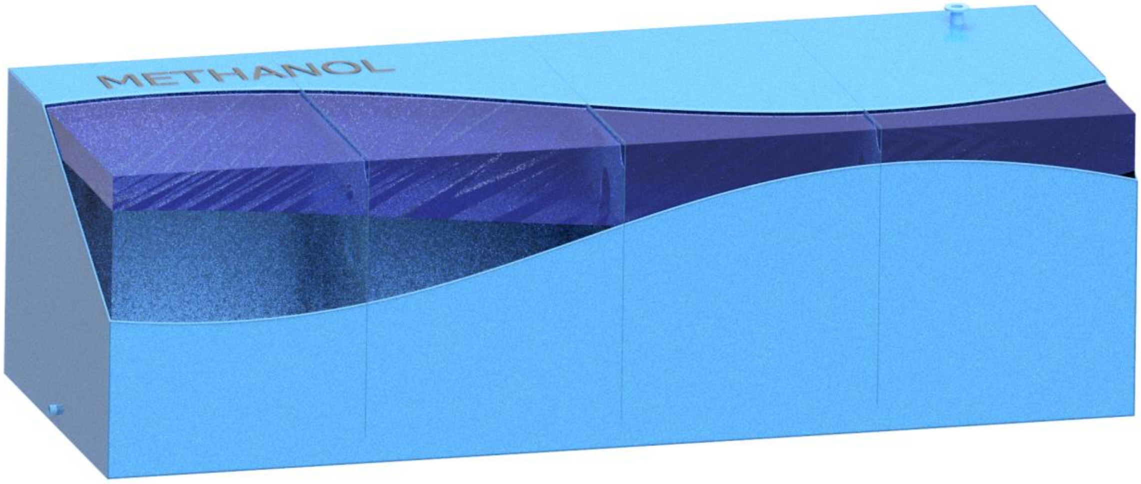


Figure 7: The methanol tank. Nitrogen gas covers the methanol surface to ensure that no combustible gases can form.

The inertion ensures that no combustible atmosphere can possibly exist inside the tanks by supressing the oxygen level. Inertion is also held at a slight overpressure, above the vapour pressure of methanol to further ensure that fuel vapours in the tank will be suppressed.

In addition to inertion of the tanks nitrogen is used to purge the fuel pipes before service to ensure a safe working environment and minimize the fire hazard.

Nitrogen can either be supplied by portable bottles or from an on board nitrogen generator.

3.3.1.1 Portable bottles

Nitrogen is readily available as compressed gas in portable bottles. As nitrogen gas is supplied to the fuel tank at the same rate as fuel is burnt in the engines, nitrogen consumption is as large as the methanol consumption, i.e. approximately 1.14 m^3/day. During a fuel cycle the corresponding nitrogen consumption would be 2.6 50-litre bottles of nitrogen. With refill every other week the nitrogen store on board would need to be 6 bottles.

3.3.1.2 Nitrogen generator

An alternative to exchangeable bottles it to install a nitrogen generator on board. The costs of the generator need to offset the cost of the gas bottles including work for bottle changes.

In order to power the nitrogen generator a compressed air supply system is needed including dryer and filter for the air. A pressure tank to store the compressed nitrogen is also needed.

The nitrogen generator arrangement has not been studied in the hazid workshops but does not provide significant additional hazards. Measures to ensure a breathable atmosphere in the nitrogen storage/generator compartment are similar.

An on board inert gas generator provide significant advantages in terms of logistics and maintenance as the need for bottle exchange is mitigated. The investment cost is higher but is somewhat offset by the absence of gas and bottle costs.

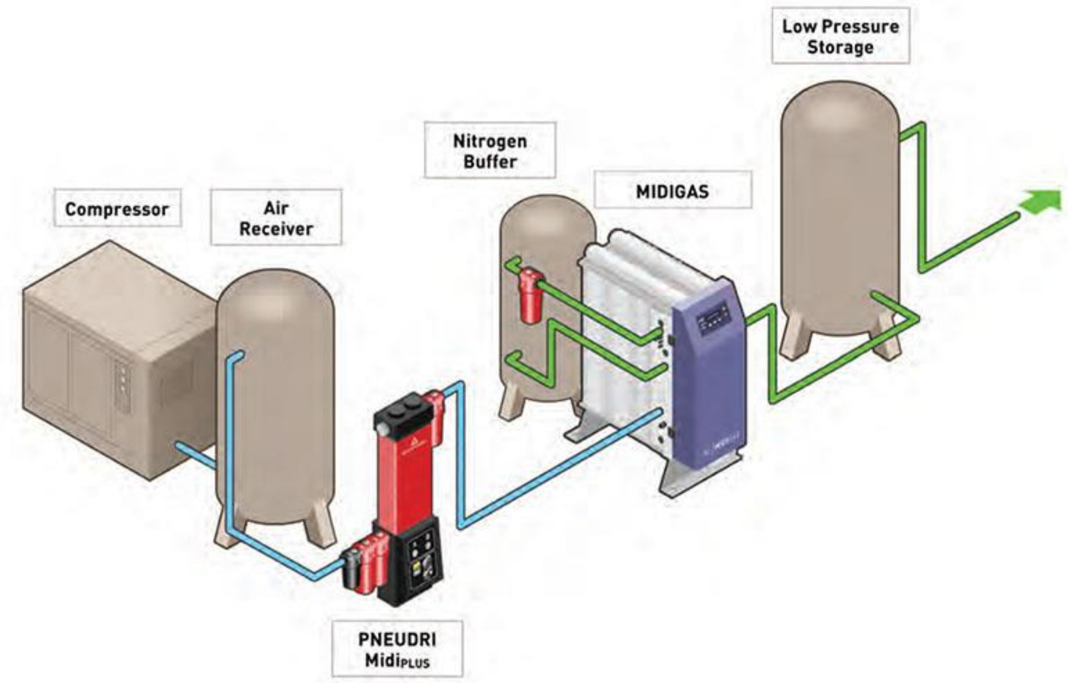


Figure 8: Principal layout of an inert gas generator. Image curtesy of: parker.com

The cost of a nitrogen generator is estimated to be approximately 240 000 SEK compared to an annual cost of about 90 000 SEK for the portable bottles. These costs do not include the distribution system which would be similar in both cases.

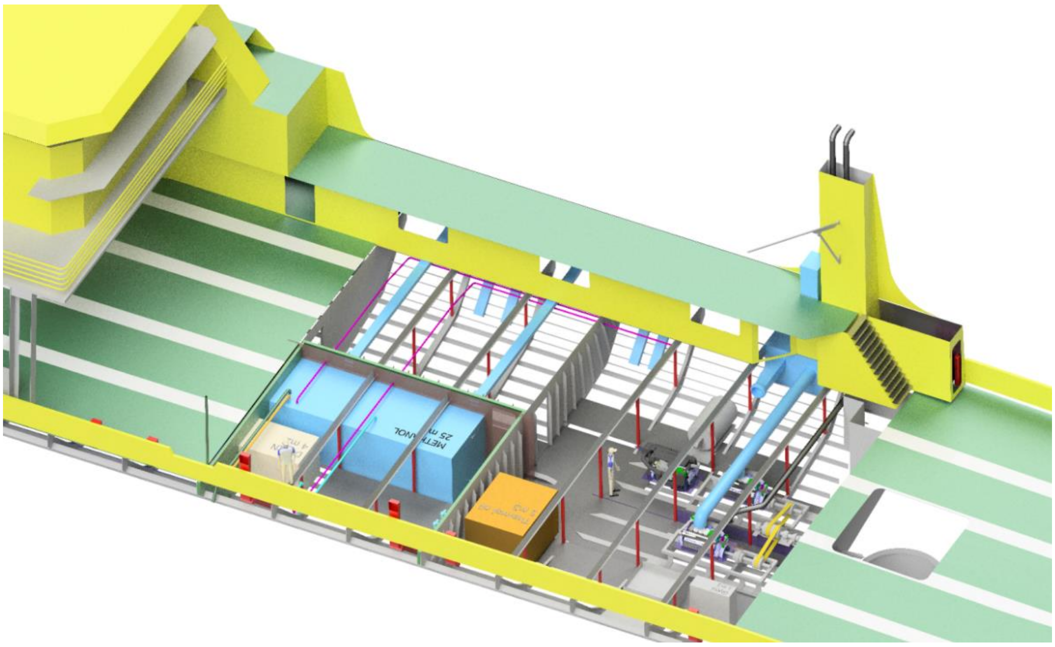


Figure 9: The aft store on port side where gas bottles for the fire extinguishing system is stored is also the proposed location for the inert gas system. In order to fit a nitrogen generator the store would most likely need to be somewhat expanded. The compartment has access from the outside and is easily ventilated which are requirements when generating inert gas.

3.3.2 Tank Ventilation

As the tank is pressurised by nitrogen the tank ventilation needs to be specially designed for methanol. The pressure is contained through the use of a P/V valve at the end of the ventilation pipe. The P/V valve will open if the overpressure exceeds 150 mBar(g). The valve will also open if the pressure is below 50 mBar(g) vacuum in order not to damage the tank.

As vapours from the tank ventilation could possibly contain methanol the ventilation is higher than for a conventional installation. The ventilation pipes extend 3 m above deck, in line with the requirements in the IGF code.

3.3.3 Emergency overflow

An emergency overflow line is fitted on the tank ventilation pipe. If the tank is overfilled during bunkering, despite high and high-high alarms, methanol will overflow to the outside. The overflow pipe is fitted with a rupture disk, with alarm, that will break in case of overfill to allow methanol in the pipe to flow through.

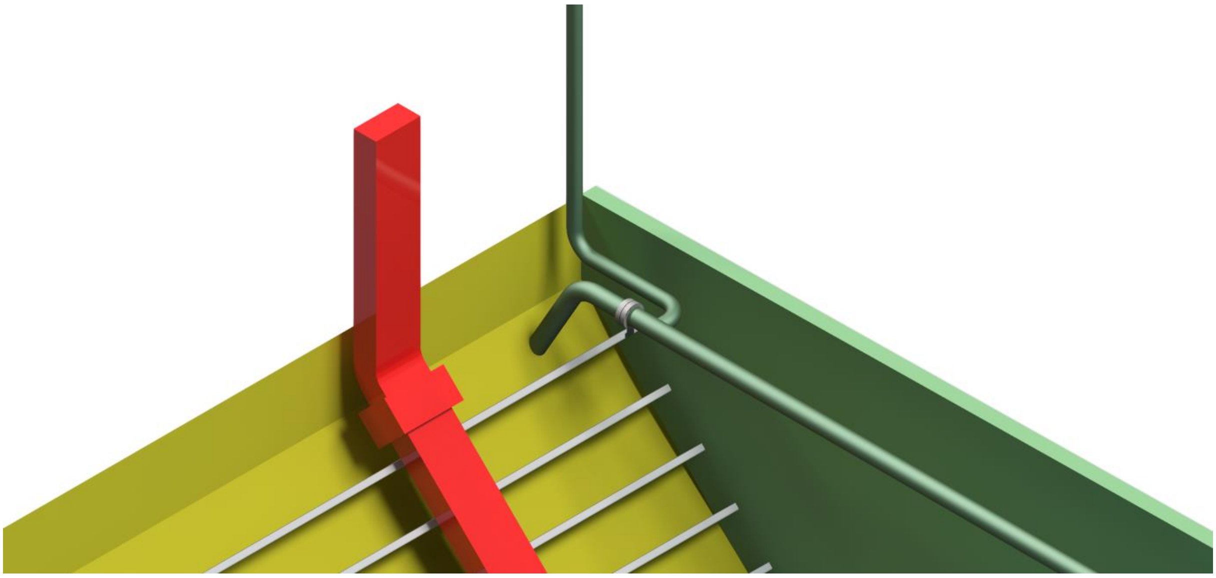


Figure 10: The tank ventilation and overflow pipe. The tank ventilation pipe extends through the deck and upwards while the overflow pipe penetrates the shell plating. A burst disk is fitted on the pipe to stop nitrogen from escaping and seawater from entering the piping.

3.3.4 Bunker connection

The bunker connection used for methanol is a dry disconnect fast coupling. Both parts of the connection are closed as long as they are not connected. This ensures no spillage during bunkering. The bunker connection is of a similar type as used for the Stena Germanica methanol bunkering and for the GreenPilot project.

The bunker connection is located on deck above the methanol tank. Bunkering will be done from a truck where the truck parks on deck close to the bunker manifold, similar to how diesel is bunkered today.

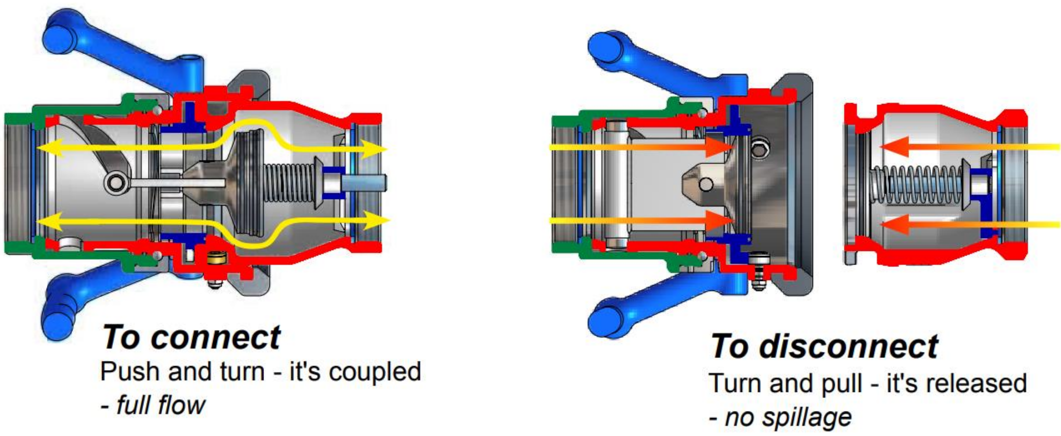


Figure 11: Illustration of the connection type engaged and disengaged. Image courtesy of MannTek.

Bunkering of methanol is done the same way as bunkering diesel fuel where a truck drives on board and parks close to the bunker manifold. Methanol is routinely transported in tank trucks and discharged by the driver at a large variety of facilities.

The truck is connected to the ferry via the drip free dry disconnect coupling whereas bunkering is started by opening the valves on the bunker line.

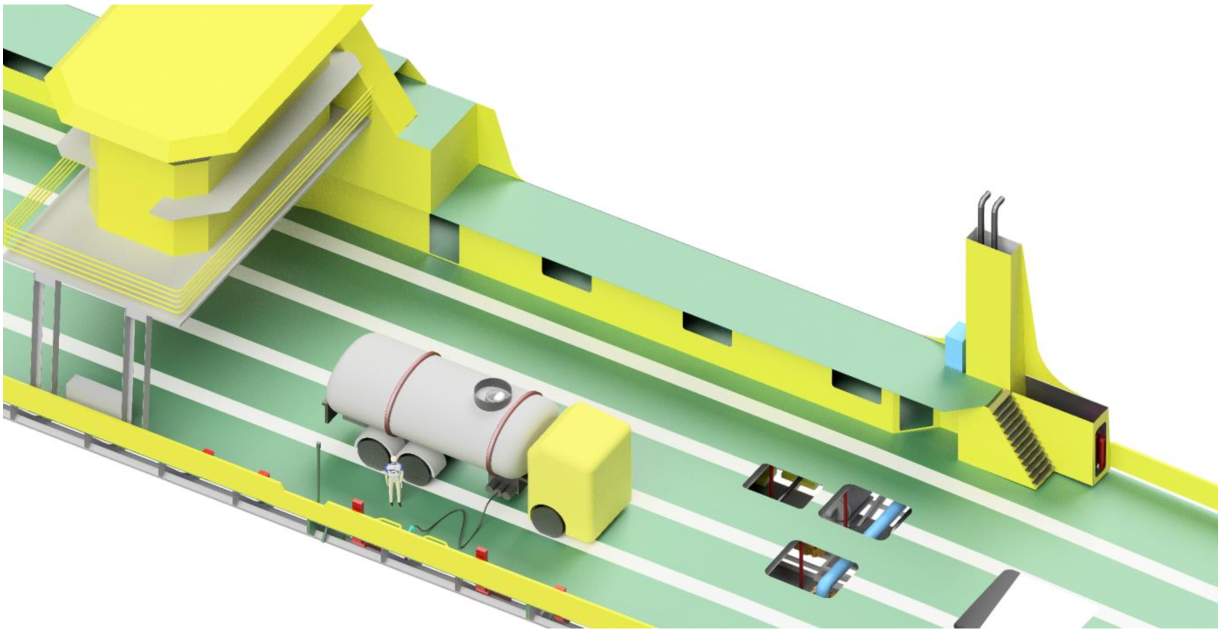


Figure 12: The truck carrying methanol parks on deck close to the bunker manifold. During bunkering no passengers are on board.

During bunkering the ferry is at port and no passengers are allowed on board.

3.4 Fuel system

As the design relies heavily in containing methanol, double walled fuel pipes are used in all areas outside of the pump room, with the exception of the bunker pipe protruding on open deck.

The outer wall of the piping acts as a second barrier to contain methanol in case of rupture of the inner pipe but also as protection from mechanical damage from the outside. For larger dimensions double walled pipes are manufactured for the application but for the smaller dimensions as required for this case double walled pipes can be bought off the shelf.

Figure 13: Detailed view of FLEXWELL Safety Pipe. An inner stainless steel pipe protected by a rubber covered corrugated steel pipe.

The inner pipe is a smooth stainless steel pipe for fuel delivery and the outer pipe corrugated with rubber coating. The pipe is delivered on roll and can be bent with conventional methods during assembly. For installations the joints should be as few as practically possible and located inside protected joint boxes at low points. Potential leakage will drain to the box where gas detectors will indicate presence of vapours. The annular space will not be ventilated as installations on large ships would require. The location of the box and necessary number of boxes is to be determined during installation but would most likely be necessary somewhere between the methanol room and the forward engine room.

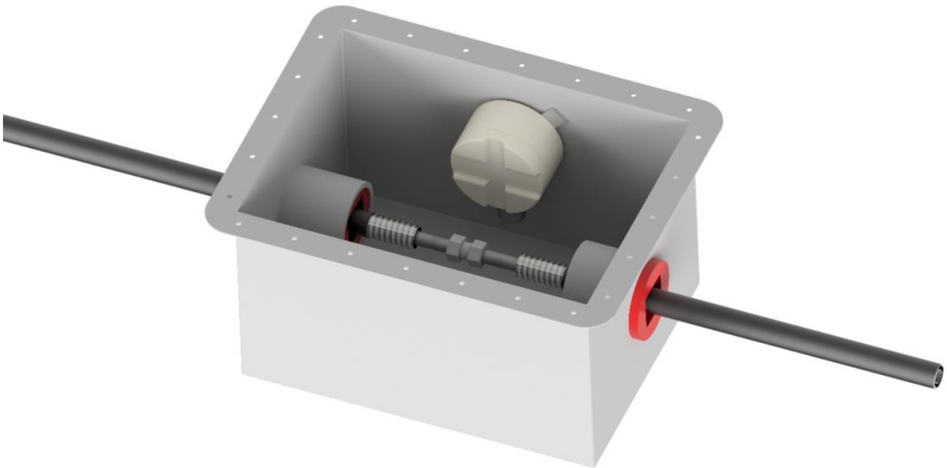


Figure 14: Pipe joints are protected inside a steel box in order to satisfy the requirements of a secondary barrier in all locations outside of the safe compartments. In case of leakage methanol will drain to the box where vapours will be detected by the gas detector.

The principal layout for the fuel system is to place individual fuel pumps for each engine inside the methanol tank room with drip drays to collect and detect leakage from the individual units. Fuel lines to each engine are thereafter routed for each engine. For the aft engines the pipes go straight to the machinery room while fuel pipes to the forward engines pass through Tank Room 1 and Tank Room 2. Each fuel line has remotely operated shutoff valves to kill the fuel supply if necessary.

The fuel supply system has a working pressure of about 3 bar.

3.4.1 Component selection

In order to secure reliable operation all components used in the fuel system are stainless steel. It is also important to select sealing materials that are compatible with methanol during component selection.

3.5 Machinery Room and Engines

The engine room modifications necessary for safe operation on methanol are minor. The engines are swapped for methanol converted engines and the fuel supply pipes are changed to double walled pipes.

Detailed specifications of the engines are at this point not available. The most likely engine technology in the short term is spark ignited engines with a low pressure fuel supply system, which is very similar to the concept tried in the GreenPilot project. See SUMMETH Report D3 for further details on methanol engines.

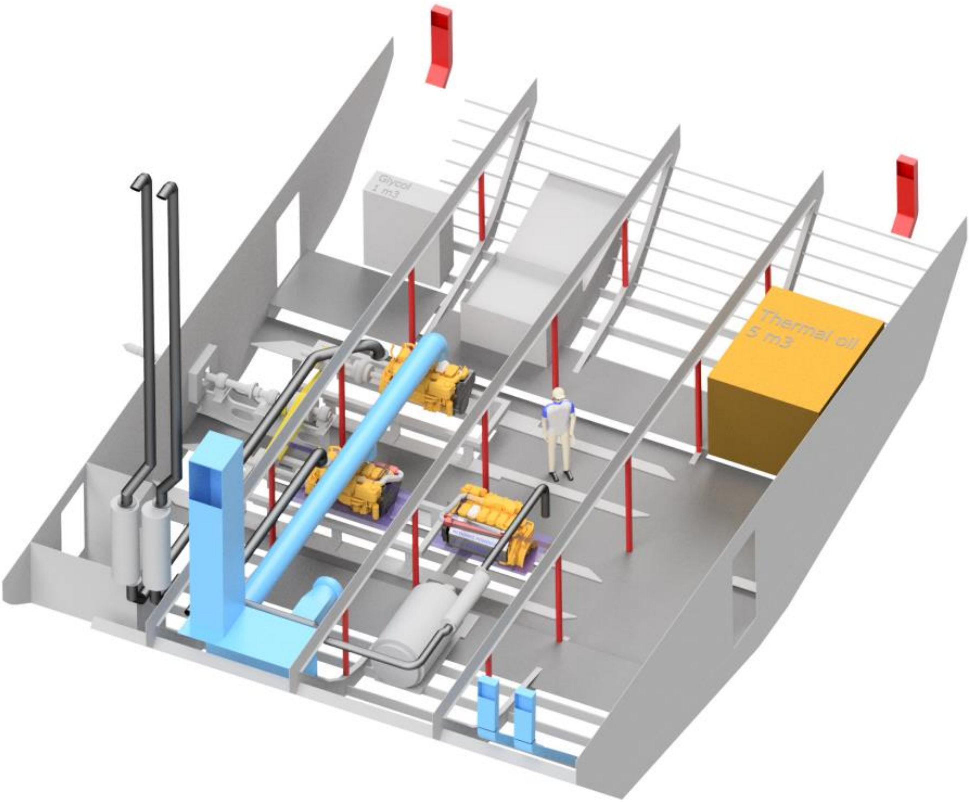


Figure 15: The aft engine room layout with the three combustion engines shown in orange. Two of the engines are connected to a belt drive that drives the shuttle. The third engine drives an electric generator. The aft engine room is also equipped with a diesel burner and thermal oil tank for heating in the superstructure.

3.6 VAPOUR DETECTION

The methanol system is designed to prevent any leakage of methanol, with double walled piping in all areas except the methanol tank room, which is considered safe as all equipment is EX-proof inside. If any methanol leakage would still occur vapour detectors are used to detect traces of methanol. Inside the engine room detectors are located close to each engine. Detectors are also installed inside the tank room to detect any leakage from the pumps or connectors.

Methanol vapour detection is efficient and small traces are easily detected. Hand held equipment can detect very small amounts of methanol inside a compartment, down to a few ppm. For reference the long term exposure limit is 250 ppm[2] and the lower explosion limit (100% LEL) is 60000 ppm.

The gas detection system will monitor the detectors continuously and alarms will go off in case of gas concentration of 15% LEL and 30% LEL.

The gas detectors provide early warning in case of technical faults to the system and allow the operator to prevent a dangerous situation from developing.

3.7 FIRE DETECTION

As a methanol fire produces virtually no soot and particles, smoke detectors will not work reliably for methanol. It is therefore necessary to install an additional detection system. In the proFLASH project, SP (now RISE) have conducted practical tests of fire suppression and detection of methanol fires for marine applications. The tests showed that infrared (IR) detectors certified for ethanol work well for

[2] AFS 2015:7: Hygieniska gränsvärden

detecting methanol fires, even when the fire itself is obstructed from the detector's direct line of sight. The IR detectors work by detecting radiation from the fire, radiation from CO_2 in particular is a strong indicator of fire. Detectors purely working in the visual spectrum are, however, not suitable for methanol.

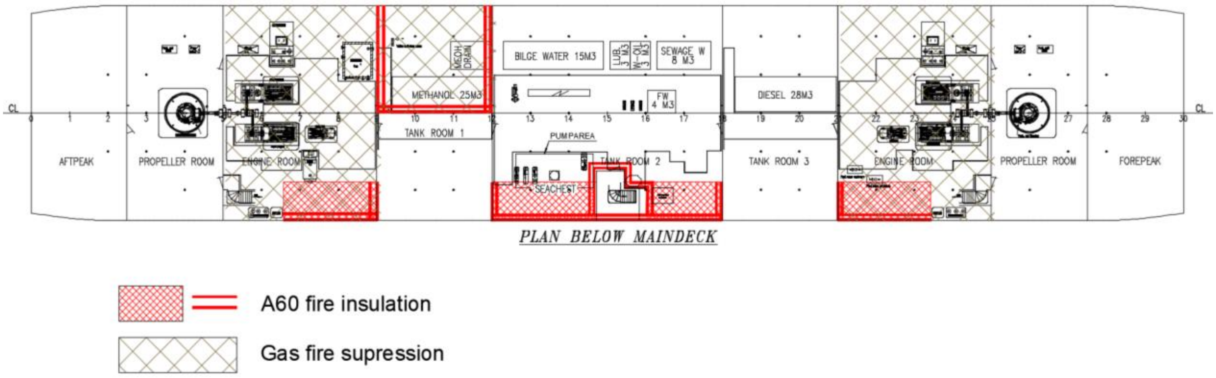


Figure 16: Fire insulation and gas fire suppression system below main deck. Fire insulation and fire suppression in the new room are new.

On the road ferry IR detectors are recommended in the engine rooms. In the pump room heat detectors would also work good as no other heat sources could cause alarms and enough heat would also quickly accumulate to trigger an alarm in case of fire.

Smoke detectors should, however, still be used for indication of fires from other sources. A methanol fire would also quickly start to emit smoke as it spread to electrical cables and other materials.

3.8 Fire suppression

The ship is equipped with a water based fixed fire fighting system. The system consists of two water cannons on the boat deck (above main deck) and connection points for fire hoses on main deck and in all the compartments below deck (bar aft and forepeak). A portable foam nozzle and foam agent is located in the forward store on main deck. A sprinkler system is installed towards the bulkhead of the superstructure towards the main deck (capacity at least 0.6 m^3 water/m^2 wall area per hour). Two fire pumps supply the system from the sea chest, both are located in tank room 2 midships.

The engine rooms are protected with a total flooding inert gas system (type FS 49 C2). The system is designed to quench a fire in one of the engine rooms from portable bottles located in the aft store.

A methanol fire would require more gas to achieve the same effect with the gas total flooding system in the machinery room. The gas fire extinguishing system is to be expanded to the methanol tank room.

3.8.1 Deck wash system

A new deck wash system is to be installed. This is a system in use on the newer ferries in order for structural protection of the deck between the engine room and roro-deck above. Normally, the deck has no other fire insulation whereas fire insulation is normally required between machinery space of category A and cargo deck.

As a deck wash system is required on new ferries it is reasonable to have it installed when a methanol conversion is done. The deck wash system would also be used in case of a major spill during bunkering in which case water would be used to dilute and evacuate the methanol overboard.

3.9 HAZARDOUS AREA PLAN

When working with flammable liquids or gases classification plans are used to identify areas where flammable liquids, vapours or gas can be expected to exist. A hazardous area plan for the road ferry identifies these locations and divides them in three categories as defined by DNV GL class rules for low flashpoint fuels.

DNV GL Rules for classification - Part 6 Chapter 2 Section 6

Part 6 Additional class notations
Section 6 Low flashpoint liquid fuelled engines - LFL FUELLED

Hazardous area is an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus. Hazardous areas are divided into Zone 0, 1 and 2 as defined below and according to the area classification specified in [5.2].

Zone 0 = Area in which an explosive gas atmosphere is present continuously or is present for long periods.

Zone 1 = Area in which an explosive gas atmosphere is likely to occur in normal operation.

Zone 2 = Area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.

Guidance note: *The definition of hazardous area is only related to the risk of explosion. In this context, health, safety and environmental issues, i.e. toxicity, is not considered.*

The class rules clearly define the areas to be classified as hazardous. The inside of the fuel tank is Zone 0 and the methanol pump room is classified as Zone 1 in line with the regulations. Deviations from the regulations are necessary on open deck as the rules define a radius around ventilation openings and a tank P/V valve is not suitable for smaller vessels. For large fuel tanks and large ships the potential volumetric flow is much greater and thus a larger zone with potentially flammable vapours will form around the outlet. For smaller vessels the volume with vapours will be much smaller and the vapours will dissolve in air faster. The hazardous area around the ventilation outlets and tank P/V valve is, on the road ferry, defined to a one meter radius around the centre point of the ventilation outlet. The corresponding class rules stipulate a radius of 4.5 m around ventilation outlets and 10 m radius around the P/V valve.

The illustration bellow shows the hazardous zones for the road ferry. During normal operation the areas on deck as well as the air in the pump room will not contain any trace of methanol. During bunkering the P/V valve will open but as the methanol fuel tank is inerted with nitrogen the exhaust will contain mostly nitrogen with only trace amounts of methanol well below any flammable or toxic concentration.

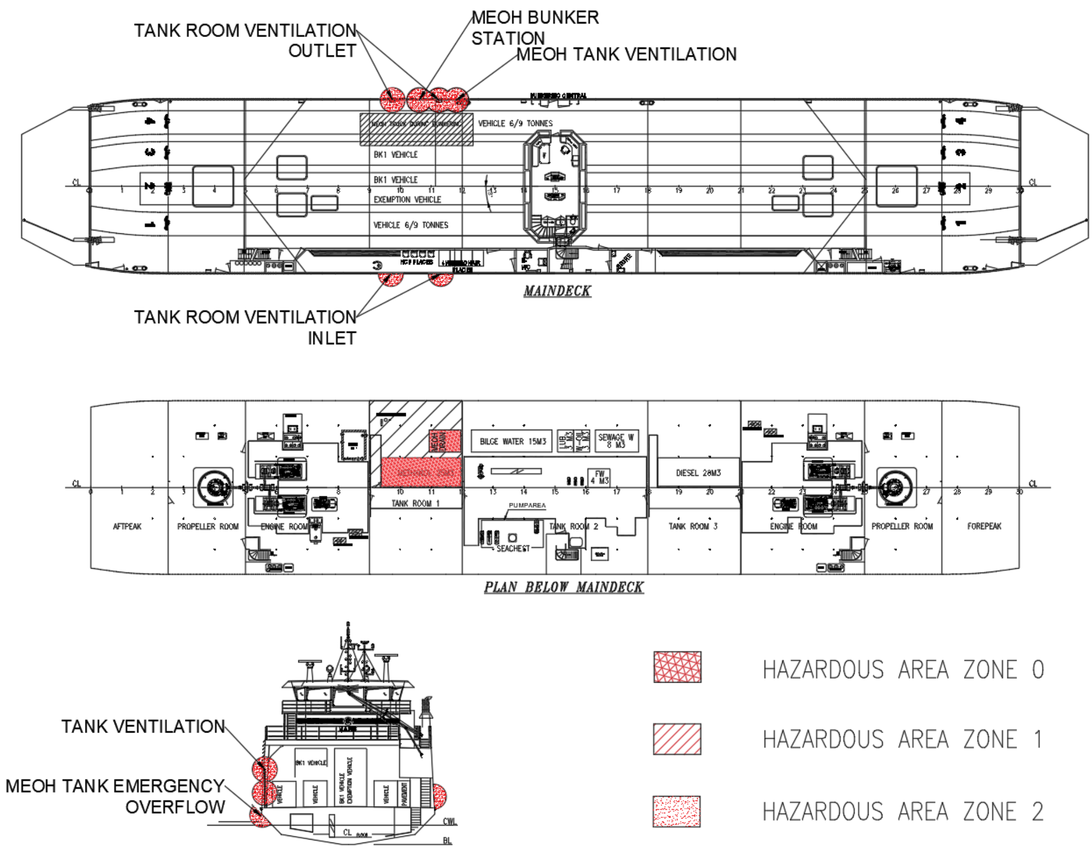


Figure 17: The hazardous areas. The pump room and ventilation inlets and outlets are by definition classified as hazardous areas.

3.10 Major design alternatives

3.10.1 Alternative to tank inertion

The possibility of using atmospheric tanks with no inertion has been considered. For smaller vessels this is a reasonable departure from the regulations and alcohols are regularly stored in atmospheric tanks without inertion. Transport of methanol on land by truck or train is generally done without any tank inertion and tank storage on land does not use inertion either. Land based storage facilities may on the other hand be equipped with floating roofs to counteract formation of a vapour layer or have in-tank fire extinguishers. For transport of methanol in bulk at sea the IBC code (for SOLAS ships) also does not require inertion for methanol. However, inertion is still a common feature for methanol carriers as a requirement from the cargo owner and there are discussions of tightening the rules as some accidents have happened when the cargo has caught fire.

With this in mind the decision was made to include tank inertion to ensure safety of the ship. The possible dangers of handling inert gas in the closed compartments have been determined to be lower than the possible consequences of alternative designs.

The possibility of using atmospheric storage could be further investigated but would need to be conducted in cooperation with the class and entities familiar with handling large quantities of methanol in bulk.

A consequence of tank inertion would be atmospheric tank ventilation with no need for a P/V valve. A flame arrestor should in that case be fitted to the ventilation line. In case of fire outside of the tank ventilation the flame arrester stops a flame from propagating to the tank through the ventilation pipe. The flame arrestor is a passive device.

3.10.2 Methanol tank bladder

The proposed design has a separate compartment for the methanol tank. The new compartment is gas tight towards the rest of the vessel with an independent ventilation system. Any damage to the methanol tank resulting in spillage would therefore be contained without risk of methanol entering any other part of the vessel, thus satisfying the requirements of secondary boundary around low flashpoint fuel tanks. An alternative to a fully separate compartment is an internal tank bladder. The internal bladder would be the primary container of the fuel while the tank would act as the secondary barrier.

There are commercial marine tank bladders for use with ethanol available on the market but these are much smaller than what would be required for the ferry case and are intended to be used without an outer shell.

Figure 18: A tank bladder from Aero Tec Laboratories Inc. Marine tank bladders are available for any commercially available fuel, including ethanol blends.

With the tank equipped with an internal bladder the design could move away from the methanol tank room. Fuel pumps and equipment would still need to be isolated but could be housed inside independent steel pump chests. The pump chest would contain any methanol spillage from the equipment and provide good serviceability of the equipment. The design is similar to the Gas Valve Units used on some LNG ships and the pump chest in the methanol powered GreenPilot project.

4 DISCUSSION AND CONCLUSIONS

Converting a road ferry to methanol is a realistic undertaking. The arrangements on board with space available below the deck allows for a safe design and also arrangements that should satisfy all requirements for monitoring and serviceability. Auxiliary systems have been kept to a minimum but with the overall goal to ensure safe and reliable operation on methanol.

From a technical point of view all parts of the design should be able to work with few problems during installations. The major question mark for commercial operation on methanol at this point is the availability of engines but from a technical point of view methanol does not provide a huge challenge.

Efficiency wise similar efficiency as a conventional ferry should be expected, resulting in bunkering methanol about twice as often to compensate for the lower heating value of the fuel.

The ferry is designed with two independent engine rooms, each equipped with two main engines mechanically connected to a propeller pod. During normal operations all engines are often running on very low load, resulting in poor efficiency and high relative emissions. Efficiency wise running on fewer engines is better but will also result in less redundancy.

5 REFERENCES

DNV GL Rules for classification - Part 6 Chapter 2 Section 6

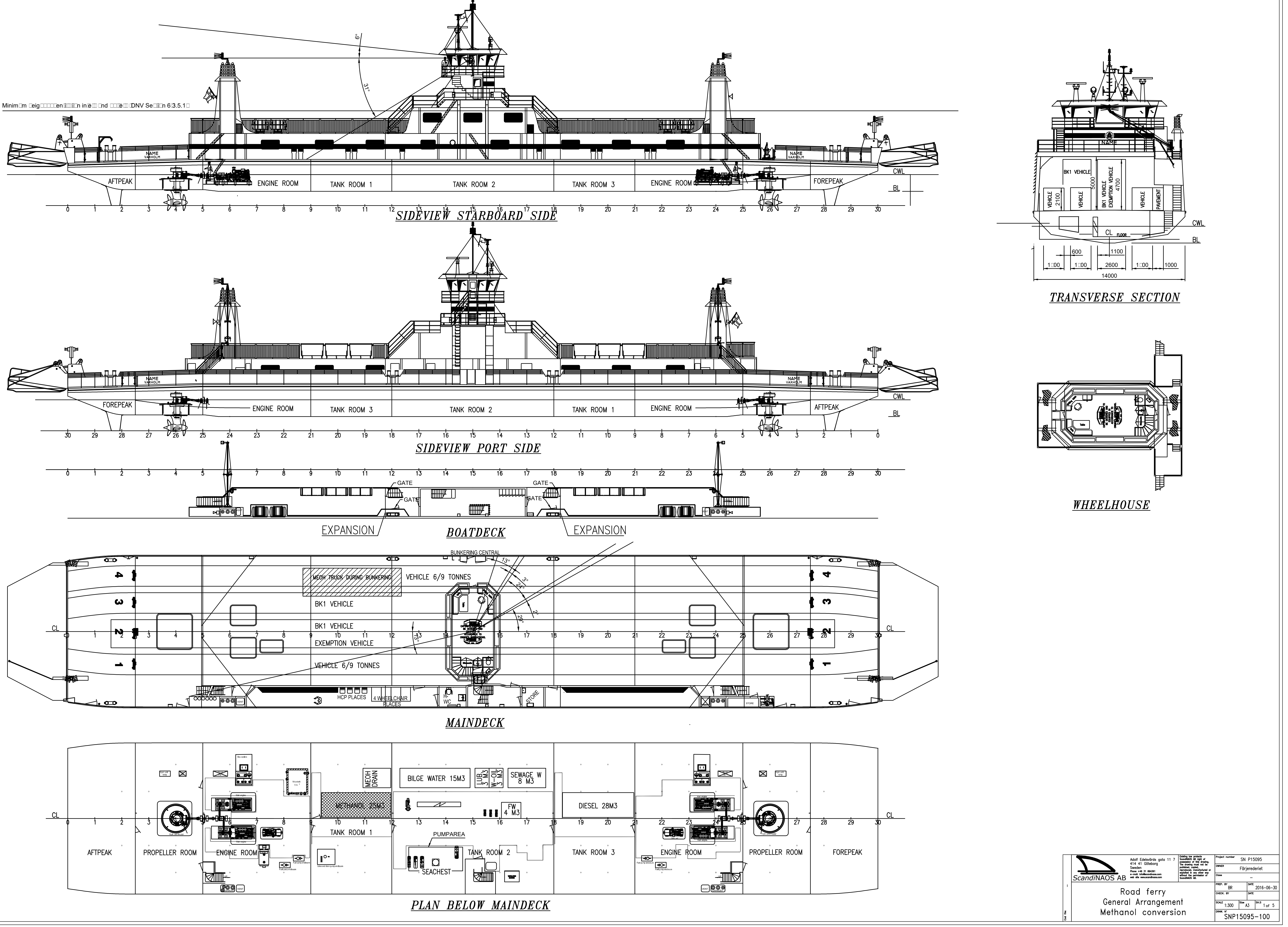
Evegren F. proFLASH: Methanol fire detection and extinguishment : SP Rapport 2017:22 [Internet]. 2017. (SP Rapport). Available from: http://urn.kb.se/resolve?urn=urn:nbn:se:ri:diva-29442

IGF Code: International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels, 2016 Edition (I109E)

Product	**Gasoline MK1 93.5, 95, 96, 98 (CAS 86290-81-5)**	**Diesel (CAS 68334-30-5)**	**Methanol**
Source	St1 Refinery AB	St1 Refinery AB	Methanex Europe S.A
Appearance:	Pale yellow, clear liquid	Clear liquid, colourless, yellow or green	Clear
Odour:	Characteristic	Characteristic	Alcohol odour
Odour threshold:	-	-	4,2 - 5960 ppm
pH:	Not applicable	Not applicable	Not applicable
Melting point/freezing point:	< -60 °C	< -10 °C	-97,8°C
Initial boiling point and boiling range:	25 - 205°C	160 - 370°C	64,7°C
Flash point:	< -40 °C	>56 °C	11°C
Evaporation rate:	-	-	-
Flammability (solid, gas)	-	-	Highly flammable liquid and vapour
Upper/lower flammability or explosive limits:	1 – 8 vol %	0,6 – 7,5 vol %	5,5 - 36,5 vol %
Vapour pressure:	45 - 95 kPa @ 37,8 °C	<0,5 kPa @ 37,8 °C	12,8 kPa @ 20°C
Relative vapour density @ 20oC:	-	.	1.1
Relative density:	720 - 775 kg/m3	820 - 860 kg/m3	791 – 793 kg/m3
Solubility(ies):	Low solubility	Not solubility	Miscible with water
Auto-ignition temperature:	> 250°C	> 225°C	464°C
Kinematics Viscosity, 40°C	< 1 mm2/s	1 - 5 mm2/s	
Explosive properties:	Not considered to be explosive	Not considered to be explosive	Vapours may form explosive mixture with air.
Oxidising properties:	Not considered to oxidise	Not considered to oxidise	Not oxidising.
Hazard pictograms (CPL)			
Signal word: (CPL)	Danger	Danger	Danger
Hazard statements (CPL)	H224: Extremely flammable liquid and vapour. H304: May be fatal if swallowed and enters airways H315: Causes skin irritation H340: May cause genetic defects H350: May cause cancer H361: Suspected of damaging fertility or the unborn child H336: May cause drowsiness or dizziness H411: Toxic to aquatic life with long lasting effects	H226: Flammable liquid and vapour. H304: May be fatal if swallowed and enters airways. H315: Causes skin irritation. H332: Harmful if inhaled. H351: Suspected of causing cancer. H373: May cause damage to organs through prolonged or repeated exposure. H411: Toxic to aquatic life with long lasting effects	H225 Highly flammable liquid and vapour. H301 Toxic if swallowed. H311 Toxic in contact with skin. H331 Toxic if inhaled. H370 Causes damage to organs.
Precautionary statements (CLP)	P201: Obtain special instructions before use P202: Do not handle until all safety precautions have been read and understood P210: Keep away from heat/sparks/open flames/hot surfaces - No smoking P233: Keep container tightly closed	P201: Obtain special instructions before use P210: Keep away from heat/sparks/open flames/hot surfaces – No smoking P240: Ground/bond container and receiving equipment P241: Use explosion-proof electrical/ventilation/ lightning	P210 - Keep away from heat. - No smoking P280 - Wear protective gloves, protective clothing, eye protection, face protection P304+P340 - IF INHALED: remove victim to fresh air and keep at rest in a position comfortable for breathing

	P240: Ground/bond container and receiving equipment P241: Use explosion-proof electrical/ventilation/ lightning equipment P242: Use only non-sparing tools P243: Take precautionary measures against static discharge P261: Do not breath fume/gas/mist/vapours/spray P264: Wash hands thoroughly after handling P271: Use only outdoors or in a well-ventilated area P273: Avoid release to the environment P280: Wear protective gloves/clothing/eye protection P301+P310: IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician P302+P352: IF ON SKIN: Wash with plenty of soap and water P303+P361+P353: IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower P304+P340: IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing P308+P313: IF exposed or concerned: Get medical advice/attention P312: Call a POISON CENTER or doctor/physician if you feel unwell P331: Do NOT induce vomiting P332+P313: If skin irritation occurs: Get medical advice/attention P370+P378: In case of fire: Use water spray or foam for extinction P391: Collect spillage P403+P235: Store in a well-ventilated place. Keep cool P405: Store locked up P501: Dispose of contents/container in accordance with local/regional/national/internationa l regulation	equipment P242: Use only non-sparing tools P243: Take precautionary measures against static discharge P260: Do not breathe dust/fume/gas/vapours/spray P264: Wash hands thoroughly after handling P270: Do not eat, drink or smoke when using this product P273: Avoid release to the environment P280: Wear protective gloves/clothing/eye protection P301+P310: IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician P302+P352: IF ON SKIN: Wash with plenty of soap and water P303+P361+P353: IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower P304+P340: IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing P308+P313: IF exposed or concerned: Get medical advice/attention P312: Call a POISON CENTER or doctor/physician if you feel unwell P331: Do NOT induce vomiting P332+P313: If skin irritation occurs: Get medical advice/attention P370+P378: In case of fire: Use water spray or foam for extinction P391: Collect spillage P403+P233: Store in a well-ventilated place. Keep container tightly closed P403+P235: Store in a well-ventilated place. Keep cool P405: Store locked up P501: Dispose of contents/container in accordance with local/regional/national/internationa l regulation	P303+P361+P353 - IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower P301+P310 - IF SWALLOWED: Immediately call a POISON CENTRE or doctor P403+P235 - Store in a well-ventilated place. Keep cool

APPENDIX II - SNP15095-100 GENERAL ARRANGEMENT METHANOL CONVERSION



ISSUE	DESCRIPTION	DATE	DRWN	DATE	CHKD
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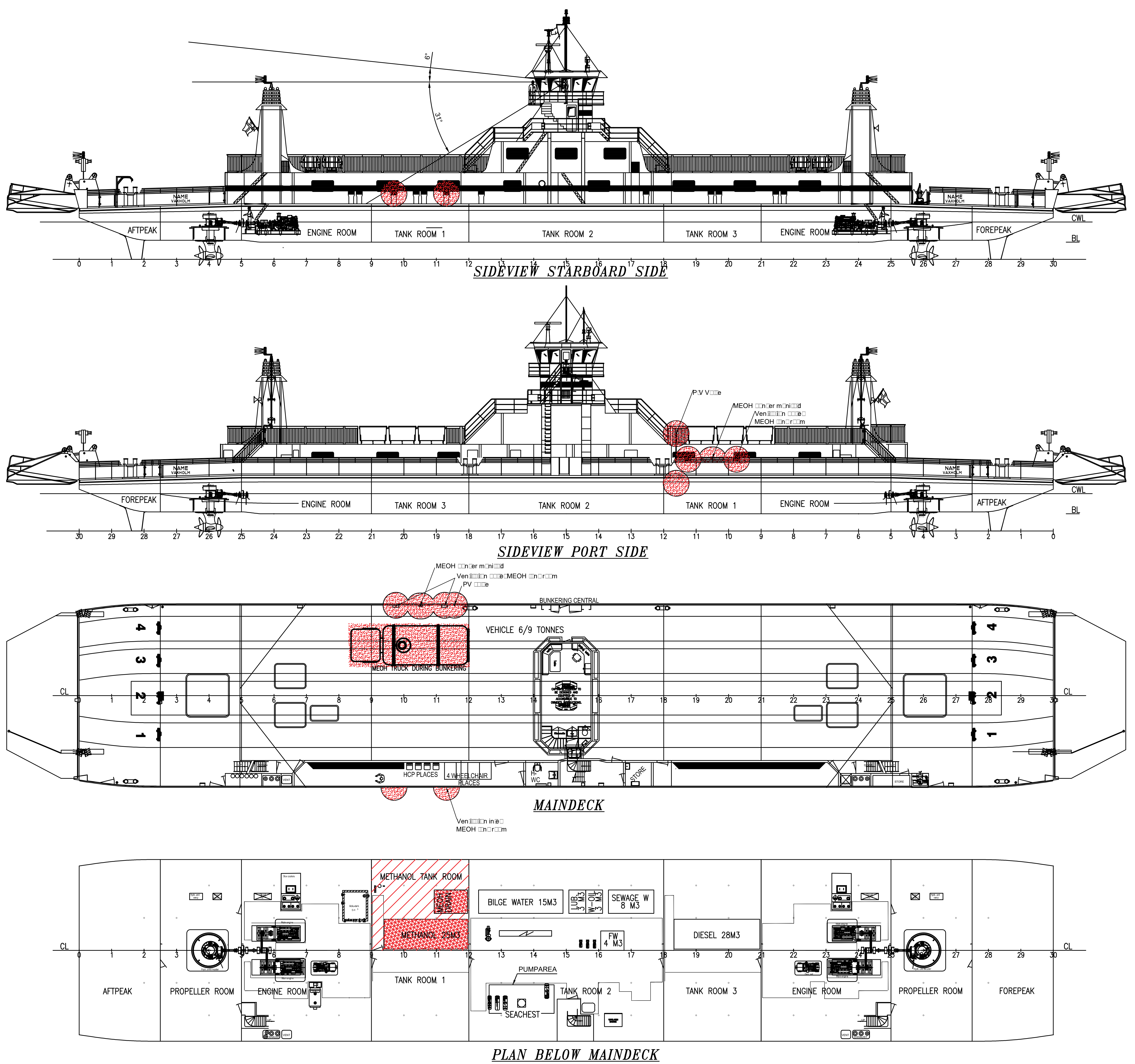

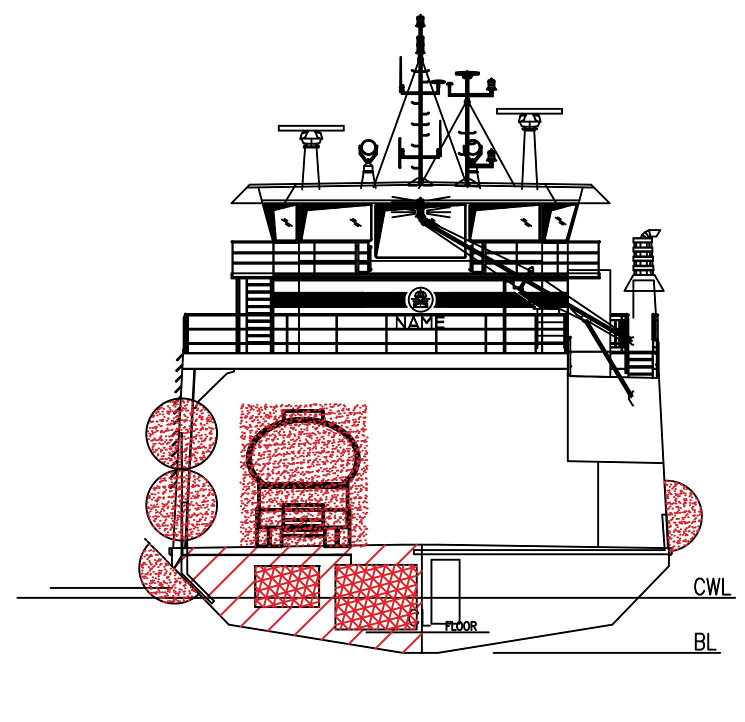

#11

- HAZARDOUS AREA ZONE 0
- HAZARDOUS AREA ZONE 1
- HAZARDOUS AREA ZONE 2

Definitions

Ref: DNV GL Rules for ships Part 6 - Additional Class notations

Zone 0
Area in which an explosive gas atmosphere is present continously or is present for long periods.

Zone 1
Area in which an explosive gas atmosphere is likely to occur in normal operation

Zone 2
Are in which an explosive gas atmosphere is not lot likely to occur in normal operation and, if it does occur , is likely to do so only infrequently and whill exist for a short period only

Guidance note:
The definition of hazardous area is only related to the risk of explosion. In this context, helth, safety and environmental issues, i.e. toxcicity, is not considered.

MAIN DIMENSIONS□

LENGTH OVER ALL	86□20 m
LENGTH OF HULL	75 m
LENGTH CWL	73□27 m
BREADTH MOULDED	14 m
BREADTH INCL. FENDER	14□16 m
BREADTH CWL	12□26 m
DEPTH MOULDED	2□□5 m
DRAUGHT CWL	1□55 m
DISPLACEMENT CWL	856 □□n
FRAME DISTANCE	2500 mm
NUMBER OF PASSENGER	3□7 □□□.

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Road ferry
Hazardous zone
Methanol conversion

Project number	SN P15095		
OWNER	Färjerederiet		
Class	–		
PREP. BY	JB	DATE	2017-09-18
CHECK. BY		DATE	
SCALE ?	Size A3	SH.S 1 of 5	
DRAW. N°	SNP15095-707		

Cad file:

APPENDIX IV - SNP15095-780 SYSTEM COORDINATION DIAGRAM

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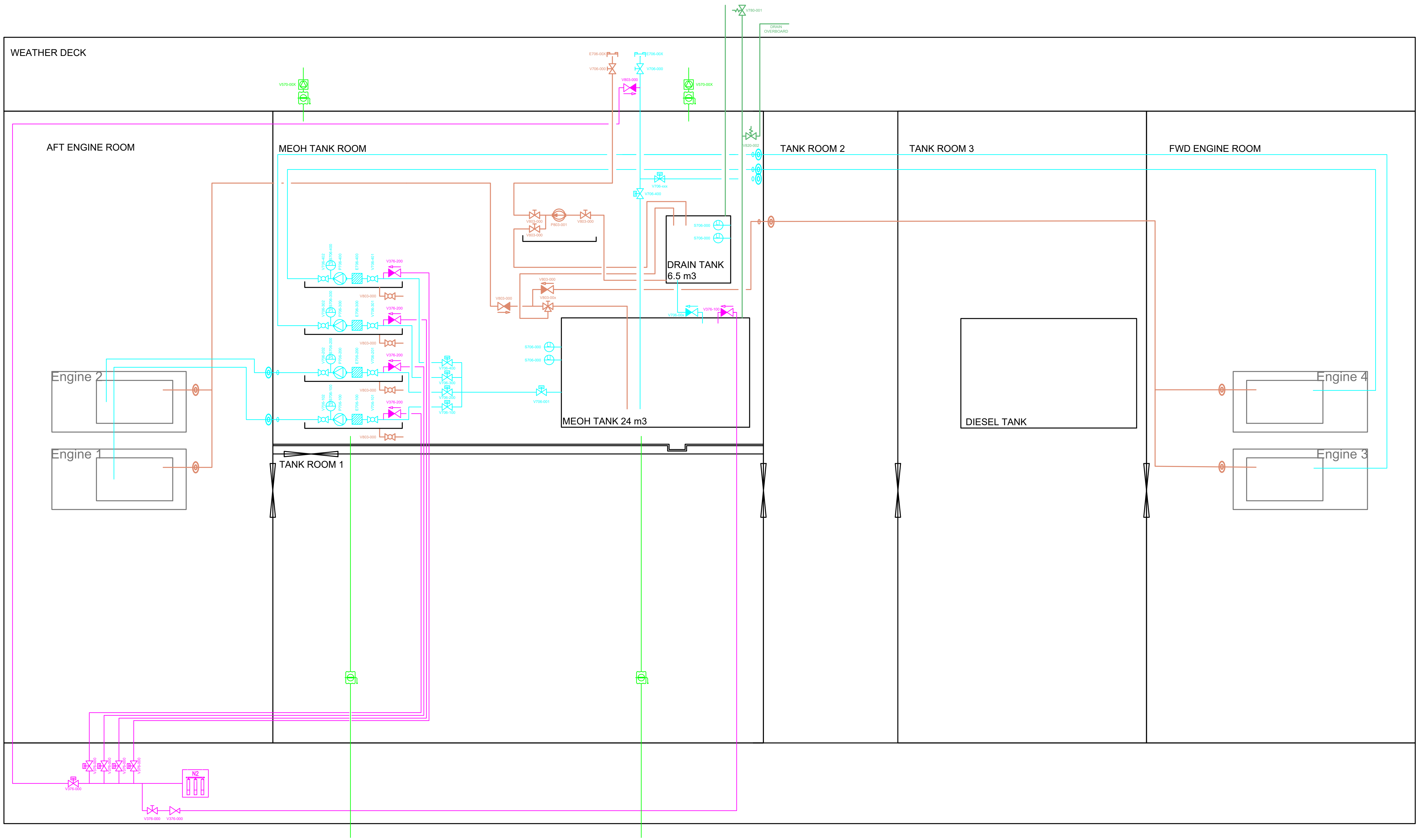

METHANOL FUEL SYSTEM
METHANOL DRAIN SYSTEM
NITROGEN SYSTEM
TANK VENTILATION AND OVERFLOW
VENTILATION

ScandiNAOS AB
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Project number	SNP15095
OWNER	FÄRJEREDERIET
Class	–
PREP. BY	JB
DATE	2016-02-11
CHECK. BY	
DATE	
SCALE	NTS
Size	A2
SH.S	1 of 1
DRAW. N°	SNP15095-780

JUPITER
METHANOL CONVERSION
SYSTEM COORDINATION DIAGRAM

SNP100
Cad file: