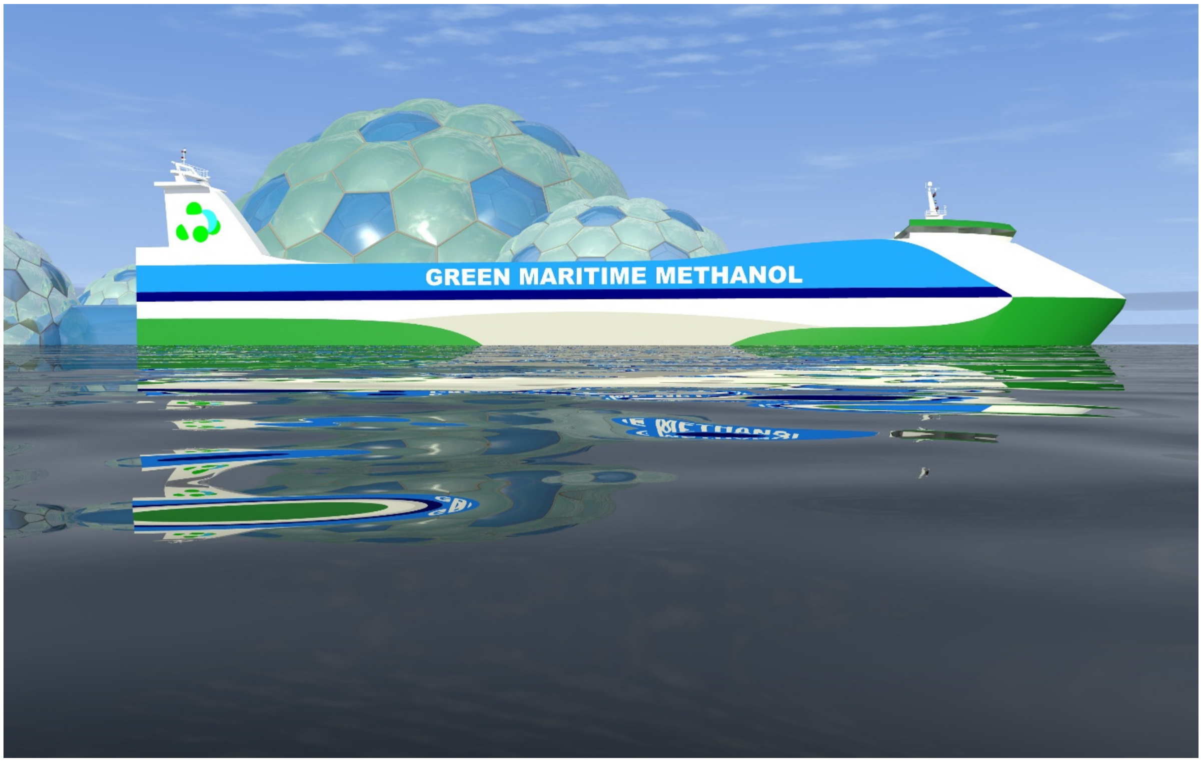

Green Maritime Methanol: WP 5 - System Design for Short Sea Shipping

SIX CASE STUDIES OF SHIPS USING METHANOL AS A FUEL

Project data

Project number:	*GMM 060.38323*
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Introduction: Work Package 5 - System design for short sea shipping

The objective of Work Package 5 - System design for short sea shipping is to apply the theoretical findings from the previous work packages into practical ship designs and to evaluate these designs with regard to safety, technical and economic feasibility in view of future pilot projects.

The market-segment of shipping that is known as “short sea shipping" relates to ships that primarily operate in coastal trades. There is a wide diversity of ships operating in it, with mutual differences in type, size, speed, operational pattern, propulsion system, etcetera. These vessels include general cargo vessels, tankers, container vessels, passenger vessels and several types of work vessels.

The result of the previous work provided the building blocks for system designs for several short sea ships and work vessels and especially focussed on ship conversion plans for existing ships. After investigation of the present situation in North European ports with regard to methanol and in consultation with ship-owners, different ships were selected. Based on the results of WP3 different engine were taken into account. For four real life vessels a benchmark design was made of a methanol propulsion system.

During the project, the need for including inland ships was expressed in the steering group. Although the focus of the project remained on short sea shipping and work vessels, it was decided to include limited design studies for a port patrol vessel and an inland patrol vessel in the project.

The results of these designs are used to formulate draft principles and pre-conditions for further development of components and subsystems. This also provided information which can be used for any fine tuning of regulations.

The selected real life vessels in this work package are shown below. Based on a number of design considerations, such as availability of methanol engines, space issues for methanol tanks, methanol is likely a more suitable fuel for some of the ships than for others.

Trailing suction hopper dredger
Hydrographic Survey Vessel
Port patrol vessel

Inland patrol vessel
Cable-laying vessel
General cargo vessel

Figure 5.0.1 Ship types evaluated in detail for methanol solutions.

The exploration of the design challenges is based on the conceptual system designs of six ships ('cases') that operate in North European Emission control Areas. Each case was elaborated by the dedicated 'case-owner' (i.e. Boskalis, Defence Material Organisation, Port of Amsterdam, Rijksrederij, Van Oord and Wagenborg) in co-operation with the project participants.

The vessels, selected from a long list, are:

- Boskalis: Trailing Suction Hopper Dredger - Willem van Oranje;
- Defence Material Organisation: Hydrographic Survey Vessels – Snellius and Luymes
- Port of Amsterdam: Port Patrol Vessel - Castor
- Rijksrederij: Inland Patrol Vessel - RWS 88
- Van Oord: Cable laying vessel - Nexus
- Wagenborg: General cargo vessel - Eemsborg

Each “case-owner” was supported by several partners from the GMM consortium to assist in the work done in each specific case, forming a dedicated design team.

- The Boskalis team was formed by Boskalis, Marin, Bureau Veritas, DEME, Royal IHC, Wärtsilä and VIV.
- The DMO team was formed by DMO, NLDA, Damen, Feadship, Lloyds Register and Pon Power.
- The Port of Amsterdam / Rijksrederij team was formed by Port of Amsterdam, Rijksrederij, Bureau Veritas, Helm Proman Methanol, MKC, MTU and TU Delft.
- The Van Oord team was formed by Van Oord, Arklow Shipping, Marin, Damen, Lloyds Register, Port of Rotterdam, Pon Power/MaK.
- The Wagenborg team was formed by Wagenborg, Bio MCN, C-Job Naval Architects, KVNR, Marine Service Noord, TNO and Wärtsilä.

Each team carried out a design study for a retrofit design chosen by the case owner. The results of these studies are presented in this report.

Paragraph 5.1 describes the results for the analysis of the Boskalis vessel - Willem van Oranje,

Paragraph 5.2 describes the retrofit for the sister naval ships HMS Luymes and HMS Snellius,

Paragraph 5.3 describes two short design studies for the patrol vessels of the Port of Amsterdam - Castor and Rijksrederij - RWS 88,

Paragraph 5.4 describes the conversion of Van Oord vessel Nexus,

Paragraph 5.5 describes the retrofit of the Wagenborg vessel Eemsborg and

Paragraph 5.6 presents some overall conclusions and recommendations.

Figure 5.0.2 Overview of the GMM members, participating in the various cases.

5.1 Boskalis case

Main editors: Chris van den Berg and Arie de Jager

The case is based on the (existing) trailing suction hopper dredger (TSHD) Willem van Oranje and investigates the option of retrofitting of this Trailing Suction Hopper Dredger to be able to use methanol as its main fuel.

Principal dimensions Trailing Suction Hopper Dredger Willem van Oranje

Built:	2010
Builder:	IHC Dredgers
Length over all:	144 m
Breadth moulded:	28 m
Depth to upper deck:	13.5 m
Max. draught dredging:	10.0 m
Displacement:	34,000 tons (approx.)
Hopper capacity	12,000 m3
Total bunker capacity:	1,585 tons HFO/MDO (incl. (daily) service tanks)
Main Power:	2 x 6 MW (2x Wärtsilä 12V32)

Operational profile

For the Willem van Oranje three (main) operational profiles can be determined:

- dredging and pump ashore,
- dredging and dumping, and
- transit

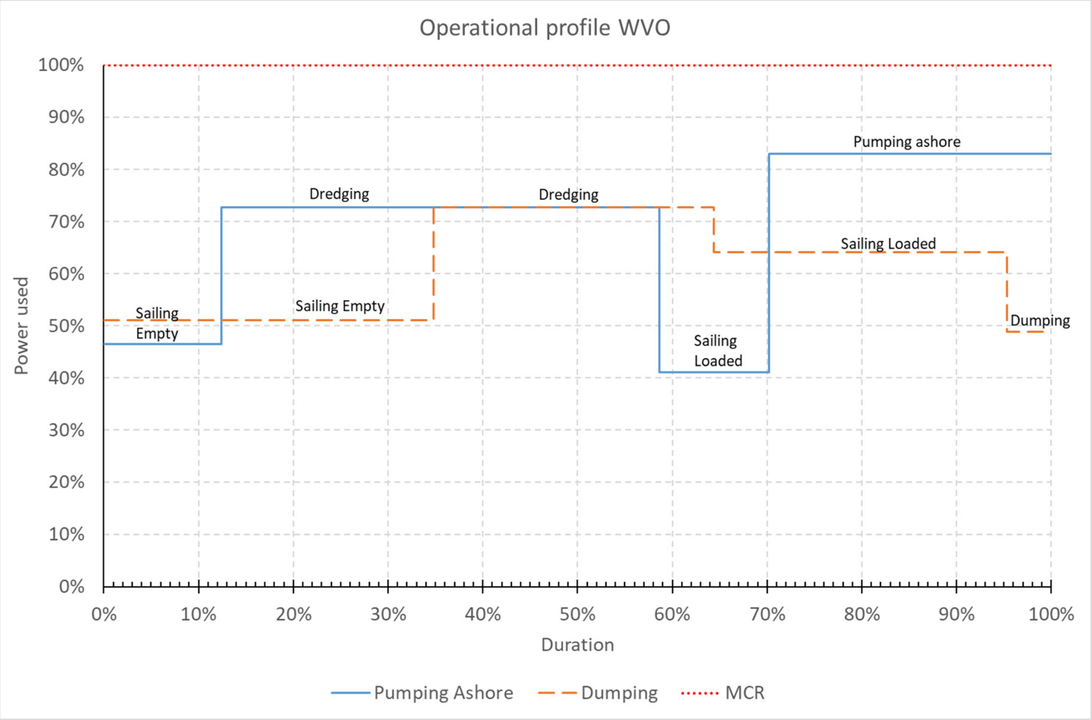

Figure 5.1.1 Dredging profiles

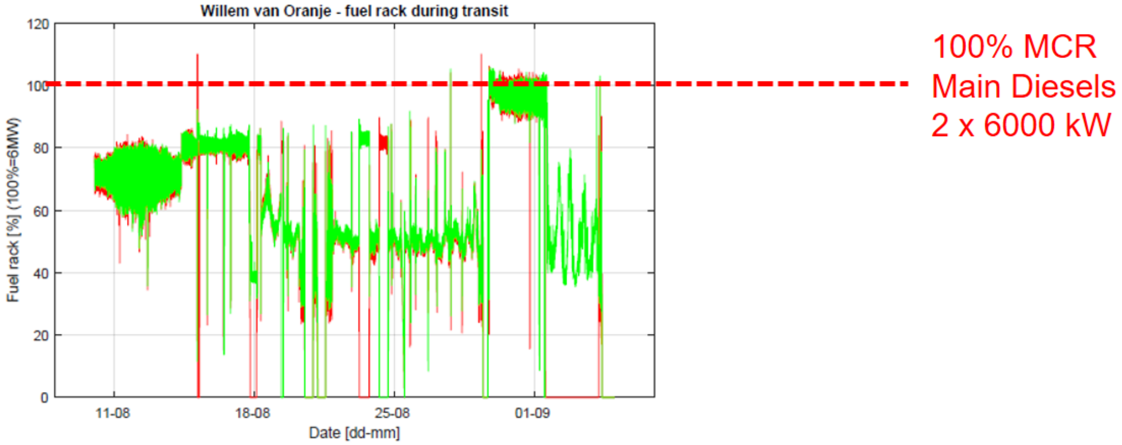

Figure 5.1.2 Profile during transit

In principle, the dredger is working 24/7.

Concept design for Methanol

The advantage of methanol over other alternative fuels is described in other parts of this project.

Due to the fact that projects to be executed by TSHD Willem van Oranje can be all over the world the concept of duel fuel is chosen. The existing engines can be modified for the use of dual fuel. The project of the Stena Germanica was used as a guideline/example for conversion to methanol.

The existing engines are suitable for a system with duel fuel injectors. Modification of the cylinder heads is required to accommodate a new injector capable of injecting methanol under high pressure in the cylinder.

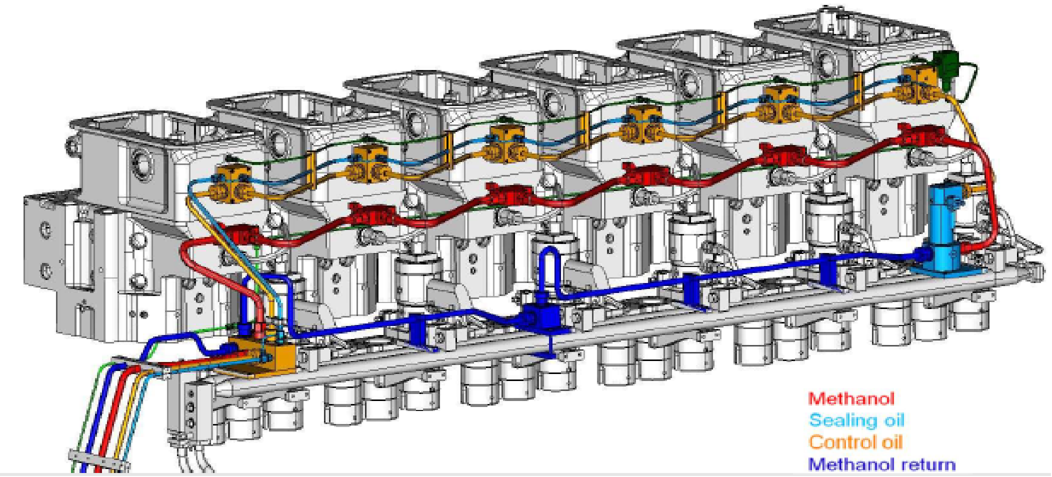

Figure 5.1.3 Cylinder heads for Methanol (Source: Wärtsilä)

Originally the Willem van Oranje was designed for operating on HFO/MDO. The option for HFO is no longer required and some HFO related equipment will be removed to make room for the methanol related equipment.

Tank size(s) and location(s)

Current tank arrangement

Hopper dredger Willem van Oranje has a number of HFO tanks and MDO tanks. The HFO tanks are situated in the midship along the hopper. The tanks are adjacent to the longitudinal hopper bulkhead, but not adjacent to the ship's side shell due to fuel outflow regulations (MEPC.141(54)). For this last reason, the bottom of the fuel tanks is not adjacent to the ship's bottom, a double bottom of 1.4 m high is in between, see Figure 5.1.6. As already mentioned, the fuel tanks are not fully symmetric. On the SB-side the foremost space is not occupied by a bunker, see Figure 5.1.4, because of the asymmetric weight distribution of the vessel. The suction tube and gantries are located on the SB-side.

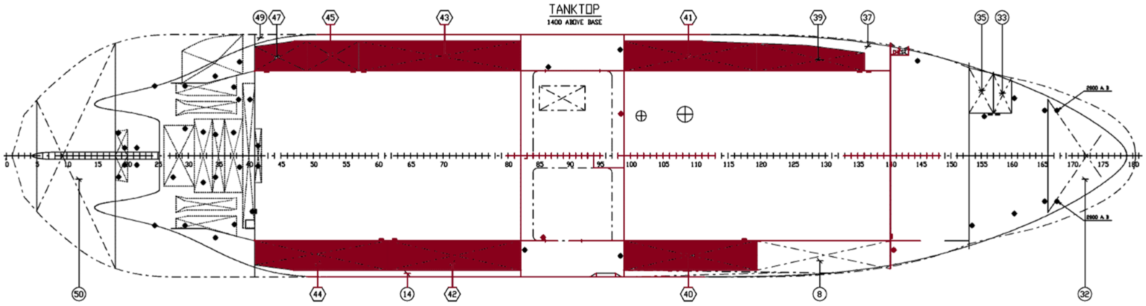

Figure 5.1.4 HFO/MDO bunker arrangement

The MDO tanks are situated in the aft ship on Port side, as shown in Figure 5.1.5.

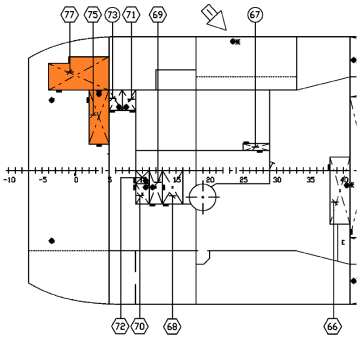

Figure 5.1.5: MDO tanks in the aft ship

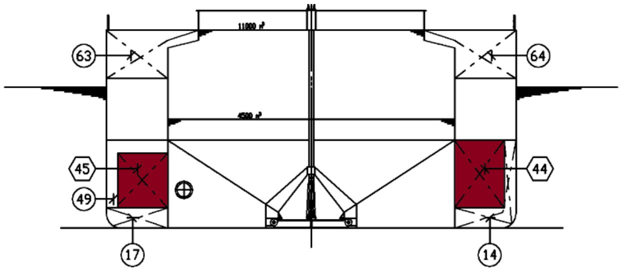

Figure 5.1.6: Cross section over the tanks

The capacity of these tanks is as follows:

- HFO bunkers, 6 in total: 1,355 m^3
- HFO Settling and Daily Service tank: 130 m^3
- MDO bunker: 66 m^3
- MDO Daily Service tank: 34 m^3

So, the total volumetric HFO capacity is 1,485 m^3 and the total MDO capacity is 100 m^3. In use, not 100% volumetric capacity can be used, 95% is more realistic. This must be taken into account when calculating the ship's autonomy.

Methanol tank arrangement

To convert the actual tank arrangement into a suitable Methanol tank arrangement, the points of departure must be clear. In the case of this hopper dredger, it is the intention to be able to switch from Methanol to (LS)MGO and back depending on the project location. This makes the conversion more complicated. Furthermore, if the same autonomy must be maintained, because of the difference in energy density the capacity of the tanks must be 2.5 times bigger than the current fuel capacity. This seemed impossible to realise in an existing ship without compromising the vessels operational capabilities. Thus, it was decided that two weeks dredging and (preferably) one large transit must be possible. Taking into account this condition, it could be concluded that the current tank arrangement has overcapacity.

On the basis of this information, IHC changed the tank arrangement. Methanol tanks may be adjacent to the side shell below the lowest draught of the vessel. However, because the vessel must be able to sail on MGO, it was no option to extend the tanks to the ship's side shell and bottom It was decided to make additional Methanol tanks under the existing fuel tanks.

Between the Methanol tank bulkhead and the longitudinal hopper bulkhead, cofferdams were required. The spaces under the hopper contain cable trays, valves, bilge lines, hydraulic installation etc. which are difficult and expensive to move, see Figure 5.1.7.

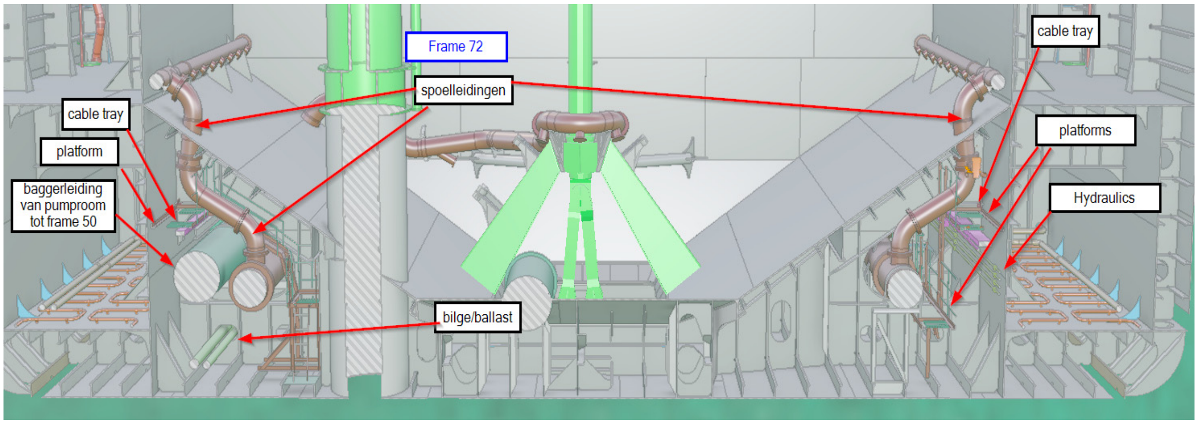

Figure 5.1.7: Space under the hopper having equipment

These spaces would be adjacent to the Methanol tanks if no cofferdam is in between. This would mean that these spaces are hazardous zones which is not allowed. Cofferdams reduce the tank capacity significantly and are not easy to manufacture because of the narrow space. (Cofferdams of 60cm wide are not easy accessible for welders.) In first instance a tank arrangement was created without modification of the pump room in the midship between the hoppers, see figure 5.1.8.

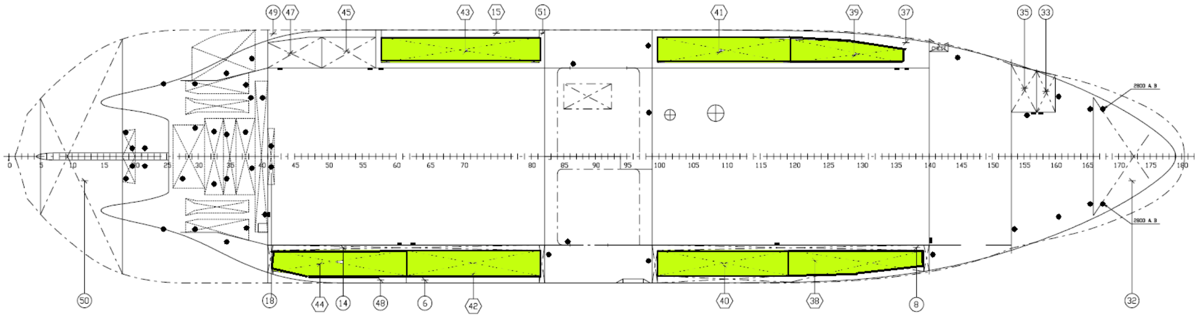

Figure 5.1.8: Initial Methanol tanks above the double bottom

As can be seen in figure 5.1.8, the HFO Settling and Daily Service tank is still not used for Methanol capacity yet. It is the idea to use these tanks for MGO. The Willem van Oranje used to run on HFO and/or MDO. In this concept it will be low sulphur (LS)MGO and/or methanol. The unoccupied space at SB-side fore has been used for an additional Methanol bunker. Compensation of the ship's transverse weight unbalance must be realised by water ballast at Port side.

On Port side fore, there are three ballast tanks in the double bottom for compensation purposes. Therefore, double bottom methanol tanks cannot be realised there. On SB-side fore, the double bottom has been used for additional Methanol capacity however.

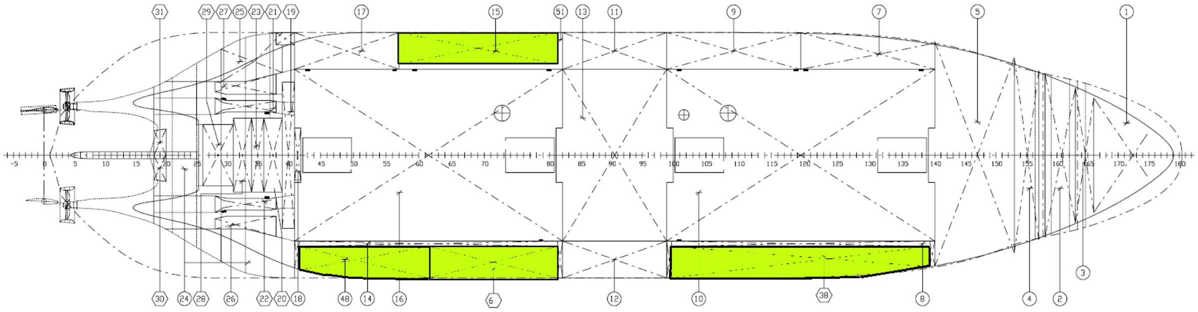

Figure 5.1.9: Initial Methanol tanks below the tanktop

The remaining tanks are used for pilot fuel, as indicated in figure 5.1.10.

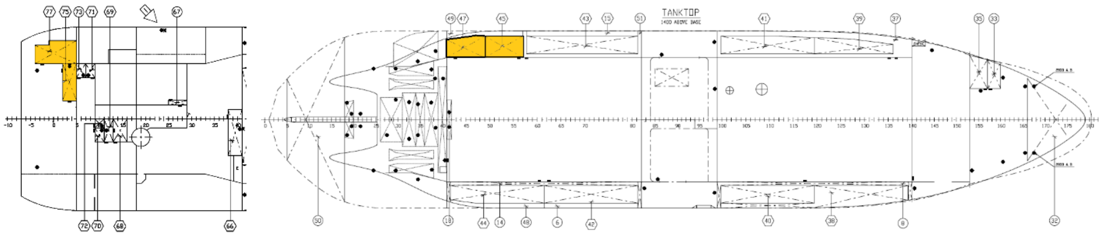

Figure 5.1.10: initial arrangement of tanks for pilot fuel

Finally, based on this initial tank arrangement, the total capacity of Methanol is 1,468 m³ and of MGO 230 m³. Excluding the Methanol return tank, the storage capacity for Methanol is only 1,320 m³.

In case of MGO only (switched from Methanol to MGO), the tank arrangement is as indicated in figure 5.1.11.

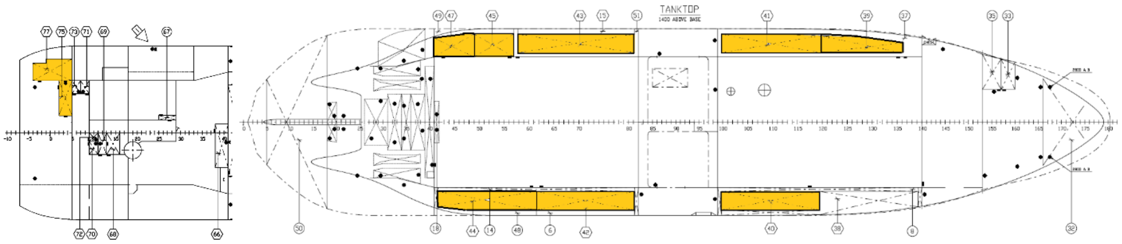

Figure 5.1.11: MGO tank arrangement

The total MGO capacity when running on MGO only is 1,175 m³, being only 80% of the original HFO/MDO capacity, due to the additional cofferdams in the fuel tank.

This study shows that changing a tank arrangement of an existing ship for Methanol and the ability to run on MGO only, is a complicated piece of work, doubtful whether this is feasible or not and finally at the cost of tank capacity and thus autonomy.

It was found that a Methanol fuel preparation room could not be situated in the existing lay-out of the engine room. So, space must be found in the midship on the cost of bunker capacity. On top of that it was found that the initial width of the cofferdams (600 mm) was too small. A minimum width of 800 mm is required to be able to manufacture it. So, a new search was done for additional tank capacity. This additional capacity was found by extending the SB-side Methanol bunkers in the aft part of the midship through transverse bulkhead of the pump room. In the fuel preparation room a service tank can be located and the double bottom tank can be extended under the fuel preparation room, see Figure 5.1.12.

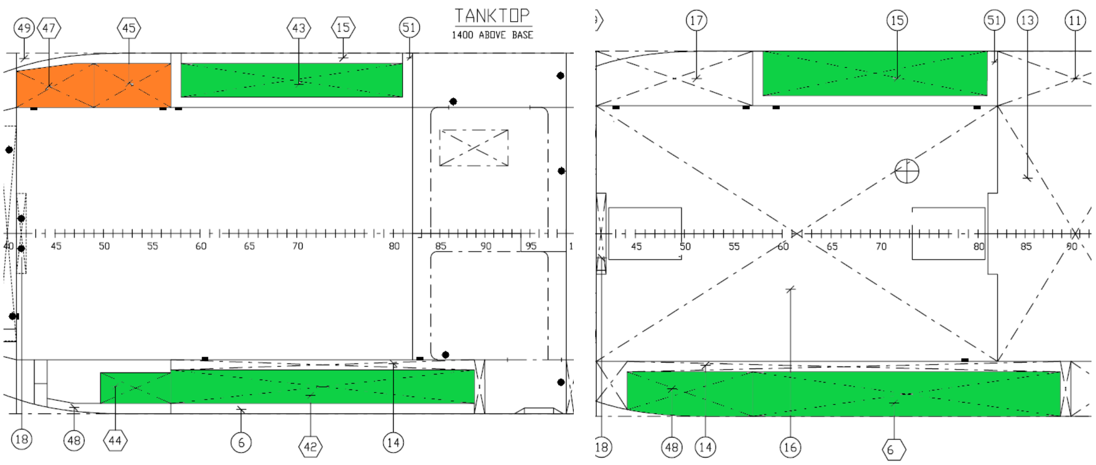

Figure 5.1.12: Modified Methanol tank arrangement, above double bottom (left), below tanktop (right)

The final Methanol capacity is now 1,337 m³ (green in figure 5.1.12) together with 231 m³ pilot fuel (orange in figure 5.1.12) , and in MGO mode the total capacity is 1,012 m³. Although not according to what was preferred, this seems to be the maximum which can be achieved reasonably.

The following important issues with regard to methanol tanks must be considered:

- The number of bunkers has increased from 6 HFO bunkers to 11 Methanol bunkers. This implies much more pipelines, valves, ventilation pipes etc.
- Methanol tanks are not allowed to be adjacent to the side shell above the lowest draught line.
- Double bottom fuel tanks are not easy to empty completely. However, Methanol remainders are not allowed if the tank above it is filled with MGO (IGF). An exemption conform tankers (IEC) must be investigated. Another solution is (maybe) a deep well pump.
- The Methanol remainders can be flushed with water. The mixture must be collected in a contaminated methanol tank. In that case, such a tank must be installed yet. It is yet not known whether methanol may be pumped overboard or not.
- Methanol tanks to have a Nitrogen connection in order to keep them inert during use and to be able to make them degassed.
- Ventilation of Methanol tanks requires a relative high capacity air supply. Fans and pipes of a large diameter are required. Maybe the use of a working air compressor is an option.
- Overpressure after bunkering Methanol must be blown off. High velocities of 20m/s to 30 m/s by degassing require special P/V tanker valves.
- Cofferdams of 600 mm wide are not easy to construct. Cofferdams of 800 mm wide are not easy to ventilate sufficiently.
- It must be possible to fill the cofferdams around Methanol tanks with Nitrogen (or water).
- Cofferdams to be closed voids without permanent connections for ventilation, purging or drainage. Emptying and ventilation of the cofferdams to be done by a separate system.

- Methanol fuel pipelines must be on a distance of at least 800 mm from the ship's side shell.
- In first instance two separate pipeline systems for fuel transfer were considered in order to find the impact. Finally, one pipeline system for both fuel may suffice and can be investigated in the end.
- The walls of Methanol tanks are to be protected with zinc. Until now no there is no adverse experience with this protection.

The autonomy for the resulting Methanol and MGO capacity, taking into account the energy density of Methanol and MGO and a daily consumption of 45 m^3 MGO, is given in the next table.

Fuel type	Volumetric capacity			Autonomy[1]		
	Current (HFO/MDO) [m^3]	Methanol mode [m^3]	MGO mode [m^3]	Current (HFO/MDO) [days]	Methanol mode [days]	MGO mode [days]
MGO	1,585[2]	231	1,012	33		21
Methanol	-	1,337			16	

From this table it can be concluded that 2 weeks dredging is feasible for the achieved Methanol capacity. The MGO pilot fuel storage capacity makes up about 28% of the stored fuel energy in the methanol mode of the vessel. This amount is capable of covering the expected 20% pilot fuel energy required for the engine. However, the preferred 20% pilot fuel is not achieved.

Apart from the autonomy, the resulting payload when running on Methanol is an important figure for the production rate. The estimated increase of the Light Ship Weight is approx. 250 ton. To compensate the mass of the suction tube and gantries, on the average an amount of water ballast of approx. 115 ton is required. This is an average for the use of 95%, 50% and 10% of the Methanol fuel storage capacity. On top of that the required amount of Methanol fuel is 2.5 times higher than that of MGO. This means that an additional payload loss of approx. 600 ton is valid: (1,337 – 1,337/2.5) x 95% x 0.79 t/m^3 (600 ton). The maximum weight of the cargo would be approx. 23.000 ton, so 2,5% loss of capacity.

For full tanks the total reduction of payload is approx. 965 ton (250 + 115 + 600).

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[1] The autonomy is based on 95% volumetric tank capacity

[2] This is the sum of the volume of all initial MDO and HFO tanks

Engine room configuration

IHC changed the lay-out of the engine room of the vessel and sent it to Boskalis for comments. Because the vessel's diesel engines initially were running on HFO, HFO separators were installed in the separator room on Port side, the so called FO TREATMENT ROOM. These separators can be removed in order to use the space for components of the Methanol fuel system. High pressure pumps for sealing oil and control oil can be positioned in this room on floor level, see Figure 5.1.13. The MDO separator unit is expected to be maintained due to the required pilot fuel. This space can be named now "Auxiliary oil pump room".

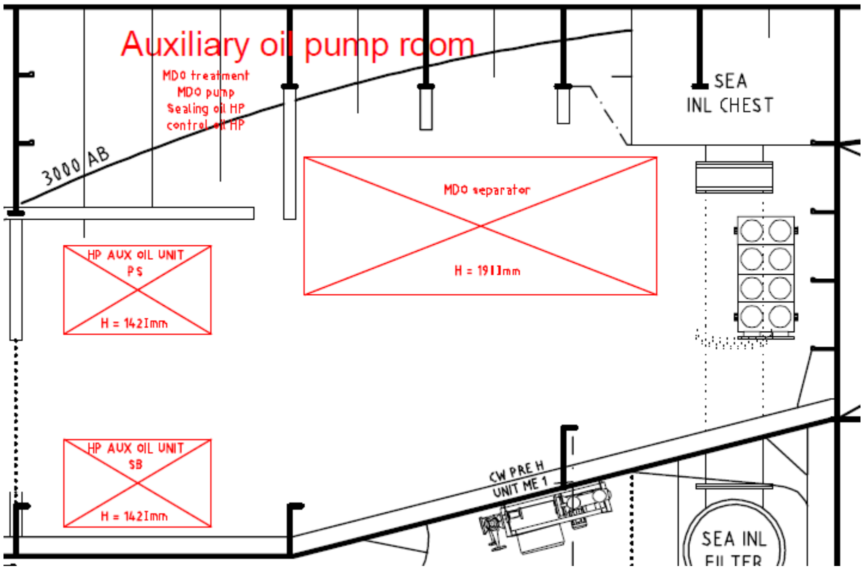


Figure 5.1.13: Auxiliary oil pump room Port side, floor level

The high pressure Methanol fuel pumps are positioned in the Methanol fuel preparation room. This room was created in the aft most part of midship on SB-side under the tween deck. A daily service tank is positioned in this room as well.

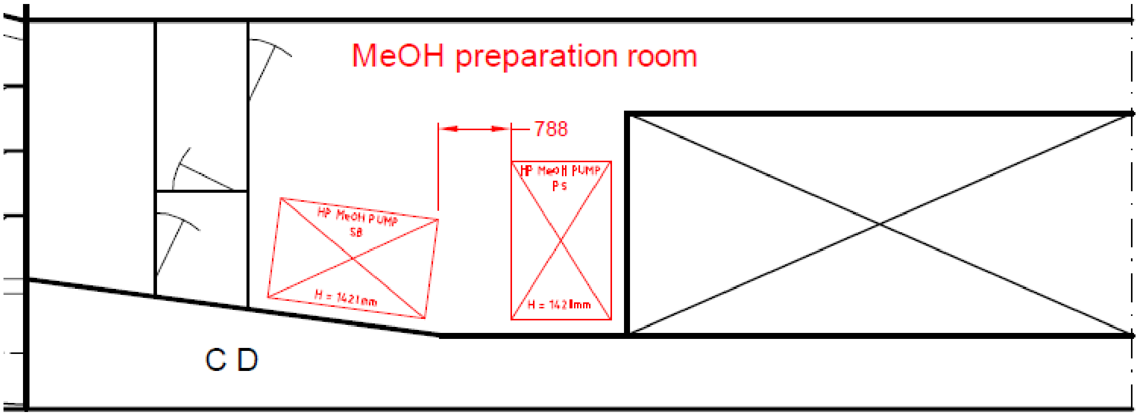


Figure 5.1.14 : Methanol fuel preparation room SB-side, floor level

In order to meet the requirements for IMO NO_x Tier III level, a selective catalytic reduction (SCR) system must be installed. The components are positioned on the tween deck of the engine room and the Urea storage tank on the upper tween deck. Furthermore, a nitrogen generator is positioned on the upper tween deck in the existing technical space. The nitrogen is used for blanketing the Methanol tanks.

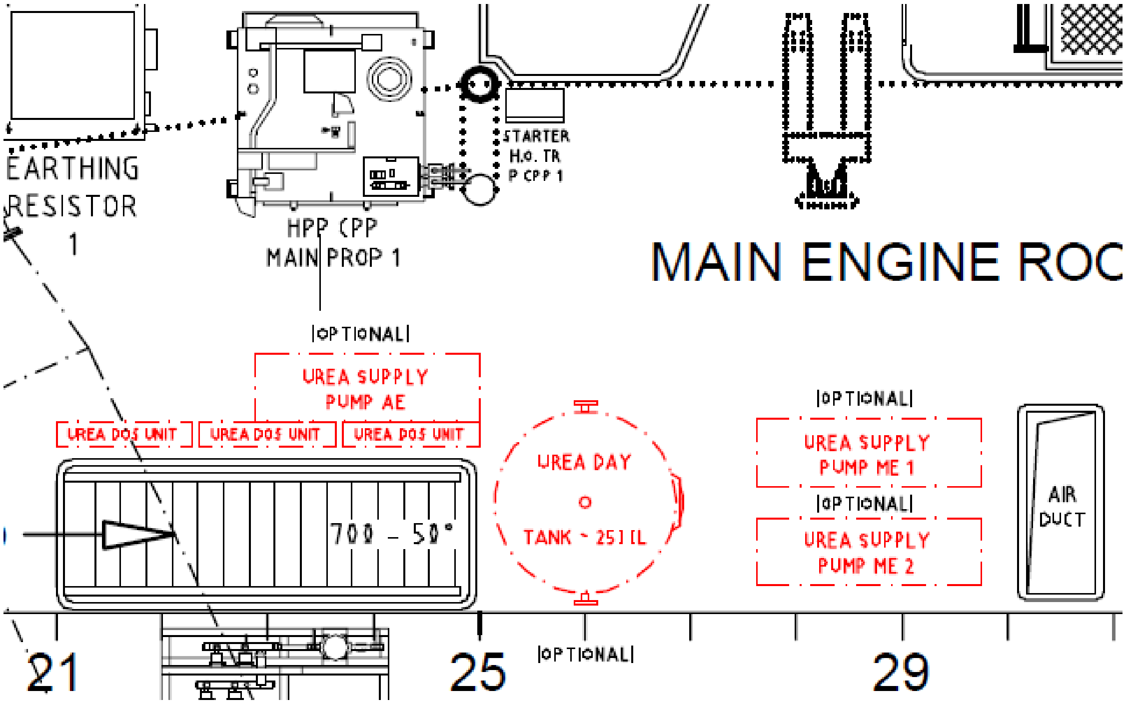


Figure 5.1.15: Tween deck level between the engines

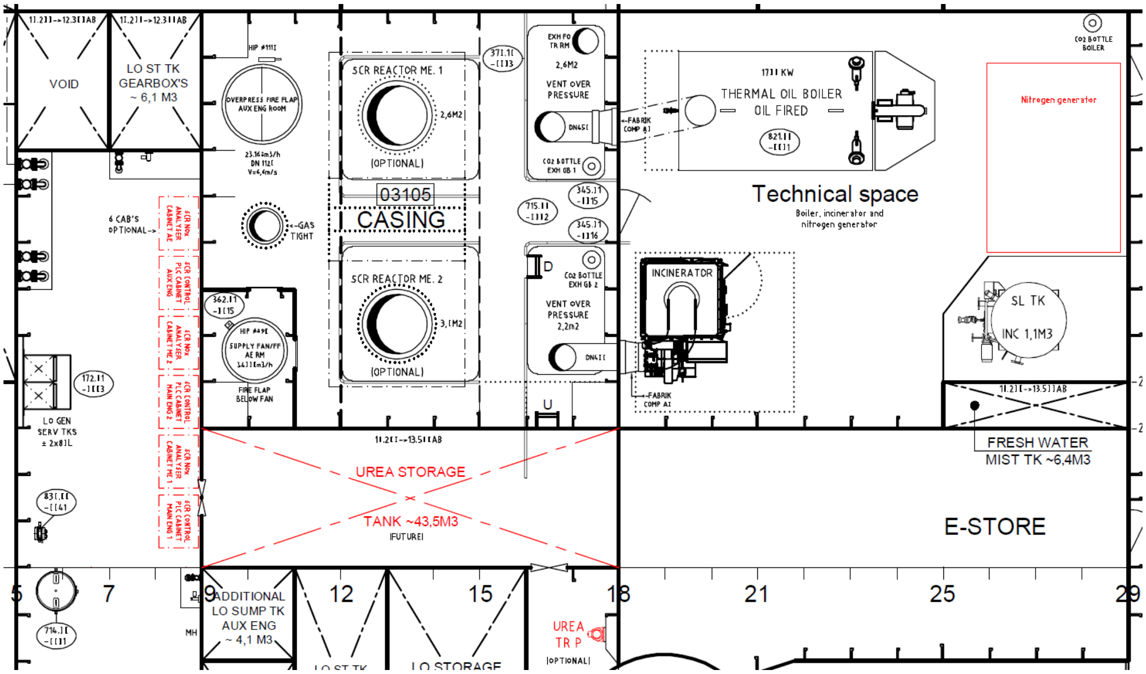


Figure 5.1.16: Upper tween deck level

Although the Methanol fuel system requires considerable additional space, it seems to be possible within the arrangement of the Willem van Oranje. Nevertheless, attention must be paid on surrounding space for maintenance of the components.

HAZID - Regulations and classification

A HAZID was not performed. It is concluded that due to the current state of the project it was not useful to do a HAZID, due to the fact that (some) crucial persons (operational, supply, manufacturers) were not involved in the project.

Conversion costs – Life Cycle Analyses

Conversion cost (engine conversion, tanks, pipelines, nitrogen, fuel preparation room, etc) have been reported indicatively only and are quite substantial amounting to approx. 20% of new building price.

Findings of the case and solutions for design challenges

The subject of the study was to check if it was feasible to use methanol as an alternative fuel for the Willem van Oranje using a dual fuel system.

During the study it appeared that a big challenge is the bunker capacity in relation to sufficient autonomy (time between bunkering, trans-ocean crossing). The choice for dual fuel even more complicated the case.

Tanks for methanol need cofferdams above the water line and where they are adjacent to other (accessible) areas (inside the ship) and also between the methanol and the MGO tanks. Tanks used for MGO need cofferdams when they are adjacent to the hull.

Using tanks for both methanol and MGO means that quite some space is used for cofferdams thus reducing the bunker capacity considerably.

The main conclusion is that in a retrofit case the tanks cannot be optimized completely. In case of new building a better optimization may be found.

Autonomy reduced from approx. 33 days for the existing vessel to approx. 16 days when sailing on methanol with MGO as a pilot fuel. This means more frequent bunkering stop while executing a project.

Due to additional construction weight, ballast, and weight of fuel the max. carrying capacity is reduced with 4%.

It is roughly estimated that due to the additional investment for conversion the weekly cost will increase approx. 5%.

In total based on items investigated the cost price per m3 dredged material is increasing with approx. 10 - 12%..

In case it is assumed that not on all future projects the conversion will be rewarded by the client (either no interest or no methanol available) the increase in cost price (for projects in which the client is willing to reward the use of methanol, for instance the Dutch government) will be more. This is still without increased price of methanol over MDO.

5.2 DMO case

Main editors: William Astley and Dorien Stroeve

The Netherlands Ministry of Defence aims to reduce its dependency on fossil fuels by at least 20% by the year 2030 and 70% by the year 2050 (compared to 2010). The Royal Netherlands Navy (RNLN) operates five seagoing support vessels, of which two Hydrographic Survey Vessels (HSV) approaching their end of life, representing an opportunity to introduce an alternative fuel source and begin the journey towards reduced fossil fuel dependency.

The intention of this case study executed by the Defence Materiel Organisation (DMO) was to compare a methanol design with that of an updated re-design of the existing HSV class (*Zr.Ms. Snellius* and *Zr.Ms. Luymes)*, both complying to the latest standards and regulations. The goal was to assess the steps necessary to introducing methanol as an alternative to diesel, highlighting technical, safety, operational and financial implications. The environmental implications of adopting methanol over diesel are well documented elsewhere within the GMM report.

Principal dimensions Hydrographic Survey Vessel Zr.Ms. Snellius / Zr.Ms. Luymes

Built:	2003
Builder:	Damen Shipyards
Length over all:	75.0 m
Breadth moulded:	13.1 m
Draught:	4.0 m
Displacement:	1,875 tons (approx.)
Main Power:	1,150 kW
Speed:	12 knots

This work was limited to conceptual design bringing the existing Snellius class design up to date within current standards and regulations and comparing it to an equivalent methanol design of the same vessel. Both hull and machinery are to fall within the latest Lloyd's Register (LR) Naval Ship Code regulations 2020. Where regulations do not exist or are found to be deficient, a Risk Based Design process has been followed in accordance with LR (Jan 2018).

In order to assess the viability of a methanol version of the HOV the starting point for any such analysis is to identify the performance of the existing HOV. The following assumptions are based on *Zr.Ms. Snellius* operational data from 2019.

Operational Profile

The vessels have the following operational profile:

- Days at sea: 150/year

- Distance sailed: 26,000 nautical miles/year

- Total Fuel Consumption: 830 m3/year

- Average Daily Fuel Consumption: 5-6 m3

- Typical duration between fuelling: 2 - 4 weeks

- Average amount fuel embarked: 93 m3 (21% of total 435m3 capacity including RAS tank)

- Target amount fuel held onboard at any one time: 95%

- Minimum amount fuel held onboard at any one time: 60%

Diesel Electric design and considerations based on an assumed maximum power requirement of 1,500kW with the following operational profile:

Operating Mode	Speed (knots)	Duration (%)	Power Requirement (kW)
Low speed and station-keeping	4	15	141
Hydrographic operations	9	40	436
Economic Transit	9	15	436
High Speed Transit	12	25	880
Maximum Speed	13	5	1,150

Concept design for Methanol

HOV re-design Starting Points

- 2-5 diesel/methanol generators (single fuel - pure methanol or methanol with a small quantity of diesel 8-10%)
- Each generator capable of developing in the range of 400-1,000kW
- Range of 4,300nm @ 12 knots
- As a starting point, the design will be based on the requirements of the IGF code, in particular the IMO “draft interim guidelines for the safety of ships using methyl/ethyl alcohol as fuel” as published 12 September 2019. (IMO, 2019)
- Total fuel capacity of 435m3, with 20% reservation for diesel when applying dual-fuel, leaving 357m3 fuel capacity for methanol.

The methanol power system will be used to supply electrical power to the ship’s network from the main generators. Since the methanol power system is the single source of propulsion power on board, redundancy shall be built into all subsystems to assure that the system will not fail or fully shut down in a single incident scenario, other than a single incident incapacitating the engine room (like an engine room fire or engine room collision). A fully independent diesel fuelled emergency generator is installed as per conventional regulations.

The Methanol refuelling subsystem includes all components needed for filling the fuel tanks. It shall be permanently installed, completely separated from other pipeline systems, and clearly marked.

The bunkering station shall be located on the foredeck. The slight buoyant character (density 1.1 kg/m^3) of Methanol vapour shall be considered when designing the bunkering station in order to keep methanol vapours from accumulating.

Methanol will be supplied by bunker trucks, by a bunker vessel or by fixed refuelling installations. Via a bunkering station, through piping and required equipment it will be transported to the storage tanks.

Tank size(s) and location(s)

The primary function of the methanol storage subsystem is to store methanol in a safe manner, regardless of the operational mode of the vessel. No additional tanks have been introduced in the methanol design – the existing diesel tanks are repurposed to hold a total embarked volume of 357 m^3 of methanol and a 20% reservation of diesel for dual-fuel purposes (78m^3 diesel). To fit the methanol tanks and corresponding cofferdams in the vessel, the ship is elongated with 2.4 meter. Owing to the hydrophilic nature of methanol there is no requirement for double-hulled tanks; however, the tanks are surrounded by a safety zone in the form of cofferdams. In addition to the fuel tanks, the methanol storage subsystem consists of several auxiliary components needed for fuelling and system safety such as pressure relief devices (PRD), (main) shut-off valves and a nitrogen blanketing and purging system.

Methanol is delivered from the tanks to the main generators via a series of piping, pumps, valves and flow meters. The fundamental purpose of a methanol flow control system is to reliably deliver fuel to the main generator combustion engines. The subsystem will be located in two physically separate and segregated fuel preparation spaces adjacent to the engine room. The purpose of the design is to ensure that the piping system is installed and tested to maintain the required pressure and flow safely without leakage or rupture throughout its service life. The inclusion of two separate fuel preparation spaces, outside of the engine room ensures that if there is a problem with one, the other can safely maintain provision of fuel to the combustion engines.

Engine room configuration

The Main Generators shall be installed in the Engine Room at mid-ship Tank deck / Lower Deck, next to the methanol fuel preparation spaces. The Main Generators shall be driven by specially designed methanol fuel engines with case approval, derived from type approved diesel engines. They are considered intrinsically safe and therefore remove the requirement for the engine room to be considered a hazardous zone. This does implicate that a case or type approval is needed in the future.

The “Main Generator subsystem” consists of several auxiliary components needed for the effective and efficient operation. These components include such items as injectors and injector pumps, exhaust treatment systems, engine monitoring and control systems, sensors, et cetera.

The engine room ventilation flow will be designed to prevent any accidental vapour release flowing to ignition sources. Within the engine room there are several other, non-related systems present, of which the certified safe type is expected to be less than required.

HAZID - Regulations and classification

The objective of the HAZID was to:

- Consider the functional requirements outlined in Section 3.2 of the IGF Code, with a view to demonstrating an equivalent level of safety;

- Identify hazards associated with the installation of a methanol power system onboard the vessel, and how they may arise - what can go wrong and how?

- Understand reasonably foreseeable consequences of these hazards and assess the level of risk, based on predefined and appropriate risk evaluation criteria;

- Review system safeguards / control measures to ensure suitability and understand what measures could be taken to reduce the risk to ALARP or eliminate it;

- Record actions and make recommendations on how these risks can be closed out.

The outcome from the HAZID process was a risk matrix which highlighted the technical challenges to the introduction of methanol and a number of areas of uncertainty where additional research is required to fully understand the technical implications.

Conversion costs – Life Cycle Analyses

Considering the original sales price of the HOVs and accounting for 3% per year inflation, a like-for-like new build of the diesel driven vessel would cost approximately 41 million EUR in the year 2021.

For the methanol version, the cost price calculation includes available price levels, estimations and uncertainties due to the immaturity of COTS methanol fuelled generator sets. Therefore the new build prices calculated are to be considered ‘rough order of magnitude (ROM)’ (+/- 15%).

The price difference between the two variants, for this study given as a percentage, is found to be approximately +7.3% for the methanol variant. Resulting in a fictional new build price of 44,2 million EUR.

The stated total cost price increase is based on information received from the project group and decisions made by the project group as a whole. In this respect the chosen solution regarding brand and type of generator set engine is based on current availability, thereby introducing a higher risk in the electrical generator solution applied than would normally be considered acceptable.

The technical solutions on which the cost price calculation is based is focused on the methanol fuel system and its safety aspects. Additional attention regarding the electrical power and distribution system has not been considered and further work may be required for optimal performance.

To provide an overview of the main cost drivers in converting a diesel fuelled HOV to a methanol fuelled HOV, the main cost centres for the price increase are shown below as a percentage of the total increase (3,0 million EUR).

Cost center	**% of cost increase (approximate values)**	
Engineering*	10 %	(300,000 EUR)
Production support*	2.5 %	(75,000 EUR)
Classification (HAZID, excluding increased cost of suppliers due to HAZID requirement)	2 %	(60,000 EUR)
Commissioning / HAT / SAT / Sea Trials*	1 %	(30,000 EUR)
Increased ship length	4.5 %	(135,000 EUR)
Paint protection (tanks)	3 %	(90,000 EUR)
Methanol compartments bilge, tank venting, ventilation	5 %	(150,000 EUR)
Stainless steel piping, double wall piping, appendages etc.	18 %	(540,000 EUR)
Methanol generator set*, consisting of: 1. *20-25% increase of generator sets with same total power generation capacity (3 x 590 ekW -> 5 x 375 ekW)* 2. *Added 10% for level/availability of technology*	`	(990,000 EUR)

Electrical components (Ex) and Alarm Monitoring System*	12%	(360,000 EUR)
Supporting safety systems*	4 %	(120,000 EUR)
Coverages for uncertainties*	5 %	(150,000 EUR)

These calculated figures take into account the fact that the methanol variant is based on new technology and as such, knowledge on the subject is not widely available where production is concerned. As a ‘first of kind’ it is anticipated that overall costs will reduce into the future with subsequent methanol driven vessels building towards enhanced knowledge and experience within the shipbuilding and supply industries. Cost centres subject to a ‘first of kind’ effect are marked with an asterisk (*).

Findings of the case and solutions for design challenges

The following paragraphs summarise the findings of this project derived from conceptual design work and the HAZID process:

Bunker station

Hazardous area

Since the bunker station is only operational during bunker operations, it is assumed that the hazardous area need only apply during these operations. Electrical equipment within the hazardous area can be isolated from the ship’s electrical power and therefore EX certification is not necessary, expect for e.g. lighting needed during bunkering operations.

Fuel distribution

Double-walled Pipes

All methanol pipework is to be double-walled to mitigate the risk of methanol leaking into spaces in the event of a pipework failure. Piping in cofferdams or through hazardous spaces can be single-walled, that space will functions as the ‘annular space’.

Annular spaces

To detect leakage in the double-walled annular space, the annular space will be kept at a pressure lower than the fuel pressure, but higher than ambient pressure. A leakage in inner piping will then cause a rise in pressure, where a leakage of the outer pipe will cause a decrease in pressure.

Annular spaces are connected via the annular space drain, which lead to the drain tank. A valve should be placed in between the annular space drain and the annular space to be able to determine the location of the leakage. If all annular spaces are connected without valves in between, this is not possible.

It is considered that methanol will probably never be present in the annular space drain. Therefore, the annular space drain itself is not made double walled

The positioning of annular space drains may pose a real challenge, since it should always be placed at the lowest point of the annular space.

Maintenance and Defect Repair

Isolation valves are to be installed at regular intervals along the length of the methanol venting pipework to allow for removal of sections without compromising the integrity of the rest of the system.

Fuel Preparation Room

Redundancy

It is advised to include two separate fuel preparation spaces. When a methanol leakage does occur in one of the rooms, it is too hazardous for a mechanic to enter the space and perform maintenance. When two separate fuel preparation spaces are included in the design, the fuel preparation space containing the leakage can be isolated from the methanol supply. Spilled methanol can be drained and the room can be ventilated. After completion the mechanic can enter the room and fix the issue. In the meantime the other fuel preparation space will ensure fuel supply to the engines.

Fuel Crossover

A crossover is included between the fuel piping of the two rooms. When one of the fuel preparation rooms is not operational, the crossover will enable one of the fuel pumps to provide fuel to all engines onboard.

Storage and tanks

Cofferdams

A cofferdam is placed between the tanks and other spaces within the ship. The cofferdam should not be occupied during operation. Forced ventilation and drain lines are installed to remove any methanol vapours and/or spilled fluid. Each cofferdam is to have a manhole/hatch through which crew can gain access to the space. Atmospheric monitoring will alarm within the cofferdam, immediately outside the access point and in the SCC if the condition of the air in the space is starting to deteriorate and become a danger to personnel.

Main Tanks

The methanol inlet should be placed as low as possible, to be able to drain the methanol from the tanks via the bunker line when the tanks are to be emptied for inspection or maintenance.

Drain and Bilge Tanks

The drain tank connects to fuel piping as well as annular spaces. The drain tank is positioned in the cofferdam as it is designed to hold methanol. The drain tank can be emptied by a dedicated pump, located in the fuel preparation room, and collected via a dedicated connection in the bunker station.

Engines and the Engine Room

Gas safe

The engine room houses the engines which are supplied with fuel via double walled piping – the fuel is routed directly from the Main Storage Tanks to the engines via the Fuel Supply Pumps in the Fuel Preparation Rooms. It is assumed that the engines are designed in such a matter, that a methanol leakage in the engine room can never occur. In this way, the engine room can be labelled “gas safe” and thus can be equipped in the same way as a normal engine room and negating the requirement for a gas tight enclosure and dedicated ventilation system for each engine. For this project, 5 retrofitted combustion ignited (CI) SandiNAOS engines, each capable of delivering 375kWe are chosen, with mechanical output expected at 390ekW (96% alternator efficiency). These engines run on methanol with a 2-3% ignition improver and are IMO Tier III compliant.

Ventilation

Since the engine room is considered gas safe, the ventilation ducts (air inlet and exhaust) are to be segregated from other ventilation ducts associated with methanol containing spaces.

Emergency Generator

Conforming to conventional classification rules, the design includes a separate diesel driven Emergency Generator.

Bilge system

Bilge Drains

The bilge system drains the fuel preparation spaces and the cofferdams – safely removing any spilled methanol to the Bilge Tank.

Bilge Pump

The Bilge Pump is located in the Fuel Preparation Room, since it is expected to require maintenance frequently. Placing the Bilge Pump in a cofferdam will make it difficult to service, owing to the lack of accessibility to cofferdams when at sea.

Storage and handling

The bilge drains remove methanol to the Bilge Tank and then overboard via the Bilge Pump either directly into the water or shoreside/vessel.

Safety systems

Nitrogen System

A nitrogen generator and storage system is to be installed onboard to provide the ability to purge pipework and tanks of methanol vapours and also act as a blanket to sit atop the methanol in the storage tanks. The inert gas displaces air within the tank, removing the possibility of an explosive mixture of methanol and air forming as well as the methanol absorbing moisture from the air – water and methanol creates a mild corrosive substance that can damage steel hulls over prolonged periods of exposure. Hence the additional requirement for the Main Tank interiors to be coated with a protective paint and for venting pipework, where the methanol mixes with air, to be made from stainless steel.

When methanol pipework is not in use, the pipes will be purged with the nitrogen/methanol vapour mix discharged to fresh air. The outlet points are to be located away from areas frequented by the crew and each outlet should be protected from the weather and the sea – no water is to enter and no ice capable of forming at the outlet and blocking it.

Nitrogen is non-life supporting and the nitrogen generator should be installed in its own dedicated compartment with forced ventilation and atmospheric sensors.

All system valves are non-return to prevent methanol entering the nitrogen system.

Oxygen sensors

The release/leak of nitrogen and/or methanol poses a serious threat to human life, therefore oxygen sensors are placed in each space that contains methanol/nitrogen pipework.

Firefighting

The Engine Room and Fuel Preparation Spaces are to be fitted with an Alcohol Resistant Aqueous Film Forming Foam (ARAFFF) firefighting system.

Methanol Sensors

Methanol sensors are to be installed in the Engine Room and Fuel Preparation Spaces in order to detect the leakage of methanol vapours.

Fuel Safety System

The Fuel Safety System monitors methanol pressures and temperatures and will isolate the supply of methanol to the engines in the event over-/under-pressure or excessive temperatures. The system is fitted with its own UPS to provide power backup during an electrical failure and a hand operated master valve is available should the system not function as intended and the supply of methanol to the Engine Room needs to be isolated.

Forced Ventilation

All spaces fitted with forced ventilation for the removal of methanol and/or nitrogen are to be fitted with 2 exhaust and 2 inlet fans to ensure continuous operation in the event of a failure.

Pressure Relief Valves (PRVs)

Each Main Storage Tank is to be fitted with its own PRV which can also be remotely operated during bunkering.

Vapour return line

It is unknown if methanol suppliers have a provision for a vapour return from the tank. Therefore, the tanks are connected to a vent stack which enable the tanks to vent to air when bunkering methanol. If the methanol suppliers provide a vapour return line, the venting of the tanks via the vent stack is no longer necessary, but the bunker station should include a vapour return connection and the means of collecting and disposing of the condensate.

Ignition improver

Further research is necessary to explore the most effective means of adding ignition improver to methanol that will be stored for a prolonged period – consider days and weeks before consumption. The stability of the methanol and ignition improver mix must be considered and will determine whether or not the mixing can occur prior to embarkation of fuel. Alternatively, stores of ignition improver would need to be held onboard and an effective means of mixing it prior to it reaching the engines would be necessary, both of which carry further technical and safety considerations.

Day tank

The inclusion of a methanol day tank within the Engine Room would require additional cofferdams, making it largely impractical, though not necessarily something to rule out entirely. Without a day tank, the introduction of ignition improver to the methanol would be 'on-demand' and linked to the loading of the engines.

Alternative Engines and Water blending

Should there be a requirement to adopt alternative combustion engines than those considered in this Use Case, the installation of an SCR or the addition of water to the fuel may be necessary to achieve IMO Tier III. Whilst the technical and logistical requirements of installing and operating an SCR are clear, further work is needed exploring the viability of water blending and its impact on engine performance.

Main Tank Seawater Flushing

Prior to entering dry dock there may be a requirement to empty the Main Tanks of methanol for the purpose of inspection and/or any maintenance or repair work on the vessel. Since methanol can be discharged into water without adverse environmental implications one option would be to utilise seawater to flush out the tanks. The filling of the tanks with seawater would also aid in the docking down process as the vessel stability could be managed by the careful and graduated discharge of the Main Tanks. Finally, as a vessel entering dry dock is an infrequent task, the opportunity would be exploited to inspect the Main Tanks as well as carry out any remedial repair work, including cleaning the tanks – thus removing any salt deposits left over from flushing with seawater. Further work would be necessary to assess the technical implications of extending the vessel's seawater cooling system to include the Main Tanks. Seawater ballasting could also be used as fuel compensation, thereby allowing the vessel to utilise the maximum fuel holding.

Discharge of Methanol Overboard

Further work is necessary to understand the behaviour of methanol and its vapours when discharged above and below the waterline, including the rate of dispersion (absorption by the sea) based on the operating mode of the vessel and the environmental conditions (weather and sea).

Vessel Stability and Range

Extensive assessment of the stability of the vessel with a reduced fuel payload and significantly lower viscosity was beyond the scope of this project. Further work would be required to understand the technical and safety implications of vessel stability when operating with methanol.

The SandiNAOS engine has a SFOC of 405-430g/kWh and therefore assuming the higher, more conservative value (430g/kWh), the range of the vessel is calculated: 357m3 methanol = 28,2744 kg (density @ 792kg/m3)

Assuming 5% unpumpable fuel, gives **26,8607 kg available methanol.**

Based on High Speed Transit @ 12kts with a power requirement of 880kW this gives 865 hours running, or a **total sailing distance of 10,380nm**.

Depending on the stability characteristics of the vessel, there may only be a portion of the total methanol holding which can be safely consumed without compromising the vessel stability.

40% fuel consumption = 4,152 nm or **2,076 nm range**

83% fuel consumption = 8,615 nm or **4,307 nm range (TARGET)***

100% fuel consumption = **5,190 nm range***

**Most likely requires water ballast to compensate.*

5.3 Port of Amsterdam and Rijksrederij cases

Port of Amsterdam

Main editors: Jan Egbertsen and Pieter 't Hart

Principal dimensions Port patrol vessel Castor

Built:	2013
Builder:	Damen Shipyards
Length over all:	19.64 m
Breadth moulded:	7.94 m
Depth to upper deck:	3.39 m
Draught design approx:	2.49 m
Displacement:	176 tons
Total bunker capacity:	14 tons MGO
Power:	896 kW (2x Caterpillar C18, 425 kW, 1,800 rpm)
Bollard pull:	16.6 tons

Speed: 11.2 knots

Operational profile:

On an annual basis port patrol vessel Castor will operate in the Amsterdam Port area for 315 days per year with on average 16 hours of operating time per day. The total operating time for Castor is estimated at 5,040 hours per year.

The average speed during patrols is 5.4 knots and is results in the following averaged activities and speeds per day.

Operational profile mode	Speed range (in knots)	Time (in hours)	Average speed (in knots)
Port	0	2.6	0
Patrol A	0 - 5	9.7	4.4
Patrol B	5 – 6.8	2.8	6
Tug	6.8 – 11.2	0.9	8.3
Total		16.0	

Figure 5.3.1. Operational profile Port Patrol Vessel Castor

Concept design for Methanol

For the concept design of methanol the following issues were taken into account including risk mitigation measures).

Considerations for methanol:

- Flashpoint of 11°C
  (Diesel >60°C, Gasoline ≈ -40° C)
- Low flame visibility
- No smoke from combustion
- Material compatibility
- Toxicity
- Soluble in water

Risk mitigation:

- Separated tank room
- Double walled fuel pipes in engine
- room
- Tank inertion
- Methanol vapour detection
- Updated fire detection and suppression
- Valves, pipes, tanks of stainless steel

Figure 5.3.2. Considerations for Methanol and Risk mitigation Port Patrol Vessel Castor

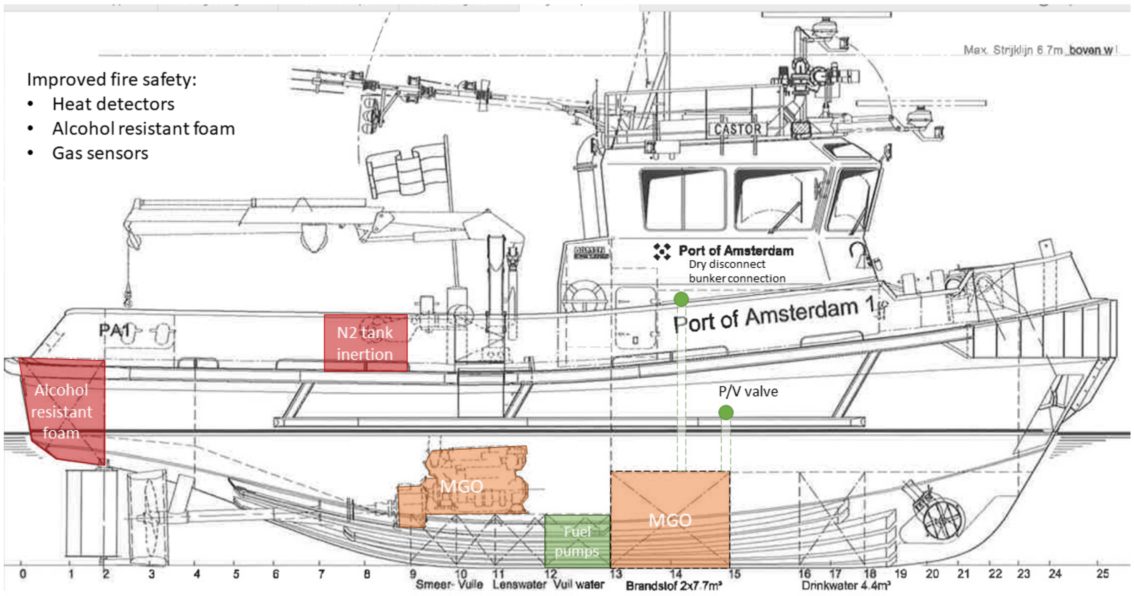
The concept design for Methanol was based upon the conversion of one main engine to methanol while the other engine would still be running on marine gasoil (MGO), with regard to system redundancy leading to the following concept design.

In this concept design only the port side engine is converted to methanol, also the port side bunker tank is converted for methanol storage and includes cofferdams for safety issues. On the port side also a dry disconnect bunker connection for methanol is installed as well a pressure vacuum (P/V) valve a waterline level for safety venting.

The starboard side engine and auxiliary engine as well as the starboard bunkering tank are designed to continue operating on marine gasoil.

The methanol pumps are located in a separately ventilated space in the engine room. The aft peak foam tank will be used as a tank for alcohol resistant foam. On the work deck behind the wheel house space is reserved for Nitrogen tank inertion and an extra CO_2 firefighting system for the engine room.

PA1 Castor – Side view – MEOH



Improved fire safety:

- Heat detectors
- Alcohol resistant foam
- Gas sensors

Figure 5.3.3. Port Patrol Vessel Castor –Side view

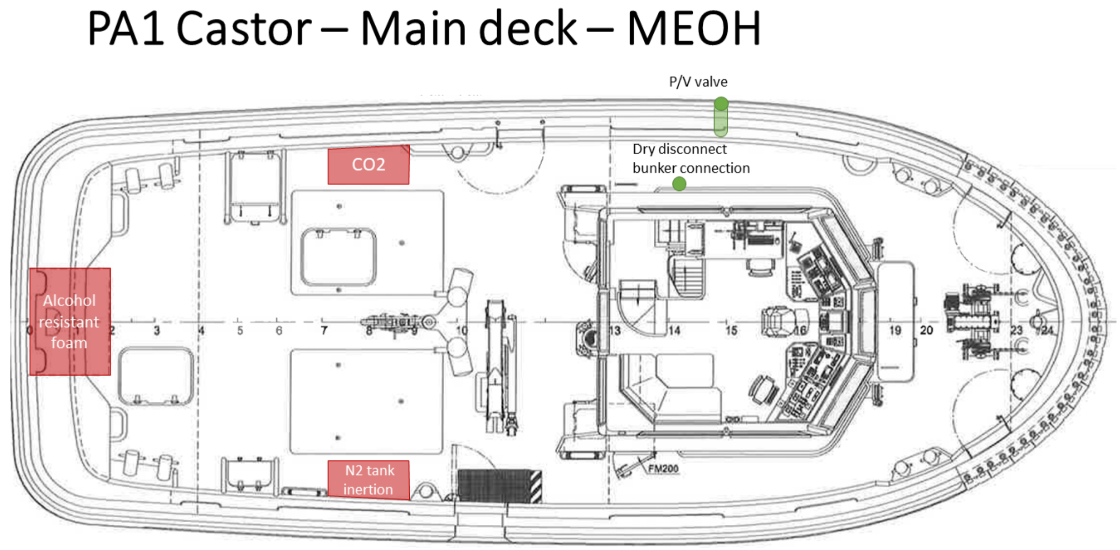


Figure 5.3.4. Port Patrol Vessel Castor – Main Deck

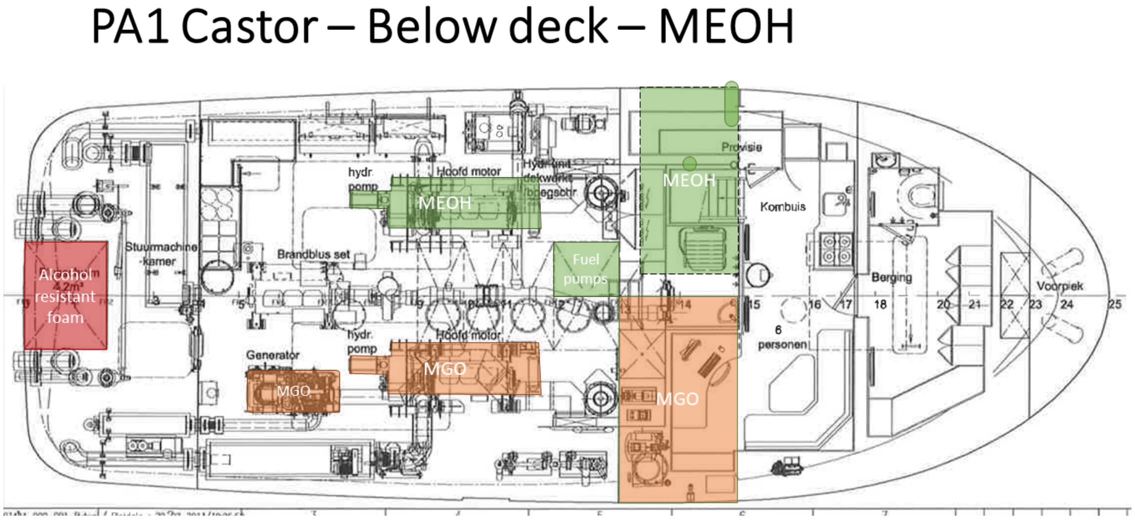


Figure 5.3.5. Port Patrol Vessel Castor – Below deck

Tank size(s) and location(s)

The most logical solution for creating bunkering volume on board for methanol is to use one of the two MGO bunker tanks for methanol. The bunker tanks for Castor are located under the waterline. This is an advantage, because in case of calamities and spills the methanol will directly be deluded by water.

Therefore methanol is stored in the port bunker tank, with cofferdams near the center line of the vessel and the engine room bulkhead. The cofferdam at the center line is installed at the expense of the MGO bunker space. The cofferdam near the engine room bulkhead is installed at the expense of the methanol bunkering space.

If a cofferdam of 900 mm (in line with CCC) is used, the bunkering capacity of the starboard MGO tank is reduced from 7 to about 4.4 tons, because due to the shape of the vessel most bunkering volume is located near the center line of the vessel. The bunker capacity of the port methanol tank is also reduced from 7 to about 3.9 tons. Roughly estimated the bunker capacity of the Castor is reduced from 14 tons MGO to 4.4 tons MGO and 3.9 tons MEOH. When considering an volumetric energy density of MEOH that is half of the one for MGO, the endurance of the vessel reduced by 55%.

If a cofferdam of 500 mm is allowed, the bunkering capacity of the starboard MGO tank is reduced from 7 to about 5.6 tons. The bunker capacity of the port methanol tank is also reduced from 7 to about 5.3 tons. Roughly estimated the bunker capacity of the Castor is reduced from 14 tons MGO tot 5.6 tons MGO and 5.3 tons MEOH. When considering again an volumetric energy density of MEOH that is half of the one for MGO, the endurance of the vessel will be reduced by 41%.

Engine room configuration

There is no conversion package available for converting the current engine towards methanol and in the power range for the vessel there are currently no methanol engines available. The only experimental methanol engines available are produced by SandiNAOS and are converted Scania MD98 13L engines (350 kW) or Weichai SI 12L engines (313kW). However, the output power of these engines is too little with regard to operational requirements of the Port of Amsterdam.

The fuel pumps for methanol should be placed in a separately ventilated space in the engine room. The methanol fuel lines should be double walled in the engine room. A nitrogen tank inertion system should be available for the methanol bunker tank. A methanol vapour detection system as well as an updated fire detection and suppression system must be installed in the engine room and all valves, pipes and tanks for methanol should be made of stainless steel to prevent corrosion.

Regulations and classification - HAZID

At present there are no rules and regulation available for inland vessels that want to use methanol as a marine fuel. Proposals to use low flashpoint fuels onboard inland waterway vessels are subject to derogation by CCR or CESNI. A request for derogation for a design shall be accompanied by engineering analysis and risk analysis and is usually supported by Class and Flag Administration.

Prescriptive requirements for fuel cells, hydrogen and methanol are in development and are expected to be included in ESTRIN 2023. Until 1 January 2024, the derogation process shall be adhered to for methanol. Derogation are in general granted in line with EU ambition to reduce emission of greenhouse gases.The Ministry of Infrastructure and Water management and class societies can play an important role in addressing these issues in the CCR.

Since no suitable methanol engines are available and the expected conversion costs are higher than expected it was decided to terminate the project and to look whether a vessel of Rijksrederij could be a better match for using methanol as a marine fuel.

Therefore a HAZID together with a classification society was not executed in this phase and no life cycle analysis was executed.

Findings of the case and solutions for design challenges

The focus of this design study was to review the possibility of a retrofit of a port patrol vessel sailing on marine gasoil towards a vessel using methanol as a marine fuel.

Port of Amsterdam concluded that in the current situation a retrofit of this vessel is not feasible yet. The existing vessel is built very compact and there is little room for extra bunker capacity and the additional safety measures that come with a retrofit towards methanol. Methanol requires new fuels tanks and piping on board which would be a major and costly conversion for the vessel. Therefore a retrofit was not regarded as a sustainable option for this patrol vessel.

For future decision making with regard to newbuilding methanol can definitely be taken into consideration as an clean fuel for the vessels of the Port of Amsterdam. In that case, several at issues still need further attention and research.

Issues for further research

The suitability of existing ship engines for using methanol, especially with regard to the specific sailing profile of these patrol vessels

Rules en regulation as well as classification: There are no rules and regulations with regard to the use of methanol as a fuel for inland vessels and there are also no classification requirements for inland vessels on methanol.

Education and training on the use of methanol as a marine fuel on vessels is not available yet.

Technical requirements with regard to fuel tanks, piping, engine room lay out (fire detection, ventilation etc.) need to be worked out in greater detail.

Possible requirements with regard to environmental code permits for bunkering with methanol.

Several questions with regard to safety arise when the patrol vessel with methanol as a fuel functions as a firefighting vessel in close proximity to heat sources.

Rijksrederij

Main editors: Loek Verheijen and Pieter 't Hart

Principal dimensions Inland patrol vessel RWS 88

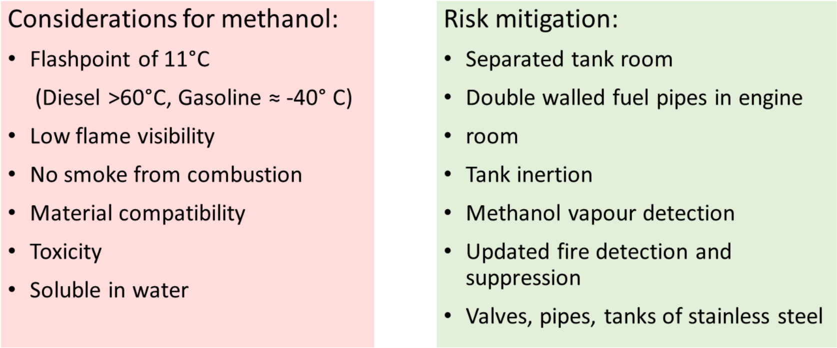
Built:	1998
Builder:	Damen Shipyards
Length over all:	18.47 m
Breadth moulded:	5.00 m
Depth to upper deck:	2.49 m
Draught design approx:	1.35 m
Displacement:	66 tons
Total bunker capacity:	3 tons MGO
Power:	1,040 kW (2x MAN D2840LE401, 520 kW, 2,100 rpm)
Speed:	16,6 knots

Operational profile

On an annual basis patrol vessel RWS 88 will operate on inland canals and (small) rivers for about 1,500 hours per year. The current maximum speed of 16,6 knots is not really required and the current maximum engine power of 1,040 kW can be reduced to approximately 700 kW.

Concept design for Methanol

For the concept design of methanol again the following issues were taken into account including risk mitigation measures).



Considerations for methanol:

- Flashpoint of 11°C
  (Diesel >60°C, Gasoline ≈ -40° C)
- Low flame visibility
- No smoke from combustion
- Material compatibility
- Toxicity
- Soluble in water

Risk mitigation:

- Separated tank room
- Double walled fuel pipes in engine
- room
- Tank inertion
- Methanol vapour detection
- Updated fire detection and suppression
- Valves, pipes, tanks of stainless steel

Figure 5.3.6. Considerations for Methanol and Risk mitigation Patrol Vessel RWS 88

The concept design for Methanol was based upon the conversion of both main engines to methanol leading to the following concept design.

In this concept design both main engines are converted to methanol and the auxiliary engine continues to operate on marine gasoil (MGO). Both starboard and port side bunker tanks are converted for methanol storage and include cofferdams for safety issues. Behind the port side methanol bunker tank a small marine gas oil tank should be installed for the auxiliary engine. On both port and starboard side a dry disconnect bunker connection for methanol is installed as well a pressure vacuum (P/V) valve a waterline level for safety venting.

The methanol pumps are located in a separately ventilated space in the engine room. The aft peak foam tank will be used as a tank for alcohol resistant foam. In the engine room close to the aft peak bulkhead space is reserved for Nitrogen tank inertion and an extra CO2 firefighting system for the engine room.

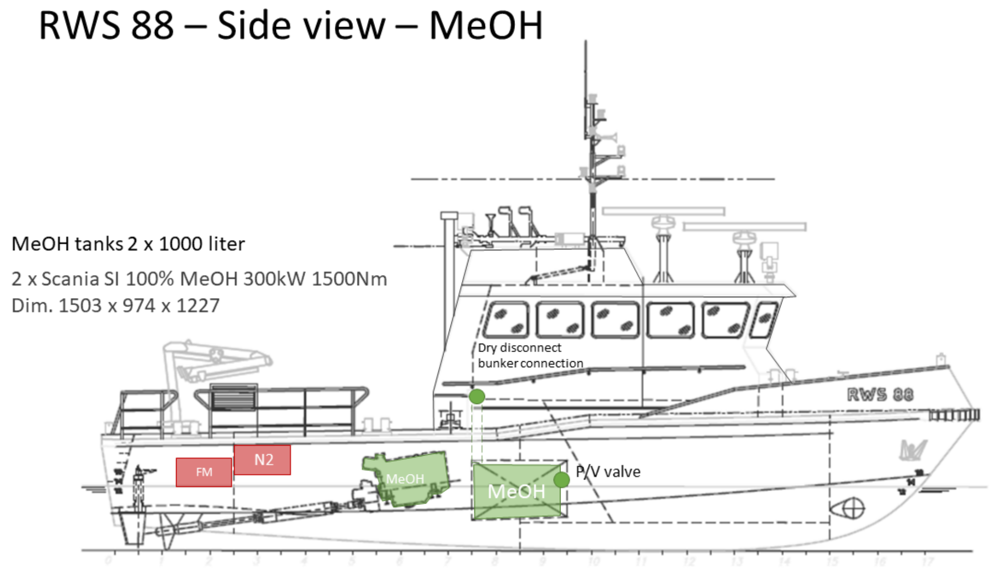


Figure 5.3.7. Patrol Vessel RWS 88 – Side view

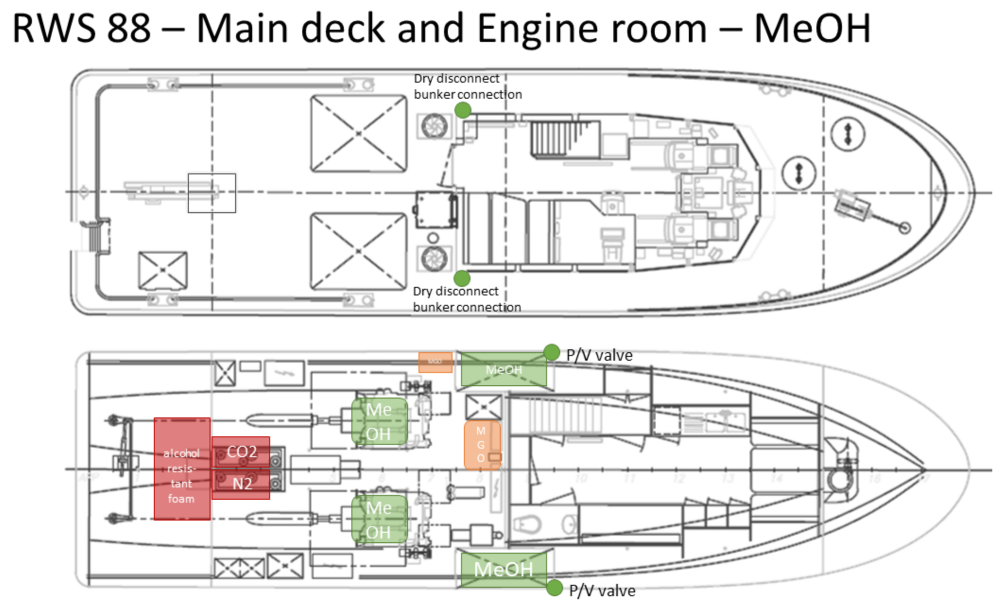


Figure 5.3.8. Patrol Vessel RWS 88 – Main deck and Engine room

Tank size(s) and location(s)

Due to the use of cofferdams the methanol bunkering capacity is reduced from 2 x 1,500 litres of MGO to an estimated 2 x 500 litres of methanol. This reduces the operating range of the vessel with 67%. The plan is to operate the RWS 88 after conversion on inland canals and (small) rivers for about 1,500 hours per year. Estimated fuel consumption on methanol is approximately 90,000 litres per year. This implies a fuel consumption of approx. 2,000 litres of methanol per running week and means bunkering two times a week. For this pilot project that is deemed acceptable.

The location of the bunkering tank is in the midships, which hardly influences the stability of te vessel. However, part of the port and starboard bunker tanks are located above the lowest waterline of the vessel. Although a nitrogen blanket system is used for the bunker tanks. this might pose problems with regard to evaporation of the methanol when exposed to the sun burning on the sides of the vessel. This issue should be further investigated in co-operation with the Netherlands Maritime Safety Authority (IL&T) and classification societies.

Engine room configuration

There is no conversion package available for converting the current engines towards methanol and in the power range for the vessel there are currently no methanol engines available. The only experimental methanol engines available are produced by SandiNAOS and are converted Scania MD98 13L engines (350 kW) or Weichai SI 12L engines (313kW). Although the output power of the SandiNAOS engines is significantly smaller than the current MAN engines, they could be used on board of the RWS 88 since the required maximum output power of the vessel is reduced from 1,040 kW to approximately 700 kW.

Another option would be the conversion to two Scania 16L V8 compression ignited engines that run on MD97 which is 97% methanol and 3% ignition enhancer. The ignition enhancer makes it possible to operate the engines compression ignited, which gives superior fuel efficiency (particular on part load) and identical drive characteristics as a conventional diesel engine (torque, response etc).

The fuel pumps for methanol should be placed in a separately ventilated space in the engine room. The methanol fuel lines should be double walled in the engine room. A nitrogen tank inertion system should be available for the methanol bunker tanks. A methanol vapour detection system as well as an updated fire detection and suppression system must be installed in the engine room and all valves, pipes and tanks for methanol should be made of stainless steel to prevent corrosion.

The picture below shows the engine room of the RWS 88 (looking backwards).

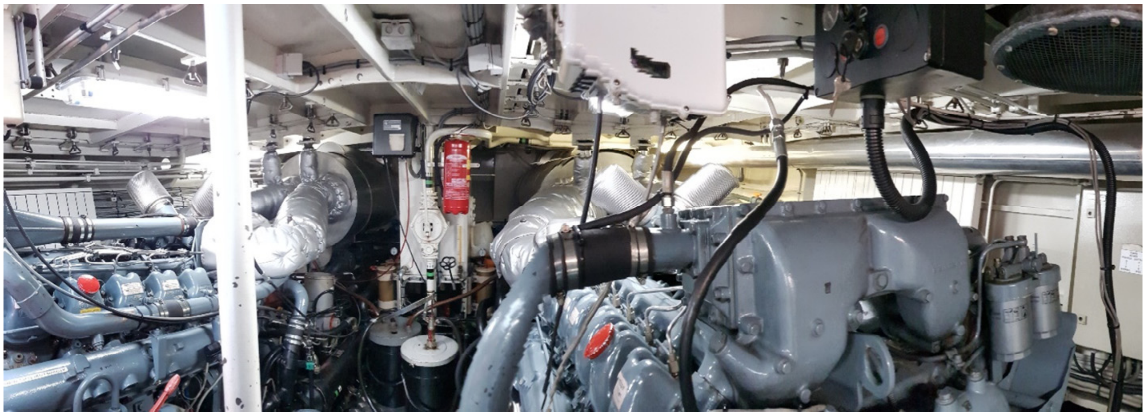


Figure 5.3.9. Engine room view Patrol Vessel RWS 88

HAZID - Regulations and classification

At present there are no rules and regulation available for inland vessels that want to use methanol as a marine fuel. *European Standard laying down Technical Requirements for Inland Navigation vessels* (ESTRIN) 2019, applicable for inland water way vessels, includes specific requirements for the use of LNG, for other low flash point fuels a derogation is to be requested. For seagoing vessels the IGF code describes rules and regulations for Low Flashpoint fuels.

The Ministry of Infrastructure and Water management and class societies can play an important role in addressing these issues in the CCR.

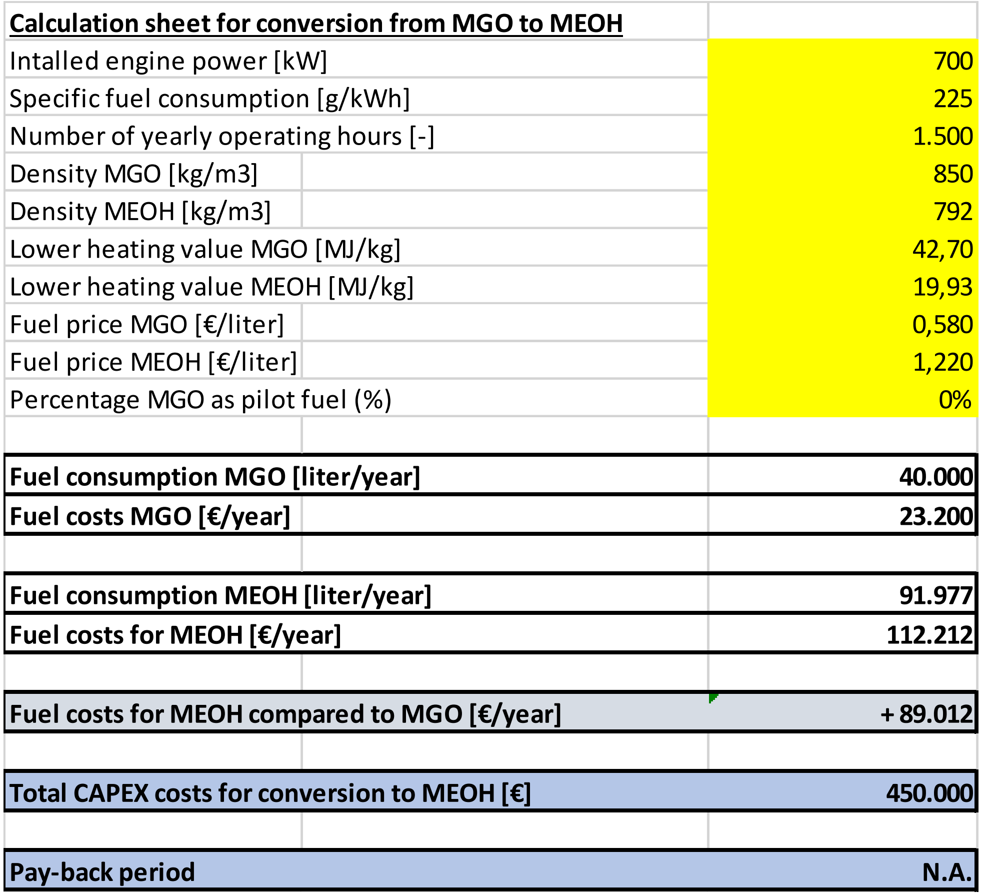
Since the RWS 88 project started as a result of the termination of the port patrol vessel of the Port of Amsterdam there was not enough time to schedule a meeting with Ministry of Infrastructure and Water management for a conversation with regard to the regulatory framework on the use of methanol on inland vessels. However, delegates from IL&T expressed that they are currently investigating potential use of hydrogen and methanol on inland waterways and suggested a similar plan of attack as for use of LNG on inland waterways that has been approved after an extensive process.

SandiNAOS mentioned on our request that they would advise to take the “alternative design route”, which that together with regulatory bodies a risk assessment is made whereby solutions are proposed to address the particular hazards with methanol.

The HAZID together with a classification society has not been executed yet and a limited life cycle analysis was executed.

Conversion costs – Life Cycle Analyses

A basic calculation sheet was used to determine capital and operational expenses of the RWS 88 when converted from gasoil to methanol. The input data for conversion costs is a rough estimate from SandiNAOS.



Calculation sheet for conversion from MGO to MEOH	
Intalled engine power [kW]	700
Specific fuel consumption [g/kWh]	225
Number of yearly operating hours [-]	1.500
Density MGO [kg/m3]	850
Density MEOH [kg/m3]	792
Lower heating value MGO [MJ/kg]	42,70
Lower heating value MEOH [MJ/kg]	19,93
Fuel price MGO [€/liter]	0,580
Fuel price MEOH [€/liter]	1,220
Percentage MGO as pilot fuel (%)	0%
Fuel consumption MGO [liter/year]	**40.000**
Fuel costs MGO [€/year]	**23.200**
Fuel consumption MEOH [liter/year]	**91.977**
Fuel costs for MEOH [€/year]	**112.212**
Fuel costs for MEOH compared to MGO [€/year]	**+ 89.012**
Total CAPEX costs for conversion to MEOH [€]	**450.000**
Pay-back period	**N.A.**

Figure 5.3.10. Basic calculation sheet Patrol Vessel RWS 88

Since the current (green) methanol price is much higher than marine gas oil the investment costs of the conversion towards methanol are not recovered. If there are no penalties on the use of fossil fuels (e.g. ETS, CO_2 price, etc.) or stimuli for using green methanol (e.g. RED II, HBE, etc.) the height of the fuel price for (green) methanol will seriously hamper its introduction in the maritime sector.

Unfortunately, the business case for the RWS 88 is not positive yet.

Findings of the case

Although the RWS 88 is a relatively small vessel, it can probably be converted to a full methanol vessel. However, discussion on the regulatory framework and/or exemptions with the Ministry of Infrastructure and Water management, and probably also with classification societies is required in order to design and built inland vessels using methanol as a marine fuel.

Although methanol engines are told to be available on short notices (within 6 months), in practice these engines are still in an experimental stage and it is not easy to receive any detail information about these engines.

Although methanol is available in most large ports, green methanol is only produced in limited amounts. The scale up of green methanol plants and the availability of green methanol for the shipping sector seems to be a prerequisite for a successful introduction and further implementation in the maritime industries.

5.4 Van Oord case

Main editors: Ilayda Genc and Moritz Krijgsman

Principal dimensions Cable laying vessel Nexus

Built:	2014
Builder:	Damen Shipyards
Length over all:	122.68 m
Breadth moulded:	27.45 m
Draught design:	5.82 m
Deadweight:	8,398 tons
Total power installed:	10,948 kW (2x 2,666kW and 2x2,200 kW aux. 1x 1.432kW)
Speed:	12,4 knots

Purpose Van Oord project

The purpose of the project is to convert the existing cable laying vessel Nexus (DP 2) for reducing the CO_2 footprint. Green methanol is a suitable potential climate neutral fuel.

The deliverables of this use case are:

1. Setting up a conceptual design of containment and distribution systems of the energy carriers methanol and diesel, which are both required for operating the combustion engines,
2. Setting up a conceptual design of the engine room systems. These design activities will result in modified logical schematics (Single Line Diagrams, Process Flow Diagrams, Automation Architecture Diagrams, etc.) and physical drawings (3-D models of the energy storage and engine room),
3. Obtaining an ‘in principle class approval’ of the new systems in the existing Nexus, and
4. Setting up a business case and a description of the environmental impact. The targeted life time is 20-25 years.

Task 1. Objectives, starting points and Operational requirements (Van Oord)

Objectives

a. The main objective is to reduce the CO_2 emissions with 50% per mission compared to the current diesel fuelled ship,
b. Concerning harmful emissions the vessel must comply with IMO Tier III. The current vessel complies with IMO Tier II,
c. The targeted bunker capacity is:

Bunker capacity	Fuel	Energy [GJ]	Volume [m^3]	Weight [Tons]
Converted ship	MeOH	10,000	642	508
	MGO	14,000	381	328
	Total	**24,000**	**1,023**	**836**
Current ship	**MGO**	**55,083**	**1,500**	**1,290**

The loss of contained energy of 31,083 GJ is possible from an operational point of view and accepted.

Starting points

a. Compliancy of the fuel with renewable production requirements may be proven by a methanol industry chain analysis,
b. The requirements for maximum stationary propulsion and auxiliary power are equal to the current vessel (based on 100% Maximum Continuous Rating (MCR) of the prime movers),
c. The requirements for dynamic propulsion and auxiliary power are equal to the current vessel, represented by the Dynamic Positioning 2 requirement. The DP Capability Plot is identical to the one of the current vessel,
d. If required for dynamic operational performance an electrical energy storage system can be added as a peak power shaver. In addition this system could act as a main energy source for short term zero missions operation,

e. Hull, propulsion, propulsion systems, main electrical distribution architecture, control and automation architecture, auxiliary systems and existing supporting systems remain the same,
f. Supporting systems for containment and distribution of methanol, for electrical energy storage systems (optional) and for the internal combustion engines (like cooling water, fuel supply and exhaust) are to be added, depending on the changes in the primary systems,
g. Safety systems are to be modified and/or extended if required by classification.

Operational requirements

Project 'Deutsche Bucht' is representative as a 'Zero measurement' for the mission profile. The power recordings shows that maximum peaks of 4,5 MW occurs during DP-operation. In case only 60% of the current MCR of the main engines would be available, which would be the case when running on methanol blend, then 2 x 2,8 MW would be available on each side of the 690VAC distribution. For the calculation of DP2 'spinning reserve', the full power of the auxiliary generator can be added to each side, which makes a total available power of about 3 MW per distribution side.

As a typical long range mission profile a job in Halifax CND is selected. This location lies at 14 days cruising from Rotterdam. For these jobs a four weeks autonomy is required for running on MGO and methanol. At location a two weeks bunkering interval for methanol is required. The latter is also the typical short range operational profile for the job in Deutsche Bucht.

The average current fuel consumption is approx. 25 m^3 MGO/day for Transit (part 1 of the long range mission profile) and approx. 15 m^3 MGO/day for Jobbing (part 2 of the long range profile and almost all time of the short range mission profile). In practice Transit means a mix of Economic Cruising (10 Kts), Fast Cruising (11 Kts), and Full Speed (12 Kts).

Nexus has a Caterpillar MEO-system installed, so these fuel consumption data can be checked on board.

10-15% of the OpEx of Nexus is fuel cost, so the business case of this working vessel less sensitive for fuel prices than in case of a transport ship (Task 7).

In order to meet the reduction of CO_2 emissions with 50% per mission (objective a.), the energy and fuel consumption for both mission profiles could for example be as shown in the following table. The last column shows the CO_2 emissions and reduction:

Fuel consumption and CO_2 emissions	**Fuel**				**CO_2–emissions**	
	Type	Energy [GJ]	Volume [m^3]	Weight [Tons]	Tons[1]	Reduction %
Short range mission profile (two weeks autonomy)	MeOH	8,050	517	409	262	**54%**
	MGO pilot[2]	403	10	9	29	
	Total	**8,453**	**527**	**418**	**291**	
	MGO only	**8,453**	**230**	**198**	**634**	**0%**
Long range mission profile (four weeks autonomy)	MeOH	8,050	517	409	262	**22%**
	MGO pilot[2]	403	10	9	29	
	MGO	12,100	329	283	906	
	Total	**20,553**	**856**	**701**	**1,197**	
	MGO only	**20,553**	**559**	**481**	**1,539**	**0%**

[1] Calculated with a Carbon Factor of 3,2 for MGO and 0,64 for green MeOH

[2] Pilot Fuel is 5% of the total energy consumption

The blue coloured cells are inputs and the orange coloured cells have to match the estimated MGO consumption, as given by Van Oord (25 m^3 MGO per day and 15 m^3 MGO per day, converted into mission profiles). The inputs can be varied in order to achieved the objectives. In this rough calculation it is assumed that the efficiency of the Dual Fuel MeOH-MGO engines equals the efficiency of the current MGO engines.

Conclusions:

1. Objectives, starting points and operational requirements are clear. The necessary information for the feasibility study is available.
2. For these typical mission profiles we need approx. 650 m^3 of MeOH tank volume and approx. 400 m^3 of MGO tank volume.
3. In the short range mission profile of two weeks the objective of 50% reduction of CO_2-emissions can largely be met. In the long range mission profile of four weeks only 22% reduction of CO_2-emissions can be met, but since approx. half of that mission occurs in IMO waters, this achievement seems sufficient.

Task 2. Methanol containment, distribution and bunkering (Damen O&T)

The designed bunker capacity is 1,300 m^3 MeOH (3 tanks) and 910 m^3 MGO, which is more than enough to meet the mission profiles (ref. Task 1).

Van Oord prefers to have a vessel as bunker facility and a one side bunkering system on board.

The bunkering position will be positioned on SB side. The engine room lay out will be adjusted according to the outline technical information of the new DF methanol engines.

The moon pool reservation can be sacrificed for methanol storage or the methanol treatment and pump room. At the time of the requirement specifications of the current ship it was not sure whether cable laying would be the only business for the vessel. If not, than a moon pool would be used for other offshore activities.

The pump rooms are designed just behind the engine room. They will be 1 deck high (2.90 m), just behind the engine room.

Methanol pre-treatment is not required, because of the purity of bunkered methanol (>99%) no filtering is required. A coarse meshed filter is installed for catching parts.

The methanol tanks of Stena Germanica have Zinc-Silicate coating. After 5 years of operations the paint has lasted perfectly.

The Urea Tank still has to be fit in, but there is enough space available.

The IMO Draft Interim Guidelines for the Safety of Ships using Methyl/Ethyl Alcohol as Fuel (CCC6 Annex 1) have been used as a reference.

These Guidelines for instance set requirements for inert gas system and define hazardous areas.

Where the requirements for hazardous areas are considered inappropriate or impractical, a hazardous area assessment may be carried out in accordance with the principles as given in standard IEC 60079-10.

Two General Arrangements were made. The first one was for assessing the engine room configuration and the pre-HAZID meeting. The second one was made after these assessments.

The figure of Appendix A shows the 3-D model of the second concept design.

Conclusions

1. The impact of the rebuild towards methanol engines on the ship design is a major conversion.
2. The ship can be modified to an engine room with DF MeOH-MGO engines in the generator sets
3. The ship can be modified to comply with the additional Rules and Regulation for safe operations with MeOH.

Task 3. Power generation (Caterpillar-MaK/Bolier)

The current MaK engines 2x 8M25C and 2x 6M25C are TIER II certified. The objectives 1.a. and 1.b. require a significant reduction of CO_2 and harmful emissions compared to the current engines.

The Caterpillar 3512 690 V/60 Hz generator set is seldom operated, so conversion to methanol does hardly contribute to reduction of CO_2 emissions.

Running on a Methanol-Diesel blend

Can applying methanol be achieved by running on a methanol-diesel blend? This could mean a minor a modification of the current diesel engines. The M25 cylinder head has only room for one fuel injector. Therefore fuel blending of methanol and diesel is the only possibility on this engine type.

At 70 vol% methanol and 30 vol% diesel blend, the achievable **maximum continuous power** will be 65-70% of the 100% MCR with 100 vol% Diesel in the reference scenario. The limiting factor is the stroke volume of the fuel pump. The largest type fuel pump at maximum stroke has been considered.

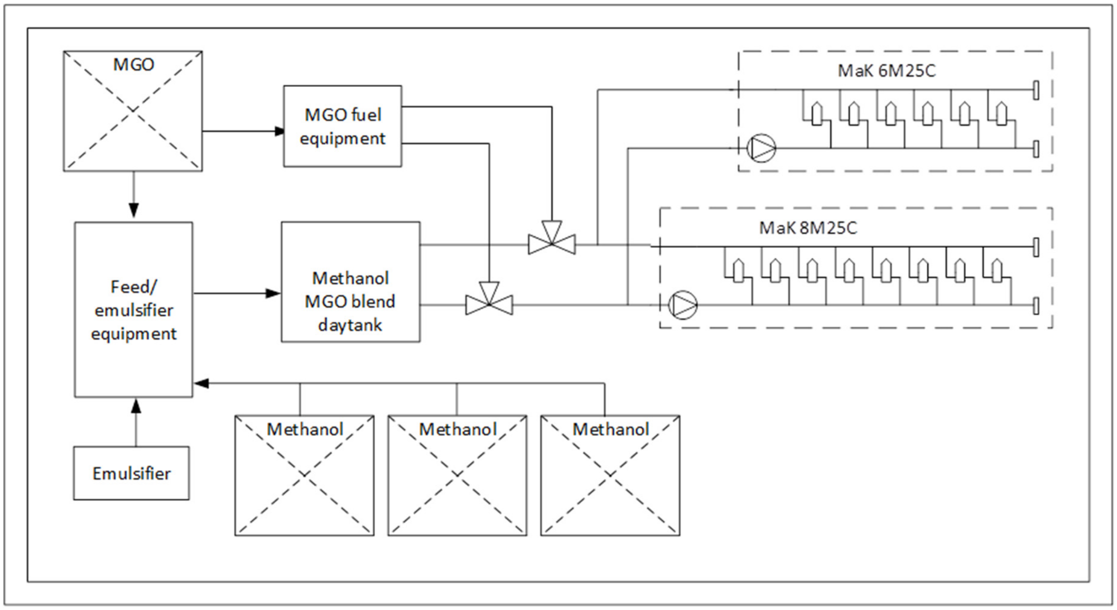
This means that with the preferred solution of fuel blending, starting point ‘2b The requirements for maximum stationary propulsion and auxiliary power are equal to the current vessel’ cannot be met.

There are a few possibilities to overcome this issue:

- Is the starting point 100% Diesel MCR really necessary? Or is 100% MCR in practice seldom the case? Van Oord shows a ‘time-power diagram of Nexus’, measured during a typical operation in project ‘Deutsche Bucht’. The occasionally occurring maximum power peaks are during DP operation and are lower than 100% Diesel MCR. Furthermore when reaching high power peaks, not all generator sets are switched on, meaning that the power management does its work properly. The power management parameters could be changed, so a lower reference than 100% Diesel MCR might be acceptable.
- In case the engines, when running on methanol, can‘t meet the transient response requirements, then dynamics could be intercepted by batteries or super capacitors. If the energy storage is large enough then the DP2 power peaks could also be provided by them. The DP capability requires that you have to maintain position in case of a single failure in DP2. Usually the worst single failure is loss of an MSB; in that case you lose two gensets. In order to keep the DP capability equal to diesel, you need ~35% MCR on battery power for spinning reserve.
- Blending with biofuel HVO instead of MGO. This could be a solution, but Van Oord warns for the huge price differences between HVO and MGO. This solution might economically not be feasible.
- Rebuild the engine to dual fuel. This is the less preferred solution, because of the large implications of a complete redesign. We will wait for the outcome of the other possibilities, before considering this.

A switching time from methanol blend to 100% diesel, that would take some minutes is acceptable in normal operational conditions. The technical background is that the 60-70 litre blending vessel must be emptied. For emergency cases a diesel bye-pass system is foreseen.

For the methanol blending concept Van Oord made a simplified diagram of the fuel/blend supply system. It was assumed that the engines have to be started on MGO and will switch over to the methanol blend.

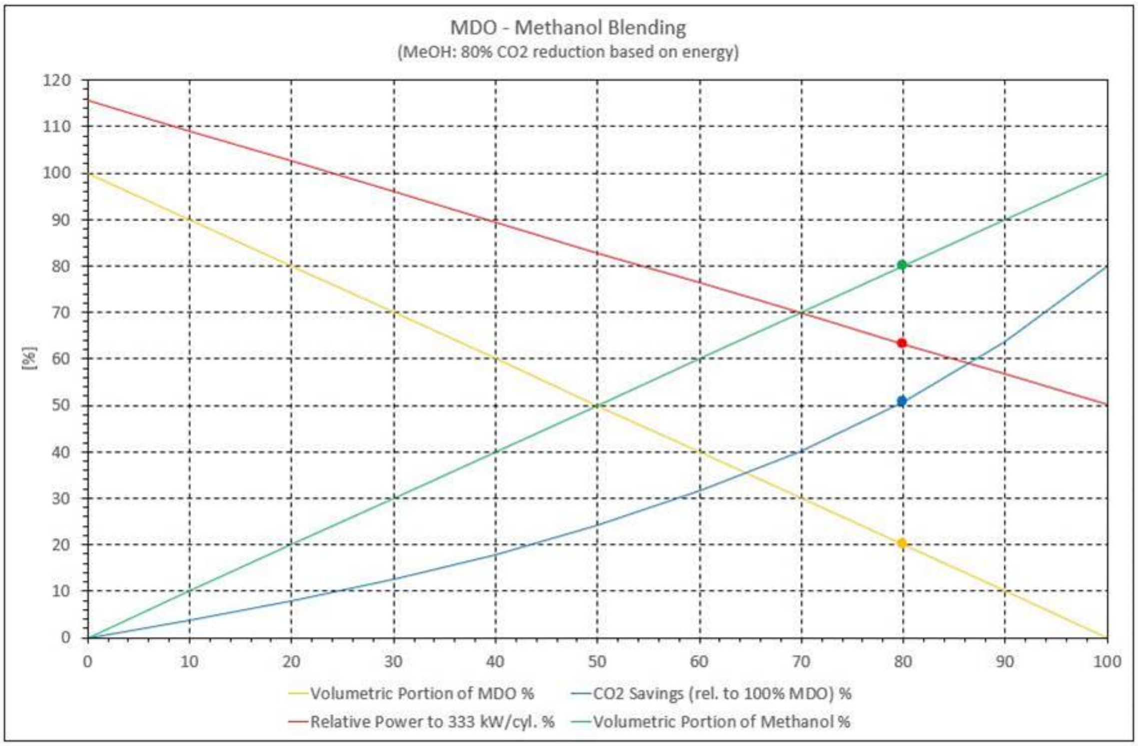


Since the vessel is DP2 with 2 redundancy groups, two independent fuel plants are required.

CO_2 Reduction

Considering starting point 2.b. (100% MCR) and objective 1.a. (50% CO_2 reduction) a volume ratio of at least 80% methanol is required.

The CO_2–reduction graph for methanol blends with 80% reduction for pure green methanol.



For 50% CO_2 reduction a blend of 80% methanol and 20% Diesel is needed, based on information about the feedstock.

The feasibility of methanol-diesel blends has been discussed with NLDA. In WP3 they did tests with mechanical blending (stirring) and after that, with emulsifiers. The lasting time with emulsified blends is long.

New Engine

After discussion on requirements, Caterpillar Motoren proposed a new Methanol Engine concept.

Main arguments are:

- high effort for IGF code requirements like inherently safe engine,
- limitation of max. available power in Diesel mode 110%,
- max available power in Methanol blending mode 60%, and
- risk of methanol leakages with standard Diesel injection system.

Due to these limitations Caterpillar Motoren sees more chance in a Dual Fuel engine concept, like the known M34DF Natural Gas, which is already IGF code compliant. The DF concept can provide more power in Methanol combustion.

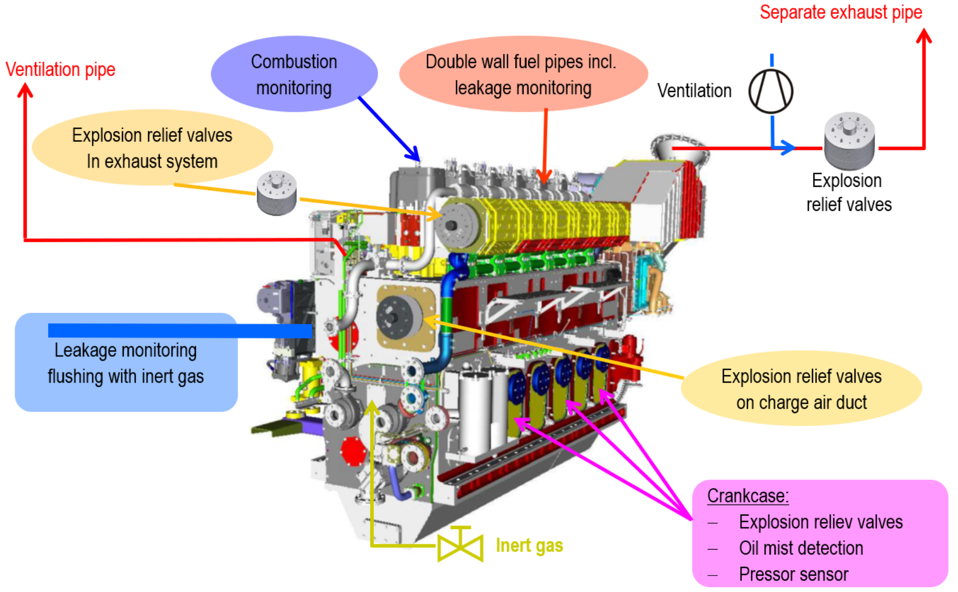
The MaK 27 DF natural gas (NG) engines will be available for the market at the end of Q4 2022 (1500-2700 kW, 250 to 300 kW/cyl). The engine has the same crankcase construction as the diesel version. A Methanol version of M27 might be available end of 2023.

This planning does probably not interfere with the rebuild project, because the implementation has been postponed to 2023. This makes replacement of the engines by the new types viable.

The new DF MeOH engine will use a strict diesel cycle. For a change-over during operation from diesel to methanol vice versa it might be that the engine will have be stopped. The methanol mixture will be ignited by a diesel pilot fuel that has its own injector. The power range of the DF Methanol engines will roughly be the same as the DF Natural Gas engines and the requirement on transient response will be the same as the current diesel engines. If, at later stage the transient response of the new MeOH engines is not sufficient to meet the DP2 requirements, then a peak shaving energy storage system could be added.

For meeting the IMO Tier III emission requirements the DF MeOH engine needs after treatment of the exhaust gasses with an SCR.

The safety concept of the new engines is sketched in the figure below.



Safety Concept - Overview of Safety Devices as on M 27 DF & M 34 DF

A mixing vessel is required for changing from methanol to diesel operation. If the room for the Methanol Booster Module is conditioned (hazardous area), then no double piping is required.

A methanol day tank is needed especially for flushing during change over. Every engine requires its own booster module. Technically the engines can share one methanol day tank, but for reliability and availability of the power supply two day tanks methanol are probably needed.

There are no class requirements for the distance between the mixing vessel and the day tank. The piping should be treated as carrying a low flash point fuel.

The configuration of day tanks (one or two) is subject to review and depends on operating profile and general redundancy requirements. Since Nexus has a DP2 notation, two day tanks are required.

It is possible that methanol will occur in the exhaust. The most probable event causing that is misfire. The cylinder pressure monitoring will detect the failure after three cycles. The affected cylinder can be deactivated and the engine output will be reduced by one cylinder.

Delayed shutdown will follow.

Due the IGF code requirements the exhaust system needs to be equipped with rupture discs or explosion relief valves (as shown in the safety system slide).

The fuel in the exhaust system is diluted by exhaust gas of the other cylinders, which are still running for short time.

The concentration of fuel after exhaust outlet will be low, but we can't judge about the concentration on board of the vessel.

The starting procedure performs an ignition health test during engine start. This secures a safe start condition and avoids misfiring during start, which is often seen on spark ignited engines.

Means in the upper statement I discussed the continuous operation with constant load.

In case an unacceptable methanol concentration would occur at the exit of the exhaust, we cannot modify to an underwater exhaust, because medium speed engines are not suitable for that.

In case of an unacceptable methanol concentration, the exit of the exhaust on deck will be a hazardous zone.

Conclusions:

1. Modification of the current MaK engines 8M25C and 6M25C for running on a MeOH-MGO blend (minor modification) is not feasible. A new DF MeOH-MGO engine concept has to be developed (major modification).
2. The engine room systems will have to be modified according to the system requirements of the new DF MeOH engines.
3. In order to meet the IMO Tier III emissions requirements an SCR unit has to be added.
4. If the transient response of the new MeOH engines is not as required for DP2, then a peak shaving energy storage system could be added.
5. According to the IGF code, the engines themselves and the exhaust systems will be sufficiently protected against an unacceptable methanol concentration. The exit of the exhaust on deck will probably be a hazardous zone.

Task 4. Systems (Damen O&T)

The current main electrical system is 690V/60 Hz. According to starting point 2.e. the system remains the same.

Since steady state and dynamic performance of the generator sets remains as they are, the generator configuration can remain as it is.

As it is now, a peak shaving energy storage system will not be required. However, if at later stage peak shaving systems are required then redesign of the power management system is necessary. Fuel specifications of methanol is so different that the behaviour of this fuel is not predictable. Combustion properties are different from conventional fossil fuels.

The power performances of the generator sets remain as they are now, so the cooling water systems can remain as they are.

If at later stage peak shaving systems are necessary to meet the required transient response, then the two spare 1 MW_{ea} electrical connections on deck (originally meant for a trencher that will not be installed) can be applied for two containerized battery packs.

In order to comply with IMO Tier III the exhaust gas systems will have to be extended with a Selective Catalytic Reduction system (SCR). The urea tank of 80 m^3 will be positioned under the engine room.

The current central control and automation system remains as it is.

Conclusions

1. Besides the system changes as opposed by the new MeOH engines and the MeOH storage and distribution, no system changes are required.
2. If peak shaving systems appear to be necessary (Ref. Task 3), then two spare 1 MW_{ea} electrical connections on deck can be applied for two containerized battery packs.

Task 5. Safety (Damen O&T, Van Oord, Lloyds Register)

In case a methanol-Diesel blend would be applied (minor modification to the engines) then the re-approval process for the engines towards IMO Tier III would be a complicated process. The consequences were extensively reported by Lloyds. In summary:

Tier III compatibility of a modified existing engine requires an 'one off' class approval or amended type approval, including design appraisal and possibly type testing. Always make sure the OEM is involved in order to be able to use existing approvals. IMO NO_x *certification requires a test bed or on board testing as specified.*

The hazardous zone plan has been made in accordance with the prescriptive requirements of the Interim Guidelines for the Safety of Ships using Methyl/Ethyl Alcohol as Fuel. The following items are of additional relevance for the concept design phase:

1. The ventilation outlets of tanks and spaces are positioned so that hazardous zones are as far away from working areas as reasonably possible. Now the working deck lies outside ATEX-zone, but the deck crane still crosses, so that must be modified to ATEX.
2. The hazardous zones as proposed in the General Arrangement and the Hazardous Zone Plan, assume the tank venting pipes are equipped with high velocity vent valves. The zones reach high above the ship, helicopters must be informed of the ATEX zone.
3. Where the prescriptive zones are deemed inappropriate, calculations in accordance with the principles in IEC 60079-10 may be applied and submitted for special consideration. Computational Fluids Dynamics calculations may be needed to demonstrate effective ventilation and dilution to lower a zone categorisation or to reduce the size of a hazardous zone.
4. If concentrations of methanol above Lowest Explosion Level would appear, then:
    - Exiting gases could be diluted, for instance with concentric fans.
    - Tank vent pipes could be led to below the water line. This has not yet been demonstrated. The solution sounds promising and should be investigated. One of the major issues would be whether a hazardous mixture could originate beside the ship. Could, because of that f.e. methanol containing fluids be sucked into the raw cooling water systems?
    - Tank vent pipes could be led to the stern section. That position is not preferred by Van Oord. It would cause plenty operational constraints.
    - The current vent stack could be split into two, of which always one is active. This condition could be ensured by inter-locking.
5. During the DMO HAZID it was proposed by TNO that venting of the methanol tanks and pipe conduits could possibly be led to the side of the ship, just below the waterline. Whether this solution is feasible depends on the behaviour of the methanol gasses emitted in water. Will they fume as gasses or will they condensate and dissolve?
6. Boom tip of the offshore crane should be made ATEX. What should be done with the hook?
7. Air locks from hazardous deck areas to non-hazardous spaces are classified as ATEX Zone 1. They must be indicated on the Hazardous Zone Plan.

    An air lock is an enclosed space for entrance between a hazardous area on open deck and a non-hazardous space, arranged to prevent ingress of gas to the non-hazardous space.

8. Air locks from cofferdams to the open deck must be able to withstand the water column of the of one methanol tank.
9. Air intakes of the ventilation of cofferdams and conduits are as classified ATEX Zone 1, because of the risk of back flow in case a ventilator would fail. As an alternative non-return valve can be applied. Air intakes of the ventilation must be indicated on the Hazardous Zone Plan.

10. The Bunker Station must be indicated on the Hazardous Zone Plan.
11. The pump room is located straight after the engine room. The intakes and outlets of the ventilation must be indicated on the Hazardous Zone Plan.
12. There must be Process and Instrumentation Diagrams (P&IDs) available for the real HAZID meeting. These should include position and schematics day tank, pressure in the methanol pipes, purging or ventilation of cofferdams and conduits, crankcase ventilation.
13. The nitrogen system should be indicated on the Hazardous Zone Plan.
14. To be defined: hazardous zones in vent and purge lines from the engine supply piping and the engine, crank case vent, exhaust system, cool water expansion tank.

The updated Hazardous Zone Plan is added as Appendix B.

Task 6. Logistics and bunkering (Damen O&T, Van Oord, Port of Rotterdam)

The generic aspects are covered by Work Package 4.

Van Oord has strong preference for shore-to-ship or ship-to-ship facilities for bunkering of MeOH.

The realization of bunkering facilities and the fuel prices will strongly depend on the total number of methanol consumers in Rotterdam and worldwide. Both aspects influence the business case (Task 7).

Conclusion

The worldwide availability of methanol is a crucial issue to achieve a break-even business case. We should start with Rotterdam.

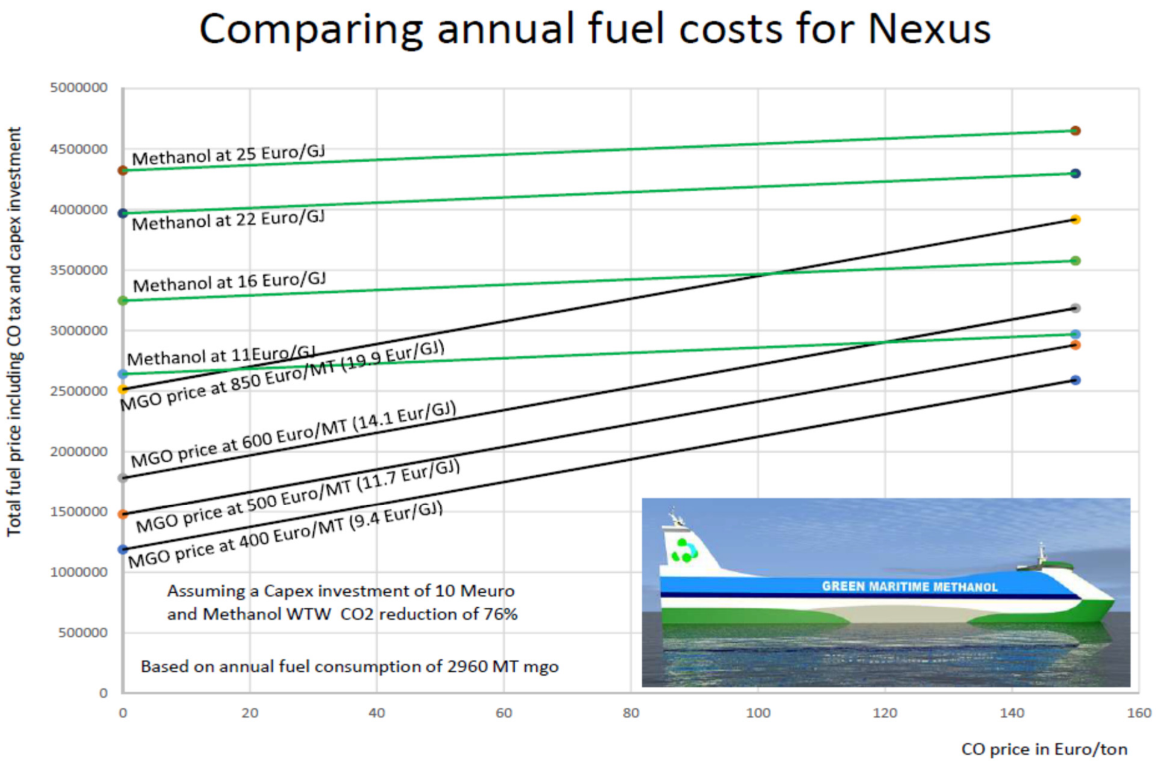
Task 7. Business case and environmental impact (Van Oord)

Some starting points for the business case have been proposed by Van Oord and the GMM-team:

- A raise of 10% of the day rate is acceptable
- CapEx of the refit investment should be depreciated in 10 years
- CapEx for modification of Nexus is assumed to be 10 M€
- We need an SCR to comply with IMO Tier III
- The MGO price will be 850-900 €/ton (@42,7 MJ/kg the price is 19.9-21 €/GJ)
- The bio-methanol price will be 500 €/ton (@19.7 MJ/kg the price is 25 €/GJ)
- *The ETS-predictions of the cost of CO_2-emissions for The Netherlands are (Financieel Dagblad 17 November 2020):*
  2021 → 30 €/ton
  2030 → 125 €/ton

The graph below shows the Total Cost of Ownership (TCO) of the modification of Nexus to DF MeOH-MGO for the remaining economical life time of 10 years as a function of the cost of CO_2-emissions. The parameter lines are the prices of MGO in € per metric ton and per GigaJoule, and Green MeOH in € per GigaJoule. The crossings of the parameter lines are the TCO break-even points. A break-even point would f.e. occur if Green Methanol would cost 11 €/GJ (which is less than half of the current price of bio-methanol) and MGO would cost 600 €/MT (which is 150 €/MT higher than the current price of MGO) at the cost of CO_2-emissions of 70 €/MT.

Since the foreseen raise of the day rate with 10% for 50% climate neutral operation (starting point of this task) we will look for a gap of one million Euro instead of 0 M€.



If we apply the starting points:

- Bio-methanol price is 25 €/GJ
- MGO price is 19.9 €/GJ

Then a gap of 1 M€ occurs at approx. 110 €/ton.

If we apply prices, like:

- Bio-methanol price is 16 €/GJ (reduction of 36% compared to the starting points)
- MGO price is 14.1 €/GJ (reduction of 29% compared to the starting points)

Then a gap of 1 M€ occurs at approx. 65 €/ton.

Conclusion

The economic feasibility of modifying Nexus to Methanol strongly depends on the penalties imposed for emitting CO_2. Break-even TCO allowing a gap of one million Euro for better day rates will be achieved at a CO_2-price of approx. 110 €/ton.

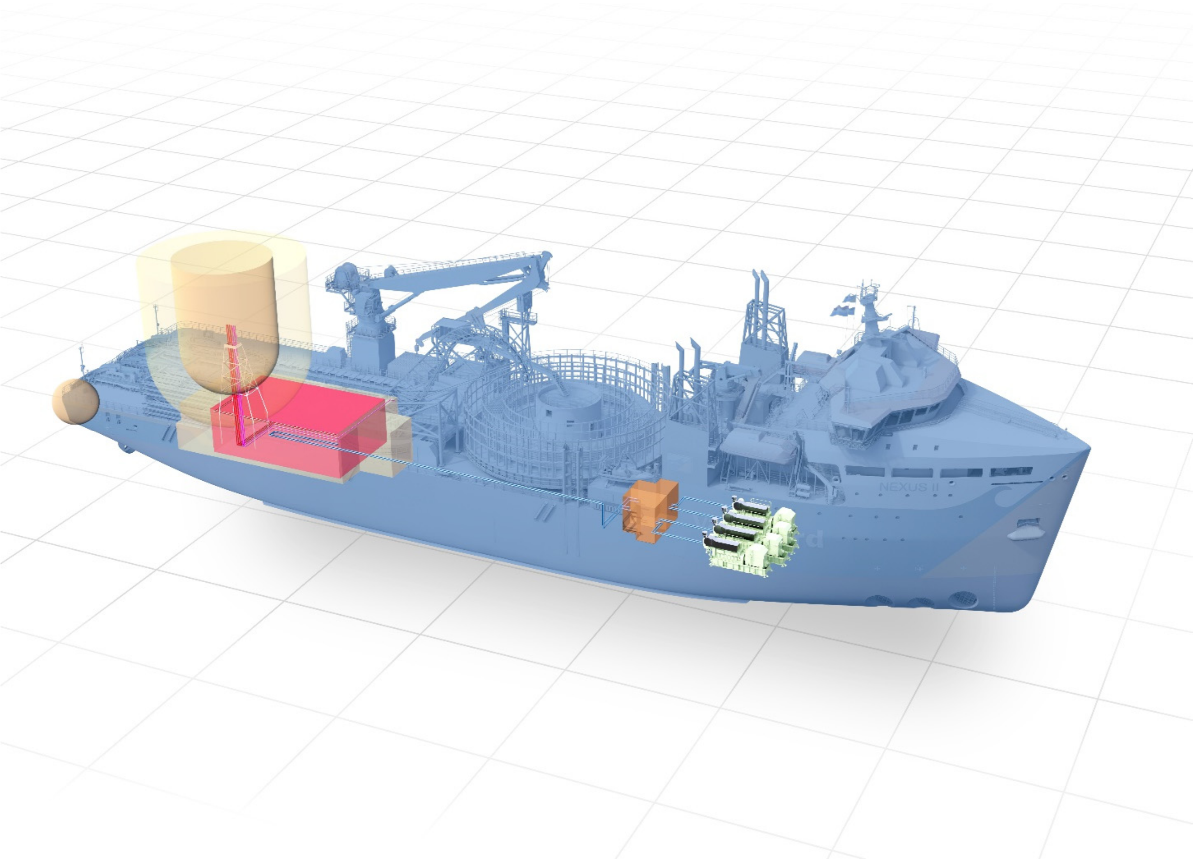
Conclusions

1. Objectives, starting points and operational requirements are clear. The necessary information for the feasibility study is available.
2. For these typical mission profiles we need approx. 650 m^3 of MeOH tank volume and approx. 400 m^3 of MGO tank volume.
3. In the short range mission profile of two weeks the objective of 50% reduction of CO_2-emissions can largely be met. In the long range mission profile of four weeks only 22% reduction of CO_2-emissions can be met, but since approx. half of that mission occurs in IMO waters, this achievement seems sufficient. The impact of the rebuild towards methanol engines on the ship design is a major conversion.
4. Modification of the current MaK engines 8M25C and 6M25C for running on a MeOH-MGO blend (minor modification) is not feasible. A new DF MeOH-MGO engine concept has to be developed (major modification).
5. The engine room systems will have to be modified according to the system requirements of the new DF MeOH engines.
6. In order to meet the IMO Tier III emissions requirements an SCR unit has to be added.
7. If the transient response of the new MeOH engines is not as required for DP2, then a peak shaving battery can be added.
8. According to the IGF code, the engines themselves and the exhaust systems will be sufficiently protected against an unacceptable methanol concentration. The exit of the exhaust on deck will probably be a hazardous zone.
9. Besides the system changes as opposed by the new MeOH engines and the MeOH storage and distribution, no system changes are required.
10. The worldwide availability of methanol is a crucial issue to achieve a break-even business case. We should start with Rotterdam.
11. The economic feasibility of modifying Nexus to Methanol strongly depends on the penalties imposed for emitting CO_2. Break-even TCO allowing a gap of one million Euro for better day rates will be achieved at a CO_2-price of approx. 110 €/ton.

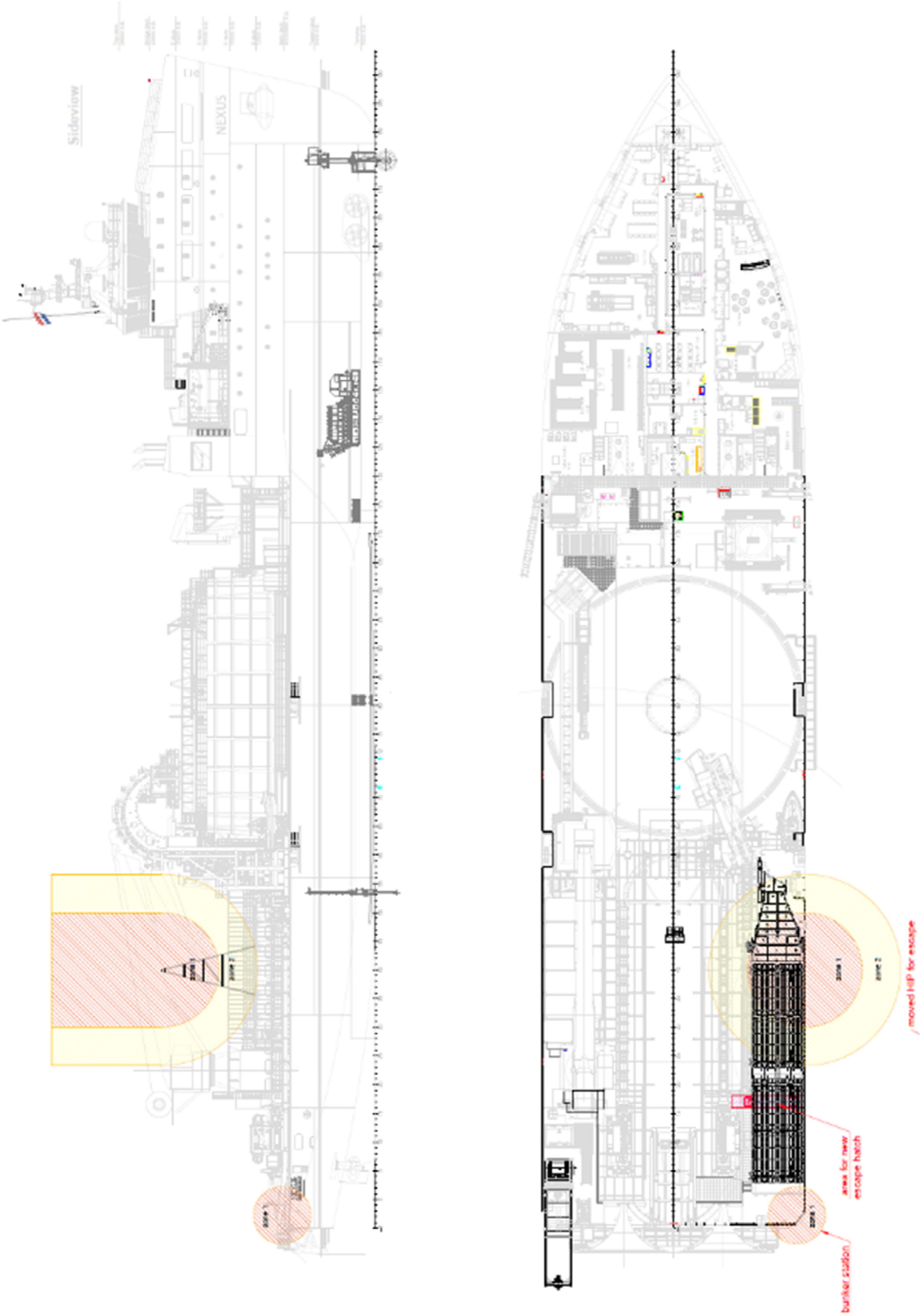
Recommendations

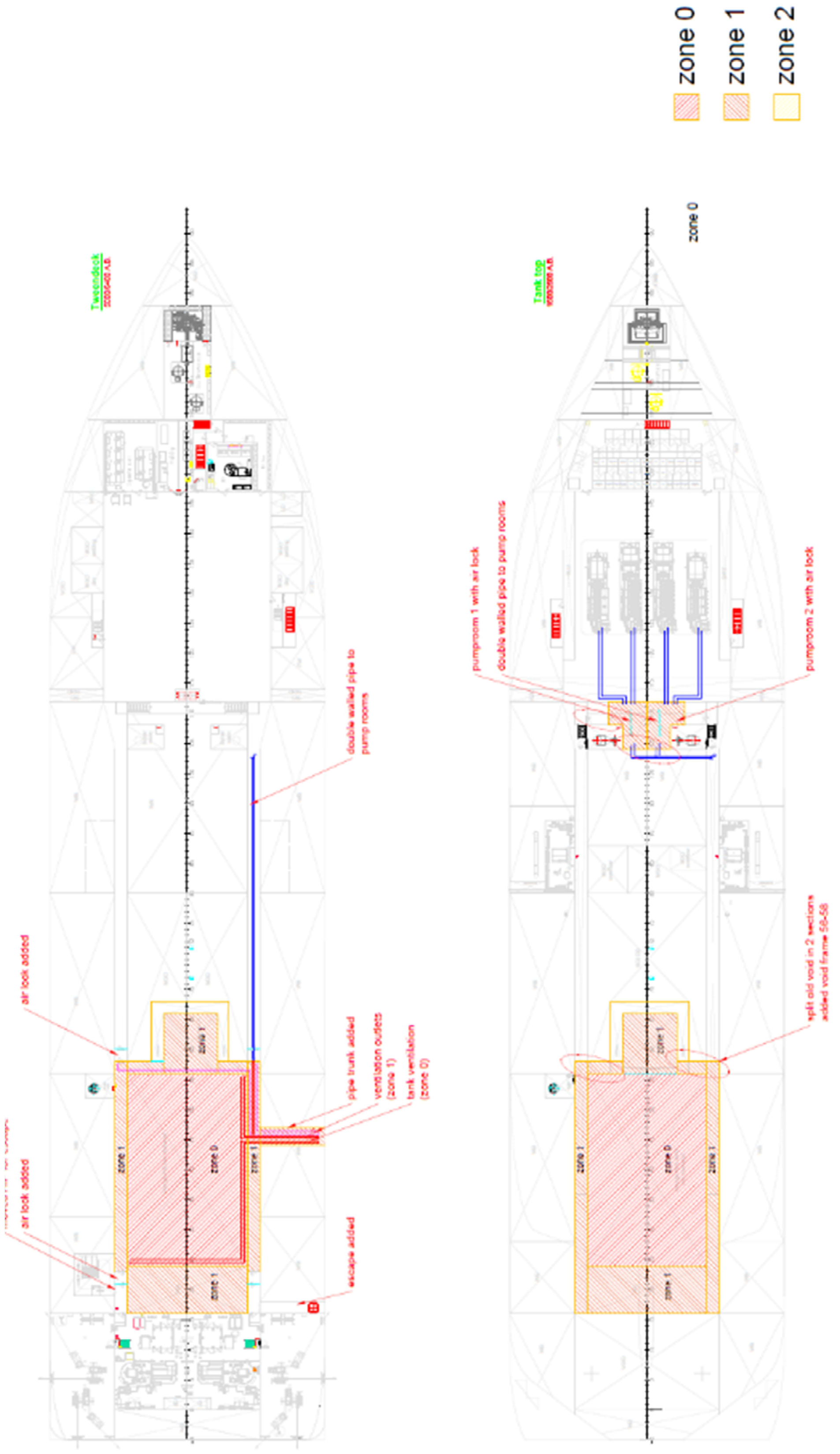
1. If Van Oord wants to go a step further, it is necessary to perform a concept design of ship’s hull and superstructure, ships arrangement and the ship systems.
2. The development of the new methanol engines might be completed in 2023/2024. It is recommended to follow the development closely in order to set up a proper concept design.
3. In order to reduce the ATEX consequences, it is recommended to investigate the application of underwater tank ventilation outlets and behaviour of methanol vapour/fluid in (damp)air/water in GMM2.
4. More insight in the future of green methanol bunker facilities should be provided, both worldwide and in Rotterdam.
5. In order to make investing in rebuild attractive, clear penalties should be imposed on emitting CO_2.

Appendix A: 3-D model of the concept design Nexus Dual Fuel Methanol-Diesel



Appendix B: Hazardous Zone Plan Nexus Dual Fuel Methanol-Diesel




zone 0
zone 1
zone 2
Tweendeck
Tank top
zone 0
air lock added
air lock added
double walled pipe to pump rooms
pipe trunk added
ventilation outlets (zone 1)
tank ventilation (zone 0)
escape added
zone 1
zone 0
zone 1
pumproom 1 with air lock
double walled pipe to pump rooms
pumproom 2 with air lock
split old void in 2 sections added void frame 58-58

5.5 Wagenborg case

Main editors: Wieger Duursema / Jorrit Dijkstra and Niels de Vries / Jidde Looijenga

Principal dimensions General cargo vessel Eemsborg

The Wagenborg E-series comprises 7 vessels which are ice class 1A 11,300 deadweight tonnage bulk carriers with a length of 137.90 metres and a breath of 15.87 metres. The vessels are currently equipped with 4,500 kW Wärtsilä 9L32C engines operating on HFO and MGO.

General

Shipyard	Royal Niestern Sander
Classification	Bureau Veritas
Ice class	Finnish /Swedish 1A
Port of registry	Delfzijl

Main particulars

DWCC (summer)	10,200 ton
Length over all	137.9 m

Breadth over all	15.87 m
Draught	7.98 m
Hold #1	41.44 x 13.2 x 11.23 m
Hold #2	54.76 x 13.2 x 11.23 m

Tank capacities

HFO	850 m^3
MGO	70 m^3
Water ballast capacity	4,053 m^3
Fresh water	56 m^3

Operational profile

The E-borg vessels operate both on coastal and transatlantic routes in ECA and non-ECA. The longest individual leg that one of the vessels sailed in 2018 was 6653 nm: between Tornio and New Orleans (Figure 5.5.1).

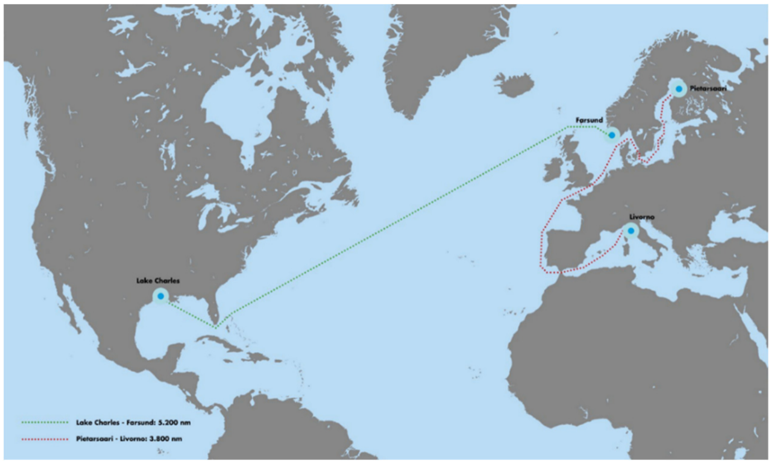


Figure 5.5.1: Typical routes of the E-borg vessels.

The 2018 annual operational data of the seven vessels in the E-series is used as benchmark for the determination of the minimum required methanol storage capacity. Figure 5.5.2 shows the main engine consumption per voyage for ECA and non-ECA. Only the fuel consumption of the main engine have been taken into account. There is no intention to use methanol as a fuel for the auxiliary engines. The total amount of voyages conducted and analysed is 263. Some observations from the data in relation to ECA operation:

- The distillate (MGO) fuel consumption is below 100 MT in 257 out of 263 voyages (97.7%);
- The distillate (MGO) fuel consumption is below 120 MT in 262 out of 263 voyages (99.6%);
- A distillate (MGO) fuel oil consumption exceeding 140 MT has not been recorded in 2018.

Some observations from the data in relation to non-ECA operation:

- The residual (HFO) fuel consumption is below 140 MT in 250 out of 263 voyages (95.1%);
- The residual (HFO) fuel consumption is below 220 MT in 261 out of 263 voyages (99.2%);
- A residual (HFO) fuel oil consumption exceeding 240 MT has not been recorded in 2018.

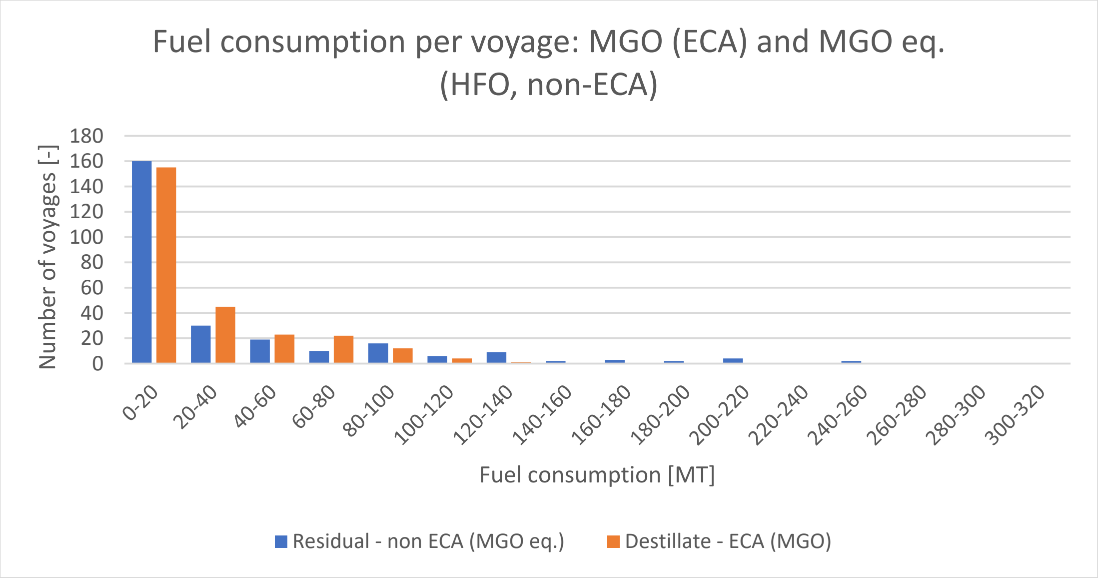


Figure 5.5.2: Fuel consumption per voyage, differentiated between ECA and non-ECA operation.

The accumulated fuel consumption per voyage is depicted in Figure 5.5.3. Only 10 out of the 263 (<4%) voyages exceeds the 200 MT accumulated fuel consumption. The highest reported consumed fuel on a single voyage has been 323 MT.

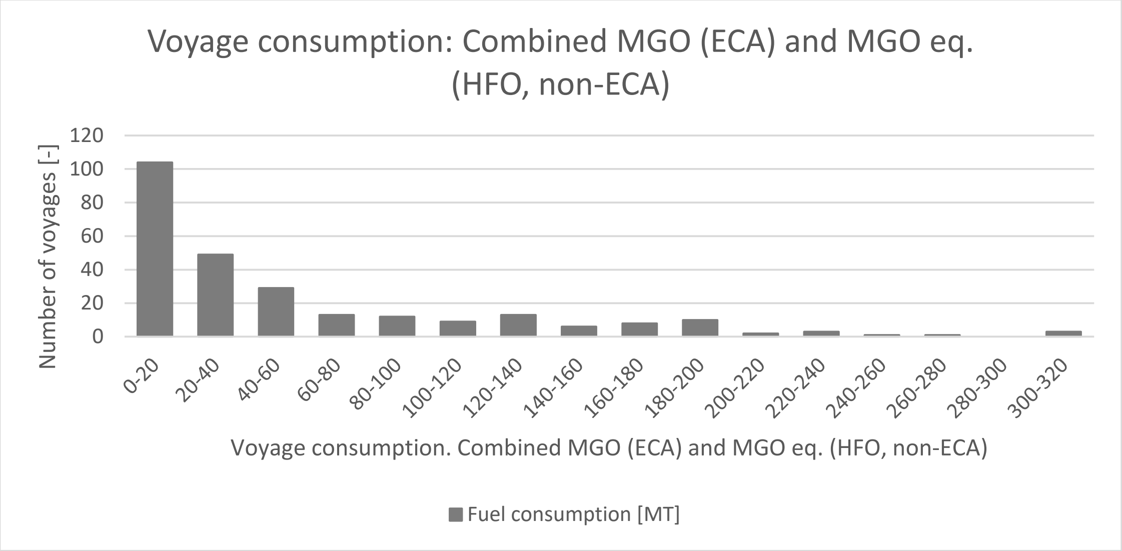


Figure 5.5.3: Accumulated voyage consumption: inside ECA (MGO 0.1%S) and outside ECA (HFO). HFO has been converted to an equivalent amount of MGO, based on energy content.

Concept design for Methanol

The propulsion of the vessel is based on the principle of diesel geared drive (Figure 5.5.4): a diesel engine driving the propeller via a gearbox. Using the second gearbox output-shaft the shaft generator feeds the electrical system. The twin Scania gensets take over the production of auxiliary power when the vessel is in port, when the vessel is operating in manoeuvring mode or when the engine and propeller are used in combinatory mode (i.e. reduced speed).

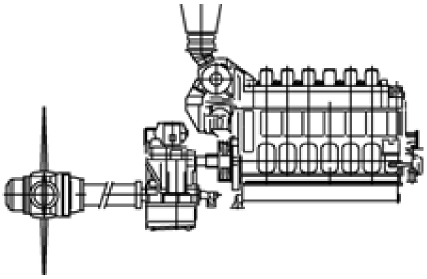


Figure 5.5.4: Diesel geared drive concept.

In the conversion of the Wagenborg E-series methanol will be used for the propulsion of the vessel. Further, the propulsion remains to be based on the principle of the geared drive. The gensets will keep running on MGO. In case the engine conversion or replacement is being considered as a major conversion under MARPOL it has to be discussed with Class if the gensets need to become Tier III compliant as well.

Sufficient methanol storage capacity will be created as necessary for fuelling the engine during ECA operations. The rest of the tanks remain MGO tanks, because:

- For long distance sailing, outside the Emission Control Area;
- To have sufficient bunker capacity for the situation that methanol is not available, or that methanol is more expensive (on energy basis) than MGO.

To be able to safely use and store methanol on board the vessel need to be equipped with a couple of dedicated systems: a methanol bunker system, methanol transfer system and a nitrogen blanketing system. The specifications of these systems and their components are described in this chapter and can be seen in the Figure 5.5.5.

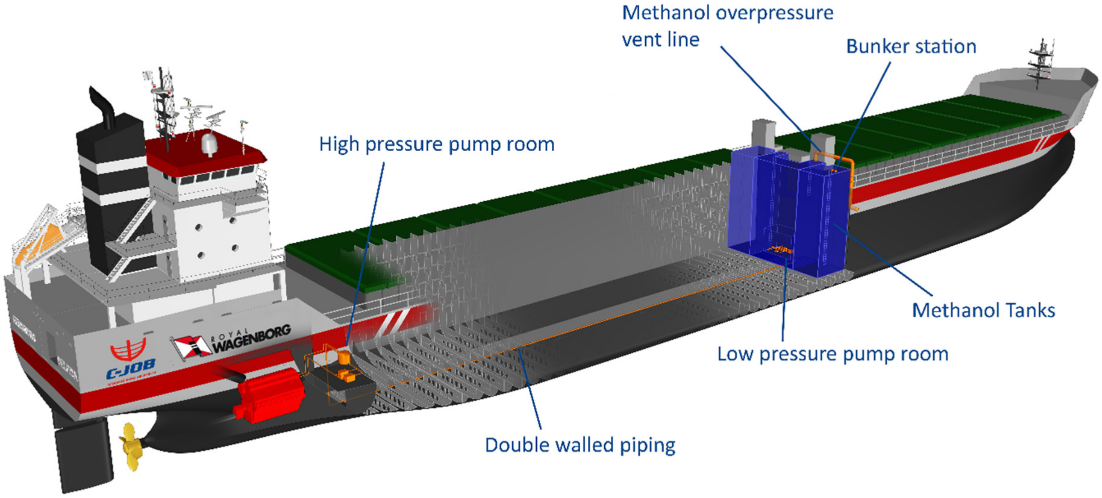


Figure 5.5.5: Methanol system design

Bunker system

Methanol storage will be located in the cross bunker section (see chapter 3: Tank size(s) and location(s)). Close to the methanol storage tanks in the cross bunker section is the location of the methanol bunker station. The bunker station will be located at one side only. The single walled bunker line above deck is connected to the single walled bunker line below deck, through the cofferdam. Since the cofferdam is already a hazardous space, a bunker line in the cofferdam can be single walled (reg. 5.7.4, 8.3.1.4 and 12.5.2.1.1). After passing through the cofferdam, the bunker line connects to a manifold in the low pressure pump room. In the pump room, which is located in the cross bunker section, the methanol piping is single-walled.

Relevant regulations for the bunker station and pump room:

- Regulation 8.3: Provisions for bunker station
- Regulation 8.4: Provisions for the manifold
- Regulation 8.5: Provision for bunkering system
- Regulation 9.7: Provisions for fuel preparation spaces and pumps
- Regulation 11: Fire safety
- Regulation 12: Hazardous area zones
- Regulation 13: Ventilation

Methanol transfer system + high pressure pump room

From the low-pressure pump room the double walled piping is routed through the pipe duct towards the high pressure pump room. The HP pump room is located next to the engine room. The HP pump room is a hazardous zone 1, and contains a buffer tank and high pressure pumps. An airlock is not obligatory, but advisable given regulation 5.11.2. The specific regulations on the air lock can be found in regulation 5.12. Again, regulation 11 (fire safety) and regulation 13 (ventilation) are relevant for the high pressure pump room. The high pressure pumps in the HP pump room compress the methanol to a pressure of 450 bar. Methanol is pumped in the methanol buffer tank before it is fed to the engine. Also the methanol retour line is fed back to the buffer tank. The use of a buffer tank also enables the addition of water to the fuel to be able to comply with Tier III regulations without the use of an SCR unit. For the complete fuel system diagram see Appendix C.

Nitrogen blanketing system

Nitrogen will be used for inerting of methanol tanks and the space in between the inner and outer pipe of double walled piping. A nitrogen generator with a capacity of 20 m^3/h is positioned in the forward part of the HFO bunker PS engine room. For the nitrogen blanketing and purging system see Appendix D.

Tank size(s) and location(s)

The evaluation of the operations of the E-borg vessel and the corresponding fuel consumption is the basis for a first assessment of the required methanol storage capacity. By having a look at the General Arrangement (Appendix A) and currently existing tank capacities, a first estimation of the potential methanol storage capacity is made. Whether methanol is a promising and feasible alternative fuel for the vessel depends on several factors, one of which is the ability to create sufficient bunker storage space. The current fuel tank capacities and tank arrangement is investigated. Then, the new methanol tank design explained. The relevant design and applicable rules are explained. Finally, the new hold and tank capacities explained.

Current tank capacities and tank arrangement

The vessel accommodates a HFO bunker capacity of approximately 850 m^3 complemented with a MGO bunker capacity of 70 m^3, see General Arrangement. About two-third of the HFO bunker capacity is stored in three tanks located in the cross bunker section: the HFO cross bunker PS, HFO cross bunker SB and HFO cross bunker centre (Figure 5.5.6). Another part of the HFO tanks and all the MGO tanks are located in the engine room. The remaining HFO capacity is divided over the SB and PS hold-tanks; tanks in the aft corners of hold number 2, against the engine room bulkhead and above the tank top.

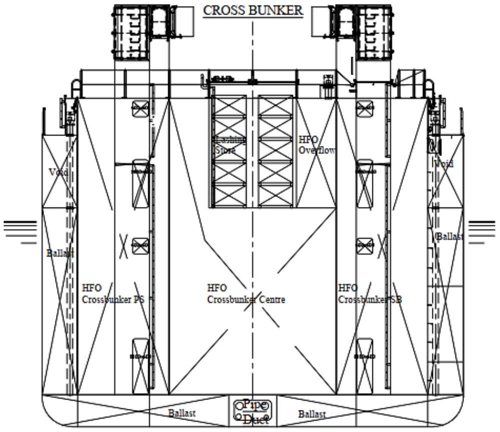


Figure 5.5.6: HFO cross bunker section.

The cross bunker section is the construction halfway the length of the vessel separating the holds in two segments. This segment further accommodates the lashing store, hold ventilation and hold entrance. The ballast pipe duct, wing- and double bottom tanks segregate the HFO tanks from the surrounding seawater. The forward and aft bulkheads of the tanks coincide with the hold bulkheads.

The cross bunker section is selected for the storage of the methanol tanks, because:

- The section intrinsically has a high volume, part of which is already used for storing fuel.
- The bunker section is relatively easily accessible, an advantage from the perspective of conversion.

Required Methanol and MGO bunker capacity

Based on the operational profile of 2018 the required methanol capacity can be estimated. In-ECA voyages with a consumption over 100 MT MGO were scarce in 2018, while a single voyage consumption over 140 MT MGO has not been reported at all. The minimum required methanol storage capacity is set to the equivalent of 140 MT MGO plus a margin of 10%. Taking into account the gravimetric energy densities of MGO 42.7 MJ/kg and methanol 19.9 MJ/kg, the required methanol storage capacity will be 330 MT.

For sailing outside ECA the rest of the fuel tanks will be MGO tanks. MGO tanks are also needed to have sufficient bunker capacity for the situation that methanol is not available, or that methanol is more expensive (on energy basis) than MGO.

Methanol storage tank design

For the minimum required methanol storage capacity of 330 MT an effective storage space of 418 m^3 is required, since the density of methanol is 790 kg/m^3. The filling grade of a methanol tank is at maximum 98%, resulting in a required tank capacity of 440 m^3.

Methanol is a low-flashpoint fuel subject to the International Code for Safety of Ships using Gases or Other Low-flashpoint Fuels (IGF Code). The IMO's IGF Code, is to provide an international standard for ships using low-flashpoint fuel. The basic philosophy of this code is to provide mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using low-flashpoint fuel to minimize the risk to the ship, its crew and the environment, having regard to the nature of the fuels involved.

The combined capacity of the three HFO tanks in the cross bunker section is 550 m^3; there is ample sufficient tank capacity for storing the methanol. The following guidelines that find their origin in the IGF code (CCC 6/WP.3) are relevant to consider for the allocation of methanol storage capacity:

- 5.3.2: Integral fuel tanks should be surrounded by protective cofferdams, except on those surfaces bound by shell plating below the lowest possible waterline, other fuel tanks containing methyl/ethyl alcohol, or fuel preparation space.
- 5.3.3 The fuel containment system should be abaft of the collision bulkhead and forward of the aft peak bulkhead.
- 5.11.3: Fuel tanks and surrounding cofferdams have suitable access from the open deck, where practical.
- 11.4.3: For fire integrity, the fuel tank boundaries should be separated from the machinery spaces of category-A and other rooms with high fire risks by a cofferdam of at least 600 mm, with insulation of not less than A-60 class.

To fulfil these requirements for methanol storage in the cross bunker section the following solutions were applied:

- Two cofferdam-bulkheads were applied in front and aft of the cross bunker section, with a distance of 600 mm.
- Bulkhead penetrations for hold entrance and ventilation were lengthened with a distance of 600 mm.

New hold and tank capacities

The hold volumes of both hold number 1 and 2 consequential decreased by placing the cofferdam bulkheads in front and aft of the cross bunker section, see General Arrangement (Appendix B). The dimensions of the bulkheads are (Figure 5.5.7) 13.2 m by 9.8 m. The lost space per hold equals 2740 cu ft (13.2 m x 9.8 m x 0.6 m x 35.15 cu ft/m^3), the new hold volumes are:

1. Hold number 1: 195247 cu ft (-1.4%);
2. Hold number 2: 281110 cu ft (-1%).

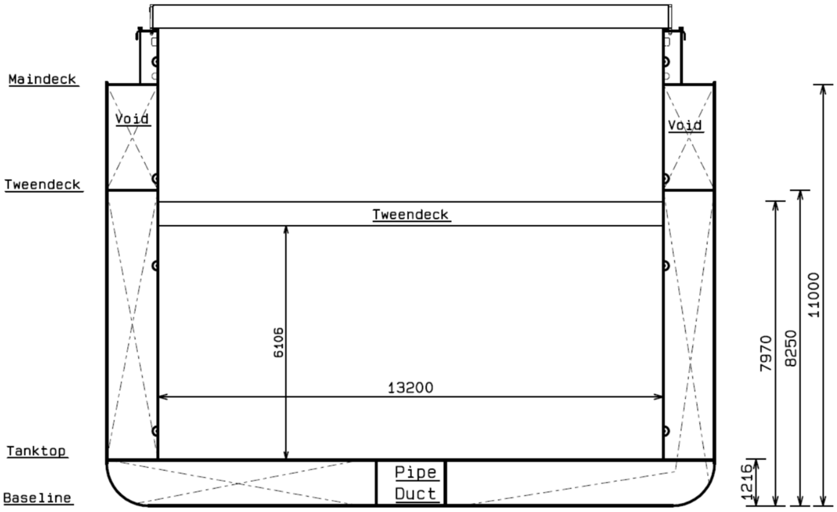


Figure 5.5.7: Hold depth and width

The HFO fuel tank capacity in the cross bunker section originally amounted 550 m^3. Most of it this capacity will be sacrificed for the required methanol tank capacity (440 m^3). Further, the low-pressure pump room and the methanol overflow tank will be positioned in the cross bunker section (Figure 5.5.8 and 5.5.9). The pump room takes 28 m^3 of the available space, the overflow tank another 12 m^3. The total methanol storage capacity will be 509 m^3.

HFO tanks not located at the cross bunker section are converted to MGO tanks, resulting in the following MGO additions:

- MGO Hold Bunker PS: 39 m^3 (from old HFO Hold Bunker PS 204)
- MGO Hold Bunker SB: 39 m^3 (from old HFO Hold Bunker SB 205)
- MGO Aft PS: 32 m^3 (from part of the old HFO Bunker PS 206)
- MGO Aft SB: 32 m^3 (from part of the old HFO Bunker SB 207)
- MGO Bunker SB ER: 162 m^3 (combination of old HFO settling tanks 208, 209, HFO day tanks 210, 211 and part HFO bunker SB 207 + part void 408)
-

This brings the total MGO storage capacity to 377 m^3.

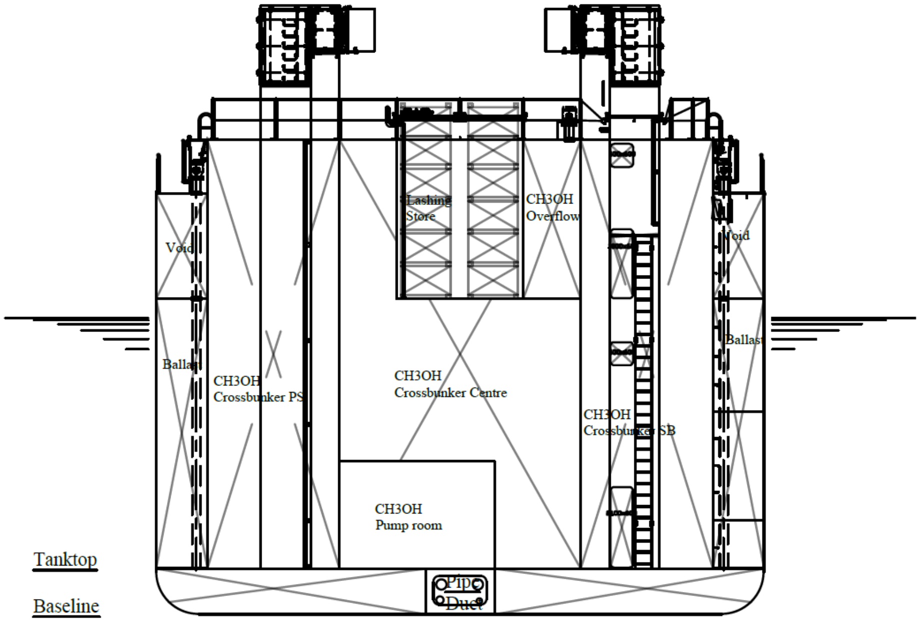


Figure 5.5.8: Cross bunker section with methanol cross bunker storages, low pressure pump room and methanol overflow tank.

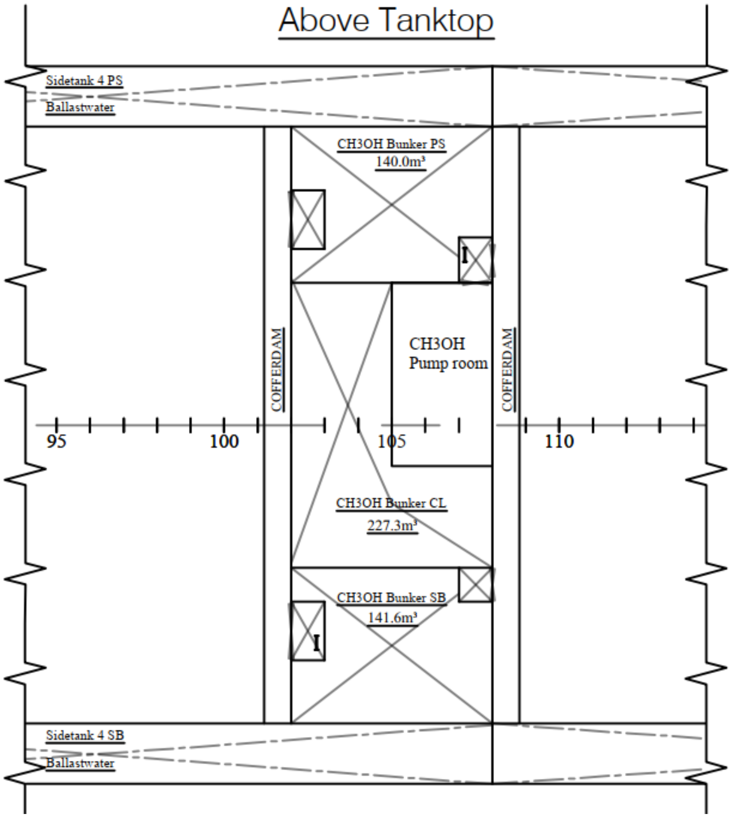


Figure 5.5.9: Cross bunker section above tank top.

HAZID - Regulations and classification

In order to identify and mitigate the risks existing in the design of the system and which are not covered by prescriptive regulations, a HAZID has been performed which is worked out in a separate HAZID report by C-Job. In this report the objective, scope and methodology can be found with the main findings. The preliminary design, including the General Arrangement, hazardous area plan and the fuel system diagram is used as a basis for the required input of the HAZID.

Identified hazards were, where possible, mitigated with appropriate existing safeguards to reduce the risks. Safeguards are used to reduce the likelihood of a hazard occurring or the severity of the

consequences of the hazardous event. Where safeguards were deemed insufficient, actions or recommendations were identified to ensure a sufficiently safe ship. However, no risk assessment

process, providing indications about the severity and likelihood of a hazardous event occurring, was carried out.

The HAZID sessions gave a lot of insight into the risks involved when using methanol on board a vessel. The end result is the conclusion that a methanol system is technically feasible on a for the Wagenborg E-borg series, but there are some unknowns left to explore in future research:

- The behaviour of methanol vapour when released in ambient conditions and thus the position of vent masts. If the vent masts are placed above the deck area and methanol vapour drops, this results in a hazardous situation. Therefore the position of the vent mast can be on the vessels side in the hull. Since it is unclear how methanol vapour disperse, this requires further research before vent masts can be placed,
- The effect of water blending of methanol. Blending could make storage less dangerous; A SCR might not be needed when water blending is used to comply with Tier III of the IMO,
- Capabilities and limitations of methanol specific equipment,
- Type of ship to shore link,
- Desired extent of redundancy for sensors and other components,
- Access to high pressure pump room by airlock in the engine room or directly from open deck.

Conversion costs – Life Cycle Analyses

Conversion Costs

For the conversion of the Wagenborg E-Series to methanol propulsion a rough order of magnitude (ROM) estimate is made of the CAPEX. This is done by consulting each party of the consortium. By adding up all costs the total ROM CAPEX of the conversion is estimated to be 3.8 million Euro. In the next sections there will be elaborated on what is inside the scope of each party.

Marine Service Noord has made an estimation of the costs for the methanol fuel system. As indicated on the process flow diagram shown in Figure 5.5.10, the methanol fuel system consists of the main methanol fuel lines marked in red, and five auxiliary systems: technical water (light blue), vent and drain (pink), nitrogen purge (green), bilge (dark blue) and scupper and drain (orange) lines. The cost analysis is made up in the same way in a work breakdown structure (wbs).

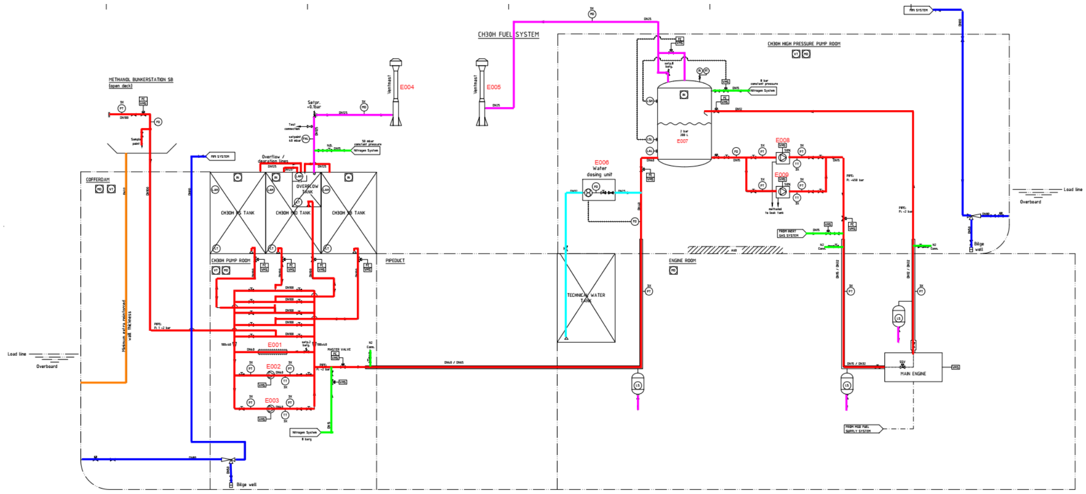


Figure 5.5.10: Process flow diagram Methanol Fuel System

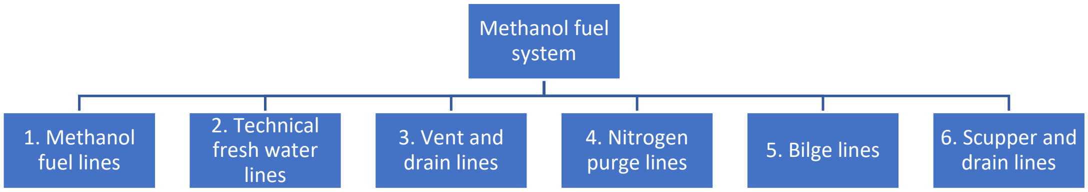


Figure 5.5.11: Work breakdown structure of the methanol fuel system

The resources provided by Marine Service Noord to build the methanol fuel system can be divided into engineering, procurement, prefabrication and installation and commissioning services. A project manager is assigned to the project to guard the projects budget, planning and overall quality.

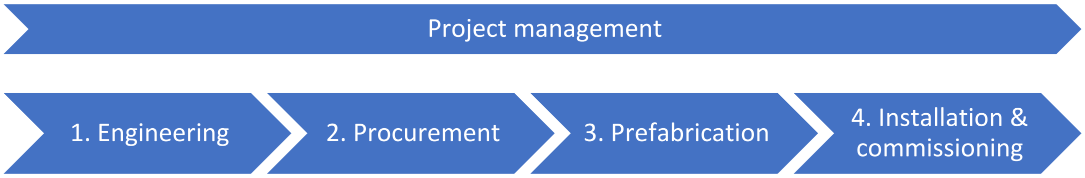


Figure 5.5.12: Marine Service Noord - Resource breakdown structure

The pie charts of Figure 5.5.13 show the breakdown of the costs by work breakdown structure and by resource.

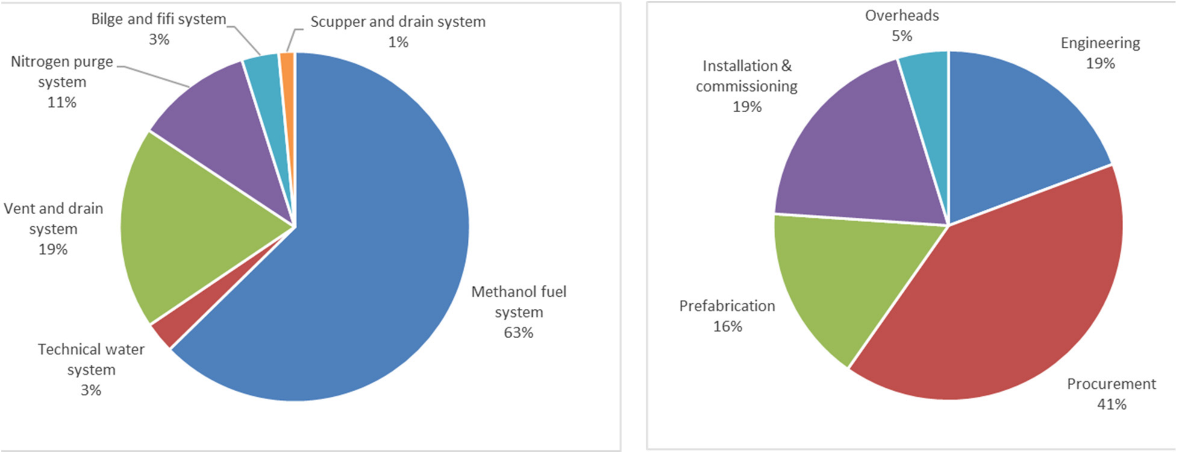


Figure 5.5.13: Cost by WBS and RBS

IMO regulations require incorporating redundancy into the systems design, because of this requirement two transfer pumps need to be incorporated which increases the overall cost of the system. Additionally because of the physical and chemical properties of methanol the main equipment have stainless steel parts and finally due to the high pressure of the methanol injection part of the system at 450 bar the procurement of OEM equipment, valves and instrumentation comprises 41% of the total CAPEX as can be seen in the pie chart above. A substantial part of the procurement of equipment are classification costs. For example, the classification costs for the transfer- and methanol/water injection pumps will be about 20% of the total cost of the pump.

It is to be assumed that equipment costs and classification costs will go down once methanol will become widely used as a shipping fuel. Costs can be reduced further by optimizing the location of the main equipment and tanks in the ship. Doing so can reduce the number of meters of pipework that needs to be installed in the ship lowering the prefabrication and installation costs.

C-Job made a rough estimate on the engineering costs for the conversion which incorporates the following:

General

General arrangement

Technical arrangement CH3OH pump room

Technical arrangement pipe duct

Technical arrangement CH3OH high pressure pump room

Technical arrangement engine room

Hazardous zone plan

Safety plan

Construction

Bulkheads

Decks

Frames

Details

Mechanical

CH3OH fuel system diagram

Stability

Stability model

CH3OH fuel system P&ID

CH3OH pipe routing (incl. pipe division and spooling)

Bilge/Fi-Fi system P&ID

Bilge/Fi-Fi pipe routing (incl. pipe division and spooling)

Nitrogen system P&ID

Nitrogen pipe routing (incl. division and spooling)

Ventilation air system P&ID

Ventilation pipe routing (incl. division and spooling)

Technical water system P&ID

Technical water pipe routing (incl. division and spooling)

Intact stability

Damaged stability

Electrical

Systems and control

Project management

Engineering project coordination

Royal Niestern Sander made an CAPEX estimation for the steelwork of the methanol tanks and high pressure pump room. This steelwork is based on the information provided by C-Job. Included are:

- Tank cleaning, grit blasting and conservation.
- Tank coating: Tankguard zinc silicate
- Modification hold ventilation
- Touch up damaged ballast tank coating
- Engineering

As last the conversion costs of the 4,500 kW Wärtsilä 9L32C diesel engine are estimated. This is a very rough estimate which has a lot of uncertainties. An engine conversion package need to be developed and high pressure injectors are still under development and therefore the costs are very uncertain. This also holds for the certification costs.

Emission life cycle analysis

In order to identify the environmental benefits of using methanol for the E-serie, the total life cycle emissions of methanol propulsion on the E-serie is compared to conventional propulsion by MGO and HFO. The life cycle emissions of SOx, NOx and greenhouse gases (GHGs: CO_2, CH_4, and N_2O) are identified for the production and combustion phases of methanol. The total life cycle (well to propeller) can be divided in two phases:

- Well to tank: emissions by extracting, production and transporting the fuel.
- Tank to propeller (combustion phase): emissions from combusting the fuel.

To estimate the environmental benefits the fuel data of the E-serie of 2018 is used. An average annual fuel consumption is considered with MGO used in ECA and HFO outside ECA. Data on the emission factors from well to propeller was obtained from TNO and JEC (Joint Research Centre – EUCAR Concawe). Feedstocks for methanol are fossil (grey), biomass (green) and renewable energy. Black liquor is considered as the biomass feedstock for green methanol.

g/MJ GHG (CO_2 eq.)

Fuel	WTT	TTP	WTP
HFO	11.7	78.0	89.7
MGO	14.6	75.0	89.5
Methanol (grey)	21.0	69.0	90.0
Methanol (green)	2.2	0.0	2.2
Methanol (renewable)	1.6	0.0	1.6

Based on the annual fuel consumption and the emissions factors, the GHG emissions savings can be estimated. For 2018 an average estimated 8,892 ton CO_2 is emitted per E-borg vessel, see Figure 5.5.14. Savings are minimal when switched to fossil methanol and this is caused by the fact HFO is replaced by MGO and MGO by methanol and not because fossil methanol has lower CO_2 emissions than HFO and MGO, see table 2. As can be seen, major savings are made when switched to bio-methanol and renewable methanol. GHG reduction of more than 50% is possible.

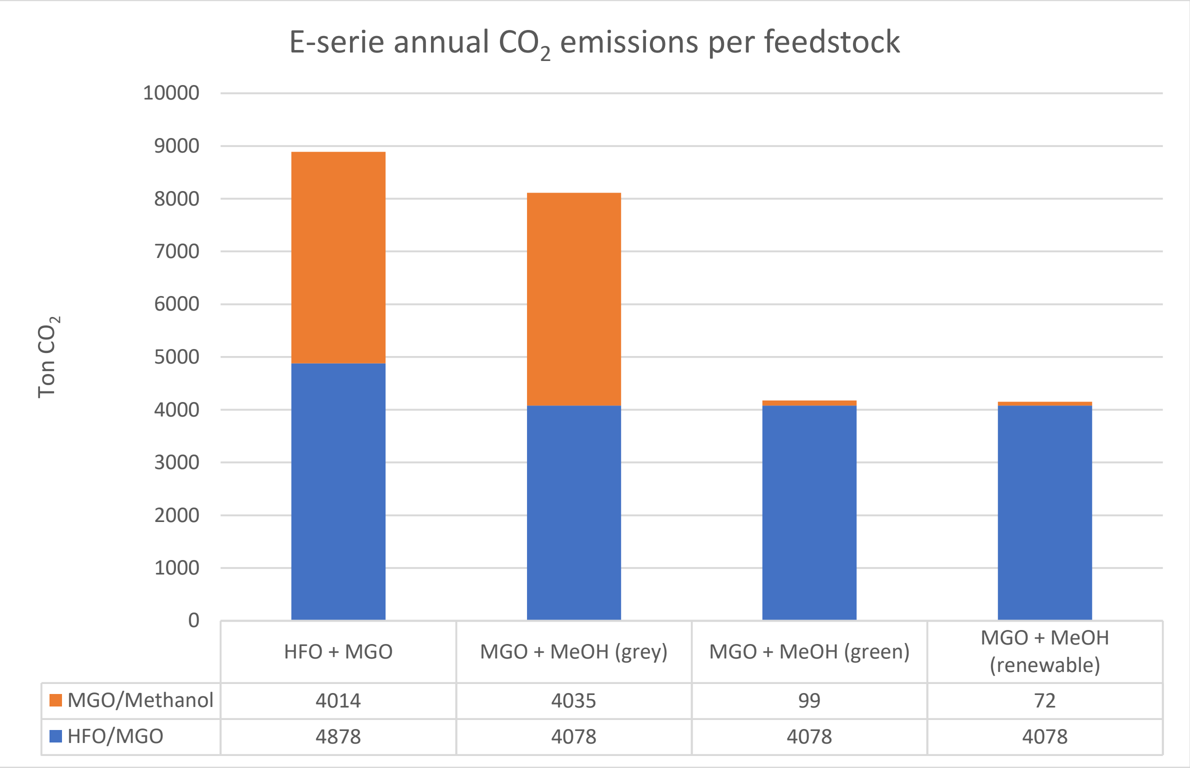
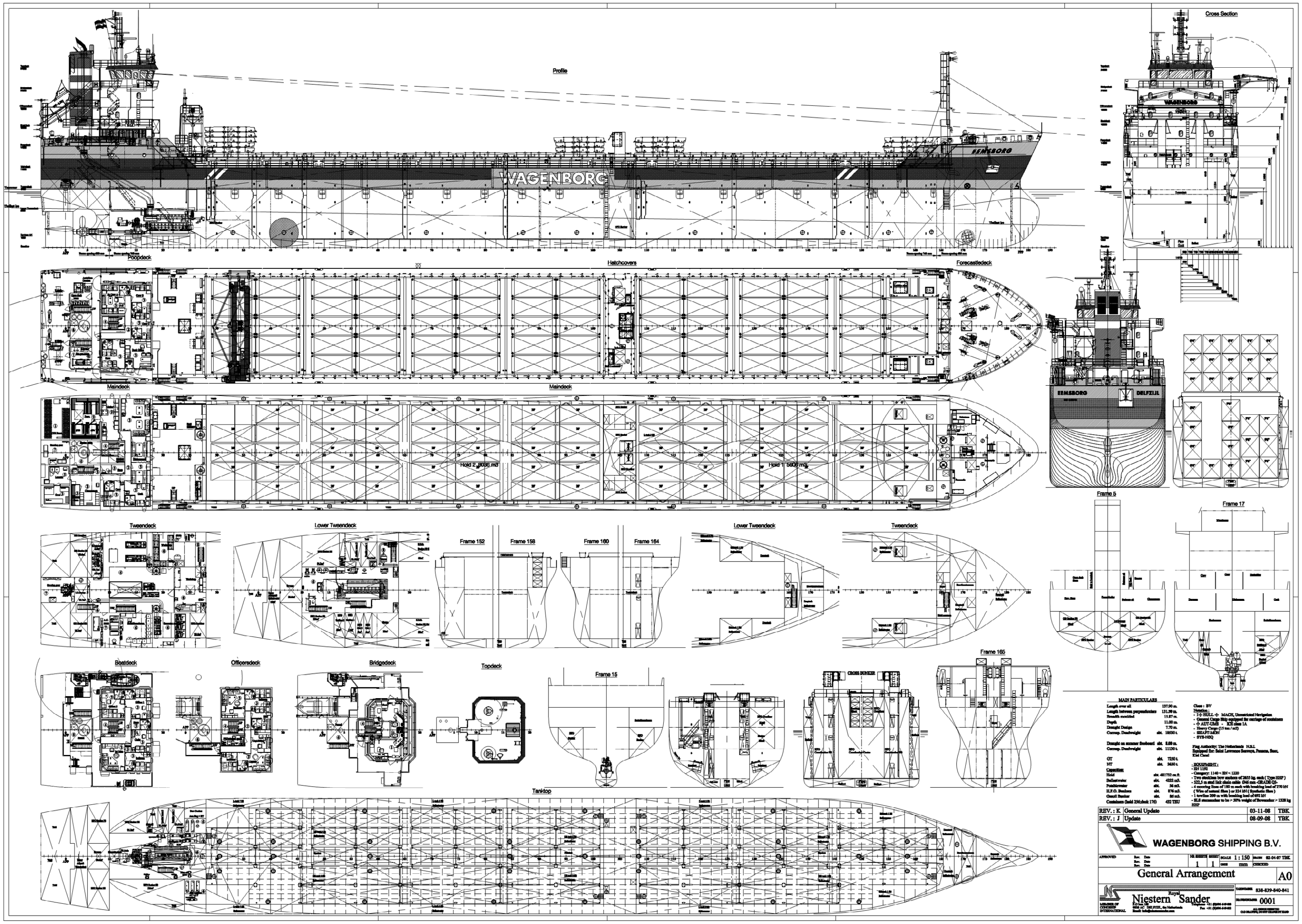


Figure 5.5.14: E-serie well to propeller CO_2 emissions per feedstock in ton per year.

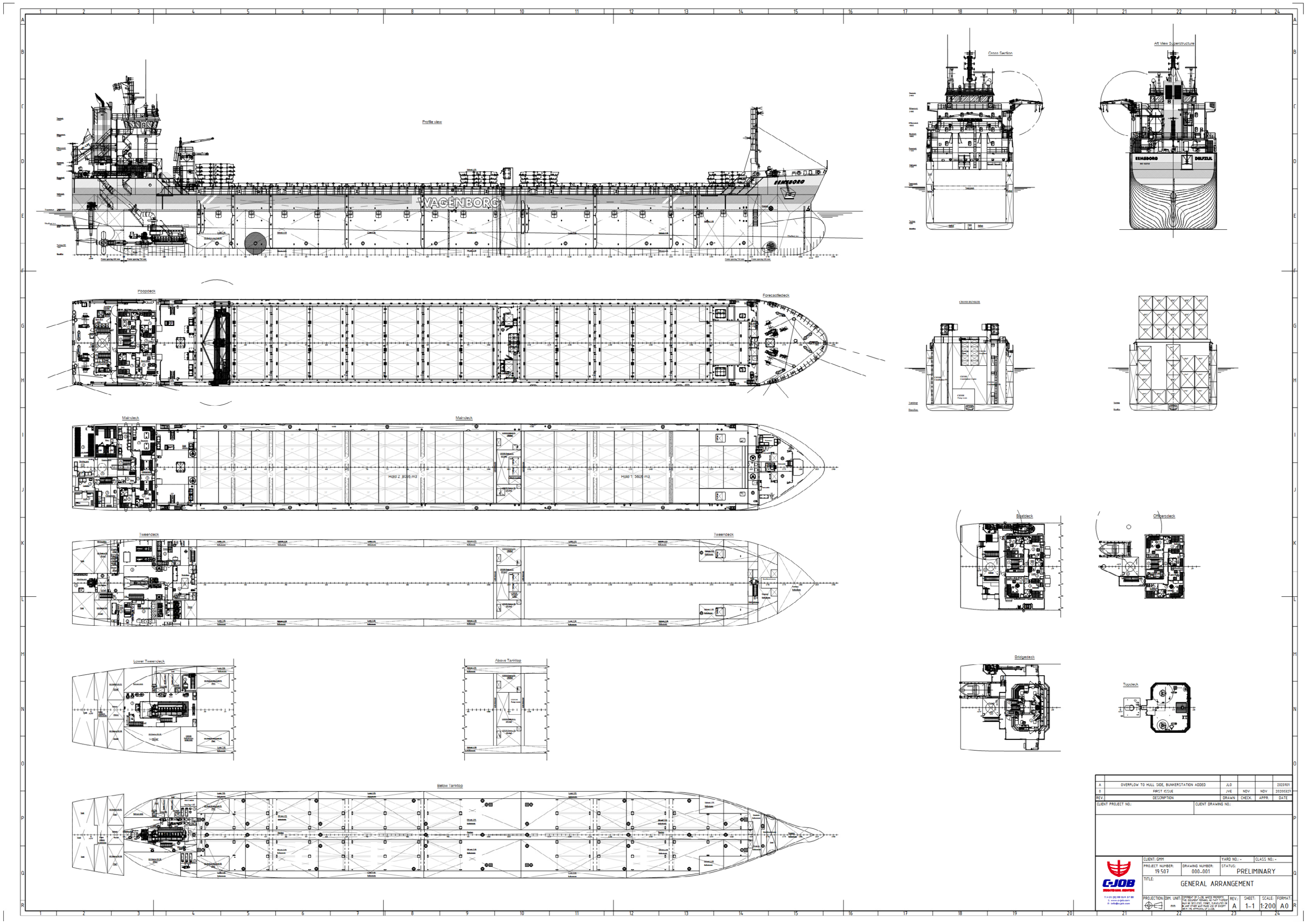
Findings of the case and solutions for design challenges

A practical ship design is made with compliant methanol systems. Knowledge of other work packages on safety items, regulations, operational aspects and environmental footprint analyses are put into a conceptual conversion of the E-series. A HAZID of the proposed methanol system design has been undertaken which has identified a range of hazards to the vessel associated with the use of methanol as a fuel. Following from the HAZID, some areas require further research, such as the location and placing of the vent masts. It can be concluded that a methanol system is technically feasible on the Wagenborg E-series.

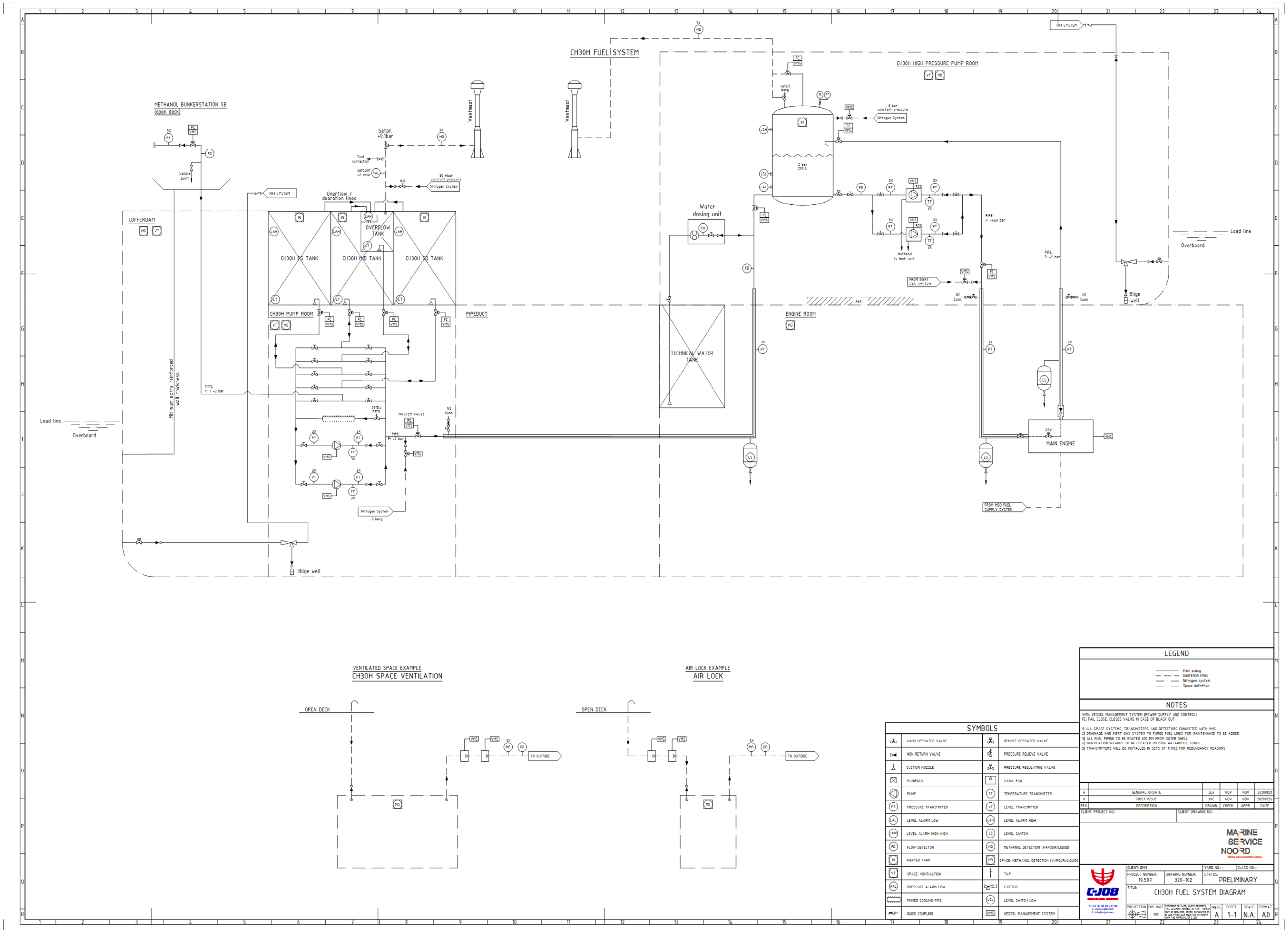
Appendix A: General Arrangement (Original)



Appendix B: General Arrangement (Methanol)



Appendix C: Fuel system diagram



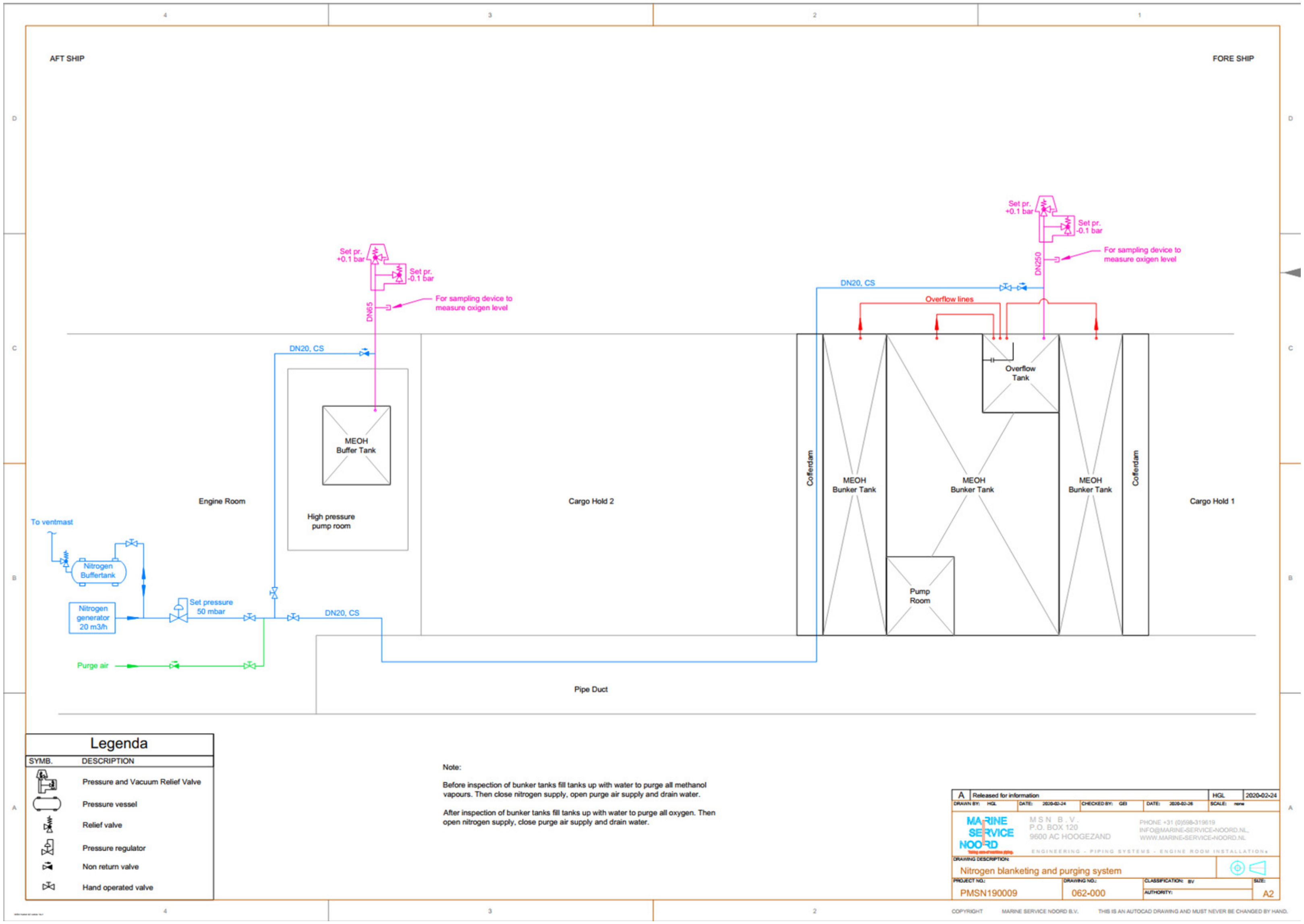
NOTES

VMS: VESSEL MANAGEMENT SYSTEM (POWER SUPPLY AND CONTROL)
FC: FAIL CLOSE, CLOSES VALVE IN CASE OF BLACK OUT

1) ALL SPACE SYSTEMS, TRANSMITTERS AND DETECTORS CONNECTED WITH VMS
2) DRAINAGE AND INERT GAS SYSTEM TO PURGE FUEL LINES FOR MAINTENANCE TO BE ADDED
3) ALL FUEL PIPING TO BE ROUTED 800 MM FROM OUTER SHELL
4) VENTILATION INTAKES TO BE LOCATED OUTSIDE HAZARDOUS ZONES
5) TRANSMITTERS WILL BE INSTALLED IN SETS OF THREE FOR REDUNDANCY REASONS

REV.	DESCRIPTION	DRAWN	CHECK.	APPR.	DATE
A	GENERAL UPDATE	JLo	NDV	NDV	20200821
0	FIRST ISSUE	JVE	NDV	NDV	20200226

CLIENT PROJECT NO.:
CLIENT DRAWING NO.:
CLIENT: GMM
YARD NO.: -
CLASS NO.: -
PROJECT NUMBER: 19.507
DRAWING NUMBER: 320-102
STATUS: PRELIMINARY
TITLE: CH3OH FUEL SYSTEM DIAGRAM
PROJECTION:
DIM. UNIT: mm
REV.: A
SHEET: 1-1
SCALE: N.A.
FORMAT: A0



Legenda

SYMB.	DESCRIPTION
	Pressure and Vacuum Relief Valve
	Pressure vessel
	Relief valve
	Pressure regulator
	Non return valve
	Hand operated valve

Note:

Before inspection of bunker tanks fill tanks up with water to purge all methanol vapours. Then close nitrogen supply, open purge air supply and drain water.

After inspection of bunker tanks fill tanks up with water to purge all oxygen. Then open nitrogen supply, close purge air supply and drain water.

A	Released for information	HGL	2020-02-24

DRAWN BY: HGL DATE: 2020-02-24 CHECKED BY: GEI DATE: 2020-02-26 SCALE: none

MARINE SERVICE NOORD
M S N B . V .
P.O. BOX 120
9600 AC HOOGEZAND
PHONE +31 (0)598-319619
INFO@MARINE-SERVICE-NOORD.NL,
WWW.MARINE-SERVICE-NOORD.NL
ENGINEERING - PIPING SYSTEMS - ENGINE ROOM INSTALLATIONs

DRAWING DESCRIPTION:
Nitrogen blanketing and purging system

PROJECT NO.: PMSN190009
DRAWING NO.: 062-000
CLASSIFICATION: BV
AUTHORITY:
SIZE: A2

5.6 Conclusions and Recommendations

The six design studies have provided their own conclusions and recommendations. They can be studied in every paragraph dedicated to each specific case. It is not the intention to repeat these conclusions and recommendations in this final chapter.

From the finding of the six design studies for conversion of the vessels towards methanol there are also some general remarks that can be concluded and are briefly summed up in the following chapter.

Conversion versus newbuilding

The GMM project started with a mix of new built and retrofit vessels, but during the project it was decided to select six existing vessel for conversion towards methanol, mainly due to EU competition legislation.

It can be concluded that for existing vessels it is more complicated and also costlier to execute a conversion from HFO/MGO towards methanol. For some of the vessels these complications proved to be a show stopper for the conversion towards methanol.

The implementation of requirements for methanol as a marine fuel at the beginning of the design process would significantly reduce the cost for the implementation of a methanol system including tanks and safety systems compared to the conversion process.

However in view of the lifespan of about thirty years for commercial vessels an average replacement rate of 3.3% per year of an entire fleet continues to justify the search for cost reduction of ship conversions with regard to future emission targets. Modular design of vessels could also be an important step in reducing costs for possible future conversions.

Major conversion versus minor conversion

In this study a major conversion is defined as a conversion where the vessel is enlarged with several frames in order to accommodate the methanol system on board. A minor conversion is a conversion where enlargement of the existing vessel is not required.

For several of the studied vessels a major conversion is required in order to realize the methanol fuel system on board. The tailor made design of these vessels simply does not allow for modifications of tanks, bulkheads and inclusion of cofferdams or double walled piping. This is the case for Trailing Suction Hopper Dredger Willem van Oranje, Hydrographic survey vessel Snellius and the Port patrol vessel Castor.

Furthermore the vessel operational range of all investigated ships is lowered considerably due to the reduced energy density of methanol. For some vessels this would require an elongation in order to obtain the required bunker volumes without compromising the vessels payload.

However for other vessels a minor conversion suffices. This is the case for Cable laying vessel Nexus, Inland patrol vessel RWS 88 and General cargo vessel Eemsborg. No elongation is required since lower bunker tank capacities can be compensated with higher bunker frequencies and there is sufficient room for system modifications towards methanol below deck and in the engine room in particular.

From a technical point of view the conversion of existing vessels towards methanol is feasible, however the financial implications of such a conversion might not always warrant such a decision.

Especially for older vessels near the end of life, the investment for a major or minor conversion cannot be justified based on economic principles.

New engines versus retrofit engines

At present only few new engines are for methanol. MAN is the only engine supplier who delivers two stroke engines for methanol tankers that can run on their own fuel.

Wärtsilä has executed a conversion of a convention diesel engine towards methanol on the Stena Germanica, but has to standardise retrofit packages for shipowners that would like to convert their engines toward the use of methanol. The demand for retrofit packages towards methanol engines is currently too small, mainly due to the price gap between MGO and (green) methanol

SandiNAOS has converted Scania engines towards spark ignited and compression ignited methanol engines for smaller vessels and power ranges up to 400 kW. Although these developments are in an early stage it is hopeful that there are some pioneers take steps toward the introduction of methanol engines in the marine market.

In the European Fastwater project which recently started Anglo Belgian Corporation (ABC) will take the initiative to convert one of her engines towards methanol. For more information see also www.fastwater.eu.

Many engine manufacturers have expressed interest in the Green Maritime Methanol project over the last two years. However it is quite a large step for most of them to start the production of conversion packages towards methanol engines (in case this is anyhow possible) or to start producing methanol engines in larger amounts. Apart from the larger two stoke engines of MAN the market demand for these engines seems presently too low.

Issues with regard to what kind of engines should be developed first (single fuel, dual fuel, compression ignited, spark ignited) should also be addressed before production on a larger scale can take place.

Dedicated tanks for methanol versus Flexi fuel tanks

For dual fuel engines fuel flexibility is of great importance. (Green) methanol might not be available in every port around the globe. This means that fuel tanks for diesel should be able to be used for methanol and also vice versa. This is an operational challenge with regard to contaminations and cleaning of the fuel tanks. This subject requires further study and also development of clear and unambiguous rules.

Venting on deck versus venting near the waterline

Finally it is concluded that venting on deck of methanol might pose a challenge based on e.g. the ambient temperatures during venting, pressures, the amounts of vented air/methanol and the people working in that deck area. Rules have been implemented, but verification of the behaviour of methanol fumes in various circumstance should be a subject of further detailed study.