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Principles for Ship Methanol Fuel System Design

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Bachelor’s Thesis | Abstract

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Principles for Methanol Fuel System Design

The purpose of my thesis was to clarify the design principles of a methanol system on a ship. The aim of the thesis is to help the reader understand the principle of a methanol system and to support the principle with related regulations and legislation.

Meyer Turku is one of the largest and most modern shipyards in the world, with the aim of reducing carbon dioxide emissions to zero in its own production and offering its customers sustainable and environmentally friendly solutions (Meyer Turku, 2024). The ultimate goal of this thesis is to provide an alternative to the use of fossil fuels by supporting the design of a near-zero emission system.

The thesis was started by studying the reference material held by Meyer Turku, public documents and studies on methanol, as well as the rules and regulations for methanol and other low flashpoint fuels. Using this information, a document was created covering the basic principles for designing a methanol-fuelled ship.

Keywords:

shipbuilding, fuels, emissions, green transition

Opinnäytetyö (AMK) | Tiivistelmä

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Valtteri Ojanperä

Metanolipolttoainejärjestelmän suunnitteluperiaatteet

Opinnäytetyöni tarkoituksena oli selventää laivan metanolijärjestelmän suunnitteluperiaatteita. Opinnäytetyön tavoitteena on auttaa työn lukijaa ymmärtämään metanolijärjestelmän toimintaperiaate ja tukea toimintaperiaatetta siihen liittyvillä säädöksillä ja lainsäädännöillä.

Meyer Turku on yksi maailman suurimpia ja modernimpia telakoita, jonka tavoitteisiin kuuluu vähentää hiilidioksidipäästöt nollaan omassa tuotannossaan ja tarjota asiakkailleen kestäviä ja ympäristöystävällisiä ratkaisuja (Meyer Turku, 2024). Opinnäytetyön pohjimmainen tavoite on tarjota vaihtoehto fossiilisten polttoaineiden käytölle tukemalla lähes nollapäästöisen järjestelmän suunnittelua.

Opinnäytetyön toteutus aloitettiin perehtymällä Meyer Turun hallussa olevaan referenssiaineistoon, julkisiin dokumentteihin ja tutkimuksiin koskien metanolia sekä perehtymällä metanolin ja muiden alhaisen syttymispisteen omaavien polttoaineiden sääntöihin ja säädöksiin. Näitä tietoja hyödyntäen luotiin työ, joka kattaa perusperiaatteet metanolikäyttöisen laivan suunnitteluun.

Asiasanat:

laivanrakennus, polttoaineet, päästöt, vihreä siirtymä

Content

Figures

Pictures

List of abbreviations (or) symbols

Abbreviation	Explanation of abbreviation (Source)
AFT	After
AL	Airlock
CL	Centerline
ESD	Emergency Shutdown
FVT	Fuel Valve Train
FPR	Fuel Preparation Room
FWD	Forward
GHG	Green House Gas
GT	Gross Tonnage
IEA	International Energy Agency
IMO	International Maritime Organization
IRENA	International Renewable Energy Agency
LEL	Lower Explosive Limit
LNG	Liquefied Natural Gas
LPPS	Low Pressure Pump Skid
ME	Main Engine
MeOH	Methanol (abbreviation for Methanol)
MFV	Master Fuel Valve
MFPU	Methanol Fuel Pump Unit

MGO	Marine Gas Oil
MT	Metric Ton
NM	Nautical Mile
P	Portside
PM	Particulate Matter
PPM	Particles Per Million
SB	Starboard
SOLAS	Safety of Life at Sea
SO_X	Sulfur Oxide
SSL	A ship-shore Link

1 Introduction

The client of my thesis is Meyer Turku. Meyer Turku is one of the largest and most modern shipyards in the world, with shipbuilding experience dating back to 1737. Meyer Turku focuses on sustainable shipbuilding, and continuously strives to develop ships and their construction to be more and more environmentally friendly (Meyer Turku, 2024). Meyer Turku shipyard aims to design a carbon neutral ship concept by 2025, and to make the shipyards' production carbon neutral by 2030 (Meyer Turku, 2022).

The aim of my thesis was to create a design guide to assist in the design of a methanol-fuelled cruise ship. The purpose of the thesis is to draw attention to the design of methanol system including its auxiliaries. The thesis covers the cornerstones of system design, and supports the topic with International Maritime Organization IMOs rules and regulations.

In the first part of my thesis, I will look at the current situation regarding the use of different fuels and emissions legislation. The first part also looks at the characteristics and uses of methanol, LNG and MGO. The practical part of the thesis deals with methanol tanks and their design, methanol bunkering, transfer, feeding and inerting. In addition, the practical part deals with the ventilation system and the safety of the system. The sources used in the thesis are Meyer Turku and public sources supported by IMO rules and regulations.

2 Backround

As emissions legislation continues to evolve and green transition continues, many companies, both on land and at sea, are constantly looking for new fuels to use. Reducing emissions and striving for zero-emissions has become an important part of many companies' goals globally, and companies are seeking to offer their customers an environmentally friendly and sustainable solution. Such solution include the development of new types of engines and mechanical equipment, such as boilers used for heating a ship, that can be fuelled by alternative and renewable fuels.

A large part of existing fleet uses HFO as fuel. The use of heavy fuel oils also generates significant emissions of sulphur dioxides and nitrogen oxides. As shipping regulations become more stringent, the importance of alternative fuels will become even more important. On the maritime side, the implementation of the Green Transition is monitored by the International Maritime Organization IMO, the United Nations' specialized organization for maritime regulation. The current IMO agreement calls for a 40% cut in greenhouse gas emissions per ship by year 2030 compared to year 2008. The larger target is to cut greenhouse gas emissions by 50% by year 2050 compared to year 2008 (mol-service.com, 2021).

Currently, around 99,5% of ships over 100 GT at sea use fuel oils as fuel for their diesel engines. Today, about 12% of new ships under construction are ordered with a fuel other heavy fuel oil (Figure 1). As the demand of alternative fuels such as ammonia, hydrogen, LNG and methanol increases, companies also need to meet customer demand (Journal of Marine Science and Application, 2013).

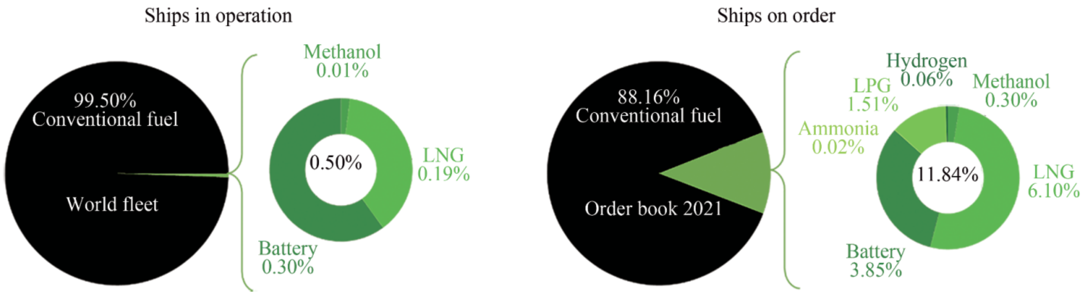


Figure 1. Uptake of alternative fuels for the world fleet (Journal of Marine Science and Application, 2013).

2.1 Methanol as a ship fuel

Methanol (CH_3OH) is a colorless, liquid, alcohol consisting of four parts hydrogen, one part oxygen and one part carbon. Methanol is the simplest organic chemical in the group of alcohols, and it can be stored at room temperature and kept in a pressurized tank during storage (Green Maritime Methanol, 2021, p. 4). Pressurization is achieved by using inert gas.

Methanol has a remarkably high energy density compared to other alternative fuels. For example, Bio-LNG has an energy density of only about 11 GJ/m^3, while methanol's energy density is 15.8 GJ/m^3 (Green Maritime Methanol, 2021, p. 6). On the other hand, methanol has a low energy density compared to, for example, the energy density of MGO 36.6 GJ/m^3 (Methanol institute, 2023, p. 7) and the energy density of fossil-based LNG 21 GJ/m^3 (Wikipedia, 2024). In practice, this means that methanol-fuelled ship requires about 2.4 times more space on board than MGO-fuelled ship to achieve the same energy coverage (Methanol Institute, 2023, p. 7). In terms of emissions, methanol combustion does not produce any SO_X or PM emissions that occur when fossil fuels are burned. Methanol only forms carbon dioxide and water when it burns. However, methanol needs a pilot fuel for its combustion, such as MGO, which produces emissions from combustion. The amount of pilot fuel required is very small, only 3-5% of the volume of fuel to be injected, so emissions from MGO combustion will not be significant (Methanol Institute, 2023, p. 10).

Methanol can be produced from a variety of resources. Methanol can be produced from non-renewable resources such as coal and natural gas, but also from renewable resources like biomass and bio-methane (figure 2). Today, methanol is produced primarily from natural gas using it as a feedstock and fuel in the process. The carbon content of methanol depends on the feedstock and the production method. When emissions from well-to-tank are taken into account, bio-methanol and e-methanol are the lowest emitting marine fuels (Methanol Institute, 2023, p. 10).

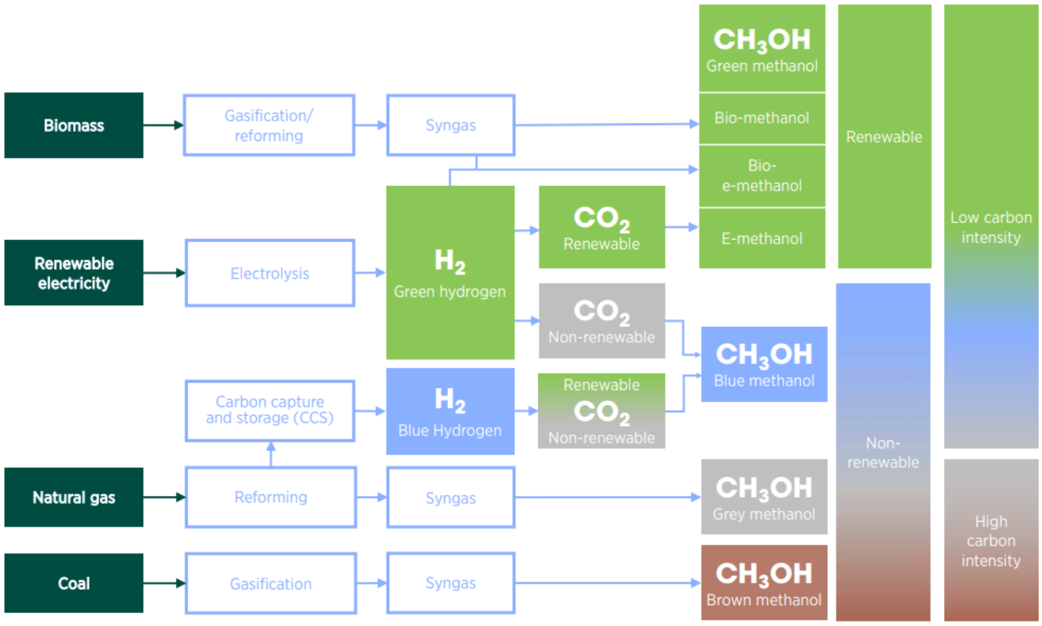


Figure 2. Methanol Production Pathways (Methanol Institute, 2021, p. 10).

Methanol is well suited as a marine fuel because it mixes and breaks down completely in water and has no long-term effects on marine life. Several fuels, such as methane and ammonia, and in particular fuels containing heavy fossil oil, are much more toxic to marine organisms and cause significant action when released into the sea (methanol.org, 2023, p. 12).

The average price of grey methanol in 2025 is estimated to be around 21 $/GJ (figure 3. The price of Bio-methanol in 2025 will be around 26 $/GJ. The notable exception in methanol prices is e-methanol, which is expected to cost over 70 $/GJ in 2025 (SEA-LNG, 2023).

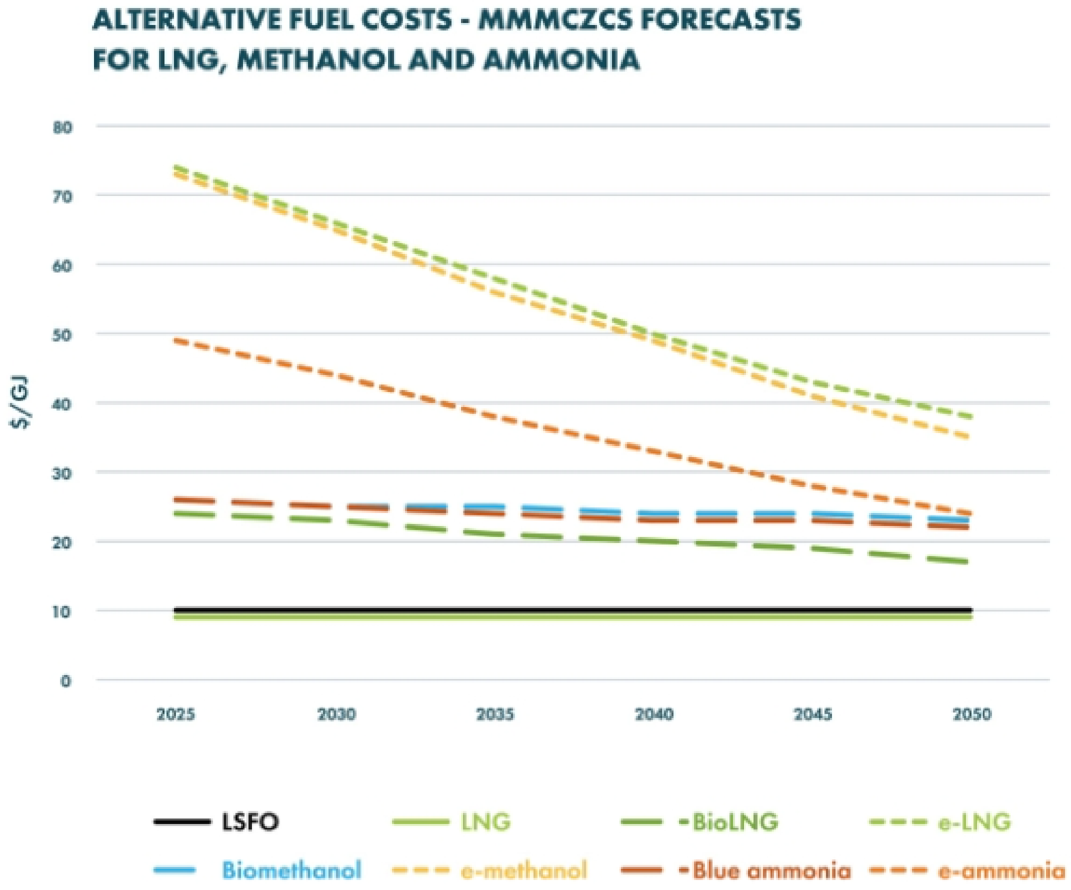


Figure 3. Price evolution of alternative fuels (SEA-LNG, 2023).

There are currently 216 methanol-fuelled vessels on order. The order book is expected to grow over the next few years. The share of cruise ships in the order book is remarkably small as most of the methanol-fuelled ships under construction are container ships. In addition to methanol, ammonia as a fuel continues to attract the interest of shipping companies (Manifold Times / DNV, 2023).

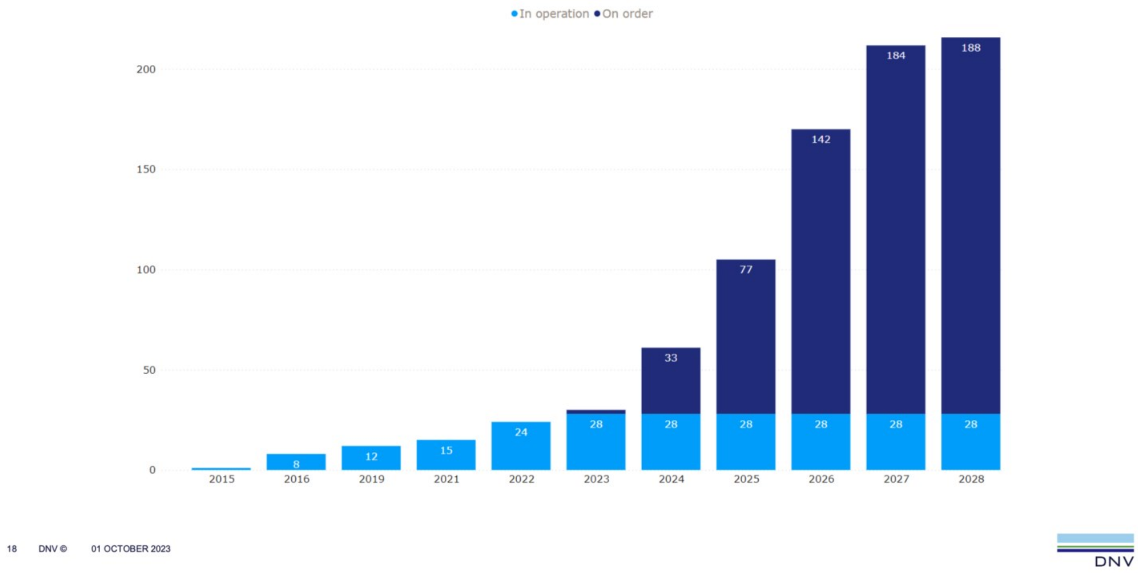


Figure 4. Forecast of methanol-fuelled ships (DNV, 2023).

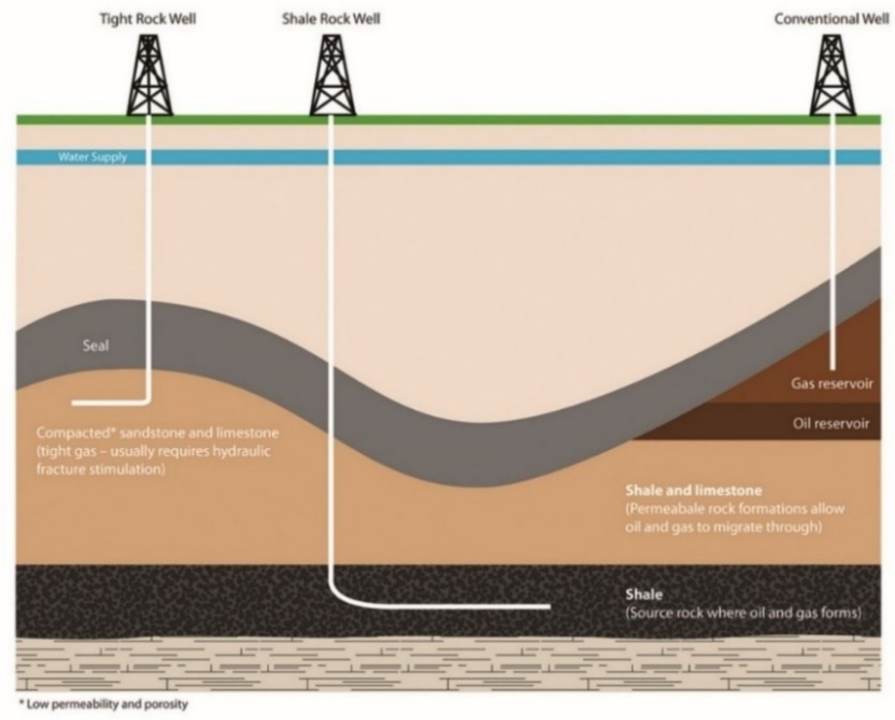
The International Maritime Organization regulates, develops and establishes regulations and guidelines for the use of methanol onboard (methanol.org, 2023, s. 12). However, the methanol legislation is still not complete and changes are still being made. The adoption of IMO interim guidelines (MSC.1/Circ.1621, Annex, Interim guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as a Fuel) allowed ship owners to order methanol-fuelled ships in 2020. These guidelines were written over a period of six years. For other alternative fuels, this legislation has not yet been made (methanol.org, 2023, p. 12).

Methanol is now seen as a promising alternative fuel for the marine industry, reflected in a growing order book. Thanks to IMO’s IGF Code for ships using low-flashpoint fuels and DNV’s mandatory class rules for methanol-powered ships, the groundwork for methanol has been laid (DNV, 2023). IMO’s MSC, Maritime Safety Committee, is the institution that sets the rules and regulations for shipping (IMO, 2024). IMO’s IGF Code, International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels, is IMO guidance covering mandatory criteria to be used by ships, such as methanol-fuelled ships (IMO, 2024). DNV is a classification organization responsible for implementing risk management (DNV, 2024).

2.2 LNG as a ship fuel

Liquefied Natural Gas (LNG) is natural gas which has been cooled down to -163ºC for shipping and storage. It consists of methane (CH_4) with some mixture of ethane (C_2H_6). The volume of natural gas is about 600 times higher in its gaseous state than in liquid state. (Office of Fossil Energy and Carbon Management, 2024)

Natural gas has been formed during millions of years. It is a long-term product of decaying plant and animal matter which has buried in the rock layers of the soil under high pressure and temperature (CAPP, 2023). Natural gas can typically be found from depths of 2 – 5 km and it's extracted with petroleum wells drilled in soil. Natural gas is typically found from permeable rock layers. Natural gases can also be found and recognized by rock type it is extracted from. These gases are categorized as shale gas, tight gas and coal seam gas. Shale and tight gas extraction requires fractures to create a path for the gas to flow. Coal seam gas usually contains water, so it requires dewatering to relieve the pressure in the rock layer and release the gas flow (Government of Western Australia, 2015). Figure 3 (below) shows the levels where natural gas can be found and drilled.



Picture 1. LNG extraction (Government of Western Australia, 2015, p. 2).

Natural gas is transported using pipelines in its gaseous state and with special cargo ships in its liquid state. The liquid state of natural gas enables the availability of gas in places where distribution is not possible with pipelines. It also enables the possibility for natural gas to be used as marine fuel (Office of Fossil Energy and Carbon Management, 2024). In ships natural gas is stored in tanks that are pressurized and cooled to the desired temperature minimum of -162ºC. In total there are 147 ports that can bunker LNG and over 50 more LNG bunkering facilities are under consideration (Offshore Energy, 2022). LNG has also many other uses. For example, natural gas plays a strong role in the US supplying about 1/3 of primary energy consumption. Mainly gas is used for heating and energy production (Office of Fossil Energy and Carbon Management, 2024).

The use of gases as a fuel also causes challenges. LNG consists mainly of methane, which is a GHG. Methane decomposes in the atmosphere in about 10 years. However, in the methane combustion process in the engine, some of the methane remains unburned. In this case, methane escapes from the engine and is released into the surrounding atmosphere. This event is called a methane slip. Methane slip is caused by flame extinction during the combustion process and by scavenging losses. The possibility of methane slip formation can be reduced by keeping the vessel well maintained, reducing energy used for propulsion, optimizing the engines and avoiding operating the vessel at low loads (Wärtsilä, 2023).

Natural gas offers an easy way for shipowners to cut their greenhouse gas emissions compared to the use of oil-based fuels. For example, on a well-to-wake basis the cut percent for greenhouse gas emissions using LNG instead oil-based fuels is 23% (SEA-LNG, 2022). According to DNVs report published in 2022, there were 240 ordered LNG fuelled vessels in 2021 (figure 5). LNG caused interest in many different shipping sectors which is reflected in the forecast of 2028, when LNG-fuelled and LNG-ready global fleet is expected to be over 850 ships (DNV, 2022).

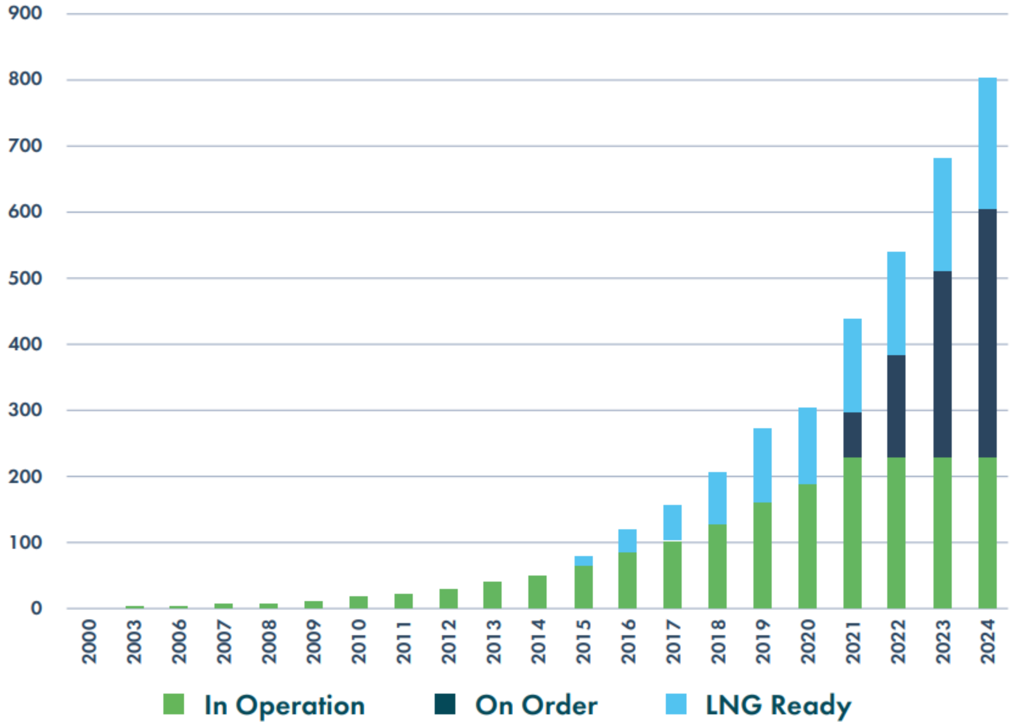


Figure 5. LNG-fuelled newbuilding (SEA-LNG, 2022, p. 3).

LNG can be produced in an environmentally friendly way, called Bio-LNG. Bio-LNG is produced from renewable resources and does not use fossil resources.

Bio-LNG can be produced from animal manure or sewage sludge, for example, but it must first be processed into biomethane. The fuel can then be cooled to liquefied natural gas (European Biogas Association, 2020).

BIO-LNG has several benefits. It can be produced with zero emissions through recycling, its chemical properties make it an easy substitute for fossil-based LNG and it supports sustainability (European Biogas Association, 2020). On the other hand, the price forecast for Bio-LNG for 2025 is around 25 $/GJ, while LNG is only around 9 $/GJ, which also has a significant impact on consumer choice (figure 3). However, the BIO-LNG is predicted to increase due to the development of refineries (SEA-LNG, 2023).

2.3 MGO as a ship fuel

Marine Gas Oil (MGO) means a marine fuel distilled from crude oil. MGO differs from heavy fuel oil in that it does not need to be heated during storage and remains ready for use. MGO can be easily pumped into the engine only at 20ºC, as it has a remarkably low viscosity compared to heavy fuel oils or marine diesel oil. MGO is transparent or light in color, but it is often colored for identification purposes. MGO is mainly used in low and medium speed engines and as a fuel for marine auxiliary systems (Oiltanking, 2024).

MGO has a lower sulphur content than heavy fuel oils, but its chemical properties are more or less the same. Its energy density is 36.6 GJ/m^3. Marine gas oil produces significantly lower particulate and soot emissions than heavy fuel oils. Sulphur emissions from the fuel combustion are controlled on board by filters and scrubbers (Oiltanking, 2024).

However, the problem with MGO is its high cost compared to, for example, HFO (Oiltanking, 2024). The price of HFO in Northern Europe is currently around 420 $/mt (Insee, 2024), while MGO is around 820 $/mt (Ship & Bunker, 2024).

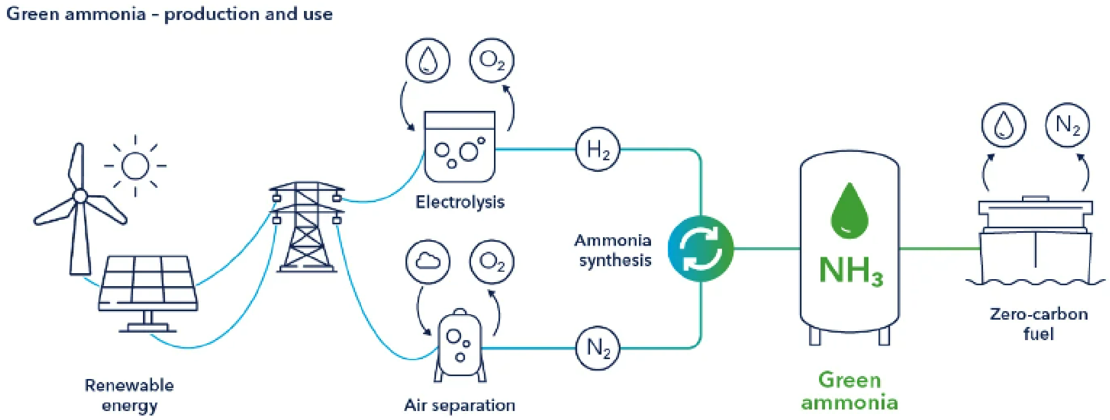
As emissions legislation becomes stricter, there is also a desire to produce MGO in an environmentally friendly way. DNV, the Norwegian accredicted registrar, predicts that Bio-MGO will become a potential new fuel for existing ships by 2050 (DNV, 2020). At present, there is not much actual production of Bio-MGO, but there is already significant production of Bio-Diesel. However, the price difference between bio-diesel and fossil-based diesel is relatively large. Diesel in Europe cost 1$/litre in March 2022, while Bio-Diesel cost 1,7 $/litre at the same time (IEA, 2022). On this basis, it can be predicted that when Bio-MGO enters the market, its price will also be almost double that of fossil-based MGO, at least at the start of the production.

2.4 Ammonia as a ship fuel

Ammonia is considered as a strong alternative fuel for shipping. Ammonia has traditionally been regarded as a fertilizer and currently about 80% of the ammonia produced is used as a fertilizer (DNV, 2022). Ammonia should be stored on board in liquid form and under pressure.

Ammonia has energy density of 15.6 GJ/m^3 (Ammonia Energy Association, 2018) more than a half the energy content of methanol 36.6 GJ/m^3. The use of ammonia as a cruise ship fuel also poses challenges due to its toxicity. Ammonia is lethal if the ammonia in the breathing air contains only 0.5 % ammonia. Another problem with ammonia is that it produces large amounts of nitrogen emissions when it burns. One of the most dangerous and noteworthy emissions during combustion is nitrous oxide, N_2O, which can be formed during the combustion process. N_2O is 283 times more powerful as a greenhouse gas thank carbon dioxide CO_2 (DNV, 2022).

Ammonia can be produced in a completely green way from renewable energy sources (picture 2). Ammonia produced in this way is called green ammonia, which is completely zero emission. Green ammonia production is not yet widespread, but is expected to start by the end of the decade (DNV, 2022).



Picture 2. Green ammonia production (DNV, 2022).

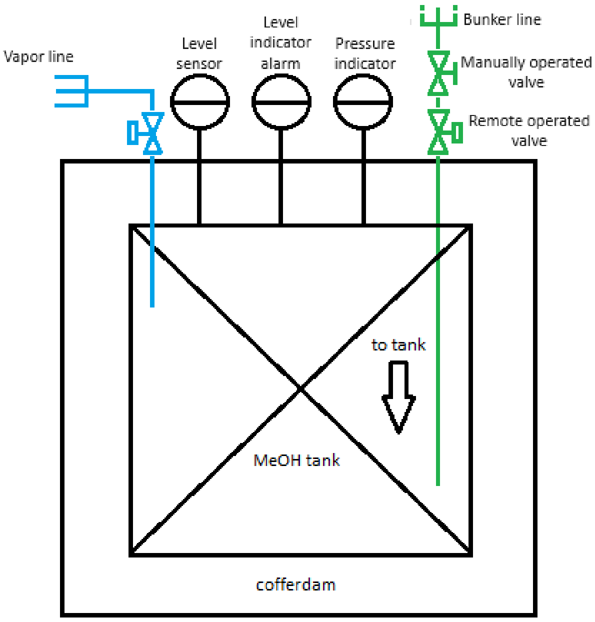
3 Methanol system

In this part of the thesis, we delve deeper into the system itself. This chapter deals with MeOH-tanks, tank material selection, space reservations, methanol fuel and auxiliary systems and methanol ventilation system.

3.1 . MeOH-tanks

When building a tank for methanol storage it must be considered that methanol tank always needs primary and secondary containment. Primary containment is the surface of the tank that is in direct contact with the fuel. Secondary containment can be provided number of ways. Usually and the most common way to ensure that the secondary containment is realized is to place one tank within another. This is called double-wall. Tank requires interstitial monitoring between the double-wall so that possible leaks can be noticed as efficiently and on time as possible (EA Engineering, 1999, p.3).

Each methanol tank should have vapor piping to equalize the pressure in the tanks during refueling and operation (picture 3). In this way, methanol vapor emissions into the atmosphere can be minimized. Methanol tanks should also have a bunker monitoring system. This can be done with the help of tank level sensors, which indicate the height of the liquid level in the tank and, if necessary, cut off the fuel supply to the tank with the help of valves. This way you can avoid overfilling the tanks (Meyer Turku, 2023).



Picture 3. Example of a methanol tank (Meyer Turku, 2023).

3.1.1 Choice of tank material

The chemical properties of methanol differ from traditional fuels such as marine diesel oil (MDO). Therefore, the effect of the fuel on the operation of the system must be considered when choosing the materials for the entire system. Methanol tanks can be built of carbon steel or 300 series austenitic stainless steel. Carbon steel is cheaper in terms of capital costs, but the use of the material causes additional costs due to maintenance of corrosion duration. This is because methanol is a polar solvent, causing galvanic corrosion (Methanol Institute, p.2).

Means for the corrosion resistance of tanks are, for example, coating. Epoxy resin has had limited success. The lifetime of coating is less than seven years, and it is complicating bonding and grounding in the tank. There have been developed electrically conductive spray-on tank liner coatings, which are more suitable for the coating (Methanol Institute, p.2).

Galvanic corrosion may be accelerated in methanol service in dissimilar trim materials like aluminium, lead, magnesium, copper, zinc and platinum alloys.

This may cause component failures, which lead to equipment failures or, in the worst scenario, for example, unsuccessful fire extinguishing (Methanol Institute, p.2).

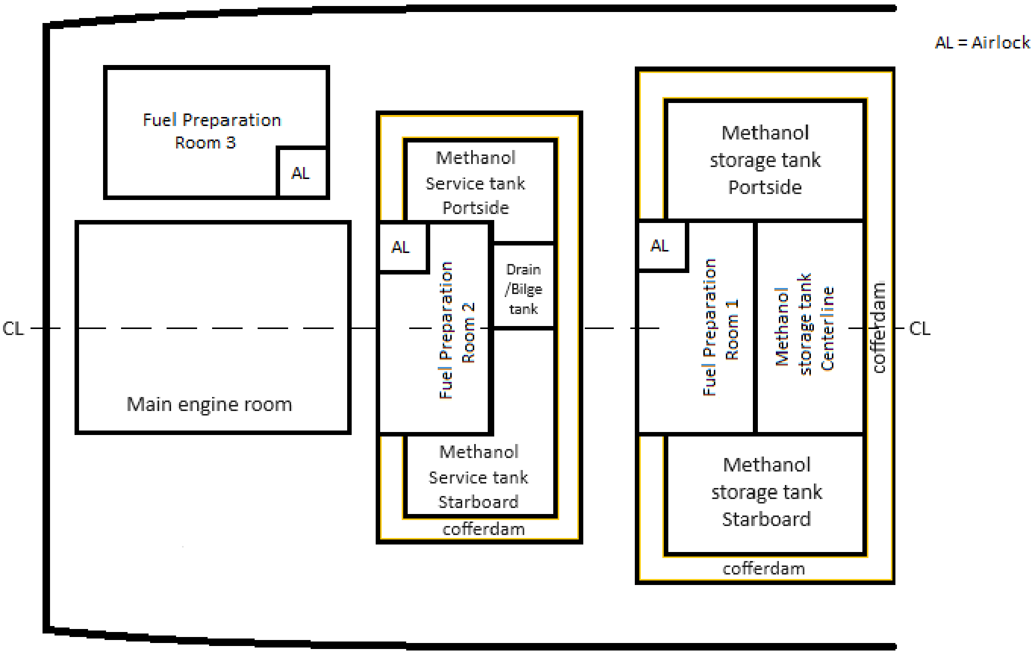
Carbon steel corrodes more likely than stainless steel and causes methanol contamination. Corrosion is the result of water forming in the tank and methanol reacting with it. This problem can be reduced by pumping inert gas such as argon or nitrogen, into the free space of the tank. (Methanol Institute, p. 3)

According to Methanol Institute, 300-series stainless steel alloys are recommended. Stainless steel is a more expensive option, but significantly reduces the risk of contamination. In the long run, tanks made of stainless-steel bring savings as they do not require the renewal of the coating and are also more maintenance-free (Methanol Institute, p. 4).

3.1.2 Tanks and cofferdams

International Maritime Organization has set functional requirements for the placement and the construction of tanks. The possibility of damage to the tanks, for example due to a collision or grounding, must be minimized. Fuel tanks must also be protected from mechanical damage. (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 5, 2022). On methanol-fuelled ships, the methanol tank can be placed below the lowest possible waterline and may be in contact with the bottom of the ship (IMO, MSC.1/Circ. 1621, Annex, Interim guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as a Fuel, chapter 5, 2020).

When building methanol tanks, space must also be reserved for cofferdams (picture 4). Structural tanks must be surrounded by cofferdams (IMO, MSC.1/Circ. 1621, Annex, Interim guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as a Fuel, chapter 5, 2020). Cofferdam means an empty space built in the immediate vicinity of the tank. The cofferdam must be gas-tight, and large enough to allow maintenance, inspections and evacuations to be carried out inside the cofferdam. Cofferdams are built to prevent the mixing of two different types of liquid and to facilitate the control of possible leaks (Marine Insight, 2019).



Picture 4. Example of cofferdam and tank arrangement. (Meyer Turku, 2023).

According to the IMO, cofferdams must be constructed in a way that the can be purged or filled with water if necessary. This is also known as a cofferdam flooding. The purpose of flooding is to mix the gas with the water and remove the gas released from the cofferdam. This method is used to control a possible gas explosion. Cofferdams should be designed to withstand the weight of the liquid when flooded. A separate bilge pump should be used to pump the contamined water into the bilge tank and drain the interior of the cofferdam (IMO, MSC.1/Circ. 1621, Annex, Interim guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as a Fuel, chapter 6, 2020).

There are few things to consider when designing cofferdams. Manholes must be arranged in each cofferdam for maintenance, inspection and cleaning. The manholes must also be tight and sealed properly, so that in case of any leakage, the gas cannot enter the surrounding space. Methanol bilge suction must be installed inside the cofferdam, so that the space can be pumped out in case of emergency. When selecting materials, for example for gas detector equipment or level sensors, the spark-production properties of the material must be taken into account (Marine Insight, 2019).

International Maritime organization requires that the cofferdam must be sufficiently ventilated to allow safe working inside the cofferdam. The minimum distance between bulkheads should be 600 mm to allow movement and operation inside the cofferdam. Cofferdams should be designed to withstand the maximum amount of liquid in the event of a leakage. Manholes horizontal openings must be at least 600x600 mm to allow for a possible rescue operation. Vertical openings must be at least 600x800 mm and no more than 600 mm from the bottom plating. Manholes can also be made smaller if the classification authority approves the solution presented (IMO, MSC.1/Circ. 1621, Annex, Interim guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as a Fuel, chapter 5, 2020).

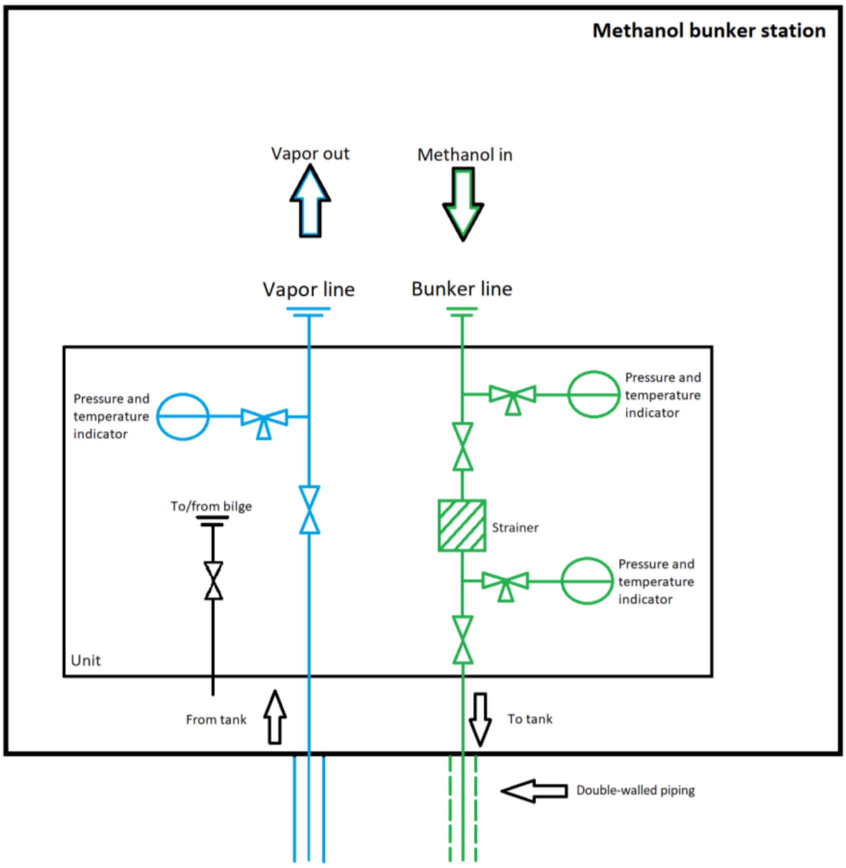
3.2 Methanol fuel and auxiliary systems

This chapter focuses on methanol fuel and its auxiliary systems. The subject area is covered through subchapters, which are bunkering, transfer, feeding and inerting.

3.2.1 Bunkering

The process of refuelling a ship is called bunkering. Methanol can be bunkered onto the ship via bunker station. Bunker unit in the ship consist of methanol, vapor return, bilge and nitrogen piping (picture 5). Vapor return should be built to shorten the bunkering time and to return the methanol vapors back to the bunkering tank located on the shore. This method can reduce methanol bunkering emissions, as they do not have to be led through the mast into the atmosphere. This also reduces the consumption of nitrogen in the suppliers' bunker barge or truck (Meyer Turku, 2023).

Bunkering is a carefully controlled procedure, which should be designed in a way to stop bunker process due to a leak or auxiliary system failure. The pipes leaving the bunker station must be double-walled pipes. The pressure must be monitored so that possible leaks and problem situations in connection with the bunkering process are noticed as quickly as possible (Meyer Turku, 2023).



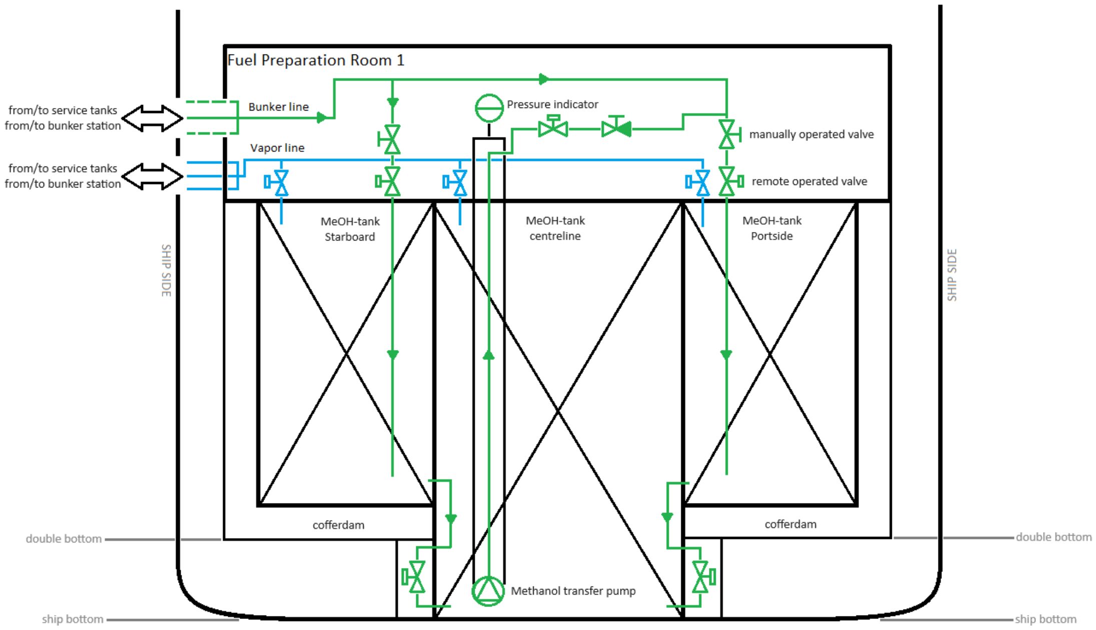
Picture 5. Example of methanol bunker station. Airlock not shown in the picture (Meyer Turku, 2023).

When bunkering methanol, it is recommended to use quick connecting/disconnecting couplings (Meyer Turku, 2023). In this way, starting and ending the bunkering process can be as quick and flexible as possible. This also enables quick disconnection of the refuelling hose when a possible fault occurs. The bunkering process must also include ESD system that can be activated via SSL (Ship-to-shore Link) either automatically or manually (IMO, 2022).

There are also several regulations for a bunker station that it must follow. The bunkering station must be located on open deck. This enables sufficient natural ventilation. Fuel spillage should be taken into account in the design of the bunkering station by using spray shields and drip trays at the connection points. Drip trays must be thermally insulated from the ship’s structure and made of a suitable material, such as stainless steel. The ship’s fuel hoses must be a material compatible with methanol and must be compliant with the National Administration and Port Authority (IMO, 2022).

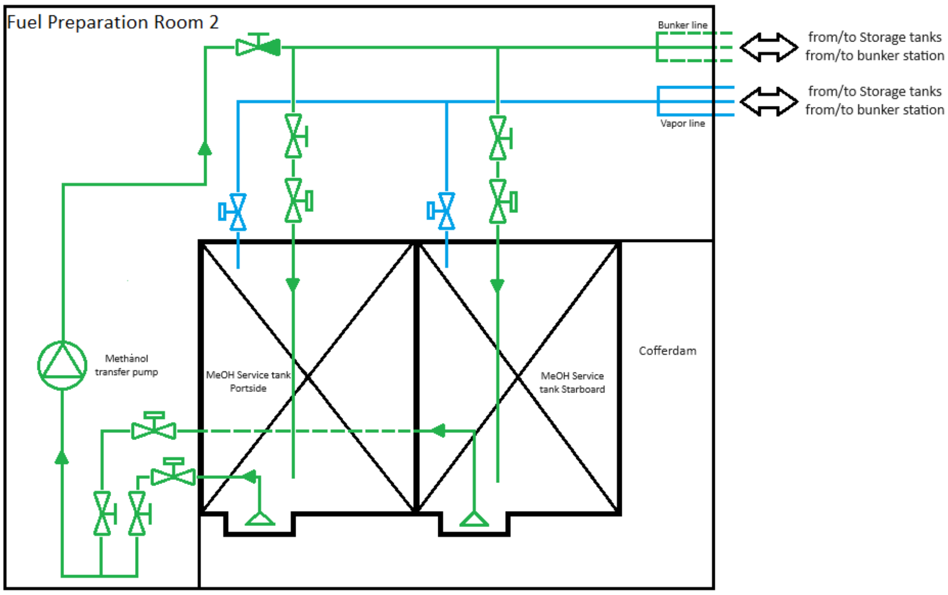
3.2.2 Transfer

Methanol transfer is a part of the process where methanol is transferred during bunkering. The transfer also includes a step where methanol is transferred between tanks. Methanol is transferred via the bunker line. The methanol transfer system should be designed in such a way that methanol can be transferred between MeOH tanks or the bunker station with a methanol transfer pump. Methanol tanks on the sides drain fuel into the centreline tank by gravity (picture 6). The transfer of methanol between the tanks is managed by remotely operated valves. The valves should be located inside the cofferdams of the centreline tank and should be open only when transferring methanol (Meyer Turku, 2023).



Picture 6. Example of methanol transfer in methanol tanks (Meyer Turku, 2023).

Methanol should be transferable between the storage tanks and service tanks or to the bunkering station (picture 7). Another methanol transfer pump for the service tanks should be planned for the transfer of methanol (Meyer Turku, 2023).

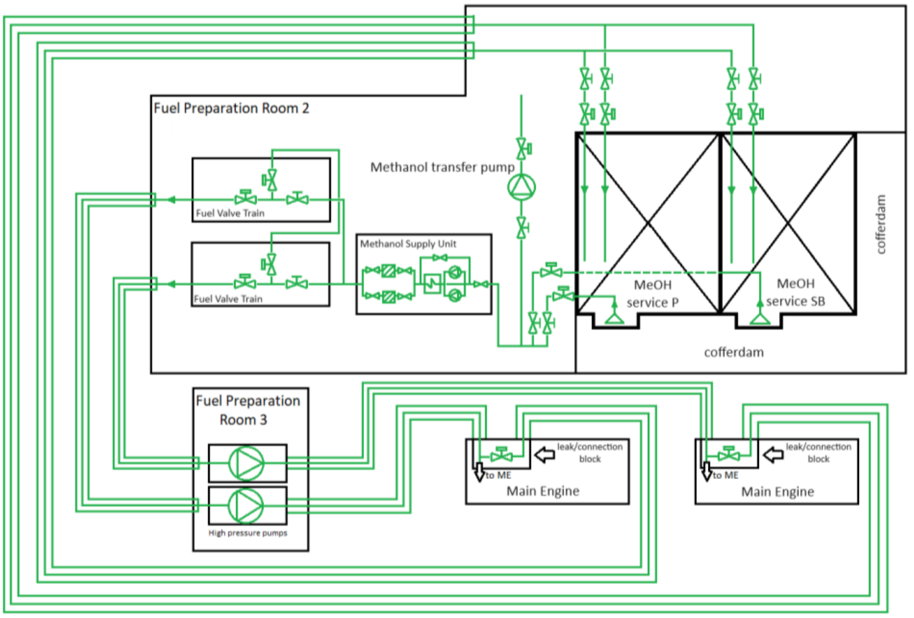


Picture 7. Example of methanol transfer in methanol service tanks (Meyer Turku, 2023).

Fuel transfer pipelines must be designed in a way that possible leakage situation does not pose a risk to persons or the ship’s environment. Fuel piping that runs in enclosed spaces should be double-walled pipes that are insulated with inert gas. Double-walled piping is not required in cofferdams around tanks or in fuel preparation areas (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 5, 2022).

3.2.3 Feeding

Fuel feeding is the step in the process where the fuel is fed from the service tanks to the engine. The fuel feeding consists of different sets of equipment. Methanol feeding should consist of service tank, Low Pressure Pump Skid (LPPS), Fuel Valve Trains (FVTs), Methanol Fuel Pump Units (MFPUs) and Leak / Connection blocks (picture 8). The fuel preparation room 1 near the service tanks should contain a methanol supply unit and FVTs. The MFPUs is located in fuel preparation room 2 where high-pressure pumps are located. Leak / connection blocks must be located next to main engines to connect the methanol fuel pipes into the methanol fuel hoses (Meyer Turku, 2023).



Picture 8. Example of methanol feeding for two main engines (Meyer Turku, 2023).

The role of the Low-Pressure Pump Skid in the system is to control the methanol feed pressure and transfer methanol fuel to the MFPUs. The LPPS consist of two low-pressure pumps, tank suction cones a methanol duplex filter, methanol cooler and the necessary valves and instruments. Of the low-pressure pumps, one is used while running and the other is in standby mode. This will ensure fuel supply even in the case of a possible failure of the second pump (Meyer Turku, 2023).

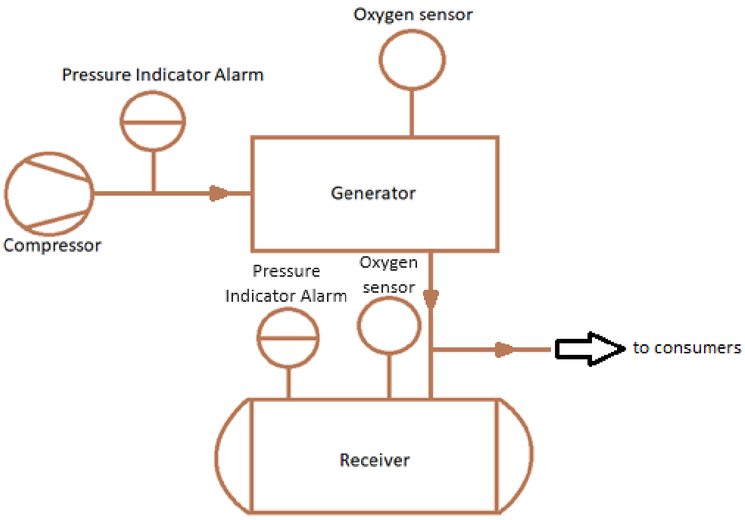
Fuel Valve Trains are used to measure methanol consumption. The FVTs are also connected to the Master Fuel Valve, which controls the ESD. FVTs include a flowmeter, a manual shut-off valve for maintenance, a double block and bleed arrangement for the feedline, two pneumatically controlled nitrogen purging valves and one terminal box. Double block and bleed arrangement includes the pneumatically operated MFV (Meyer Turku, 2023).

Methanol Fuel Pump Units must be installed in the system to raise the injection pressure high enough for the main engines. The MFPUs communicate with the engine’s automation system. The MFPU shall consist at least of a piston pump, an electric motor for the pump, a pulsation damper, a unit alarm and a lubricating oil system. Pulse vibration can also be reduced by installing methanol fuel hoses on the inlet and outlet. It is also possible to install a methanol collection system in the MFPU, which collects small MeOH spills in the methanol bilge and drain tank (Meyer Turku, 2023).

Leak / Connection blocks are part of the system that connect the fuel supply after the MFPUs to the engine. Each main engine must have its own block. The Leak / Connection blocks shall include leak detection equipment for MeOH leaks. The block is also used to maintain the nitrogen pressure in the double-walled pipe and, if necessary, to flush the annular spaces in the pipe with nitrogen in case of a methanol leak. If needed, methanol is drained from the blocks and recycled back to the service tanks (Meyer Turku, 2023).

3.2.4 Inerting

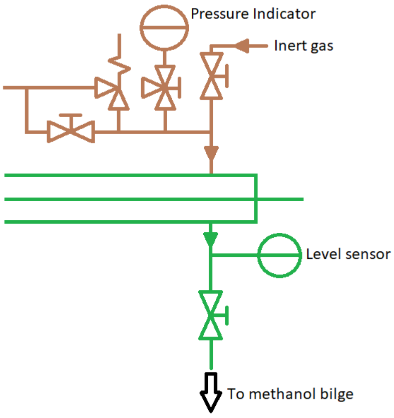
When using methanol or any low flashpoint fuel, inert gas must be used. Inert gas is used mainly as for system cleaning, but also as a leak detector, for tank and pipeline draining and tank pressurisation. The recommended inert gas is nitrogen, which can be produced on board using inert gas plant by separating oxygen and nitrogen from compressed air (picture 9). The inert gas generator must prepare nitrogen for the receiver and refill it when the nitrogen pressure in the receiver drops low enough. The system should be duplicated so that nitrogen can continue to be produced in case of a failure of one generator. In case of a failure of both generators, the ESD should be triggered (Meyer Turku, 2023).



Picture 9. Example of inert gas plant (Meyer Turku, 2023).

When feeding nitrogen into tanks or piping, block and bleed valve configurations and a closeable non-return valve are required. Pressurisation with nitrogen ensures that the tank remains in stable condition, as the properties of methanol make it an explosive atmosphere when not pressurised. Nitrogen supply must be made possible to all pipelines and tanks. In addition, nitrogen supply must be possible to feed into the cofferdams in case of any methanol leakage inside (Meyer Turku, 2023).

The pipeline must be designed in such a way that it doesn’t cause danger to people, the environment or the ship. The pressure in double-walled pipes must be monitored by pressure sensors (picture 10).



Picture 10. Inert gas feeding to double-walled pipe (Meyer Turku, 2023).

3.3 Ventilation system

The design of ventilation on a methanol-fuelled ship should take into account possible leaks and sufficient air intake for normal operation of the system. The design of ventilation depends on the number of units and machinery, but as a basic principle the methanol concentration in the air should not exceed 200 ppm. In a ship using methanol as a fuel, mechanical ventilation systems should be spark-free to prevent methanol ignition (Methanol Institute, Methanol Safe Handling Manual, p. 57, 2020).

Mechanical ventilation must be provided for several different areas on board. The fuel preparation rooms (FPRs), fuel preparation room airlocks and methanol trunk must have their own ventilation. Ventilation must be provided for the methanol bunkering station and its airlock. In addition, the methanol ventilation room must also be ventilated. Ventilation should be provided for the cofferdams. The air required for the cofferdams can be taken from the FPRs ventilation if necessary (Meyer Turku, 2024). The ventilation for the methanol trunk must also be taken into account, but this will be considered separately in another subchapter.

The IMO has specified that the ventilation of hazardous areas must be separate from the ventilation of non-hazardous areas. Ventilation must be capable of operating in all shipboard environments and at all possible shipboard temperatures. All ventilation outlets shall be located outside hazardous areas. Ventilation shall be sized to be adequate for all spaces requiring ventilation (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 13, 2022).

Electric motors for ventilation may be used in potentially explosive areas if they are designed for use in the area. Ventilation equipment shall be of non-sparking design. Ventilation impellers and casings shall be of non-metallic material. Static electricity shall not be generated (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 13, 2022).

The ventilation in the engine rooms shall be independent and shall have air change rate of 30 times per hour in ESD rooms. ESD rooms are spaces containing equipment where gas leaks can occur and gas leakage cause an emergency shutdown. For example, Fuel Preparation Rooms (FPRs) shall have an air change rate of at least 30 changes per hour. In other machinery spaces, ventilation is sufficient at 15 changes per hour if no gas is detectable. At the bunkering station, which is not located on an open deck, ventilation shall be arranged by mechanical ventilation to be adequate. In the annular space of methanol piping located outside engine room spaces, the air shall be changed 30 changes per hour (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 13, 2022).

3.3.1 Hazardous areas

On board a cruise ship, and on any ship, there are hazardous areas which must be classified according to the risks. The classification of hazardous areas is based on the explosive atmosphere and equipment in the area. Suitable equipment should always be used in the areas. In addition, electrical equipment or wiring should not be installed in hazardous areas unless there is an urgent need to do so. Hazardous areas are classified into three different categories: Zone 0, Zone 1 and Zone 2 (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 12, 2022).

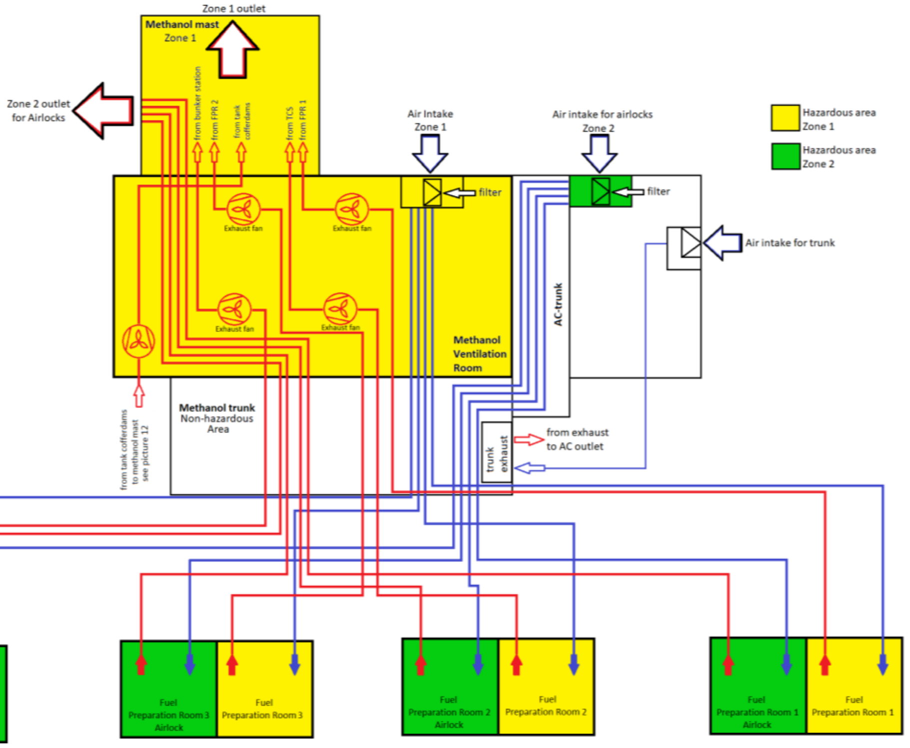
Hazardous area Zone 0 includes all fuel tank interiors, pressure relief piping or other tank ventilation systems. This zone also includes pipes and equipment containing fuel. (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 12, 2022). Hazardous area Zone 0 is the most hazardous area in the classification, as it is located practically inside tanks and pipelines containing methanol.

Hazardous area Zone 1 includes the tank connection spaces, the fuel storage spaces and the spaces between the enclosures. These spaces include methanol tank cofferdam, fuel preparation rooms, methanol bunkering station, methanol ventilation room and methanol mast. In addition, enclosures containing gas control, shut-off and bleed valves should also be defined as Zone 1. Zone 1 should also be noted on the exterior decks, but will be treated in the context of the mast. (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 12, 2022).

Hazardous area Zone 2 includes mainly airlocks that protect non-hazardous areas from Zone 1 spaces in the ship. These includes airlocks leading to the methanol bunker station and fuel preparation rooms. Zone 2 also includes, but is not limited to, open and semi-enclosed spaces 1,5 m from Zone 1. Zone 2 affects the outer decks of the ship, but is discussed separately in the context of the mast (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 12, 2022).

3.3.2 Trunk and mast

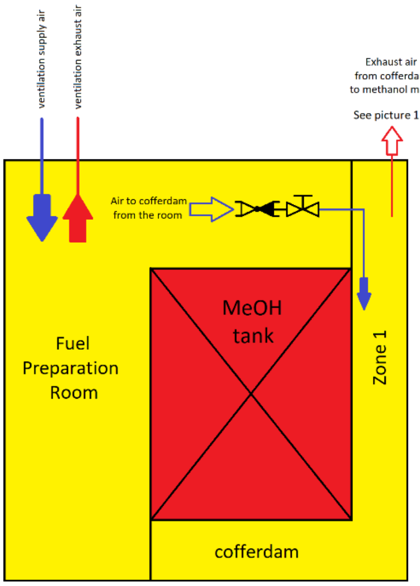
The methanol trunk is an enclosed space through which the inlet and outlet air pipes of the various system rooms pass. Through the methanol trunk, the exhaust air pipes run to the methanol mast (picture 11). The supply air and exhaust air pipes pass through a methanol trunk in the same space. Methanol trunk must have its own ventilation, and it should be considered as a non-hazardous area (Meyer Turku, 2023).



Picture 11. Example of ventilation arrangement. Dampers are not shown in picture (Meyer Turku, 2023).

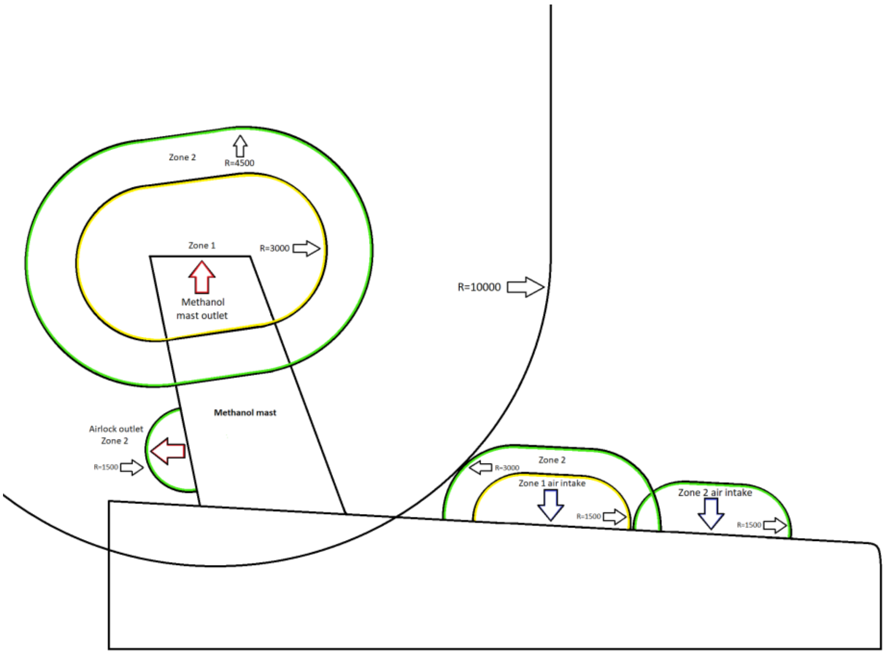
The different zones of the hazardous area should be ventilated according to the zone. This means that Zone 1 and Zone 2 intake air and exhaust air will take different routes. Exhaust air must be exhausted through the methanol mast out of the ship.

The exhaust air from the methanol tank cofferdam is marked in picture 10. The methanol tank cofferdam ventilation inlet air enters the fuel preparation room, from where it can be directed to the cofferdams through a manually operated valve (picture 12). From the cofferdams, the exhaust air can be led directly to the methanol mast (Meyer Turku, 2023).



Picture 12. Example fuel preparation room (FPR) and cofferdam ventilation (Meyer Turku, 2023).

There are several regulations for methanol mast related to hazardous zones. For methanol mast and air intakes for different hazardous area zones, the approved gas safety distances must be take into account (picture 13).



Picture 13. Example of methanol mast and its hazardous area zones (Meyer Turku, 2023).

Zone 1 of the hazardous areas must comply with certain regulated limits, which must be taken into account in the design of the ship. On open or semi-enclosed decks, the safety distance between fuel preparation rooms inlets and airlock ventilation inlets shall be at least 1,5 meter radius. On the mast with other methanol vapour outlets, the radius of zone 1 shall be at least 3 meters. The bunker station also has its own zone, as spaces containing gas bunker manifold valves must be limited by a Zone 1 with a radius of at least 3 meters. The hazardous zones of the bunkering station are not shown in the pictures (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 12, 2022).

Zone 2 of the hazardous areas in the methanol mast is delimited by zone 1. The radius of zone 2 shall be at least 1,5 meters greater than the radius of Zone 1. The same rule applies to air intake. For air entering and leaving zone 2, the radius of the zone shall be at least 1,5 meters. At the bunkering station, the same radius distance shall apply as the top of the mast, making the radius of zone 2 to be 4,5 meters (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 12, 2022). The height of the mast is also adjusted according to the air intakes. The gas outlets (including hazardous area ventilation outlets and vent pipe outlets of methanol tanks) of the mast must be located at least 10 meters from the nearest air intakes. The exhaust air must also be directed directly upwards (IMO, MSC.1/Circ.1621, Annex – Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel, page 12, 2020).

4 Safety

When using methanol as a fuel, fire safety must also be taken into account. According to experts at Meyer Turku, the best alternative for methanol extinguishing is currently being investigated. This chapter lists the IMO criteria for fire safety.

4.1 Structural Fire Protection

Any space containing equipment associated with fuel preparation shall be classified as fire protection category A. In addition, the boundaries of all accommondation, working and machinery spaces shall be protected by A-60 class boundaries (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 11, 2022). The A-60 fire rating class means that the space shall be resistant to at least 60 minutes of fire and shall be made of steel according to SOLAS (Uniteam, 2023).

Fuel storage rooms shall use equipment that does not present a fire hazard. Also, the bunkering station shall be separated by class A-60 boundaries from Class A spaces. Such spaces include accommondation, control stations and high fire risk areas. Boundaries between ESD machinery spaces and another ESD space must be classified to A-60 (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 11, 2022).

4.2 Fire extinguishing systems

According to the IMO, a water spray system may be part of a fire-extinguishing system. However, this requires that the fire pump also has sufficient capacity to allow the use of hydrants and hoses at the same time. In engine rooms, the water spraying system must cover compressor rooms, pump rooms, bunkering station and bunkering control stations. The system shall be capable of spraying water at a minimum rate of 10 liters per minute over on area of 1 m^2 on horizontal surfaces and 4 liters per minute over an area of 1 m^2 on vertical surfaces. Shut-off valves shall be installed every 40 m on the fire-extinguishing access line to isolate the damaged area if necessary. An alternative is to divide the supply lines into several sections. In this case, the controls for the lines should be in the same place and located so that they cannot be exposed to fire in the event of fire. The water spray shall have a shut-off valve to the fire main if its circuit is constructed separately from the fire main. Nozzles for fire extinguishing shall also be a type approved by the authority (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 11, 2022).

There are also powder fire extinguishing systems, for which there are specific regulations. The bunkering station must have its own powder extinguishing system, which must cover any leakage points. The capacity of the system shall be at least 3,5 kg/s for 45 seconds. The system shall be manually triggered from safe location. Powder extinguishers should also be provided in the immediate vicinity of fire risk areas (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 11, 2022).

There are also carbon dioxide fire extinguishing systems for extinguishing fires. The use of carbon dioxide for firefighting is a viable option when efficiency is required. Carbon dioxide removes oxygen from air, which the fire needs to continue. This is the means by which the fire can be suppressed. However, the effectiveness of carbon dioxide also has its drawbacks, as it is dangerous for humans and causes asphyxiation. In this case, for the importance of an evacuation plan, for example, becomes even more important (Koorsen, 2017). A carbon dioxide extinguishing system must also be taken into account in spaces reservations, as the storage of carbon dioxide requires space.

4.3 Fire and gas detectors

Fire detectors and fire detection systems shall be located in the fuel storage areas and in the ventilation ducts leading to the tank rooms. In addition, detectors shall be installed in areas where the possibility of fire cannot be excluded. Such spaces include, for example, machinery spaces and spaces around tanks (IMO, Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, Part A-1, chapter 11, 2022).

Gas detectors should be installed in ventilated areas of fuel lines, machinery spaces where fuel is present, fuel preparation areas and areas where fuel vapours may accumulate. In addition, gas detectors shall be installed in spaces where fuel piping runs, in cofferdams, airlocks and at the ends of ventilation ducts to accommondation spaces.

The number of gas detectors should be sized according to the size of the space, the ventilation and the machinery in the space. A visible and audible alarm shall be triggered when the vapour content of the gas reaches 20% of the LEL, Lower Explosive Limit (IMO, MSC.1/Circ. 1621, Annex, Interim guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as a Fuel, chapter 15.7, 2020). LEL means the lowest level at which a gas can ignite in the air in the presence of and ignition source (PK Safety, 2020). The safety system shall be triggered by two detectors at 40% of the LEL. Toxicity should be taken into account when designing the ventilation of the spaces. In methanol-fuelled ship, the LEL limit should be set at 20% of the LEL. The system detection equipment on board should be located on the bridge, the central control station, the bunkering control point, the security center and locally in the spaces where detectors are located. Gas concentration measurement and detection equipment shall operate without delay (IMO, MSC.1/Circ. 1621, Annex, Interim guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as a Fuel, chapter 15.7, 2020).

5 Conclusions

The purpose of my thesis was to clarify and create guidelines for the design principles of a methanol ship. The thesis included basic information about different fuels and the design of a methanol system, taking into account the International Maritime Organization rules and regulations regarding low flashpoint fuels. The thesis also took into account the safety aspects of methanol for the prevention and extinguishing of methanol leaks and fires. Based on extensive source material, the thesis is made to assist the reader to understand and take into account the relevant issues in the design of the system.

The need for implementation of methanol as a fuel under the green transition is becoming increasingly important. LNG has the potential to significantly reduce emissions compared to other fossil fuels, but only zero emission fuels can achieve zero emission targets. Methanol will also require an increase in its production and supply chain to make methanol production economically profitable for its users. Tighter emission targets will also drive fuel companies, so it is assumed that the price of methanol will fall to even more reasonable levels than today.

Despite the thesis, the marine industry is in a state of constant change, which requires a review the regulations every time a system is designed. The Green Transition and the Zero Emission goals are constantly setting new targets for businesses and legislators around maritime transport and forcing them to consider ways to achieve zero emission shipping. Today, it is therefore important that a company should strive to be as informed as possible about changing legislation and emission requirements, and to offer the widest possible range of solutions to customers based on the legislation.

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