BACHELOR THESIS & COLLOQUIUM – ME 141502

ANALYSIS OF THE REQUIREMENTS FOR THE DESIGN OF SHIPS USING METHANOL AS FUEL

Agus Dwy Bramastha

NRP 04211441000005

Supervisor :

Prof. Dr.Ing. Michael Rachow

M.Sc. Steffen Loest

Department of Marine Engineering

Faculty of Marine Technology

Institut Teknologi Sepuluh Nopember

Surabaya

2018

BACHELOR THESIS & COLLOQUIUM – ME 141502

ANALISIS PERSYARATAN UNTUK MENDESAIN KAPAL YANG MENGGUNAKAN METHANOL SEBAGAI BAHAN BAKAR

Agus Dwy Bramastha

NRP 04211441000005

Dosen Pembimbing :

Prof. Dr.Ing. Michael Rachow

M.Sc. Steffen Loest

Departemen Teknik Sistem Perkapalan

Fakultas Teknologi Kelautan

Institut Teknologi Sepuluh Nopember

Surabaya

2018

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Task for Bachelor-Thesis

Warnemünde, den 09.03.2018

Subject: **Analysis of the requirements for the design of ships using methanol as fuel**

Student: **Agus Dwy Bramastha**

Supervising Professor:	Prof. Dr.-Ing. Michael Rachow	Hochschule Wismar
Assistant Supervisor:	MSC Steffen Loest	Hochschule Wismar
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filing date:	June 2018	

One of major environment problem is the air pollution. Air pollution by ships have been in IMO focus since many years: Limit values are determined in MARPOL Annex VI. One possibility to meet the IMO requirement is using methanol as fuel. Legal requirements for the use of methanol as fuel are given in the IGF Code in very general form. Individual classification societies did publish rules for the use of methanol as fuel, which are to be determined for their applicability on a specific ships design of a 4000 dwt Tanker.

The following aspects should be particularly considered**:**

1. Analysis of IMO requirements and classification societies rules for Methanol as ship fuel,
2. Derivation of possible design solutions to fulfil the requirements
3. Solution for the design of the 4000 DWT Tanker

The supervising Professor reserves the rights to extend or to narrow down the scope of the task during processing. Establishing contacts with other institutions and companies must be agreed with the supervisors. The publication of the work or parts of it requires the prior permission of the supervisor. The work shall be prepared in accordance with the applicable guidelines of Hochschule Wismar for academic and scientific work. At least two consultations with the supervising Professor are required as part of the processing. The finished work is to be submitted in electronic form and in four printed copies in the organization office in Warnemünde.

Prof. Dr.-Ing. M. Rachow

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ANALYSIS OF THE REQUIREMENT FOR THE DESIGN OF SHIPS USING METHANOL AS FUEL

BACHELOR THESIS

Submitted to Comply One of the Requirement to Obtain a Bachelor of Engineering

on

Department of Marine Engineering

Faculty of Marine Technology

Institut Teknologi Sepuluh Nopember

Surabaya

Prepared By

AGUS DWY BRAMASTHA

NRP. 04211441000004

Approved By 1st Supervisor and 2nd Supervisor:

1. Prof. Dr.-Ing. Michael Rachow ( )
2. MSc. Steffen Loest ( )

Rostock, July 2018

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APPROVAL FROM

ANALYSIS OF THE REQUIREMENT FOR THE DESIGN OF SHIPS USING METHANOL AS FUEL

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Prepared by

AGUS DWY BRAMASTHA

NRP. 04211441000005

Approved by

The Head Department of Marine Engineering

Dr.Eng. M. Badrus Zaman, S.T., M.T.

NIP.1997 0802 2008 02 1007

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Declaration of Honor

I conform that the work presented in this research proposal/research report has been performed and interpreted solely by myself except where explicitly identified to the contrary.

Rostock, June 2018

Agus Dwy Bramastha

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Abstract

Bramastha, Agus, *Analysis of the Requirement for the Design of Ships Using Methanol as Fuel*. Bachelor of Engineering (Marine Engineering), June, 2018, Hochschule Wismar, Rostock, Germany.

Methanol is a safe, cost-effective alternative marine fuel. It is one of promised solution for being shipping fuel because of it feedstock and produces less pollution than fossil fuel. Methanol is one of new fuel in the shipping industry; because of that there are lack of regulation for this fuel. IMO has not release regulation of using methanol as fuel but there is some draft is in process. The document that can be found to represent the draft of IMO IGF Code is report of Sub-Committee of Carriage Cargo and Containers (CCC) 3-3. Classification society that has the regulation for using methanol is LR and DNV GL. Comparing the three regulations and selecting the regulation that has high safety level is the best way to design the methanol-fueled ship.

The result shows that there still some different opinion on the three regulations that regulate the methanol as ship fuel. Some regulation also doesn't mention about the detail material that should be use in the system. Calculation method to selecting pipes thickness also different. Implementation the regulation on board ship resulting loses the payload of their cargo. The specific fuel consumption will be increased by factor 46% compared to fuel oil SFOC and the storage tank shall be protected by cofferdam that takes a lot of space. To safe ships space the service tank is recommended put in the main deck to prevent the use of protective cofferdam.

KEY WORDS: Fuel, Emission, Regulation, Requirement, System, Design

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Abstrak

Bramastha, Agus, Analisis Kebutuhan untuk Desain Kapal Menggunakan Metanol sebagai Bahan Bakar. Sarjana Teknik (Teknik Kelautan), Juni, 2018, Hochschule Wismar, Rostock, Jerman.

Metanol adalah bahan bakar alternatif kapal yang aman dan hemat biaya. Ini adalah salah satu solusi yang dijanjikan untuk menjadi bahan bakar kapal karena kesediiannya dan menghasilkan lebih sedikit polusi daripada bahan bakar fosil. Metanol adalah salah satu bahan bakar baru di industri perkapalan, karena itu ada kekurangan regulasi untuk bahan bakar ini. IMO belum mengeluarkan peraturan penggunaan metanol sebagai bahan bakar akan tetapi ada beberapa draft yang sedang dalam proses. Dokumen yang dapat ditemukan untuk mewakili draft IMO IGF Code adalah laporan *Sub-Committee Carriage Cargo and Containers (CCC) 3-3*. Klasifikasi yang memiliki peraturan untuk menggunakan metanol adalah LR dan DNV GL. Membandingkan ketiga peraturan tersebut dan memilih peraturan yang memiliki tingkat keselamatan tinggi adalah cara terbaik untuk mendesain kapal berbahan bakar methanol. Hasilnya menunjukkan bahwa masih ada perbedaan pendapat pada ketiga peraturan yang mengatur metanol sebagai bahan bakar kapal. Beberapa peraturan juga tidak menyebutkan tentang detail material yang harus digunakan dalam system. Metode perhitungan untuk memilih ketebalan pipa juga berbeda. Implementasi methanol sebagai bahan bakar kapal mengakibatkan hilangnya kapasitas muatan. Konsumsi bahan bakar spesifik akan meningkat sebesar 46% dibandingkan dengan SFOC bahan bakar minyak dan tangki penyimpanan harus dilindungi oleh cofferdam yang membutuhkan banyak ruang. Untuk mengoptimalkan ruang, tangki servis direkomendasikan diletakkan di dek utama untuk mencegah penggunaan pelindung cofferdam.

KATA KUNCI : Bahan Bakar, Emisi, Peraturan, Kebutuhan, Sistem, Desain

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Preface

The Bachelor Thesis is submitted to fulfill the final requirement to obtain the Bachelor of Engineering Degree in Department of Marine Engineering, Institut Teknologi Sepuluh Nopember and Hochschule Wismar.

First of all, I would like to Thank God for his blessing and giving me the knowledge and opportunity to complete my Bachelor Thesis in Germany. I would like to express my gratitude to my supervisor Prof.Dr.Ing Michael Rachow and M.Sc Steffen Loest., who give me a lot of advice, support to complete this thesis.

The greatest appreciation would be dedicated to my parents and family for their support and motivation. Lastly, I would like to thank my fellow class of 2014 Marine Engineering Student for being a great friends during my study.

Rostock, 25 June 2018

Author

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List of Abbreviations

Name	Meaning
ARAFFF	Alcohol Resistance Aqueous Film Forming Foam
CCC	Committee on Carriage Cargo and Containers
ECA	Emission Control Area
IMO	International Maritime Organization
SCBA	Self Contained Breathing Apparatus
BFIV	Booster Fuel Injection Valve
EMC	Electromagnetic Compability

Symbol	Meaning	Units
d	Diameter , calculated pipe inside diameter	m, mm
d_H	Inside diameter	m, mm
f	Friction factor	-
h	Head pump	m
h_f	Major head loss	m
h_m	Minor head loss	m
h_p	Head pressure	m
h_s	Head static	m
h_{td}	Head total discharge side	m
h_{ts}	Head total suction side	m
h_v	Head velocity	m
K	Accessories coefficient for calculating minor head loss	-
L	Length	m
LCV	Lower Calorific Value	kJ/kg
Q	Capacity of pump	m^3/h
Rn	Reynolds Number	-
SFC	Specific Fuel Consumption	g/kWh
SFOC	Specific Fuel Oil Consumption	g/kWh
t	Time, operating time	hours, second

V	Volume, Volume of fuel oil consumption	m^3
v	Flow velocity	m/s
W	Fuel oil consumption	tons
n	Quantity	-
u	Kinematic viscosity	cSt, m^2/s
P_{MCR}	Engine power at maximum continuous rating	kW
A	Cross section area, Area	m^2

1 Introduction

1.1 Background

Climate change and environment problem are the most discussed issue for the future shipping industry. One major environmental problem is air pollution. Although air pollution from ships does not have the direct cause and effect associated with, for example, an oil spill incident, it causes a cumulative effect that contributes to the overall air quality problems encountered by populations in many areas, and also affects the natural environment, such as tough acid rain ("Air Pollution," n.d.) . The main international shipping convention regulating emissions to air from ships is the IMO International Convention on the Prevention of Pollution from Ships (referred to as MARPOL) Annex VI. MARPOL Annex VI, first adopted in 1997, limits the main air pollutants contained in ships exhaust gas, including sulfur oxides (SOx) and nitrous oxides (NOx), and prohibits deliberate emissions of ozone-depleting substances (ODS). Under the revised MARPOL Annex VI, the global Sulphur cap will be reduced from current 3.50% to 0.50%, effective from 1 January 2020, subject to a feasibility review to be completed no later than 2018 ("Air Pollution," n.d.). The new IMO Tier III regulation which takes effect on 1st January 2016 in North American and US Caribbean ECAs for a ship with the keel laying in 1st January 2016. Because of that, the new ships with keel laying after that date and sail in North American and US Caribbean ECAs must follow this regulation. The IMO tier III regulates the NOx emissions must be reduced by approximately 75%. One of the solutions to archive this regulation is using cleaner fuel such as Methanol.

Methanol is a safe, cost-effective alternative marine fuel. With the growing demand for cleaner marine fuel, methanol is a promising alternative fuel for ships that help the shipping industry meet increasingly strict emissions regulations(“Methanol as a Marine Fuel | Methanex Corporation,” n.d.). It is one of promised solution for being shipping fuel because of it feedstock and produces less pollution than fossil fuel. It significantly reduces emissions of sulfur oxides (SOx), nitrogen oxides (NOx) and particulate matter. It is one of the top five chemical commodities shipped around the world each year. Unlike some alternative fuels, it is readily available through existing global terminal infrastructure. Currently, methanol produced using natural gas as raw materials, but It can be produced from an enormous raw material such as coal, biomass and the most interesting from CO2. IF future technology can make methanol from CO2 more effective, it will make the world more sustainable because CO2 is one of the major cause of global warming.

Currently, IMO has not release regulation of using methanol as fuel but there is some draft is in process. Classification society that has the regulation for using methanol is LR and DNV GL. Because there is no basic international regulation to design, compared both regulations is needed before designing the ship fuel system.

1.2 Statement of Problems

Based on the background that I describe above About Analysis of The Requirements for The Design of Ships Using Methanol as Fuel, the main problems to analyze are:

I.2.1. What are the requirement for using methanol as ship fuel according to IMO requirement and classification society rules?

I.2.2. What are derivations of possible design solution to full fill the IMO and classification society requirement?

I.2.3. How the implementation of the design requirement on board 4000 DWT Tanker?

1.3 Research Limitation

In this final project, to avoid the misunderstanding of the problem, it is necessary to hold the following limitation, there are:

I.3.1. The ship is chemical tanker ship that design to bring methanol as cargo and the endurance of ship is 5 days

I.3.2. The ship size is 4000 DWT and has Main Engine MAN 7S26MC6 power of 2800kW and Auxiliary Engine MAN L16/24 660kW.

I.3.3. Ship’s Main Engine is converted to use methanol as fuel.

I.3.4. Ship's Auxiliary engine and Boiler are using MGO as fuel.

I.3.5. The ship’s Main Engine uses two type of fuel that is Methanol as main fuel and MGO as pilot fuel.

I.3.6. The P&ID Fuel System is start from storage tank until engine manifold.

1.4 Research Objective

The objectives to be archived from this paper are:

I.4.1. To analyze IMO requirement and classification society rules for using methanol as ship fuel.

I.4.2. To make derivation of possible design solution for full fills the IMO and classification society requirement.

I.4.3. To find solution of the implementation for the design requirement on board 4000 DWT Tanker Ship.

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2 Theoretical Study

2.1 Air Pollution

Currently, many ships have relied on heavy fuel oil (HFO) as a cost-efficient fuel that also provides high-energy efficiency from a well-to-propeller perspective. However, HFO has high sulfur content and impurities, which lead to emissions of sulfur oxide (SOx), nitrogen oxide (NOx) and particulates that have negative impacts on both human health and the environment. Because of the pollution caused by HFO, some are called Emission Control Area (ECA) not allowed to use that fuel. Figure 1 shows the location of existing ECA area and the potential future of ECA. Within SECAs, the maximum allowed sulfur content in marine fuels has been limited to 0.1% since January 2015. America and the Caribbean. Further SECAs have been proposed around Australia, Japan, and Mexico, and in the Mediterranean Sea. A global sulfur cap of 0.5 % by 2020 has been suggested, providing a boost to low sulfur fuels (Andersson and Salazar, 2015).

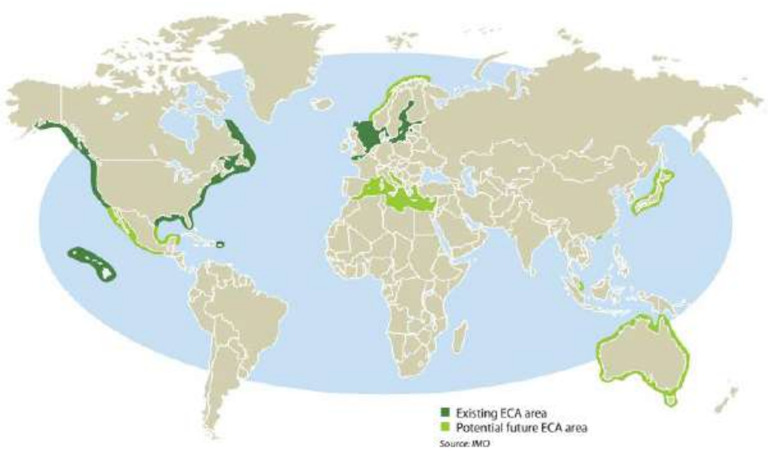

Figure 1 An Emission Control Area can be designated for SOx and PM or NOx
Source :(Lasselle, 2016)

In January 1st, 2016, the new IMO tier III Regulation is applied. IMO NOx Tier III requirements will take effect in North American and US Caribbean ECAs from January 1st, 2016 for vessels with a keel-laying date on or after January 1st, 2016 and an engine output of ≥130kW. If other ECAs for NOx are implemented, the NOx Tier III requirements will not be retroactive. That is if new NOx ECAs take effect (e.g. for the North Sea and Baltic Sea), the Tier III emission limits become applicable to vessels with keel-laying as of the date the new NOx ECAs go into effect. The IMO tier III regulates the NOx emissions must be reduced by approximately 75%.

2.2 Green House Gas Emission

MEPC 67 approved the Third IMO GHG Study 2014, providing updated emission estimates for greenhouse gases from ships. According to estimates presented in this study, international shipping emitted 796 million tons of CO_2 in 2012, that is, about 2.2% of the total global CO_2 emissions for that year. By contrast, in 2007, before the global economic downturn, international shipping is estimated to have emitted 885 million tons of CO_2, that is, 2.8% of the total global CO_2 emissions for that year.

IMO’s Marine Environment Protection Committee (MEPC) has given extensive consideration to control of GHG emissions from ships and finalized in July 2009 a package of specific technical and operational reduction measures. In March 2010 MEPC started the consideration of making the technical and operational measures mandatory for all ships irrespective of flag and ownership. This work was completed in July 2011 with the breakthrough adoption of technical measures for new ships and operational reduction measures for all ships, which are, consequently, the first ever-mandatory global GHG reduction regime for an entire industry sector. The adopted measures add to MARPOL Annex VI a new

Chapter 4 entitled "Regulations on energy efficiency for ships", making mandatory the Energy Efficiency Design Index (EEDI) for new ships and the Ship Energy Efficiency Plan (SEEMP) for all ships. The regulations entered into force through the tacit acceptance procedure on 1 January 2013 and apply to all ships over 400 gross tonnage and above.

2.3 Methanol

Methanol or Methyl Alcohol (CH3OH or MeOH) is an alcoholic chemical compound that is considered to be the simplest alcohol. It is a light, colorless, flammable liquid at room temperature, and contains less carbon and more hydrogen than any other liquid fuel. It has good results in emission but has low energy content compared to diesel fuel. Table 1 shows the comparison between methanol and diesel fuel.

Table 1 Properties of Methanol and Diesel Fuel

Properties	Methanol	Diesel Fuel
Molecular Formula	CH_3OH	$C_nH_{1.8n}$;C_8-C_{20}
Carbon Contents (wt%)	37.49	86.88
Density at 16°C (kg/m3)	794.6	833 to 881
Net heating value (MJ/kg)	20	42.5
Net heating value (GJ/m3)	16	35
Auto-ignition temperature °C	464	257
Flashpoint (°C)[c]	11	52 to 96
Kinematic Viscosity 25°C (cSt)	0.56	2
Flammability limits(vol% in air)	6.72 to 36.5	1.0 to 5.0
Water solubility	Complete	No
Sulfur content (%)	0	Varies <0.5 or <0.1

Source: (Andersson and Salazar, 2015)

From table 1 shows that methanol has lower density and Net heating value than diesel fuel. Methanol density and net heating value are 794.6 kg/m3 and 16 GJ/m3 compared to diesel fuel that has 881 kg/m3 and 42.5 GJ/m3. It shows that to achieve same energy, it needs more quantities of methanol compared to diesel fuel. Methanol also has a lower flash point than diesel fuel. Because of that, It needs more safety protection than diesel fuel to prevent any catastrophic failure. In another hand, Methanol has an environmental benefit because has less carbon content and less sulfur content. Methanol has 37.49 wt% carbon content and 0 of sulfur content compared to diesel fuel that has 86.88 wt% and less than 0.5 % sulfur content. Because of this properties, methanol has a chance to become environmental friendly fuel.

Methanol is widely used in the chemical industry, and fuel applications are starting to grow. The vast majority of methanol is produced from gas and coal. Steam reformation of fossil natural gas is the lowest cost production method. Production of methanol is done close to the feedstock when natural gas is used. Production plants have even been moved to take advantage of a cheaper and more reliable source of gas – as was done when Methanex relocated a plant from Chile to Geismar, Lousiana. The transport of the finished product, methanol, is cheaper and more efficient than liquefying and transporting the feedstock gas to the production plant. In figure 2 explain comparison between fuel oil, LNG, and methanol supply chain from well to tank and tank to wake. Currently, methanol production is from the natural gas feedstock. Future there is the solution to produce methanol from CO_2.

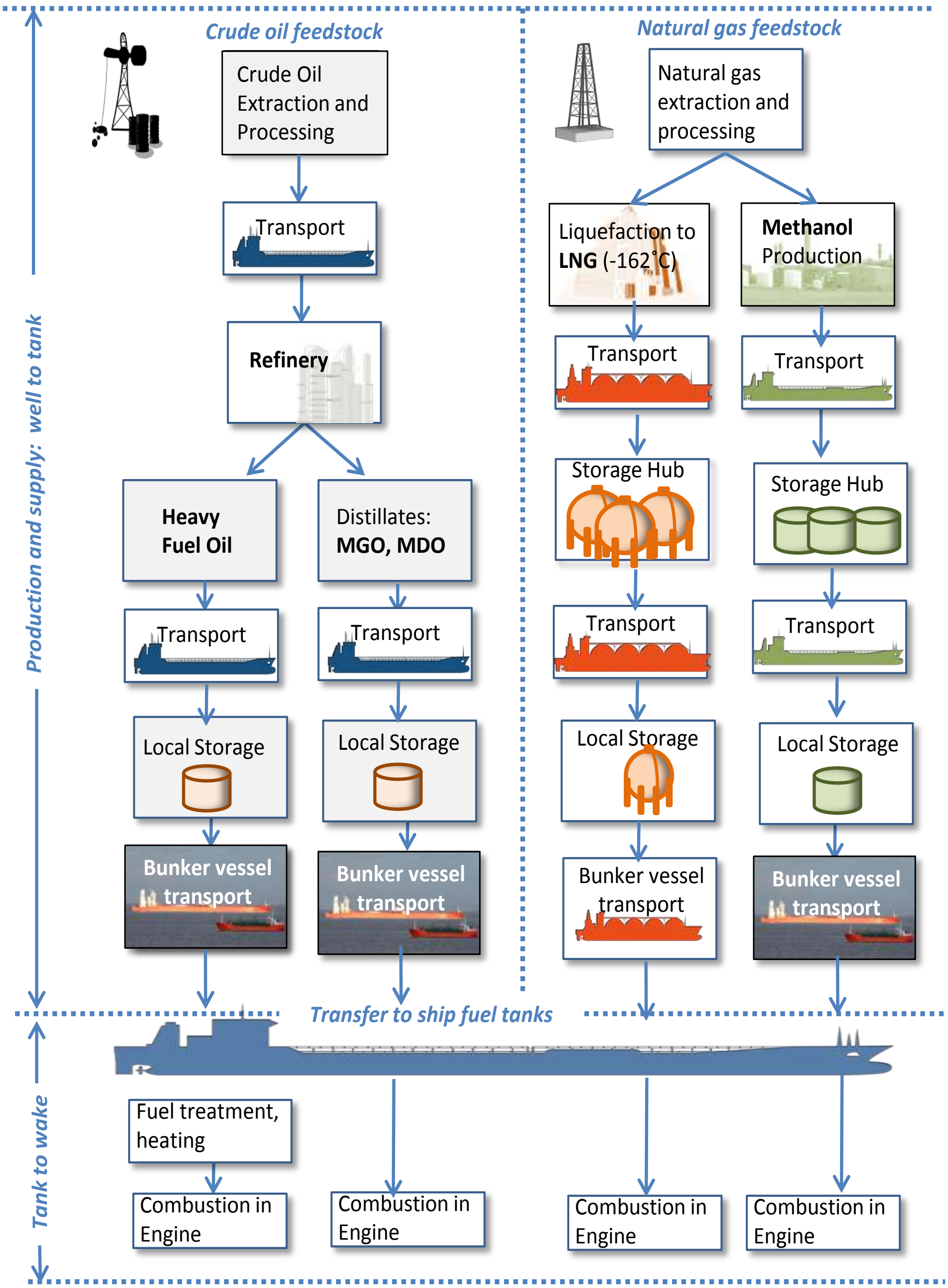

Figure 2 Comparison between fuel oil, LNG and Methanol supply chain

Source : (Ellis and Tanneberger, 2015)

2.4 Methanol Fuel Risk

Using methanol as a fuel there will be some risk to the safety, fire prevention, and extinguisher. To prevent expose of methanol to human body there should be an expose control. Based on methanol safe handling fact sheet, there are four methods to do it. There are engineering controls, personal protective equipment, respiratory protection and chemical resistance clothing/materials. In engineering control, transferring methanol possibly by automatic pump to minimize the potential of exposure. Methanol should be kept in closed system and not left to open atmosphere. Other important thing is the ventilation system in the system. Ventilation requirement should be determined on a site-specific basis and the target is to ensure the methanol concentration less than 200 ppm(Ellis and Tanneberger, 2015). Methanol can expose human body from inhalation, skin absorption, contact with the eyes or ingestion. To reduce the risk of exposed, at minimum safety glasses with side shields or safety goggles and task appropriate are recommended. To prevent methanol exposed from inhalation there should be respiratory protection. Respiratory protection should be selected based on hazards present and the likelihood of potential exposure. In table 2 shows respiratory protection guide for the different level of methanol-air concentration.

Table 2 Respiratory Protection Guide

Air Concentration of Methanol	Respiratory Protection
<200 ppm	No protection required
200 – 250 ppm	Protection required if the daily time-weighted average exposure is exceeded. A supplied air system must be used if protection is needed.

Air Concentration of Methanol	Respiratory Protection
>250 ppm	A supplied air system must be used (i.e., positive pressure SCBA)

Source : (Alliance Consulting International, 2008)

To prevent methanol skin contact, there should be chemical-resistance clothing/materials. These may include rubber boots, resistant gloves, and other impervious and resistant clothing. Chemical-resistant materials include butyl rubber and nitrile rubber. Use chemical goggles when there is a potential for eye contact with methanol, including vapor. A full face-shield may be worn over goggles for additional protection, but not as a substitute for goggles. Table 3 shows personal protective equipment selection based on the risk of vapor and risk of volume splash.

Table 3 Personal Protective Equipment Selection

Low risk of vapor/ low risk of volume splash	High risk of vapor / low risk volume splash	High risk of vapor / high risk of volume splash
Fire retardant clothing	Full chemical suit	Full chemical suit
Gloves (Silver shield or disposable nitrile)	Chemical-resistance rubber gloves	Chemical-resistance rubber -gloves
Safety glasses with side shields	Full face respirator with organic vapor cartridge	SCBA / compressed air breathing apparatus (CABA)
Full boot cover	Chemical-resistant rubber boots	Chemical-resistant rubber boots

Source : (Alliance Consulting International, 2008)

Besides the risk of methanol to the human body, there also the high risk of methanol fire because of its low flash point. Methanol combustion emits almost no light and creates no smoke. Methanol burns in the air so cleanly that it emits almost no visible light compared with all conventional hydrocarbon fuels (MacCarley, 2013). Because of the fire risk, there shall be fire controlling and extinguisher method. For detection purpose, there should be a vapor control and heat detection to know potential methanol fires. If there is any methanol fire, an alcohol-resistant foam is needed to extinguisher the fire Streams of water can be used to cool surrounding process equipment. Methanol-water solutions and aerosols are flammable to 75% by volume composition of water. If water is chosen as the first response, the provisions must be made for preventing the methanol-water solution from spreading and carrying the fire into other parts of the facility (Alliance Consulting International, 2008).

2.5 Methanol as Ship Fuel

Use of fuel in marine is large. It estimated that international shipping consumes around 300 million tons of HFO annually. The North Sea/Baltic Sea SECA area accounts for 20 to 25 million tons of annual HFO consumption. These figures highlight the potential market for low sulfur fuels such as methanol. There are some researchers about using methanol as fuel..

(Ellis and Tanneberger, 2015) do "Study on the use of ethyl and methyl alcohol as alternative fuels in shipping in Europe" They research for availability, environmental consideration, regulation, and safety assessment for fuel system on the passenger and cargo ship. The availability of methanol is widely available because it is used extensively in the chemical industry like shows in figure 3. Total global production capacity in 2013 was just over 100 million tons.

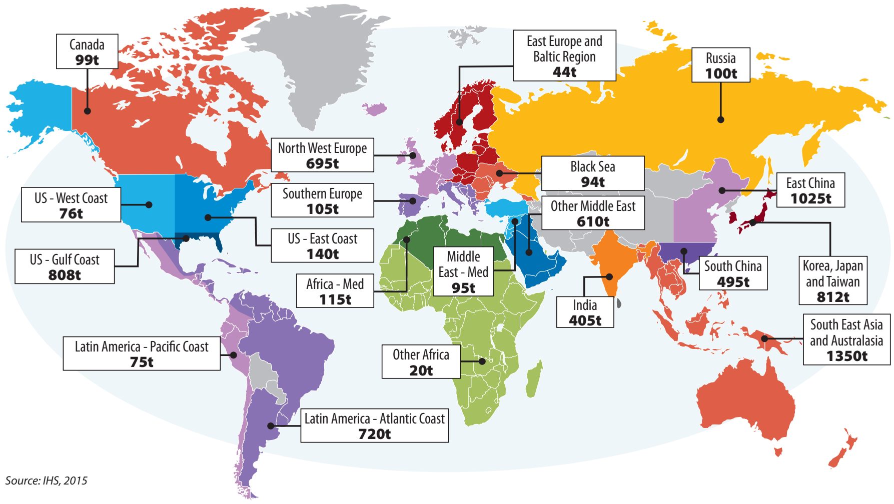

Figure 3 Methanol storage capacity across the world (thousand tons)

In Europe, there are large bulk storage terminals in both Rotterdam and Antwerp, and it is transported both with short sea shipping and by inland waterways to customers. Methanol has many advantages regarding environmental impact as compared to conventional fuels – they are clean burning, contain no sulfur, and can be produced from renewable feedstock. They do the safety assessment in fuel system by using HAZID method on passenger and cargo ship.

(Brynolf et al., 2014) do study about "Environmental assessment of marine fuels: liquefied natural gas, liquefied biogas, methanol, and bio-methanol". They compare the life cycle environmental performance of methane, the energy carrier in LNG, and methanol as marine fuels, considering both natural gas and biomass as raw material by using Life cycle assessment (LCA). The results of this research explain that methanol produced from natural gas would significantly improve the overall environmental performance. However, the impact on climate change is of the same order of magnitude as with the use of heavy fuel oil. For methanol produced from has the potential to reduce the impact of climate change. In other hands, (Pérez-Fortes et al., 2016) do research about "Methanol synthesis using captured CO_2 as raw material: Techno-economic and environmental assessment". In this paper, they explain that if using CO_2 as raw material there is 0.239 MtCO2/yr not produced compared to conventional MeOH plant. If this plan has effective enough to produce methanol, it will be competitive enough to be environmental friendly fuel.

2.6 Ship's Main Engine

Converting Ship fuel system to use methanol will change some parts of the Main Engine. There is some engine manufacturer that successfully converts the engine from oil fuel to methanol such as Wartsila and MAN Diesel and Turbo. Based on ship's resistance, power, and EPM calculation, the engine that will fit in the ship is MAN 7S26MC6 with 2800 kW of power. Nowadays, methanol engine that has certain of power are not yet available because of that need some engine modification. MAN says the engine modification that needed the retrofit engine are cylinder cover modification and fuel injection system. the cylinder cover of the engine must be equipped with the fuel booster injector valve (BFIV) and liquid gas injection (LGI) block. This block contains a control valve for methanol fuel injection, a sealing booster activation valve, an LGI purge valve and methanol fuel inlet/outlet valves. All pipes for hydraulic oil and fuel are double-walled.

The methanol fuel injection is approx. 500 – 550 bar. To achieve the injection pressure, BFIV using 300 bar hydraulic power to raise the fuel (methanol) pressure as illustrated in figure 4. The methanol booster injector valve must be cooled and the surface must be lubricated. Therefore there is a combined sealing and cooling system for lubricates all running surface and controls the temperature in the booster valve (max 60℃). To ensure the correct temperatures of the BFIV, the oil is cooled in a heat exchanger in the low-temperature cooling system.

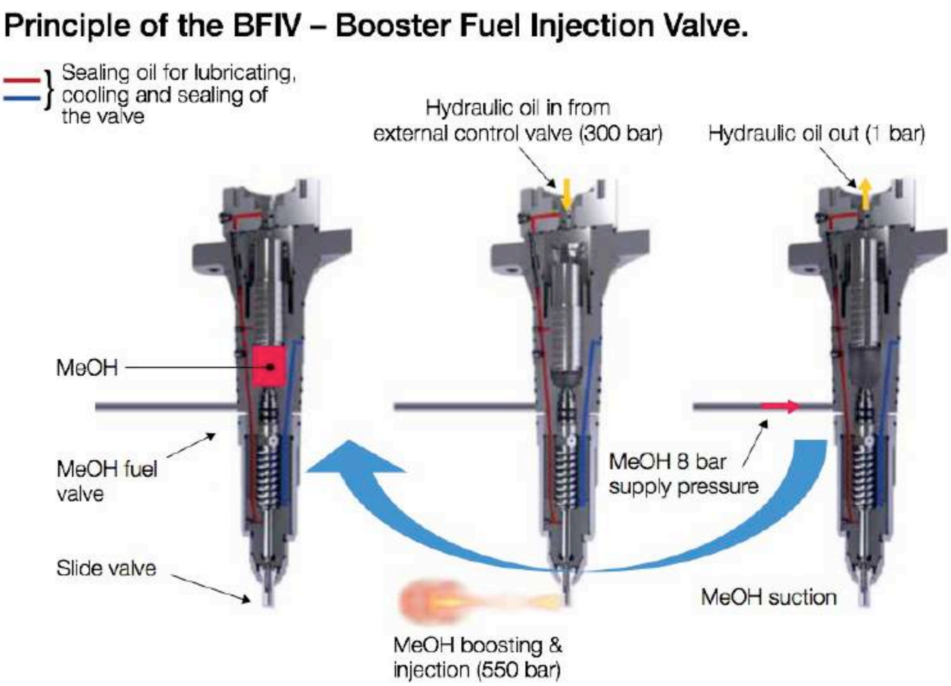

Figure 4 Principle of the BFIV-Booster Fuel Injection Valve
Source : (MAN, 2015)

2.7 Fuel Consumption Calculation

Fuel oil consumption is one of important indicator on ship because it indicates the emission from the ship. To calculate fuel oil consumption in tons is using equation 1. Because MAN S26MC6 is not methanol fueled engine and has to be convert first to use methanol as fuel, for SFOC calculation is based on MAN Project Guide for methanol engine, especially MAN S40ME-B9.

$$W = P_{MCR} \times SFOC \times t \times 10^{-6} \quad (1)$$

Where :

W	: Fuel oil consumption	[tons]
P_{MCR}	: Engine power	[kW]

SFOC : Specific fuel oil consumption [g/kWh]

t : Operating time [hours]

Table 4 Lower calorific values of fuels.

Fuel Type	LCV, kJ/kg
Diesel	42,700
Methane (GI)	50,000
Ethane (GIE)	47,500
Methanol (LGIM)	19,900
LPG (LGIP)	46,000

When the engine converted from using HFO or MDO to methanol as fuel there will be some changing in fuel consumption. In the table 4 explain that Diesel has higher LCV than methanol. It causes some changing in SFC of the engine. In the table 5 explain increasing 1% of standard LCV (42,700) will be reduce the SFOC by factor 1% (MAN, 2017).

Table 5 Specific fuel oil consumption conversion factor.

Parameter	Condition Change	SFOC Change
Scav, air coolant temperature	Per 10 C rise	+0.41%
Blower inlet temperature	Per 10 C rise	+71%
Blower inlet pressure	Per 10 mbar rise	-0.05%
Fuel, lower calorific value	Per 1%	-1.00%

2.8 Simpson's Rule

Simpson's rule is a method of numerical integration that provides an approximation of a definite integral over the interval("Chegg.com," n.d.). In the ship design, this rule is used to calculate the area and volume of the ship section or dimension. Figure 5 shows the example of the curve. In this graph assume the curve as equation 2.

$y = a_0 + a_1x + a_0x^2$ .... (2)

Integration from 0 to 2h used to find the Area below the curve as shows in equation 3.

$Area = \int_0^{2h} a_0 + a_1x + a_0x^2\,dx$ .... (3)

And the result of integration shows in equation 4.

$Area = 2a_0h + 2a_1h^2 + \frac{8}{3}a_0h^3$ .... (4)

Assume the area below the curve as shows in equation 5 .

$Area = Ay_1 + By_2 + Cy_3$ .... (5)

And substitute the x value of x1 = 0; x2 = h ; and x3 = 2h

$Area = Aa_0 + B(a_0 + a_1h + a_0xh^2) + C(a_0 + 2a_1h + 4a_0h^2)$

$Area = \ a_0(A + B + C) + a_1h(B + 2C) + a_2h^2(B + 4C)$ .... (6)

Substitute the equation 4 and equation 6 to find the value of A, B and C.

$2a_0h + 2a_1h^2 + \frac{8}{3}a_0h^3 = a_0(A + B + C) + a_1h(B + 2C) + a_2h^2(B + 4C)$

Where,

$A + B + C = 2h\,; B + 2C = 2h; B + 4C = \frac{8}{3}h$

Then the value of A, B and C is

$A = \frac{h}{3}; B = \frac{4h}{3}\ and\ C = \frac{h}{3}$

Substitute the value of A, B and C to equation 5, and the result shows in equation 7.

$$Area = \frac{h}{3}(y_1 + 4y_2 + y_3) \quad (7)$$

The Constanta for y1 , y2 and y3 that are 1- 4 – 1 is called Simpson's factor. For calculating the area of the section, usually using Simpsons table.

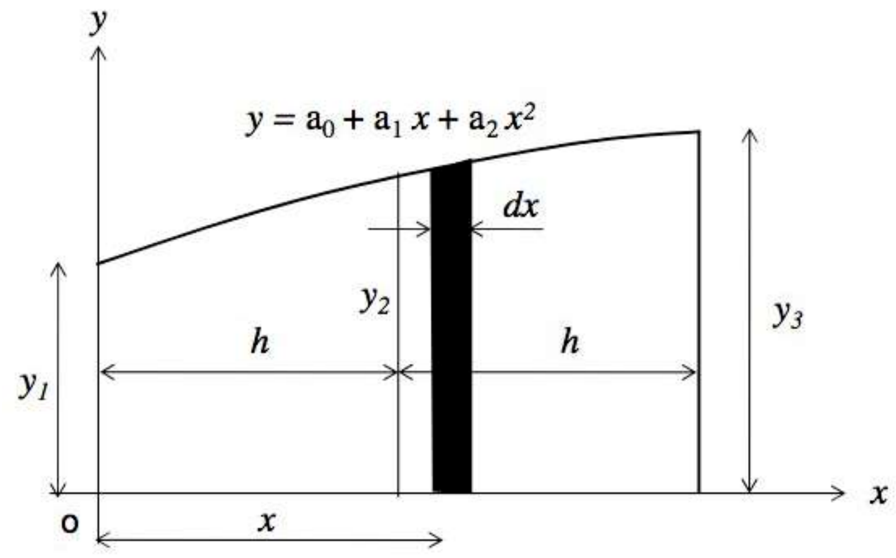

Figure 5 The example of the curve

Table 6 Simpsons table to calculating area or volume

No. Ordinate	High /Area of Ordinate (y_i)	Simpsons Factor (FS)	y_i . FS
1	y_1	1	y_1
2	y_2	4	4 y_2
3	y_3	2	2 y_3
4	y_4	4	4 y_4
…	…	…	…
n-1	y_{n-1}	4	4 y_{n-1}
n	y_n	1	y_n
		Σ	…
		Area	$1/3 \times h \times \Sigma$

If calculating area of the section, the value of y is the high of the section. To calculate the volume of certain shape, the value of y is the cross section of the shape. The cross section can be horizontal or vertical as shows in figure 6.

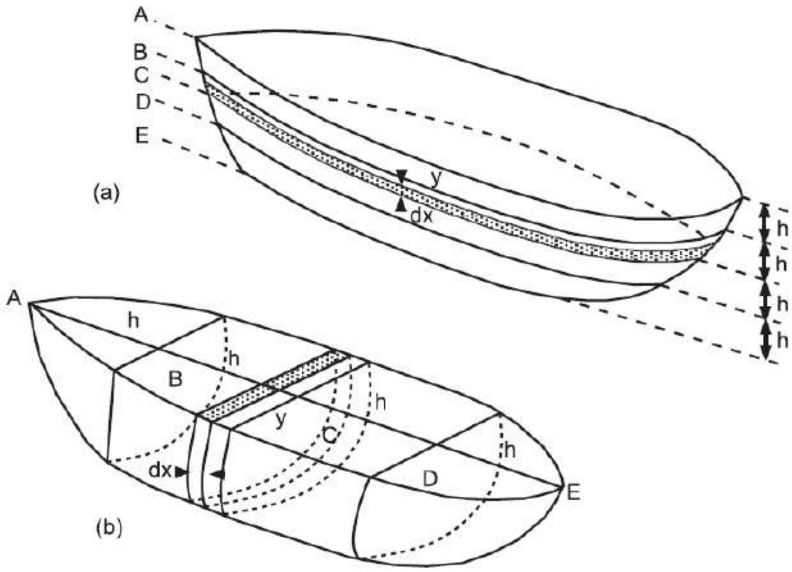

Figure 6. Ships vertical or horizontal crosses section to calculate the volume.

2.9 Fuel Transfer System

Fuel transfer system is the system that transfers fuel from tank to other tank or consumer. The main component in this system are pump, pipe and pipe accessories. To choose the pump, there are two main factor should be considered. First is capacity of the pump and second is the head of the pump.

$$Q = \frac{V}{t}\ [\frac{m^3}{h}] \quad \text{(8)}$$

Equation 8 shows the formula to calculate the capacity of the pump or Q [m3/h]. Where V [m^3] is the volume of fuel that would be transfer and t [h] is the required time to transfer the fuel.

To calculate head pump, First thing need to know is the pipe specification such as the diameter and materials of the pipe. Minimum internal diameter of the pipe is calculated by equation 9.

$$Q[\frac{m^3}{s}] = A[m^2] \times v[\frac{m}{s}]$$

$$Q[\frac{m^3}{s}] = 0.25\pi d^2[m^2] \times v\ [\frac{m}{s}]$$

$$d = \sqrt{\frac{Q}{0.25\pi v}}[m] \quad \text{(9)}$$

After get the minimum diameter of the pipe, the minimum thickness of the pipe should be calculated. The equation to get the minimum pipe thickness is depending on the regulation or classification society rules. CCC 3-3 using calculation based to get the minimum pipe thickness. Equation 10 is the formula for pipe thickness based on CCC 3-3 Regulation. The detail formula can be seeing in the *CCC 3-3 Section 7.3 Requirement for general pipe design.*

$$t[mm] = \frac{(t_0+b+c)}{1-(\frac{a}{100})} \quad \text{(10)}$$

Lloyd Register using calculation to know minimum pipe thickness but there is minimum requirement for it based on the minimum internal diameter of the pipe. Lloyd Register explain the minimum pipe thickness in *Rules and Regulation for the Classification of Ship Part 5 Chapter 12 Section 10 for Austenitic and Duplex stainless steel.*

$$t[mm] = \left(\frac{Pd}{20\sigma e+P} + c\right)\frac{100}{100-a} \quad \text{(11)}$$

Equation 11 shows the minimum pipe thickness equation from Lloyd Register. The result must be compared to the table in in *Rules and Regulation for the Classification of Ship Part 5 Chapter 12 Section 10 Table 12.10.1.* If the result less than requirement in the table, the thickness requirement will follow the table requirement. DNV GL Regulation doesn't have equation to calculate the minimum pipe thickness. They only use table requirement. They explain the minimum pipe thickness in *DNV GL RU Ship Part 4 System and Component Chapter 6 Piping system Section 9.* After gets the inside diameter and minimum thickness of the pipe, the next step is to selecting the pipe based on the standard such as JIS, ANSI, DIN or ISO.

Once the pipe specification have been selected, now head pump can be calculated. Head pump consist of 4 variables. First is head static. Head static pump is calculated from pump inlet till the end of discharge. Second is head pressure, which is the different pressure between outlet and inlet of the pump. Third is Head Velocity. It is difference velocity of fluid between in suction line in suction and discharge of pump. The last is head loss. There are two type of head loss there are minor loses and mayor loses. Mayor loses is loses come from the friction of liquid to the pipe. To calculate the major head loss, Rn number is used to know the characteristic of the flow. Equation 12 is the formula for Rn number.

$$Rn = \frac{v[\frac{m}{s}] \times dH[m]}{u[\frac{m^2}{s}]} \quad \text{......} \quad (12)$$

From Rn find the value of f (friction factor) by using moody diagram or moody friction factor calculation and find the head loss. Figure 7 shows the moody diagram.

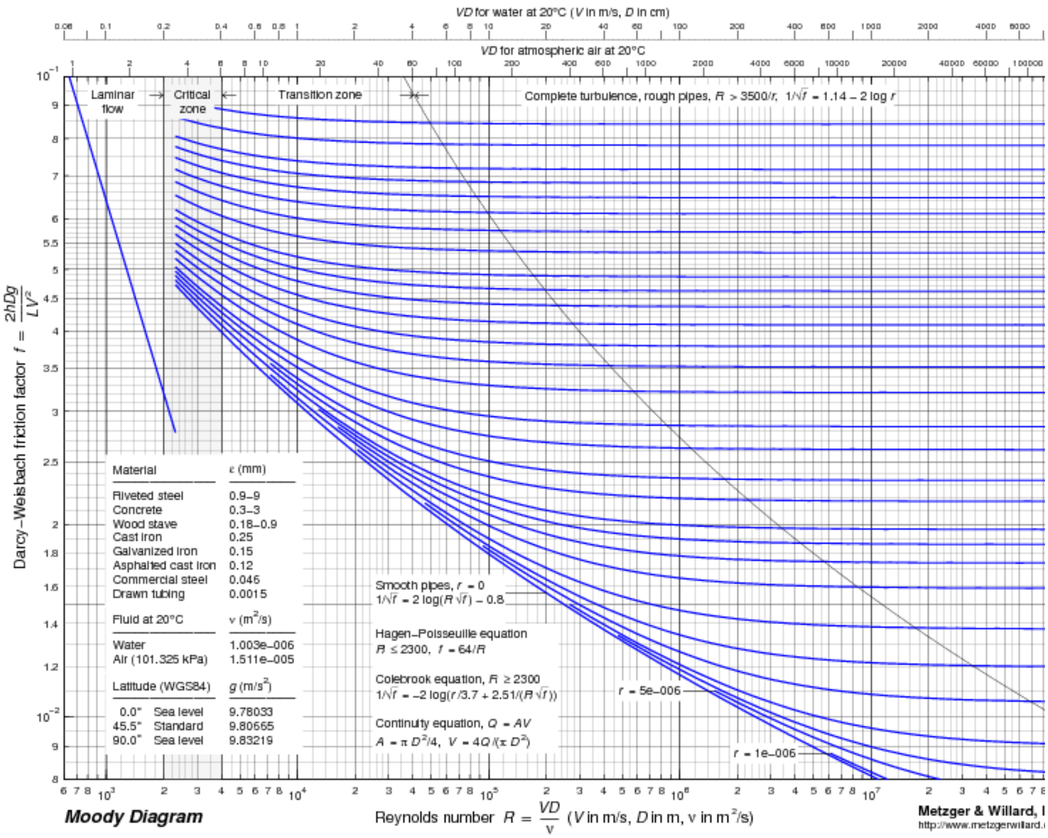

Figure 7 Moody Diagram

Equation 13 shows the formula to calculate mayor head loss.

$$h_f = \frac{f \times L[m] \times v^2\left[\frac{m}{s}\right]^2}{dH[m] \times 2g[\frac{m}{s^2}]} \quad \dots\dots\dots (13)$$

Minor loses is loss from installation of pipe accessories such as valve, elbow strainer, etc. Each of these accessories has loses factor the symbol is k. For calculate the minor loses, the formula is explain in equation 14.

$$h_m = \frac{k \times v^2\left[\frac{m}{s}\right]^2}{2g[\frac{m}{s^2}]} \quad \dots\dots\dots (14)$$

Mayor and minor loses have to be calculated both in suction side and the discharge side. After, those four variables have been defined; the next step is to sum the head static, head pressure, head velocity and the head loss.

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3 Discussion

3.1 IMO Requirement and Classification Rules

Methanol is one of new fuel in the shipping industry; because of that there are lack of regulation for this fuel. Currently, the regulation for gases and low flash point fuel IMO IGF Code 2016 Edition Part A-1 until C-1 only explain about using natural gases as fuel. According to IMO Sites, A new mandatory code for ships using gases or other low-flashpoint fuels enters into force on 1 January 2017, along with new training requirements for seafarers working on those ships("Safety for gas-fuelled ships – new mandatory code enters into force," n.d.) but in their publication sites, there have not release the new edition of IGF Code. The document that can be found to represent the draft of IMO IGF Code is report of Sub-Committee of Carriage Cargo and Containers (CCC). Some country in CCC3 meeting proposes the document about amendment draft for IGF Code. The document for methanol are C 3/3/1 about "*Proposals for further amendments to the draft technical provisions for the safety of ships using methyl/ethyl alcohol as fuel, based on findings from the German project MethaShip*" submitted by Germany, C3/3 about "*Correspondence Group on Development of Technical Provisions for the Safety of Ships using Low-flashpoint Fuels*" submitted by Sweden, CCC 3/INF.22 about "*Study on the use of ethyl/methyl alcohols in shipping*" submitted by the European Commission.

Classification regulation is one of important aspect to be considered to design methanol as fuel. Currently there are two classifications that already has the regulation, there are DNV GL and Lloyd Register. DNV GL explains in Part 6 Additional class notations Chapter 2 Section 6 and for Lloyd Register in Provisional Rules for the Classification of Methanol Fueled Ships.

Table 7 High-level rules comparison about methanol as ship fuel.

Currently Methanol Provision and Rule Requirement as Ship Fuel		
CCC 3-3 Draft	LR Provision Rule Jan.2016	DNV GL Jul.2016
Ship Design and Arrangement	Section 5 Location and Arrangement of spaces 5.2 Methanol Bunkering Station 5.3 Fuel Storage Tanks 5.4 Fuel Supply Equipment 5.5 Methanol-Fueled Consumer 5.8 Hazardous Area	Sec 6.3 Arrangement and Design
Fuel Containment System	6.3 Fuel Storage Tanks 6.4 Cofferdams	Sec 6.3.2 Fuel Storage
Inerting and atmospheric control within the fuel storage system Inert gas production on board	6.8 Inert Gas System	Sec 6.3.7 Inert Gas/Nitrogen Installations
Material and General Pipe Design	Section 4 Materials, Component and Equipment	Sec 6.2 Materials
Bunkering	3.7 Bunkering safety	Sec 6.3.6 Fuel Bunkering

Currently Methanol Provision and Rule Requirement as Ship Fuel		
CCC 3-3 Draft	LR Provision Rule Jan.2016	DNV GL Jul.2016
	study 6.2 Methanol Bunkering System 8.6 Bunkering System	
Fuel Supply to Consumers	6.5 Methanol supply system Section 7 Piping	Sec 6.3.3 Fuel Transfer and Supply
Power Generation Including Propulsion and Other Energy Converters	6.6 Methanol-Fueled reciprocating internal combustion engine and turbines	Sec 6.6.4 Engine Monitoring Sec.6.7 Engine and Pumps
Fire Safety	Section 10 Fire safety 10.2 Structural fire protection 10.3 Fire main 10.4 Deck-fixed pressure water spraying system 10.5 Deck foam fire-extinguishing system 10.6 Fire-extinguishing arrangement in machinery spaces	Sec 6.4 Fire safety
Ventilation	5.7 Ventilation and	Section 6.3.5 Ventilation

Currently Methanol Provision and Rule Requirement as Ship Fuel		
CCC 3-3 Draft	LR Provision Rule Jan.2016	DNV GL Jul.2016
	Pressurization	of hazardous spaces containing LFL fuel installation
Control Monitoring and Safety System	Section 8 Control, alert and safety system	Section 6.6 Control, Monitoring and safety system

3.1.1 Ship Design and Arrangement

DNV GL and CCC 3-3 draft have detail explain about portable fuel tank and have same opinion on it. Otherwise LR provision rules haven't explain about portable fuel tank LR and DNV GL have same opinion about minimum distance between fuel tanks and ship side that is 800 mm, but in the CCC 2-3 in paragraph 15 said there need further discussion in distance between fuel tanks and ship side, the reason was the minimum distance may need to be different to that required for LNG fuel tanks. Because of that in the CCC 3-3 there is no explanation about minimum distance for fuel tank.

3.1.2 Fuel Containment System

In DNV GL and LR Rules, they mention about minimum 2 number of fuel tanks installed on board ship, Otherwise in CCC3-3 there is no explanation about minimum number of tank. CCC 3-3, LR and DNV GL agree to make the protective cofferdam for fuel containment system

3.1.3 Inert Gas System

In the inert gas system there are a different opinion about vertical efflux velocity between DNV GL and CCC 3-3, In the DNV GL recommendation is at least 20m/s but CCC recommendation is 30m/s. In the LR Provision Rules there is no explanation about it. CCC 3-3 explain about detail configuration for inert gas supply line. Inert gas supply line shall be fitted with two shutoff valves in series with venting valve in between. In additional non-return valve shall be installed between the block and bleed arrangement.

3.1.4 Material and General Pipe Design

CCC 3-3 explains about the general pipe design such as the minimum wall thickness but there is no explanation about the type material that should be use for methanol. Same as DNV GL there is no detail material that should be use for using methanol as fuel. The detail type material is explained in LR Provision rules. They don’t recommend using material that sensitive to methanol such as aluminums alloys, galvanized steel, lead alloys, Nitrile, Butyl and not using austenitic stainless steel if the methanol containing water. They recommended using duplex type stainless steel or austenitic manganese steel.

For minimum wall thickness calculation they have different method. In CCC only using calculation to determine the minimum wall thickness. LR also using calculation but there is a minimum wall thickness for each material based on pipe diameter. For DNV GL only using table for the minimum wall thickness.

3.1.5 Fuel Supply to Consumer

In the fuel supply to consumer section both CCC, LR and DNV GL are agree to use double walled pipe when passing enclosed spaces. The double walled pipe is not required in cofferdams surrounding fuel tanks, fuel pump room/fuel preparation room, or other space considered as hazardous. In the fuel pump room or in the CCC the called fuel preparation room there is a different between DNV GL and CCC. CCC recommended that the air change is at least 15 air change per hour if there are no leakage in fuel penetration room ad increase to 30 air change per hour if there is any leakage. DNV GL only explain the minimum air change is 30 air change per hour.

3.1.6 Fire Safety

In this section there are several different between CCC, LR and DNV GL. For the structural fire protection, in CCC there is minimum size of cofferdam that is 900 [mm] in the fire integrity tank of fuel tank cofferdam boundaries facing high risk space but there is no explanation about it in LR or DNV GL. ARAFFF system is explain in CCC and LR. In CCC the system shall be install in fuel tank that located in open deck, bunker station. In LR the installation of ARAFFF shall be install in deck for the coverage and positioning shall be addressed in the risk-based studies. DNV GL doesn't mention about ARAFF installation. For fire extinguishing of engine room and pump room CCC and DNV GL only said the fire extinguisher medium shall be suitable for the extinguishing of methyl alcohol fires. Otherwise LR mention the fire extinguisher shall comply with MSC/Circ.1165. They don't mention specifically about what type of fire extinguisher shall be use in machinery room and pump room.

3.1.7 Ventilation

For the ventilation system CCC, LR and DNV GL has same opinion about the system. They agree that the minimum air change is 30 air change per hour in the hazardous area.

3.1.8 Control Monitoring and Safety System

CCC3-3, LR and DNV GL have same opinion about control monitoring and safety system for methanol fueled ship. Beside in LR and DNV GL, they have detail explanation in form of table compared to CCC3-3 only the general explanation.

Beside of those three regulations, there also some additional guideline that help the design such as CCC3/INF.23. In this guideline there are example of tank arrangement and ventilation arrangement as show in figure 8 and 9.

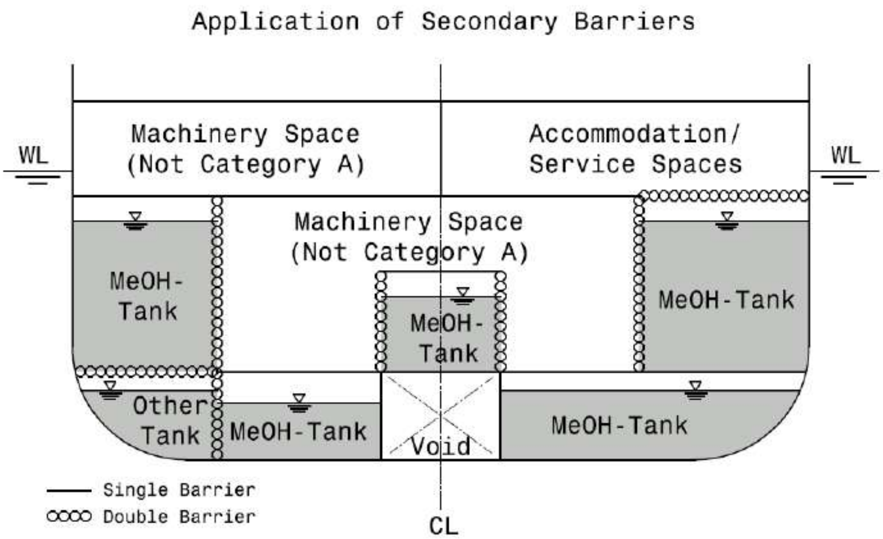

Figure 8 Tank arrangements in MethaShip Project
Source: CCC 3-3-1

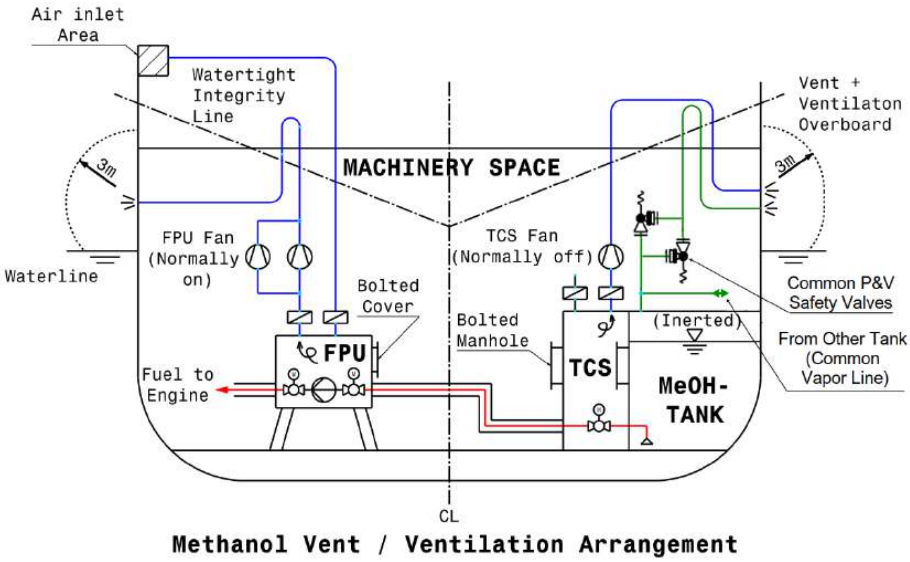

Figure 9 Ventilation arrangement in MethaShip Project
Source: CCC 3-3-1

3.2 Design Requirement

As the result of the comparison between three types of regulation that are CCC3-3, LR and DNV GL, there are some different between three of those rules. In this section there will be discussion, which regulation will be taken to design the ship in the study case and the reason. In the table 5 are the result of the discussion.

Table 8 Summary of design requirement that will be used in designing the ship.

Part of Regulation	Design Requirement	Reason
Ship Design and Arrangement	Fuel tank and ship side distance minimum is 800mm	In the CCC 3-3 there is no explanation of the minimum distance between fuel tank and ship side. In the previous CCC 2-3, the regulation is being remove because they think

Part of Regulation	Design Requirement	Reason
		there should be different minimum distance between methanol and LNG fuel because methanol has liquid form. Current MethaShip and 7 methanol ship project they both follow the 800mm minimum distance. From the safety aspect if there is any collusion, there will be some second barrier but have to remind the void space must have the gas inert system.
Fuel Containment System	Minimum 2 fuel tanks have to be onboard ship	CCC 3-3 doesn't explain about the minimum fuel tanks. Otherwise in the SOLAS Regulation II-1/26.11 and classification society for fuel tank there are minimum 2 fuels tanks.
Inert gas System	Vertical efflux velocity 30 m/s	AMS Glossary said efflux velocity is the average flow rate of material emitted into atmosphere. Compared to 20 m/s efflux velocity, 30 m/s has more safety benefit to prevent methanol concentration in certain room.

Part of Regulation	Design Requirement	Reason
Material General Pipe Design	Duplex type stainless steel or austenitic manganese steel. Minimum pipe wall thickness	Duplex type stainless steel or austenitic steel are more reliable to methanol corrosive compare to other metal. Author will be calculate minimum wall thickness by using three type of method and choosing the greater wall thickness for the safety reason.
Fuel Supply to Consumer	30 air change per hour in fuel pump room/fuel preparation room	In CCC they explain that if there is no leakage the minimum air change is 15 air change per hour and if there is leakage the air change is improve to 30 air change per hour. Because methanol is low flash point fuel and if there is any leakage will be very dangerous. For safety aspect it better to take the highest air change.
Fire Safety	Using 900 mm cofferdam between fuel preparation room and engine room	900 mm cofferdam as a second barrier between fuel preparation room/pump room and engine room but have in remind that the room shall have enough ventilation system

Part of Regulation	Design Requirement	Reason
	Installation of ARAFFF system	

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4 Study Case

In this section, author makes study case to design fuel system of 4000 DWT Tanker. Table 8, 9 and 10 shows the ship, main engine and auxiliary engine data. This data is needed to design ship fuel system. The ship has not existed and still in design process.

Table 9 Ships general data

Name of Ship	Doris Tanker	Units
Type	Oil Product/Chemical Tanker	
Lwl	102.96	m
Lpp	99	m
Breadth (B)	15.8	m
Height (H)	8.4	m
Draught (T)	6.336	m
Coefficient Block (Cb)	0.62	
Vs	13.5	knot
Voyage Endurance	5	days
GT	3352	
DWT	4000	DWT
Payload	3880.7	ton

Table 10 Main Engine specification

Specification	Detail	Units
Type	MAN B&W 7S26MC6	
Power	2800	kW
Speed	250	rpm
SFOC	179	g/kWh
$SFOC_{MeOH}$	260.9	g/kWh
$SFOC_{MGO}$	8.95	g/kWh
Quantity	1	

Based on MAN LGI system overview shows in Figure 10, there will be 5 main point of component that should be found. The first is the capacity of the storage tank, second the transfer system from storage to service tank, third is transfer system from methanol service tank to fuel valve train, fourth is find the fuel valve train specification and the last is transfer system from fuel valve train to main engine.

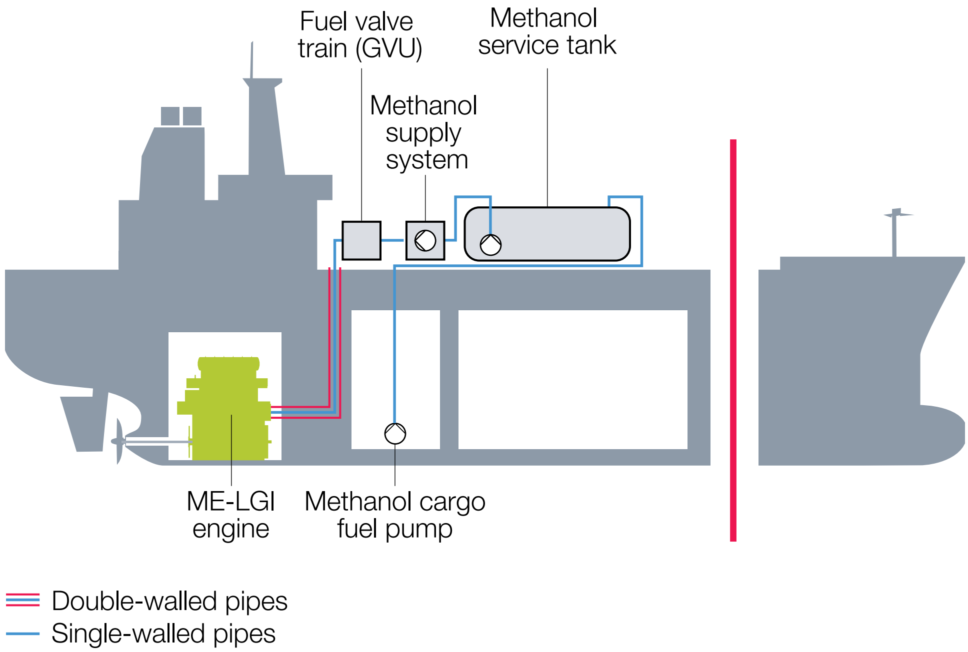

Figure 10 ME-LGI System overview.
Source : (MAN, 2015)

4.1 Main Engine Fuel System

4.1.1 Tank Capacity

Ship is planned have endurance for 5 days (120 hours). The ship needs minimum 126 m3 of methanol and 3.5 m3 of MGO for pilot fuel. For ship service tank size, the tank shall be supply minimum 8 hours to main engine.

Table 11 Fuel tank requirement and tank design capacity

Type	Requirement for 5 days [m^3]	Design [m^3]
MeOH Storage Tank	126.9	131.86
MeOH Service Tank	8.8	10 x 2
MGO Pilot Tank	3.5	7.97 x 2

Methanol storage tank will be placed in between engine room and slop tank from frame 28 until frame 33. The distance between storage tank shipside and fuel preparation room is 800 mm. This distance is used as a second barrier if there is any leakage in the tank.

Methanol service tank will be placed in ship's main deck. This location gives advantage in the ventilation side. The tank that will be use is Lapesa LF 10P and in the table 12 shows the detail specification.

Table 12 Methanol Service tank and MGO Pilot Tank Technical Drawing Dimension.

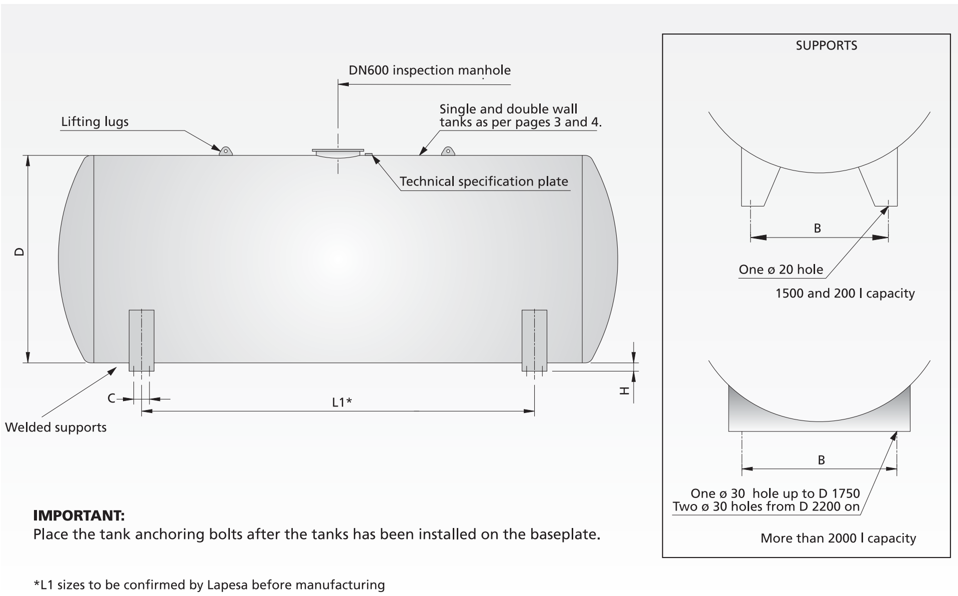

Table 13 Methanol service tank dimension.

Series	Lapesa LF 10 P	Units
Net Volume	10	m3
Nominal Diameter	1750	mm
L1	3400	mm
H	100	mm
B	1200	mm

For MGO Pilot Fuel Tank will be located Inside Engine room. It joins with MGO Service Tank for Generator and has capacity of 7.97 m^3.

4.1.2 Pump and Pipe Specification

To design methanol fuel system, there will be 2 pump that should be find. The first is methanol transfer pump and methanol supply pump. The specification of the pump chose based on the capacity and minimum head of the pump. For the methanol transfer pump the minimum capacity is 4.38 m3/h this based on the minimum capacity of methanol service tank and the assumption of minimum time to fill the tank that is 2 hours. From the capacity of the pump, will get the minimum internal diameter for the pipe. Head of pump is fined by calculation loss in pipe system suction and discharge side of the pump.

Selecting pipe for the fuel system is based on two factors that are materials of the pipe and the thickness of the pipe. The material of the pipe will be used duplex stainless steel type (EN.1.4462-UNS S31803, S32205 – 2205) with the mechanical properties explained in the table 15.

Table 14 Mechanical properties of duplex stainless steel acc. To EN 10272

Tensile strength Rm	650 - 880	N/mm2
Proof strength Rp0,2	min 450	N/mm2
Proof strength Rp1,0	min 340	N/mm2

Hardness	max 270	HB

Source : Valbruna Nordic

Table 15 Summary of fuel system pump.

Type	Calculation		Design	
	Q [m3/h]	H [m]	Q [m3/h]	H [m]
Transfer Pump	4.83	9.11	5	10
Supply Pump	1.18	63.16	1.6	60
Circulation Pump	4.05	46.81	5.9	50
Pilot Supply Pump	0.04	60	0.04	60
Pilot Circ. Pump	0.14	40	0.7	50

Table 16 Summary of fuel system pipe thickness based on CCC 3-3, LR, DNV GL.

Type	CCC 3-3	LR	DNV GL	Design
	[mm]	[mm]	[mm]	[mm]
Transfer Pipe	1.11	1.60	1.60	2.00
Supply Pipe	1.10	1.60	1.60	2.00
Circulation Pipe	1.09	1.60	1.60	1.60

Table 17 Detail pipe specification for methanol fuel system used in study case ship.

Specification	Transfer Pipe	Supply Pipe	Circulation Pipe	Pilot Supply Pipe	Pilot Circ. Pipe
Materials	Duplex Stainless Steel	Duplex Stainless Steel	Duplex Stainless Steel	Carbon Steel	Carbon Steel
Diameter Nominal	DN 40	DN 25	DN 20	-	--
Inside Diameter	40.50 mm	26.00 mm	21.80 mm	4.00 mm	6.00 mm
Outside Diameter	44.50 mm	30.00 mm	25.00 mm	8.00 mm	10.00 mm
Schedule Number	DIN/ISO Series 1	DIN/ISO Series 1	DIN/ISO Series 1	DIN/ISO Series 1	DIN/ISO Series 1
Thickness	2.00 mm	2.00 mm	1.60 mm	2 mm	2 mm

4.1.3 Fuel Valve Train

The Fuel Valve Train (FVT) is a valve unit that requires to operate a ME-LGI Engine design by MAN Diesel and Turbo. As the assumption of this engine is using MAN Engine, this FVT is requiring in the methanol fuel system. There are four basic functions of FTV; the first is supply methanol to the two strokes LGI Engine. Second, In case of a normally or emergency shutdown, to stop the fuel supply to the engine and send the fuel from the piping system and FVT back to the tank. Third, Purge of the piping system between the FVT and the ME-LGI engine and through the LGI engine to the tank. The last is purge the piping system between FVT and the LFSS. As explained in Figure 11, the FVT is located between LFSS and the Main Engine.

The methanol fuel valve train that can be found is from electronic fueltech. The detail specification can be seen in the table 18.

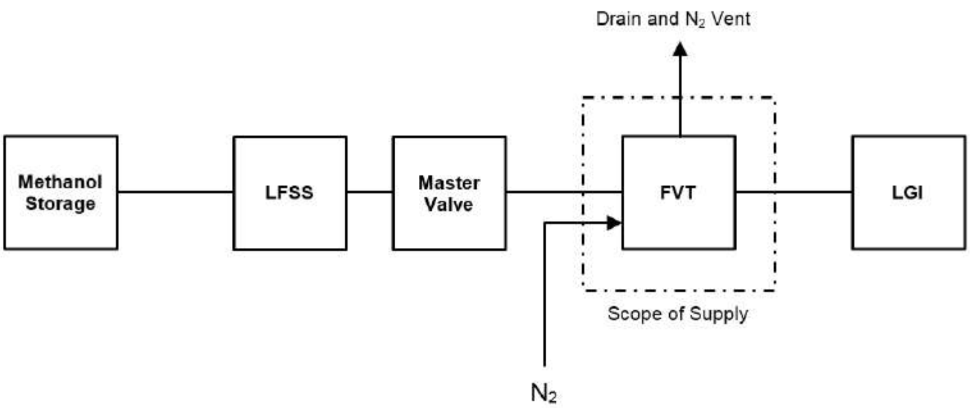

Figure 11 The location of FVT in the fuel system.

Source : electrofueltech technical specification

Table 18 Specification of electro fueltech methanol FVT

Design Pressure	**16 bar**
Nominal working pressure	10 bar
Recommended flow speed	3 m/s
Media purge	Nitrogen
Methanol design temperature	-10°C to +60°C
Materials	Stainless steel

Source : electrofueltech technical specification

4.2 Engineering Technical Solution

Methanol concentration in the room is recommended not more than 200ppm. To reduce the risk of the pipe is divided to the section-using valve. If there is any leakage the valve will between the pipes will be closed. This makes the amount of methanol content that been release can be controlled.

4.2.1 Fuel Preparation Room

Fuel preparation room located from frame 28 to frame 35. There is 900mm separation between fuel preparation room and engine room. This cofferdam is used based on regulation to reduce the risk of fire. Between methanol storage tank and the room, there is 800mm double barrier for the tank. In this coffined space will be support by venting system. The room has length of 4.7 m; width 4.5 m; and the high is 7.2m. The total volume of the room is **152.28** m3.

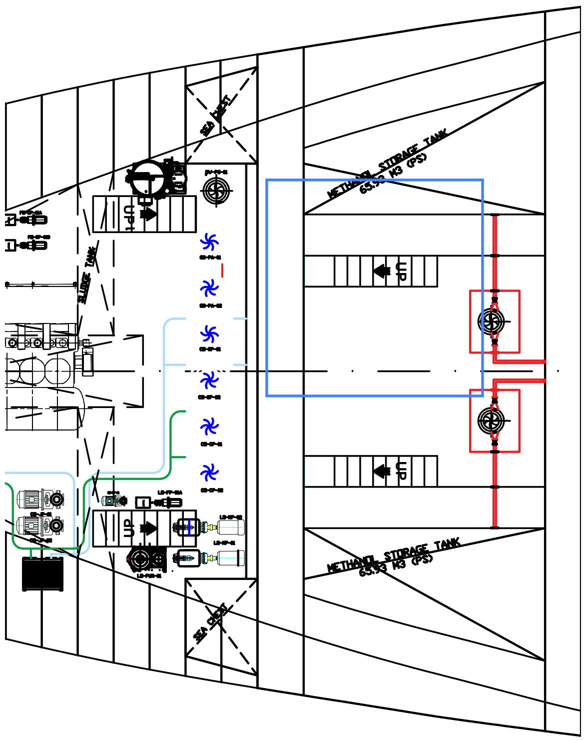

Figure 12 Location of Fuel preparation room

The fuel preparation room is recommended to have maximum 200ppm of methanol content. This makes the maximum volume of methanol can be released if there is any leakage is **0.0305** m3 of methanol.

4.2.2 Pipe Mitigation

The fuel transfer pipe has the diameter of 40.5 mm. The pipe has been divided by flange into three sections. The first section is from the tank to fuel preparation room that has the length of 0.8 m. Second, is from preparation room wall to pump. This section has the length of 0.68m. The last and the longest is from the pump to fuel service tank which has the length of 8.4 m.

The minimum distance between valves is getting by dividing the maximum leakage volume by the surface area of the pipes. The results, the minimum distance between valves is 23.65 m. Compared to the longest pipe in the transfer system that is 8.4 m, this transfer pipe is in the low-risk condition, even without installing any additional valves.

4.3 Fuel System P&ID

In the P&ID System there will be some component number to easily check the specification, quantity and location. List codes are according to the designer. Based on Main Engine Project Guide, Author makes the equation for coding the equipment, such as:

XX-AA-BB or XX-AAA-BBB

Where :

XX or XXX : System Code

AA or AAA : Component Code

BB or BBB : Component Number

For design Methanol Fuel System, the system code is FS and continued by component code. In the table 19 shows the list of component for the fuel system. The table also explain the require quantity and specification of each component.

Table 19 P&ID Component List for Fuel System

No	Symbol	Code	Name	Specification	Qty.
1		FS-BV-01-08	Butterfly Valve	DN40, PN6, Duplex Stainless Steel	**8**
2		FS-NRV-01-04	Screw Down Non Return Valve	DN40, PN6, Duplex Stainless Steel	**4**
3		FS-NRV-05-	Screw Down Non	DN25, PN6,	**4**

No	Symbol	Code	Name	Specification	Qty.
		08	Return Valve	Duplex Stainless Steel	
4		FS-NRV-09-12	Screw Down Non Return Valve	DN20, PN6, Duplex Stainless Steel	**4**
5		FS-SV-01-02	Safety Valve	1 bar, Duplex Stainless Steel	**2**
6		FS-SV-03-04	Safety Valve	6 bar, Duplex Stainless Steel	**2**
7		FS-SV-05-06	Safety Valve	10bar, Duplex Stainless Steel	**2**
8		FS-CVR	Remotely Operated Closing Valve	Duplex Stainless Steel	**5**
9		FS-TBV	Three Way Globe Valve	DN20,PN6, Duplex Stainless Steel	**2**
10		FS-ST	Simplex Filter	Finished Product	**2**
11		FS-DS	Discharge Side	Finished Product	**9**
12		FS-BS	Bell mount Suction	Finished Product	**5**
13	PI	FS-PI	Pressure Indicator	Finished Product	**15**
14	TI	FS-TI	Temperature Indicator	Finished Product	**5**
15	LAH	FS-LAH	High Level Alarm	Finished Product	**5**
16	LAL	FS-LAL	Low Level Alarm	Finished Product	**5**
17		FS-APF	Air Pipe with Flame Screen	Finished Product	**4**
18		FS-SN	Sounding Pipe	Finished Product	**4**
19		FS-TP-01-02	Methanol Transfer Pump	Sili Pump-05-CWF-10	**2**
20		FS-SP-01-02	Methanol Supply Pump	Sili Pump-YCB-16/06	**2**

No	Symbol	Code	Name	Specification	Qty.
21		FS-CP-01-02	Methanol Circulation Pump	Sili Pump-CYB-40-200	**2**
22		FS-BUC	Bunker Connection	Finished Product	**4**

Fuel System P&ID explain about the process flow and the component of the system. In figure 13 shows P&ID of methanol fuel system in the study case ship. As explained before, there are 5 main point of component that should be found to complete the methanol fuel system. In the figure there are number start from1 to 5 that representing the component.

Number 1 explains the methanol storage tank. It is located in the fuel preparation room start from frame 28 until 35 at starboard and portside. It shall be protected by 800 mm cofferdam. It equipped with 3 sensors, there are LAH (High Level Alarm), LAL (Low Level Alarm), TI (Temperature Indicator). Sounding pipe and Air pipe with flame screen are installed in the tank. Sounding pipe to measure the depth of liquid and Air pipe to maintain pressure on the tank.

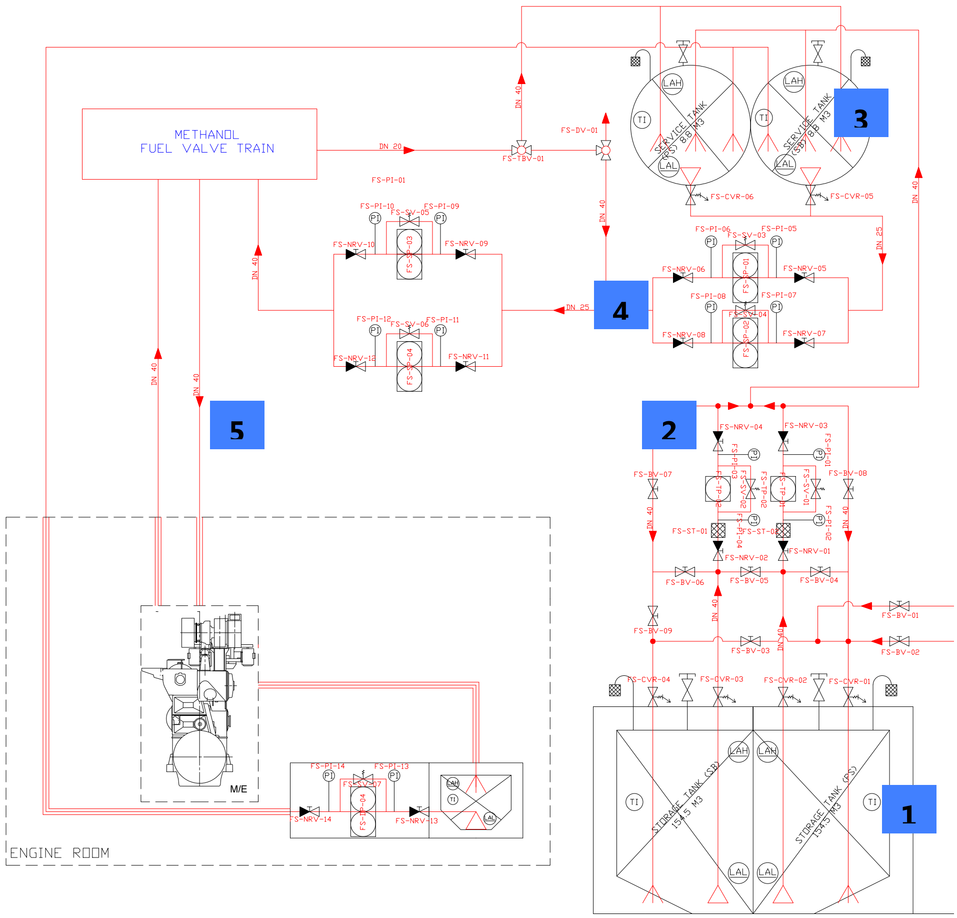

Figure 13 Fuel System P&ID

Number 2 is fuel transfer system from storage tank to service tank. This system shall have 2 pumps to comply with regulation and for the safety reason if one of the pump doesn't work. The pump that used in the system is centrifugal type pump, which has capacity of 5m3 and 10m of head. Because of the limited access to the methanol pump specification, in this study case author using regular pump specification.

In the transfer pump, each pump shall be transfer fuel from both tank and can be transferring fuel from PS (Portside) tank to SB (Starboard tank) tank. In the

Figure 14 and 15 shows the scenario of transferring fuel from starboard tank and portside tank using both of the pump.

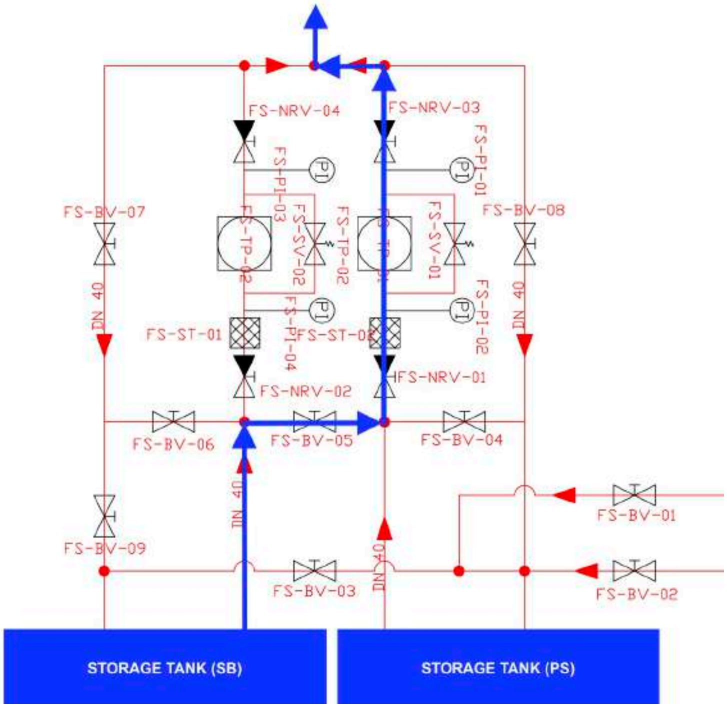

Figure 14 Transfer fuel from storage tank (SB) to service tank

Figure 14 shows the floe for transferring fuel to service tank using pump no.1 from starboard tank, the FS-BV-05v valve shall be in open position for the FS-BV-04, FS-BV-06,FS-BV-07 and FS-BV-08 in the closed position.

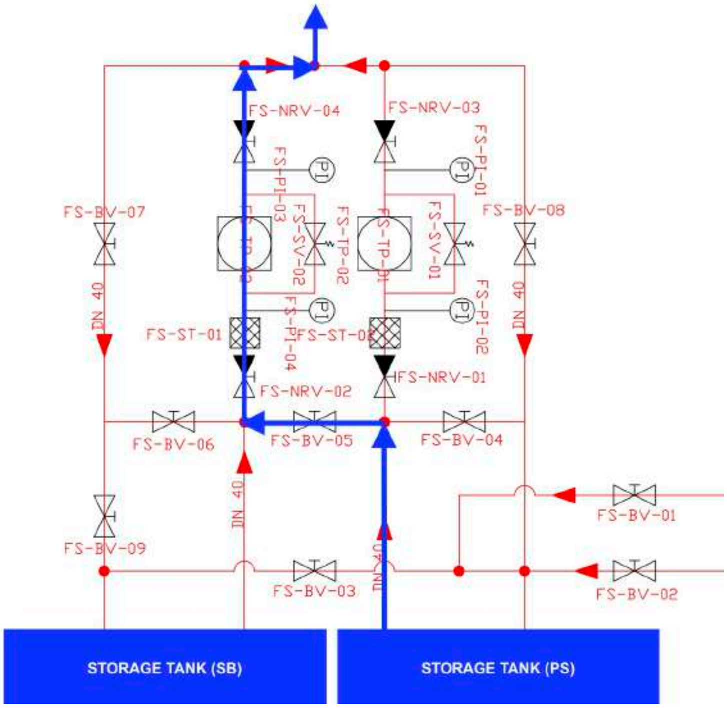

Figure 15 Transfer fuel from storage tank (PS) to service tank

Figure 15 shows the floe for transferring fuel to service tank using pump no.2 from portside tank, the FS-BV-05v valve shall be in open position for the FS-BV-04, FS-BV-06, FS-BV-07 and FS-BV-08 in the closed position.

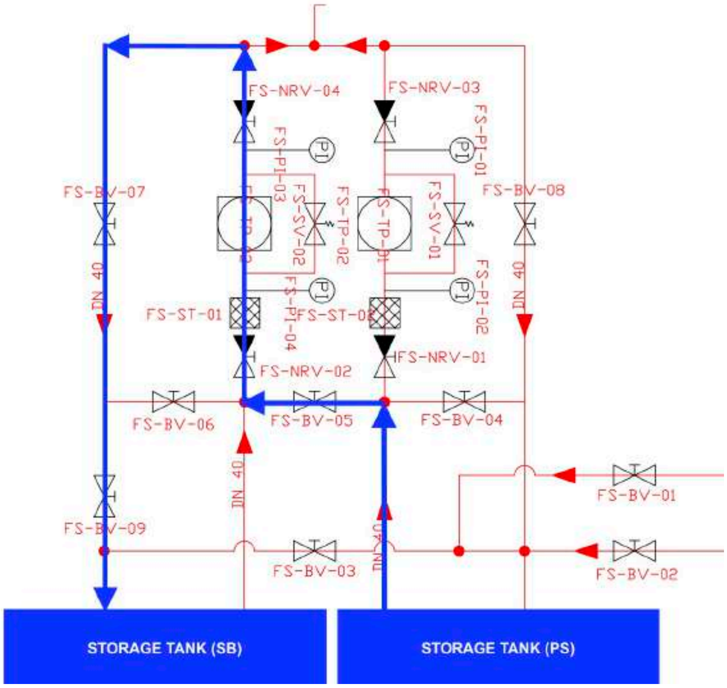

Figure 16 Transfer fuel from storage tank (PS) to storage tank (SB)

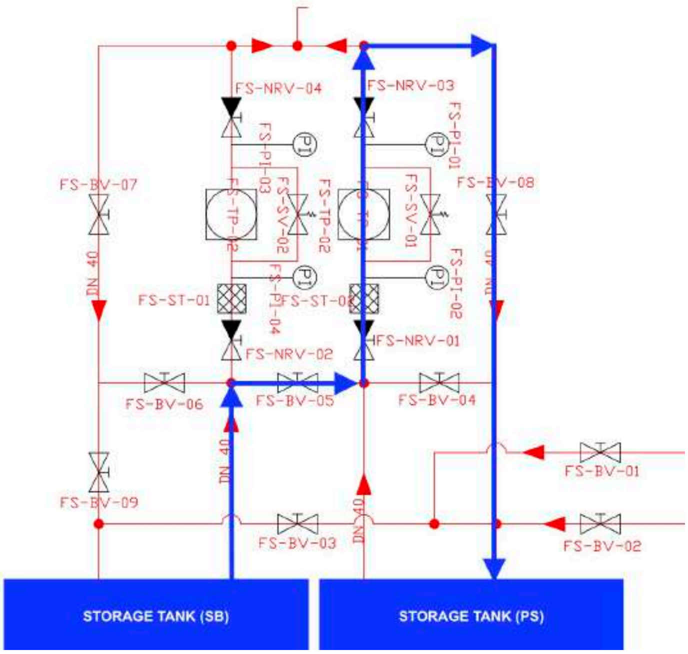

Figure 17 Transfer fuel from storage tank (SB) to storage tank (PS)

Figure 16 and Figure 17 explain about the transfer fuel from tank to tank. This scenario is important to keep the ship in balance position. Figure 16 shows the flow for transferring fuel to starboard tank using pump no.1 from portside tank. The FS-BV-05, FS-BV-07 valve shall be in open position for the FS-BV-04, FS-BV-06, and FS-BV-08 in the closed position. For figure 17 shows the flow for transferring fuel to starboard tank using pump no.1 from portside tank. The FS-BV-05, FS-BV-08 valve shall be in open position for the FS-BV-04, FS-BV-06, and FS-BV-07 in the closed position.

Number 3 is methanol service tank. It is located in the main deck. It manufactured by Lapesa and build from duplex stainless steel to prevent the methanol corrosion. Same as methanol storage tank, service tank also equipped with 3 sensors, there are LAH (High Level Alarm), LAL (Low Level Alarm), TI (Temperature Indicator). Sounding pipe and Air pipe with flame screen are installed in the tank.

Number 4 is called methanol supply system. The system consist of two main components, there are supply pump and circulation pump. The specifications of the pump usually explain in the Project Guide of the Main Engine. Because the main engine hasn't yet existed, Author make approaching by find out the ration of the fuel injection to the engine, circulation pump, and supply pump. The result, supply pump has capacity of 1.6 m^3 and circulation pump has capacity of 5.9m^3. The head pressure of the pump is same as fuel oil system. Where the supply pump has 6 bar and circulation pump 4 bar of head. Because the pumps are put in series, the final head will be 10 bar, it is same as the FVT nominal working pressure.

The last is number 5, which is transfer fuel from FVT to Maine Engine. The only manufacture for methanol fuel valve train is electrofueltech. FVT function is to delivery and to prevent any failure when the system in emergency condition. For pipe specification transfer fuel from FVT to Main Engine same as the circulation pipeline, except when the pipe enter engine room. In this part , pipe shall be used is double walled type. Double walled pipe that used in study case ship is manufactured by UWIRA, which has inner pipe diameter of 25 mm and the outer pipe diameter of 38 mm. If there is any overflow of fuel the fuel will be back to FVT. From FVT the fuel can be transferred to service tank or back to the circulation pump to be transfer again to Main Engine.

4.4 Fuel System Component Layout

Fuel system component layout is plotting the component that has been selected in the methanol fuel system to the location inside the ship. There are 3 main locations for the component. First is in the main deck. In this deck there are several of methanol component such as methanol service tank, methanol fuel supply system and fuel valve train as shows in figure 18. Methanol service tank located in the main deck to make it well ventilated. This makes the tank do not need extra double barrier.

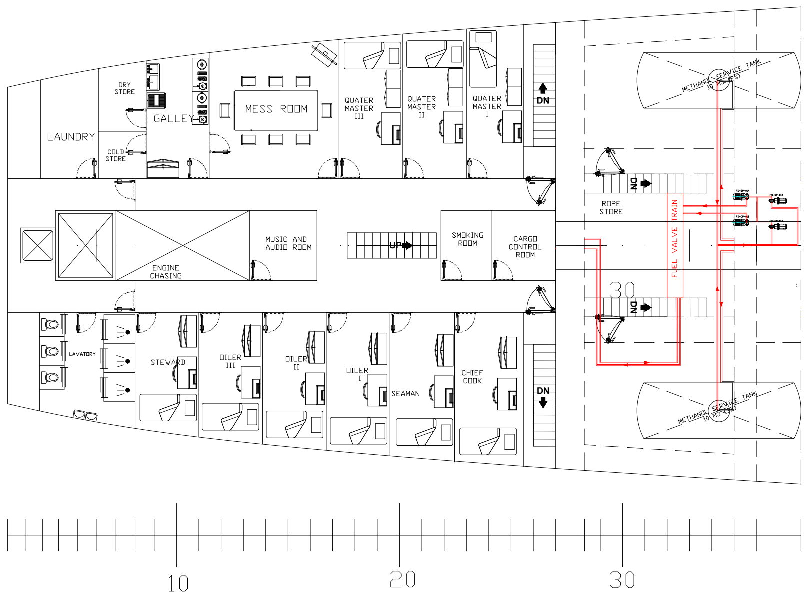

Figure 18 Methanol Fuel System on Main Deck

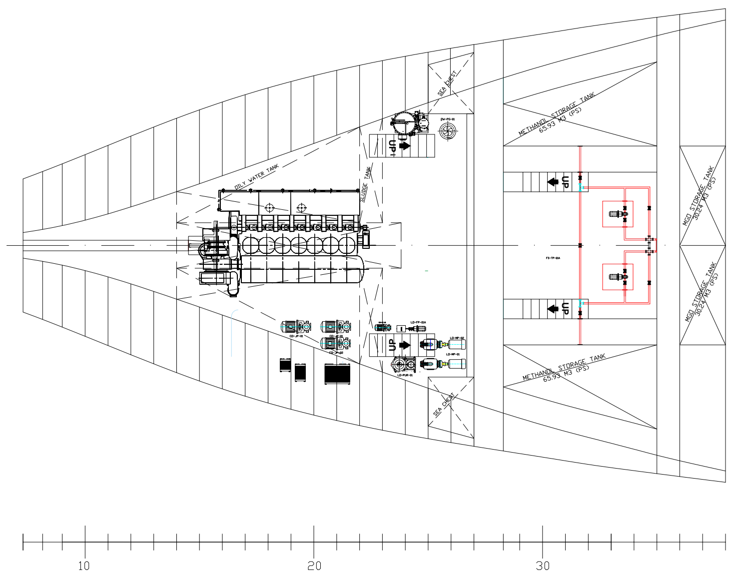

Figure 19 Methanol Fuel System on Double Bottom

Second is on the double bottom where the location of the methanol fuel transfer pump and methanol storage tank as shows in Figure 19. Because located inside ships hull, the tank should be protected by double barrier. Based on the regulation, the distance between shipside to the tank and tank to fuel preparation room is 800 mm, from storage tank to engine room is 900 mm. Beside the storage tank, there are also two-fuel transfer pump. These pumps will be covered and has own ventilation system like shows in the figure 9. These ventilation systems needed to prevent increasing of methanol vapor concentration inside the room if there is any leakage on the pump system.

The recommendation for methanol vapor concentration room is below 200 ppm. Based on the methanol pipe mitiagation calculation the maximum pipe and valves length is 21.48 m. As shows in Figure 19, the average distance between pipes and valves is 4 m. For access to fuel preparation room there are two stairs in the room from main deck.

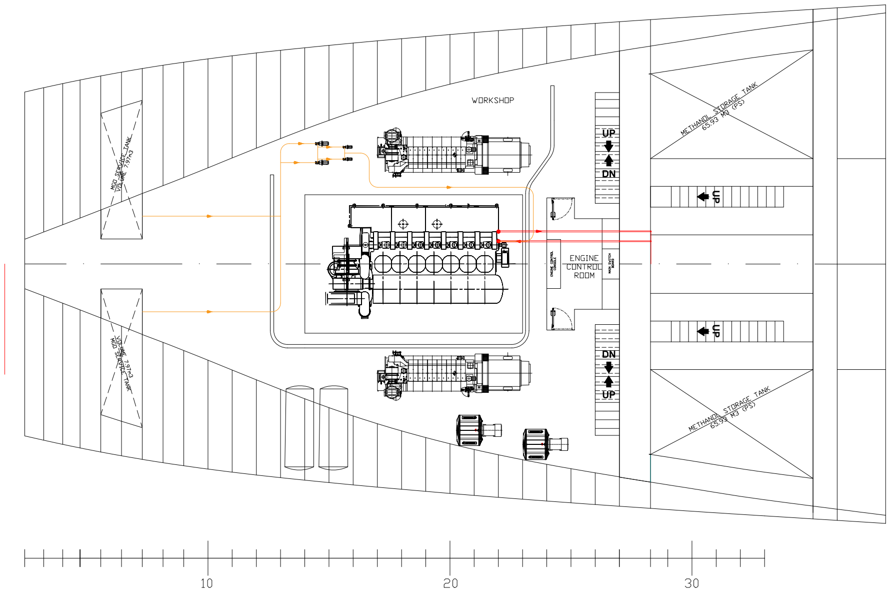

Figure 20 Methanol Fuel System on Platform

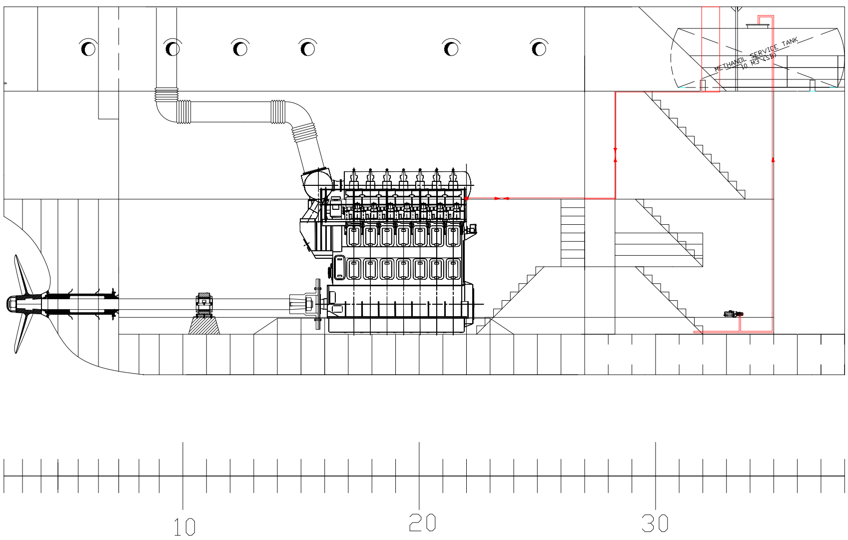

Figure 21 Side View of Methanol Fuel System

The last is the fuel injection location. It located near the platform deck as shows in Figure 19. In this also where the overflow fuel comes out. The yellow line is representing the MGO fuel. It use as pilot fuel in the system. Figure 21 shows the side view of the ship to get exact location of the component.The ship also has cofferdam to separate the fuel preparation room from engine room. The distance is 900 mm and it's complied with CCC 3-3 Regulation.. The cofferdam should be well ventilated Surrounding the tank by cofferdam is one of solution to prevent failure when there is a leakage. The fuel transfer pump located in fuel preparation room shall be in enclosed space. It make easier to monitories when there is any leakage in the pump.

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5 Conclusion

Based on the study of regulation and the design process of methanol fuel supply system, there are conclusions can be obtained as below:

5.1. There all still some different opinion on the three regulations that regulate the methanol as ship fuel. In ship and design arrangement section, DNV GL and LR explain about 800mm minimum distance between tank and ship side but there is no explanation in CCC 3-3. For fuel containment system DNV GL and LR explain about minimum 2 fuel tank have to be onboard ship, but CCC 3-3 doesn't explain it. In the inert gas system, there are the different opinion about vertical efflux velocity between DNV GL and CCC 3-3, In the DNV GL recommendation is at least 20m/s but CCC recommendation is 30m/s. In the LR Provision Rules, there is no explanation about it. For the material of the pipe only LR explain it in detail and recommended using duplex type or austenitic manganese steel otherwise DNV GL and CCC 3-3 doesn’t explain it in detail. For general pipe design CCC 3-3, LR and DNV GL have the different method. For fire safety, there are several differences between CCC, LR and DNV GL. For the structural fire protection, in CCC there is the minimum size of cofferdam that is 900 [mm] in the fire integrity tank of fuel tank cofferdam boundaries facing high-risk space but there is no explanation about it in LR or DNV GL.

5.2. To full fill the IMO and classification society requirement, the regulation that will be used to design is the regulation, which can provide the high level of safety. The fuel tank and shipside distance minimum 800 mm will be taken. Onboard, the ship will be minimum 2 fuel tanks. For the material of the pipe will be used duplex type stainless steel and for minimum pipe wall thickness, will choose the thick one. In the structural fire, safety aspect will be using 900 mm barrier between fuel preparation room and engine room.

5.3. Implementation of the regulation on board ship is quite challenging. The ship will lose the payload of their cargo. The specific fuel consumption will be increased by factor 46% compared to fuel oil SFOC and the storage tank shall be protected by cofferdam that takes a lot of space. To prevent the protected cofferdam, the service tank is recommended put in the main deck. Where in the main deck the tank in well-ventilated condition. For pilot fuel, it's recommended to join it with MGO service tank for the generator, because of the small consumption. For the safety aspect when there is any leakage in the transfer pipe is good. Because the last and the longest is from the pump to fuel service tank which has a length of 8.4 m. The minimum distance between valves is getting by dividing the maximum leakage volume by the surface area of the pipes. The results, the minimum distance between valves is 23.65 m. Compared to the longest pipe in the transfer system that is 8.4 m, this transfer pipe is in the low-risk condition, even without installing any additional valves.

There are three main conclusion that author get when doing bachelor thesis task about Analysis of the Requirement for Design of Ships Using Methanol as Fuel.

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Appendix

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	Ship's Data		
		Project	BT
		Doc.No	01-14-1005-FS
		Rev.No	4

A SHIP'S DATA

1 GENERAL DATA

Name	=	Doris Tanker	
Type	=	Oil Product/Chemical Tanker	
Lwl	=	102.96	m
Lpp	=	99	
B	=	15.8	m
H	=	8.4	
T	=	6.336	
Cb	=	0.62	
Vs	=	13.5	
Voyage	=		
Endurance	=	5	days
GT	=	3352.2	
DWT	=	4000	DWT
Payload	=	3880.73	ton

2 MAIN ENGINE

Type	=	MAN B&W 7S26MC6	
Power	=	2800	kW
Speed	=	250	rpm
SFOC	=	179	g/kWh
$SFOC_{MeOH}$	=	170.05	g/kWh
$SFOC_{MGO}$	=	8.95	g/kWh
Quantity	=	1	
Fuel	=	MGO	
	=	MeOH	

3 AUXILARY ENGINE

Type	=	MAN 6L16/24	
Power	=	660	kW
Gen Power	=	627	kW

Speed	=	1200	rpm
SFOC	=	195	g/kWh
Quantity	=	2	
Fuel	=	MGO	

4 MeOH SFOC Correction

Because MeOH has lower LHV than diesel there will be correction in SFOC. Based on MAN LGIM Projectguide, 1% increasing in LHV will effect on 1% ruducing in SFOC. MeOH LHV is 53.4 % lower than diesel. The MeOH SFOC will increase by factor of 53.4%.

Main Engine

$SFOC_{MeOH}$ = **260.86** gr/kWh

B MAIN ENGINE FUEL SYSTEM

Fuel is one of most important thing in the ship. In this ship the main engine using Methanol as main fuel and MGO as pilotfuel. Because use of LFL fuel there will be some additional equipment in the fuel system.In this chapter will be explain about the detail calculation of Fuel System in the Main Engine.

1 MAIN ENGINE FUEL CONSUMTION

Main Engine use Methanol as main fuel and MGO as pilot fuel.The endurance of ship is 3 days 72 hours. The quantitiy of fuel needed by ship is :

$W_{MeOH} = P_{MCR}$ x SFOC x hours x $10^{-6 \times 1.15}$

$= 2800 \times 261 \times 72 \times 10^{-6 \times 1.15}$

$= 100.8$ ton

$W_{MGO} = P_{MCR}$ x SFOC x hours x $10^{-6 \times 1.15}$

$= 2800 \times 8.95 \times 120 \times 10{-6}$

$= 3.5$ ton

Then the volume of the tank is

$V_{MeOH} = W_{MeOH}/\rho \times c$

$= 87.6/0.794$

$=$ **126.9** m^3

$V_{MGO} = W_{MGO}/\rho$

$= 0.7/0.89$

$=$ **3.9** m^3

To calculate the tank requirement onboard ship. Author using simpsons methon and below is the results

WL	1/2 Area	Faktor	1/2AXF
1.2	10.22	1	10.22
1.6	10.72	4	42.88
2	11.11	1	11.11
h	0.4	Sum	64.21
		Volume	17.12 m^3

WL	1/2 Area	Faktor	1/2AXF
2	11.11	1	11.11
3	11.87	4	47.48
4	13.55	1	13.55
h	1	Sum	72.14
		Volume	48.09 m^3

WL	1/2 Area	Faktor	1/2AXF
4	13.55	1	13.55
5.168	14.27	4	57.08
6.336	14.96	1	14.96

h	1.168	Sum	85.59	
		Volume	66.65	m^3

TOTAL TANK VOL **131.86** m^3

MGO Fuel Tank will be put in ships main deck. The tank dimension will be from manufacturer.

2 SERVICE TANK CALCULATION

W_{MeOH} = P_{MCR} x SFOC x t x C x 10^{-6}
= 2800 x 261 x 8 x 10-6
= 5.8 ton

V_{MeOH} = W_{MeOH}/ρ x c
= 5.8/0.794 x 1.2
= 8.8 m3

Because of the preventive's action and Rules requirement 2 service tank for are needed.

Service tank will be placed in the maindeck to maximaze the ventilation of the tank. The tank is manufactured by lapensa and has spesification :

Volume	=	10.9	m3
Length	=	6065	mm
Diameter	=	2200	mm
Height	=	2450	mm

3 METHANOL TRANSFER PUMP CALCULATION

3.1 CAPACITY

The time that need to transfer methanol from storage tank to Service tank is planned 2 hour.

Q = V/t

Where

V = Volume of service tank
= 8.8 m^3

t = tansfer time
= 2 h

Then the capacity of the pump is

Q = V/t
= 4.38 m^3/h

3.2 PIPE DIAMETER AND SPESIFICATION

Q = $0.25 \times \pi \times d^2 \times v$

d = $(Q/(0.25 \times \pi \times v))^{0.5}$

Where

d = calculated pipe inside diameter

v = flow velocity
= 0.7 m/s
Q = capacity
= 4.38 m3/h
= 0.0012 m3/s

Then the pipe diameter is

d = $(Q/(0.25 \times \pi \times v)^{0.5}$
= 0.040 m
= 40 mm

Find the minimum pipe thickness based on 3 regulation, CCC, LR and DNV GL

CCC 3-3

**in the CCC 3-3 Section 7.3 Requirement for general pipe design, the equation to calculate t_0 is PD/(2Ke+P) and D stand for the outside diameter of pipe. Author does not using outside diameter because pipe ouside diameter is know when the minimum pipe thickness have been find out. Author will be use d (calculated inside diameter) to calculate the value of t_0*

t = $(t_0+b+c)/(1-(a/100))$
= **1.11** mm

Where

b = allowance for bending
= 0
c = corrosion allowance
= 1 mm
a = manufacture negative tolerance
= 5 %
t_0 = theoritical thickness
= P d/(2Ke+P)
= 0.055 mm
P = 1 MPa
d = 40 mm
K = allowable stress
= Rm/B
= 361
Rm = specified minimum tensile strenght
= 650 N/mm^2 *(based on pipe technical data)*
B = 1.8
e = 1

Lyold Register

Lyold Register explain minimum pipe thickness in Rules and Regulation for the Classification of Ship Part 5 Chapter 12 Section 10 for Austenitic and Duplex stainless steel.

t = $((Pd/(20\sigma e+P))+c)(100/(100-a))$
= 1.15 mm

= **1.60** mm

In the LR Part 5 Chapter 12 Section 10 Table 12.10.1 there are minimum thickness requirement for austenitic and duplex stainless steel. And for pipe diameter size 21.3 up to 48.3 the minimum value is 1.6 mm

Where

d = 40 mm

P = 10 bar

e = 1

c = 1

a = 5 %

σ = maximum permissible design stress

σ = $E_t/1.6$ σ = $R_{20}/2.7$

= **213** N/mm^2 = 240.741 N/mm^2

Et = temperature; in the case of stainless steel, the 1,0 per cent proof stress at design temperature is to be used

= 340 N/mm^2

R20 = specified minimum tensile strength at ambient temperature

= 650 N/mm^2

**to calculate the value of σ there are Et/1.6 ; R20/2.7 and SR/1.6. Where the value of SR (average stress to produce rupture in 100 000 hours at the design temperature) does not exist in pipe technical data. Author will compare the value of Et and R20 and takes the lower one.*

DNV GL

DNV GL explain the minimum pipe thickness in DNV GL RU Ship Part 4 System and Component Chapter 6 Piping system Section 9 based on table. For stainless steel (no metion about austenitic and dublex stainless steel) the minimum wall tickness with diameter from 21.3 to 48.3 mm is 1.6 mm

t = **1.60** mm

CONCLUSION FOR MINIMUM PIPE THICKNESS

Based on table and calculation for minimum wall thickness as see in table below. The author using 1.6 mm thickeness for the transfer pipe with dublex stainless steel type.

	CCC	LR	DNV GL
t	1.11	1.60	1.60

Spesification for wallthickness based on DIN 10253-2

Diameter Nominal = DN 40

Inside Diameter [dH] = 40.5 mm

Outside Diameter = 44.5 mm

Schedule Number = DIN/ISO Series 1

Thickness = 2 mm

3.3 HEAD PUMP

To calculate the head total of the pump we need to know the head static, head pressure , head velocity and head loss. The total head loss equation is

h = hs + hp + hv + hts + htd

Head Static

head static pump is calculated from pump inlet till the end of discharge, in this case,its calculated till the overboard

hs = 7.20 m

Head Pressure

hp = 0

Head Velocity

Head Velocity (Hv) is difference velocity of fluid between in suction line in suction and discharge of pump. we can make assumption not difference between suction and discharge about flow velocity.

hv = 0

Head Loss

Head losses are the sum of head major and minor on both of suction and discharge.

Head Loses = Hsuction + Hdischarge

Suction Head Major Head Losses

To calculate the major head loss we use the Rn number to know the characteristic of the flow. The equation need the viscosity of the fluid or fuel. At the temperature 25°C the viscosity of methanol is 0.56 cSt

Reynold number (Rn)

Rn = (v*dH)/u

= 50625

Where

v = 0.7 m/s

dH = 0.0405 m 40.5 mm

u = 0.0000006 m^2/s 0.56 cSt

From Rn find the value of f (friction factor) by using moody diagram or moody friction factor calculaton and find the head loss.

hf = f x L x v^2 / (dH x 2g)

= 0.275 m

Where

f = 0.0208

L = 15 m (estimation)

g = 9.8 m/s^2

Suction Minor Head Losses

No	Accessories	n	k	k x v
1	Globe Valve	3	10	30
2	SDNRV	1	1.23	1.23
3	Strainer	1	1.5	1.5
4	Enlargement	1	0.17	0.17
5	T Joint	1	1	1
6	Bell mounted	1	0.05	0.05
7	Elbow 90	3	0.3	0.9
			k	34.85

*Accessories number and type still in estimation

hm = k x v^2 / 2g

= 0.87 m

h_{ts} = 1.146 m

Discharge Major Head Losses

Reynold number (Rn)

Rn = (v*dH)/u

= 50625

Where

v = 0.7 m/s

dH = 0.0405 m 40.5 mm

u = 0.0000006 m^2/s 0.56 cSt

From Rn find the value of f (friction factor) by using moody diagram or moody friction factor calculaton and find the head loss.

hf = f x L x v^2 / (dH x 2g)

= 0.364 m

Where

f = 0.0275

L = 15 m (estimation)

g = 9.8 m/s^2

Discharge Minor Head Losses

No	Accessories	n	k	k x v
1	Globe Valve	1	10	10
2	SDNRV	1	1.23	1.23
3	Gate Valve	1	0.15	0.15
4	Strainer	0	1.5	0
5	Enlargement	1	0.17	0.17
6	T Joint	2	1	2
7	Elbow 90	1	0.3	0.3

K 13.85

hm = $k \times v^2 / 2g$

= 0.35 m

h_{td} = 0.71 m

Head Total

The value of total head loss is

h = hs + hp + hv + hts + htd

= **9.06** m

3.4 TRANSFER PUMP SPESIFICATION

Based on the calulation the pump spesification is

Q = 4.38 m3/h

h = 9.06 m

Therefore the pump that will be use is Silipump 0.5CWF-10. It has spesification

Type = SiliPump 0.5CWF-10

Q = 5 m3/h

h = 10 m

METHANOL SUPPLY PUMP AND CIRCULATION PUMP

In section 4 and 5 will be explaine about methanol supply and circulation pump calculation. Ussualy, both of pump spesification are explain in the Project Guide of the engine.For the head pressure supply pump has 6 bar and ciculation pump 4 bar but there are no explanation about the capcity of the pump because of the engine have exist yet. Author make approcing by find out the ration of the fuel injection to the engine,

Qfi = SFOC x PMCR x 1.15

= 576380 g/h

= 576.38 kg/h

= **0.63** m3/h

Assume the engine using RME 180 fuel which has density 991kg/m^3 at 15°C. When the fuel pumped by supply pump, It has temperature approximately 125°C. For the density it calculated by volumetric thermal expansion calculation.

ρ_1 = $\rho_0/(1+\beta(t_1-t_0))$

= 920.15 kg/m3

Where

ρ0 = 991 kg/m3

β = 0.0007

t1 = 125 °C

t0 = 15 °C

And find the flow rate of the methanol by same method. Because there no significant increasing of temperature the density of methanol is 794.6 kg/m3

Q_{fiMeOH} = SFOC x PMCR x 1.15

= 839958.57 g/h

= 839.95857 kg/h
= **1.06** m3/h

from MAN 7S26MC6 Project Guide, the capacity of circulation and supply pump are 2.4 m3/h and 0.7 m3/h. Compare capcacity of fuel oil system to get the spesification in methanol fuel system

Type	Qfi	Cir.Pump	Sup.Pump
	[m^3/h]	[m^3/h]	[m^3/h]
Ratio	1	3.8	1.1
Fuel Oil	0.63	2.4	0.7
Methanol	**1.06**	**4.05**	**1.18**

4 METHANOL SUPPLY PUMP CALCULATION

4.1 CAPACITY

Capacity of supply pump based on calculation ratio is

Q = 1.18 m^3/h

4.2 PIPE DIAMETER AND SPESIFICATION

Q = $0.25 \times \pi \times d^2 \times v$

d = $(Q/(0.25 \times \pi \times v))^{0.5}$

Where

d = calculated pipe inside diameter

v = flow velocity

= 0.7 m/s

Q = capacity

= 1.18 m3/h

= 0.0003 m3/s

Then the pipe diameter is

d = $(Q/(0.25 \times \pi \times v))^{0.5}$

= 0.021 m

= 20.65 mm

Find the minimum pipe thickness based on 3 regulation, CCC, LR and DNV GL

CCC 3-3

t = $(t_0+b+c)/(1-(a/100))$

= **1.10** mm

Where

b = allowance for bending

= 0

c = corrosion allowance

= 1 mm

a = manufacture negative tolerance

= 5 %

t_0 = theoritical thickness

= P d/(2Ke+P)

= 0.046 mm

P = 1.6 MPa

d = 21 mm

K = allowable stress

= Rm/B

= 361

Rm = specified minimum tensile strenght

= 650 N/mm^2 *(based on pipe technical data)*

B = 1.8

e = 1

Lyold Register

Lyold Register explain minimum pipe thickness in Rules and Regulation for the Classification of Ship Part 5 Chapter 12 Section 10 for Austenitic and Duplex stainless steel.

t = ((Pd/(20σe+P))+c)(100/(100-a))

= 1.13 mm

= **1.60** mm

In the LR Part 5 Chapter 12 Section 10 Table 12.10.1 there are minimum thickness requirement for austenitic and duplex stainless steel. And for pipe diameter size 21.3 up to 48.3 the minimum value is 1.6 mm

Where

d = 21 mm

P = 16 bar

e = 1

c = 1

a = 5 %

σ = maximum permissible design stress

σ = $E_t/1.6$ σ = $R_{20}/2.7$

= **213** N/mm^2 = 240.741 N/mm^2

Et = temperature; in the case of stainless steel, the 1,0 per cent proof stress at design temperature is to be used

= 340 N/mm^2

R20 = specified minimum tensile strength at ambient temperature

= 650 N/mm^2

DNV GL

DNV GL explain the minimum pipe thickness in DNV GL RU Ship Part 4 System and Component Chapter 6 Piping system Section 9 based on table. For stainless steel (no metion about austenitic and dublex stainless steel) the minimum wall tickness with diameter from 21.3 to 48.3 mm is 1.6 mm t = **1.60** mm

CONCLUSION FOR MINIMUM PIPE THICKNESS

Based on table and calculation for minimum wall thickness as see in table below. The author using 1.6 mm thickeness for the transfer pipe with dublex stainless steel type.

	CCC	LR	DNV GL
t	1.10	1.60	1.60

Spesification for wallthickness based on DIN 10253-2

Diameter Nominal = DN 25

Inside Diameter [dH] = 26.0 mm

Outside Diameter = 30.0 mm

Schedule Number = DIN/ISO Series 1

Thickness = 2 mm

4.3 HEAD PUMP

To calculate the head total of the pump we need to know the head static, head pressure , head velocity and head loss. The total head loss equation is

h = hs + hp + hv + hts + htd

Head Static

head static pump is calculated from pump inlet till the end of discharge, in this case,its calculated till the overboard

hs = 2.00 m

Head Pressure

hp = 6 bar

= 60.7 m

Head Velocity

Head Velocity (Hv) is difference velocity of fluid between in suction line in suction and discharge of pump. we can make assumption not difference between suction and discharge about flow velocity.

hv = 0

Head Loss

Head losses are the sum of head major and minor on both of suction and discharge.

Head Loses = Hsuction + Hdischarge

Suction Head Major Head Losses

To calculate the major head loss we use the Rn number to know the characteristic of the flow. The equation need the viscosity of the fluid or fuel. At the temperature 25°C the viscosity of methanol is 0.56 cSt

Reynold number (Rn)

Rn = (v*dH)/u

= 32500

Where

v = 0.7 m/s

dH = 0.0260 m 26.0 mm

u = 0.0000006 m^2/s 0.56 cSt

From Rn find the value of f (friction factor) by using moody diagram or moody friction factor calculaton and find the head loss.

hf = f x L x v^2 / (dH x 2g)

= 0.126 m

Where

f = 0.023

L = 4 m (estimation)

g = 9.8 m/s^2

Suction Minor Head Losses

No	Accessories	n	k	k x v
1	Globe Valve	0	10	0
2	SDNRV	1	1.23	1.23
3	Strainer	1	1.5	1.5
4	Enlargement	1	0.17	0.17
5	T Joint	0	1	0
6	Bell mounted	0	0.05	0.05
7	Elbow 90	3	0.3	0.9
			k	3.85

*Accessories number and type still in estimation

hm = k x v^2 / 2g

= 0.10 m

h_{ts} = 0.223 m

Discharge Major Head Losses

Reynold number (Rn)

Rn = (v*dH)/u

= 32500

Where

v = 0.7 m/s

dH = 0.0260 m 26.0 mm

u = 0.0000006 m^2/s 0.56 cSt

From Rn find the value of f (friction factor) by using moody diagram or moody friction factor calculaton and find the head loss.

hf = f x L x v^2 / (dH x 2g)

= 0.126 m

Where

f = 0.023

L = 4 m (estimation)

g = 9.8 m/s^2

Discharge Minor Head Losses

No	Accessories	n	k	k x v
1	Globe Valve	0	10	0
2	SDNRV	1	1.23	1.23
3	Gate Valve	1	0.15	0.15
4	Strainer	0	1.5	0
5	Reducer	1	0.17	0.17
6	T Joint	1	1	1
7	Elbow 90	3	0.3	0.9
			K	3.45

hm = $k \times v^2 / 2g$

= 0.09 m

h_{td} = 0.21 m

Head Total

The value of total head loss is

h = hs + hp + hv + hts + htd

= **63.16** m

4.4 SUPPLY PUMP SPESIFICATION

Based on the calulation the pump spesification is

Q = 1.18 m3/h

h = 63.16 m

0.62 Mpa

Therefore the pump that will be use is Silipump YCB-1.6/0.6 It has spesification

Type = SiliPump YCB-1.6/0.6

Q = 1.6 m3/h

h = 0.6 Mpa

5 METHANOL CIRCULATION PUMP CALCULATION

5.1 CAPACITY

Capacity of supply pump based on calculation ratio is

Q = 4.05 m^3/h

5.2 PIPE DIAMETER AND SPESIFICATION

Q = $0.25 \times \pi \times d^2 \times v$

d = $(Q/(0.25 \times \pi \times v))^{0.5}$

Where

d = calculated pipe inside diameter

v = flow velocity

= 3.0 m/s (*based on FVT Recommendation*)

Q = capacity

= 4.05 m3/h

= 0.0011 m3/s

Then the pipe diameter is

d = $(Q/(0.25 \times \pi \times v)^{0.5}$

= 0.018 m

= 18.47 mm

Find the minimum pipe thickness based on 3 regulation, CCC, LR and DNV GL

CCC 3-3

t = $(t_0+b+c)/(1-(a/100))$

= **1.11** mm

Where

b = allowance for bending

= 0

c = corrosion allowance

= 1 mm

a = manufacture negative tolerance

= 5 %

t_0 = theoritical thickness

= P d/(2Ke+P)

= 0.051 mm

P = 2.0 MPa

d = 18 mm

K = allowable stress

= Rm/B

= 361

Rm = specified minimum tensile strenght

= 650 N/mm^2 *(based on pipe technical data)*

B = 1.8

e = 1

Lyold Register

Lyold Register explain minimum pipe thickness in Rules and Regulation for the Classification of Ship Part 5 Chapter 12 Section 10 for Austenitic and Duplex stainless steel.

t = $((Pd/(20\sigma e+P))+c)(100/(100-a))$

= 1.14 mm

= **1.60** mm

In the LR Part 5 Chapter 12 Section 10 Table 12.10.1 there are minimum thickness requirement for austenitic and duplex stainless steel. And for pipe diameter size 21.3 up to 48.3 the minimum value is 1.6 mm

Where

d	=	18 mm
P	=	20 bar
e	=	1
c	=	1
a	=	5 %
σ	=	maximum permissible design stress

σ = $E_t/1.6$ σ = $R_{20}/2.7$

= **213** N/mm² = 240.741 N/mm²

Et = temperature; in the case of stainless steel, the 1,0 per cent proof stress at design temperature is to be used

= 340 N/mm²

R20 = specified minimum tensile strength at ambient temperature

= 650 N/mm²

DNV GL

DNV GL explain the minimum pipe thickness in DNV GL RU Ship Part 4 System and Component Chapter 6 Piping system Section 9 based on table. For stainless steel (no metion about austenitic and dublex stainless steel) the minimum wall tickness with diameter from 21.3 to 48.3 mm is 1.6 mm

t = **1.60** mm

CONCLUSION FOR MINIMUM PIPE THICKNESS

Based on table and calculation for minimum wall thickness as see in table below. The author using 1.6 mm thickeness for the transfer pipe with dublex stainless steel type.

	CCC	LR	DNV GL
t	1.11	1.60	1.60

Spesification for wallthickness based on DIN 10253-2

Diameter Nominal		=	DN 20
Inside Diameter	[dH]	=	21.8 mm
Outside Diameter		=	25.0 mm
Schedule Number		=	DIN/ISO Series 1
Thickness		=	1.6 mm

Spesification for Double Walled Pipe from FVT to Main Engine based on UWIRA Manufacture

Inner Pipe Diameter	=	25 mm
Outter Pipe Diameter	=	38 mm
Anular Gap	=	6.5 mm

5.3 HEAD PUMP

To calculate the head total of the pump we need to know the head static, head pressure , head velocity and head loss. The total head loss equation is

h = hs + hp + hv + hts + htd

Head Static

head static pump is calculated from pump inlet till the end of discharge, in this case,its calculated till the overboard

hs = 2.00 m

Head Pressure

hp = 4 bar

= 40.5 m

Head Velocity

Head Velocity (Hv) is difference velocity of fluid between in suction line in suction and discharge of pump. we can make assumption not difference between suction and discharge about flow velocity.

hv = 0

Head Loss

Head losses are the sum of head major and minor on both of suction and discharge.

Head Loses = Hsuction + Hdischarge

Suction Head Major Head Losses

To calculate the major head loss we use the Rn number to know the characteristic of the flow. The equation need the viscosity of the fluid or fuel. At the temperature 25°C the viscosity of methanol is 0.56 cSt

Reynold number (Rn)

Rn = (v*dH)/u

= 116786

Where

v = 3.0 m/s

dH = 0.0218 m 21.8 mm

u = 0.0000006 m^2/s 0.56 cSt

From Rn find the value of f (friction factor) by using moody diagram or moody friction factor calculaton and find the head loss.

hf = f x L x v^2 / (dH x 2g)

= 0.489 m

Where

f = 0.0174

L = 4 m (estimation)

g = 9.8 m/s^2

Suction Minor Head Losses

No	Accessories	n	k	k x v
1	Globe Valve	0	10	0
2	SDNRV	1	1.23	1.23
3	Strainer	1	1.5	1.5

4	Enlargement	1	0.17	0.17
5	T Joint	0	1	0
6	Bell mounted	0	0.05	0.05
7	Elbow 90	3	0.3	0.9
			k	3.85

*Accessories number and type still in estimation

hm = $k \times v^2 / 2g$
= 1.77 m

h_{ts} = 2.257 m

Discharge Major Head Losses

Reynold number (Rn)

Rn = (v*dH)/u
= 116786

Where

v = 3.0 m/s

dH = 0.0218 m 21.8 mm

u = 0.0000006 m^2/s 0.56 cSt

From Rn find the value of f (friction factor) by using moody diagram or moody friction factor calculaton and find the head loss.

hf = $f \times L \times v^2 / (dH \times 2g)$
= 0.489 m

Where

f = 0.0174

L = 4 m (estimation)

g = 9.8 m/s^2

Discharge Minor Head Losses

No	Accessories	n	k	k x v
1	Globe Valve	0	10	0
2	SDNRV	1	1.23	1.23
3	Gate Valve	1	0.15	0.15
4	Strainer	0	1.5	0
5	Reducer	1	0.17	0.17
6	T Joint	1	1	1
7	Elbow 90	3	0.3	0.9
			K	3.45

hm = $k \times v^2 / 2g$
= 1.58 m

h_{td} = 2.07 m

Head Total

The value of total head loss is

h = hs + hp + hv + hts + htd

= **46.81** m

5.4 CIRCULATION PUMP SPESIFICATION

Based on the calulation the pump spesification is

Q = 4.05 m3/h

h = 46.81 m

Therefore the pump that will be use is Silipump CBY40-200 It has spesification

Type = SiliPump CBY40-200

Q = 5.9 m3/h

h = 50 m

C PILOT FUEL SYSTEM

Because methanol is not self ignition fuel, there is pilot fuel to start the ignition. In this chapter will be explain about the detail calculation of Pilot Fuel System

1 PILOT FUEL CONSUMTION

Main Engine use Methanol as main fuel and MGO as pilot fuel.The endurance of ship is 3 days 72 hours. The quantitiy of fuel needed by ship is :

W_{MeOH} = P_{MCR} x SFOC x hours x 10^{-6}

= 2800 x 261 x 72 x $10^{-6 \text{ x } 1.15}$

= 100.8 ton

W_{MGO} = P_{MCR} x SFOC x hours x 10^{-6}

= 2800 x 8.95 x 120 x10-6

= 3.5 ton

Then the volume of the tank is

V_{MeOH} = W_{MeOH}/ρ

= 87.6/0.794x 1.2

= 126.9 m^3

V_{MGO} = W_{MGO}/ρ

= 0.7/0.89 x 1.2

= 3.9 m^3

2 PILOT FUEL SERVICE TANK

Pilot fuel service tank will be located in Engine Room. It join with MGO service tank for the auxilary engine. It has capacity of 7.9 m3

PILOT FUEL SUPPLY PUMP AND CIRCULATION PUMP

author using same method as calculating methanol supply pump and circulation pump.

Q_{fiMeOH} = SFOC x PMCR x 1.15

= 28819 g/h

= 28.819 kg/h

= **0.04** m3/h

are 2.4 m3/h and 0.7 m3/h. Compare capcacity of fuel oil system to get the spesification in pilotl fuel system

	Calculation and Technical Spesification of Pilot Fuel System	Project	BT
		Doc.No	03-14-1005-FS
		Rev.No	4

Type	Qfi	Cir.Pump	Sup.Pump
	[m^3/h]	[m^3/h]	[m^3/h]
Ratio	1.0	3.8	1.1
Fuel Oil	0.63	2.4	0.7
Pilot	**0.04**	**0.14**	**0.04**

3 PILOT FUEL SUPPLY PUMP

3.1 CAPACITY AND HEAD

Capacity of the pump based on calculation and project guide is

Q = 0.04 $m^{3/h}$

H = 0.6 Mpa

3.2 PIPE DIAMETER AND SPESIFICATION

$Q = 0.25 \times \pi \times d^2 \times v$

$d = (Q/(0.25 \times \pi \times v)^{0.5}$

Where

d = calculated pipe inside diameter

v = flow velocity

= 1.0 m/s

Q = capacity

= 0.04 m3/h

= 0.000011 m3/s

Then the pipe diameter is

$d = (Q/(0.25 \times \pi \times v)^{0.5}$

= 0.003 m

= 3.19 mm

group is N for fuel line passing machinary space . Where in the group N the minimum diameter is 2 mm.

Spesification for wallthickness based on DIN 10305

Inside Diameter	[dH]	=	4.0 mm
Outside Diameter		=	8.0 mm
Schedule Number		=	DIN/ISO Series 1
Thickness		=	2 mm

	Calculation and Technical Spesification of Pilot Fuel System	Project	BT
		Doc.No	03-14-1005-FS
		Rev.No	4

4 PILOT FUEL CIRCULATION PUMP

4.1 CAPACITY AND HEAD

Capacity of the pump based on calculation and project guide is

Q = 0.14 $m^{3/h}$

H = 0.4 Mpa

4.2 PIPE DIAMETER AND SPESIFICATION

Q = $0.25 \times \pi \times d^2 \times v$

d = $(Q/(0.25 \times \pi \times v)^{0.5}$

Where

d = calculated pipe inside diameter

v = flow velocity

= 1.0 m/s

Q = capacity

= 0.14 m3/h

= 0.000038 m3/s

Then the pipe diameter is

d = $(Q/(0.25 \times \pi \times v)^{0.5}$

= 0.006 m

= 5.91 mm

group is N for fuel line passing machinary space . Where in the group N the minimum diameter is 2 mm.

Spesification for wallthickness based on DIN 10305

Inside Diameter	[dH]	=	6.0 mm
Outside Diameter		=	10.0 mm
Schedule Number		=	DIN/ISO Series 1
Thickness		=	2 mm

4.3 CIRCULATION PUMP SPESIFICATION

Type = Castle Pump BTMB25D

Q = 0.7 m3/h

h = 50 m

D. ENGINEERING TECHNICAL SOLUTION

Methanol concentration in the room is recommended not more than 200ppm. To reduce the risk of high concentration methanol when there is any leakage in the pipe, the pipe is divided to the section using valve. In this document is calculation of the minimum valve in the fuel transfer pipe line, from methanol

1 FUEL PREPARATION ROOM

Fuel preparation room will be located from frame 28 until 35. The room has lenght of 4.7 m; width 4.5 m; and the high is 7.2m.

Fuel preparation dimension :

Lenght	=	4.7	m
Width	=	4.5	m
High	=	7.2	m
Volume	=	152.28	m3

Minimum methanol content in the room

max. concent	=	200	ppm
V_{MeOH}	=	0.0305	m3

2 PIPE MITIGATION

The fuel transfer pipe has diameter of 42.5. The pipe have been divided by flange into three section.

From tank to Fuel prep. room	=	0.8	m
Fuel prep. room to pump	=	0.68	m
pump to service tank	=	8.4	m

Minimum valve distance to ensure 200ppm methanol content

dH	=	0.0405	m	40.5	mm
min. distance	=	**23.65**	m		

In this case, the fuel transfer pipe has low risk potential. Even without installing extra valve and there is any leakage, the methanol concent still below 200ppm.

ABOUT THE AUTHOR

The author was born on 15th December 1996 in Denpasar, as the second child of 2 siblings. His father is I Ketut Murdana,S.E. and his mother is Ida Ayu Komang Indira Lakshmi, S.Pd. The author has completed the formal education in SD Saraswati 2 Denpasar, SMP 3 Denpasar, and SMAN 1 Denpasar. The author continued his study for bachelor degree in Marine Engineering Double Degree (DDME) program of Institut Teknologi Sepuluh Nopember (ITS) and Hochshcule Wismar, with student id number: 04211441000005 and took area of expertise in Marine Power Plant (MPP). The author has done on the job training in PT. Bandar Abadi Shipyard, Batam and PT. Biro Klasifikasi Indonesia, Cabang Madya Klas Palembang.