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DESIGN SYSTEM FOR A CHEMICAL TANKER SHIP WHICH USING METHANOL FUEL

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DESIGN SYSTEM FOR A CHEMICAL TANKER WHICH USING METHANOL AS A FUEL

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ABSTRACT

Starting in 2020, IMO has already implemented regulations whereby sulfur oxide emissions must be a maximum of less than 0.5 percent according to IMO Annex IV regulation 14. Although Indonesia still does not meet the requirements for emission reduction according to IMO tier III, it is hoped that later it can follow developments especially in meeting the conditions tier III IMO. One way to fulfill IMO tier III requirements is to use Methanol as an alternative fuel. In this paper shows the results of mathematical calculations and several designs according to the IGF Code and rules classification. Methanol systems required a high level of security to meet IMO regulations and classifications. Fuel tank and a minimum distance of 800 mm will be taken. In this case, the ship will have at least 2 fuel tanks.The tank capacity needed by methanol fuel on ships requires a larger tank. amounting to 142.8 m3, so a larger tank volume is needed. there are some additional components not found in conventional fuel systems but the addition of components is not significant. The methanol fuel cost is about Rp.307,145,433 and the HFO fuel cost is about Rp. 298,395,683.50. in this case relatively more expensive than the conventional fuel. The retrofit of the engine is about Rp.7.859.500.236 So overall the total additional costs needed for the methanol fuel system are depends of the specification of the ship.

Keywords: *Tier III* IMO, emission, Methanol, MDO,Engine Fuel, Diesel Engine, Dual Fuel Engine;

DESAIN SISTEM PERPIPAAN PADA KAPAL CHEMICAL TANKER YANG MENGGUNAKAN METANOL SEBAGAI BAHAN BAKAR

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ABSTRAK

Mulai tahun 2020, IMO telah menerapkan peraturan di mana emisi sulfur oksida harus maksimum kurang dari 0,5 persen menurut peraturan IMO *Regulation* IV 14. Meskipun Indonesia masih belum memenuhi persyaratan untuk pengurangan emisi menurut IMO *tie*r III, diharapkan yang nantinya bisa mengikuti perkembangan terutama dalam memenuhi kondisi tier III IMO. Salah satu cara untuk memenuhi persyaratan IMO tier III adalah dengan menggunakan Methanol sebagai bahan bakar alternatif. Dalam tulisan ini ditampilkan hasil perhitungan matematis dan beberapa desain sesuai dengan IGF Code dan aturan kelas. Sistem metanol membutuhkan tingkat keamanan yang tinggi untuk memenuhi peraturan dan klasifikasi IMO. Tangki bahan bakar dan jarak minimal 800 mm akan dipasang. Dalam hal ini kapal akan memiliki minimal 2 tangki bahan bakar, kapasitas tangki yang dibutuhkan bahan bakar methanol pada kapal membutuhkan tangki yang lebih besar. sebesar 142,8 m3, sehingga dibutuhkan volume tangki yang lebih besar. Ada beberapa komponen tambahan yang tidak ditemukan pada sistem bahan bakar konvensional tetapi penambahan komponen tidak signifikan. Biaya bahan bakar methanol sekitar Rp.307.145.433 dan harga bahan bakar HFO sekitar Rp. 298.395.683,50. dalam kasus ini relatif lebih mahal dibandingkan dengan bahan bakar konvensional. Biaya retrofit mesinnya sekitar Rp.7.859.500.236 Jadi secara keseluruhan total biaya tambahan yang dibutuhkan untuk sistem bahan bakar methanol sangat tergantung dari spesifikasi kapal.

Kata Kunci: *Tier III* IMO, Emisi, Metanol, MDO, Bahan Bakar Mesin, Mesin Diesel, Mesin Bahan Bakar Ganda;

FOREWORD

All the thanks to the authors say to Allah SWT, for all the grace and His gift, the author was able to complete a bachelor thesis with the title "Design System for A Chemical Tanker Ship which Using Methanol as A Fuel". This report has been prepared to meet the thesis course of the Department of Marine Engineering. In the preparation and execution of this thesis, the author received significant assistance and support from various parties. Therefore, the authors express special thanks to:

1. Buya, Bunda, and Brothers who has provided material support, encouragement and love, and support every time to the author.
2. The Government of the Republic of Indonesia for the opportunity given to the author so that the author can study at ITS Surabaya.
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5. All lecturers and teaching staff in the Department of Marine Engineering has provided knowledge during the authors study.
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10. And all parties that I cannot mention one by one. thank you or all the support and assistance provided to the author.

In writing this thesis the author realizes that the report is done far from perfection so that constructive criticism and advice is needed for author. Finally, the authors hope that this report will provide benefits readers and the Indonesian people.

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LIST OF NOMENCLATURE

Name	Meaning
IMO	International Maritime Organization
SCBA	Self Contained Breathing Apparatus
BFIV	Booster Fuel Injection Valve
MARPOL	Maritime Pollution

Symbol	Meaning	Units
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

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CHAPTER I

INTRODUCTION

1.1 Background

Energy is one of the most important things in human life in its daily activities. Along with the increase in humans is also directly proportional to the increasing energy needs to be consumed. The world community, especially Indonesia, currently the use of energy is still dependent on fossil fuels. With the ability to produce fossil fuels such as Indonesian oil is not as much as before and accompanied by the increasing use of fuel oil will make Indonesia experience an energy crisis going forward. Plus emissions from fossil fuels are also among the highest.

One of the biggest energy uses comes from transportation. The marine or shipping industry is one that uses the highest fossil fuels in the transportation sector. Moreover, Indonesia, as a country with two-thirds of its territory, is needed by ships as a liaison between islands. it will become an environmental problem. One of the main environmental problems is air pollution. Although air pollution from ships has no direct cause and effect, for example, incidents of oil spills, it causes cumulative effects that contribute to the overall air quality problems faced by populations in many areas, and also affects the natural environment, such as heavy acid rain ("Air Pollution," nd). International Maritime Organization (IMO) Council, asserted that it will implement any provisions or regulations that have been issued by IMO, including the application of Marine Pollution (Marpol) Annex VI Regulation 14 on Sulfur Oxides (SOx) and Particulate Matter starting 1 January 2020. Under the revised MARPOL Annex VI, the global Sulfur cap will be reduced from current 3.50% to 0.50%. To support this regulation, the Ministry of Transportation has issued Minister of Transportation Regulation PM Number 29 of 2014, which in article 36 regulates the limitation of sulfur content in fuel on ships by 0.5% starting on January 1, 2020.

This is one of the promising solutions to become a fuel because of its raw materials and produces less pollution than fossil fuels. Methanol significantly reduces sulfur oxide (SOx), nitrogen oxide (NOx) and particulate matter emissions. With methanol clean-burning qualities as marine fuel, it reduces emissions of sulfue oxides (SOx) by approximately 99%, nitrogen oxides (NOx) by up to 60% and particulate matter by 95% compared to conventional fuels like HFO. Methanol has a long history of safe handling. Unlike some alternative fuels, this fuel is available through the existing global terminal infrastructure. It is a cost-effective alternative marine fuel in terms of storage and fueling infrastructure as a liquid fuel. Only minor modifications are needed for current fuel infrastructure to handle methanol.

Methanol is produced from natural gas and can also be made from renewable resources essentially future-proofing it has alomg-term sustainable fuel and the most interesting from CO2. If future technology has developed in making methanol from

CO2 more effective, it will make efforts to prevent global warming be reduced because CO2 is one of the main causes of global warming.

Today methanol is one of the top chemical commodities shipped worldwide every year. The availability of methanol in Indonesia is currently still unable to meet its consumption needs. However, with a production capacity of 660,000 tons per year, the potential availability of methanol in Indonesia is still possible to meet consumption.

Currently, IMO does not yet have any regulations regarding using methanol as a fuel but there are several concepts in the process. Classification societies that have regulations for using methanol are LR and DNV GL. Because there are no basic international and Indonesian regulations to design, these two regulations are needed before designing a ship's fuel system.

1.2 Statement of the problem

The statement of the problems that will be discussed in this study are as follows:

1. How to design methanol fuel system for a chemical tanker ship with safety considerations?
2. How to design methanol fuel system for a chemical tanker ship with bill of quantity ?
3. How to design methanol fuel system for a chemical tanker ship with 3D model drawing?

I.3 Research Limitation

To focus on the execution of this thesis, it is necessary to limit the issues to be discussed as follows:

1. A chemical tanker ship as case study.
2. Ship's Main Engine will be modified
3. The design created involve economic analysis limited by bill of quantity.

I.4 Research Objectives

The objectives of this study are as follows:

1. Knowing what safety parameter considerations need to be used and added to the methanol fuel system of the ship.
2. Estimating bill of quantity need to be considered to the methanol fuel system of the ship.
3. Drawing the 3D model of the methanol fuel system of the ship.

I.5 Benefits of Research

1. In the shipping industry, this design is expected to be able to realize a methanol fuel system that can later be applied massively.
2. For academics, especially students, this research is expected to increase the references of studies on the design of methanol fuel systems and can apply them as one of the engineering values to be useful for others.
3. For the public, can open views on the methanol fuel system used in the ship system.

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CHAPTER II

THEORITICAL STUDY

II.1 Methanol

Methanol is an Alcohol compound with 1 Carbon chain. Chemical formula CH3OH, with a molecular weight of 32. Boiling point 640-650 C (purity dependent), and specific gravity 0.7920-0.7930 (also purity dependent). Physically Methanol is a clear liquid, smells like alcohol, can mix with water, ethanol, chloroform in any ratio, hygroscopic, volatile and flammable with blue flame (if the afternoon is not visible).

Methanol also known as methyl alcohol, wood alcohol or spiritus, is a chemical compound with the chemical formula CH3OH. It is the simplest form of alcohol. In the atmosphere of methanol in the form of liquid which is lightweight, volatile, colorless, flammable and toxic with a characteristic odor (smelling lighter than ethanol). Methanol is used as an antifreeze coolant, solvent, fuel and as an additive for industrial ethanol. Methanol is also a by-product of wood distillation. Methanol is currently produced through a multi-stage process. Briefly natural gas and water vapor are burned in a furnace to form hydrogen gas and carbon monoxide, then this hydrogen and carbon monoxide gas reacts at high pressure with the help of a catalyst to produce methanol. The formation stage is endothermic and the synthesis stage is exothermic (Engler, 2001).

In the last decade, the world community, including Indonesia, faced an energy crisis due to the decline in fossil fuel reserves, especially petroleum which is the raw material for making gasoline, diesel and fuel oil. So far, Indonesia is fixated on fossil energy and is late in developing renewable energy sources.

Alternative renewable fuels really need to be developed given that we might not be able to forever enjoy the natural wealth in the form of non-renewable petroleum. One time, petroleum reserves will run out both sooner and later. One of the alternative energy sources whose use is the largest at this time is biomass such as wood cellulose, straw, reeds, and so on. This energy source is very much found in nature reaching 70% of the total life energy.

The alternative energy that is still not widely used and its development is methanol. Methanol, also known as methyl alcohol, wood alcohol or spiritus, is a chemical compound with the chemical formula CH3OH. He is the simplest form of alcohol. On "circumstances the atmosphere "methanol is a light, volatile liquid, colorless, flammable, and toxic with a characteristic odor (smells lighter than ethanol). Methanol is sometimes also referred to as wood alcohol because it was a by-product of distillation wood. Currently methanol is produced through a multi-stage process. Briefly, natural gas and water vapor are burned in a furnace form hydrogen gas and carbon monoxide, then gas hydrogen and carbon monoxide react under high pressure with the help of a catalyst to produce methanol. Methanol has a much shorter carbon chain than ethanol so that it will burn more completely and release fewer carbon monoxide emissions. Based on this fact, methanol is likely to be able to lead us to the goal of creating environmentally friendly fuels. Therefore, the need for a literature study on methanol as an alternative fuel.

II.2 Emissions

Currently, many ships used to 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 particulate matters.

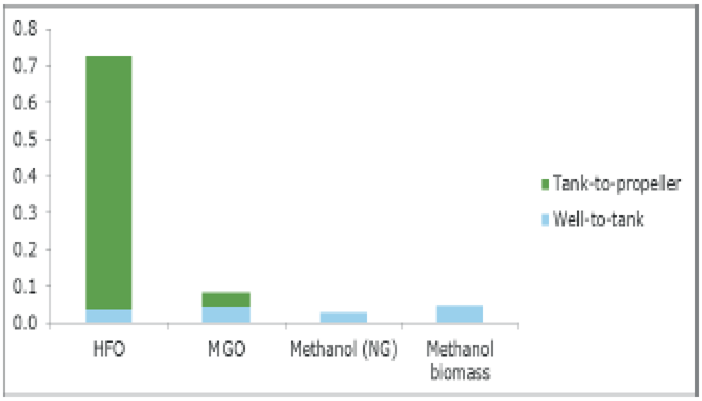

Figure 2. 1 Comparison Lifecycle Emissions of SOx

When using conventional fuels such as HFO, SOx emissions are very large. but if a ship uses methanol as a fuel for the ship, the emissions produced will be reduced by 92%. As seen in Figure 2.1, the SOx content of HFO at the time of the tank to propeller is so large. This is inversely proportional to the SOx content in methanol which is very small and can even be said to be almost non-existent.

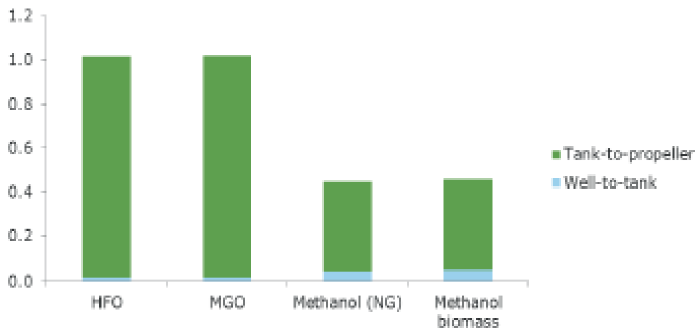

Figure 2. 2 Comparison Lifecycle Emissions of NOx

The picture above shows that when using conventional fuels such as HFO, NOx emissions are so large. but if the ship uses methanol as fuel for the ship, the emissions produced will be reduced by 55%.

II.3 Classification Perspective

As for today, Classification from Indonesia, namely Biro Klasifikasi Indonesia (BKI), does not mention methanol as a fuel for ships in the latest edition of BKI but still on progress to be amended. Lloyd's Register (LR) has drafted rules for the use of methanol in marine environments. DNV GL has published tentative rules on the same subject. Det Norske Veritas – Germanischer Lloyd (DNV-GL) has done equivalent efforts. In July 2013 they published tentative rules for low flashpoint fuels, including methanol. In the same period, IMO published the drafted IGF code which now addresses methanol as a low flashpoint, sulphur- free, 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 study 6.2 Methanol Bunkering System 8.6 Bunkering System	Sec 6.3.6 Fuel Bunkering
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 Pressurization	Section 6.3.5 Ventilation 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

Table 2 1 comparison standard LR and DNV GL rules

II.4 Availability of Methanol

The availability of methanol is one of its strong points as a marine fuel. As a widely used petrochemical feedstock, it is present at hundreds of ports worldwide – and at nearly all the current centres for conventional marine bunkering. Methanol is the world's most widely shipped chemical commodity, with an estimated 26.7 million tonnes shipped in 2017, according to Clarksons Platou.

What needs to be developed is the bunkering infrastructure to support widespread distribution – though this is also true of LNG as fuel. Options include bunkering from trucks (as with early LNG as marine fuel projects), or via dedicated vessels and it is perfectly feasible for existing bunker barges to be converted to handle methanol.

Onshore storage of methanol is simpler than LNG because no cryogenic facilities are required as methanol is a liquid at ambient temperature and there are some well understood and readily available methods of safely storing and handling methanol that present no exceptional safety risk.

Reported by liputan6.com, the need for methanol in Indonesia in 2021 is predicted to reach 871 thousand tons per year while the only producer currently in Indonesia is PT Kaltim Methanol Indonesia, which is only able to supply 330 thousand tons of domestic needs.

PT. KMI is one of the producers of methanol in Indonesia, which is located in the City of Bontang and close to a strategic port for PT. KMI. The capacity of methanol produced is 2000 metric tons / day or 660000 tons of metric / year. The source of the gas used for methanol production comes from a gas-producing field around Bontang. PT Karya Mineral Jaya will build oil refineries with a capacity of 1 million tons per year with a construction period of up to 4 years. Raw material for methanol will be sent from PHENC.

II.5 Characteristics of Methanol

Fuel properties

Property	DME	Methanol	Ethanol	Diesel	HFO 45	Gasoline
Chemical formula	CH_3-O-CH_3	CH_3-OH	C_2H_5-OH	C8-C25	-	C4-C12
Fuel carbon (wt%)	52.2	38	52	85	-	86
Fuel hydrogen (wt%)	13	12	13	15	-	14
Fuel oxygen (wt%)	34.8	50	35	0	-	0
Molar mass (kg/kmol)	46	32	46	183	-	114
Liquid density (kg/m³)	660	798	794	840	982	740
Lower heating value (MJ/kg)	22.8	20.1	27.0	42.7	40.9	-
Boiling temperature (°C at 1 bar)	-24.9	65	78	180-360	-	27-245
Vapour pressure (bar at 20°C)	5.3	0.13	0.059	«1	-	0.25-0.45
Critical pressure (bar)	53.7	81	63	30	-	-
Critical temperature (°C)	127	239.4	241	435	-	-
Kinematic viscosity (cSt at 20°C)	0.19-0.25	0.74	1.2	2.5-3.0	-	0.6
Surface tension (N/m at 20°C)	0.012	0.023	0.022	.027	-	-
Bulk modulus (N/mm² at 20°C 2MPa)	1,549	823	902	553	-	1,300
Cetane number	55	<5	8	38-53	-	-
Octane number	Low	109	109	15-25	-	90-100
Auto ignition temperature in air (°C)	350	470	362	250-450	-	250-460
Heat of vaporisation (kJ/kg at 1 bar)	467	1,089	841	250	-	375
Minimum ignition energy (mJ at ϕ=1)	0.33	0.21	0.65	0.23	-	0.8
Stoichiometric air/fuel ratio	9	6.5	9.1	14.6	13.5	14.7
Peak flame temperature (°C at 1 bar)	1,780	1,890	1,920	2,054	-	2,030
Flamability limits (vol%)	3.4-18.28	6-36	3-19	0.5-7.5	-	1.4-7.6
Flash point (°C)	-41	12	14	52	-	-45

Table 2 2 Comparison Properties Methanol than others fuel

Methanol is a methyl alcohol with chemical structure CH3OH. The Hydrogen to Carbon (H/C) ratio is 4/1 for methanol (similar to the H/C ratio of LNG), which allows classifying it as a low carbon content fuel. Accounting on molar mass and lower heating value, this results in around 20% less CO2 emitted while combusting methanol, compared to diesel with similar efficiencies. Methanol is miscible in water, gasoline and alcohols, yet creates a stratified mixture with diesel and other oils. Only 25% of methanol mixed in water leads to a flammable liquid. As shown in Table 2.2 the boiling point of methanol is 64.5◦ C and its freezing point is -97◦ C, which results in a liquid phase of methanol at room temperature. This gives the possibility to use storage tanks with the same provisions as for gasoline. The flash point refers to the temperature at which the fuel forms an ignitable mixture with air. The value of this parameter for methanol (11◦ C) is lower compared to diesel (78◦ C), Despite that, MeOH is classified as a low flash point fuel. It needs more safety protection than diesel fuel to prevent any catastrophic failure.

II.6 Risk of Methanol Fuel

Methanol as fuel will pose a risk to safety, fire prevention and fire fighting. methanol is very dangerous if exposed to the human body. therefore, open controls are needed. Based on the fact sheet of safe handling of methanol, there are four methods, they are :

a) Technical controls
b) Personal protective equipment
c) Respiratory protection
d) Chemical resistant clothing/material.

Methanol as fuel will pose a risk to safety, fire prevention and fire fighting. methanol is very dangerous if exposed to the human body. therefore, open controls are needed. Based on the fact sheet of safe handling of methanol, there are four methods for doing it. There are technical controls, personal protective equipment, respiratory protection, and chemical resistant clothing / materials. In engineering control, to minimize the potential for exposure, methanol can be transferred with an automatic pump and must also be stored in a closed system and should not be left open. and also in the ventilation system, to ensure methanol concentrations of less than 200 ppm, the conditions must be determined for specific locations and targets. . Methanol can expose the human body to inhalation, skin absorption, contact with eyes or swallowed. To reduce the risk of exposure, minimum safety glasses with side protectors or safety glasses and suitable tasks are recommended. To prevent methanol from being exposed to inhalation there must be respiratory protection. Respiratory protection must be based on the danger present and the possibility of potential exposure.

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.
>250 ppm	A supplied air system must be used (i.e., positive pressure SCBA)

Table 2 3 Respiratory Protection Guide
Source : (Alliance Consulting International, 2008)

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

Table 2 4 Personal Protective Equipment Selection
Source : (Alliance Consulting International, 2008)

II.7 Methanol Engines

Methanol is difficult to ignite in an ordinary diesel engine. There are today two leading engine manufactures developing large marine engines compatible to run on methanol. The first one is 44 Wärtsilä who are focused on developing four-stroke diesel cycle engines (Danbratt & Haraldson, 2013). The second company is MAN Diesel Turbo which is focused on remodelling their two-stroke diesel cycle engines to be methanol compatible (Laursen, 2014). In comparison to a conventional marine-diesel engine the most considerable things that differ are:

1. The cylinder head, where an extra injector is added.
2. A Fuel Block, that accommodates fuel for injection
3. The fuel delivery system, a part of the piping is double walled to detect any leakage.
4. A special ventilation system for possible leakage because of the low flashpont.

Booster Fuel Injector Valve (BFIV) The BFIV is the second injector added to the cylinder head. The BFIV is a combination of an old conventional slide valve design and the newer booster design (Laursen, 2014). This valve is working by building up a pressure high enough to start the injection, this by using a hydraulic pressure of 300 Bar. When the injection pressure is sufficient the valve opens and the fuel is injected into the engine. The fuel is pumped from and stored inside a fuel block that is added beside each cylinder. Each fuel block contains enough fuel to accommodate for at least one injection.

II.8 Formula of Calculation

Here is the formulas of calculation used in working on this project such as:

a. Calculation of Volume of Tank

$$Vol_{tank} = BHP\ mcr \times SFOC \times (hours) \times C / \rho\ fuel$$

Vol_{tank} = Volume Tangki (m^3)
BHP_{mcr} = Brake Horse Power maximum continous rating (kW)
SFOC = Specific Fuel consumpsion of main engine (g/kW)
(hours) = The tank that can last for .... hours
C = Margin because of construction of ships = 4%
ρ Fuel = density of fuel

b. Calculation of Head total

Htotal = Hs + Hp + Hv + total Head-loss

Htotal = Head Total (m)
Hs = Head Statis
Hp = Head Pressure

Hv = Head Velocity
Total head loss = Friction losses + Fitting losses

c. Energy Calculation

E = C x NCV

Where:

E = Energy (MJ)

C = Fuel consumption (tons)

NCV = Net calorific value (MJ/tons)

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CHAPTER III

REASEARCH METHODOLOGY

III.1. General

At the beginning of this final project is to do the formulation of existing problems. The formulation of the problem can be sought by observing the fuel system used or linking the present conditions to the conditions that will come. The formulation of the proposed problem will later get a solution from the final work being done. The problem taken in this thesis is to design a fuel system so that it can operate properly.

III.2. Flowchart

Flowchart shows that the steps that is conducted by the author from the first step until the last step to achieve the research purposed. There are many types of symbols in this flow chart such as parallelogram to explain the process of input/output data, parameter, or information, square to explain data processing or calculation process while tha arrows indicate the direction of the program flow.

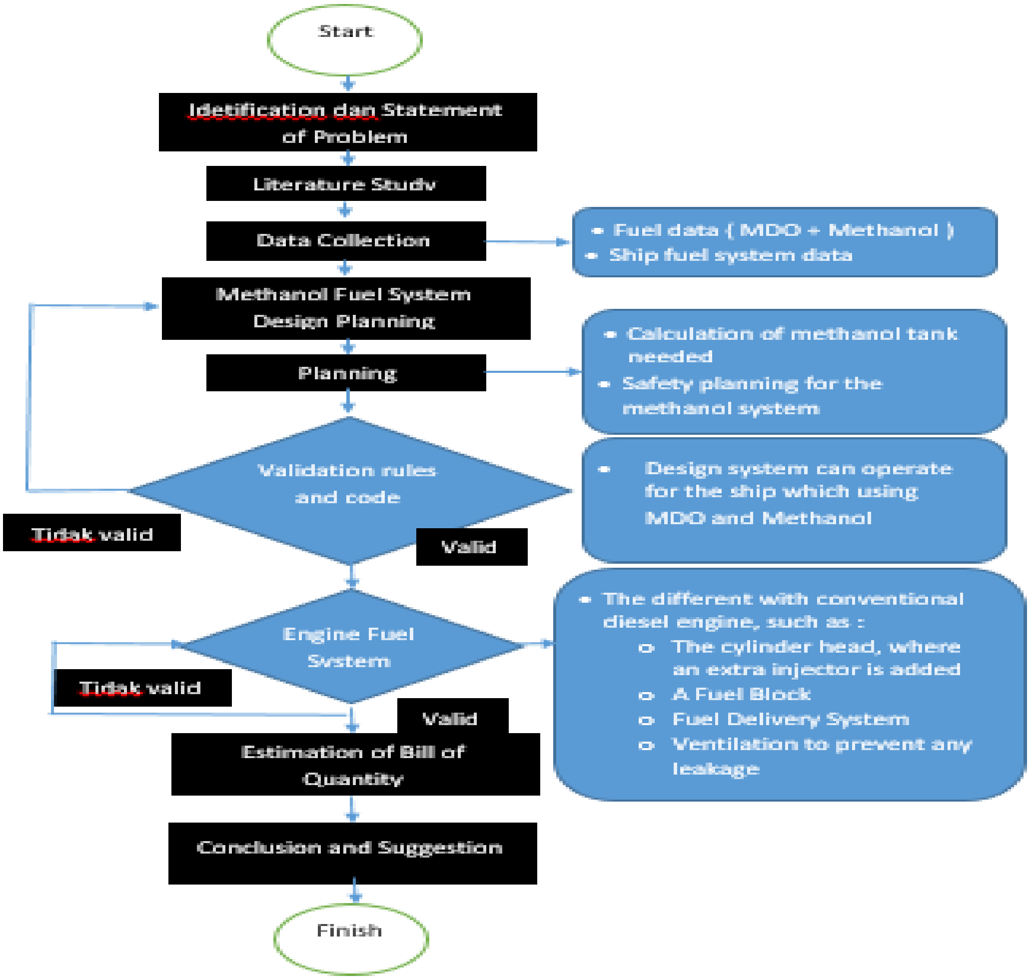

Figure 3. 1 Flowchart

III.3 Literature study

The next step is literature study. In this stage, all kinds matters relating to the problems raised are studied. So have a picture how problem can be solved. Literature study can be done by reading the books, papers, internet or journalas related to methanol fuel system in ship.

III.4 Data Collection

The next is data collection aimed at obtaining data and information that supports thesis work. In this case data needed include :

1. Ship’s data
2. Main engine data such as RPM, fuel viscosity, fuel system.

III.4.1 Ship's Data

Ship data used in this thesis is ship data chemical tanker.

III.4.2 Main Engine Data

Main engine data needed is rpm data, density of fuel, the viscosity of fuel, fuel main engine system. This matter used to determine temperature and viscosity.

a. RPM Engine
   Engine RPM is needed because of the engine rpm itself, we can determine the type of fuel used by the engine. For low speed engines (RPM less than 250), because it requires a high torque and the combustion process is not too long so we can use HFO is the main fuel while the role of MDO in the low speed engine system as HFO rinse media available in the pipeline. For medium speed engines (500 to 1000 RPM), fuel which can be used only MDO or also a combination of HFO and MDO. While for High speed engines (RPM 1000 and above), the fuel is used only MDO or MDF.

b. Fuel Viscosity
   Fuel viscosity determines the characteristic of fuel viscosity. The higher viscosity then the thicker the fluid. The viscosity that considered is Methanol as fuel with MDO.

c. Engine Fuel System
   Engine fuel system has different characteristics. One of the matters are considered is the pressure of fuel. so whether or not the fuel booster injector valve (BFIV) and liquid gas injection (LGI) block must be considered. Other than that, because of low flashpoint of the methanol there are must be a ventilation system installed to prevent any leakage from entering the engine room atmosphere and in the piping system must be equipped a double walled pipe.

d. Engine selection
   Because in engine selection has to select dual fuel engine, author has a reference that may be used in this thesis. Here are the specifications of the main engine:

III.5 Calculation

In this step the calculation is carried out from the data that already got. The calculations performed are as follows:

- Engine Propeller Matching (EPM)
- Volume of Methanol and MDO in ship
- Fuel Consumption

III.6 Methanol Fuel System

In this step the design is made where the hope is able to be applied in the future. The parameters to be considered are the material to be used, the amount of equipment, and the safety parameters that follow the International Code of Safety for Ships using Gases or other Low Flashpoint Fuels (IGF Code).

There are some diffenrences between a conventional marine-diesel engine between methanol engine, the most considerable things that differ are:

- The cylinder head, where an extra injector is added.
- A Fuel Block, that accommodates fuel for injection
- The fuel delivery system, a part of the piping is double walled to detect any leakage.
- A special ventilation system for possible leakage.

III.7 Analysis and Explanation

Analysis carried out is the estimated cost required in modifying the ship can operate using dual fuel engines and comparison of operational costs in the use of fuel when single fuel (HFO/MDO) with dual fuel (Methanol and MDO).

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CHAPTER IV
DATA ANALYSIS AND EXPLANATION

IV.1 Data

In this thesis, the author makes a study case that will be applied on the MT Griya Flores ship. In applying this design system to the ship, it requires some vessel data such as ship's general data, general arrangement, and main engine specifications.

IV.1.1 General Data

Ship data that used in this Final Project is ship data chemcica; tanker "MT Griya Flores". The data are as follows:

Name of Ship	MT Griya Flores	Units
Type	Oil Product/Chemical Tanker	
LOA	78.25	m
Lpp	72	m
Breadth (B)	12	m
Height (H)	5.6	m
Draught (T)	5.1	m
Coefficient Block (Cb)	0.68	
Vs	12	knot
GT	1372	
DWT	2350	DWT

Table 4. 1 General Data Ship

IV.1.2 Main Engine Data

The Main engine that uses for this ship is HYUNDAI AKASAKA AX31. The data are as follows :

Specification	Detail	Units
Type	HYUNDAI AKASAKA AX31	
Power	1800	kW
Speed	290	rpm
SFOC	160	g/kWh
$SFOC_{MeOH}$	260.9	g/kWh
$SFOC_{MDO}$	8.95	g/kWh
Quantity	1	

Table 4. 2 Main Engine Data

IV.1.3 General Arrangement

The General Arrangement for this ship. The picture is as follows :

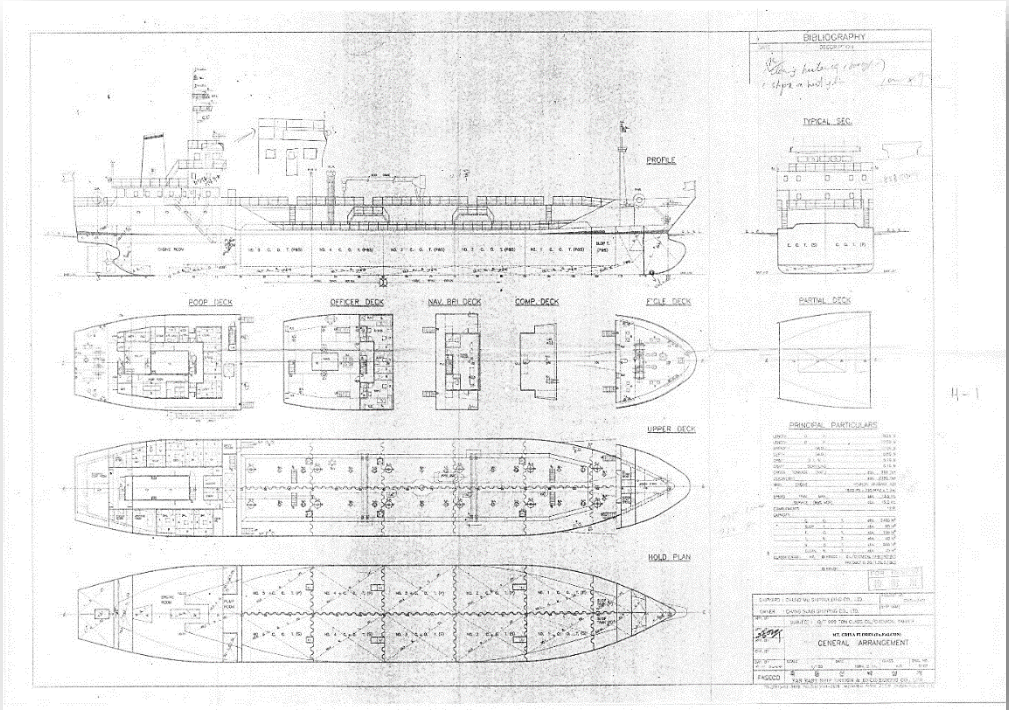

Figure 4. 1 General Arrangement of Ship

IV.2 Analysis Requirement for Fuel System

IV.2.1 Tank Capacity

IV.2.1.1 Energy Consumption Calculation for HFO

In the general data said the capacity of the fuel oil tank is about 105 m^3. And the author takes the cases to plan the sea routes from PT Kaltim Methanol Indonesia to Tanjung Priok. The distance of between both point is 1731 Nm. So we need to calculate the fuel consumption of the engine with HFO as fuel. The calculation is as follows :

WFO = BHPME . bME . (S/Vs) . 10-6 . C
WFO = 1800 . 179 . (1731/12) . 10-6 . 1.3
WFO = 60.42 ton

Because of this engine will be converted to dual fuel engine with methanol as main fuel and MDO as pilot fuel. There are some changes tank capacity with additional pilot tank capacity. Before we know how much the requirement of fuel the ship with methanol as a fuel. We need to calculate how much the energy that needed during the voyage to meet the requirement of the tank. So we need to calculate the energy consumption of HFO during the operation.

E = C x NCV
C = 60.420555 Ton
NCV (HFO)= 40000 MJ/tons
E = 2416822.2 MJ
From the calculation above, we get data of tank capacity according to design, fuel consumption, energy consumption of HFO as fuel during operation.

HFO as fuel		
Tank Capacity	**Fuel Consumption**	**Energy Consumption**
105 m^3	**60.42 ton**	**2416822.2 MJ**

Table 4. 3 HFO as Fuel of Ship

According to table above we know that the tank capacity has volume enough to put HFO as fuel during operation. And consume energy 2416822.2 MJ.

IV.2.1.2 Energy Consumption for Methanol and MDO

After we knew the energy consumption during voyage, we also need to calculate the Energy consumption of 95 % of fuel is methanol and 5 % of fuel is MDO to meet requirement for fuel consumption. So the author get the result, the data as follows :

The needs of energy =	2416822.2	MJ
95% of energy is Methanol =	2295981.09	MJ
5% of energy is MDO =	120841.11	MJ

Table 4. 4 Energy Consumption of Fuel

IV.2.1.3 Fuel Consumption for Methanol and MDO

After we know how much the energy needed so we calculate the fuel consumption. The calculation as follows :

C =	E / NCV	
E (Methanol) =	2295981.09	MJ
NCV (Methanol) =	20100	MJ/tons
C (Methanol) =	114.2279149	tons
E (MDO) =	120841.11	MJ
NCV (MDO) =	42700	MJ/tons
C (MDO) =	2.830002576	tons

Table 4. 5 Fuel Consumption

From the calculation above, we get data of tank capacity according to design, fuel consumption, energy consumption of Methanol and MDO as fuel during operation.

Methanol and MDO as fuel			
	Tank Capacity	**Fuel Consumption**	**Energy Consumption**
Methanol (95%)	**142.8 m^3**	**114.23 ton**	**2295981.09 MJ**
MDO (5%)	**3.18 m^3**	**2.83 ton**	**120841.11 MJ**

Table 4. 6 General Data of Fuel

According to table above we know that the tank capacity based on design doesn't have volume enough to put Methanol as fuel and need additional tank for MDO during operation. Because minimum requirement of capacitiy is 142.8 m^3 for methanol and 3.18 m^3 for MDO. So the tank volume has to be increased.

IV.3 Methanol Fuel System along with Safety Parameters

there are things that need to be considered where the safety parameters from the methanol tank to the main engine must also be safe. Basically there are 5 main point of component that should be found to complete the methanol fuel system. They are bunker station, storage tank, methanol fuel system, fuel valve train, and the engine system. The details will be explained further in the next session.

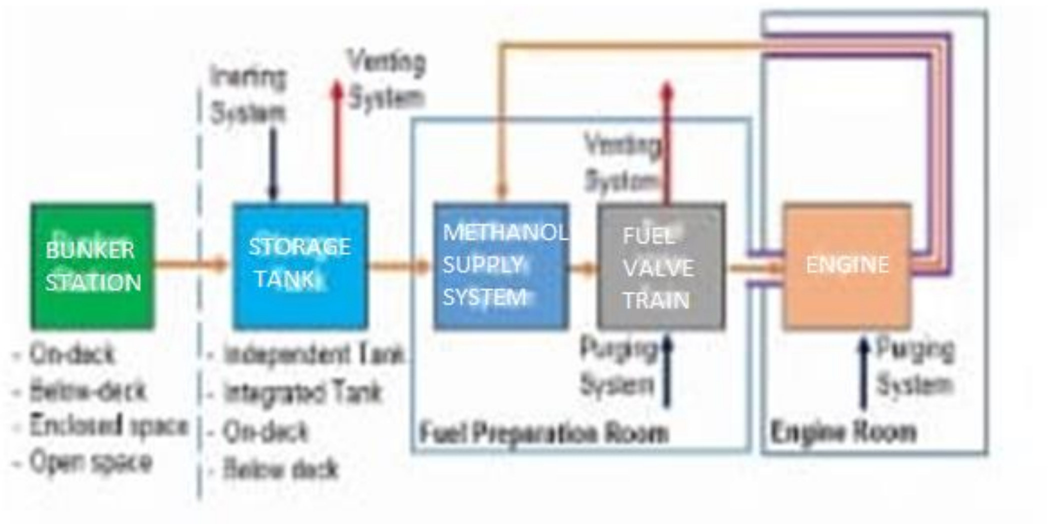

Figure 4. 2 Flow Diagram of Methanol Fuel System

IV.3.1 Laying Bunkering Station

The bunkering station laying must be considered, because the surrounding area is very dangerous and can cause death. Therefore, this placement must meet the requirements of the IGF Code (The International Code of Safety for Ships using Gases or other Low-flashpoint Fuels) which is very strict in regulating the hazardous zone area. Here are some hazardous zones need to be considered to implement this Code:

12.5 Hazardous area zones
12.5.1 Hazardous area zone 0
This zone includes, but is not limited to the interiors of fuel tanks, any pipework for pressure-relief or other
venting systems for fuel tanks, pipes and equipment containing fuel.
12.5.2 Hazardous area zone 122
This zone includes, but is not limited to:
.1 tank connection spaces, fuel storage hold spaces23 and interbarrier spaces;
.2 fuel preparation room arranged with ventilation according to 13.6;
.3 areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet, gas or vapour outlet,24 bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room ventilation outlets
and fuel tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;
.4 areas on open deck or semi-enclosed spaces on deck, within 1.5 m of fuel preparation room entrances, fuel preparation room ventilation inlets and other openings into zone 1 spaces;
.5 areas on the open deck within spillage coamings surrounding gas bunker manifold valves and 3 m beyond these, up to a height

of 2.4 m above the deck;

.6 enclosed or semi-enclosed spaces in which pipes containing fuel are located, e.g. ducts around fuel pipes,
semi-enclosed bunkering stations;
.7 the ESD-protected machinery space is considered a non-hazardous area during normal operation, but will
require equipment required to operate following detection of gas leakage to be certified as suitable for zone
1;
.8 a space protected by an airlock is considered as non-hazardous area during normal operation, but will require equipment required to operate following loss of differential pressure between the protected space and the hazardous area to be certified as suitable for zone 1; and
.9 except for type C tanks, an area within 2.4 m of the outer surface of a fuel containment system where such surface is exposed to the weather.
12.5.3 Hazardous area zone 225
12.5.3.1 This zone includes, but is not limited to areas within 1.5 m surrounding open or semi -enclosed spaces of zone 1.
12.5.3.2 Space containing bolted hatch to tank connection space.

Therefore, laying bunkering stations must be considered considering the safety factor affects the safety of the ship. Here is a picture of the position of the bunkering station.

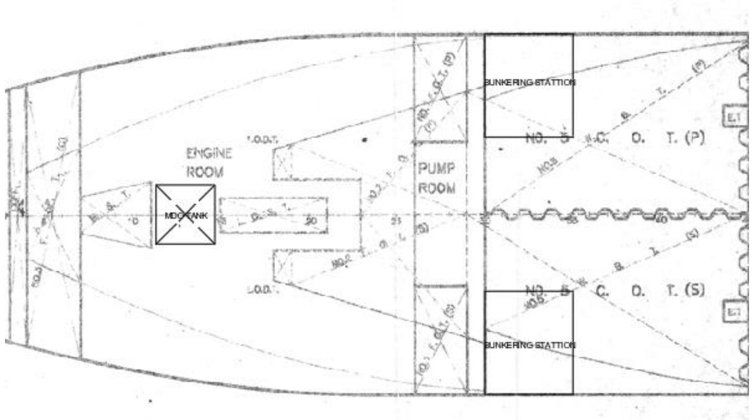

Figure 4. 3 Position of Bunkering Station

According to DNV GLs rules (ref. /19/), The bunkering station shall be so located that sufficient natural ventilation is provided. The bunkering station shall be separated from other areas of the ship by gas tight bulkheads, except when located in the cargo area on tankers. Bunkering station located from frame 30 to frame 35. There is 600 mm separation between Bunkering station and engine room and located in cargo area. This station has a length of 3 m; width 3 m; and the high is 4 m. The total volume of the room is 28 m^3.

IV.3.2 Storage Tank on Board

According to DNV GLs rules (ref. /19/), because of methanol fuel is low flashpoint liquid, the fuel tanks must be surrounded by protective cofferdams. And shall not be located in engine room. So the storage tank located in fuel preparation room. The room has 1200mm separation with the engine room to reduce the risk of fire according to regulation. And between methanol storage tank and the room, there is 800mm double barrier for the tank. For sensor requirement, 3 sensors installed. namely LAH (High Level Alarm), LAL (Low Level Alarm), TI (Temperature Indicator). To measure the depth of liquid and maintain pressure on the tank, the sounding pipe and air pipe are equipped in the tanks.

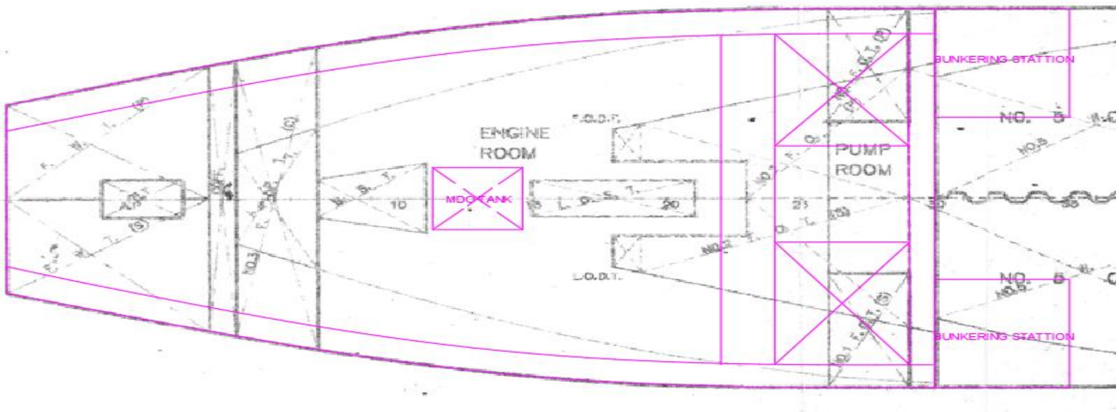

Figure 4. 4 Storage Tank on Board

The figure above is the location tank with the requirement of the safety parameters that we talk above. There are some modification which is the pump room is converted to fuel preparation room that consists methanol storage tank with surrounded by cofferdam, pump room, and duel supply system.

IV.3.3 Methanol Fuel System

Besides bunkering, there are other things that need to be considered where safety parameters from the methanol tank to the main engine must also be safe. This matter usually focus on the Methanol Fuel Valve Train (FVT) which is able to do ventilation if methanol has an inappropriate pressure before entering the engine and is able to shut down the supply when in a state emergency. Here is a picture of the safety system from the methanol tank to the main engine:

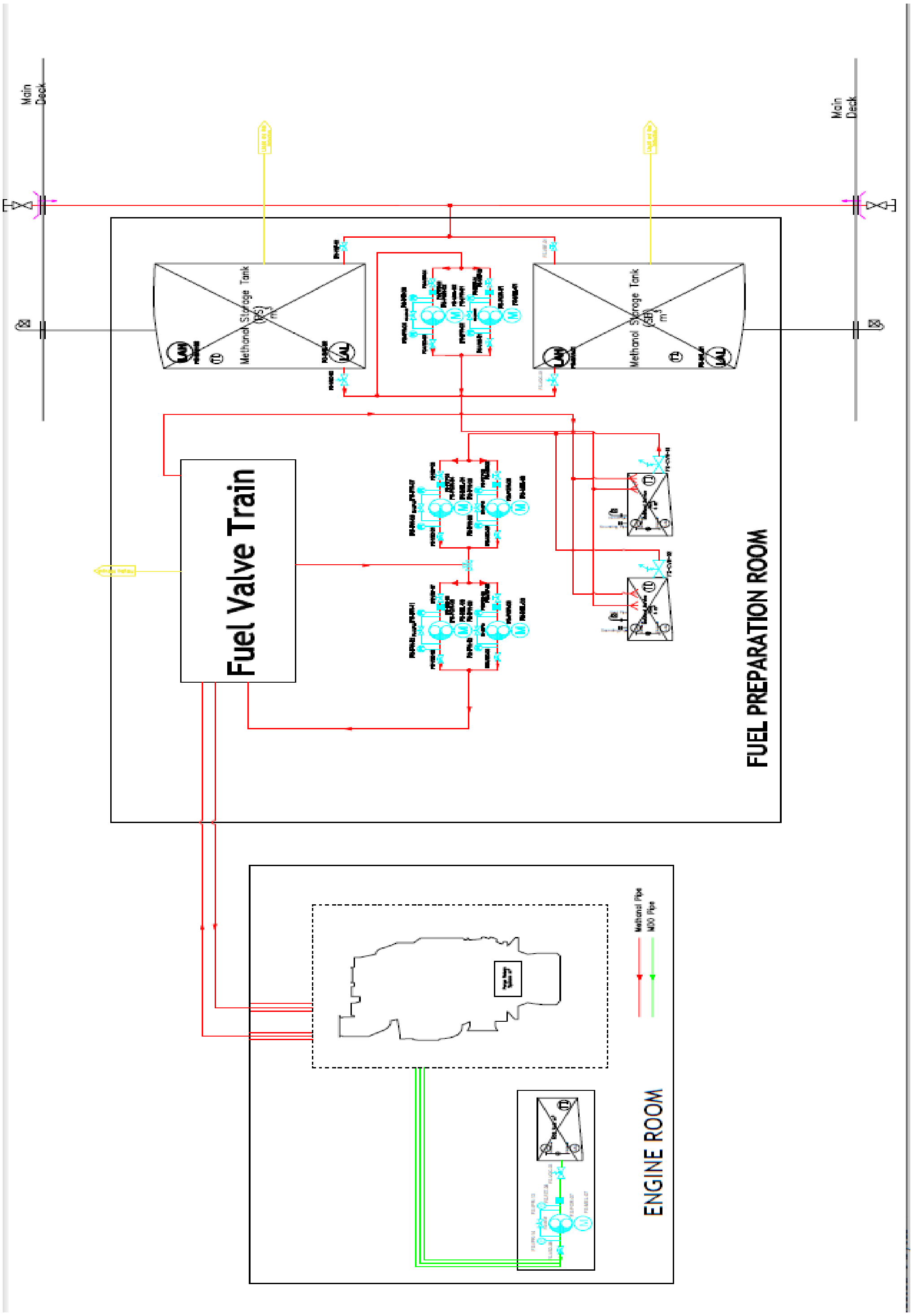

Figure 4. 5 Methanol Fuel System

IV.3.3.1 from Storage Tank to Service Tank

Methanol is a low flashpoint fuel, so the tank shall be arranged with vapour and liquid leakage detection to detect tha leakeages. For sensor requirement, 3 sensors installed. namely LAH (High Level Alarm), LAL (Low Level Alarm), TI (Temperature Indicator). To measure the depth of liquid and maintain pressure on the tank, the sounding pipe and air pipe are equipped in the tanks. To transfer from the storage tank to service tank, the system needs 2 pumps to required the safety reason if one of the pump doesn't work.

The methanol service tank shall be installed 3 sensor, they are LAH (High Level Alarm), LAL (Low Level Alarm), TI (Temperature Indicator). Sounding pipe and air pipe with flame screen are also installed in the tank.

IV.3.3.2 Methanol Supply System

According to the rules, there are some requirement shall be applied in the methanol supply system. Such as FVT, fuel pumps, protection in the piping system for safety issues. The piping system shall be entirely separated from the engine room and shall be arranged for gas-freeing and inerting. The double walled fuel pipe must be ventilated for open air and be equipped with a vapour and liquid leak detection. All the component of supply system are located in the fuel preparation room and vented to open air. The tank must be installed quick close valve to automatically shut off the fuel supply.

In this system there are circulation and supply pump to supply the fuel. Which is those component as main component of methanol supply system. And the other important component is the FVT. The function of FVT is to flow fuel to the engine and prevent any failure when the system in emergency condition with emergency shutdown to stop the fuel supply to the engine. So if there is overflow, the fuel will be back to the FVT and can flow to the circulation pump to be transfer again to the main engine.

IV.3.3.3 Combustion of Methanol Engine

Because of methanol is the fuel that quite enough to get the ignition. So the ignition needs more pressure to ignite the methanol so MDO as pilot burner directly injected to the combustion chamber. In this part there is some additional injection which is BFIV (Booster Fuel Injection Valve). The function of BFIV is increasing the pressure until reach the high enough pressure to ignite the fuel. this by using a hydraulic pressure of 300 Bar. When the injection pressure is sufficient the valve opens and the fuel is injected into the engine. The fuel is pumped from and stored inside a fuel block that is added beside each cylinder. Each fuel block contains enough fuel to accommodate for at least one injection.

IV.4 Cost Estimation

IV.4.1 Bill of Quantity Estimation

As the author has discussed in this thesis, the components of a conventional fuel system with a methanol fuel system have several differences. That makes the costs required are also different. The following is the estimation of bill of quantity in the methanol fuel system:

No	Item	Specification	Quantity	Unit Cost	Total Cost
1	Gear Pump		6 pcs	Rp 933,600,000	Rp 5,601,600,000
2	Duplex Stainless Steel	DN 20,27 m	60.21 kg	Rp 57,646	Rp 3,470,866
3	Duplex Stainless Steel	DN 40,9 m	29.61 kg	Rp 57,646	Rp 1,706,898
4	Duplex Stainless Steel	DN 15,12 m	19.80 kg	Rp 57,646	Rp 1,141,391
5	Butterfly Valve	DN40, PN6,	8 pcs	Rp 1,556,000	Rp 12,448,000
6	Elbow 90	DN40, PN6,	12 pcs	Rp 155,600	Rp 1,867,200
7	Elbow 90	DN40, PN6,	2 pcs	Rp 311,200	Rp 622,400
8	Elbow 90	DN40, PN6,	8 pcs	Rp 933,600	Rp 7,468,800
9	Screw Down Non Return Valve	DN40, PN6, Duplex Stainless Steel	2 pcs	Rp 1,400,400	Rp 2,800,800
10	Screw Down Non Return Valve	DN20, PN6, Duplex Stainless Steel	1 pcs	Rp 1,322,600	Rp 1,322,600
11	Safety Valve	1 bar, Duplex Stainless Steel	1 pcs	Rp 933,600	Rp 933,600
12	Safety Valve	6 bar, Duplex Stainless Steel	1 pcs	Rp 778,000	Rp 778,000
13	Safety Valve	10bar, Duplex Stainless Steel	1 pcs	Rp 2,053,920	Rp 2,053,920
14	Filter	Finished Product	2 pcs	Rp 2,053,920	Rp 4,107,840
15	Three Way Globe Valve	DN20,PN6, Duplex Stainless Steel	5 pcs	Rp 142,500	Rp 712,500

16	T Joint	10"	11 pcs	Rp 142,500	Rp 1,567,500
17	Level Alarm	Finished Product	5 pcs	Rp 169,000	Rp 845,000
18	Remotely Operated Closing Valve	Duplex Stainless Steel	2 pcs	Rp 794,417	Rp 1,588,835
19	Pressure Indicator	Finished Product	12 pcs	Rp 144,440	Rp 1,733,274
20	Temperature Indicator	Finished Product	5 pcs	Rp 117,285	Rp 586,424
21	Air Pipe with Flame Screen	Finished Product	4 pcs	Rp 1,081,054	Rp 4,324,215
22	Sounding Pipe	Finished Product	4 pcs	Rp 414,299	Rp 1,657,197
23	Bunker Connection	Finished Product	2 pcs	Rp 86,664	Rp 173,327
24	Temperature Indicator	Finished Product	5 pcs	Rp 739,820	Rp 3,699,100
25	Pressure Indicator	Finished Product	5 pcs	Rp 147,964	Rp 739,820
26	MeOH Fuel Valve Train	Finished Product	1 pcs	Rp 23,585,049	Rp 23,585,049
				Total	Rp 5,783,698,001

Table.4.7 Estimation of Bill of Quantity

IV.4.2 Fuel Cost Estimation

In this case, to estimate the operational cost of the ship we need to calculate how much cost will takes in using methanol as a main fuel and MDO as pilot fuel. The following prices of methanol is shown in the figure 4.6.

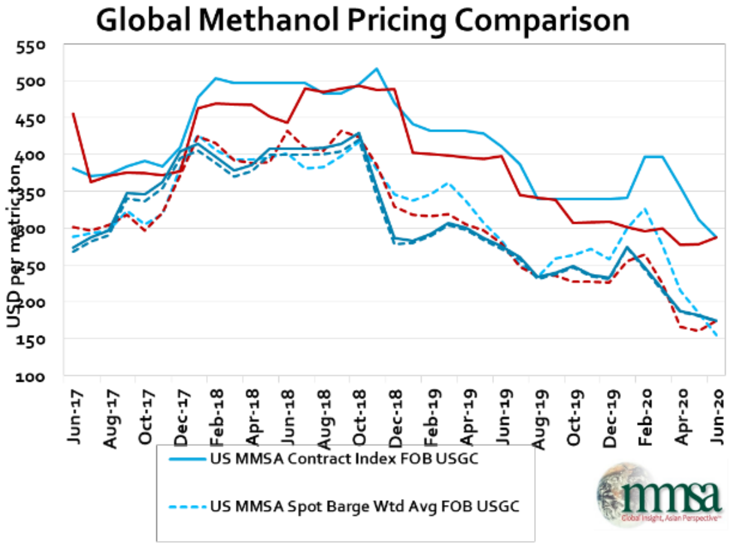

Figure 4. 6 Methanol Fuel Price

As the author discuss above, the fuel consumption of methanol is 114.23 ton and the consumption of MDO is 2.83 ton.

Methanol and HFO as fuel				
	Price	Fuel Consumption	Fuel cost (USD)	Fuel Cost (Rp)
Methanol	174 usd/ton	114.23 ton	19.876 usd	Rp. 292,595,589.89
MDO	349.25 usd/ton	2.83 ton	988.37 usd	Rp. 14,549,844.19
HFO	335.5 usd/ton	60.42 ton	20.270 usd	Rp. 298,395,683.50

Table.4.8 Estimation of Fuel Cost

According of table above, as we can see the total of methanol and MDO cost is a little bit higher than HFO as fuel. The total Methanol and MDO is about 20,864.38 usd and the total cost of HFO is about 20.270 usd.

IV.4.3 Engine Retrofit Cost Estimation

Because of in this case the ship is converted from conventional engine to methanol engine. There are some additional cost for engine retrofit. According to FCBI energy Methanol as a Marine Fuel Report, retrofit cost of an engine from diesel fuel into dual-fuel (methanol and diesel), has been estimated to be € 250 – 350/kW for large engine (10 – 25 MW). MAN also has converted an engine with 10 MW and the result of the conversion cost is € 270/kW.

The ship has main engine Hyundai Akasaka AX31 that has 1800 KW. So the engine retrofit cost will be shown on the table below :

Engine Size	Cost/KW	Total Cost(€)	Total Cost (Rp)
1800 KW	€ 250/KW	€450,000	Rp.7.859.500.236

Table.4.9 Estimation of Engine Retrofit Cost

IV.5 3D Drawing for Methanol Fuel System Layout

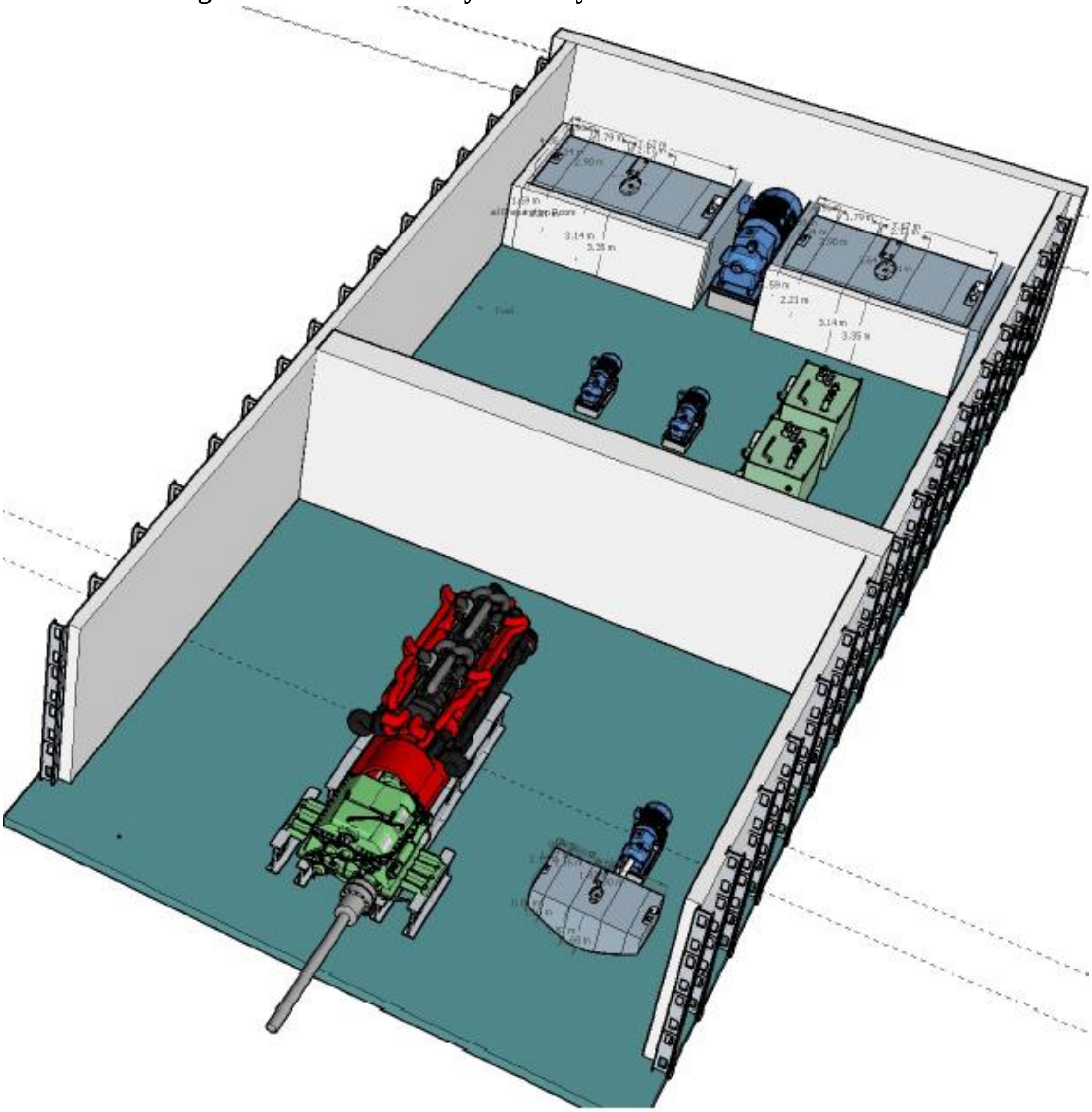

Figure 5.1 Fuel System 3D Layout

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CHAPTER V

CONCLUSION

V.1. Conclusion

From the results of mathematical calculations and several designs according to the IGF Code and rules classification, the conclusions that can be drawn from this final project research are as follows:

1. Methanol systems required a high level of security to meet IMO regulations and classifications. Fuel tank and a minimum distance of 800 mm will be taken. On the board, the ship will have at least 2 fuel tanks.
2. The components required in the methanol fuel system are different from conventional fuel systems. in the methanol fuel system there are some additional components not found in conventional fuel systems but the addition of components is not significant. The methanol fuel cost is about Rp.307,145,433 and the HFO fuel cost is about Rp. 298,395,683.50. in this case relatively more expensive than the conventional fuel. The retrofit of the engine is about Rp.7.859.500.236 So overall the total additional costs needed for the methanol fuel system are depends of the specification of the ship.
3. The tank capacity needed by methanol fuel on ships requires a larger tank. amounting to 142.8 m3, so a larger tank volume is needed. Ships will lose their cargo. Storage tanks must be protected by cofferdam which requires a lot of space.

V.2 Suggestion

This thesis research still has some shortcomings making the reason for the use of the methanol fuel system to be better than the conventional fuel system, especially in the analysis of emissions produced and economic analysis. Maybe in analyzing emissions and economic value in the future can be calculated by research or analysis that has a relationship with this thesis so that the reason for methanol as a fuel system is one of the options in reducing emissions.

BIBLIOGRAPHY

[1] Marine Pollution (Marpol) Annex VI Regulation 14
[2] E M Priyanto, Biro Klasifikasi Indonesia, Indonesia, A I Ölçer, D Dalaklis, and F Ballini, World Maritime University, Sweden "EXAMINING METHANOL AS AN ALTERNATIVE MARINE FUEL FOR INDONESIAN DOMESTIC SHIPS"
[3] https://pubchem.ncbi.nlm.nih.gov/compound/Methanol
[4] IMO, Methanol as marine fuel: Environmental benefits, technology readiness, and economic feasibility
[5] Alliance Consulting International, 2008
[6] https://www.livebunkers.com/methanol-marine-fuel
[7] Mark Penfold, December 11, 2018 "Methanol as a Marine Fuel:
[8] ME-LGI Engines Liquid Gas Injection – Methanol and LPG
[9] Ulf T Freudendahl, 17th March 2015, "Methanol as Ship Fuel Handling of Safety Matters"
[10] Using Methanol Fuel in the MAN B&W ME-LGI Series

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