BACHELOR THESIS – ME 184841

SCRUBBER APPLICATION FOR MT SENIPAH TO MEET THE REGULATIONS IN 2020

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DOUBLE DEGREE PROGRAM
DEPARTMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
2020

TUGAS AKHIR – ME 184841

PEMASANGAN SCRUBBER UNTUK MT SENIPAH UNTUK MEMENUHI PERSYARATAN DI TAHUN 2020

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APPROVAL SHEET

SCRUBBER APPLICATION FOR MT SENIPAH TO MEET THE REGULATIONS IN 2020

BACHELOR THESIS

Proposed to fulfill a requirements for Bachelor Engineering Degree
On
Marine Machinery Fluid and System (MMS)
Bachelor Program Department of Marine Engineering
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember

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AUGUST, 18th 2020

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DECLARATION OF HONOR

As the result of this who signed below declare that:
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Name	: Oscar Alfinza Fadiwi
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Bachelor Thesis Title	: Scrubber Application For MT Senipah To Meet The Regulations In 2020
Department	: Marine Engineering

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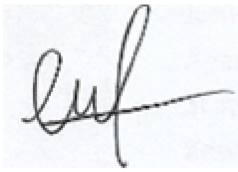

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SCRUBBER APPLICATION FOR MT SENIPAH TO MEET THE REGULATIONS IN 2020

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ABSTRAK

Jika kita melihat aturan IMO tentang mengendalikan emisi lingkungan yang disebabkan oleh mesin utama kapal, pada tahun 2020, semua kapal yang berlayar di area Internasional, harus membatasi kandungan sulfur pada gas buang sebesar 0,5% atau kurang. Melihat kurangnya batasan sulfur yang diatur oleh IMO, hampir semua kapal harus mengurangi kandungan sulfur yang terkandung di Exhaustnya. Jadi, alternatif untuk mengurangi kandungan sulfur di gas buang adalah menginstal alat, bernama Scrubber. Prinsip kerja Scrubber adalah membersihkan gas buang dari partikel keras dan menurunkan suhu gas hingga batas tertentu. Kandungan sulfur pada gas buang berkurang karena air pancuran. Dan kemudian, air diproses dan dialirkan kembali ke laut. Jadi, kapal berbendera Indonesia yang berlayar di area Internasional harus siap memasang scrubber untuk berlayar sampai tujuan yang kami tuju. Karena harga Scrubber terlalu mahal dan peralatan ini relatif baru, kita perlu mempersiapkan scrubber dan dianggap mungkin untuk efektivitas lingkungan laut. Harga pemasangan Scrubber Hybrid loop ini sekitar 1,282 Juta Euro dan diprediksi perbedaannya 57% lebih murah dari perkiraan Berqvist et al yang mencapai 3 juta Euro. Perbedaan estimasi biaya per tahun dalam *Open Loop* dan *Closed loop* berbeda sekitar 1,073 Miliar Rupiah atau 1061,1% per tahun. Sedangkan pada *Operational Expenditure*, *Open Loop* dan *Closed Loop* memiliki nilai perbedaan yang sama, namun dengan persentase 100,23% per tahun.

Kata Kunci: Scrubber, kandungan sulfur, gas buang, estimasi biaya, kapal

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SCRUBBER APPLICATION FOR MT SENIPAH TO MEET THE REGULATIONS IN 2020

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ABSTRACT

If we see IMO rules about controlling environmental emissions caused by ship's main engine, by 2020, all the ship that sailed in International zone, must limit the sulphur content at the exhaust gas at 0.5% or less. See the lack of sulphur limitation refered by IMO, almost all ships must decrease the sulphur content that contain at its exhaust. So, the alternative for decreasing sulphur content at the exhaust gas is installing the tool, named Scrubber. The work principal of Scrubber is to clean the exhaust gas from hard particles and decrease gas temperature until at certain limit. The sulphur content at exhaust gas is decreased because of the shower water. And then, the water is processed and flowed back to the sea. So, the ship with Indonesian flag that sail at International area must be prepared for attaching a scrubber for sailing until the destination that we demand. Because Scrubber price is too expensive and this equipment is relatively new, we need to prepare the scrubber and considered as possible for effectivity of marine environment. The cost estimated for Scrubber attachment is about 1,282 Million Euro and predicted difference is about 57% cheaper than Berqvist et al Estimation which is 3 Million Euro. Cost Estimation per year between Open Loop and Closed Loop is about 1,073 Billion Rupiah or 1061,1% per year. While at Operational Expenditure, Open Loop and Closed Loop have a same difference, but in percentage is 100,23% per year.

Keyword: Scrubber, sulphur content, exhaust gas, cost estimation, ship

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PREFACE

Thanks to Allah SWT that gives me chance to make this thesis named "SCRUBBER APPLICATION FOR MT SENIPAH TO MEET THE REGULATIONS IN 2020" with an optimal result. This thesis is proposed for a graduation requirement for Bachelor Engineering at Double Degree Marine Engineering program at Institut Teknologi Sepuluh Nopember Surabaya. Writer also think this thesis also have some mistake so this needs critics and suggestions, so this thesis would be useful later on.

In the way of working this thesis, and process to get Bachelor Engineering achievement can be achieved by help from people and another side. So, the writer say thank you for these people below,

1. Writer Family, Ms. Hermin Fariyana, Mr. Edy Widarto, Auviera Pascafiwi that always support and bless this writer
2. Mr. Gandung and Mrs. Linda that give me some required data for this thesis
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4. Mr. Ir. Dwi Priyanta, M.SE as Lecturer that always bless and motivate this writer.
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9. And everyone that I cannot mention one by one

Surabaya, 30 May 2020

Oscar Alfinza Fadiwi

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LIST OF NOMENCLATURE

- SECA: Sulphur Emission Control Areas
- IMO: International Maritime Organization
- ppm: Parts Per Million
- MW: Mega Watt
- USD: US Dollar
- ECA: Emission Control Areas
- mmbtu: million british thermal unit
- LNG: Liquefied Natural Gas
- DNV GL: Det Norske Veritas – Germanischer Lloyd
- rpm: Revolution per Minute
- g/kWh: Gram per Kilowatt Hour
- SO_x: Sulphur Oxide
- m/m: Mass by Mass
- MGO: Marine Gas Oil
- MDO: Marine Diesel Oil
- HFO: Heavy Fuel Oil
- HSD: High Speed Diesel
- EGE: Exhaust Gas Economizer
- SCR: Selective Catalytic Reduction
- MEPC: Marine Environment Protection Committee
- Add. : Addendum
- Pa: Pascal
- Nm^3/h: Normal Meter Cubic per Hour
- m/s: Meter Per Second
- F.W: Fresh Water
- P: Power
- t: Time
- SFOC: Specific Fuel Oil Consumption

- mm: milimetre
- ft: feet
- kW: Kilo Watt
- CL: Continous Load
- NRV: Non Return Valve
- S.W: Sea Water

CHAPTER 1
INTRODUCTION

1.1. Background

In Indonesia, there are many ships that sails to international areas to export commodities or import commodities. Based on IMO Regulations, the ship that sails at International areas start at 1 January 2020, must limit the sulphur content at 0,5 % at local SECA (Sulphur Emission Control Areas) and 0,1% (SECA Areas) (Makkonen, 2017). If we see the lack of emission that refered to IMO rules, almost all ships in Indonesia must attach the Scrubber into their ships. It will be predicted about 3000 ships, new built or existing one will chose Scrubber attachment to comply the rules of IMO 2020. Based on DNV GL, the ship that install scrubber until May 2019 reached 3266 units. And for the tanker itself have 470 ships including MT Senipah.

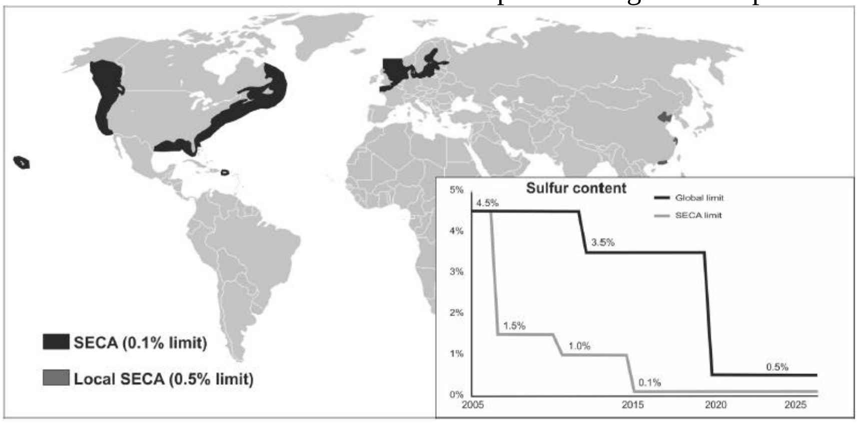


Figure 1.1 The geographical and regulatory aspects (sulfur content in bunker fuel) of Sulfur Emission Control Areas (SECAs) [4]

Based on the regulation, the sulphur content that will be permitted in marine fuels is 3,5% while ships operating at ECA (Emission Control Areas) at 1%(10000 ppm), global limitations will decrease the sulphur content at 0,5%(5000 ppm) at 2020 and at Emission Control areas is decreased from 1% to 0,1% (1000 ppm) since 2015.

Table 1.1 Outside and Inside ECA Limit of SOx and particulate matter [11]

Outside an ECA established to limit Sox and particulate matter emissions	**Inside an ECA established to limit Sox and particulate matter emissions**
4.50% m/m prior to 1 January 2012	1.50 % m/m prior to 1 July 2010
3.50% m/m on and after 1 January 2012	1.00% m/m on and after 1 July 2010
0.50% m/m on and after 1 January 2020	0.10% m/m and after 1 January 2015

Based on MT Senipah's data, the first data will be

Table 1.2 MT Senipah's first data

Parameter	Results
Fuel Oil Consumption (100%)	181,31 g/kWh (+5% margin)
Engine Power	4440 kW
Engine Speed	173 rpm
Exhaust Gas temperature (110% load)	418^{O} C
Fuel Oil Sulphur Content	0,23% m/m

For the equivalence with Sulphur Content itself with Emission ratio, can be seen on data below:

Table 1.3 Sulphur Content and Ratio Emission Equivalence [12]

Fuel Oil Sulphur Content (%m/m)	Emission Ratio (SO2(ppm)/CO_2(% v/v))
4,50	195,0
3,50	151,7
1,50	65,0
1,00	43,3
0,50	21,7
0,10	4,3

Based for the equivalence predictions, the fuel of MT Senipah have an emission ratio about 9,959 SO_2(ppm)/CO_2(%v/v)

For the estimation cost for Scrubber Application, there are several types of scrubbers as shown on data below:

Table 1.4 Cost Estimation of Scrubber Application [14]

Types of Scrubbers	Retrofit cost(20 MW Cargo Vessel	New Buid cost (20 MW Cargo Vessel)
Open System	2,4 Million Euro	2,1 Million Euro
Closed System	2,4 Million Euro	1,9 Million Euro
Hybrid System	3,0 Million Euro	2,6 Million Euro

Based on the table, the retrofit cost may be expensive than new build cost because we add an addition systems to the ship.

For the fuel oil price prediction can be arise from 57% to 85% from some studies

Table 1.5 Comparation price of Fuel Oil by some Studies [14]

Study	Forecasted price of MGO/MDO with 0.1 % sulphur content year 2015 per tonne	Forecasted price increase between HFO with 1.5% sulphur content and MGO/MDO with 0.1 % sulphur content
COMPASS	883 USD	65%
ISL	Low Cost Scenario: 850 USD High Cost Scenario: 1300 USD	70-86% 57-75%
Kalli et al.	633-673 USD	73-85%

And the prediction of LNG fuel mentioned by Santoso, 2014 is 21 USD /MMBTU and assumption with using 65% LNG and 35% Diesel. Sometimes LNG and Low Sulphur Diesel oil is available only in several areas, but Heavy Fuel Oil is cheap and available on many ports. So, retrofitting Scrubber is an option to comply Marpol IMO Regulation Annex 6 to keep allowance to use HFO.

1.2. Problem Statement

From the description above, then we can determine the main issues that will be discussed more as mentioned below:

1. How is the effect of Scrubber Application for MT Senipah?
2. How to determining the result after Scruber Application?
3. How to calculate the system before Scrubber Application?
4. How much the price estimation for Scrubber Application?

1.3. Research Objectives

Based on problems mentioned above, the goals of this research are:

1. Provide the effect of Scrubber Application for MT Senipah.
2. Provide the result after Scrubber Application.
3. Calculating the Scrubber system to Applied in MT Senipah
4. Estimating the cost for Scrubber Application

1.4. Scope of Study/Research Limitation

This final project will be focused and organized with limitations on problem, which are:

1. Analysis of Sulphur content after Scrubber attachment.
2. Analysis of calculation at Scrubber System.
3. This research will be done on MMS – PT. Pertamina Shipping International Project with SEPCO
4. Estimating cost for Scrubber Application
5. Assuming if this ship using Hybrid loop system

1.5. Research Benefits

This final project is expected to give benefits for various parties. The benefits that can be obtained are:

1. Sulphur content can comply to the IMO Regulations in 2020.
2. Knowing the effect after Scrubber Application.
3. Estimating costs for scrubber application

1.6. Pros and Cons of Scrubber Application

There are several pros about Scrubber Instalation, such as:

1. The Sulphur content (SO_x) can comply to regulations in Marpol regulation in 2020
2. Can continously run with HFO which is cheaper than Compliant fuel.

Beside of that, there are several consequences of Scrubber Application, such as:

1. Redesign the system of the aft side of the ship
2. Off duty due to scrubber system installation (approx. 18 days)
3. Class approval
4. Engine Room space may be limited
5. Weight addition of required systems
6. Calculating the existing electrical system and make sure the generator can supply all electricals including scrubber system (e.g monitoring systems and water pumps)

CHAPTER 2
LITERATURE STUDY

2.1 Scrubber

Scrubber is a system that used to remove harmful materials from exhaust gases that can give an effect to the environment. The basic of the Scrubber system is spraying the exhaust gas with the seawater to capture the carbon particles and SO_x gas content that formed into Sulphuric Acid (H_2SO_4) when the gas is on contact with water and reduce PM (Particulate Matter). Before the wash water is discharge into the sea, the wash water itself is filtered from sludge that contains carbon particles and other particulate fuel impurities. Depending on onboard treatment and discharge pipe configuration it is likely that the wash water will be in the form of a warm acidic jet. The immediate effects of the acidic discharge are mitigated due to rapid pH recovery back to ambient levels in the vicinity of the discharge nozzle. The scrubber itself has 2 categories of Scrubbers, which is Wet Scrubbers (Open Loop, Closed Loop, Hybrid) and Dry Scrubbers.

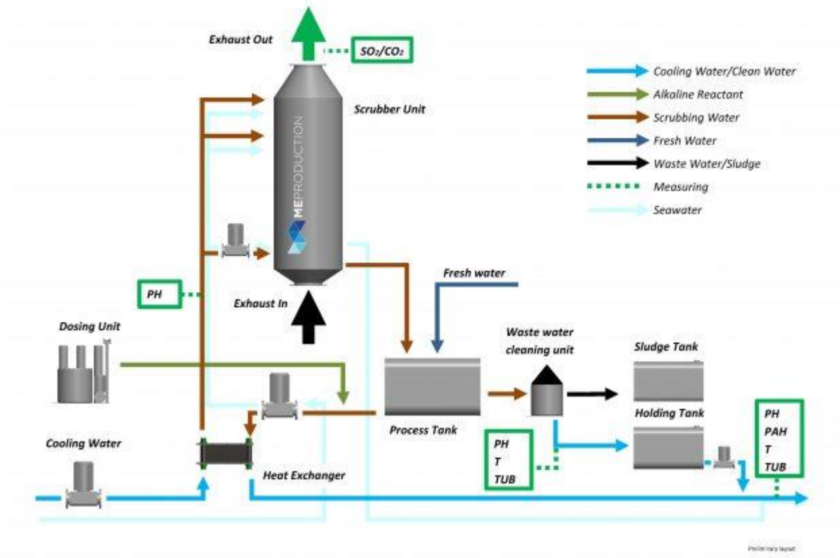


Figure 2.1 Scrubber System [15]

2.2 Wet Scrubber

Wet Scrubbing is an Original type of Scrubbing Systems. In a wet Scrubber System, the gas is going through in an exhaust pipe and then, seawater is actively sprayed. Water is used when the gas needs dust and particulate matter is removed. Basically, other chemicals are added that react with certain airborne contaminants. Since this process adds so much vapor to the exhaust, if the gas is vented, it typically looks like white smoke.

The sprayed liquid is collected in the Sludge Tank. This liquid is funneled away from the spraying chamber and collected for disposal. Since the liquid contains a wide range of potentially harmful materials, it cannot be reused or simply poured down the drain. Wet Scrubber also have a several components, such as a scrubber unit, a treatment plant, a residue handling facility for sludge, and a scrubber control and its monitoring system.

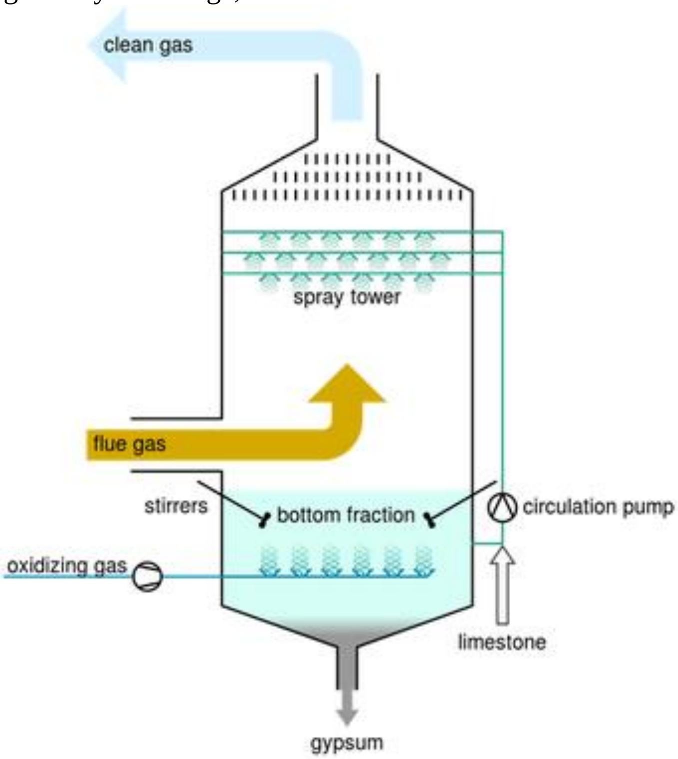


Figure 2.2 Wet Scrubber [3]

2.3 Dry Scrubber

Dry Scrubber or Dry Scrubbing system is a system that remove the pollution from harmful gases. Dry Scrubbers are used to remove harmful gases and particulate matter from Industrial exhaust gas, even to reduce exhaust gases that cause acidic rain. These scrubbers are applicated on Asphalt Processing, Pharmanauticals, and Oil and Gas. And the works is same as Wet Scrubbers but it uses dry reagents as a spray on this system. There are three steps to neutralize the gas, such as gas cooling, reagent injection, and filtering. First, gas cooling can be done to prepare exhaust gases. In gas cooling, the exhaust gas is cooled to remove the pollutant easier to remove pollutants and other toxins at the gas, then the dry reagents can be injected into the system. The compontent of dry reagent is Sodium Bicarbonate because of the neutralizing capabilities. And the system can be placed before gas exhaust economizer (EGE) or by using Selective Catalytic Reduction (SCR) which is require an exhaust gas above 350^0 C to enable the catalyst to operate corretly. This system also uses Caustic Lime ($Ca(OH)_2$) as granules and react with Sulphur Dioxide (SO_2) which form calcium Sulphate

$$SO_2 + Ca(OH)_2 \rightarrow CaSO_2 + H_2O \quad (1)$$

Then, Calcium Sulphate is Air-oxidized to form Gypsum (calcium sulphate dehydrate)

$$CaSO_3 + \frac{1}{2}O_2 \rightarrow CaSO_4 \quad (2)$$

And, the reaction of caustic lime with sulphur trioxide is:

$$SO_3 + Ca(OH)_2 \rightarrow CaSO_4 + H_2O \quad (3)$$

Figure 2.3 Dry Scrubber [17]

2.4 Open Loop Scrubber System

In Open Loop Scrubber System, it uses seawater for purification, and then the water is pumped back to the sea. This system is efficient in sea areas with high salt levels and also needs sea environments with high salinity and alkalinity to discharge the wash water to neutralize. The systems located near chimney of the ship and also needs space for water monitoring system and pumps, so it takes a lot of space, which can reduce the cargo capacity. Sea water is supplied by pump. CO_2 dissolves into sea water forms carbonic acid, bicarbonate, or carbonate ions. Depends on pH. The positive ions can be Calcium (Ca^{2+}) or sodium (Na^{+}), the example of salts in this case is sodium carbonate. When the ions reacts with an acid, CO_2 is released with the following formula.

$$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2 \quad (4)$$

$$Na_2SO_3 + \frac{1}{2}O_2 \rightarrow Na_2SO_4 \quad (5)$$

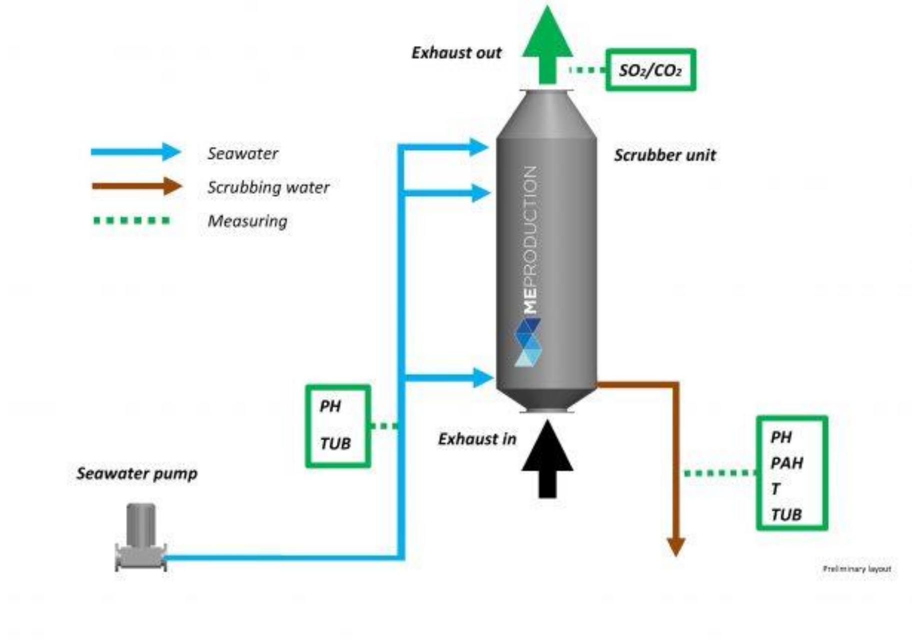


Figure 2.4 Open Loop Scrubber System [18]

2.5 Closed Loop Scrubber System

Closed Loop Scrubber system use freshwater and seawater to clean the exhaust gas. The filtered waste is generated and collected in special tanks. And then, the waste is unloaded in specialized port facilities that can handle the scrubber waste. In some ports, vessels will charged per amounts of scrubber waste discharged. This system requires more equipment that open loop system because this system requires extra tanks for chemicals (caustic soda) and waste. The water is circulated through the system to keep the scrubbing process, in addition possibility of water discharge is little or no water discharge. Most of the wash water will be processed and this system uses a chemical which is sodium hydroxide or caustic soda. And some manufacturers claim that this system is more efficient because this system requires half or less of the wash water at the same scrubbing efficiency because of the higher levels of alkalinity levels can be controlled using caustic soda injection process. For the fresh water scrubbers, SO_2 Combines with a salt and do not react with the natural bicarbonate of seawater. And no release of CO_2. The reaction formula for closed loop can be seen on the formula below:

$$Na_2SO_3 + SO_2 + H_2O \rightarrow 2NaHSO_3 \quad (6)$$

$$NaOH + H_2SO_4 \rightarrow NaHSO_4 + H_2O \quad (7)$$

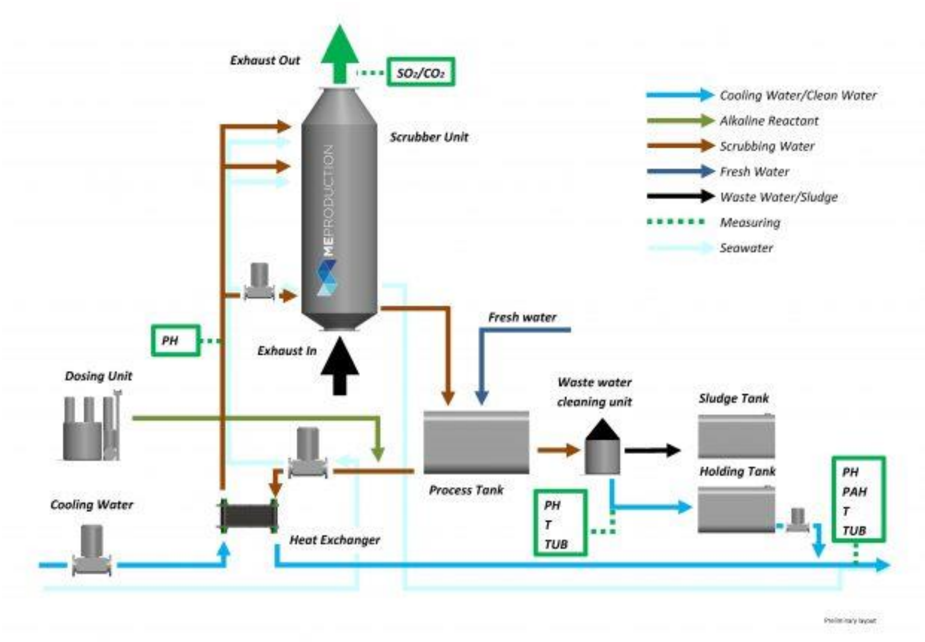


Figure 2.5 Closed Loop Scrubber System [16]

2.6 Hybrid Loop Scrubber System

Hybrid Loop Scrubber System is a combination of open loop scrubber system and closed loop scrubber system. This system enables closed loop operation if needed. Sometimes, at sea the system can be made to open loop system that using only seawater. Hybrid loop Scrubber System can combine many advantages of scrubber system, such as avoiding of purchasing and handling caustic soda in open loop system and have the same efficiency when there is zero discharge zone in Closed loop system.

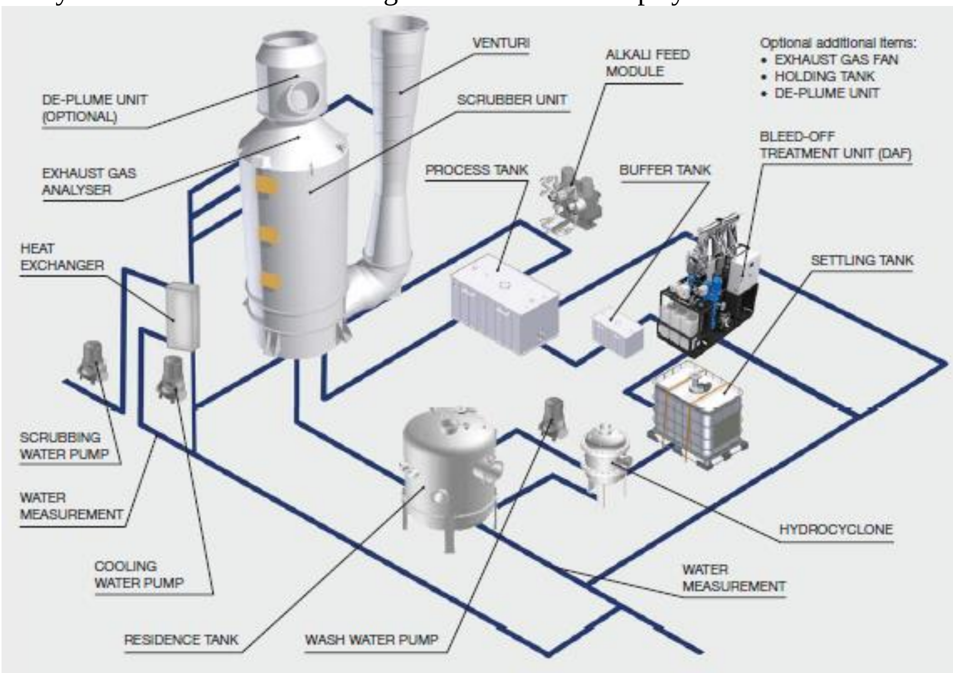


Figure 2.6 Hybrid Loop Scrubber System [8]

2.7 Wash Water Requirements

Based on Ülpre (2014), the wash water requirements are comply with the MEPC 59/24/Add.1 Annex 9 regulation, which is:

I. The discharge wash water have a required pH at minimum 6,5 measured at ship's overboard discharge via monitoring systems. Except during manouvering and transit, the maximum difference between inlet and outlet is 2 pH units is allowed measured at the ship inlet and overboard discharge via monitoring systems.
II. After scrubber installation, the discharged wash water should be measured externally from the ship, and the discharge pH at the ship's monitoring point will be recorded when the plume at 4 m from the discharge point equals or is above 6,5

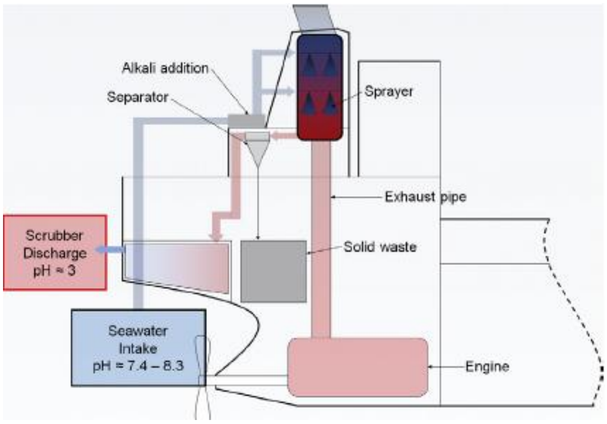


Figure 2.7 Schematic of a typical wet open loop exhaust gas scrubber setup [9]

2.8 The Effect if The Sulphur Content is Too High

Based on IMO regulation 14 that regulates Sulphur Oxides (SO_X) and Particulate matter, SO_X and another particulate matter is a component that apply on all fuel oils. SO_X is generated by combustion of fuel oil due to sulphur content that will not be removed from fossil oils. If the sulphur content is too high (SO_X) have many effects, e.g Acidic rain that will decrease the water pH, plant damage (that happened at 0,5 ppm of sulphur) and so on.

2.9 Heat Exchanger

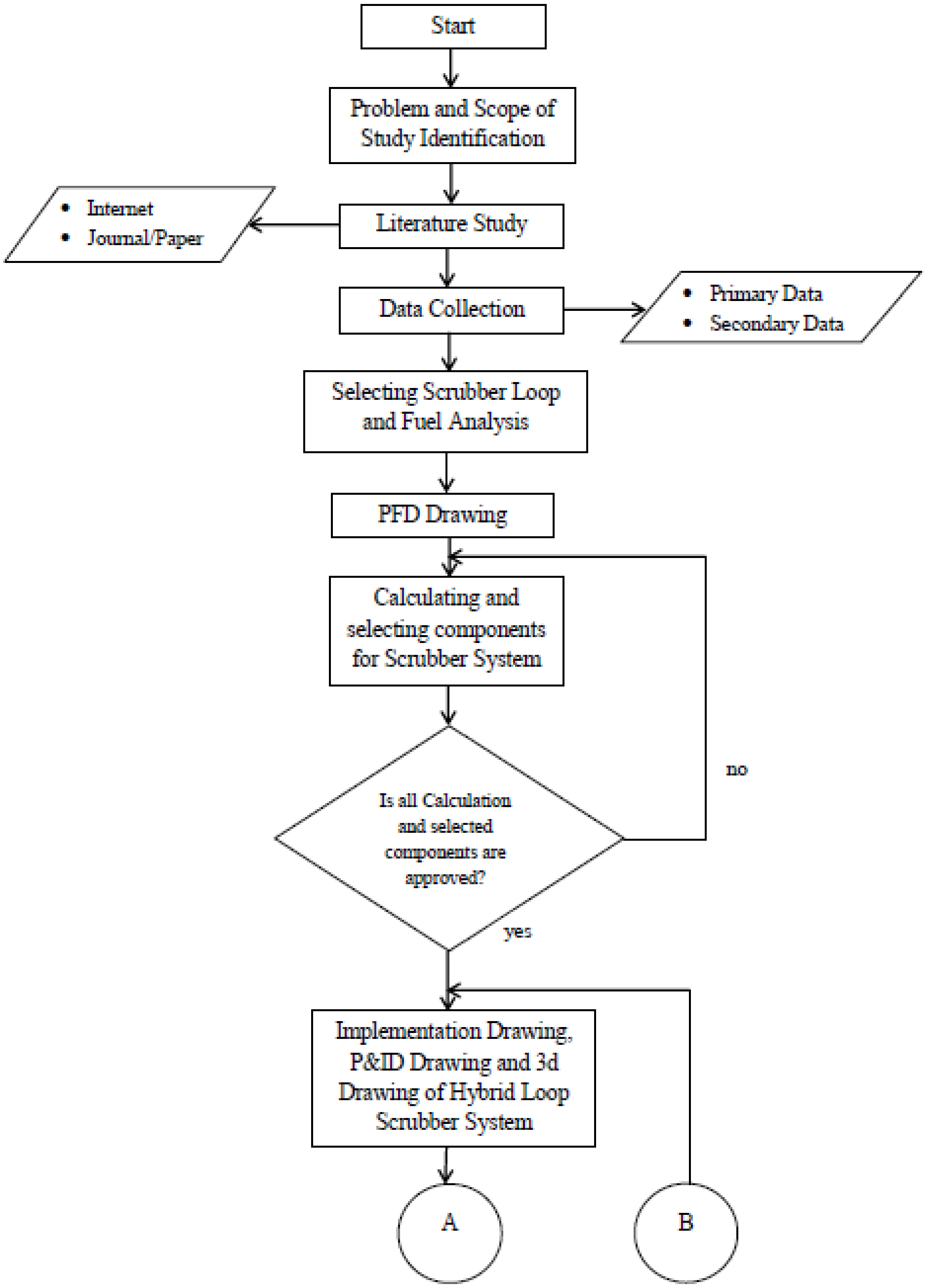
Heat Exchanger is a heat transfer device that is used to transfer the heat one fluid to another fluid or more fluid at different temperatures. This system consists of heat exchanging elements such as a core or matrix contains heat transfer surface, and fluid distribution elements, such as headers or tanks, inlet and outlet nozzles or pipes, etc. There are several types of Heat Exchangers such as tubular heat exchanger, plate heat exchangers,etc. This system is used on automobile radiators, air conditioning, and scrubber system (closed-loop or hybrid loop) in this case.

(b)

Figure 2.8 Heat Exchanger [20]

CHAPTER 3
METHODOLOGY

3.1 Research Scheme



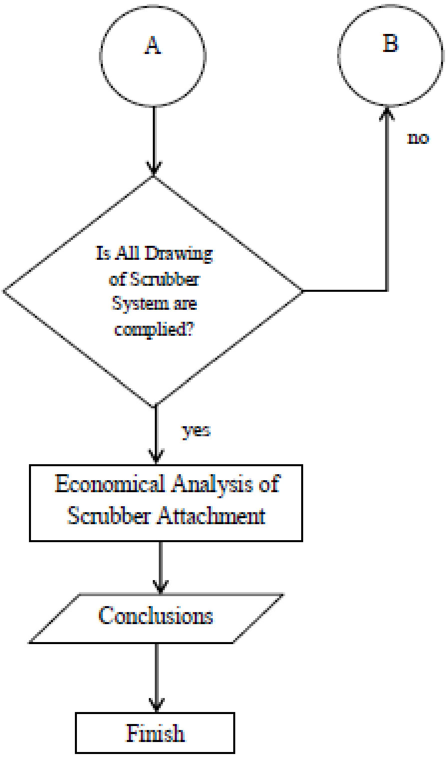


Figure 3.1 Research Scheme

3.2. Methodology Identification

The methodology identification is an explanation based on analysis method that will be conducted in order to encounter the problem of this research. The problem analysis in this research is Sulphur content that need to be comply in 2020, which is 0,1% for SECA areas, and the cost when the Scrubber is applied, and Emission content from the ship.

3.3. Research Steps

The research will be based on a various steps to achieve its result and goals. Hereby are the further explanation of methodological flow from the beginning of the process, collecting data, until the final process resulting the objectives of this research:

3.3.1. Problem and Scope of Study Identification

In the initial step of this research, the researcher will learn about the regulations of IMO, the effect of sulphur content, and . The research process will be based on literature, observation, and discussion with supervisor. From the initial identification, then the parameter, data analysis, research method, and limitation of this research will be determined.

3.3.2. Literature Study

The next step of this research is study literature. The study shall be related to the existing problems and in accordance with the purpose of the study. The aim of literature study is to have a better understanding for the researcher about the supporting information and problem related to this research. Literature-related issues can be used as a reference to understand the problem.

3.3.3. Data Collection

At this stage, the researcher do an analysis of Scrubber Application on MT Senipah based on following data that provided from internet and the ship owner, PT Pertamina Shipping .

3.3.4. Selecting Scrubber Loop and Fuel Analysis

At this stage, the researcher will choose the Scrubber Loop of MT Senipah, in this case the researcher will use Hybrid Loop and analyse the difference of fuel consumption per trip

3.3.5. PFD Drawing

In this stage, the researcher will draw the PFD (Process Flow Diagram) comply to the scrubber system that the researcher use to make the flow of water in the scrubber system.

3.3.6. Calculating and Selecting Components for Scrubber System

After that, the researcher will calculate the required components for scrubber system, calculating load factors for each system and comparing between the existing one and new one.

3.3.7. Implementation Drawing, P&ID Drawing, and 3d Drawing

After calculating all components for Scrubber system, the researcher will continue to draw the Implementation Drawing, P&ID Drawing, and 3d Drawing of the system based on Engine Room Layout from MT Senipah. And possibility to draw Heat and Balance diagram based on P&ID Diagram

3.3.8. Economical Analysis of Scrubber Attachment

After Selecting the components and make the allocation on the drawing, the researcher will calculate the cost of all components that the ship uses, including Installation costs, indirect costs, Capital Expenditure, and Operational Expenditure for additional items on this ship.

3.3.9. Conclussions

This is the final stage of this research when the researcher will conclude the result of this research.

3.4. Data Sources

The source of data in this thesis are divided into two parts, which are:

3.4.1. Primary Data

The primary data is data that will be received from the original source. The data will be obtained through a resource or expert that are capable in their field. The information will be directly send from the Ship Owner, in this case the reliable source will be coming from PT Pertamina Shipping. Through interviews the author will received the information that will be used for data processing of this thesis.

3.4.2. Secondary Data

The secondary data is known from indirect source. The indirect source can be obtained from data of documentation, journals, books, and Internet as references. The secondary data act as a support for primary data.

3.5. Data Collection Method

3.5.1. Literature Study

Literature study is an information research on related data, methods, and problems that are raised in the research, through internet, journals, papers, project guide, and books.

3.5.2. Calculation and Estimation

For this case, the researcher will calculate the requirements of Scrubber System, and estimating the price for scrubber attachment for MT Senipah.

3.6 Research Schedule

Below is the research schedule based on studying activities in Even Semester 2019/2020. The research, from problem identification to the final report will be done in 16 weeks, until the fourth week of May 2020.

Table 3.1 Research Schedule

No.	Activity	Week No.															
		February				March				April				May			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Problem Identification																
2	Literature Study																
3	Research																
4	Conclusion																
5	Report Drafting																
6	Report Finalization																

CHAPTER 4

RESEARCH AND ANALYSIS

4.1 Ship's Main Data

Figure 4.1 MT Senipah [21]

The main data of the ship is based on following table below:

Table 4.1 Main Data of MT Senipah

Ship Name	MT Senipah
Ship Owner	PT Pertamina Persero
Manager	PT Pertamina Persero – Shipping Department
Vessel Type	Product Oil Tanker
Flag State	Indonesia
Class	DNV
Year of Built	2014
Length	180 m
Draught	9,204 m
Breadth	30,53 m
Deadweight	29754 tons

4.2 Why Hybrid Loop?

Hybrid Loop Scrubber system is a combination of Open Loop and Closed Loop system, so the ship can choose Open Loop or Closed Loop based on the sailing route. This system also use remote controlled equipment to switch between Open Loop and Closed loop. Even this type can help ships to sail over zero discharge areas without compliance based on Marpol Annex VI.

4.3 Fuel Analysis

Taken from Vesselfinder.com about the trips of MT Senipah, the ship sails from Wayame – Cilacap – Gresik – Cilacap – Tanjung Priok (based on the latest voyage). Voyage range is 2859,079 Nautical Miles with a duration of 10 days. Based on a trip on this ship, shown the data of fuel consumption below

Table 4.2 Fuel Consumption of all engines

Parameter	HFO Combined (t)	MDO Combined (t)
Main Engine	432,682	432,682
Auxiliary Engine (all)	271,696	271,696
Boiler	156,832	149,320

Based on the fuel data, the density of fuel in kg/l, are 0,89 (MDO, Exxon Mobil), 1,01 (HFO, powerplants.man-es.com) and 0,85 (HSD, Speight J.G, 2011), the volume of the fuel are based on the data below:

Table 4.3 Fuel Consumption (in Liter)

Parameter	HFO and HSD (l)	MDO and HSD (l)
Main Engine	428397,68	486159,17
Auxiliary Engine	319642,47	319642,47
Boiler	155279,62	167775,64

Based on Pertamina, the fuel price of HSD is IDR 9700, and for MDO is IDR 9550, and for HFO is IDR 7000, the price can be seen on the table below:

Table 4.4 Fuel Price per Trip

Parameter	HFO and HSD	MDO and HSD
Fuel Price per trip	Rp7.186.273.084,39	Rp9.345.609.338,48
Price Difference (IDR)	Rp 2.159.336.254,09	
Price Difference (%)	30,05%	

4.4 Data of Main Engine

The main data of Main engine can be seen on the following data:

Table 4.5 Data of Main Engine

Maker / Model	Hyundai MAN B&W 6S42MC7
Power @100% MCR (MW)	6,48
Fuel Consumption @ 100% MCR (mt/day)	25,92
Flue Gas Temp After Economiser	220°C
Allowable Exhaust Gas Backpressure (mmAq)	50
Max Flue Gas Flow (kg/hr)	6798,825
Annual Fuel Consumption Mt/Year	14824,01

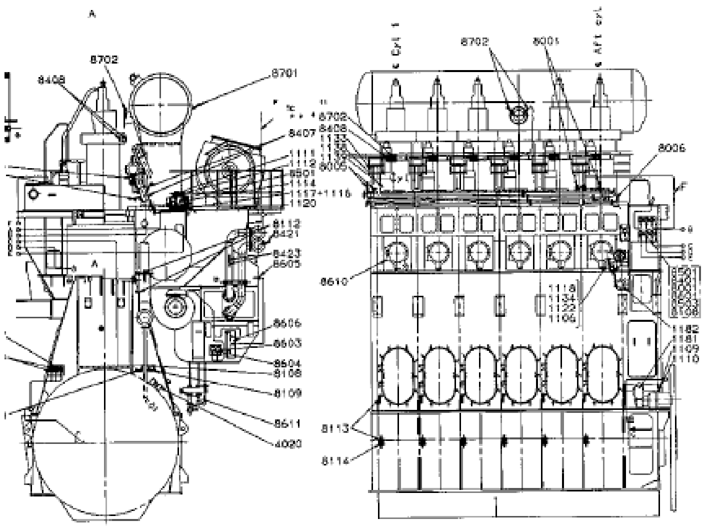


Figure 4.2 Main Engine [22]

4.5 Data of Auxiliary Engine

The data of Auxiliary Engine can be seen based on the following data:

Table 4.6 Data of Auxiliary Engine

Maker/Model	Anqing Daihatsu 6DK-26
Quantity of AE	3
Power @100% MCR (MW)	1,3
Fuel Consumption @ 100% MCR (mt/day)	6,27
Flue Gas Temp After TC , C	340
Max Flue Gas Flow (kg/hr)	2695,385 (per unit)
Annual Fuel Consumption Mt/Year	9308,52

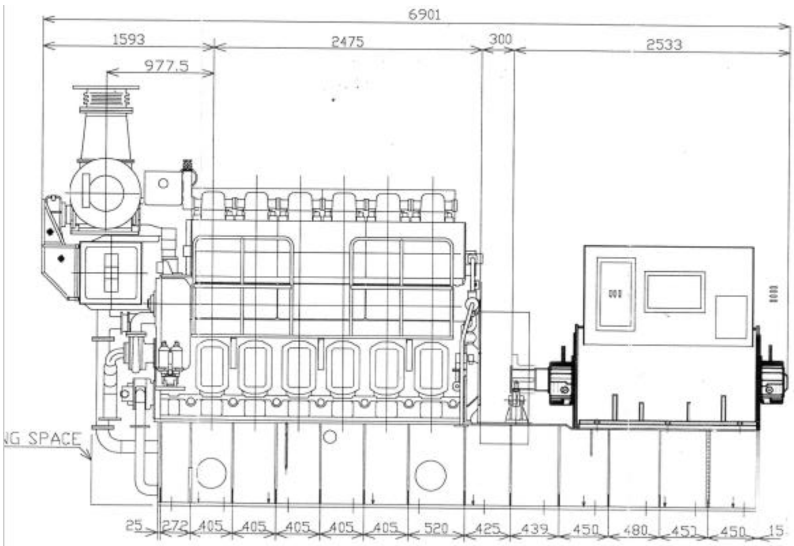


Figure 4.3 Auxiliary Engine

4.6 Data of Boiler

Data of Boiler can be seen in following data:

Table 4.7 Data of Boiler

Maker/ Model	Euroboiler THM/V 5000
Max Power (kW)	4300
Steam @Max Power T/hr	0,008
Max FO Cons. , Oil- Fired section; kg/hr	439
Flue Gas Temp; IN/OUT ISO NCR, C	140/190
Max Flue Gas Flow (kg/hr) / Back pressure (mBar)	8495/
Annual Fuel Consumption Mt/year	5373,2

4.7 Vessel Load Patterns

Vessel load patterns at testing can be seen at the following data:

Table 4.8 Vessel Operating Patterns

Parameter	**Design Capacity (Max)**	**Required Design Capacity**	**At-Sea 1**	**In-Port**	**Maneuvering**
Number of Days per Year	340	340	340	340	340
% of Power of ME	100	85	58	0	85
% of Power of AE1	100	70	70	70	70
% of Power of AE2	100	70	70	70	70
% of Power of AE3	100	70	70	70	70
% of Power of AE4	-	-	-	-	-
% of Power of Boiler	100	75	75	75	50

4.8 Gas Rate

To calculate the gas rate, we need to calculate fuel mass and air mass for each engines to know the mass result for the next calculation

4.8.1 Gas Rate of Main Engine

Brand	=	Hyundai MAN B&W	
Type	=	6S42MC7	
Horse Power	=	6480	kW
Rotation	=	136	RPM
Number of Cylinder	=	6	
Bore	=	420	mm
Stroke	=	1764	mm
SFOC	=	0,1869	kg/kWh
Quantity	=	1	

To calculate the flow rate of exhaust gas, we can use the formula below:

$$\dot{m}E = \dot{m}f + \dot{m}a$$

Where:

- $\dot{m}E$: Exhaust Gas Mass Flow Rate
- $\dot{m}f$: Fuel Mass Flow Rate
- $\dot{m}a$: Air Mass Flow Rate

to calculate fuel mass flow rate, we can calculate the rate, so we can get

$\dot{m}f$ = SFOC x Power

= 0,1869 x 6480

= 1211,112 kg/h

Then, we calculate the Air Mass flow rate based on the formula

$\dot{m}a = \eta_v \times \rho_a \times n \times V_s$

Where:

- η_v : volumetric efficiency (0.8-0.9) (assumed at 0,8)
- ρ_a : Air Fuel Density (1,167 kg/m^3)
- n : Speed/2 (136/2 = 68 rpm)
- V_s : Volume of Combustion Chamber

To calculate Volume of Combustion Chamber can be calculated on the following formula

$$V_s = \pi \text{ x bore}^2 \text{ x stroke x number of cylinder / 4}$$

Then, we can get

$V_s = \pi$ x $0,42^2$ x 1,764 x 6 / 4

= 1,466942 m^3

So, the result of Air mass flow rate is

$\dot{m}a = \eta_v$ x ρ_a x n x V_s

= 0,8 x 1,167 x 68 x 1,466942

= 93,12854 kg/min

= 5587,713 kg/h

Then, the total air mass flow rate of Main Engine is

$\dot{m}E = \dot{m}f + \dot{m}a$

= 1211,112 + 5587,713

= 6798,825 kg/h

To calculate into m^3/hr, the result is divided by the density of Air, which is 1,225 kg/m^3, and the result is

Flow rate = air mass flow rate / Air density

= 6798,825 / 1,225

= 5550,061 m^3/h

4.8.2 Gas Rate of Auxiliary Engine

Brand	=	Anqing Daihatsu	
Type	=	6DK-26	
Horse Power	=	1300	kW
Rotation	=	720	RPM
Number of Cylinder	=	6	
Bore	=	260	mm
Stroke	=	380	mm
SFOC	=	0,195	kg/kWh
Quantity	=	3	

To calculate the flow rate of exhaust gas, we can use the formula below:

$$\dot{m}E = \dot{m}f + \dot{m}a$$

Where:

- $\dot{m}E$: Exhaust Gas Mass Flow Rate
- $\dot{m}f$: Fuel Mass Flow Rate
- $\dot{m}a$: Air Mass Flow Rate

to calculate fuel mass flow rate, we can calculate the rate, so we can get

$\dot{m}f$ = SFOC x Power

= 0,195 x 1300

= 253,5 kg/h

Then, we calculate the Air Mass flow rate based on the formula

$\dot{m}a = \eta_v \times \rho_a \times n \times V_s$

Where:

- η_v : volumetric efficiency (0.8-0.9) (assumed at 0,8)
- ρ_a : Air Fuel Density (1,167 kg/m^3)
- n : Speed/2 (720/2 = 360 rpm)
- V_s : Volume of Combustion Chamber

To calculate Volume of Combustion Chamber can be calculated on the following formula

$$V_s = \pi \text{ x bore}^2 \text{ x stroke x number of cylinder / 4}$$

Then, we can get

$V_s = \pi$ x $0,26^2$ x 0,38 x 6 / 4

= 0,121101 m^3

So, the result of Air mass flow rate is

$\dot{m}a = \eta_v$ x ρ_a x n x V_s

= 0,8 x 1,167 x 360 x 0,121101

= 40,70142 kg/min

= 2442,085 kg/h

Then, the total air mass flow rate of Auxiliary Engine is

$\dot{m}E = \dot{m}f + \dot{m}a$

= 253,5 + 2442,085

= 2695,585 kg/h

To calculate into m^3/hr, the result is divided by the density of Air, which is 1,225 kg/m^3, and the result is

Flow rate = air mass flow rate / Air density

= 2695,585/ 1,225

= 2200,478 m^3/h

Because, Auxiliary engine in this ship has 3 units, so the total is 6601,433 m^3/h

4.8.3 Total Gas Flow Rate

Based on the calculation above known as the summary of calculation

- Total Main Engine Gas Flow Rate : 5550,061 m^3/h
- Total Auxiliary Engine Gas Flow Rate : 6601,433 m^3/h
- Boiler Gas Flow Rate : 6585 m^3/h (refer to Scrubber detail measurement data)

So, the total flow rate is:

$Q_{Total} = Q_{ME} + Q_{AE} + Q_{Boiler}$

$= 5550,061 + 6649,188 + 6585$

$= 18736,49\ m^3$

4.9 Emission Content

For the data shown is the data for emission content of MT Senipah based on Following data below (assumed as Diesel Engine)

Table 4.9 Emission Content

Substance	Content
N_2	76% by Volume
CO_2	10% by Volume
H_2O	3 % by Volume
O_2	5 % by Volume
SO_2	0.23 % by Volume
NO_x	0.3 % by Volume
CO	0.4 % by Volume

Based on the data, we calculate the emission rate of the ship.

Known: Gas Rate = 18736,49 m^3/h

Item that to be removed:

- SO_2 = 0.23%
- NO = 90% from 0,04% Vol. NOx
- NO_2 = 10% from 0,04% Vol. NOx

Sulphur Dioxide (SO_2)

V SO_2 = 18736,49 x 0.23%
= 43,093 m^3/h
ρ SO_2 = 2.63 kg/m^3

m SO_2 = 43,093 x 2.63
= 113,33 **kg/h**

Nitrogen Monoxide (NO)

V NO = 18736,49 x 0.03% x 90%
= 5,058 m^3/h
ρ NO = 1.34 kg/m^3

m NO = 5,058 x 1,34
= **6,777 kg/h**

Nitrogen Dioxide (NO_2)

V NO_2 = 18736,49 x 0,03% x 10%
= 0,562 m3/h
ρ NO_2 = 1450 kg/m3

m NO_2 = 0,562 x 1450
= 814,9 **kg/h**

4.10 Chemical Reaction and NaOH Addition

Based on the Chemical Reaction, The Chemical reaction of SO_x Scrubber divided into 3 reactions, which is:

Reaction 1. NaOH + SO_2

Mass Number: Na = 23 H = 1
S = 32 O = 16

Reaction	2NaOH	+	SO_2	↔	Na_2SO_3	+	H_2O
Mass Rate	**141,51 kg/h**		113,33 kg/h		**222,97 kg/h**		31,86 kg/h
Mass Number	40		64		126		18
Mole rate	3,54 mol/h		1,77 mol/h		1,77 mol/h		1,77 mol/h

Reaction Results:

- Na_2SO_3 = 222,97 kg/h
- H_2O = 31,86 kg/h

Reaction Remaining:

- NaOH = 28,18 kg/h

Reaction	$2Na_2SO_3$	+	O_2	↔	$2Na_2SO_4$
Mass Rate	**222 kg/h**		28,18 kg/h		**250,18 kg/h**
Mass Number	126		32		142
Mole Rate	1,76 mol/h		0,88 mol/h		1,76 mol/h

Reaction Result:

- Na_2SO_4 = 250,18 kg/h

Reaction remaining

- Na_2SO_3 = 193,82 kg/h

Reaction 2. NaOH + NO

Mass Number: Na = 23 H = 1
O = 16 N = 14

Reaction	2NaOH	+	4NO	↔	$2NaNO_2$	+	N_2O	+	H_2O
Mass Rate	**4,516 kg/h**		6,777 kg/h		**7,79 kg/h**		**2,48 kg/h**		**1,01 kg/h**
Mass Number	40		30		69		44		18
Mole Rate	0,113 mol/h		0,226 mol/h		0,113 mol/h		0,056 mol/h		0,056 mol/h

Reaction Result:

- $NaNO_2$ = 7,79 kg/h
- N_2O = 2,48 kg/h

- H_2O = 1,01 kg/h

Reaction Remaining:

- NO = 2,261 kg/h

Reaction 3. NaOH + NO_2

Mass Number: Na = 23 H = 1
O = 16 N = 14

Reaction	2NaOH	+	$2NO_2$	↔	$NaNO_2$	+	$NaNO_3$	+	H_2O
Mass Rate	**708,47 kg/h**		814,9 kg/h		**611,06 kg/h**		**752,75 kg/h**		159,55 kg/h
Mass Number	40		46		69		85		18
Mole Rate	17,71 mol/h		17,71 mol/h		8,85 mol/h		8,85 mol/h		8,85 mol/h

Reaction Result:

- $NaNO_2$ = 611,06 kg/h
- $NaNO_3$ = 752,75 kg/h
- H_2O = 159,55 kg/h

For NaOH addition for one scrubbing process, we need to know NaOH Required for all chemical reactions

Reaction 1. NaOH + SO_2

NaOH Required = 113,33 kg/h

Reaction 2. NaOH + NO

NaOH Required = 4,516 kg/h

Reaction 3. NaOH + NO_2

NaOH Required = 708,47 kg/h

So, the total NaOH required for one scrubbing process is:

Total NaOH Required = 113,33 kg/h + 4,516 kg/h + 708,47 kg/h

= 826,31 kg/h

Then, calculating the flow rate of NaOH with following formula:

$$NaOH\ Flow\ Rate = \frac{NaOH\ Required}{NaOH\ Density}$$

$$NaOH\ Flow\ Rate = \frac{826{,}31\ kg/h}{2130\ kg/m^3}$$

Then, the flow rate of NaOH is 0,387 m^3/h

4.11 Heat Exchange

Based on the exhaust gas content, this is the detail of exhaust gas content can be seen on table below

Table 4.10 Detail of Exhaust Gas Content

Sub.	Total Vol. (m3/hr)	Content (%)	Content (m^3/hr)	Density (kg/m^3)	Flow Mass (kg/hr)	Specific Heat, Cp (kJ/kgK)	m x Cp
N_2	18736,49	76,0%	14239,73527	1,0564	15042,85634	1,042	15674,66
CO_2		10,0%	1873,649377	1,6597	3109,696	0,8666	2694,862
H_2O		3,0%	562,0948132	0,6794	381,8872161	1,874	715,6566
O_2		5,0%	936,8246886	1,2068	1130,560	0,9217	1042,037
SO_2		0,23%	43,09393568	2,927	126,136	0,64	80,72701
NO		0,30%	56,20948132	1,34	75,32070496	0,995	74,9441
NO_2		0,03%	5,620948132	1450	8150,374791	4,69	38225,26
CO		0,4%	74,94597509	1,0563	79,16543348	1,039	82,25289
						Total	**58590,4**

Where:

- ρ Water = 997 kg/m^3
- m Water = 269578 kg/h
- cp water = 4.18 kJ/kgK
- m x cp Gas = 58590,4 kg/h

4.11.1 Calculation of Heat Exchange

Q1	=	Q2
m x c x ΔT	=	m x c x ΔT
269578 x 4.18 x (T2-308,15)	=	58590,4 x (553,15-323,15)
T2-308,15	=	13475792 / 269578 x 4.18
T2-308,15	=	11,95
T2	=	320,1 K
	=	46,95℃

4.11.2 Heat Exchange between Washwater and Seawater

Known:

- T Water Inlet = 46,95°C (320,1K)
- T Water Outlet = 35°C (308,15 K)
- m Water = 269578 kg/h
- cp Water = 4,18 kJ/kgK

so, the Calories released is

Q = m x c x ΔT
Q = 269578 x 4.18 x (320,1-308.15)
Q = 13465690,68 kJ/hr
Q = 3740,46 kW
Q = 5012,21 HP

4.11.3 Sea Water Coolant Required

known :

- T Water Inlet = 35°C = 308.15 K
- T Water Outlet = 50°C = 323,15 K
- Calories (Q) = 13465690,68 kJ/h
- cp Sea Water = 4.012 kJ/kgK

So, the mass of Sea Water can be calculated using the formula:

$$m = \frac{Q}{cp\ x\ \Delta T}$$

Where:

m = Mass of Water

ΔT = Temperature difference (K)

So,

$$m = \frac{13465690{,}68}{4{,}012 \times (323{,}15 - 308{,}15)}$$

m = 223756,9 kg/hr

ρ Sea Water = 1025 kg/m^3

Sea Water Flow Rate = 218,29 m^3/hr

4.12 Tank Calculation

Because this ship is using scrubber as the modification to comply with IMO 2020, we need to calculate the tank capacity to contain NaOH, Expansion Tank, and Sludge tank for Scrubbing. It's also to know tank capacity required for this system

4.12.1 Calculation of Expansion Tank

Fresh water tank in system = 269,578 m^3

Tank size estimation = 3-4 %

Expansion Tank Required = 269,578 x 3,5%

= 9,435 m^3

4.12.2 Calculation of NaOH Tank

Flow rate = 0,387 m^3/hr

Tank size Estimation = Capacity of Exhaust gas

= 18736,49 m3/h

Cargo Tank = 42072,403 m^3

NaOH Required tank = 42072,403 / 18736,49 x 0,387

= 5,8 m^3 per trip

= 11,6 m^3

4.12.3 Calculation of Sludge Tank

Estimation of Sludge	= 0,1 - 0,4 gr / MWh of Scrubbed engine
Power of Engine	= 6,48 MW (Main Engine)
	= 1,3 MW (3 set of Auxiliary Engine; 3,9 mW)
	= 4,3 MW (Boiler)
	= 14,68 MW
Sludge Quantity	= 0,3 x 14,68 x 23
	= 101,292 kg
Ash Density	= 610 kg/m^3
Sludge Tank Volume	= 101,292 / 610
	= 0,16 m^3

4.13 Pipe Calculation

The Scrubber system also requires a piping system, in this case, we used Carbon Steel pipe to recover all the piping systems of the Scrubber

4.13.1 NaOH Pipe Calculation

Flow Rate	= 0,387 m^3/hr
Pipe Diameter	= 14,95 mm
	= 0,01495 m
Pipe Area	= 3,14 x (0,01495)^2 /4
	= 0,0001754 m2
flow rate	= 0,387/0,0001754
	= 2206,38 m/h
	= 0,612 m/s

4.13.2 Fresh Water Pipe Calculation

Flow Rate	= 270 m^3/hr
Pipe Diameter	= 261 mm
	= 0,261 m
Pipe Area	= 3,14 x (0,261)^2 /4
	= 0,0534 m2
flow rate	= 270/0,0534
	= 5056,17 m/h
	= 1,404 m/s

4.13.3 Sea Water Pipe Calculation

Flow Rate	= 467 m^3/hr
Pipe Diameter	= 311,5 mm
	= 0,3115 m
Pipe Area	= 3,14 x (0,3115)^2 /4
	= 0,0761 m2
flow rate	= 467/0,0761
	= 6136,66 m/h
	= 1,704 m/s

4.13.4 Makeup Water Pipe Calculation

Flow Rate	= 20 m^3/hr
Pipe Diameter	= 24,3 mm
	= 0,0243 m
Pipe Area	= 3,14 x (0,0243)^2 /4
	= 0,00463 m2
flow rate	= 20/0,00463
	= 4319,65 m/h
	= 1,199 m/s

4.14 Pump Calculation

This system also requires a pump to transfer fluids for seawater, freshwater, and NaOH to do a scrubbing process. To know the required specs to flowing the fluid on Hybrid Loop Scrubber System

4.14.1 Sea Water Pump

a) Head Static (Hs)

Head static is the difference height of suction and the Scrubber (from the seachest)

- Head at Z= 0 at Discharge = 17,73 m
- Head at Z= 0 at Suction = 0 m

So, H_s = 17,73 + 0 = 17,73 m

b) Head Velocity (Hv)

Head velocity is the difference velocity of suction and discharge side. Since the velocity is same, which is 1,704 m/s each

$Hv = (V^2d – V^2s) / 2\ g$

Where

$g = 9{,}81\ m/s^2$

Hv = (2,9-2,9) / 2 x 9,81

= 0 m

c) Head Pressure (Hp)

at Suction Side = Atmospheric Pressure + Hidrostatic Pressure
= 101.325 N/m^2 + (0 ρ g)
= 101.325 N/m^2 + (0 x 1025 x 9,81)
= 101.325 N/m^2

At Discharge side = 101.325 N/m^2

Hp = (Pd – Ps) / ρ x g

Where

$\rho = 1025\ kg/m^3$

$g = 9{,}81\ m/s^2$

Hp = (101.325 – 101.325) / (1025 x 9,81)

Hp: 0 m

d) Reynold Number

For calculating reynold Number, you can use the formula below:

$$Rn = \frac{v \times dH}{n}$$

Where:

n = Kinematic Viscosity (0,000000796 N.s/m^2)

dH = Inside diameter of Seawater pipe (0,3115 m)

v = Fluid Velocity of Seawater (1,704 m/s)

so,

Rn = (1,704 x 0,3115)/ 0,000000796

= 666829,1

If Rn < 2300 is Laminar Flow and Rn > 2300 is Turbulent flow, in this case is turbulent flow.

Based on the calculation above, it is known that the flow is a turbulent flow. Therefore, the value of friction factor can be defined with Colebrook Equation.

f = 0.02+(0.0005/D)

= 0,02 +(0,0005/0,3115)

= 0,022

e) Major Losses (h_f) at Suction Side

For Major losses, we can calculate the major losses using the formula below

$$h_{f\ suction} = \frac{f \times L \times v^2}{D \times 2g}$$

Where:

L = Pipe Length at suction side (61,2 m)

g = Gravity (9,81 m/s^2)

So, the major losses at the suction side of the pump is

$h_{f\ suction}$ = 0,022 x 61,2 x $1,704^2$/ (0,3115 x 2 x 9,81)

= 0,639 m

f) Minor Losses (h_m) at Suction Side

No	Accessories	n	k	n x k
1	Butterfly Valve	7	0,4	2,8
2	T joint	5	1	5
3	Elbow	8	0,3	2,4
4	Filter	1	2,5	2,5
5	NRV	1	2	2
			Σnk =	14,7

So, the value of minor losses at suction side is:

$h_{m\ suction}$ = Σnk x v² / 2g

= 14,7 x $1{,}704^2$ / 2 x 9,81

= 2,17 m

g) Total Head Loss at Suction Side

$h_{L\ suction} = h_{f\ suction} + h_{m\ suction}$

= 0,639 + 2,17

= 2,809 m

h) Major Losses (hf) at Discharge Side

For Major losses, we can calculate the major losses using the formula below

$$h_{f\ discharge} = \frac{f \times L \times v^2}{D \times 2g}$$

Where:

L = Pipe Length at discharge side (37 m)

g = Gravity (9,81 m/s^2)

So, the major losses at the discharge side of the pump is

$h_{f\ discharge}$ = 0,022 x 37 x $1,704^2$/ (0,3115 x 2 x 9,81)

= 0,386 m

i) Minor Losses (h_m) at Discharge Side

No	Accessories	n	k	n x k
1	Non Return Valve	1	2	2
2	Butterfly Valve	1	0,4	0,4
3	T joint	1	1	1
4	Elbow 90	4	0,3	1,2
			Σnk =	4,6

So, the value of minor losses at discharge side is:

$h_{m\ discharge}$ = Σnk x v^2 / 2g

= 4,6 x $1,704^2$ / 2 x 9,81

= 0,68 m

j) Total Head Loss at Discharge Side

$h_{L\ discharge}$ = $h_{f\ discharge}$ + $h_{m\ discharge}$

= 0,386 + 0,68

= 1,06 m

k) Total Head Loss of Pump

$h_{L\ pump}$ = $h_{L\ suction}$+ $h_{L\ discharge}$

= 2,809 + 1,06

= 3,869 m

l) Head Total of Pump

H_{pump} = H_s + H_v + H_p + H_L + HE

= 17,73 + 0 + 0 + 3,869 +12,75

= 34,34 m

m) Heat Exchanger

This ship is using Hisaka LX-30 which is have 1,25 MPa means have 12,75 meter head

n) Required Pump's Specification

Head: 34,34 m

Capacity: 467 m^3/h

4.14.2 Fresh Water Pump

a) Head Static (Hs)

Head static is the difference height of suction and the Scrubber (from the Expansion Tank)

- Head at Z= 0 at Discharge = 10,59 m
- Head at Z= 0 at Suction = 0 m

So, H_s = 10,59 + 0 = 10,59 m

b) Head Velocity (Hv)

Head velocity is the difference velocity of suction and discharge side is same, which is 1,404 m/s each

Hv = (V^2d – V^2s) / 2 g

Where

g = 9,81 m/s^2

Hv = (1,97-1,97) / 2 x 9,81

= 0 m

c) Head Pressure (Hp)

at Suction Side = Atmospheric Pressure + Hidrostatic Pressure
= 101.325 N/m^2 + (0 ρ g)
= 101.325 N/m^2 + (0 x 1000 x 9,81)
= 101.325 N/m^2

At Discharge side = 101.325 N/m^2

Hp = (Pd – Ps) / ρ x g

Where

ρ = 1000 kg/m^3

g = 9,81 m/s^2

Hp = (101.325 – 101.325) / (1000 x 9,81)
Hp: 0 m

d) Reynold Number

For calculating reynold Number, you can use the formula below:

$$Rn = \frac{v \ \times dH}{n}$$

Where:

n = Kinematic Viscosity (0,000000796 $N.s/m^2$)

dH = Inside diameter of Freshwater (0,261 m)

v = Fluid Velocity of Freshwater (1,404 m/s)

so,

Rn = (1,404 x 0,261)/ 0,000000796

= 460356,8

If Rn < 2300 is Laminar Flow and Rn > 2300 is Turbulent flow, in this case is turbulent flow.

Based on the calculation above, it is known that the flow is a turbulent flow. Therefore, the value of friction factor can be defined with Colebrook Equation.

f = 0.02+(0.0005/D)

= 0,02 +(0,0005/0,261)

= 0,022

e) Major Losses (h_f) at Suction Side

For Major losses, we can calculate the major losses using the formula below

$$h_{f\ suction} = \frac{f \times L \times v^2}{D \times 2g}$$

Where:

L = Pipe Length at suction side (45,5 m)

g = Gravity (9,81 m/s^2)

So, the major losses at the suction side of the pump is

$h_{f\ suction}$ = 0,022 x 45,5 x 1,404^2/ (0,261 x 2 x 9,81)

= 0,38 m

f) Minor Losses (h_m) at Suction Side

No	Accessories	n	k	n x k
1	Butterfly Valve	6	0, 4	2,4
2	T joint	5	1	5
3	Elbow	4	0,3	1,2
4	Filter	2	2,5	5
5	NRV	1	2	2
			Σnk =	15,6

So, the value of minor losses at suction side is:

$h_{m\ suction}$ = Σnk x v² / 2g

= 15,6 x 1,404^2 / 2 x 9,81

= 1,56 m

g) Total Head Loss at Suction Side

$h_{L\ suction} = h_{f\ suction} + h_{m\ suction}$

= 0,38 + 1,56

= 1,94 m

h) Major Losses (hf) at Discharge Side

For Major losses, we can calculate the major losses using the formula below

$$h_{f\ discharge} = \frac{f \times L \times v^2}{D \times 2g}$$

Where:

L = Pipe Length at discharge side (38,2 m)

g = Gravity (9,81 m/s^2)

So, the major losses at the discharge side of the pump is

$h_{f\ discharge}$ = 0,022 x 38,2 x 1,404^2/ (0,261 x 2 x 9,81)

= 0,323 m

i) Minor Losses (h_m) at Discharge Side

No	**Accessories**	**n**	**k**	**n x k**
1	NRV	0	2	0
2	Butterfly Valve	2	0,4	0,8
3	T joint	1	1	1
4	Elbow 90	4	0,3	1,2
			Σnk =	3

So, the value of minor losses at discharge side is:

$h_{m\ discharge}$ = Σnk x v² / 2g

= 3 x 1,404^2 / 2 x 9,81

= 0,3 m

j) Total Head Loss at Discharge Side

$h_{L\ discharge}$ = $h_{f\ discharge}$ + $h_{m\ discharge}$

= 0,323 + 0,3

= 0,623 m

k) Total Head Loss of Pump

$h_{L\ pump} = h_{L\ suction} + h_{L\ discharge}$

$= 1,94 + 0,623$

$= 2,56$ m

l) Head Total of Pump

$H_{pump} = H_s + H_v + H_p + H_L + HE$

$= 10,59 + 0 + 0 + 2,56 + 12,75$

$= 25,9$ m

m) Heat Exchanger

This ship is using Hisaka LX-30 which is have 1,25 MPa means have 12,75 meter head

n) Required Pump's Specification

Head: 25,9 m

Capacity: 300 m^3/h

4.14.3 NaOH Pump

a) Head Static (Hs)

Head static is the difference height of suction and the Scrubber (from NaOH Tank)

- Head at Z= 0 at Discharge = 3 m
- Head at Z= 0 at Suction = 0 m

So, $H_s = 3 + 0 = 3$ m

b) Head Velocity (Hv)

Head velocity is the difference velocity of suction and discharge side. In this case, the velocity is same, which is 0,612 m/s each

$Hv = (V^2d – V^2s) / 2 g$

Where

$g = 9,81 m/s^2$

Hv = (0,37-0,37) / 2 x 9,81

= 0 m

c) Head Pressure (Hp)

Head pressure is the difference pressure of suction and discharge side. The design pressure of both side is same, so the head pressure is 0.

at Suction Side = Atmospheric Pressure + Hidrostatic Pressure
= $101.325 N/m^2 + (0 \rho g)$
= $101.325 N/m^2 + (0 x 1500 x 9,81)$
= $101.325 N/m^2$

At Discharge side = $101.325 N/m^2$

Hp = (Pd – Ps) / ρ x g

Where

$\rho = 1500 kg/m^3$

$g = 9,81 m/s^2$

Hp = (101.325 – 101.325) / (1000 x 9,81)
Hp: 0 m

d) Reynold Number

For calculating reynold Number, you can use the formula below:

$$Rn = \frac{v \ \times dH}{n}$$

Where:

n = Kinematic Viscosity (0,085 $N.s/m^2$)

dH = Inside diameter of NaOH pipe (0,01495 m)

v = Fluid Velocity of NaOH (0,612 m/s)

so,

Rn = (0,635 x 0,01495)/ 0,085

= 0,1

If Rn < 2300 is Laminar Flow and Rn > 2300 is Turbulent flow, in this case is Laminar flow.

Based on the calculation above, it is known that the flow is a laminar flow. Therefore, the value of friction factor can be defined with Colebrook Equation.

f = 0.02+(0.0005/D)

= 0,02 +(0,0005/0,01495)

= 0,053

e) Major Losses (h_f) at Suction Side

For Major losses, we can calculate the major losses using the formula below

$$h_{f\ suction} = \frac{f \times L \times v^2}{D \times 2g}$$

Where:

L = Pipe Length at suction side (0,76 m)

g = Gravity (9,81 m/s^2)

So, the major losses at the suction side of the pump is

$h_{f\ suction}$ = 0,053 x 0,76 x $0,612^2$/ (0,01495 x 2 x 9,81)

= 0,05 m

f) Minor Losses (h_m) at Suction Side

No	Accessories	n	k	n x k
1	Gate Valve	0	0,14	0
2	T joint	0	1	0
3	Elbow	0	0,3	0
			Σnk =	0

So, the value of minor losses at suction side is:

$h_{m\ suction} = \Sigma nk \times v^2 / 2g$

$= 0 \times 0{,}612^2 / 2 \times 9{,}81$

$= 0$ m

g) Total Head Loss at Suction Side

$h_{L\ suction} = h_{f\ suction} + h_{m\ suction}$

$= 0{,}05 + 0$

$= 0{,}05$ m

h) Major Losses (hf) at Discharge Side

For Major losses, we can calculate the major losses using the formula below

$$h_{f\ discharge} = \frac{f \times L \times v^2}{D \times 2g}$$

Where:

L = Pipe Length at discharge side (3,2 m)

g = Gravity (9,81 m/s^2)

So, the major losses at the suction side of the pump is

$h_{f\ discharge} = 0{,}053 \times 3{,}2 \times 0{,}612^2 / (0{,}01495 \times 2 \times 9{,}81)$

$= 0{,}22$ m

i) Minor Losses (h_m) at Discharge Side

No	Accessories	n	k	n x k
1	NRV	1	2	2
2	Gate Valve	0	0,14	0
3	T joint	0	0	0
4	Elbow 90	2	0,3	0,6
			Σnk =	2,6

So, the value of minor losses at discharge side is:

$h_{m\ discharge} = \Sigma nk \times v^2 / 2g$

$= 2{,}6 \times 0{,}612^2 / 2 \times 9{,}81$

$= 0{,}049$ m

j) Total Head Loss at Discharge Side

$h_{L\ discharge} = h_{f\ discharge} + h_{m\ discharge}$

$= 0{,}22 + 0{,}049$

$= 0{,}269$ m

k) Total Head Loss of Pump

$h_{L\ pump} = h_{L\ suction} + h_{L\ discharge}$

$= 0{,}05 + 0{,}269$

$= 0{,}319$ m

l) Head Total of Pump

$H_{pump} = H_s + H_v + H_p + H_L$

$= 3 + 0 + 0 + 0{,}319$

$= 3{,}319$ m

m) Required Pump's Specification

Head: 3,319 m

Capacity: 0,387 m^3/h

4.14.4 Makeup Water Pump

a) Head Static (Hs)

Head static is the difference height of suction and Expansion Tank

- Head at Z= 0 at Discharge = 0 m
- Head at Z= 0 at Suction = 0 m

So, H_s = 0 m

b) Head Velocity (Hv)

Head velocity is the difference velocity of suction and discharge side is same, is 1,404 m/s each

$Hv = (V^2d – V^2s) / 2\ g$

Where

$g = 9{,}81\ m/s^2$

Hv = (1,97-1,97) / 2 x 9,81

= 0 m

c) Head Pressure (Hp)

Head pressure is the difference pressure of suction and discharge side. The design pressure of both side is same, so the head pressure is 0.

at Suction Side = Atmospheric Pressure + Hidrostatic Pressure
= $101.325\ N/m^2 + (0\ \rho\ g)$
= $101.325\ N/m^2 + (0 \times 1000 \times 9{,}81)$
= $101.325\ N/m^2$

At Discharge side = $101.325\ N/m^2$

Hp = (Pd – Ps) / ρ x g

Where

$\rho = 1000\ kg/m^3$

$g = 9{,}81\ m/s^2$

Hp = (101.325 – 101.325) / (1000 x 9,81)
Hp: 0 m

d) Reynold Number

For calculating reynold Number, you can use the formula below:

$$Rn = \frac{v \ \times dH}{n}$$

Where:

n = Kinematic Viscosity (0,000000796 N.s/m^2)

dH = Inside diameter of Freshwater pipe (0,0243 m)

v = Fluid Velocity of Freshwater (1,199 m/s)

so,

Rn = (1,199 x 0,0243)/ 0,000000796

= 36602,63

If Rn < 2300 is Laminar Flow and Rn > 2300 is Turbulent flow, in this case is Turbulent flow.

Based on the calculation above, it is known that the flow is a Turbulent flow. Therefore, the value of friction factor can be defined with Colebrook Equation.

f = 0.02+(0.0005/D)

= 0,02 +(0,0005/0,0243)

= 0,041

e) Major Losses (h_f) at Suction Side

For Major losses, we can calculate the major losses using the formula below

$$h_{f\ suction} = \frac{f \times L \times v^2}{D \times 2g}$$

Where:

L = Pipe Length at suction side (1,37 m)

g = Gravity (9,81 m/s^2)

So, the major losses at the suction side of the pump is

$h_{f\ suction}$ = 0,041 x 1,37 x 1,199^2/ (0,0243 x 2 x 9,81)

= 0,17 m

f) Minor Losses (h_m) at Suction Side

No	Accessories	n	k	n x k
1	Gate Valve	0	0,14	0
2	T joint	0	1	0
3	Elbow	0	0,3	0
			Σnk =	0

So, the value of minor losses at suction side is:

$h_{m\ suction}$ = Σnk x v² / 2g

= 0 x 1,199^2 / 2 x 9,81

= 0

g) Total Head Loss at Suction Side

$h_{L\ suction} = h_{f\ suction} + h_{m\ suction}$

= 0,17 + 0

= 0,17 m

h) Major Losses (hf) at Discharge Side

For Major losses, we can calculate the major losses using the formula below

$$h_{f\ discharge} = \frac{f \times L \times v^2}{D \times 2g}$$

Where:

L = Pipe Length at discharge side (12,22m)

g = Gravity (9,81 m/s^2)

So, the major losses at the discharge side of the pump is

$h_{f\ discharge}$ = 0,041 x 12,22 x 1,199^2/ (0,01495 x 2 x 9,81)

= 1,5 m

i) Minor Losses (h_m) at Discharge Side

No	Accessories	n	k	n x k
1	NRV	1	2	2
2	Gate Valve	0	0,14	0
3	T joint	0	1	0
4	Elbow 90	0	0,3	0
			Σnk =	2

So, the value of minor losses at discharge side is:

$h_{m\ discharge} = \Sigma nk \times v^2 / 2g$

$= 2 \times 1{,}199^2 / 2 \times 9{,}81$

$= 0{,}146$ m

j) Total Head Loss at Discharge Side

$h_{L\ discharge} = h_{f\ discharge} + h_{m\ discharge}$

$= 1{,}5 + 0{,}146$

$= 1{,}646$ m

k) Total Head Loss of Pump

$h_{L\ pump} = h_{L\ suction} + h_{L\ discharge}$

$= 0{,}17 + 1{,}646$

$= 1{,}82$ m

l) Head Total of Pump

$H_{pump} = H_s + H_v + H_p + H_L$

$= 0 + 0 + 0 + 1{,}82$

$= 1{,}82$ m

m) Required Pump's Specification

Head: 1,82 m

Capacity: 20 m^3

4.15 Summary list of Electrical Load

Table 4.11 Summary list of Electrical Load

READY RECKONER OF POWER CONSUMPTION

	NORMAL SERVICE	DEP. & ARR./PORT	NAV. WITH TANK CLEAN.	CARGO SERVICE	HARBOUR SERVICE	EM'CY SERVICE BLACK OUT	EM'CY SERVICE FIRE
CONTINUOUS LOAD (KW)	500.4	500.4	625.3	1727.4	225.6	102.1	117.5
INTERMITTENT LOAD – TOTAL (KW)	522.1	649.4	512.8	639.8	573.1		
INTERMITTENT LOAD – DIVERSITY FACTOR	1.5	1.5	1.5	1.5	1.5		
INTERMITTENT LOAD – REQUIRED POWER	348.0	432.9	341.8	426.5	382.1		
TOTAL REQUIRED POWER (KW)	848.4	933.3	967.2	2153.9	607.7	102.1	117.5
OUTPUT OF GENERATOR (KW)	1300KW x 1	1300KW x 1	1300KW x 1	1300KW x 2	1300KW x 1	150KW x 1	150KW x 1
LOAD FACTOR OF GENERATOR	65.3%	71.8%	74.4%	82.8%	46.7%	68.1%	78.4%
AFTER PREFERENCE TRIP – CONTINUOUS LOAD (KW)				734.9			
AFTER PREFERENCE TRIP – INT. REQUIRED POWER – TOTAL				391.4			
AFTER PREFERENCE TRIP – INT. REQUIRED POWER – DIVERSITY FACTOR				1.5			
AFTER PREFERENCE TRIP – INT. REQUIRED POWER – REQUIRED POWER				260.9			
AFTER PREFERENCE TRIP – TOTAL POWER (KW)				1126.3			
AFTER PREFERENCE TRIP – OUTPUT OF GEN.				1300KW x 1			
AFTER PREFERENCE TRIP – LOAD FACTOR OF GEN.				86.6%			

4.16 Scrubber Specifications

This ship will be retrofitted with a scrubber with following specifications:

Table 4.12 Scrubber Specifications

Description	Value
Model	U-Type
Diameter (mm)	2700
Length (mm)	5300
Height (mm)	8700
Weight (tons)	16,9

4.17 Water Consumption for Scrubber Use

Based on the Project guide of Scrubber, we use 2 different capacities that seen on the table below

Table 4.13 Water Consumption for Scrubber Use

Operation Condition	Open Loop	Closed Loop
Sea Water Pump to Scrubber	467 m^3/h	
Fresh Water Pump for Circulating		300 m^3/h

4.18 Power Consumption for Scrubber

Table 4.14 Power Consumption of Scrubber usage

Item	Operation (kW)	Open Loop (kW)	Closed Loop (kW)	Load (%)
No. 1 Sealing Air Fan	6,4	6,4	6,4	100
No. 2 Sealing Air Fan	6,4			0
No. 1 S.W Feed Pump	98	98	98	100
No. 2 S.W Feed Pump	98	0	0	0
No. 1 F.W Circulating Pump	45		45	100
No. 2 F.W Circulating Pump	45		0	0
Makeup Water Pump	5,5		5,5	100
NaOH Pump	0,18		0,18	100
Others	16,5	16,5	16,5	100
Wash Water Treatment	6		6	100
Total		120,9	177,58	

4.19 Pumps for Scrubber

After we calculate the head and knowing capacity requirement, we need to choose the right pump for scrubbing process, the result is on the table below

4.19.1 Sea Water Pump

Table 4.15 Sea Water Pump (Goulds 3181 M)

Description	Value
Capacity (m^3/h)	467
Head (m)	50
Motor (kW)	98 @1800 rpm
Type	Vert. Centrifugal
Control	VFD
Quantity	2

4.19.2 Fresh Water Pump

Table 4.16 Fresh Water Pump (Taiko EMC250-C)

Description	Value
Capacity (m^3/h)	300
Head (m)	28,9
Motor (kW)	45 @1800 rpm
Type	Centrifugal
Control	VFD
Quantity	2

4.19.3 NaOH Pump

Table 4.17 NaOH Pump (Teflow CQB20-15-75F)

Description	Value
Capacity (m^3/h)	1,6
Head (m)	7
Motor (kW)	0,18 @2900 rpm
Type	Magnetic
Control	VFD
Quantity	1

4.19.4 Makeup Water Pump

Table 4.18 Makeup Water Pump (Taiko EMC100-C)

Description	Value
Capacity (m^3/h)	20
Head (m)	1,7
Motor (kW)	5,5 @1800 rpm
Type	Centrifugal
Control	VFD
Quantity	1

4.20 Fans

4.20.1 Sealing Air Fan

Table 4.19 Sealing Air Fan (Kruger ASA 355)

Description	Value
Static Head (Pa)	5000
Capacity (m^3/h)	2500
Motor (kW)	6,4
Quantity	2

4.21 Others

At this case, we choose the right equipment to be installed on the Scrubber system, the data of selected component is on the table below, including pipe, wash water treatment, fittings, etc.

4.21.1 Wash Water Treatment

Table 4.20 Wash Water Treatment

Brand	Wartsila SWT 500
Capacity	5 m3/h
Power	6 kW

4.21.2 Heat Exchanger

Table 4.21 Heat Exchanger

Merk	Hisaka LX-30
Max. Flow Rate	481 m3/h
Max. Working Temperature	180 °C
Max. Working Pressure	12,5 Bar

4.21.3 Pipe and Fittings

Table 4.22 Pipe List

No	Material	Nominal Diameter		length	Schedule
1	Carbon Steel	20	mm	13,59 m	40
2	Carbon Steel	250	mm	83,7 m	40
3	Carbon steel	10	mm	3,47 m	40
4	Carbon steel	300	mm	98,2 m	40

Table 4.23 Fittings list

No	Item	Size	Qty.
1	Butterfly Valve	300 mm	8
2	Elbow 90	300mm	12
3	Filter	300 mm	1
4	NRV	300 mm	2
5	T Joint	300 mm	5
6	Elbow 90	250 mm	8
7	Filter	250 mm	2
8	NRV	250 mm	1
9	T Joint	250 mm	5
10	Butterfly Valve	250 mm	8
11	Gate Valve	20 mm	0
12	Butterfly Valve	25 mm	0
13	Elbow 90	10 mm	2
14	T Joint	10 mm	0
15	Pressure Indicator		12
16	Safety Valve	5 Bar	3
17	Level Alarm		3
18	Sounding Pipe		2
19	NRV	20 mm	1
20	NRV	10 mm	1

4.22 Electrical Load after Scrubber Attachment

Electrical load of all components are supplied by generator, generator uses to supply all electrical component on the ship. If more components it means more load to be supplied by generator. So, we need to recalculate load factor to know the new demand power for this ship.

Table 4.24 Electrical load before Scrubber Attachment

Item		Sea going	Manuvering	Cargo Operation	Harbour	Emergency
Intermitten load (kW)	Total	522,1	649,4	639,8	573,1	0
	Diversity factor	1,5	1,5	1,5	1,5	1,5
	Demand power	348,1	432,9	426,5	382,1	0,0
Continous load (kW)	Demand power	500,4	500,4	1727,4	393,77	117,5
Total continous & intermitten load		848,47	933,33	2153,93	775,84	117,50
Design margin (2%) (kW)		16,97	18,67	43,08	15,52	2,35
Total demand power with provision for design margin (kw)		**865,44**	**952,00**	**2197,01**	**791,35**	**119,85**

In the table above, this is the old electrical load data and we calculate the new factor of continous load, will be

New CL = Old CL + (Load Factor x Required power for scrubbing)

= 1727,4 + (1 x 177,58)

= 1904,98 kW

Total demand power = Total IL & CL x (1 + design margin)

= 426,5 + 1904,98 x (1 + 2%)

= 2369,6 kW

Then, we calculate the new load factor of Generator and the result is

Load Factor = Required power / Total generator power

= 2369,6 /(1300 x 2)

= 91%

and, if we use all generators, the new percentage will be

Load Factor = Required power / Total generator power

= 2369,6/(1300 x 3)

= 60,75 %

And then, we calculate the start power, and the total is

Start Power = Loading Unloading (w/o Cargo oil pump) + Cargo Oil Pump

= 670,06 + (618,28 x 3)

= 2524,9 kW

And the generator efficiency is:

Generator Efficiency = Start power / total generator force

= 2524,9 / (1300 x 3)

= 64,74%

4.23 Cost Estimation

Next, we need to find all components and prices, so all components and prices can be seen on the table below

4.23.1 Cost Estimation of All Components

Table 4.25 Cost Estimation of All components

No	Item	Specification	Quantity		Unit Cost		Total Cost	
1	Sea Water Pump		2	pcs	Rp	933.600.000	Rp	1.867.200.000
2	Fresh Water Pump		2	pcs	Rp	139.495.400	Rp	278.990.800
3	NaOH Pump		2	pcs	Rp	6.410.720	Rp	12.821.440
4	Heat Exchanger		1	pcs	Rp	7.780.000	Rp	7.780.000
5	Wash Water Treatment		1	pcs	Rp	141.265.000	Rp	141.265.000
6	Carbon Steel Pipe	300 mm	322,19	ft	Rp	10.182.620	Rp	3.280.781.105
7	Carbon Steel Pipe	250 mm	274,62	ft	Rp	10.182.620	Rp	2.796.348.050
8	Carbon Steel Pipe	20 mm	44,59	ft	Rp	14.988.014	Rp	668.297.409
9	Carbon Steel Pipe	10 mm	11,39	ft	Rp	16.131.986	Rp	183.663.790
10	Butterfly Valve	12"	8	pcs	Rp	1.556.000	Rp	12.448.000
11	Butterfly Valve	10"	8	pcs	Rp	3.656.600	Rp	29.252.800
12	Elbow 90	12"	12	pcs	Rp	155.600	Rp	1.867.200
13	Elbow 90	0,4"	2	pcs	Rp	311.200	Rp	622.400
14	Elbow 90	10"	8	pcs	Rp	933.600	Rp	7.468.800
15	NRV	12"	2	pcs	Rp	1.400.400	Rp	2.800.800
16	NRV	10"	1	pcs	Rp	1.322.600	Rp	1.322.600
17	NRV	3/4"	1	pcs	Rp	933.600	Rp	933.600
18	NRV	0,4"	1	pcs	Rp	778.000	Rp	778.000
19	Filter	12"	1	pcs	Rp	2.053.920	Rp	2.053.920
20	Filter	10"	2	pcs	Rp	2.053.920	Rp	4.107.840
21	T Joint	12"	5	pcs	Rp	142.500	Rp	712.500
22	T Joint	10"	5	pcs	Rp	142.500	Rp	712.500
23	Level Alarm		3	pcs	Rp	169.000	Rp	507.000
24	Sealing Air fan	2500 m3/h	2	pcs	Rp	9.930.236	Rp	19.860.472
25	Plastic Tank	1000 l	2	pcs	Rp	1.000.000	Rp	2.000.000
26	Scrubber Tower		1	pcs	Rp	389.000.000	Rp	389.000.000
27	Sensor package		2	pcs	Rp	113.577.975	Rp	227.155.950
28	Makeup Water Pump		1	pcs	Rp	20.383.600	Rp	20.383.600
29	Temperature Indicator		2	pcs	Rp	209.000	Rp	418.000
30	Pressure Indicator		12	pcs	Rp	209.000	Rp	2.508.000
31	Sounding Pipe		2	pcs	Rp	18.672.000	Rp	37.344.000
32	Safety Valve		6	pcs	Rp	209.000	Rp	1.254.000
33	Emission Monitoring	(Scrubber)	1	pcs	Rp	113.577.975	Rp	113.577.975
					Total		Rp	10.116.237.550

Based on the table above, the total price is 10,116 Billion Rupiah

4.23.2 Direct Costs

Direct costs is based on Equipment Cost, Instrumentation, Tax, and freight. Tax is based on Bea Cukai, which is now Import Duty is 7,5% and PPN 10% , the rest is based on HarlanH.

Table 4.26 Direct Costs

Direct Costs	
Equipment Cost	Rp 10.116.237.550,00
Instrumentation (10%)	Rp 1.011.623.755,00
Sales Taxes (17,5%)	Rp 1.770.341.571,25
Freight (5%)	Rp 505.811.877,50
Total Direct Costs	Rp 13.404.014.753,75

4.23.3 Direct Installation Costs

The price of Direct Installation costs are based on total direct costs that we calculated before for Scrubber modification on this ship, and the price based on IPERINDO 2019, can be seen on attachments.

Table 4.27 Direct Installation Costs

Direct Installation costs	
As Summarized	Rp 3.096.412.615,00

4.23.4 Indirect Costs

Indirect Installation costs are also based on Direct Costs.

Table 4.28 Indirect Costs

Indirect Costs	
Engineering (10%)	Rp 1.340.401.475,38
Construction and Field Expenses (10%)	Rp 1.340.401.475,38
Contractor Fees (10%)	Rp 1.340.401.475,38
Start up (1%)	Rp 134.040.147,54
Performance Test	-
Model Study (3%)	Rp 402.120.442,61
Contingencies (3%)	Rp 402.120.442,61
Total Indirect Costs	Rp 4.959.485.458,89

4.23.5 Total Costs

Table 4.29 Total Costs

Summary	
Total Costs (USD)	$ 1.379.171,77
Total Costs (EURO)	€ 1.282.629,75
Total Costs (IDR)	Rp 21.459.912.787,10
Cost Estimated by Berqvist et al.	€ 3.000.000,00
Estimated difference (€)	€ 1.717.418,06
Estimated difference(%)	57%

4.24 Operational Expenditure Calculation

After Scrubber attachment, we need to analyze the economical aspect between Open Loop and Closed Loop, and also we need to predict the cost for all equipment's spare parts by calculating the total cost. so, we will know the operational costs after scrubber installation.

4.24.1 Component Cost for Operational Expenditure

Table 4.30 Component Cost for OPEX

Component List						
No	**Item**	**Specification**	**Qty**	**Unit**	**Cost / Item**	**Total Cost**
1	Sea Water Pump	Brand : Goulds 3181 M Flow Rate : 467 m3/h Head : 50 m Power : 98 kW	2	Pcs	Rp 933.600.000	Rp 1.867.200.000
2	Fresh Water Pump	Brand : Taiko EMC250-C Capacity : 300 m3/h Head : 28,9 m Power : 45 kW	2	Pcs	Rp 139.495.400	Rp 278.990.800
3	NaOH Pump	Brand : Teflow CQB20-15-75F Capacity : 1,6 m3/h Head : 7 m Power : 0,18 kW	2	Pcs	Rp 6.410.720	Rp 12.821.440
4	Makeup Water Pump	Brand : Taiko EMC100-C Capacity : 20 m3/h Head : 7 m Power : 5,5 kW	1	Pcs	Rp 20.383.600	Rp 20.383.600
4	Heat Exchanger	Brand : Hisaka LX-30 Max. Flow Rate : 481 m3/h Max. Working Temperature : 180°C Max. Working Pressure : 12,5 Bar	1	Pcs	Rp 7.780.000	Rp 7.780.000
5	Wash Water Treatment	Brand : Wartsila SWT 500 Capacity : 5 m3/h Power : 6 kW	1	Pcs	Rp 141.265.000	Rp 141.265.000
6	Component Spare Parts	5% of Component Cost				Rp 116.422.042
					Total Component Cost	**Rp 2.444.862.882**

4.24.2 Additional Fuel Consumption

Table 4.31 Additional Fuel Consumption

Fuel Consumption Cost Calculation				
No	**Formula/Data**	**Information**	**Value**	**Unit**
1	Equipment's Power Consumption	Sea Water Pump : 98 kW x 2 Fresh Water Pump : 45 x 2 NaOH Pump : 0,18 kW x 2 Wash Water Treatment : 6 kW Makeup Water Pump: 5,5 kW	297,86	kW
2	*Exhaust gas production* t = V/Q	t = (42072,403 / 18736,49) x 2	4,49	hour
3	Equipment's Energy Consumption kWh = P x t	kWh = 261,5 x 22,8	1337,68	kWh
4	SFOC	Generator Specification	195	g/kWh
5	Additional Fuel Consumption (ton) Fuel Consumption = Energy Consumption x SFOC x 10^{-6}	Fuel Consumption = 5962,2 x 189 x 10^{-6}	0,26	ton
6	HSD Fuel Price	Pertamina	9700,00	IDR/l
7	Fuel Consumption Cost Cost = ((Fuel Consumption x 1000)/0,85) x fuel price	Cost = ((0,26 x 1000)/0,85) x 9700	2.976.725	Rupiah

4.24.3 Cost Estimation (Open Loop)

Table 4.32 Cost Estimation (Open Loop)

Operational Cost						
No.	**Price Type**	**Specification**	**Quantity**	**Unit**	**Price/Unit**	**Total Price**
1	Fuel Consumption	((0,26 ton x 1000)/0,85) x 9700	34	Voyage	Rp 2.976.725	Rp101.208.642,55
2	NaOH	No NaOH Required	0	Voyage	Rp 31.586.800	-
3	Fresh Water	Generated by F.W Generator	34	Voyage	-	-
					Total	**Rp101.208.642,55**

4.24.4 Cost Estimation (Closed Loop)

Table 4.33 Cost Estimation (Closed Loop)

Operational Cost						
No.	**Price Type**	**Specification**	**Quantity**	**Unit**	**Price/Unit**	**Total Price**
1	Additional Fuel Consumption	((0,26 x 1000)/0,85) x 9700	34	Voyage	Rp 2.976.725	Rp101.208.642,55
2	NaOH	5,8 m3	34	Voyage	Rp 31.586.800	Rp1.073.951.200,00
3	Fresh Water	Generated by F.W Generator	34	Voyage	-	-
					Total	**Rp1.175.159.842,55**

In those Table, we know if Cost estimated for open loop at 101 Million Rupiah and for Closed loop is estimated at 1,175 Billion Rupiah. So, it has a difference about IDR 1,073 Billion Rupiah per year. And this have a difference about 1061,1%

4.24.5 Operational Expenditure (Open Loop)

Table 4.34 Operational Expenditure (Open Loop)

Operation Cost per Year			
No.	**Item**	**Estimation**	**Total Cost**
1	Maintenance & Repair Cost	15% of Installation Cost	Rp 464.461.892
2	Maintenance of Equipment	5% of Equipment Cost	Rp 505.811.878
3	Operational Cost	Described at 4.24.3	Rp 101.208.643
		Total	**Rp 1.071.482.412,21**

4.24.6 Operational Expenditure (Closed Loop)

Table 4.35 Operational Expenditure (Closed Loop)

Operation Cost per Year			
No.	**Item**	**Estimation**	**Total Cost**
1	Maintenance & Repair Cost	15% of Installation Cost	Rp 464.461.892
2	Maintenance of Equipment	5% of Equipment Cost	Rp 505.811.878
3	Operational Cost	Described at 4.24.4	Rp 1.175.159.843
		Total	**Rp 2.145.433.612,21**

At another case, they have same difference, but at 100,23% per year.

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CHAPTER 5

CONCLUSION

5.1 Conclusions

So, we can conclude this research, and the research results are:

- Scrubber System is divided into 3 kinds, such as Open Loop, Closed Loop, and Hybrid Loop
- Hybrid loop is a combination between open loop and closed loop so the operators can choose between open loop and closed loop, so the operators can not worried if the ship is on Zero Discharge areas as ruled on IMO 2020 Annex VI but with cheaper operation price outside Zero Discharge Area.
- If we assumed Main engine and boilers on this ship using HFO but generators is using HSD, the predicted cost as at IDR 7,18 Billion per trip, and increase just a little bit if Generators and Boilers using MDO. If Main Engine and Boilers using MDO, the predicted cost will be IDR 9,34 Billion per trip using Pertamina Price which is 9550 IDR per litre for MDO and 7000 IDR per litre for HFO and 9700 IDR per litre for HSD, resulting with a price difference at 30,05%
- The total of required powers are now increasing about 120,9 kW at Open Loop and 177,58 kW at Closed Loop
- The new total demand for this ship is 2341,9 kW
- For scrubber components, the cost of all components is 650143,80 USD or 10,116 Billion Rupiah(based on 24th April exchange rate which is IDR 15560 per USD)
- For Scrubber attachment, the cost is predicted about 1,282 million Euro. Based on Hybrid Loop Scrubber Application cost based on Berqvist et al. Which is 3 million Euro, the price differences is predicted about 57%
- The estimated price for Cost estimation between Open Loop and Closed Loop have a price difference at IDR 1,073 Billion per year and estimated at 1061,1%. And for the operational expenditure, cost per year between Open Loop and Closed Loop is estimated at same value as Cost estimation per year but at 100,23% in difference
- Overall, The Scrubber system is also an effective way to face based on IMO Regulation Annex VI 2020, the installation take time about 18 days.

5.2 Suggestions

After designing, calculating, and designing system for this ship, here are the suggestions:

- To modify this system for this ship needs analysis on required dimension, so the attachment will be precisely attached
- Make sure the new load factor can endure by existing generator at ship.
- To analyse cost estimation, we need to know installation costs, indirect costs, direct costs, and operation cost each loop so we can compare them.

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ATTACHMENTS

a. Data of Main Engine

HYUNDAI HEAVY INDUSTRIES CO., LTD.

Official shop test result for Main Engine	Hull No.	CH-0802	Weather	FINE
	Engine No	AA3983	Measuring Time	19:20
	Eng. Type	6S42MC7	Test Date	May.23,2010
Data sheet of 100% Load test	Owner	PERTAMINA	Engineer	J.Y.PARK
	Class	DNV	Operator	S.C.KIM

* Room Temperature : 20.4 ℃ * Atmospheric Pressure : 1014.0 mbar

Engine Speed	Water Brake	Brake Power	Indicated Power	Mech.Efficiency	NOTCH
136.0 rpm	64.78 tonf	6480 kW	6834 kW	94.82 %	7.7

System		Main L.O	P.C.O	Cam L.O	Fuel Oil	Cooling F.W
In	Press.(bar)	2.1			7.4	4.0
	Temp.(℃)	43.0			38.0	70.0

Cyl. No.		Avg.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pmax.	bar	145.0	145	145	145	145	145	145								
Pcomp.	bar	125.8	126	125	126	126	126	126								
Pi	bar	20.56	20.69	20.59	20.57	20.51	20.44	20.56								
F.O Pump	P0	66.0	66	66	66	66	66	66	BLANK							
	VIT	-	-	-	-	-	-	-								
Exh.Gas Out.	℃	378.0	380	376	388	372	372	380								
C.F.W Out.	℃	78.0	78.0	77.0	78.0	78.0	78.0	79.0								
Cam L.O Out.	℃	45.0	45.0													
P.C.O Out	℃	55.3	56.0	54.0	56.0	54.0	56.0	56.0								

Air Cooler

No.		1	2	3	4	Avg.
Bef. Cooler Press	mmHg	2160				2160
Press. Drop	mmAq	195				195
Air In.	℃	186	BLANK			186
Air Out.	℃	40.0				40.0
Cooling Water In	℃	15.0				15.0
Cooling Water Out	℃	54.0				54.0

Scavenging Air

Pressure		Temperature	
2.91	bar	40	℃
Air receiver pressure		2130	mmHg
Exhaust Manifold Pressure		2.62	bar

Specific Fuel Oil Consumption

Meas.(kg/h)	Meas.(g/kWh)	Correct(g/kWh)
1211.2	186.914	183.520

Turbocharger

Turbocharger	Speed	Blower Inlet			Before Turbine		After Turbine		L.O.(℃, bar)			F.W Temp
	rpm	℃		mmAq	℃	mmHg	℃	mmAq	In	Out	Press.	℃
No. 1	19260	20.0	20.0	50	449	1880	266	230	43.0	87.0	1.70	-
No. 2												
No. 3		BLANK										
No. 4												
Avg.	19260	20.00		50	449	1880	266	230	43.0	87.0	1.70	-

* Pressure vit : - bar *Governor Position : 89.6 * Thrust Pad : 52.0 ℃

Note : The Fuel Oil Consumption is corrected to Lower Calorific Value 10200 kcal/kg & I.S.O condition

b. Data of Auxiliary Engine

CHAPTER 1		General
ITEM 1,2	DK-26	Engine Specifications and Auxiliary Equipment

1-1 Engine Specifications

Model		5DK-26	6DK-26
Type		Vertical water-cooling direct injection type 4-cycle diesel engine	
Number of cylinders		5	6
Cylinders bore	mm	260	
Piston stroke	mm	380	
Engine speed	min^{-1}	※	
Output	kW	※	
Ignition sequence	Constant speed	1-3-5-4-2	1-5-3-6-2-4
	Variable speed	—	1-2-4-6-5-3
Rotating direction		Clockwise when seen from the flywheel	
Turbocharging method		Turbocharged by exhaust gas turbine equipped with air cooler	
Starting method,Compressed air		Air motor	Direct (Starting valve)
Cooling method	Jacket	Fresh water	
	Cooler	Fresh (or Sea) water	

c. Data of Emission Measurement

Type	Division	Unit	MCR	Design	at SEA	In-Port	Maneuvering
Main Engine	No. of set		1	1	1	1	1
	Power	kW	6,480	5,508	5,508	0	4,212
	Exhaust Gas Flow	kg/h	55,080	46,818	46,818	0	35,802
		Nm³/h	42,304	35,959	35,959	0	27,498
	Temp.	℃	220	220	220	220	220
	Load	%	100%	85%	85.0%	0%	65%
Auxiliary Engine	No. of set		3	3	1	3	1
	Power (each)	kW	1,020	714	714	714	714
	Exhaust Gas Flow (each)	kg/h	8,160	5,712	5,712	5,712	5,712
		Nm³/h	6,267	4,387	4,387	4,387	4,387
	Power (Total)	kW	3,060	2,142	714	2,142	714
	Exhaust Gas Flow (Total)	kg/h	24,480	17,136	5,712	17,136	5,712
		Nm³/h	18,802	13,161	4,387	13,161	4,387
	Temp.	℃	300.0	300.0	300.0	300.0	300.0
	Load	%	100%	70%	70%	70%	70%
Aux. Boiler	No. of set		1	1	1	1	1
	Max. Power	kW	4,300				
	Steam Capacity	kg/hr	8.0	6.0	6	6	4
	Exhaust Gas Flow	kg/h	8,495	6,371	6,371	6,371	33,979
		Nm³/h	6,585	4,939	4,939	4,939	3,293
	Temp.	℃	346	346	346	346	346
	Load	%	100%	75%	75%	75%	50%
Data of Max. power is provided by the customer	Max. Power	kW	13,840	7,650	6,222	2,142	4,926
	Exhaust Gas Flow	kg/h	83,860	70,325	58,901	23,507	75,493
		Nm³/h	67,691	54,059	45,284	18,100	35,177
	Temp.	℃	254	251	241	313	242

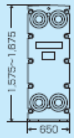
c. Data of Boiler

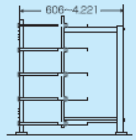
1.2. Technical description Thermal Oil Heater

Model:		THM/V 5000
Version:		Vertical
Number of units:		1
Capacity:	Kcal/h	3706897
	kW	4300
Efficiency:	%	87
Out-let temperature:	°C	190
Δ T - Temperature jump	°C	50
Thermal oil content:	lt.	1851
Fuel		MDO/HFO 380cSt at 50oC
Fuel consumption :		
Diesel oil (10.200 Kcal/kg)	Kg/h.	418
Heavy oil (9.700 Kcal/kg)	Kg/h.	439
Electric data		440/60/3
		MDO/HFO Riello
Burner regulation:		Modulating
Burner installed electrical power :		
Diesel oil	kW	18
Heavy oil	kW	0
Thermal oil circulation pump capacity:	m³/h	168
Pressure loss oil side heater	m	21
Dimensions (burner excluded) :		
Length	mm	2100
Width	mm	2300
Height	mm	5700
Weight	kg	7950
Exhaust gas connection diameter	Ø mm	ø550

d. Data of Heat Exchanger

LX-30	Max. flow rate / unit	481m³/h
	Max. working pressure	1.25MPaG
	Max. working temperature	180℃
	Max. heat transfer area / unit	100m²
	Porthole Dia.	156mm
	Connection Dia.	150A

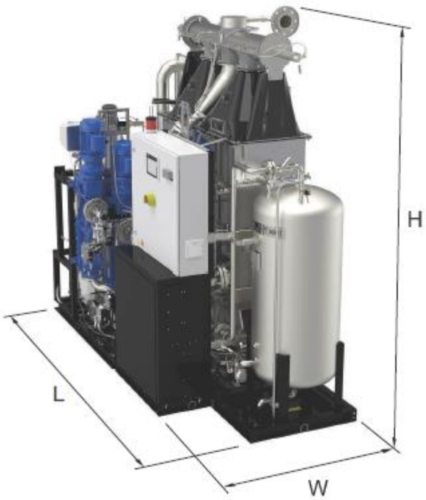




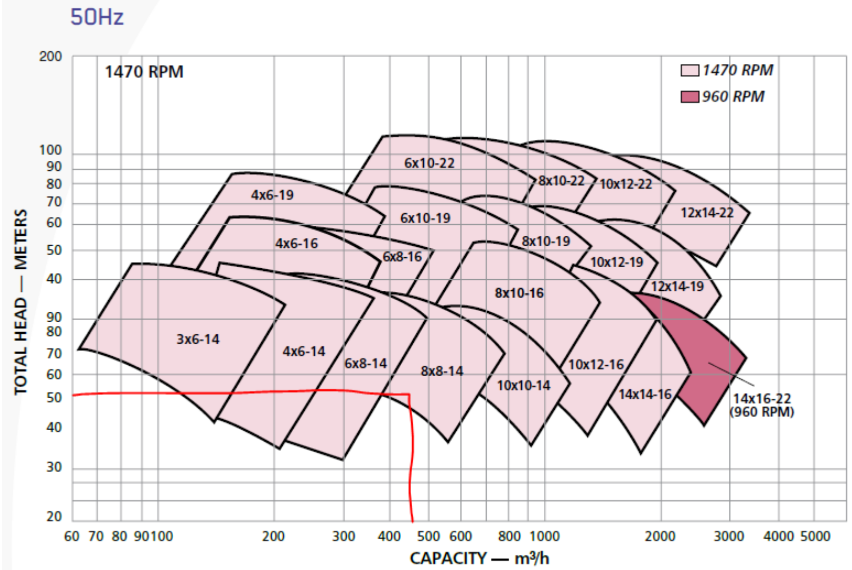
e. Wash Water Treatment

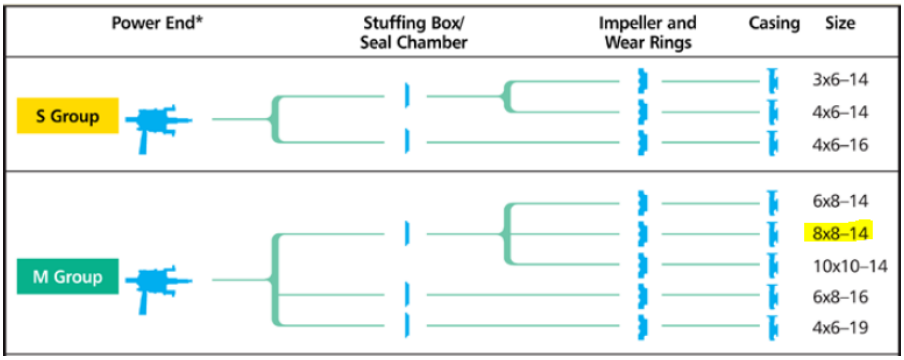
FOOTPRINT SWT 500

Model	Capacity m³/h	Capacity gal/h	Size (mm)			Size (inches)		
			Length (L)	Width (W)	Height (H)	Length (L)	Width (W)	Height (H)
SWT	5.0	31700	2760	1100	2565	108.7	43.3	101.0

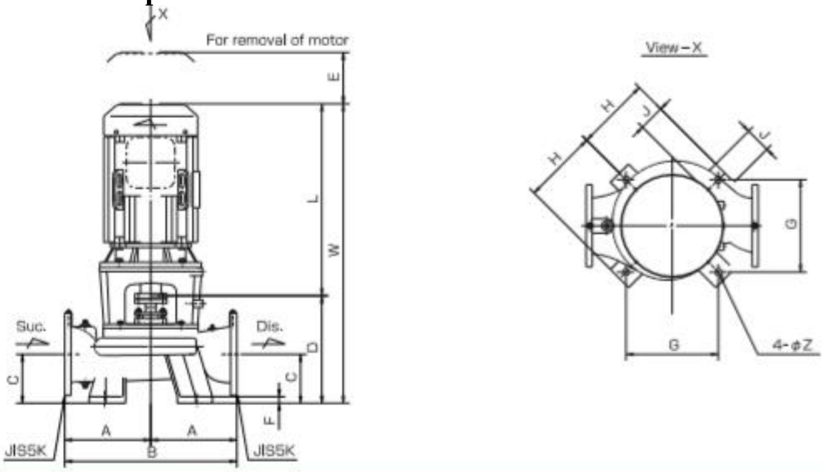


f. Data of Sea Water Pump



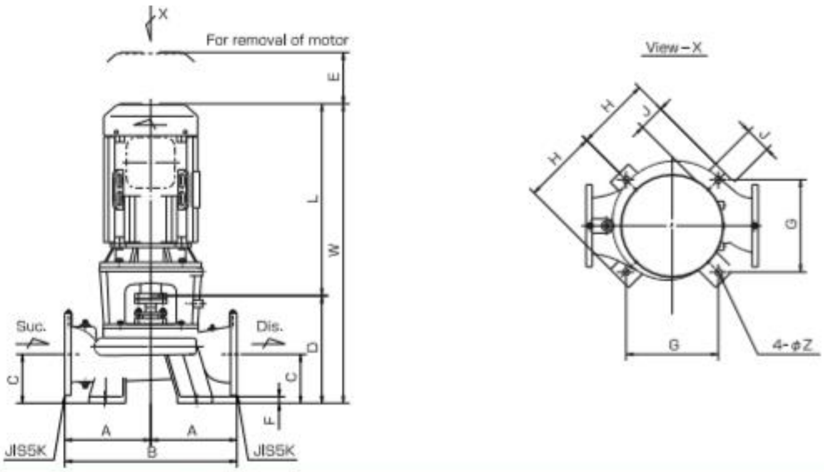


g. Data of Freshwater Pump



Model No.	Motor		Bore		Dimension (mm)											
	kW	min^{-1}	Suc.	Dis.	A	B	C	D	E	F	G	H	J	L	W	Z
EMC-100C	5.5	1800	100	100	280	560	150	360	150	25	290	240	100	480	840	28
	7.5															
	11								200					595	955	
EMC-125C	7.5	1800	125	125	300	600	160	370	150	25	290	240	100	480	850	28
	11								200					595	965	
	15													635	1005	
EMC-150C	11	1800	150	150	315	630	160	393	200	25	360	290	100	595	988	28
	15													635	1028	
	18.5													685	1078	
EMC-200C	15	1800	200	200	335	670	190	418	200	25	360	290	100	635	1053	28
	18.5													685	1103	
	22															
	26													725	1143	
EMC-250C	22	1800	250	250	400	800	220	490	200	25	410	325	100	685	1175	28
	26													725	1215	
	30															
	37								250							
	45													800	1290	
EMC-260C	30	1800	250	250	400	800	220	520	200	25	410	325	100	725	1245	28
	37								250					800	1320	
	45															
	55													950	1470	
	65													1050	1570	

h. Data of Makeup Water Pump



Model No.	Motor		Bore		Dimension (mm)											
	kW	min⁻¹	Suc.	Dis.	A	B	C	D	E	F	G	H	J	L	W	Z
EMC-100C	5.5	1800	100	100	280	560	150	360	150	25	290	240	100	480	840	28
	7.5															
	11								200					595	955	
EMC-125C	7.5	1800	125	125	300	600	160	370	150	25	290	240	100	480	850	28
	11								200					595	965	
	15													635	1005	
EMC-150C	11	1800	150	150	315	630	160	393	200	25	360	290	100	595	988	28
	15													635	1028	
	18.5													685	1078	
EMC-200C	15	1800	200	200	335	670	190	418	200	25	360	290	100	635	1053	28
	18.5													685	1103	
	22															
	26													725	1143	
EMC-250C	22	1800	250	250	400	800	220	490	200	25	410	325	100	685	1175	28
	26													725	1215	
	30															
	37								250							
	45													800	1290	
EMC-260C	30	1800	250	250	400	800	220	520	200	25	410	325	100	725	1245	28
	37								250					800	1320	
	45															
	55													950	1470	
	65													1050	1570	

i. Data of NaOH Pump

NO.	Type	Flow	Head	EFF	NPSH	Aperture	Speed	Power	Weight
NO.	TYPE	FLOW m^3/h	HEAD m	EFF %	NPSH m	Import× export mm	SPEED r/min	POWER kw	WEIGHT kg
Classical type	CQB16-12-50F	0.6	2	8	9	16×12	2900	0.025	5
	CQB15-15-65F	0.8	3.2	16	6	15×15	2900	0.18	7
	CQB20-15-75F	1.6	7	22	6	20×15	2900	0.18	8
	CQB25-20-100F	2.5	10.5	28	6	25×20	2900	0.37	12
	CQB32-20-110F	5.5	13	35	6	32×20	2900	0.55	18
	CQB32-20-160F	5.5	32	35	6	32×20	2900	2.2	65
	CQB40-25-120F	6.3	15	42	5	40×25	2900	0.75	35
	CQB40-25-125F	6.3	20	43	5	40×25	2900	1.1	20
	CQB40-40-125F	6.5	17.5	42	3.7	40×40	2900	1.1	40
	CQB40-32-160F	6.5	32	42	3.7	40×32	2900	4	70

j. Pipe Price List

SIZE INCH	SIZE Nominal Bore	MSL PRICE LIST	ISMT PRICE LIST	JSL PRICE LIST	USL PRICE LIST	BAO PRICE LIST	Lontrin PRICE LIST	SMTM PRICE LIST	TNRS PRICE LIST	V&M PRICE LIST	Wuxi PRICE LIST
1/2	15	1,323.53	1,316.18	1,330.88	-	1,029.41	1,036.76	1,460.59	1,396.06	1,425.47	1,012.06
3/4	20	1,102.94	1,095.59	1,110.29	-	954.88	963.24	1,250.00	1,176.47	1,205.88	938.53
1	25	945.88	948.53	963.24	-	881.35	889.71	1,102.94	1,029.41	1,058.82	875.00
1.25	32	901.76	904.41	919.12	-	851.94	860.29	1,058.82	985.29	1,014.71	845.59
1.5	40	808.82	801.47	816.18	-	807.82	816.18	955.88	882.35	911.76	801.47
2	50	784.12	786.76	801.47	-	617.65	625.00	941.18	867.65	897.06	610.29
2.5	65	784.12	786.76	801.47	-	617.65	625.00	941.18	867.65	897.06	610.29
3	80	794.12	786.76	801.47	-	617.65	625.00	941.18	867.65	897.06	610.29
3.5	90	794.12	786.76	801.47	-	617.65	625.00	941.18	867.65	897.06	610.29
4	100	794.12	786.76	801.47	735.29	617.65	625.00	941.18	867.65	897.06	610.29
5	125	794.12	786.76	801.47	735.29	617.65	625.00	941.18	867.65	897.06	610.29
6	150	794.12	786.76	801.47	735.29	617.65	625.00	941.18	867.65	897.06	610.29
8	200	794.12	786.76	801.47	735.29	647.06	654.41	941.18	867.65	897.06	639.71
10	250	794.12	786.76	-	735.29	647.06	654.41	941.18	867.65	897.06	639.71
12	300	852.94	-	-	735.29	647.06	654.41	1,000.00	926.47	955.88	639.71
14	350	852.94	-	-	735.29	661.76	669.12	1,000.00	926.47	955.88	654.41
16	400	882.35	-	-	-	661.76	669.12	1,029.41	955.88	985.29	654.41
18	450	882.35	-	-	-	676.47	683.82	1,029.41	955.88	985.29	669.12
20	500	882.35	-	-	-	676.47	683.82	1,029.41	955.88	985.29	669.12
22	550	-	-	-	-	705.88	713.24	1,176.47	1,029.41	1,132.35	698.53
24	600	-	-	-	-	705.88	713.24	1,176.47	1,029.41	1,132.35	698.53

k. Fuel Price

MINYAK SOLAR/HSD (High Speed Diesel) :

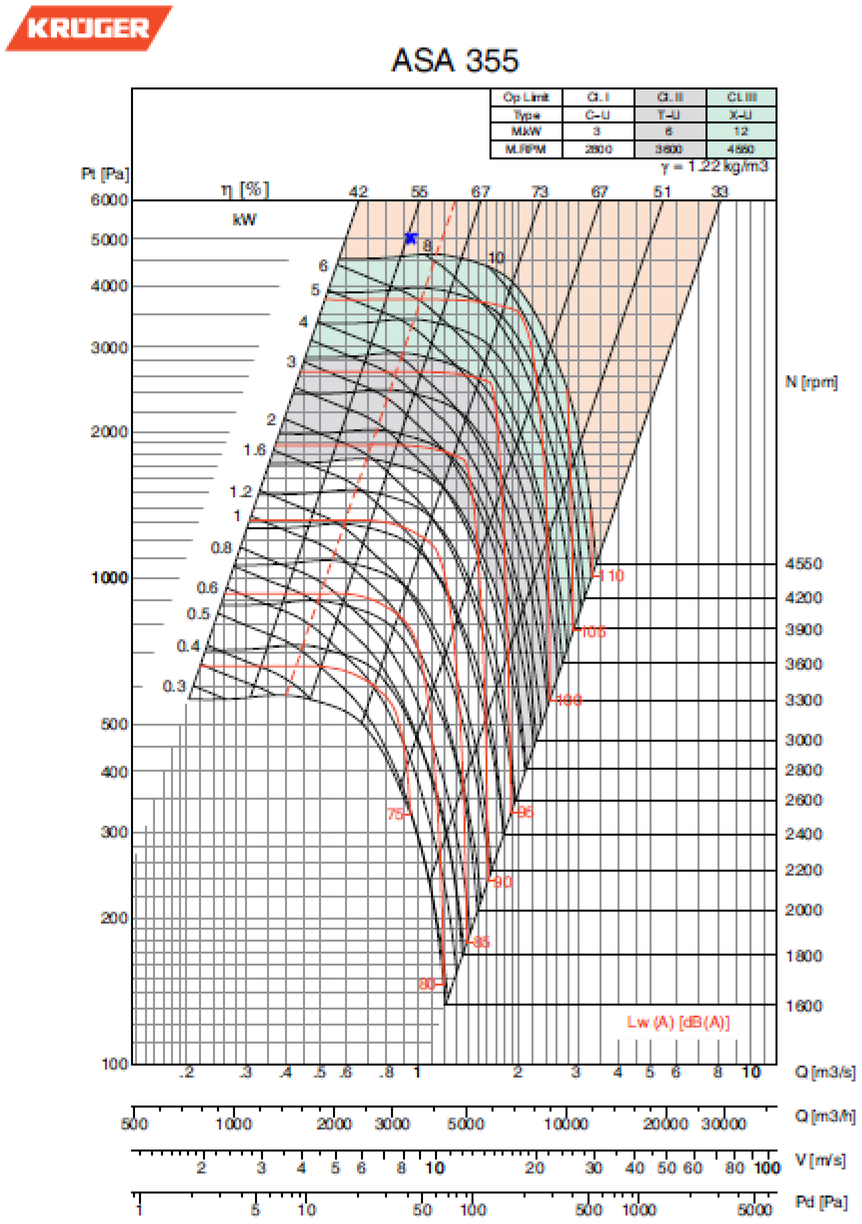
HARGA DASAR HSD Solar Industri (Wilayah 1)	Rp. 9.450,-
HARGA DASAR HSD Solar Industri (Wilayah 2)	Rp. 9.450,-
HARGA DASAR HSD Solar Industri (Wilayah 3)	Rp. 9.550,-
HARGA DASAR HSD Solar Industri (Wilayah 4)	Rp. 9.700,-

(Harga diatas belum termasuk PPn, PPH dan PBBKB)

MINYAK BAKAR/MFO (Marine Fuel Oil) :

HARGA DASAR MFO (Wilayah 1)	Rp. 7.000,-
HARGA DASAR MFO (Wilayah 2)	Rp. 7.000,-
HARGA DASAR MFO (Wilayah 3)	Rp. 7.000,-
HARGA DASAR MFO (Wilayah 4)	Rp. 7.000,-

l. Sealing Air Fan



- Performance shown is for installation type B – free inlet, ducted outlet. Performance ratings do not include the effects of appurtenances in the airstream. Power rating kW does not include drive losses.
- The A-weighted sound ratings shown have been calculated per AMCA standard 301. Values shown are for inlet Lw(A) sound power levels for installation type B – free inlet, ducted outlet. Ratings do not include the effect of duct end corrections.
- The AMCA Certified Ratings Seal applies to air performance rating only.

m. Installation Costs list

QUOTATION OF DOCKING REPAIR

Vessel Name : MT Senipah
Owner : PT Pertamina Persero – Shipping Department
Class : DNV
Survey :
Date :

Ship Particular

LOA	:	180,00	Meter
LBP	:	173,00	Meter
BM	:	30,50	Meter
Draft	:	9,20	Meter
GRT	:	24.167	Ton
H	:	15,90	Meter

Job Code	URAIAN PEKERJAAN	VOLUME		UNIT PRICE (RP)	TOTAL (RP)
I.	GENERAL SERVICE				
1. 1	Dry docking and docking preparation				
	a. Assistance for Docking Undocking	1	Ship set	47.312.640	47.312.640
	b. Docking undocking	1	Ship set	217.645.056	217.645.056
	c. Docking Report	1	Ship set	27.905.472	27.905.472
	d. Vessel to be on dry dock for service and repair	18	Days	32.645.376	587.616.768
	Drawing reference : General Arrangement, Docking Plan & Tank Capacity				
1. 2	Tug boat service				
	a. Tug's assistant during vessel's arrival and sail out at yard (x2 tugboat)	2	Hours	32.758.000	65.516.000
	b. Tug's assistant during docking undocking, using yard own tug's	2	Hours	32.758.000	65.516.000
1. 3	Pilotage				
	a. Pilotage assistant during vessel's arrival and sail out at yard.	2	Hours	3.377.376	6.754.752
	b. Pilotage assistant during docking undocking, est. 2 hours.	2	Hours	3.377.376	6.754.752
1. 4	Rigging Service				
	a. Line handler assistant during vessel's arrival and sail out at yard (mooring unmooring)	1	Ls	30.753.216	30.753.216
	b. Line handler assistant during docking undocking.	1	Ls	30.753.216	30.753.216
1. 5	Wharfage				
	a. To be provided wharf age facilities during floating repair	2	Days	16.322.688	32.645.376
1. 6	Shore Power Supply				
	a. Supply electricity during on repair periode assume (380 Volt, 50A, 50Hz, 3 Phase)	18	Days	1.737.542	31.275.763
	b. Assistant for connect disconnect cable line	1	Times	346.000	346.000
1. 7	Fire Line				
	a. Supply fire patrolmen (2 men at normal hour)	18	days	396.000	7.128.000
	b. Suppy 2 Hose During Repair	18	Days	400.000	7.200.000
	c. Assistant for connect disconnect fire line	2	Times	241.000	482.000
1. 8	Fire Guard				
	To be provided firewatchman and fire patrols during repair period 2 men/day	18	Days	768.000	13.824.000
1. 9	Gas Free Inspection				
	To carry out gas free inspection and reported to OS (for 3 tanks x 1 time)	3	times	577.000	1.731.000
1. 10	Toilet Facilities				
	To be provided toilet facilities for ships crew during on docking	18	Days	350.000	6.300.000
1. 11	Garbage Disposal				
	To be provided manpower and place for galley garbage disposal	18	Days	250.000	4.500.000
1. 12	Fresh Water Supply				
	a. Fresh water supply, est 40 tons	40	Tons	83.300	3.332.000
	b. Assistant for connect disconnect for line	1	Times	241.000	241.000
1. 13	Gangway				
	To be provided gangway facilities during docking period	18	Days	300.000	5.400.000
1. 14	Crane Services				
	a. To be provided docking crane facilities (cap. 10.0 tons), est.	5	Hours	644.000	3.220.000
1. 15	Staging				
	To be provided staging				
	a. Engine room 1st floor 6,8 x 0,5 x3,1	11	M3	50.400	531.216
	b. Engine Room 2nd Floor 11,8 x 0,5 x 3,1	18	M3	50.400	921.816
	c. Engine Room 3rd floor 11,8 x 0,5 x 4,19	25	M3	50.400	1.245.938
	d. Upper deck 2,45 x 0,5 x 5,14	6	M3	64.800	408.013
II.	INSTALLMENT SCRUBBER SYSTEM				
2.1	Sea Water Pump 467 m3 /hour 2 unit (material by owner)	2	unit	16.365.710	32.731.420
	Fresh Water Pump 300 m3 /hour 2 unit (material by owner)	2	Unit	11.178.000	22.356.000
	NaOH Pump 1,6 m3 /hour 2 unit (material by owner)	2	Unit	2.608.200	5.216.400
	Makeup Water Pump 20 m3 /hour 1 unit (material by owner)	1	Unit	3.726.000	3.726.000
	Butterfly Valve 12" 8 pcs (material by owner)	8	pcs	4.725.600	37.804.800

	Butterfly Valve	10"	8 pcs	(material by owner)	8	pcs	3.955.200	31.641.600
	Heat Exchanger		1 pcs	(material by owner)	1	Unit	10.498.393	10.498.393
	Sensor Package		2 pcs	(material by owner)	2	pcs	5.600.000	11.200.000
	Pressure Indicator		8 pcs	(material by owner)	8	pcs	800.000	6.400.000
	Emission Monitoring		1 pcs	(material by owner)	1	pcs	5.600.000	5.600.000
	Level Alarm		3 pcs	(material by owner)	3	pcs	800.000	2.400.000
	Wash Water Treatment		1 pcs	(material by owner)	1	pcs	3.200.000	3.200.000
	Safety Valve		6 pcs		6	pcs	4.725.600	28.353.600
	Sounding Pipe		2 pcs		2	pcs	200.000	400.000
	NRV	12"	2 pcs		2	pcs	2.624.400	5.248.800
	NRV	10"	1 pcs		1	pcs	2.239.200	2.239.200
	NRV	3/4"	1 pcs		1	pcs	2.239.200	2.239.200
	NRV	0,4"	1 pcs		1	pcs	2.239.200	2.239.200
	Sealing Air fan		2 pcs		2	pcs	600.000	1.200.000
2.2	Piping Installment in Engine Room							
	- Carbon Steel dia. 12" SCH.40 x 1376,4 mm				1,376	meter	2.658.528	3.658.135
	- Carbon Steel dia. 12" SCH.40 x 530,4mm				1	meter	2.658.528	2.658.528
	- Carbon Steel dia. 12" SCH.40 x 1593,6 mm				1,594	meter	2.658.528	4.236.630
	- Carbon Steel dia. 12" SCH.40 x 5119,2 mm				5,119	meter	2.658.528	13.609.537
	- Carbon Steel dia. 12" SCH.40 x 6643,2 mm				6,643	meter	2.658.528	17.661.133
	- Carbon Steel dia. 12" SCH.40 x 9871,2 mm				9,871	meter	2.658.528	26.242.862
	- Carbon Steel dia. 12" SCH.40 x 1732,8 mm				1,724	meter	2.658.528	4.582.771
	- Carbon Steel dia. 12" SCH.40 x 5475,6 mm				5,476	meter	2.658.528	14.557.036
	- Carbon Steel dia. 12" SCH.40 x 10890 mm				10,890	meter	2.658.528	28.951.370
	- Carbon Steel dia. 12" SCH.40 x 211,2 mm				1	meter	2.658.528	2.658.528
	- Carbon Steel dia. 12" SCH.40 x 3972 mm				3,972	meter	2.658.528	10.559.673
	- Carbon Steel dia. 12" SCH.40 x 4494 mm				4,494	meter	2.658.528	11.947.425
	- Carbon Steel dia. 12" SCH.40 x 7752 mm				7,752	meter	2.658.528	20.608.909
	- Carbon Steel dia. 12" SCH.40 x 331,2 mm				1	meter	2.658.528	2.658.528
	- Carbon Steel dia. 12" SCH.40 x 3740,4 mm				3,740	meter	2.658.528	9.943.958
	- Carbon Steel dia. 12" SCH.40 x 854,4 mm				1	meter	2.658.528	2.658.528
	- Carbon Steel dia. 10" SCH.40 x 2252,4 mm				2,252	meter	2.197.080	4.948.703
	- Carbon Steel dia. 10" SCH.40 x 1737,6 mm				1,738	meter	2.197.080	3.817.646
	- Carbon Steel dia. 10" SCH.40 x 138 mm				1	meter	2.197.080	2.197.080
	- Carbon Steel dia. 10" SCH.40 x 225,6 mm				1	meter	2.197.080	2.197.080
	- Carbon Steel dia. 10" SCH.40 x 8977,2 mm				8,977	meter	2.197.080	19.723.627
	- Carbon Steel dia. 10" SCH.40 x 1173,6 mm				1,174	meter	2.197.080	2.578.493
	- Carbon Steel dia. 10" SCH.40 x 9300 mm				9,300	meter	2.197.080	20.432.844
	- Carbon Steel dia. 10" SCH.40 x 4268,4 mm				4,268	meter	2.197.080	9.378.016
	- Carbon Steel dia. 10" SCH.40 x 6638,4 mm				6,638	meter	2.197.080	14.585.096
	- Carbon Steel dia. 10" SCH.40 x 349,2 mm				1	meter	2.197.080	2.197.080
	- Carbon Steel dia. 10" SCH.40 x 3057,6 mm				3,058	meter	2.197.080	6.717.792
	- Carbon Steel dia. 10" SCH.40 x 5770,8 mm				5,771	meter	2.197.080	12.678.909
	- Carbon Steel dia. 10" SCH.40 x 2878,8 mm				2,878	meter	2.197.080	6.323.196
	- Carbon Steel dia. 10" SCH.40 x 747,6 mm				1	meter	2.197.080	2.197.080
	- Carbon Steel dia. 10" SCH.40 x 2107,2 mm				2,107	meter	2.197.080	4.629.687
	- Carbon Steel dia. 10" SCH.40 x 9841,2 mm				9,841	meter	2.197.080	21.621.904
	- Carbon Steel dia. 3/4" SCH.40 x 3277,2 mm				3,277	meter	222.768	730.055
	- Carbon Steel dia. 3/4" SCH.40 x 11886 mm				11,886	meter	222.768	2.647.820
	- Elbow dia. 12" SCH. 40				6	pcs	1.488.000	8.928.000
	- T Joint dia. 12" SCH. 40				2	pcs	1.488.000	2.976.000
	- Flange 12 K				74	pcs	890.000	65.860.000
	- Bolt and Nut (12 K Flange)				1.776	pcs	10.000	17.760.000
	- Packing 3 mm (for 12 inch Flange)				37	pcs	60.000	2.220.000
	- T Joint dia. 10" SCH. 40				3	pcs	1.126.800	3.380.400
	- Elbow dia. 10" SCH. 40				6	pcs	1.126.800	6.760.800
	- Flange 10 K				60	pcs	788.000	47.280.000
	- Bolt and Nut (10 K Flange)				1.440	pcs	50.000	72.000.000
	- Packing 3 mm (for 10 inch Flange)				30	pcs	8.000	240.000
	- Filter 12 mm				1	pcs	1.653.960	1.653.960
	- Filter 10 mm				2	pcs	1.384.320	2.768.640
	- Flange 3/4 inch				8	pcs	113.000	904.000
	- Bolt and Nut (3/4 inch Flange)				48	pcs	5.000	240.000
	- Packing 3 mm (for 3/4 inch Flange)				4	pcs	11.250	45.000
	(all Materials are provided by owner)							
2.3	**Piping Installment at Upper Deck**							
	- Carbon Steel dia. 12" SCH.40 x 3747,6 mm				3,748	meter	2.658.528	9.963.100
	- Carbon Steel dia. 12" SCH.40 x 226,8 mm				1	meter	2.658.528	2.658.528
	- Carbon Steel dia. 12" SCH.40 x 896,4 mm				1	meter	2.658.528	2.658.528
	- Carbon Steel dia. 12" SCH.40 x 1054,8 mm				1,054	meter	2.658.528	2.802.089
	- Carbon Steel dia. 12" SCH.40 x 1017,6 mm				1,018	meter	2.658.528	2.705.318
	- Carbon Steel dia. 12" SCH.40 x 973,2 mm				1	meter	2.658.528	2.658.528
	- Carbon Steel dia. 12" SCH.40 x 224,4 mm				1	meter	2.658.528	2.658.528
	Carbon Steel dia. 12" SCH.40 x 441,6 mm				1	meter	2.658.528	2.658.528
	- Carbon Steel dia. 12" SCH.40 x 895,2 mm				1	meter	2.658.528	2.658.528
	- Carbon Steel dia. 12" SCH.40 x 4234,8 mm				4,235	meter	2.658.528	11.258.334
	- Carbon Steel dia. 10" SCH.40 x 3757,2 mm				3,757	meter	2.197.080	8.254.869
	- Carbon Steel dia. 10" SCH.40 x 1248 mm				1,278	meter	2.197.080	2.807.868
	- Carbon Steel dia. 10" SCH.40 x 565,2 mm				1	meter	2.197.080	2.197.080
	- Carbon Steel dia. 10" SCH.40 x 1089,6 mm				1,090	meter	2.197.080	2.393.938

	Description	Qty	Unit	Unit Price	Total
	- Carbon Steel dia. 10" SCH.40 x 3886,8 mm	3,887	meter	2.197.080	8.539.611
	- Carbon Steel dia. 0,4" SCH.40 x 306 mm	1	meter	283.560	283.560
	- Carbon Steel dia. 0,4" SCH.40 x 969,6 mm	1	meter	283.560	283.560
	- Carbon Steel dia. 0,4" SCH.40 x 1083,6 mm	1,084	meter	283.560	307.266
	- Carbon Steel dia. 0,4" SCH.40 x 536,4 mm	1	meter	283.560	283.560
	- Elbow dia. 12" SCH. 40	2	pcs	1.488.000	2.976.000
	- T Joint dia. 12" SCH. 40	3	pcs	1.488.000	4.464.000
	- Flange 12 K	46	pcs	890.000	40.940.000
	- Packing 3 mm (for 12 inch Flange)	23	pcs	60.000	1.380.000
	- Bolt and Nut (12 K Flange)	1.104	pcs	10.000	11.040.000
	- T Joint dia. 10" SCH. 40	3	pcs	1.126.800	3.380.400
	- Elbow dia. 10" SCH. 40	3	pcs	1.126.800	3.380.400
	- Flange 10 K	40	pcs	788.000	31.520.000
	- Packing 3 mm (for 10 inch Flange)	20	pcs	8.000	160.000
	- Bolt and Nut (10 K Flange)	960	pcs	8.000	7.680.000
	- Elbow dia. 0,4" SCH. 40	2	pcs	166.800	333.600
	- Flange 0,4"	16	pcs	90.000	1.440.000
	- Packing 3 mm (for 0,4 inch Flange)	8	pcs	6.000	48.000
	- Bolt and Nut (0,4" Flange)	128	pcs	5.000	640.000

3 Replating

a. Exhaust Gas main deck

NO.	Description	DIMENSION (mm) Length	Breadth	thk	QTY	REMARKS	Qty	Unit	Unit Price	Total
1	- Plate	6873,6	8180,4	6	1		2.648	kg	34.200	90.574.471
	Plate side cover	3094,8	8180,4	6	2		2.385	kg	34.200	81.561.300
	Plate Cover top	4182	3094,8	6	1		610	kg	34.200	20.847.963
	side Cover (p)	4182	5937,6	6	1		1.170	kg	34.200	39.998.341
	Web Frame	734,4	5937,6	6	4		822	kg	34.200	28.096.396
	Sideboard Stiffener	10371,6	211,2	6	19		1.960	kg	47.880	93.857.357

4 1. Painting (Primary Coat)

No	Description	Length (m)	Breadth (m)	Area (m2)	Paint (litre)	Layer	Qty.	Qty	Unit
1	Plate side cover	3,095	8,180	25,317	6,329	1	2	13	Litre
2	Plate cover top	4,182	3,0948	12,942	3,236	1	1	3	Litre
3	Side Cover (p)	4,182	5,9376	24,831	6,208	1	1	6	Litre

Total: 20 Litre — 45.000 — 900.000

Reference Price: jualcatkapal (Cat Merek Sigma (Rp. 900.000/20 liter)

2. Painting (Finish Coat)

No	Description	Length (m)	Breadth (m)	Area (m2)	Paint (litre)	Layer	Qty.	Qty	Unit
1	Plate side cover	3,095	8,180	25,317	6,329	1	2	13	Litre
2	Plate cover top	4,182	3,0948	12,942	3,236	1	1	3	Litre
3	Side Cover (p)	4,182	5,9376	24,831	6,208	1	1	6	Litre

Total: 20 Litre — 45.000 — 900.000

No	Description	Qty	Unit	Unit Price	Total
5	**Crane** in this case, we use dock Goliath Crane with est. 24 hours	24	Hours	21.479.000	515.496.000
6	**Scrubber Tower Installment** Installment included Erection and Setting	1	set	75.000.000	75.000.000

Says : Three billion Ninety six million four hundred twelve thousand six hundred fifteen Rupiah **Minimum Charge Applied is Rp. 350,000,000**	**TOTAL**	**3.096.412.615**

Note: In Dollars: One Hundred Ninety Eight Thousand Nine hundred Ninety eight Dollars and Twenty Four Cent ($ 198998,24)

n. costs based on IPERINDO 2019

A. PELAYANAN UMUM

			1.2
			Thn 2019
1	Periksa bebas gas per tangki	Rp.	577,000
2	Pembuangan sampah kapal per hari	Rp.	241,000
3	Pemadam kebakaran		
	3.1 Penjaga kebakaran/orang/hari	Rp.	198,000
	3.2 Sambung & lepas 1x pelaksanaan	Rp.	241,000
	3.3 Sewa selang pemadam kebakaran/hari	Rp.	200,000
4	Pelayanan air :		
	4.1 Air tawar dari tongkang	Rp.	98,600
	4.2 Air tawar dari darat / kade	Rp.	83,300
	4.3 Pasang/lepas slang/pipa air satu kali sambungan	Rp.	241,000
5	Pelayanan listrik :		
	5.1 Disesuaikan dengan tarip PLN		
	5.2 Penyambungan dan pelepasan kabel satu kali sambung dan lepas	Rp.	346,000
6	Penjagaan Keamanan		
	Selama kapal docking / floating	Rp.	384,000
7	Pelayanan Telephon lokal		
	a. Sambung lepas kabel	Rp.	-
	b. Tarip telephon	Rp.	
8	Pelayanan Saluran Ventilasi		
	a. Sambung saluran	Rp.	698,000
	b. Tarip penggunaan(day/unit)	Rp.	262800
9	Perança/m3, pemasangan di :		
	a. Luar ruangan	Rp.	31,200
	b. Dalam ruangan	Rp.	50,400
	c. Posisi tinggi	Rp.	64,800
10	Pelayanan Derek		
	a. Derek apung (floating crane)		
	1) Kapasitas s/d 50 ton/jam	Rp.	8,258,000
	2) Kapasitas s/d 200 ton/jam	Rp.	21,479,000
	3) Tidak termasuk biaya kapal tunda		
	4) Penggunaan dihitung minimum 2 jam		
	b. Mobile Crane		
	1) Kapasitas 10 ton/jam	Rp.	328,000
	2) Kapasitas 20 ton s/d 25 ton/jam	Rp.	644,000
	3) Kapasitas 50 ton s/d 75 ton/jam	Rp.	1,817,000
	4) Kapasitas 100 ton/jam	Rp.	2,724,000
	Penggunaan dihitung minimum 8 jam (termasuk mob/demob)		

11 **Jasa TUNDA dan PANDU**

1 Penundaan Kapal di daerah Perairan Galangan

NO	GRT KAPAL	Harga per Jam (Rp.)
1	s/d 500 GT	2,285,000
2	501 GT s/d 1500 GT	2,666,000
3	1501 GT s/d 3500 GT	3,428,000
4	3501 GT s/d 8000 GT	4,952,000
5	8001 GT s/d 14000 GT	7,237,000
6	14001 GT s/d 20000 GT	11,616,000
7	20001 GT s/d 30000 GT	16,379,000

Catatan :

Penggunaan minimum 2 jam

Penundaan kapal berbendera asing tarif diperhitungkan tersendiri

2 Pelayanan PANDU per gerakan di daerah Galangan

NO	GRT KAPAL	Harga per Jam (Rp.)
1	s/d 500 GT	353,000
2	501 GT s/d 1500 GT	476,000
3	Lebih dari 1000 GT	-
	dan setiap kelebihan s/d 500 GT	64,000

12 Tarif sewa / biaya dibedakan menurut jam hari

Jam / Hari	07.30 - 16.30	16.30 - 22.30	22.30 - 07.30
Senin s/d Jum'at	100%	150%	200%
Sabtu / Minggu Libur resmi	200%	250%	300%

catatan :

1 proses di intrnal galangan

2. Bila ada kepentingan dari sisi owner

3. Kapal sudah selesai

C BANÇUNAN KAPAL

C1 Pembersihan badan kapal :

1	Water jetting air tawar	Rp.	27,700	/M²
2	Water jetting air laut	Rp.	10,000	/M²
3	Spot blasting	Rp.	82,300	/M²
4	Full Sand blasting	Rp.	72,100	/M²
5	Sweep blasting	Rp.	61,600	/M²
6	Scrapping	Rp.	21,560	/M²
7	Wire brushing	Rp.	41,100	/M²
8	Ultrasonic test	Rp.	30,900	/titik
9	Amplashing	Rp.	45,200	/M²
10	Cuci air tawar pada lambung	Rp.	15,990	/M²
11	Chipping	Rp.	30,900	/M²

Catatan :

a. Pengerjaan dengan lembur dihitung tersendiri
b. Untuk ultrasonic minimum 100 titik
c. Gambar laporan bukaan kulit sebagai lampiran ultrasonic maksimal 6 lembar.

d. Penambahan gambar laporan bukaan kulit sebagai lampiran ultrasonic — Rp. 440,000 / lembar
e. Pekerjaan di dalam ruangan menjadi 200%
f. Area Top Side, ditambah 10% dari tarip diatas
g. Untuk pekerjaan blasting, minimum keluasan 100 M²
h. Dikenakan penambahan tarip untuk :
   h.1 Kondisi kapal sangat kotor
   h.2 Pembersihan dengan chemical
   h.3 Kondisi cat yang menyebabkan ekstra kerja, waktu
   h.4 Korosi yang sangat parah
   h.5 Penetapan pengecatan SPC, ditambah 50% dari tarip.
I. Dikenakan tarip ekstra untuk :
   I.1 Pekerjaan dalam tangki menjadi 250%
   I.2 Pekerjaan badan kapal bagian dalam (inside hull)
j. Untuk pekerjaan blasting, untuk Sa = 2,5 dihitung tersendiri

C2 Pengecatan (cat owner supplied)

1. Lambung
   1.1 Pengecatan per lapis : Rp. 8,900 M² / layer
   1.2 Pengecatan per Touch Up : Rp. 15,600 M² / layer touch up

Catatan : Untuk pengecatan dalam tangki menjadi 250%

2 Tanda syarat dan garis air

GT	PAINTING OF DRAFT & PLIMSOL MARK	PAINTING OF WATER LINE	PAINTING OF SHIP NAME + REGISTER PORT
s/d - 300	791,600	1,243,800	452,000
301 - 500	1,130,600	1,696,000	565,000
501 - 1500	1,469,900	2,261,300	792,000
1501 - 2500	1,809,000	3,391,900	967,000
2501 - 3500	2,148,300	4,522,400	1,131,000
3501 - 5000	2,487,300	6,218,400	1,357,000
5001 - keatas	2,487,300	8,005,900	1,357,000
	+ 120 (GRT-5000)	+ 200 (GRT-5000)	+ 70 (GRT-5000)

Catatan : Tidak termasuk biaya peranca

B TARIP PENGEDOKAN

1 TARIP PENGEDOKAN

GT	Assistensi Naik & Turun Dock (Rp.	Docking & Undocking (Rp.)	Docking Per Hari (Rp.)	Docking Report (Rp.)
s/d - 500	6,501,000	11,304,000	1,719,000	4,847,000
501 - 1500	7,267,000	14,534,000	2,202,000	4,847,000
1501 - 2500	8,882,000	17,764,000	2,686,000	4,847,000
2501 - 3500	10,497,000	22,607,000	3,389,000	8,073,000
3501 - 5000	12,112,000	29,067,000	4,360,000	8,073,000
5001 - 7000	13,723,000	38,754,000	5,815,000	8,073,000
7001 - 9000	15,340,000	48,442,000	7,267,000	8,073,000
9001 - 11000	17,764,000	61,361,000	9,204,000	8,073,000
11001 - 13000	20,184,000	74,279,000	11,143,000	8,073,000
13001 - 15000	22,607,000	90,428,000	13,564,000	8,073,000
15001 - 17000	25,031,000	106,575,000	15,986,000	11,304,000
17001 - 19000	27,380,000	125,952,000	18,892,000	16,149,000

Catatan :

a. Tarip ini berlaku naik / turun dock di dalam jam kerja normal pada hari kerja, di luar jam kerja normal akan dikenakan tarip sesuai butir 8

b. Pengedokan kurang dari 2 hari, dihitung dua hari.

c. Apabila selama docking perlu dilakukan penggeseran balok lunas, akan dikenakan biaya tambahan sebesar 100% dari tarip docking / undocking.

d. Apabila diperlukan pengaturan khusus balok lunas atau fasilitas darat lainnya akan dikenakan biaya tambahan.

e. Emergency docking dikenakan biaya ekstra.

f. Kapal type khusus (KRI, Ferry Roro, TD, Yacht, Barge, Kapal Kerja) dihitung tersendiri

g. Untuk kapal type khusus dikenakan index / dihitung tersendiri berdasarkan :

- a. KRI, Ferry Roro, Yacht = index tambahan min. 150% tarip
- b. Kapal dengan draft 4 Meter s/d 5 Meter, = index tambahan min. 200% tarip
- c. Kapal dengan draft 5 Meter s/d 6 Meter, = index tambahan min. 500% tarip

h. Bongkar & pasang kembali Dock block dikenakan biaya :

- a. Keel Block Rp. 650.000,-/buah
- b. Side Block Rp. 520.000,-/buah
- c. Bottom Share Rp. 650.000,-/buah

Catatan : Dock block khusus dikenakan tarip tersendiri

i Docking Report diberikan maksimal 6 rangkap.

j Air Bag dihitung tersendiri

k Biaya sandar 50 % dari docking perhari

C3 Penggantian baru plat baja/plat lurus

TEBAL PLAT	BIAYA DASAR
s/d 1/4" / 6 mm	Rp. 34,200 / Kg
8 mm s/d 12 mm	Rp. 32,600 / Kg
lebih besar 12 mm	Rp. 32,600 / Kg

Catatan :

1 a. Penggantian plat baja (mild steel) menurut jumlah :

s/d	-	50 kg =	200%
s/d	51 -	100 kg =	175%
s/d	101 -	500 kg =	150%

Material dari galangan

b. High Tensile Steel, Grade plate type D&E dikenakan tarip ekstra
c. Doubling plate, tarip ditambah 75% dari tarip replating (minimal 10 kg/pieces)
d. Plat dengan dimensi khusus (trapesium) dihitung berdasarkan dimensi terbesar.
e. Berlaku untuk plat (marine use) dengan standar BKI
f. Bila berat replate atau doubling kurang dari 50 kg, maka dihitung 50 kg
g Asumsi harga plat di pasaran Rp. 10.000/ kg. Apabila terjadi perubahan dari asumsi tersebut tarip akan disesuaikan.
h Apabila material plat disuplai oleh owner maka harga jasa sebesar 65% dari tarif.
i Belum termasuk peranca
j Belum termasuk test kekedapan

2 Penggantian plat menurut lokasi :

LOKASI :	%
a. Side shell	100
b. Bottom	110
c. Keel plates	115
d. Deck plates	100
e. Tank tops	110
f. Engine room (side shell and deck)	150
g. Bulkhead	120
h. Fore and aft peak keel plate	140
I. Internals in DBT	250
j. Internals in room and casings	120
k. Mixed frame	140
l. Internal in aft and fore peak	140
m. Fore and aft stem (linggi haluan dan buritan)	200
n. Bulbows Bow	300
o. Internal Engine room & propulsion system (bottom)	300

F SISTIM MINYAK

F1 GANTI BARU PIPA LURUS PER METER

DIAMETER		PIPA SCH 40 (Rp.)	PIPA SCH 80 (Rp.)
s/d	1/2"	236,300	347,500
s/d	1"	309,400	455,000
s/d	2"	601,800	885,000
s/d	3"	858,500	1,262,500
s/d	4"	1,179,800	1,735,000
s/d	5"	1,487,500	2,187,500
s/d	6"	1,774,800	2,610,000
s/d	8"	2,383,400	3,505,000
s/d	10"	3,051,500	4,487,500
s/d	12"	3,692,400	5,430,000

Catatan :

a. Bongkar / pasang pipa sebagai penghalang 40% harga per meter.
b. Bongkar / pasang pipa dan perbaikan 60% harga per meter.
c. Panjang pipa kurang dari 1 meter dihitung jadi 1 meter.
d. Pekerjaan pipa di dalam DBT 150% harga per meter.
   Pekerjaan pipa di dalam tangki 125% harga per meter.
e. Pipa aluminium dihitung 1½ kali pipa putih.
g. Pipa tembaga dihitung 3½ kali pipa putih.
h. Pipa Cuni dihitung 4½ kali pipa putih.
i. Proses galvanish dihitung tersendiri.
j. Untuk pipa diameter lebih dari 12", minimum dihitung 6 meter.
k. Untuk pipa di engine room dan funnel menjadi 120%

Karena berlaku dibawah Jawa Timur (Font Merah)

F2 Penggantian Klem Pipa

DIAMETER (INCH)			Per BUAH (Rp.)
	s/d	1/2"	90,000
0.55	s/d	1"	113,000
1.1	s/d	2"	134,000
2.1	s/d	3"	198,000
3.1	s/d	4"	266,000
4.1	s/d	6"	355,000
6.1	s/d	8"	534,000
8.1	s/d	10"	788,000
10.1	s/d	12"	890,000
diatas 12"			dihitung tersendiri

F3 Penggantian Plendes

DIAMETER (INCH)			Per BUAH (Rp.)
	s/d	1/2"	113,000
0.55	s/d	1"	140,000
1.1	s/d	2"	198,000
2.1	s/d	3"	265,000
3.1	s/d	4"	378,000
4.1	s/d	5"	461,000
5.1	s/d	6"	562,000
6.1	s/d	8"	758,000
8.1	s/d	10"	936,000
10.1	s/d	12"	1,190,000
diatas 12"			dihitung tersendiri

Catatan :

1 Ukuran standard katup s/d 10K / 150 psi

2 Tekanan diatas 16K harga ditambah 100%

3 Material packing dan baut dihitung tersendiri

F4 Penggantian Elbow, Potongan-T

DIAMETER (INCH)	HARGA Per BUAH	
	Elbow Galvanish (Rp.)	Elbow Steel (Rp.)
s/d 1/2"	86,000	139,000
1"	95,000	155,000
2"	152,000	202,000
3"	212,000	286,000
4"	324,000	467,000
5"	377,000	545,000
6"	429,000	621,000
8"	515,000	746,000
10"	647,000	939,000
12"	857,000	1,240,000
diatas 12"	dihitung tersendiri	dihitung tersendiri

Catatan :

1 Untuk bahan Sch 40 ditambah 100%

F5 Bengkokan (Bending) per Bengkokan (Untuk Pekerjaan Pipa Putih)

DIAMETER (Inch)	Per BUAH (Rp.)
s/d 1/2"	83,000
0.55 s/d 1"	126,000
1.1 s/d 2"	179,000
2.1 s/d 3"	306,000
3.1 s/d 4"	380,000
4.1 s/d 5"	436,000
5.1 s/d 6"	494,000
6.1 s/d 8"	722,000
8.1 s/d 10"	1,520,000
10.1 s/d 12"	1,777,000
diatas 12"	dihitung tersendiri

G. SISTIM AIR LAUT

Penggantian pipa, flendes, Elbow dan sebagainya lihat item F1 - F5

G1. Katup-katup air laut

a. Kran-kran laut

DIAMETER (INCH)	GLOBE VALVE (BUAH) (Rp.)	GATE VALVE (BUAH) (Rp.)
s/d 1"	385,000	876,000
1.1 s/d 2"	701,000	1,107,000
2.1 s/d 3"	876,000	1,313,000
3.1 s/d 4"	1,107,000	1,749,000
4.1 s/d 5"	1,547,000	2,189,000
5.1 s/d 6"	2,189,000	2,625,000
6.1 s/d 8"	2,625,000	3,062,000
8.1 s/d 10"	3,296,000	3,732,000
10.1 s/d 12"	3,938,000	4,374,000
12.1 s/d 14"	5,045,000	5,481,000
14.1 s/d 16"	6,123,000	6,560,000

<u>Catatan :</u>

1 Buka pasang, dibersihkan, diperiksa dikonserver untuk pemeriksaan dicat meni, untuk pemeriksaan class dan dicoba sampai baik.

2 Pekerjaan dan test di bengkel biaya menjadi 200%.

3 Belum termasuk biaya bongkar pasang penghalang.

4 Lokasi pekerjaan di tangki, DBT menjadi 120%.

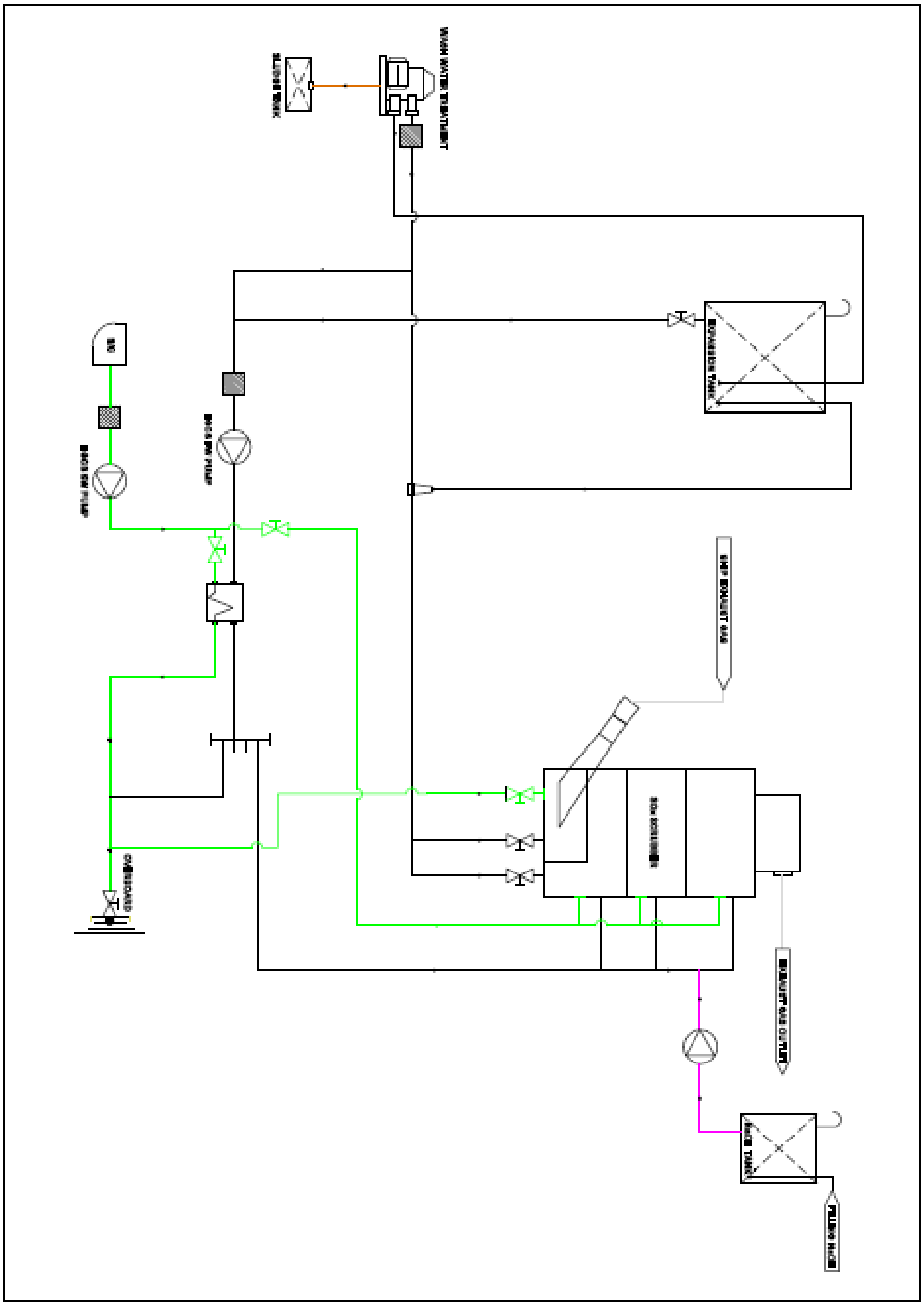
5 Pekerjaan Butterfly Valve menjadi 200% dari type Globe Valve.

6 Pekerjaan Angle Valve menjadi 300% dari type Globe Valve.

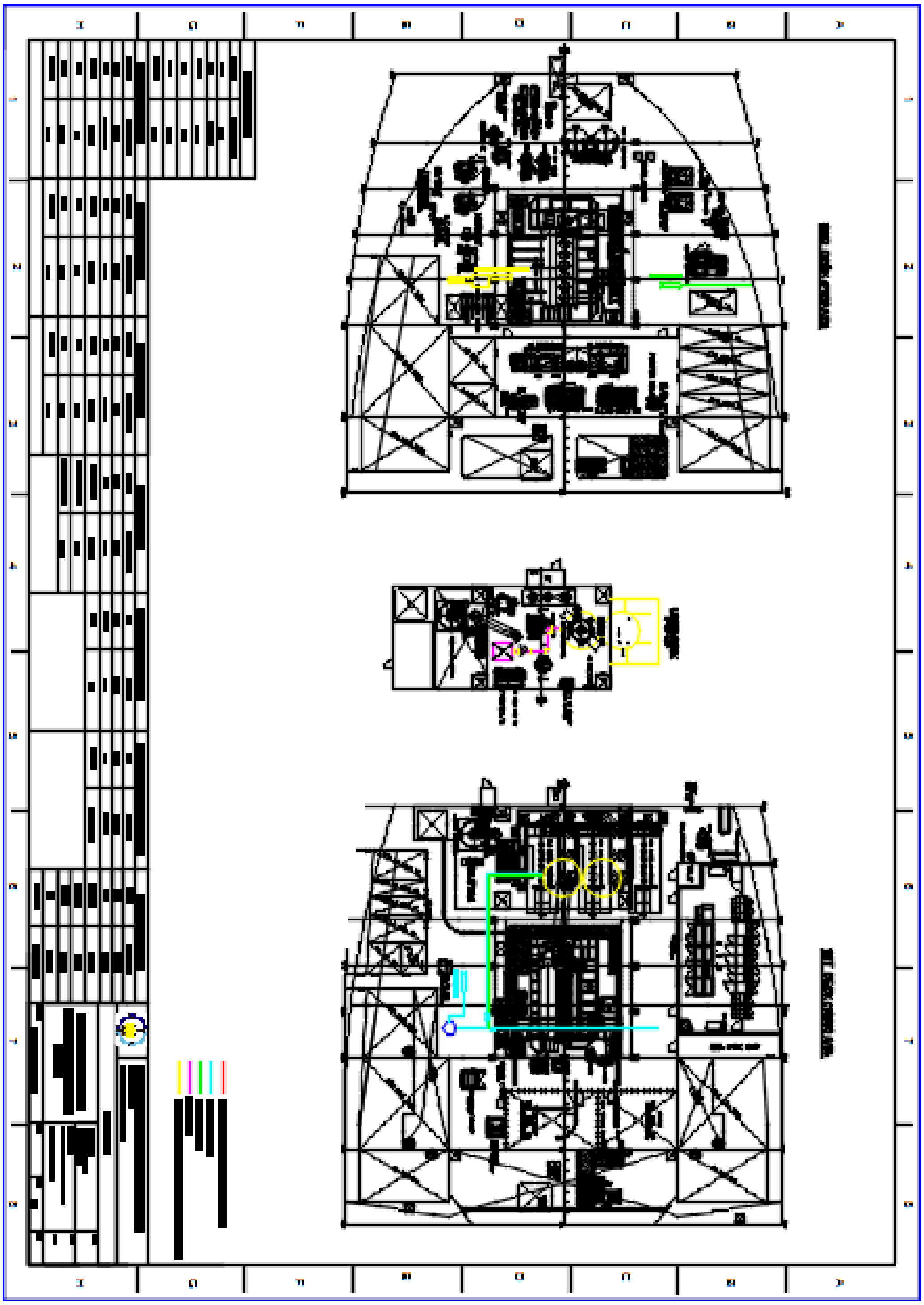
7 Penggantian material packing dan baut mur dihitung tersendiri.

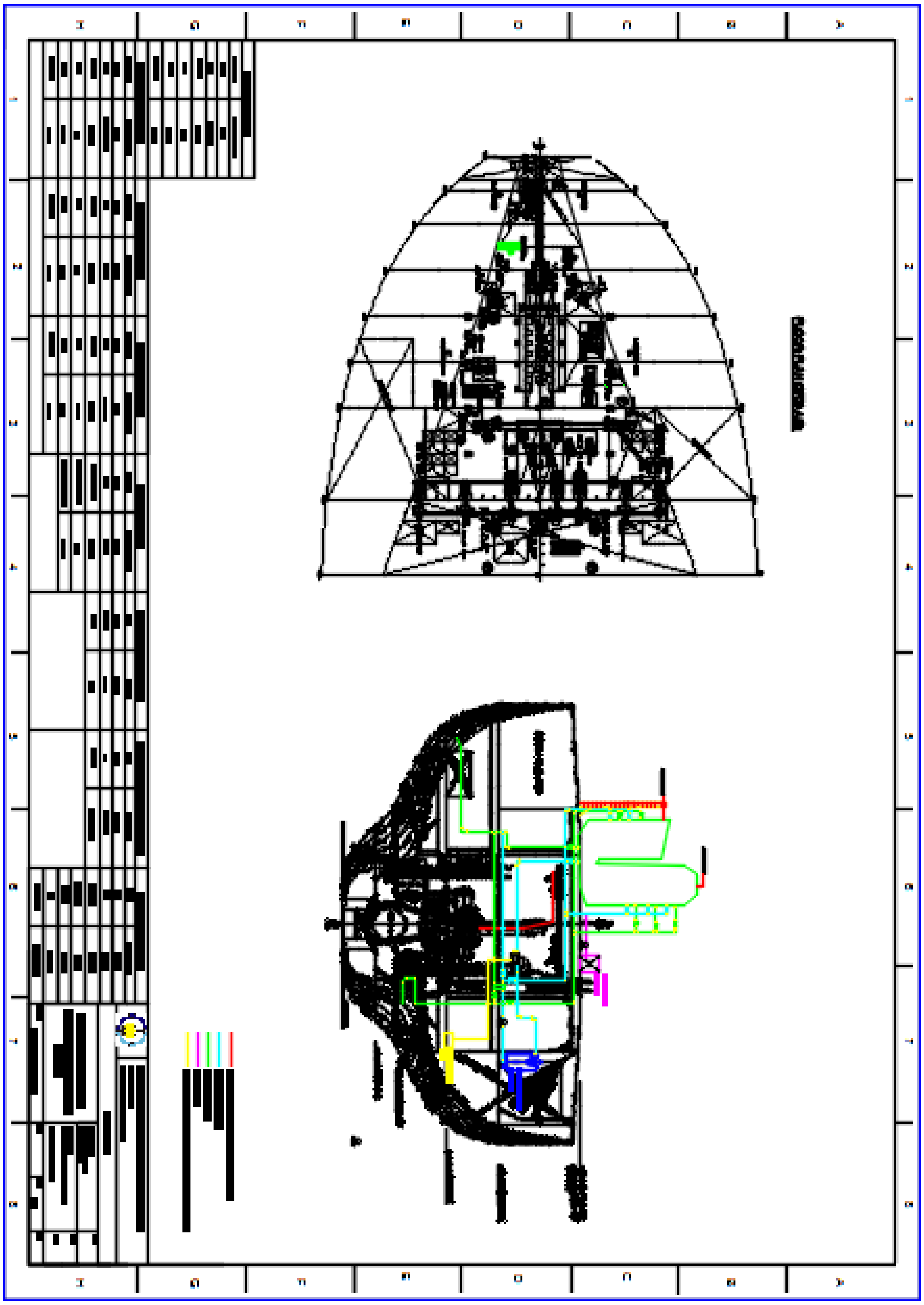
8 Stop Valve dan jenis katup lainnya dihitung tersendiri.

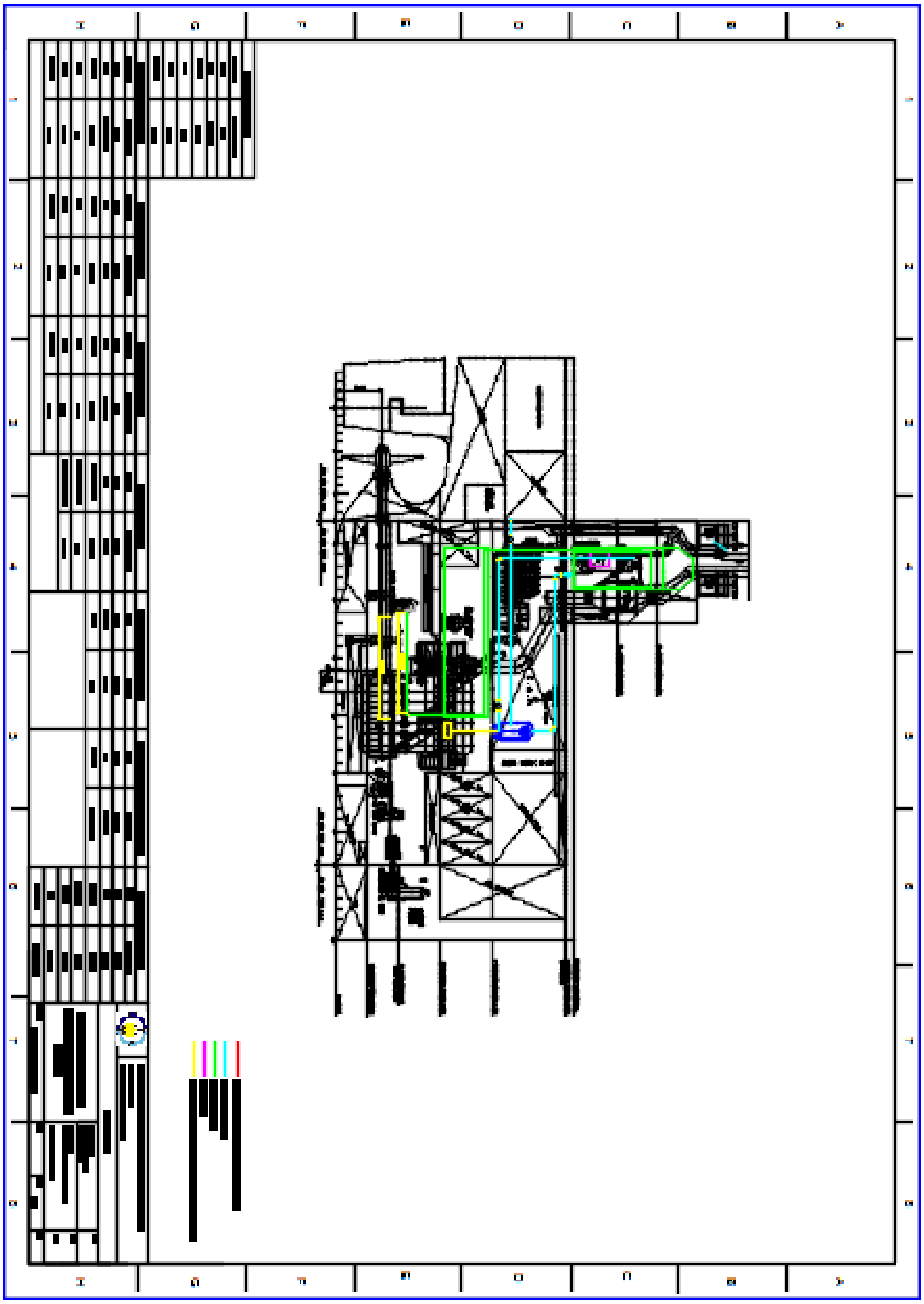
o. Pipe Flow Diagram Drawing

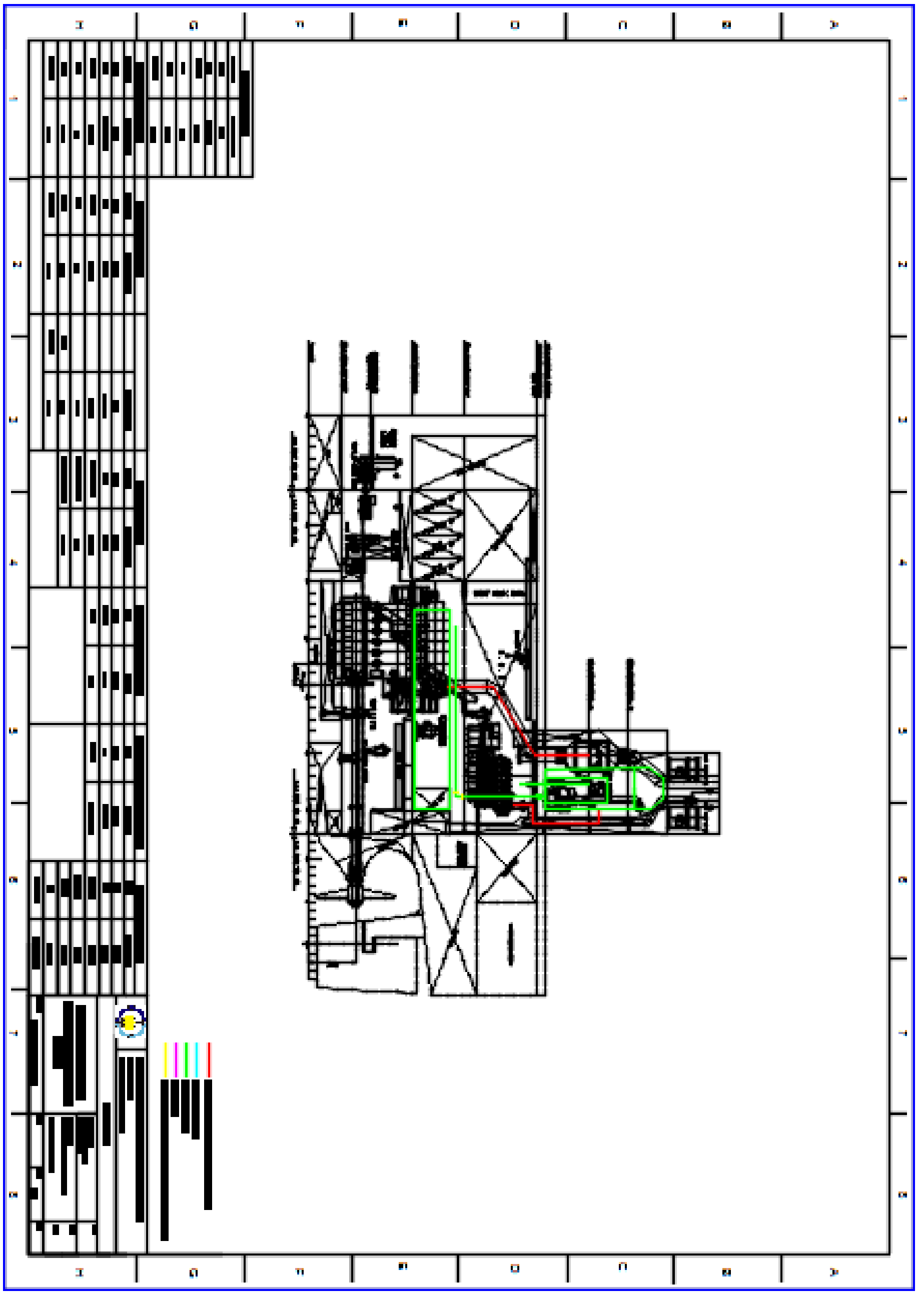


p. Implementation Drawing

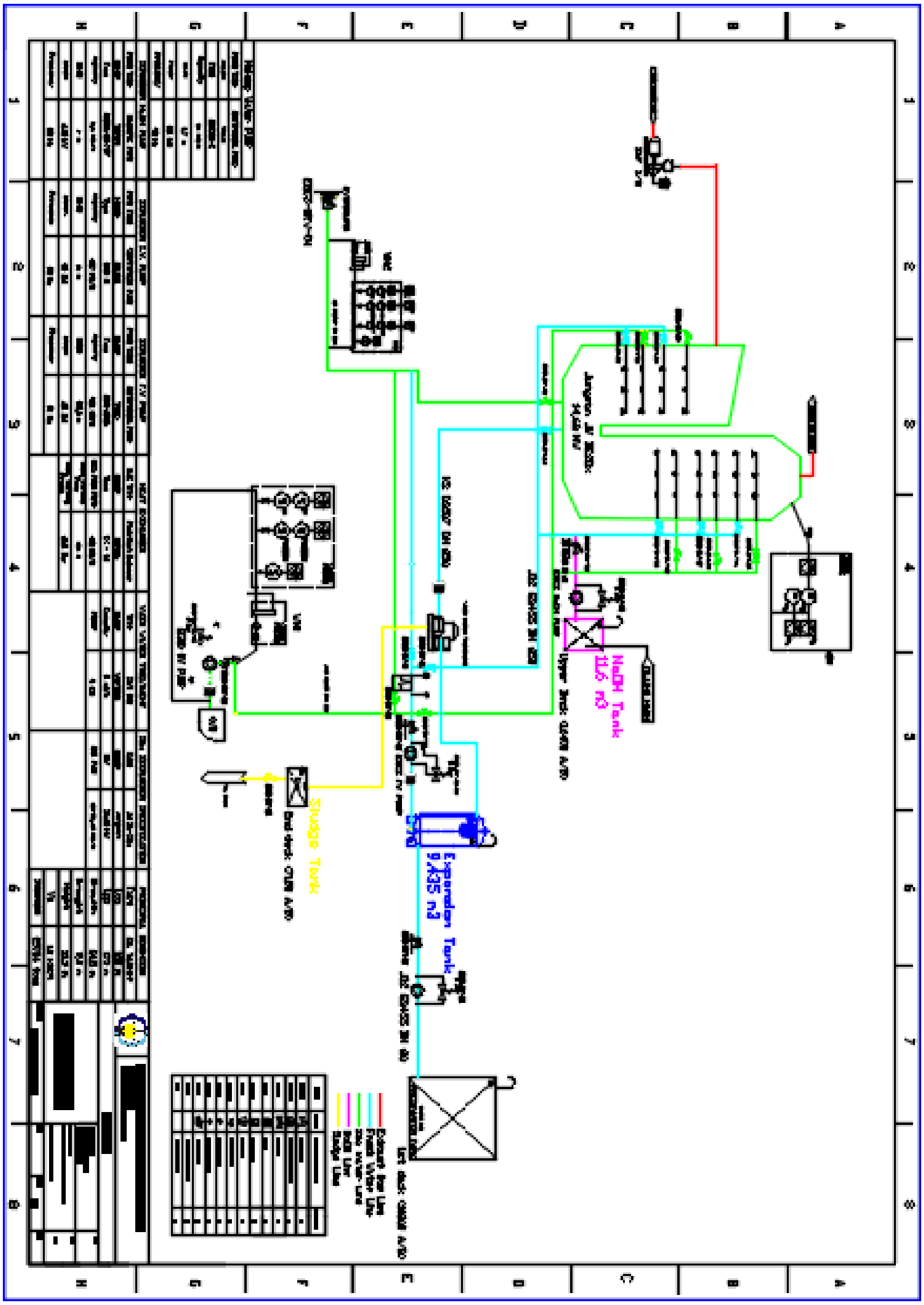




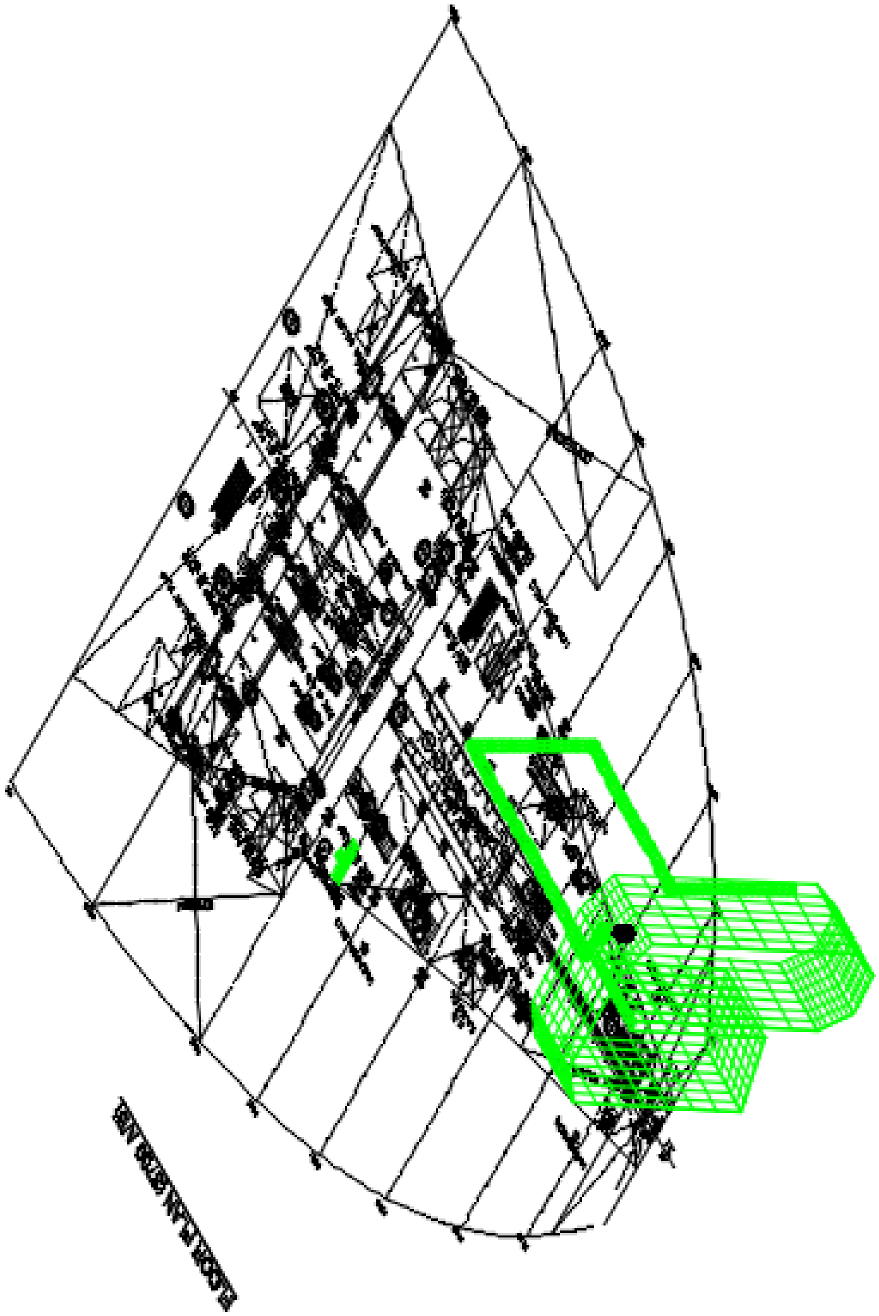


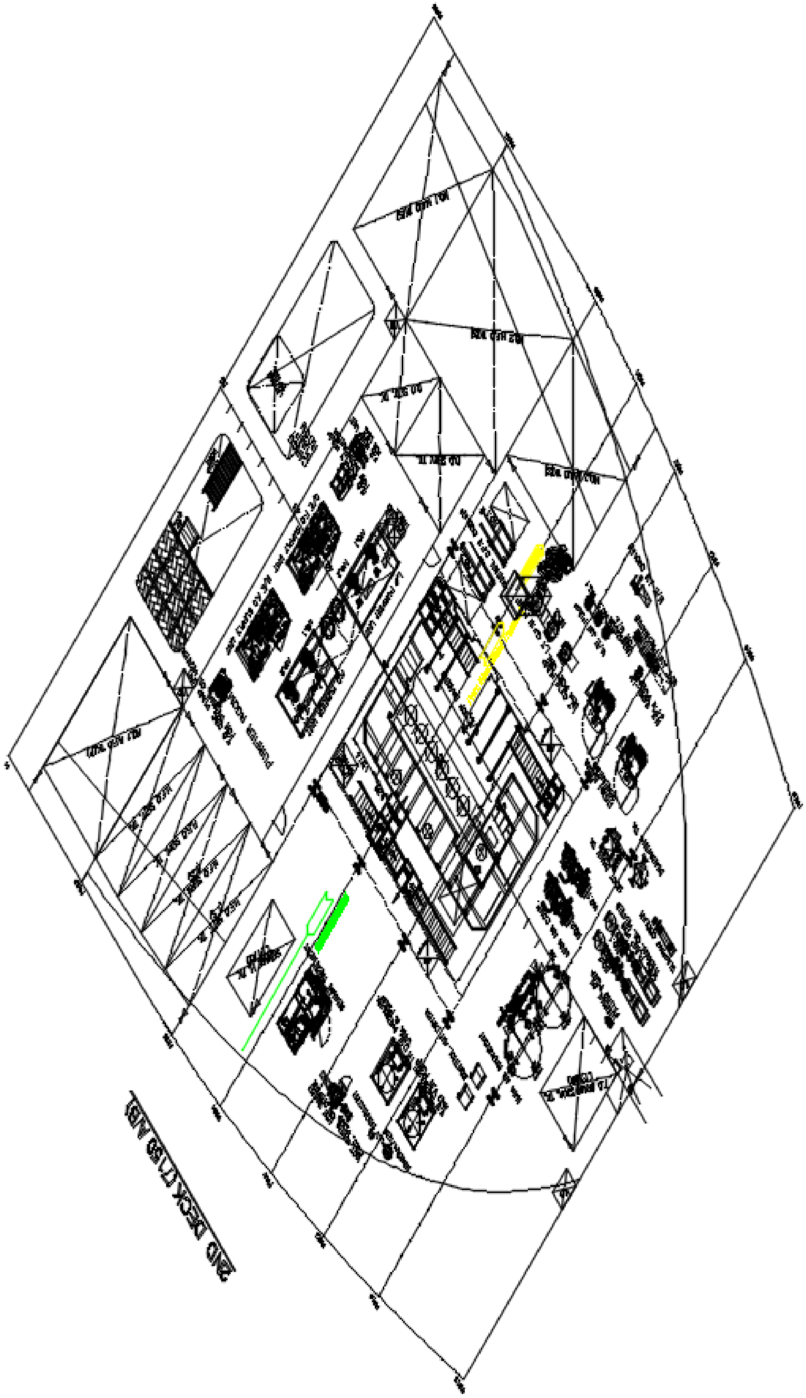


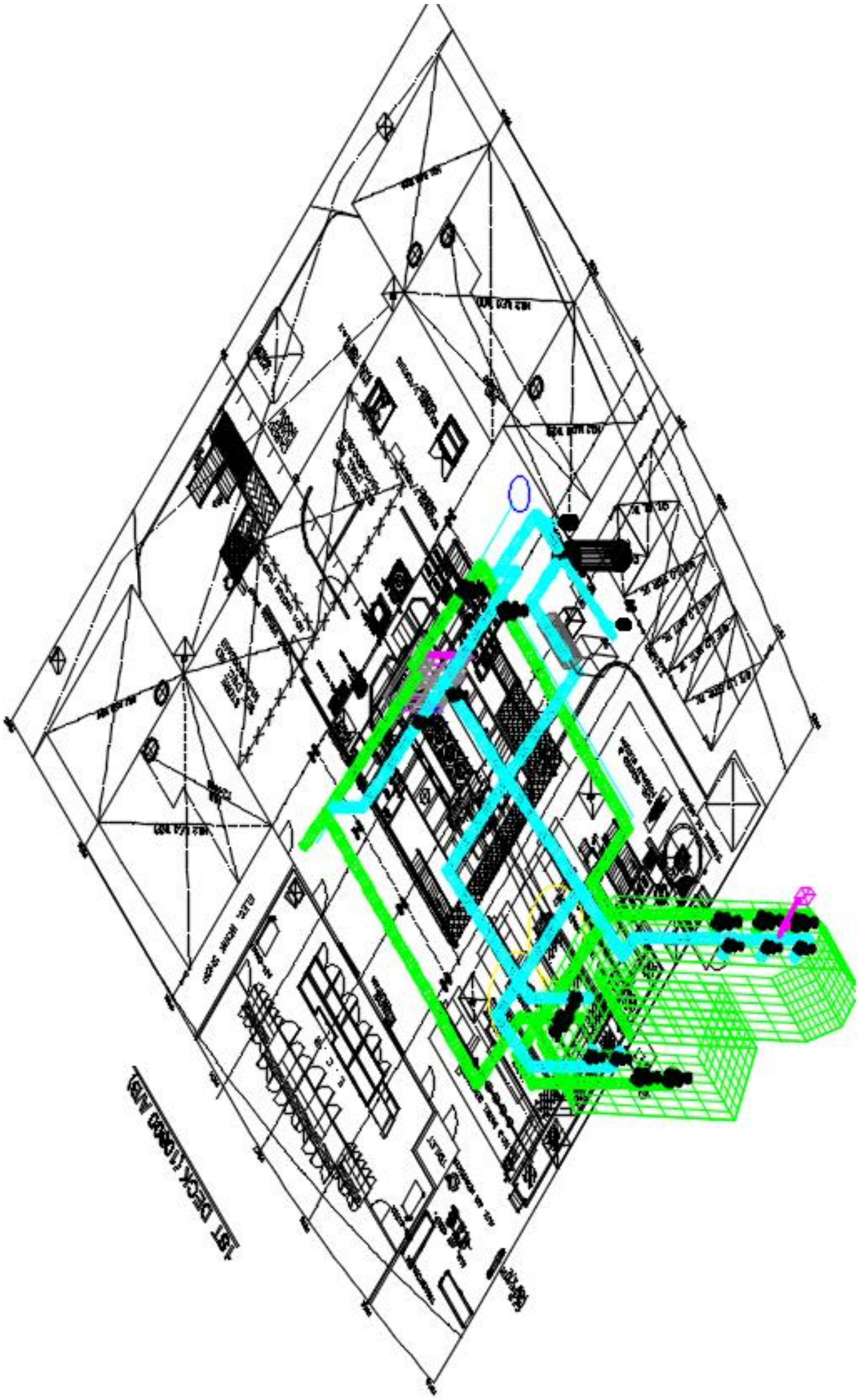
q. P&ID Drawing

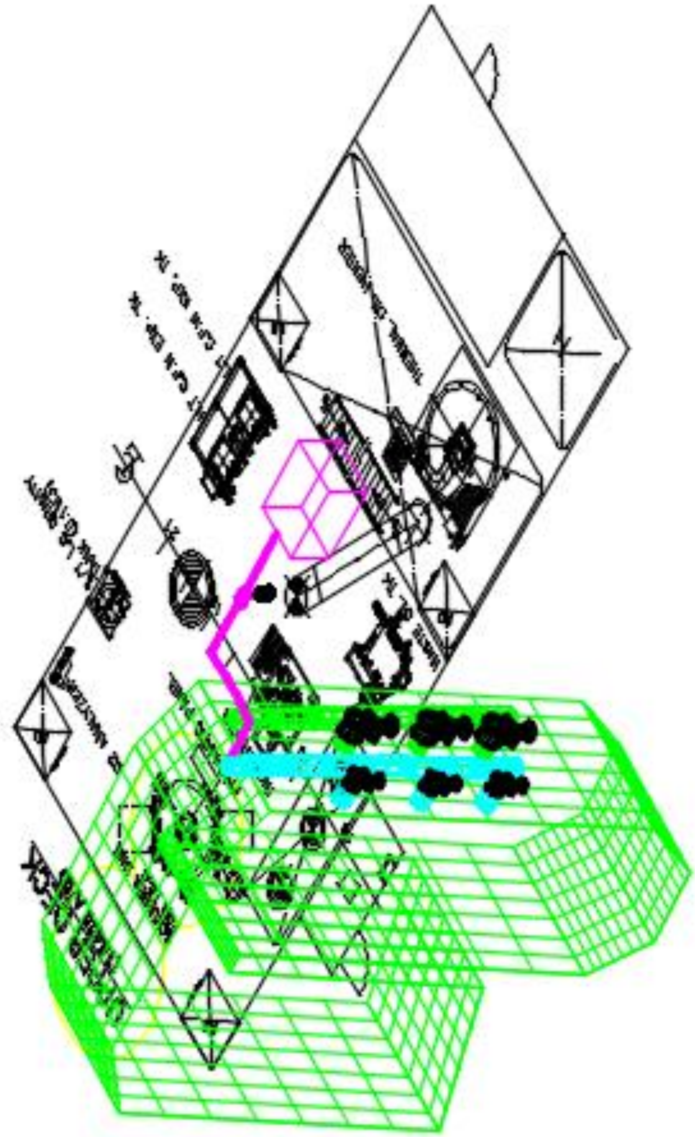


r. 3d Drawing

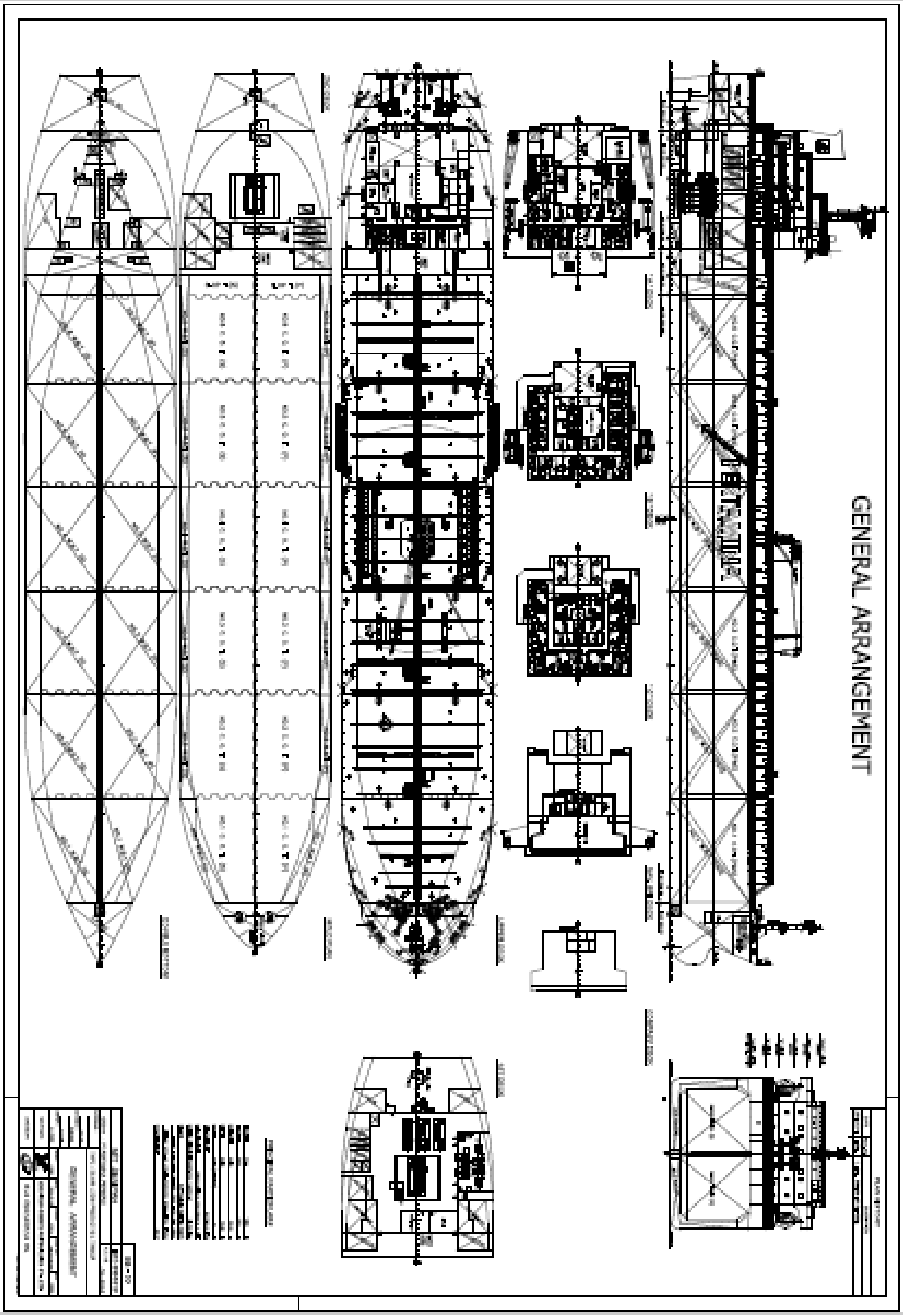








s. General Arrangement of Ship



t. Carbon Steel Pipe List

1. STEEL PIPE STANDARD (JIS & METRIC SIZE)

* ABBREVIATION

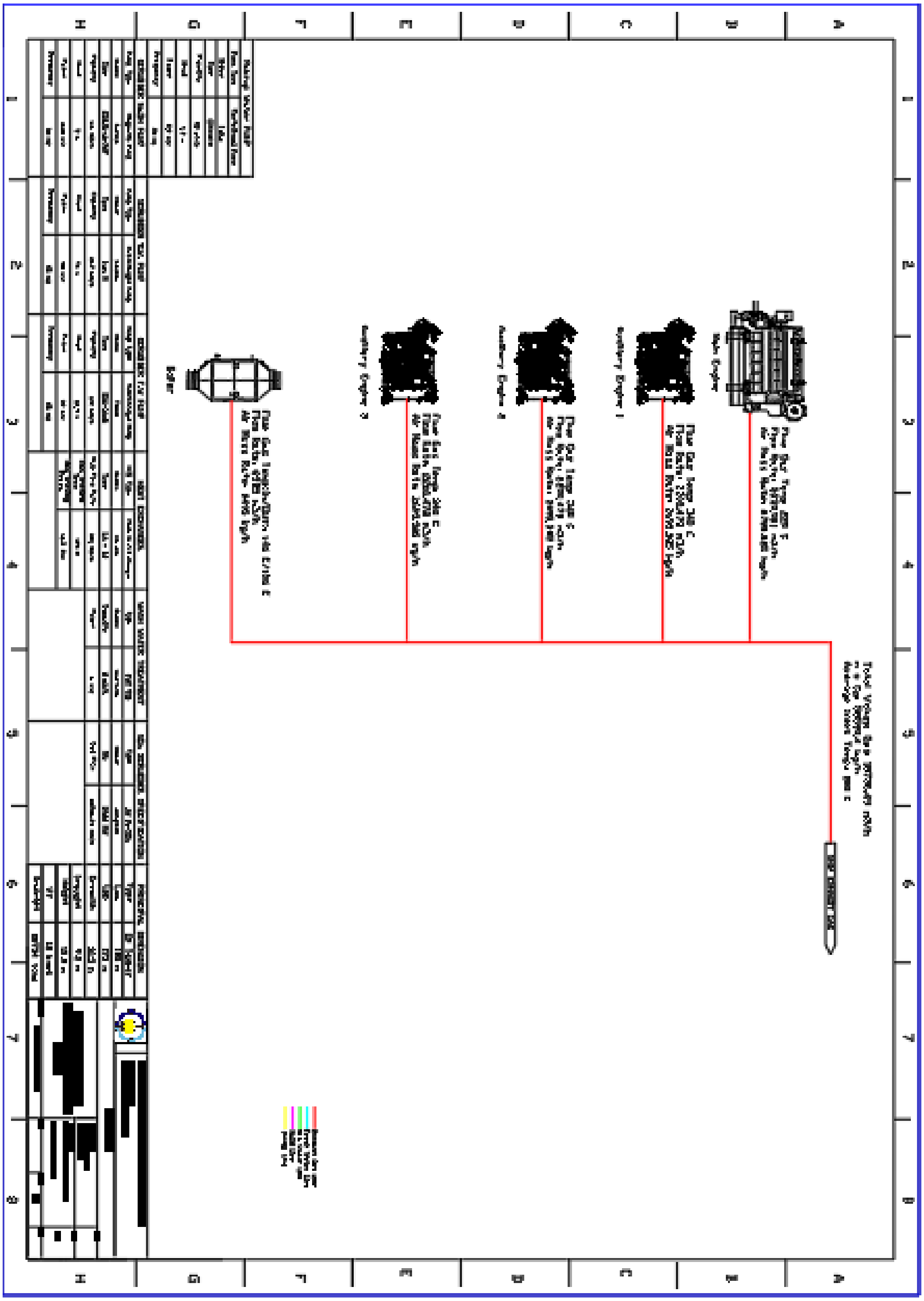
1) SGP (KS D3507) :CARBON STEEL PIPE FOR ORDINARY PIPING.
2) STPG(JIS G3454):CARBON STEEL PIPE FOR PRESSURE SERVICE.
3) STS (JIS G3455):CARBON STEEL PIPE FOR HIGH PRESSURE SERVICE
4) STPY(JIS G3457):ELECTRIC ARC WELDED CARBON STEEL PIPE.
5) ERW S :ELECTRIC RESISTANCE WELDED SPECIAL CARBON STEEL PIPE.
6) STPT(JIS G3456):CARBON STEEL PIPE FOR HIGH TEMPERATURE SERVICE.

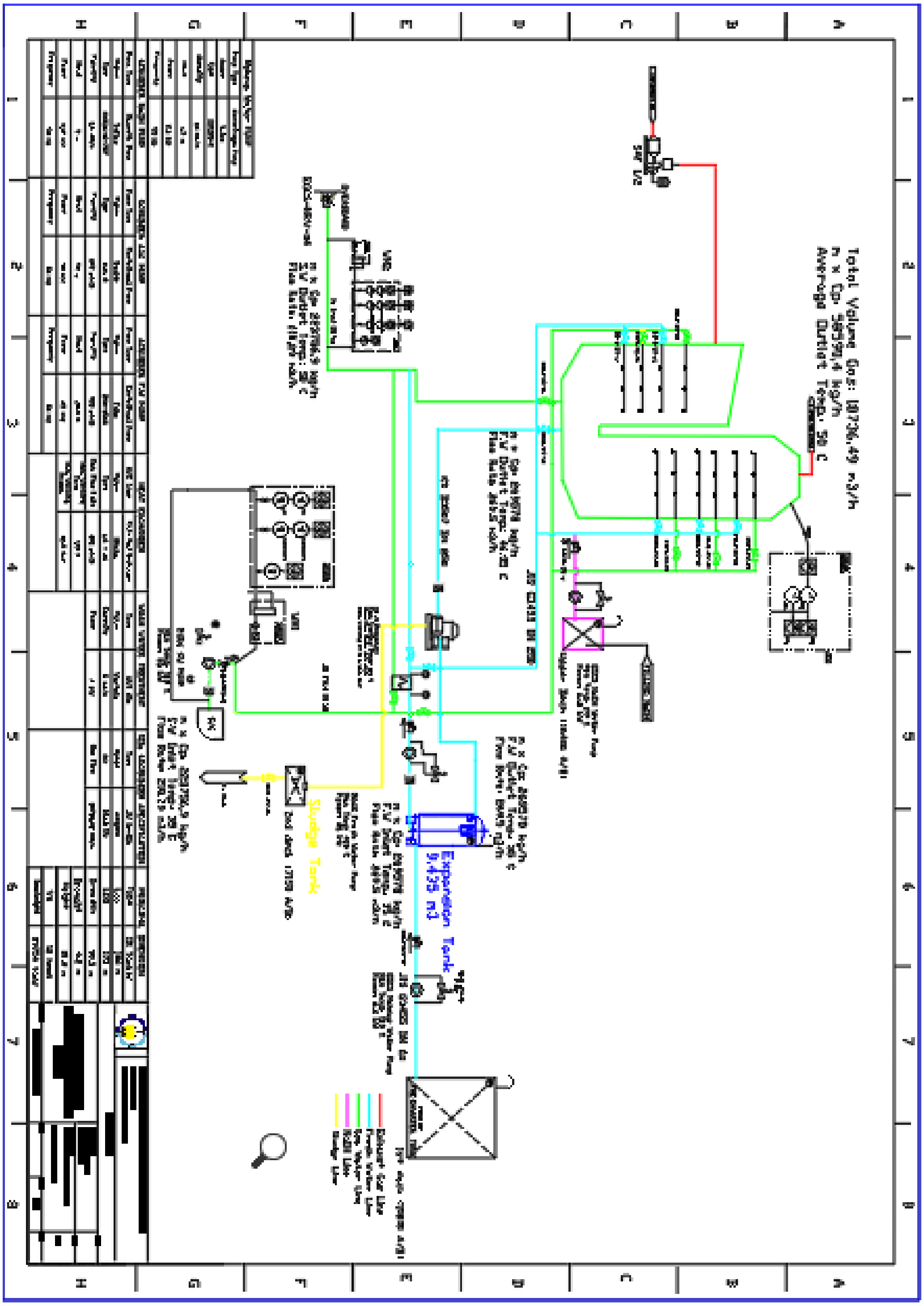
NOM. DIA. (A)	OUT. DIA. (mm)	PIPE WALL THICKNESS (MM)									
		–	7.9MM	# 40	9.5MM	9.5MM	# 80	12.7MM	12.7MM	#160	16.0MM
10	17.3	2.35		2.3	FOR # 40 PIPING SYS.		3.2	FOR # 80 PIPING SYS.		–	FOR #160 PIPING SYSTEM
15	21.7	2.65		2.8			3.7			4.7	
(20)	27.2	2.65		2.9			3.9			5.5	
25	34.0	3.25		3.4			4.5			6.4	
(32)	42.7	3.25		3.6			4.9			6.4	
40	48.6	3.25		3.7			5.1			7.1	
50	60.5	3.65		3.9			5.5			8.7	
65	76.3	4.0		5.2			7.0			9.5	
80	89.1	4.05		5.5			7.6			11.1	
100	114.3	4.5		6.0			8.6			13.5	
125	139.8	4.85		6.6			9.5			15.9	
150	165.2	4.85		7.1			11.0				16.0
200	216.3	5.85		8.2			12.7				16.0
250	267.4	6.4		9.3				12.7			16.0
300	318.5	7.0			9.5			12.7			16.0
350	355.6	7.6			9.5			12.7			16.0
400	406.4	7.9			9.5			12.7			16.0
450	457.2	7.9			9.5			12.7			16.0
500	508.0	7.9			9.5			12.7			16.0
550	558.8	7.9			9.5			12.7			16.0
600	609.6	7.9			9.5			12.7			16.0
650	660.4		7.9			9.5			12.7		
700	711.2		7.9			9.5			12.7		
750	762.0		7.9			9.5			12.7		
800	812.8		7.9			9.5			12.7		
850	863.6		7.9			9.5			12.7		

u. Trip Information

MT Senipah	
Route	Wayame - Cilacap - Gresik - Cilacap - Tanjung Priok
Total Range (km)	5236
Total Range (Nm)	2858,079
Vs (knot)	12
Time (hr)	238,1732
Time (day)	10
Days/year	340
Trips	34

u. Heat and Balance Diagram




Expansion Tank
Sludge Tank

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WRITER BIODATA

Oscar Alfinza Fadiwi or Oscar is a first son of two brothers. Born in Surabaya, 20 September 1997. This writer is located at Pondok Tjandra Indah, Kecamatan Waru, Kabupaten Sidoarjo, East Java. Education background that taken by the authors is at Permata Hati Kindergarten School, SDN Wadungasri 1 Waru, Sidoarjo graduated at 2010. SMP Al-Hikmah Kebonsari Elveka, Surabaya, Graduated at 2013. And SMA Al-Hikmah Kebonsari Elveka, Surabaya, Graduated at 2016. This author also had an experience at First On The Job Training at PT. Industri Kapal Indonesia, Makassar and Second On The Job Training at PT. Pelabuhan Indonesia IV (First Class), Makassar. In other side, the author also join student activity units at Ju-Jitsu and Robotics at 2016 to 2017. This writer also join Ini Lho ITS as committee from SMA Al Hikmah Surabaya at 2016. Members of Students Association of Marine Engineering at 2017 until now. This writer also joins 3 Marine Company Visits (MCV) at Bali and Jakarta. And join the seminar named “Optimis Saja” at the first week of 7th semester. Also, this writer also a member of Marine Electrical and Automation System (MEAS), Marine Power Plant (MPP), and Marine Fluid Machinery and System (MMS) as Thesis Member. And also, the writer also contribute at at PLC Training as Committee, International Workshop on Alternative fuels for Marine Diesel Engine and Propulsion System as Committee. AutoCad Training, Character Building by Student Organization, if you want further discussion about this paper and this author, this writer can be emailed via oscaralfinzaf@gmail.com