BACHELOR THESIS & COLLOQUIUM – ME184834

INTEGRATED HOMOGENIZER BLENDING SYSTEM DESIGN TO OVERCOME B30 STORAGE ISSUES

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DEPARTMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2020

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SKRIPSI – ME184834

DESAIN SISTEM BLENDING HOMOGENIZER TERPADU UNTUK MENGATASI PERMASALAHAN STORAGE PADA B30

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ENDORSEMENT PAGE

INTEGRATED HOMOGENIZER BLENDING SYSTEM DESIGN TO OVERCOME B30 STORAGE ISSUES

BACHELOR THESIS

Submitted in fulfillment of the requirement for the
degree of Bachelor in Engineering

at

Digital Marine Operation and Maintenance (MOM) Laboratory
Bachelor Program Department of Marine Engineering
Faculty of Marine Technology
Sepuluh Nopember Institute of Technology

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APPROVAL FORM

INTEGRATED HOMOGENIZER BLENDING SYSTEM DESIGN TO OVERCOME B30 STORAGE ISSUES

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DECLARATION OF HONOR

I hereby who signs below declare that:

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Department	: Marine Engineering

If any plagiarism act is to be found in this work, I will take full responsibility and receive the penalty given by ITS according to the regulation applied.

Surabaya, July 2020

Tatyana A. Ibrahim

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INTEGRATED HOMOGENIZER BLENDING SYSTEM DESIGN TO OVERCOME B30 STORAGE ISSUES

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ABSTRACT

World's energy needs increase each year as technology progresses along, so do the emissions. The levels of heat-trapping CO2 in the atmosphere rose to 441 ppm in 2019, setting the record as the highest amount of CO2 in the atmosphere observed in nature in 800.000 years. Indonesia was discovered as the second highest contributor of CO2 emissions in 2018 among the G20 countries. The national government is committed to reduce the amount of emissions by ratifying the Paris Agreement whilst also trying to improve the national economy by decreasing oil imports. This led to the creation of a set of policies that support the implementation of biodiesel. According to the Ministrial Regulation No. 12/2015, four main sectors in Indonesia are required to use B30 biodiesel blend as their main fuel. To this date, the feed stock that is used to make Fatty Acid Methyl Esters (FAME) as the biodiesel blend is Crude Palm Oil (CPO), and since 1 January 2020, the utilization of B30 biodiesel became mandatory in Indonesia. The implementation of this program leads to several problems caused by the storage issues of the fuel such as; gelling, precipitation, sludging, and fuel contamination. Among the effects of long-term biodiesel storage are; increase of precipitation, acid value, density, viscosity, water content, and decrease of heating value. These storage issues get increasingly worse as the storage time progresses. The design of the integrated homogenizer system is aimed to re-blend the B30 biodiesel so that the degraded properties improve as it was before being stored. The implementation of the mandatory biodiesel program faces several challenges such as; palm oil as raw material for biodiesel production, the distribution of biodiesel blend, shortage of production due to the pandemic, and EU as the biggest importer of Indonesian biodiesel to ban biodiesel usage by 2030.

Keywords: biodiesel, B30, FAME, CPO, homogenizer, degradation.

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DESAIN SISTEM *BLENDING HOMOGENIZER* TERPADU UNTUK MENGATASI PERMASALAHAN *STORAGE* PADA B30

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ABSTRAK

Seiring dengan kemajuan teknologi, kebutuhan energi di dunia pun meningkat setiap tahunnya, demikian juga dengan emisi yang dihasilkan. Tingkat CO_2 yang memerangkap panas di atmosfer naik menjadi 441 ppm pada 2019, jumlah tersebut merupakan rekor jumlah CO2 di atmosfer tertinggi dalam 800.000 tahun. Pada tahun 2018, Indonesia merupakan penyumbang emisi CO_2 tertinggi kedua di antara negara-negara G20. Pemerintah berkomitmen untuk mengurangi jumlah emisi dengan meratifikasi *Paris Agreement*, selain itu pemerintah juga berusaha meningkatkan ekonomi nasional dengan mengurangi impor minyak. Hal ini mengarah pada pembuatan serangkaian kebijakan yang mendukung implementasi biodiesel. Menurut Peraturan Pemerintah No. 12/2015, empat sektor utama di Indonesia diharuskan untuk menggunakan campuran biodiesel B30 sebagai bahan bakar utama mereka. Hingga saat ini, bahan pokok yang digunakan untuk membuat *Fatty Acid Methyl Esters* (FAME) sebagai campuran biodiesel adalah *Crude Palm Oil* (CPO). Sejak 1 Januari 2020, pemanfaatan biodiesel B30 menjadi wajib di Indonesia. Implementasi program ini menyebabkan beberapa masalah yang disebabkan oleh masalah penyimpanan biodiesel, seperti; pembentukan gel, *precipitates*, *sludge*, dan kontaminasi bahan bakar. Di antara efek penyimpanan biodiesel jangka panjang adalah; peningkatan *precipitates*, *acid value*, *density*, *viscosity*, *water content*, dan penurunan *heating value*. Desain sistem *homogenizer* yang terintegrasi bertujuan untuk *blending* kembali biodiesel B30 sehingga kualitas bahan bakar yang terdegradasi dapat kembali seperti semula. Implementasi program biodiesel di Indonesia menghadapi beberapa tantangan seperti; CPO sebagai bahan baku untuk produksi biodiesel, distribusi *blend* biodiesel, dan UE sebagai importir terbesar biodiesel dari Indonesia yang memberhentikan penggunaan biodiesel pada tahun 2030.

Keywords: biodiesel, B30, FAME, CPO, homogenizer, degradation.

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PREFACE

The writer would like to thank The Almighty for His grace and empowerment throughout the process of completing this bachelor thesis. This thesis has been written to fulfill the requirements to achieve the Bachelor of Engineering degree on Marine Engineering Departement, Faculty of Marine Technology, Sepuluh Nopember Institute of Technology.

This thesis was written in such a time where many obstacles were in the way, but many parties assisted the writer to finally achieve credible and useful thesis results. This success is inseparable from the contribution, prayer, support, ideas, and technical assistance of others. Therefore, the writer would like to utter gratitude to;

1. Writer's mother and brothers for the unconditional support,
2. Beny Cahyono, S.T., M.T., Ph.D., as Head of Marine Engineering Departement,
3. Ir. Hari Prastowo, M.Sc. as the writer's bachelor thesis supervisor,
4. Dr. Eng. Trika Pitana, ST., M.Sc. as the writer's bachelor thesis supervisor,
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15. Members of DMOM, MEAS, and MPP Laboratories for all the fun and laughter we shared the past year,
16. And fellow Voyage'16 friends for the four-year companion. The writer could never ask for anything more.

The author sincerely apologizes for the imperfections that this thesis may have, the author also hopes that the thesis will be beneficial to all the readers. Lastly, the author wishes that this thesis may provide some knowledge for the reader especially in scope of technology development.

Surabaya, July 2020

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CHAPTER I
INTRODUCTION

1.1. Background

Energy supply such as coal fired power plants and oil refineries contribute as the biggest source of greenhouse gasses (GHGs). In 2016, their emission was accounted for 34% of emissions worldwide. The number continued to rise when it was found that global energy-related CO_2 emissions rose by 1.7% in 2018 (International Energy Agency, 2019) and the levels of heat-trapping CO_2 in the atmosphere rose to 441 ppm (parts per million) in May 2019, this set the record as the highest amount of CO_2 in the atmosphere observed in nature in 800.000 years (United Nations Development Programme, United Nations Framework Convention on Climate Change, 2009). Albeit having ratified the Paris Agreement in 2016, Indonesia was discovered to be the second highest contributor to CO_2 emissions in 2018 among countries in the G20.

Indonesia currently only has 0.20% of the world's oil reserves while national oil needs increase every year, the country's oil imports peaked at 2014 with 401.721 barrels per day (BPD). The country's dependency on oil imports has a negative impact to the national economy. The Indonesian government is committed to reduce the amount of national carbon emissions and to fulfill national energy needs, and one of the ways to achieve that is by starting to transition from the use of fossil fuel to renewable energy, specifically biofuel. Indonesia's biofuel blending mandate is one of the most ambitious in the world, this is demonstrated through Presidential Instruction No. 1/2006 on Biofuel Supply and Utilization.

The Ministerial Regulation No. 12/2015 issued by the Ministry of Energy and Mineral Resources (MEMR) further strengthens the target for national biofuel consumption. The table below presents the mandate according to MEMR Regulation 12/2015;

Table 1- 1 MEMR Regulation 12/2015 Mandate on Biofuel Consumption

Sector	April 2015	January 2016	January 2020	January 2025
Micro-business, fisheries, agriculture, and public service (subsidized)	15%	20%	30%	30%
Transportation	15%	20%	30%	30%
Industry and commercial	15%	20%	30%	30%
Electricity	25%	30%	30%	30%

To this date, the raw material that is used to make biodiesel in Indonesia are fatty acid methyl esters (FAME) that's derived from crude palm oil (CPO). Palm oil is the most desirable raw material for biofuel since Indonesia is the largest palm oil producer in the world, accounting for more than half of global production at 54% (FAOSTAT, 2016). The blending mandate is commonly referred to as the B30 program where the government obliges the mixture of 30% desired biodiesel with 70% diesel fuel oil. FAME is supplied to fuel producers and distributors such as Pertamina to then be blended with diesel fuel before being sold to end-users.

B30 is considered to be more environmentally friendly compared to B0, this is due to the higher amount of cetane and oxygen contained in B30 that supports a more complete combustion process therefore reducing the emissions produced. Other than that, one of the most prominent reasons that supports the migration to B30 is that diesel engines that formerly use B0 can directly change to B30 with only little to no modifications needed. The B30 program is also economically beneficial to the country since it boosts the demand of local-grown CPO and minimizes the cost of importing fuel. The MEMR also revealed that from January to July 2019, the 20% CPO biodiesel has managed to save Rp23.7 trillion of Indonesia's foreign exchange reserves (*cadangan devisa*).

Table 1- 2 Reduction of Emission from Biodiesel Utilization (B20)

BIODIESEL REDUCES EMISSIONS		
Emissions	**B100**	**B20**
Carbon monoxide	-43.2%	-12.6%
Hydrocarbons	-56.3%	-11.0%
Particulates	-55.4%	-18.0%
Nitrogen oxides	+5.8%	+1.2%
Air toxics	-60% - -90%	-12% - -20%
Mutagenicity	-80% - -90%	-20%

Although it has several advantages, B30 still has its downsides. Even though B30 combustion emissions is notably lower than that of B0, It is not yet identified whether B30 does reduce the national amount of emissions from its production process up to consumption by the consumers. Adding up to that, companies that use B30 fuel for their engines usually buy the fuel in metric tons to then reserve in storage tanks before usage, but it is found that biodiesel cannot be stored for long periods of time due to its hygroscopic nature. A substance that's hygroscopic tends to attract water due to its polar molecular structure at one end. A study discovered that biodiesel absorbed 1.000 – 1.700 ppm (0.10% to 0.17%) of moisture at temperature of 4°C to 35°C, the number was 15 to 25 times higher compared to regular diesel fuel in the same temperature range (He, Van Gerpen, Thompson, & Routt, 2007).

The hygroscopic nature of the biofuel will support water absorption; therefore, if the biodiesel was stored for long periods of time, accumulation of the water will form precipitates at the bottom of the storage tanks and then form sludge. Other than that, it has been found that B30 tends to gel at a temperature higher than pure diesel fuel, this is due to the biodiesel production process that produces impurities such as saturated monoglycerides (SMG) which enhances precipitation when mixed with pure diesel fuel, this problem further enhances unique storage issues for B30. The presence of precipitates, impurities, and sludge can cause corrosion inside the storage tank, clog oil pipes, filters, and valves. This can also cause major economic loss to said companies that purchase biodiesel in bulk regularly because the contaminated fuel will not be effective to use anymore.

Based on the previous explanation, it is concluded that more research has to be done to overcome B30 storage issues. This research intends to explore more regarding the causes and effects of the said storage issues of biodiesel and propose integrated system to restore the properties and characteristics of stored B30 biodiesel into its ideal condition. The integrated homogenizer blending system will consist of a homogenizer and a purifier as the main components.

1.2. Problem Statements

From the background stated previously, the problem statements that can be formulated are as follows:

a. How does B30 biodiesel cause storage issues?
b. How is the design of the integrated B30 processing homogenizer system?
c. How is the national regulation and implementation progress for the B30 program in Indonesia?

1.3. Scope of Study/Research Limitations

This final project will be focused and organized within these determined limitations, which are:

a. The literatures review will be done to journals of primarily FAME biodiesel blends
b. The instruments used for the design will be a separator and a homogenizer provided by PT Turbotech Indonesia
c. The initial system design will be provided by PT Turbotech Indonesia

1.4. Research Objectives

Based on the problems that have been formulated, the objectives of this research are as follows;

a. To determine how B30 biodiesel contribute to causing storage issues
b. To design the integrated B30 processing homogenizer system
c. To understand holistically and extensively regarding the B30 program national regulation and its implementation progress

1.5. Research Benefits

This final project is expected to result in benefits for various parties, among the benefits expected are;

a. Provide insights on how biodiesel properties and characteristics are affected by the storage duration of the fuel
b. Present proposed design of integrated homogenizer system for B30 blending
c. Provide insights on the current progress of the B30 blending program implementation

CHAPTER II
LITERATURE STUDY

2.1. Biodiesel

Biodiesel is one of three main branches derived from biofuel. The term biofuel refers to liquid and gaseous fuels produced from biomass. Characteristics and benefits of biofuels depend on the categorization of the specific biofuel, type of the feedstock used to generate it, and the technology applied to produce it. Biofuels are typically divided into three main parts which are as follow;

a. Biodiesel – typically generalized as a diesel-like fuel meant to be used for conventional diesel engines, biodiesel can be used as is or as a blend with diesel fuel. It is typically made from vegetable oils or animal fats consisting of a long chain of alkyl (methyl, ethyl, propyl) esters that are chemically reacted with an alcohol produced from different fatty acids.
b. Bioethanol – works with the same principle as biodiesel but is meant to be used for conventional petrol engines. Bioethanol is more common to be blended in small amounts prior to using rather than being used as is. Pure bioethanol can be used in specialist engines. This fuel is made by fermented sugars from crops
c. Biomethane – is made out of organic waste from animal waste or food residues through anaerobic digestion. It is designed to be used for engines/devices that run on natural gas, it can be used for electricity generation, water heating, space heating, cooking as well as to fuel vehicles

Figure 2-1 shows the sources of the main liquid biofuels in more detail:

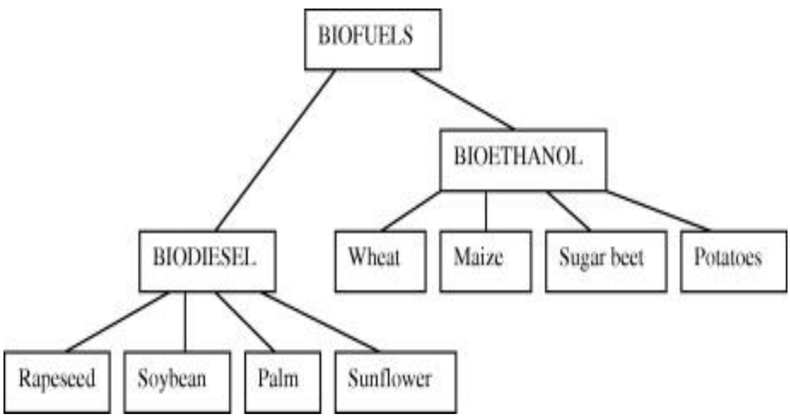

Figure 2- 1 Sources of Biofuels

Since the source of biodiesel is renewable, it possesses several positive impacts to the economy, environment, and energy security (Dermibas, Political, Economic and Environmental Impacts of Biofuels: A Review, 2009). Table 2-1 on the next page will describe the positive impacts of biodiesel usage.

Table 2- 1 Positive Impacts of Biodiesel Usage

Economic impacts	Sustainability Fuel diversity Minimizes oil imports Increased income taxes Increased investments in plant and equipment Agricultural development International competitiveness Reducing the dependency on imported petroleum
Environmental impacts	Greenhouse gas reductions Reducing of air pollution Non-toxic & biodegradable Higher combustion efficiency Improved land and water use Carbon sequestration
Energy security	Domestic targets Supply reliability Reducing use of fossil fuels Ready availability Domestic distribution Renewability

The application of biodiesel in engines has to follow the standardized biodiesel characteristics determined by Standar Nasional Indonesia (SNI) 7182:2012, the specification is as follows:

Table 2- 2 Biodiesel Specification in Indonesia
(Source: SNI 7182:2012)

No.	Test Parameter	Unit	Limit
1	Density at 40 °C	kg/m3	850-890
2	Kinematic viscosity at 40 °C	mm2/s (cST)	2,3 – 6.0
3	Cetane number	-	Min. 51
4	Flash point (closed cup)	°C	Min. 100
5	Cloud point	°C	Max. 18
6	Copper strip corrosion (3 hours, 50 °C)	-	Number 1
7	Carbon residue in: - Original Sample - Or 10% residue of distillation	%-mass	Max. 0.05 Max 0.3
8	Water and sediment	%-volume	Max 0.05
9	90%-distillation temperature	°C	Max. 360
10	Sulfated ash	%-mass	Max. 0.02
11	Sulphur	mg/kg	Max. 50
12	Phosphorous	mg/kg	Max. 4
13	Acid value	mg-KOH/g	Max .0.5
14	Free Glycerol	%-mass	Max. 0.02
15	Total Glycerol	%-mass	Max. 0.24
16	Methyl ester content	%-mass	Min. 96.5
17	Iodine Value	g-l_2/100 g	Max. 115
18	Oxidative Stability: - Rancimat Induction Period - Or Petro-Oxy Induction Period	minute	Min. 480 Min. 36
19	Monoglyceride	%-mass	Max. 0.8

2.1.1. Fatty Acid Methyl Esters (FAME)

Fatty acid methyl ester (FAME) is an ester of fatty acids, it is a biodegradable and non-toxic biodiesel that can be made from a wide range of vegetable oils and fats. FAME is produced through transesterification process, it is commonly used as both a blending component in fossil diesel and pure fuel (f3, 2017). Usage of pure FAME as fuel is known as B100, the number refers to the amount of FAME mixed in the blend. So then B50 is composed of 50% FAME, B30 is composed of 30% FAME, B20 is composed of 20% FAME and so forth. The general properties of FAME can be seen on the table below:

Table 2- 3 FAME Properties (Source: f3, 2017)

Chemical formula	**:**	$CH_3(CH_2)_nCOOCH_3$ (general formula of methyl esters)
Molecular mass	:	RME: 296g/mol (OIeic acid C18:1)
Density at 15°C 1.013 bar	:	860-900 kg/m^3
Heating value	:	RME: 38 MJ/kg
Cetane number	:	> 51

Each country uses different FAME feedstocks as their biodiesel base. The international biofuel sectors are strongly influenced by national policies with three major goals; farmer support, reduced greenhouse gas emissions, and increased energy independency. Table on the next page explains the key feedstocks used as biodiesel base in some countries:

Table 2- 4 Biofuel Production Key Feedstocks (Source: OECD - FAO, 2019)

Country	Major Feedstock
United States	Soybean oil
European Union	Rapeseed oil
Brazil	Soybean oil
China	Waste oils
India	Palm oil
Canada	Waste oils
Indonesia	Palm oil
Argentina	Soybean oil
Thailand	Palm oil
Colombia	Palm oil
Paraguay	Soybean oils

2.1.2. Crude Palm Oil (CPO)

Palm oil is an edible vegetable oil extracted from the mesocarp of the fruit of oil-palm tree (Elaeis guineensis) (Sheil, et al., 2009). The trees in which the oil comes from aren't very demanding in terms of the soil requirements they need to grow in, as long as the pH-level is above 4, these trees are able to tolerate a wide variety of water status and acidity (Corley & Tinker, 2015). It is deemed as the world's most efficient oilseed crop due to its high productivity per hectare, palm oil has the oil production efficiency (oil produced/land area) of 4000 kg/ha (Yusoff & Hansen, 2007). Due to its cheap price and readiness for downstream processing, palm oil is considered as the most potential raw material to be used to manufacture biodiesel, crude palm oil (CPO) being its desired by-product to produce biodiesel.

Indonesia still remains as the market leader for exported palm oil, according to a report by Gabungan Pengusaha Kelapa Sawit (GAPKI), Indonesia's palm oil production from January – August 2019 is seen to increase by 14% (34.7 million tonnes) compared to the previous year's production (30.66 million tonnes). As of 2018, Indonesia supplies 54.5% of total palm oil exports.

Figure 2- 2 Palm Oil Plantation (Source: GAPKI.id)

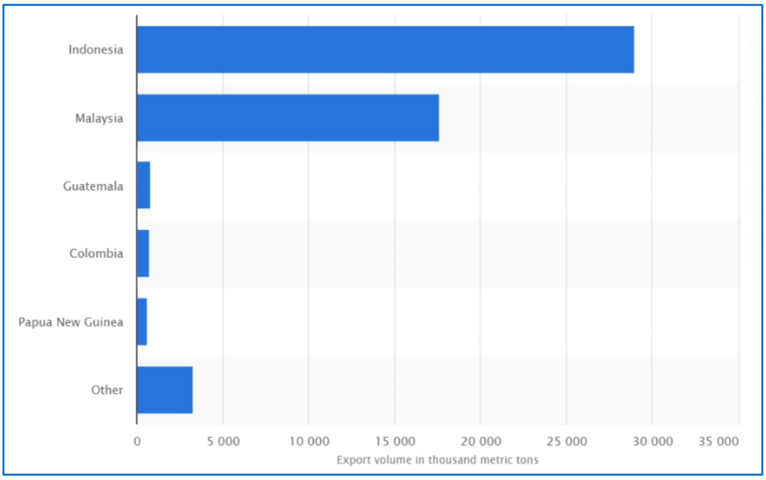

Figure 2- 3. Palm Oil Export Volume Worldwide 2018/19, By Country (Source: statista.com/statistics/620219/palm-oil-export-volume-worldwide-by-country/)

In Indonesia, the high economic value of palm oil is represented by its intermediate products such as CPO and palm kernel oil (PKO). A few of derivations from CPO include cooking oil, margarine, cosmetics, lubricants, and detergents, while PKO has derivative products such as fatty acids and lauric acids (Pahan, 2007). Figure 2-3 below presents Indonesia's palm oil production since 1960 in million metric tons. The growth has increased tremendously over the past two decades. On average, more than 70% of Indonesia's palm oil and its products are exported (FAOSTAT, 2016).

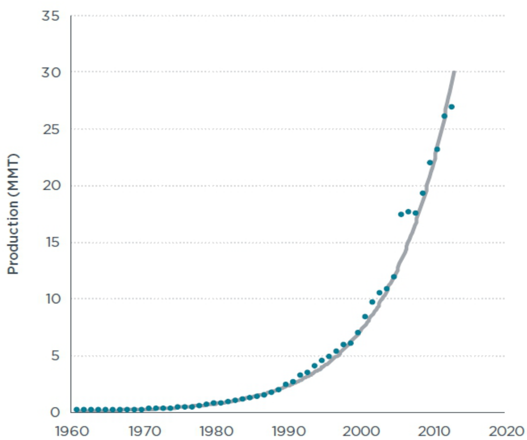

Figure 2- 4 Indonesia Palm Oil Production Since 1960 (in Million Metric Tons) (Source: FAOSTAT, 2016)

ough transesterification process. During this process, vegetable oil referred as triglycerides is reacted with an alcohol (methanol or ethanol) to form fatty acid methyl/ethyl esters and glycerol. The transesterification process efficiency is determined through different operational parameters, the parameters include;

1. Temperature of the mixture
2. Moisture quantity in the mixture
3. Intensity of mixing (mass transport)
4. Molar ratio of alcohol to vegetable oil
5. Type of catalyst used (Korus, 1993; Mamilla, et al., 2012).

Other derivative products from palm oil can be seen on the figure below.

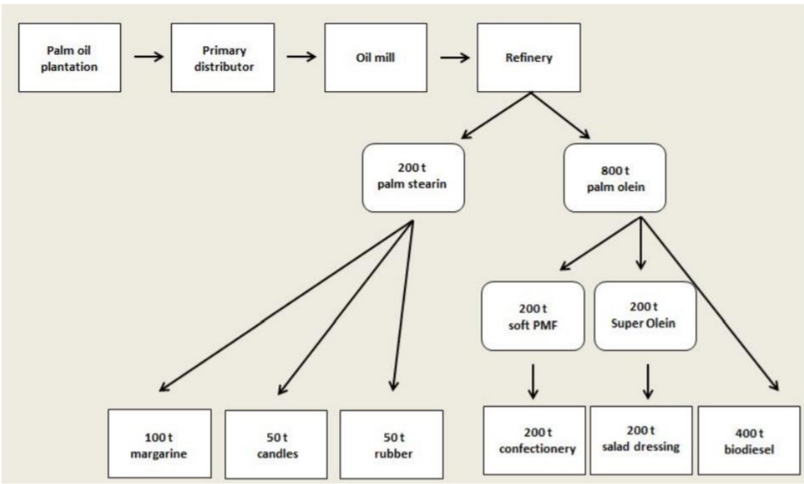

Figure 2- 5 General Simplified Palm Oil Supply Chain
(Source: Oeko-Institut e.V, 2018)

2.1.3. Properties of B30

Pertamina as a national oil company is one of the producers and suppliers for biodiesel fuel, they have managed to comply with the national regulations regarding national biofuel utilization. The blending mandate is commonly referred to as the B30 program where the government obliges the mixture of 30% desired biodiesel with 70% diesel fuel oil.

Figure 2- 6 General Simplified Palm Oil Supply Chain
(Source: Tempo.co, 2019)

To support the implementation of the mandate, the National Technical Committee on Biofuel Standard conducted tests to improve the previous existing biodiesel specifications (SNI 7182 – 2012), the result of this activity is the present national quality standard of B20 biodiesel (SNI 7182 – 2015). The B20 specifications to execute the B20 mandate in 2016 were as the table follow:

Table 2- 5 B20 Specifications According to SNI 7182 - 2015

No.	Test Parameter	Unit	Limit
1	Density at 40 ^{0}C	kg/m^3	850-890
2	Kinematic Viscosity at 40 ^{0}C	mm^2/s (cSt)	2,3 – 6.0
3	Cetane Number	-	Min. 51
4	Flash Point	^{0}C	Min. 100
5	Cloud Point	^{0}C	Max. 18

6	Copper Strip Corrosion (3 hours, 50 ^{0}C)	-	Number 1
7	Carbon residue in: - Original sample - 10% residue of distillation	%-mass	Max. 0.05 Max. 0.3
8	Water and Sediment	%-volume	Max. 0.05
9	90% Distillation Temperature	^{0}C	Max. 360
10	Sulfated Ash	%-mass	Max. 0.02
11	Sulfur	mg/kg	Max. 250
12	Phosphorous	mg/kg	Max. 4
13	Acid Value	mg-KOH/g	Max. 0.5
14	Free Glycerol	%-mass	Max. 0.02
15	Total Glycerol	%-mass	Max. 0.24
16	Methyl Ester Content	%-mass	Min. 96.5
17	Iodine Value	g-l_2/100g	Max. 115
18	Oxidative Stability - Rancimat Induction Period - Petro-Oxy Induction Period	Minute	Min. 480 Min. 36
19	Monoglyceride	%-mass	Max. 0.8

And the following are the specifications of B30 product by Pertamina according to the B30 Safety Data Sheet:

Table 2- 6 B30 Identification
(Source: PT Pertamina)

Identification:

Product identifier	:	Biosolar
Other means of identification	:	Biosolar B30, Biodiesel Blend, Campuran Biodiesel,

		Automotive Diesel Fuel, High Speed Diesel Fuel, Gasoli
Recommended use of the chemical and restriction on use	:	Designed for diesel-fueled engine with high rotation and some of middle rotation. Not recommended for gasoline fueled engine
Manufacturer	:	PT Pertamina (Persero)

Table 2- 7 B30 Composition/Information
(Source: PT Pertamina)

Composition/Information on Ingredients:

Chemical Name	**CAS No.**	**Concentration (%)**
Hydrocarbon	-	70
FAME	-	30

Table 2- 8 Properties and Characteristics of B30
(Source: PT Pertamina)

Physical Properties, Chemical Properties, and Safety Characteristics:

Characteristic		Test Result
Organoleptic (physical appearance, color, etc)	:	Liquid, clear, bright
Odor	:	Diesel
Odor threshold	:	No data available
Melting/freezing point	:	Cannot be applicated
Flammability	:	Flammable liquid
Flash point	:	60 ^{o}C
Evaporation rate	:	No data available
Lower/upper flammability limit and explosion limit	:	LEL 1.3%; UEL 6.0%
Vapor pressure	:	No data available

Vapor density	:	No data available
Relative density	:	No data available
Water solubility	:	Not soluble
Auto-ignition temperature	:	260 ^{o}C
Viscosity	:	2.0 – 5.0 mm^2 at 40 ^{o}C

Comparatively, biodiesel contains about 8% less energy per gallon than petroleum diesel. When applied to B30, the difference ranges from 1% - 2%. Benefits of B30 use correlating to greenhouse gas and air-quality adjusts to the blend composition. Generally, B30 provides 30% of the benefit of B100 use (U.S. Department of Energy, n.d.). The properties of the biodiesel which degradation level will be observed are:

a. Flash Point

   The flash point of any oil is defined as the lowest temperature at which it forms vapors and produces combustible mixture with air. Lower flash point is desirable for fuel oil. The flash point is not an intrinsic property of a material. Its value will depend on the apparatus design, condition of the apparatus used, and the test procedure used. Flash point tests are used to assess flammability for shipping and safety regulations. detect presence of contamination of material by volatiles, and to determine if a product meets specifications.

b. Pour Point

   The pour point is the lowest temperature at which a sample of petroleum product will continue to flow when it is cooled under specified standard conditions (ISO, 1994).

c. Heating Value/Calorific Value

   Heating value is a physical property of all fuels. It represents the actual amount of heat in a combustion process (expressed most often in kilocalorie, kilojoule or megajoule) of one kilogram or one liter of fuel. Measuring the calorific value of fuel is performed by calorimetry (Bouabid, Nahya, & Azzi, 2013).

d. Acid Value/Acid Number

   Acid value or acid number is the mass of potassium hydroxide (KOH) in milligrams that is required to neutralize one gram of chemical substance. Acid number is important in biodiesel properties since the number increases when the fuel deteriorates

e. Cetane Number

The cetane number is a measure of how readily the fuel starts to burn (auto-ignites) under diesel engine conditions. A fuel with a high cetane number starts to burn shortly after it is injected into the cylinder; therefore, it has a short ignition delay period. On the other hand, a fuel with a low cetane number resists autoignition and has a longer ignition delay period (Chevron, 2007).

f. Fuel Viscosity

Viscosity is a measure of resistance to flow. Viscosity decreases as the temperature increases. Low viscosity fuel produces a fine, atomized mist of fuel which improves its mix with incoming air to encourage a complete combustion for better power and lower emissions. High viscosity fuel tends to result in a heavier mist of fuel which can result in hard starting and white smoke issues.

g. Fuel Density

This is defined as the ratio of the mass of the fuel to the volume of the fuel at a reference temperature of 15°C.Density depends on the raw materials used for biodiesel fuel production and the biodiesel methyl ester profile (Blangino, Riveros, & Romano, 2008).

h. Water and Sediment Content

Water and sediment content in fuel causes rusting and damage to fuel system components. Biodiesel with high water content can cause iron oxide particles to form inside the fuel tank. This problem is observed in biodiesel that's stored for a long period of time.

i. Fuel Microbes

The presence of water in biodiesel supports microbial growth in between the oil and water or the tank walls itself, depending on the species of the microbes and whether or not they need oxygen.

2.2. B30 Storage Issues

Biodiesel can be used as is or blended with diesel oil in any percentage. The regular storage and handling procedures used for biodiesel are, however, the main problem because of the fuel specifications. Biodiesel with palm oil as its raw material is produced through transesterification process. A side effect that comes along with the transesterification of vegetable oil is an increased water hazard (Lele, n.d.). This is due to FAME being a hygroscopic compound, it means that it is able to absorb more humidity than regular diesel because it supports water absorption. A substance that's hygroscopic tends to attract water due to its polar molecular structure at one end. A study discovered that biodiesel absorbed 1.000 – 1.700 ppm (0.10% to 0.17%) of moisture at temperature of 4°C to 35°C, the number was 15 to 25 times higher compared to regular diesel fuel in the same temperature range (He, Van Gerpen, Thompson, & Routt, 2007).

Because palm-oil-based biodiesel is hygroscopic, it is not recommended for biodiesel blends to be stored for long periods of time. If the biodiesel was stored for long periods of time, accumulation of the water will form precipitates at the bottom of the storage tanks and then form sludge. Moreover, biodiesel blends are susceptible to growing microbes when water is present in fuel (Lele, n.d.). Also, since biodiesel is a mild solvent, biodiesel has a tendency to dissolve the sediments normally encountered in old tanks. This causes filter blockage, injector failures, in addition to clogging of fuel lines.

Biodiesel storage stability was first studied in 1985 by du Plessis et al. The research found that the exposure of heat and air greatly accelerated degradation of biofuel (du Plessis, de Viliers, & van der Walt, 1985). During degradation, FAME molecules are broken down, resulting in the increase of the acid value due to the fatty acid chains. Thus, the fuel acidity increases along with the amount of degradation that happens, therefore decreasing fuel stability (Khalid, et al., 2013). Other things that support fuel quality degradation include oxygen exposure, contamination from metals and other radical initiators, water exposure, light exposure, and heat (Christensen & McCormick, 2014). The stability of biodiesel in storage is critical because oxidation reactions give rise to substances that can degrade different parts and materials used in biofuel storage systems.

In 2018, there were reported cases from bus and truck drivers in Indonesia that they changed their fuel filters twice as many because the filters kept getting blocked with a gel-like substance that was the B20 biodiesel blend they used. Some cases were also reported by people who lived in high-altitude areas in Indonesia that gelling in the biodiesel tank happen on low ambient temperature.

Another disadvantage is that the viscosity increases at lower ambient temperatures, hence requiring additives for lowering the fuel's gel point.

To conclude the previous explanation, what can be considered as B30 storage issues are as follow;

1. FAME is hygroscopic, it can absorb more humidity than regular diesel. it is not recommended for biodiesel blends to be stored for long periods of time because accumulation of the water will form precipitates at the bottom of the storage tanks and then form sludge.
2. Biodiesel absorbed 15 to 25 times higher moisture compared to regular diesel fuel in the same temperature range
3. Biodiesel blends are susceptible to growing microbes when water is present in fuel
4. Biodiesel is a mild solvent; it dissolves the sediments in tanks. This causes filter blockage, injector failures, and clogging of fuel lines.
5. Exposure of heat and air accelerated degradation of biofuel. FAME molecules are broken down, resulting in the increase of the acid value due to the fatty acid chains. This decreases fuel stability.
6. Low ambient temperatures increase viscosity and supports biodiesel gelling.

2.3. Homogenizer

Fuel homogenization was first introduced to be used for boilers and diesel engines in 1970 when fuel prices skyrocketed. The initial purpose of the homogenizer was for onsite fuel blending of heavy fuel oil (HFO) with distillate fuel oil. This was aimed to reduce fuel costs by a slight amount (Burak). Homogenization is a process of achieving homogeneity throughout a product by particle size modification. A material that is homogeneous is uniform in composition or character. The homogenizer basically consists of a positive displacement pump to which is attached a homogenizing valve assembly. The pump forces fluids through the homogenizing valve under pressure. The term “homogenization” refers to the process or action that occurs within the homogenizing valve assembly (Dhankar, 2004).

The homogenizer works as a dynamic milling machine, commonly used on board ships for their fuel oil system. It is designed to improve fuel quality which will lead to a better combustion and less maintenance, it also reduces sludge in case of fuel incompatibility. The objective of the homogenizer is to increase the amount of burnable fuel in the case of bad fuel quality. In general, homogenizing processes are broken down into three methods; ultrasonic, pressure, and mechanical. In this case, the homogenizer used is a mechanical homogenizer with rotor stator principle.

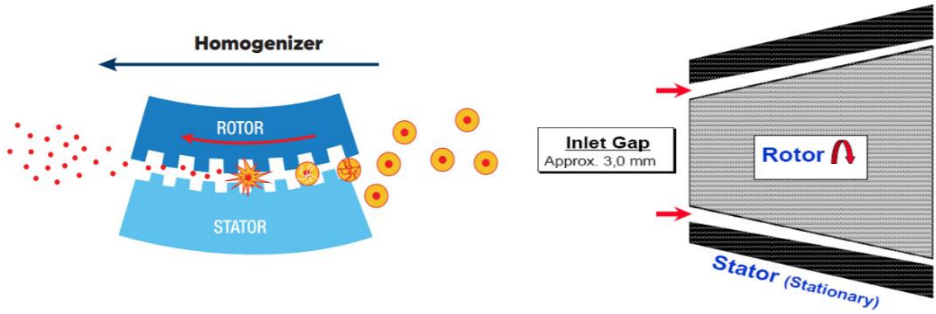

Figure 2- 7 Rotor-Stator Homogenizer Principle

A conical rotor with an efficient grinding profile in the homogenizer will run against the stator with large clearance but high rotating speed. This creates the strong frictional forces required to break up the long chains, it acts like a high-speed mill and the fuel is forced through an entryway between stator and rotor and cut the substance into smaller size (3–5 micron), therefore homogenizing the substance for its next purpose.

2.4. National Regulations on Biodiesel

Regulated biofuel development in Indonesia started when the President came up with the 2006 Presidential Instruction on Biofuel Supply and Utilization which states that the government is to provide a policy package of incentives tariff exemptions for biofuel development. Strengthening the Presidential Instruction, the government further came up with Presidential Regulation No. 5/2006 on Indonesia's National Energy Policy that sets a national target for the optimal energy mix in 2025 to look as the following:

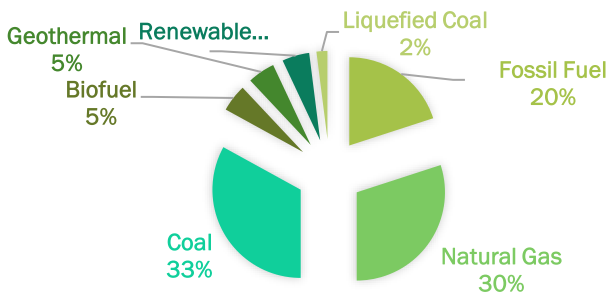

Figure 2- 8 2025 National Optimal Energy Mix
(Source: Presidential Regulation No. 5/2006)

Along with the global commitment to reduce greenhouse gasses emissions and the declining crude oil from fossil energy production, the government is further encouraged to increase the role of new and renewable energy to maintain national energy security and independence. In 2014, the government issued Government Regulation No. 79/2014 that mandates the optimal Primary Energy mix that shall be achieved. The regulation states that the role of New Energy and Renewable Energy (NRE) should contribute to at least 23% in 2025 and 31% in 2050.[1] Figure 2-6 explains Indonesia's energy mix in 2018, new and renewable energy source sits at the 3rd position, powering 14% of the national energy needs.

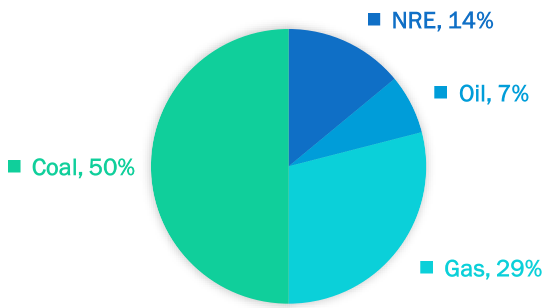

Figure 2- 9 National Energy Mix
(Source: HEESI, 2018)

Biofuel is seen the leading way to achieve the target of NRE, therefore in 2008, Indonesia's Ministry of Energy and Mineral Resources (MEMR) issued a regulation to set out plans for a greater role for biodiesel in transport.[2] This regulation features a target for biofuel blending mandate from 2008 – 2025 time frame. After its initial release in 2008, this mandate has been revised several times up until the latest MEMR Regulation in March 2019.[3] The mandate regulates as follows;

Table 2- 9 MEMR Regulation 12/2015 Mandate on Biofuel Consumption

Sector	April 2015	January 2016	January 2020	January 2025
Micro-business, fisheries, agriculture, and public service (subsidized)	15%	20%	30%	30%
Non-subsidized transportation	15%	20%	30%	30%

[1] *Government Regulation No. 79/2014 on National Energy Policy*
[2] *Indonesian MEMR Regulation No. 32/2008, first Indonesian biofuel mandate*
[3] *Indonesian MEMR Regulation No. 12/2015, Indonesian biofuel mandate update*

Industry and commercial	15%	20%	30%	30%
Electricity	25%	30%	30%	30%

At the end of December 2019, President Jokowi formally commenced the B30 Mandatory Program. The President expressed that he wanted B30 to be ready to supply by January 2020 (Gorbiano, 2019). Among the goals of the B30 Mandatory Program implementation are:

1. Fulfilling the government's commitment to reduce 29% of business as usual (BAU) GHGs emissions by 2030
2. Increasing national energy security and independence
3. CPO price stabilization
4. Increasing added value through downstream palm oil industry
5. Fulfilling 23% of contribution target on RNE 2015 total energy mix
6. Reducing fuel consumption and fuel imports
7. Reducing GHG emission
8. Improving the trade balance deficit (Ditjen EBTKE, 2019)

The biodiesel program timeline is as figure below.

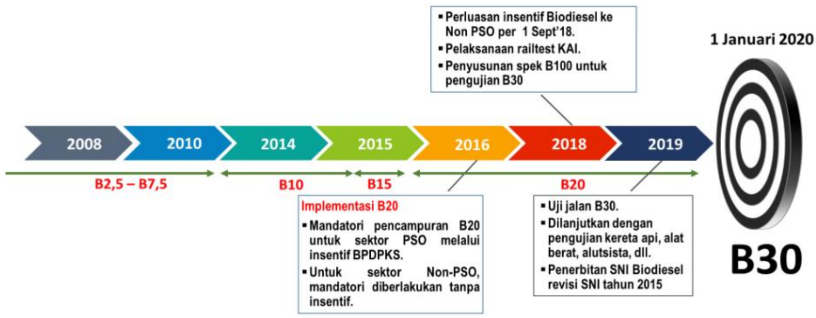

Figure 2- 10 National Biodiesel Program Timeline
(Source: HEESI, 2018)

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CHAPTER III
METHODOLOGY

3.1. Research Scheme

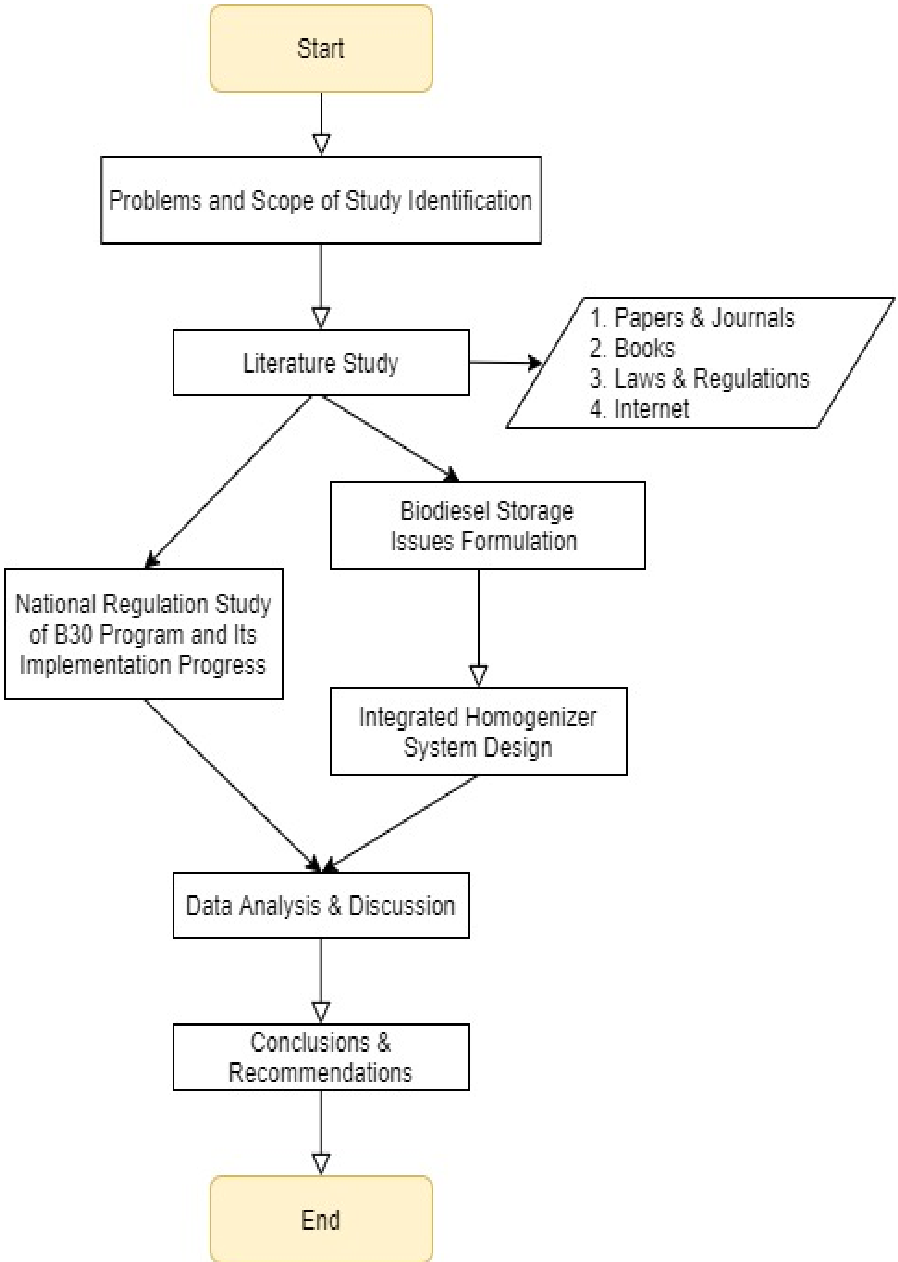


Figure 3- 1 Research Scheme

3.2. Research Flow

The research will be done through various steps to achieve its results and goals. Further explanation of the methodological flow from the beginning of the process, data collecting, until the final process of completing the objectives will be elaborated here:

3.3.1. Problem and Scope of Study Identification

Identifying the problem is one of the earliest steps in writing this thesis. The questions that this thesis is supposed to answer are formulated through problem identification. Questions and problems are specifically prepared to determine the objectives of this thesis. The content of the thesis is hoped to overcome the identified problems by doing experiment, data collection, and analyzing the data obtained. In the initial step of this research, the researcher will conduct an observation on the current conditions of B30 implementation and consumption in Indonesia. The research process will be based on literature and discussions with lecturers. From the initial identification, the objectives, research method, and limitations of this research will be determined.

3.3.2. Literature Study

The next step of this research is to study the literature available concerning the subject. The study shall be related to the existing problems and go in accordance with the purpose of the research. The aim of literature study is to give the author better understanding about the supporting information and problem related to this research. The information sifted will be used as reference and data to go through with the research.

3.3.3. Literature Review of Journals Regarding Biodiesel Storage Issues

In this step, the writer will do a thorough review on scientific literatures relating to the storage issues encountered in the utilization of FAME biodiesel. This literature review is aimed for the writer to gain a deep understanding regarding the existing research in the related to the particular issue, the writer aims to review around 20 journals about the topic. The materials gained from various scientific journals will be presented in the form of a concise written report to formulate the storage issues in FAME biodiesel faced by other researchers.

3.3.4. Analysis of Journal Review

After doing a thorough review of journals, an analysis of the review would be done to identify inconstancies in the various researches. The purpose of this analysis is to find gaps in research, conflicts in previous studies, also to identify new ways to interpret prior research. The analysis is hoped to find open questions left from other research and to suggest what further research needs to be done regarding the topic.

3.3.5. Integrated B30 Homogenizer-System Design

The initial design of the system will be provided by PT Turbotech Indonesia which will then be redrawn into a standardized piping and instrumentation diagram through AutoCAD 2D and subsequent to that will be improved to a 3D model of the system through Autodesk Inventor.

3.3.6. National Regulation Study of B30 Program Implementation Progress

This step will be executed through a descriptive analysis of related national regulations, reports, news, interviews, official documents and other relevant sources concerning the national B30 implementation program. This is done to collect data that would further be used to analyze the implementation progress of the program. The expected outcome of this step is to get a holistic view of the subject and the ability to add insights to the event should there be any.

3.3.7. Data Analysis & Discussion

At this stage, the data that has been obtained from the literature study will be analyzed further to get results that will answer the problem statements.

3.3.8. Conclusions and Recommendations

The last step of the research would be to conclude the processes that had been done. Conclusions and recommendations will be assessed after the result from the experiment is obtained. This stage will contain short answers to problems that have been identified at the first place. From conclusions, there will be recommendations given based on the results to improve the next projects.

3.2. 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 6 months, until the fourth week of June 2020.

No	Activity	Jan				Feb				Mar				Apr				May				Jun			
		1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1	Problem identification																								
2	Literature study																								
3	Regulation study of the B30 program																								
4	Homogenizer blending system design																								
5	3D system design and video design																								
6	Data collection																								
7	Data analysis & discussion																								
8	Conclusion and recs																								
9	Report drafting																								

Table 3- 1. Thesis Execution Schedule

CHAPTER IV
DATA ANALYSIS

4.1. Effect of Storage Time to B30 Biodiesel Blend

Biodiesel can be utilized pure as it is or blended with diesel/petroleum oil in any proportion, however due to its specifications, biodiesel has an issue with its storage and handling procedures that tends to degrade its properties (Hanis Zakaria, 2014). Researches have been done to study the effect of storage duration, temperature, and material to biodiesel properties and characteristics. Biodiesel properties are able to degrade during long-term storage through one or more of the following mechanisms:

a. oxidation or autoxidation from contact with oxygen present in ambient air;
b. thermal or thermal-oxidative decomposition from excess heat;
c. hydrolysis from contact with water or moisture in tanks and fuel lines;
d. microbial contamination from migration of dust particles or water droplets containing bacteria or fungi into the fuel (Pullen & Saeed, 2012)

Degraded biodiesel may include products such as insoluble sludge and organic acids, these products not only create problems in the storage period but also during engine operation (Pattamaprom, Pakdee, & Ngamjaroen, 2012). One of the insoluble sludges in this case is precipitates. During the production process, biodiesel forms impurities such as saturated monoglycerides (SMG) in the form of monostearin that precipitates at low temperature. This is due to melting point of SMG will form solid deposits above cloud point (Dunn, 2009). Poor oxidative stability that results in oxidation is also one of the major drawbacks of biodiesel utilization (Loha, Chew, & Choo, 2006). Hydro-peroxide produced from the oxidative degradation undergo the complex secondary reactions further oxidize into acids, leading to an increase in acid value (Obadiah & Kannan, 2012). Pattamaprom et al. and Zakaria et al. both found that increasing rate of acid value depends on the storage duration.

Just as storage duration determines the increasing amount of acid value in a biodiesel blend, storage duration also affected the heating value and density of biodiesel that has been stored for 6 months, resulting in lower heating value and higher density of the blend. The increased density was caused by the increasing molecular interaction as peroxides formed in the blend (Pattamaprom, Pakdee, & Ngamjaroen, 2012). Further research by Obadiah et al. found that during storage, the kinematic viscosity of the methyl esters increases by the formation of more polar, oxygen containing molecules and also by the formation of oxidized polymeric compounds that can lead to the formation of gums and sediments that clog filters. Another research found that palm oil biodiesel will occur gradual precipitation during storage at room temperature although the biodiesel has complied to the standards such as ASTM D 6751 and EN-14214 (Na-Ranong & Kitchaiya, 2014).

4.2. Biodiesel Properties and Characteristic Degradation Due to Storage Time

4.2.1. Precipitation

To investigate precipitates above the cloud point (CP) in biodiesel, one research from University of Indonesia spiked monostearin content into B10, B20, and B30 biodiesel blends. The total volumetric contents of monostearin added were 0.4%, 0.71%, and 0.92% in each blend, therefore concluding nine samples in total. Before adding the monostearin substance, the properties of the biodiesel samples were as follow:

Table 4- 1 Characterization of B10, B20, and B30

Parameter	Units	Results			Methods
		B10	**B20**	**B30**	
Density at 15 ºC	kg/m^3	848.7	841.1	849.1	ASTM D4052
Cloud Point	ºC	3.4	4.3	4.7	ASTM D5773
Sediment	% mass	0	0	0	ASTM D473
FAME Content	% vol	10.1	19.9	29.9	ASTM D664
Oxidation Stability Rancimat Methods	Hour	44.22	36.87	36.59	EN 15751

The characterization these biodiesel blends without monostearin content as the table above shows that all cloud points of the blends were below the lowest temperature used in this study which was 15 ºC. The cloud points for B10, B20, and B30 were found on 3.4 ºC, 4.3 ºC, and 4.7 ºC respectively. The results showed that the blends are qualified to be used to quantify the formation of precipitate above the cloud points. The storage duration for the samples were for two weeks. In this study, the biodiesel blends were stored in cooling chambers with temperatures of 15 ºC, 20 ºC, 25 ºC, and room temperature that ranged from 30 °C to 33 °C. The result after two weeks of storage time are as below:

Table 4- 2 Precipitation Formed from the Samples (mg/ml)

BXX – Monostearin Content	**Temperature**			
	15	**20**	**25**	**Room Temperature**
B10 – 0.4%	0.192	0.141	0.100	0.070
B10 – 0.71%	0.372	0.238	0.111	0.109
B10 – 0.94%	0.540	0.445	0.277	0.279
B20 – 0.4%	0.313	0.215	0.182	0.063
B20 – 0.71%	0.853	0.481	0.226	0.254
B20 – 0.94%	1.302	1.109	0.726	0.627
B30 – 0.4%	0.358	0.282	0.185	0.127
B30 – 0.71%	0.853	0.481	0.226	0.254
B30 – 0.94%	2.187	1.711	1.096	1.049

The result of the experiment showed that the amount of precipitate formed increased along with the increase of monostearin content. It is also discovered that the temperature had more precipitation effect on biodiesel with a higher blending ratio. This study proved that lower temperature and higher monostearin content produced more precipitate (Ghaizani, Abdurrosyid, Paryanto, & Gozan, 2018).

4.2.2. Acid Value

The acid value is a measure of the amount of acidic substances in fuel (Hanis Zakaria, 2014). Acid value is an important indicator to determine the oxidation in oil, this value is the number of mg of potassium hydroxide required to neutralize the free acid in 1 g of the substance. In a good quality fuel, the acid value should be < 0.1 or categorized as very low. If the acid value in a biodiesel increases, it should be taken as an indicator that the biodiesel is oxidizing therefore degrading one of its properties. This may lead to corrosion in the tank or sludge formation (Sharma & Jain, 2015). The increase of acid value depends on its storage temperature, higher storage temperature will lead to higher result of acid value (Hanis Zakaria, 2014).

In Zakaria’s study, B5, B10, B15, B25, B35 and B45 biodiesel blended from crude palm oil (CPO) were used. The samples were stored in transparent glass bottles in three conditions: low temperature (0°C–5°C), ambient temperature (26°C-32°C) and high temperature (40°C-50°C). These samples were kept for 84 days and they were tested every week using European standard testing procedures. The reason why higher temperature resulted in higher acid value is due to the hydroperoxide that's produced from the oxidative degradation undergoes the complex secondary reactions including a split into more reactive aldehydes, these aldehydes will further oxidize into acids leading to an increase in acid value. On the contrary, lower storage temperature will give the stability to the sample. Higher ratio of diesel fuel also resulted to more stability to the sample.

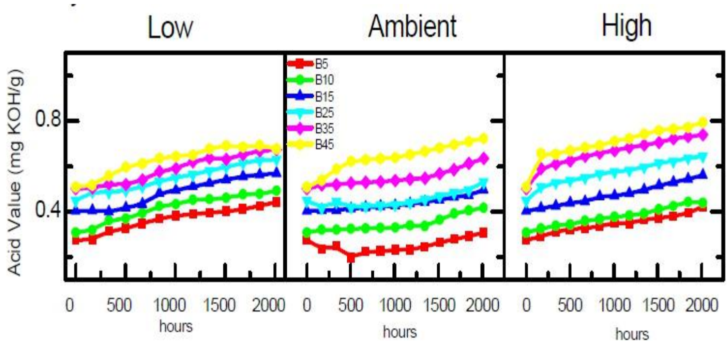


Figure 4- 1 Acid Value of Biodiesel

4.2.3. Density

Pattamaprom in 2012 stored palm oil biodiesels in dark closed containers at 25 – 30 ºC (room temperature) for the period of 6 months, the chemical properties were analyzed monthly. This research took samples from two FAME derivatives which were Palm Stearin and Palm Olein. Palm Olein is a fractionationed palm oil (extracted liquid portion from the solid portion), it is commonly sold as cooking oils. While Palm Stearin is the solid fat portion, it is commonly used to formulate trans-free fats such as margarine and vegetable ghee. The biodiesels used in this research were pure biodiesel, also known as B100.

Pattamaprom et al. previously found that peroxide values increased as the storage time got longer, and the research found that the densities of biodiesels also increased with storage time by the same pattern as the peroxide values. It was thought that the increase is due to the increase in molecular interaction of degraded biodiesels that's caused by the production of peroxides.

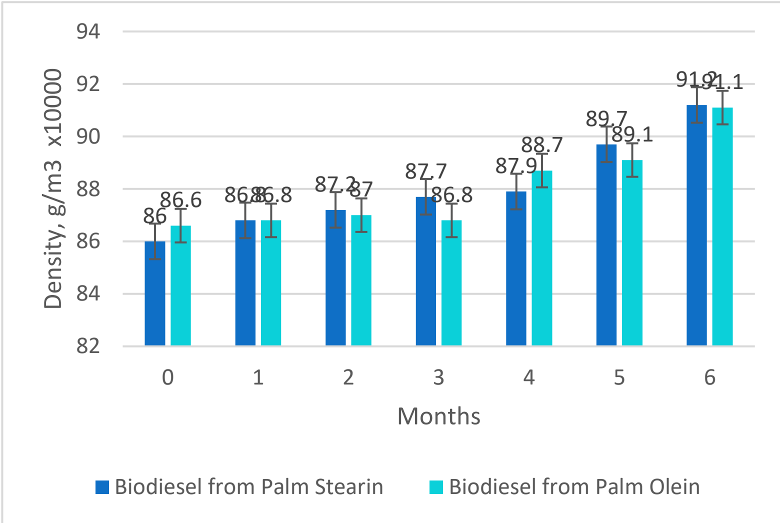


Figure 4- 2 Densities at 15 ^{O}C Of Palm Stearin and Palm Olein Biodiesels Kept for 6 Months in Closed Containers

Zakaria's research also demonstrated the changes in the density of biodiesel blends during storage time. According to Zakaria, fuel density generally increases with increasing molecular weight of the fuel molecules.

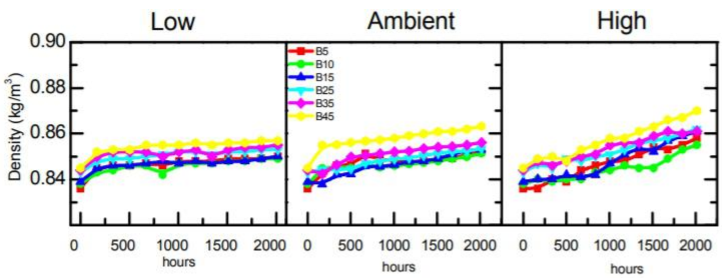


Figure 4- 3. Density Change of Stored Biodiesel

As seen in the figure above, the increase in the density of B45 biodiesel blend was more prominent than the other biodiesel blends due to the presence of saturated fatty acid percentages present in the blend. More biodiesel percentage means that the fuel contain shorter chain hydrocarbons, and more saturated fatty acid makes it more prone to be crystallized; thus reducing the volume and increasing the density of the blend (Hanis Zakaria, 2014).

4.2.4. Kinematic Viscosity

In the year 2020, Berrios et al. did a research on B5 and B20 FAME biodiesel storage stability. The samples of B5 and B20 biodiesel were stored in glass bottles and metal containers, all were placed in thermostatized cupboards at temperatures of 15ºC and 45ºC. The samples were stored with the absence of light for 6 months and 20 mL were extracted every 15 days for testing, the kinematic viscosity of the samples was determined in accordance with ISO 3104.

After 6 months of storage, it was found the viscosity of the samples increased during storage time. The increase of the kinematic viscosity was mainly due to the formation of oxidation and formation of acids in the samples. Heat and storage material influenced the breakage of the double bond, then unsaturated fatty acids reacted to form dimers (a molecule composed of two identical subunits or monomers linked together) and polymers. After being tested, it was discovered that the viscosity of the samples increased higher at low temperatures due to the higher oxygen solubilization in metal presence, it was concluded that the oxygen influence was lower in metal absence than in metal presence. This supports prior research that stated metal storage increases the rate of kinematic viscosity, this fact also exhibits the catalytic effect of the metal.

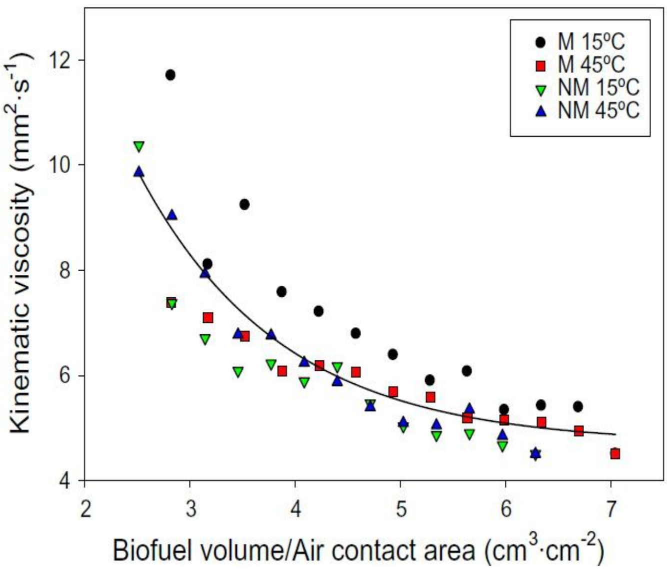


Figure 4- 4 Influence of Biofuel Volume/Air Contact Area

On this experiment, it was found that temperature had a strong impact in degradation since degradation increased at higher temperatures. Thus, Berrios et al. recommends the use of underground storage tanks.

Before Berrios, in 2014, Zakaria et al. also monitored the change of kinematic viscosity during storage time. According to Zakaria's research to various percentages of biodiesel blends, storage in low temperature gives kinematic viscosity more stability. When stored in a high storage temperature, the graph projected that the kinematic viscosity increased as storage time progresses. Higher viscosity may lead to severe effects on engine performance (Hanis Zakaria, 2014). The figure of the changes in kinematic viscosity can be seen below.

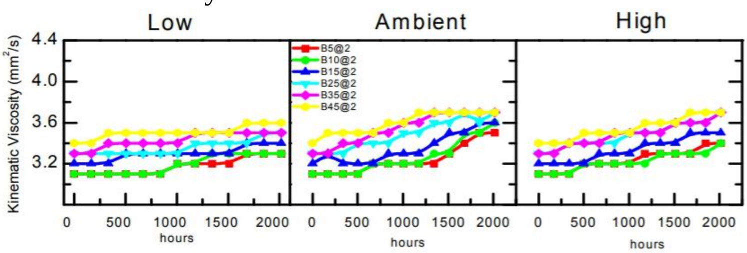


Figure 4- 5. Kinematic Viscosity Changes in Storage Time

4.2.5. Heating Value/Calorific Value

Heating value of the biodiesels is also analyzed by Pattamaprom et al. The analyzed variable in their research is the higher heating value, also commonly known as gross calorific value. The higher heating value is defined as the amount of heat released by a specified quantity (at its initial temperature) once it is combusted and the products have returned to its initial temperature, it takes into account the latent heat of vaporization of water in the combustion products. The higher heating value (HHV = MJ/kg) was recorded by the 1261 Isoperibol Bomb Calorimeter according to ASTM D 2015.

Heating values are higher for fuel with longer chain and higher degree of saturation (Dermibas, Fuel Properties and the Calculation of HHV of Vegetable Oil, 1998). From the experiment, it was found that even though palm stearin contains higher degree of saturation, the heating value of palm olein biodiesel was higher than the one from palm stearin biodiesel. This is due to the major component of palm stearin contains molecules with 16 carbon atoms (C16), while palm olein contains molecules with 18 carbon atoms (C18). When the biodiesels were stored for 6 months, their heating values decreased steadily along with their degradation into shorter peroxide compounds. This caused a reduction in carbon and hydrogen percentages in the fuel molecules, therefore lowering the heating values.

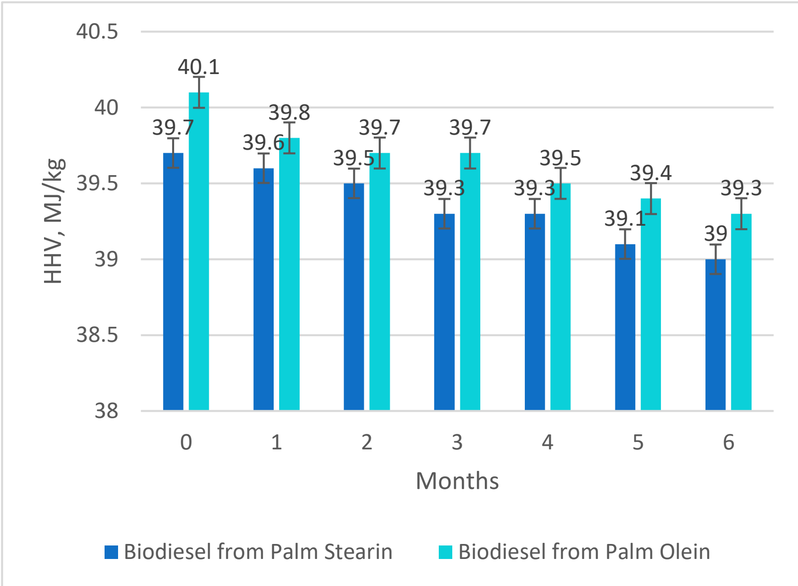


Figure 4- 6 High Heating Value (HHV) of Palm Stearin and Palm Olein Biodiesels Kept for 6 Months in Closed Containers

4.2.6. Water Content

Zakaria's study also monitored the increase of water content of biodiesel blends during storage. In this study, B5, B10, B15, B25, B35 and B45 biodiesel blends from crude palm oil (CPO) were used. The samples were stored in transparent glass bottles in three conditions: low temperature (0°C–5°C), ambient temperature (26°C-32°C) and high temperature (40°C-50°C). These samples were kept for 84 days and they were tested every week using European standard testing procedures.

According to the experiment, it was found that the highest increase of water content happened during storage in the highest temperature. Other than temperature, sample with the most biodiesel ratio also showed the highest increase of water content compared to the other ones. The water content increase of biodiesel blends was 56% in blends stored in low temperature, 89% in blends stored in ambient temperature, and 139% in blends stored in high temperatures.

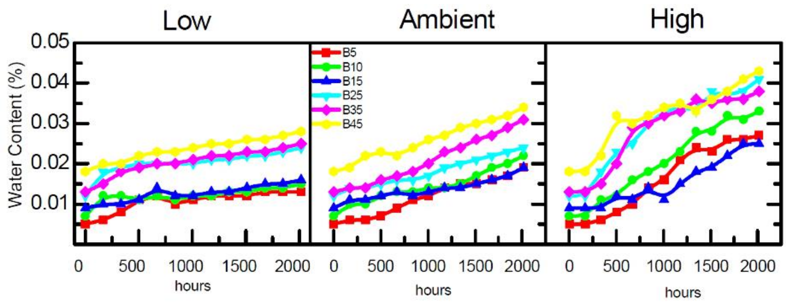


Figure 4- 7 Water Content in Stored Biodiesel Blends (Source: Zakaria, 2014)

Komariah et al. did an experiment to monitor the water content of biodiesel blends during storage, this is also to measure the fuel stability of the blends. In this research, blends of B0 pure diesel oil, B20, and B100 FAME biodiesel were prepared to be stored in three different storage materials; metal (stainless steel) and polymerics (high-density polyethylene (HDPE) and glass). The biodiesel blends that were used was palm oil based that met standards of ASTM D613 and SNI 04-7182-2006. The initial properties of the samples were as follow:

Table 4- 3 Initial Properties of the Fuel Samples

Property	Units	B0 (Pure Diesel Oil)	B20	B100
Kinematic Viscosity	mm2/s	2.798	3.112	5.142
Density	g/mL	0.825	0.831	0.868
Water Content	mg/kg	83.300	261.200	1644.660

The methods for fuel properties analysis are summarized in the following table:

Table 4- 4 Methods for Fuel Properties Analysis

Property	Units	Method
Kinematic Viscosity	cSt (mm2/s)	ASTM D445

Density	kg/m3	ASTM D941
Water content	mg/kg	Karl Fischer

All three different tanks where the blends were stored were placed aboveground in a wide room with high ceiling, they were exposed to normal room temperature without any additional heating methods. These samples were stored for twelve weeks and monitored weekly to observe the degradation of the biodiesel blends. In the B100 sample, the greatest water content change during storage time occurred in the glass tank. However, in the case of the B20 sample, the highest water content change occurred in the HDPE tank. One of the factors that affected the water content change in the samples was the humidity in the storage area. In this research, the relative humidity around the location was 65% to 90%.

According to the experiment results, the B100 properties degraded the most during storage in glass tank. As of the B20, the blend degraded the most in the HDPE tank with a degradation rate of 11.6%. This supports the theory that biodiesel cannot be stored for long periods of time due to its hygroscopic nature. A substance that's hygroscopic tends to attract water due to its polar molecular structure at one end. A study discovered that biodiesel absorbed 1.000 – 1.700 ppm (0.10% to 0.17%) of moisture at temperature of 4°C to 35°C, the number was 15 to 25 times higher compared to regular diesel fuel in the same temperature range (He, Van Gerpen, Thompson, & Routt, 2007). The hygroscopic nature of the biofuel will support water absorption; therefore, if the biodiesel was stored for long periods of time, accumulation of the water will form precipitates at the bottom of the storage tanks and then form sludge (Komariah, Marwani, Aprisah, & Rosa, 2017).

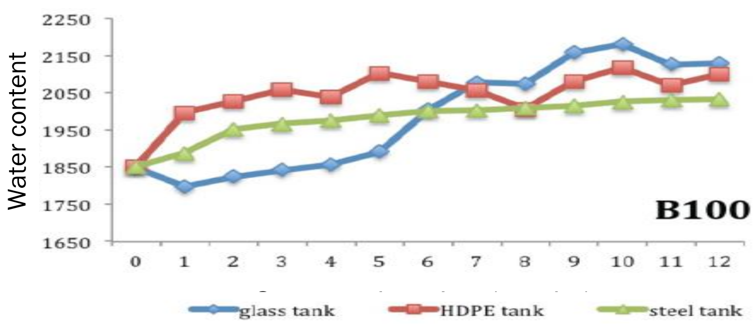


Figure 4- 8 Water Content Changes in Biodiesel (B100) Blend

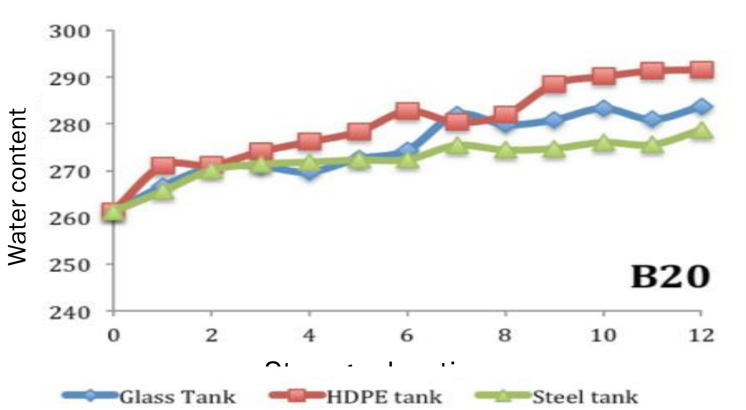


Figure 4- 9 Water Content Changes in Biodiesel (B20) Blend

4.3. Impacts of Biodiesel Properties Degradation

4.3.1. Degradation of Engine Performance

Pattamaprom stored palm oil biodiesels in dark closed containers at 25 – 30 ^oC (room temperature) for the period of 6 months and tested the engine performance using the stored biodiesel blends afterwards. This experiment tested the comparison of engine performance using fresh and stored biodiesel blends. The determining factors of this experiment were the brake power (*P*), brake fuel conversion efficiency (*ηbf*), and brake specific fuel consumption (*bsfc*) compared with using pure petroleum diesel. *Bfsc* is calculated to indicate the fuel consumption rate per unit power, whereas the *ηbf* is calculated to measure the efficiency in converting the heating value of fuel into engine power.

$$bsfc = \frac{fuel\ mass\ flow\ rate\ (m_f)}{P}$$

When calculating the ṁ in the brake fuel conversion efficiency (η_{bf}), ṁ represents the mass flow rate of the injected fuel.

$$\eta_{bf} = \frac{P}{\dot{m}_f\ x\ Fuel\ Heating\ Value}$$

The engine test was done with a 4-cylinder, 4-stroke, direct injection Nissan BD-30 diesel engine. The tests were performed with engine speeds ranging from 1800 to 4000 rpm at full load, and the maximum power of the engine was found at the speed of 3600 rpm. The specifications of the engine were as follow:

Table 4- 5 Specifications of Nissan BD-30

Engine model	Nissan BD-30
Engine type	4-cylinder, 4-stroke, in-line
Displaced volume	2953 cc
Bore	96 mm
Stroke	102 mm
Compression ratio	18.5 : 1
Maximum power	70.8 kW (95 HP)

Other than the mentioned parameters, the biodiesel samples were also tested for exhaust emissions NOx.

a. Brake power (P)

In engine braking, the engine will act as a compressor. This action produces the required braking power. There are two ways to generate the braking power; by reducing the volumetric efficiency or increasing the pressure difference across the cylinder (Saggam, Edke, Alagarsamy, & Kohli, 2019). Different fuel types produce different effects on brake power in a diesel engine, the determining factors are; heating value, density, and viscosity. In terms of brake power, higher heating value and higher density in fuel will provide higher brake power. The results of average brake power using stored biodiesels from Pattamaprom's experiment can be observed in the following figure.

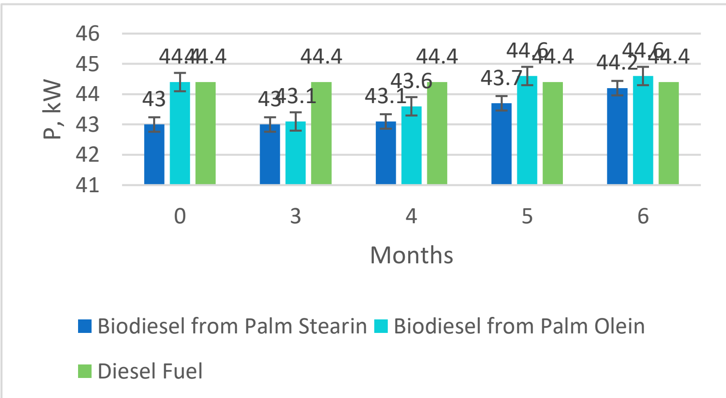


Figure 4- 10 Average Brake Power of a Diesel Engine using Palm Stearin and Palm Olein Biodiesels

When tested with regular diesel fuel within 0 – 6 months of storage time, the average brake power stayed steady at 44.4 kW, while the results of the average brake power using palm stearin and palm olein biodiesel vary within 0 – 6 months of storage time. When being stored for a longer period of time, the brake power of biodiesels gradually increased regardless of their heating value decreasing. Referring to Figure 4-2 where the density of stored biodiesels was observed, we can conclude that the increase in density dominated other effects such as the decreasing of heating value.

b. Brake specific fuel consumption ($bsfc$)

Brake specific fuel consumption measures the fuel efficiency of a prime mover that burns fuel and produces rotational or shaft power. The *bsfc* is used to compare the efficiency of internal combustion engines with a shaft output. Just as brake power, the *bsfc* also depends on the heating value of the used duel.

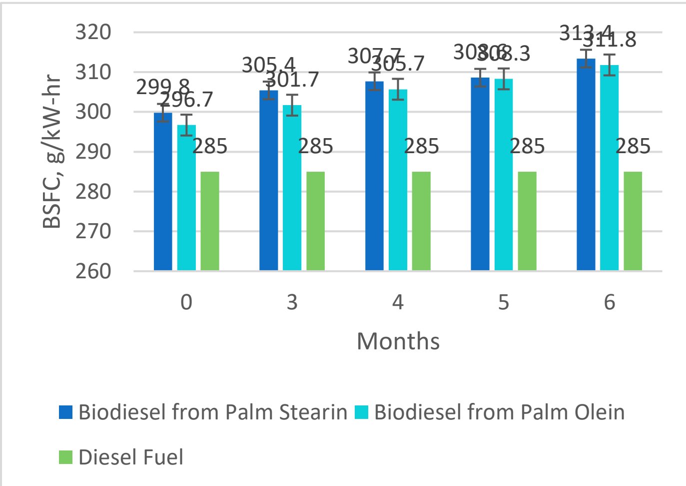


Figure 4- 11 Average Brake Specific Fuel Consumption (BSFC) of Diesel Engine using Palm Stearin and Palm Olein Biodiesels

Due to the higher heating value of the pure diesel fuel, the fuel consumption rates were higher for the biodiesel blends. Based on the chart, we can observe that to produce the same amount of power, a larger volume of biodiesels would be needed because the biodiesels consumed 4 – 5% more fuel than the pure diesel fuel. This also shows that the inefficiency and degradation of quality of biodiesels occur when they are stored for a long period of time.

c. Brake fuel conversion efficiency (η_{bf})

η_{bf} is utilized to measure the prime mover's ability to convert chemical energy that's contained in a fuel into mechanical power. The result of η_{bf} tests all through storage time can be seen in the following graph.

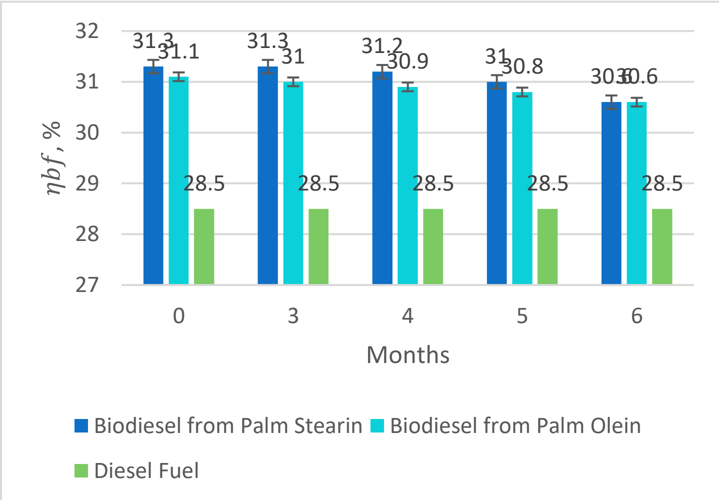


Figure 4- 12 Average Brake Fuel Conversion Efficiency of Diesel Fuel and Stored Biodiesels

The graph shows that both palm stearin and palm olein biodiesels have higher fuel conversion efficiency by 11% compared to that of the petroleum diesel's, and it is shown that the degradation of η_{bf} only changed slightly over the course of 6 months.

4.3.2. Increase of Emissions

a. CO Emission

A study by Khalid, et al. stored various blends of FAME biodiesel (B5, B10, B15, B20, B25, B30, B35, and B40) in storage conditions with low temperature (6 ^{0}c), ambient temperature (25 ^{0}c), and high temperature (30 ^{0}c). These samples were tested every week for a period of eight weeks. Gradually for a period of eight weeks, increasing storage duration increased the biodiesel density, especially with the highest blend of 45% biodiesel. The experimental analysis of CO emissions was done through the burner system. The results of the emission test after the storage duration is as in the following figure.

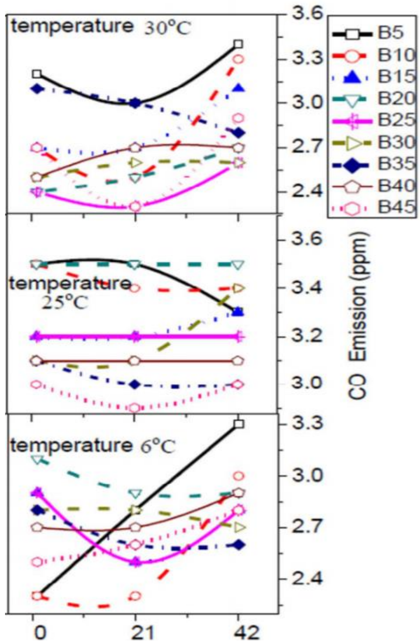


Figure 4- 13 . Effect of Storage Duration on CO Emission

The experiment discovered that the amount of CO emission tends to gradually increase in high temperature, stayed mostly stable on ambient temperature, and varies on low temperature. According to the figure, the high blend ratio of B45 showed relatively small increase in CO emissions despite having higher amount of biodiesel. This is thought to be due to the higher oxygenated fuel that's contained in B45 biodiesel blend, therefore the combustion is more thorough, and the CO emissions got more advanced for the lower blending ratio.

b. NOx Exhaust Emission

Pattamaprom also studied NOx exhaust emission using stored biodiesel blends. NOx is classified as either nitrogen monoxide (NO) and nitrogen dioxide (NO_2). These gasses are produced through exhaust emissions of engines, they could cause acid rain, over-fertilization of lakes and soil, and ozone formation in the lower atmosphere (The International Council on Combustion Engines, 2008). The increase of NOx emission amount occurs during combustion with an excessive amount of oxygen at high temperature.

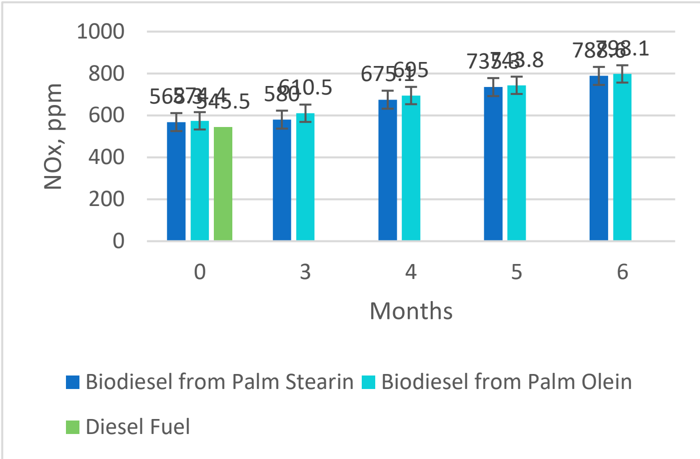


Figure 4- 14 Concentration of NOx Emitted from Diesel Engine

According to the figure, it can be seen that as the biodiesels degraded, they increase in NOx concentration during combustion. This is due to the high degree of oxidation that happens to the stored the biodiesels.

4.3.3. Corrosion on Metallic Materials in Storage Tanks

Although biodiesel has some technical advantages over regular diesel, it tends to be more corrosive than pure diesel fuel. The presence of free water and free fatty acids produced by incomplete transesterification process in the biodiesel supports the corrosion that happens. Supporting the previous statements, the hygroscopic nature of biodiesel also encourages the water absorption into the blend. The corrosion reactions between a non-noble metal and water are shown below.

$$M \longrightarrow M^{n+} + ne^{-}$$ Anodic reaction

$$O_2 + 2H_2O + 4e^{-} \longrightarrow 4OH^{-}$$ Cathodic reactions

$$2H_2O + 2e^{-} \longrightarrow H_2 + 2OH^{-}$$

Figure 4- 15 Corrosion Reactions Between a Non-Noble Metal and Water

The water content in the biodiesel blend will gradually condense on the metal surface, this condensation will eventually cause corrosion and deterioration of the storage material. The previous figure showed the reactions that happens during that case. The oxidation process of biodiesel blends increases the blends' corrosive and degradation properties. It has been found that copper, zinc, aluminum, brass, and bronze are not compatible with his fuel (Zuleta, Libia, Rios, & Calderon, 2012).

A few researches found that corrosion products and metal compounds generated in biodiesel are exposed to metals at different storage temperatures. One recent study found pitting corrosion in a copper storage tank exposed to biodiesel at 80 ^{0}c (Fazal, Haseeb, & Masjuki, 2010). Pitting corrosion is a form of metal deterioration, it shows small holes in the surface of the material. These holes cause loss of thickness to the material affected. When happening in a large scale, this type of corrosion will eventually cause breach in the tank (Glister, 2017).

Figure 4- 16 Pitting Corrosion Inside a Storage Tank (Source: abfad.co.uk)

The forming of the pits depends on the relative concentrations of positive and negative ions. The pit corrosions found on the surface of the copper storage tank were formed by the substitution of oxygen ions from Cu_2O through the destruction of the CuO layer. Another study related to the corrosion that happens in biodiesel storage tanks found that an oxide layer of $CuCO_3$ was formed on the surface of copper tank containing B100 biodiesel. While at a temperature of 60 ^{0}C, the layer that was formed on the surface of the tank was CuO or copper oxide, the forming of this layer was due to an increased quantity of dissolved oxygen in the biodiesel. Among things that increase the corrosivity of biodiesel are exposure to different metals, presence of dissolved oxygen, changes in acid values, increase of water content, and presence of other oxidation products (Zuleta, Libia, Rios, & Calderon, 2012)

4.4. Methods to Improve Stored Biodiesel Properties

4.4.1. Blending Biodiesel with Additives

The degradation of biodiesel's fuel properties such as lower heating value, higher viscosity, higher density, and poor cold weather flow properties such as cloud point, pour point, and filter clogging limits the usage of biodiesel in industries. The degradation of biodiesel's properties has many impacts including poor atomization of fuel, injector clogging, and incomplete combustion (Madiwale, Bhojwani, & Karthikeyan, 2017).

The effect of degradation in the fuel properties may be minimized through the utilization of additives that can be blended in the fuel. Additives will help enhance the fuel properties of the biodiesel and increase the biodiesel's performance and even reduce exhaust emissions from the engine. There are different additives for biodiesel, the selection is based on the different properties of the additives itself such as flash point, viscosity, density, and calorific value (Silitonga, et al., 2013). Table 4-6 below shows the different properties of biodiesel additives:

Table 4- 6 Properties of Biodiesel Additives
Source: (Madiwale, Bhojwani, & Karthikeyan, 2017)

Additive	Kinematic Viscosity at 40 ºC (cSt)	Density (kg/m^3)	Calorific Value (kJ/g)	Cetane Number	Flash Point (ºC)
Ethanol	1.14 (measured at 20 ºC)	791 (measured at 20 ºC)	27.33	5-8	-
n-Butanol	3.00	812	34.33	25	35
Diethyl Ether	0.22	712	33.89	25	-

In 2013, researchers in Malaysia tested and observed the properties of biodiesel when blended with additives. The study was focused on improving the quality palm biodiesel (20%) with diesel fuel (80%) with the assistance of additives. The additives were used with a ratio of 5% replacing the biodiesel, so the blends were composed of 80% diesel, 15% palm biodiesel and 5% additive. The blend containing ethanol was referenced as B15-E, the blend containing n-butanol was referenced as B15-B and the blend containing diethyl ether was referenced as B15-D respectively (Imtenan, et al., 2014). The result and comparison of B20 blend and B20 blend with additives is as the following table:

Table 4- 7 Properties of B20 and B20 Blends with Additives

	B20	B15-E	B15-B	B15-D
Kinematic Viscosity at 40 °C (mm^2/sec)	3.62	3.23	3.29	3.27
Density (kg/m^3)	837	833	833	832
Calorific Value (kJ/g)	43.71	43.08	43.43	43.41
Cetane Number	48	46	47	52
Flash Point °C	93.5	84.5	85.5	81.5

The test and comparison revealed that the tested properties did indeed decrease through the addition of additives of Ethanol, n-Butanol, and Diethyl Ether. Among the additives added, the one that showed the highest rate of improvement is B15-D due to the decrease of kinematic viscosity and density, accompanied with a high calorific value. The biodiesel blend with Ethanol (B15-E) had the lowest calorific value.

4.4.2. Modification of Biodiesel Blend Storage Conditions

Based on the previous researches mentioned, it is known that the degradation of biodiesel blends tends to proceed at a more rapid speed when being stored in spaces with higher temperatures. To counteract this issue, the stability of biodiesel blends can be increased by modifying the storage conditions. A research concluded that the storage temperature of pure biodiesel blends should be between 7 – 10 °C to protect them from oxidation. When biodiesel is being stored underground extreme cold weather, the storage temperature needs to be optimized to avoid the formation of crystals that will lead to creation precipitates and sludge on the blend (Karavalakis & Stournas, 2010)

It should be minded that certain precautions need to be taken if the biodiesel blend is planned to be stored for a period of more than 6 months. For longer storage durations, pure biodiesel and its blends require appropriate antioxidants to increase biodiesel stability and lower the rate of degradation. Since biodiesel is hygroscopic, it tends to attract water due to its polar molecular structure at one end. A study discovered that biodiesel absorbed 1.000 – 1.700 ppm (0.10% to 0.17%) of moisture at temperature of 4°C to 35°C, the number was 15 to 25 times higher compared to regular diesel fuel in the same temperature range (He, Van Gerpen, Thompson, & Routt, 2007). Therefore, to avoid contamination from water that may lead to the growth of bacteria in the fuel, biocides is recommended to be added to the blends as to prevent water contamination in the fuel. Metals that are proven to accelerate the degradation process of biodiesel blends and form higher levels of sediment are iron, rust, copper, bras, bronze, lead, tin, and zinc (U.S. Department of Energy, 2016) The recommended storage container materials for the biodiesel blends are aluminum steel, polypropylene or fluorinated polyethylene, and teflon. Table 4-8 explains regarding different materials and their compatibility with FAME biodiesel blends. It is advised that tanks should be thoroughly cleaned to minimize the presence of water impurities prior to for use biodiesel storage purposes (Rashed, Masjuki, Kalam, & Rashedul, 2015).

Table 4- 8. Elastomer Compatibility with Biodiesel

Material	Compatibility with FAME
Buna-N	Not recommended
Butadiene	Not recommended
Butyl	Mild effect
Chemraz	Satistactory
Ethylene propylene (EPDM)	Moderate effect
Fluorocarbon	Satisfactory
Fluorosilicon	Mild effect; increase swelling
Fluorosilicone	Mild effect
Hifluor	Satisfactory
Hypalon	Not recommended
Natural rubber	Not recommended
Neoprene	Not recommended
Neoprene/Choloroprene	Not recommended
Nitrile	Not recommended
Nitrile, high aceto-nitrile	Mild effect with B20 and above, swilling and break strength affected
Nitrile, hydrogenated	Not recommended
Nitrile, peroxide-cured	Mild effect with B20 and above, swelling and break strength affected
Nordel	Moderate to severe effect
Nylon	Satisfactory
Perfluoroelastomer	Satisfactory
Polypropylene	Moderate effect; increased swelling, hardness reduced
Polyurethane	Mild effect; increase swelling
Styrene-butadiene	Not recommended
Teflon	Satisfactory
Viton	Satisfactory; type of cure affects compatibility with oxidized biodiesel see specific types of Viton below
Viton A-401C	Satisfactory with fresh RME; not recommended for oxidized blends B20 and above

Viton F-605C	Satisfactory with fresh RME; not recommended for oxidized blends B20 and above
Viton GBL-S	Satisfactory with RME and with all oxidized blends
Viton GF-S	Satisfactory with RME and with all oxidized blends
Wil-Flex	Moderate to severe effect

4.4.3. Winterization

Winterization is a biodiesel treatment method that removes saturated fatty acid contents in a biodiesel blend, this is done to improve the blend's cold flow properties. The winterization method is commonly studied for vegetable oil applications. Previous researches found that biodiesels sourced from different oil sources will require different winterization processes and temperatures to achieve specific saturated fatty acid reductions because the oils have different initial saturated fatty acid constituents (Zhong, et al., 2016).

In this experiment, Zhong, et al., carried out the experiments in a refrigerator that's installed with programmable controller. These samples were put in a refrigerator for 24 hours with varying temperatures; starting with the winterization temperature (T_w) of the oil, proceeding with lower temperatures, and finally being held at T_w for 16 hours. After the winterization process was finished, the biodiesel blend was separated into the liquid phase and crystallized phase at the final winterization temperature by filtration through a Millipore glass fiber filter paper at a pressure drop of 20 – 40 kPa. Zhong's research found that a slow to moderate cooling rate seemed to be favorable to separate between the liquid and crystals compared to a fast cooling rate.

4.5. Analysis of Journal Reviews

Through the various past experiments and researches that have been mentioned, some measures can be taken to slower the oxidation and degradation rate of biodiesel blends. Through Zakaria's study in 2014, oxidation and degradation of biodiesel blends' properties can be avoided by not storing the blend in a glass container put in a storage room that has access to sunlight. This is due to the transparency of glass as storage, it tends to absorb more sunlight that could lead to the increase of acid value. Therefore, the biodiesel storage should also be put away from the exposure of sunlight. Other than exposure of sunlight, it is better for the biodiesel blend when its storage material is able to inhibit the increase of storage temperature and contact with humid air, as the hygroscopic nature of biodiesel will absorb water when it is exposed to it. Zakaria's study also confirmed that high temperature does indeed lead to higher water content increase, therefore Indonesia might be prone to biodiesel degradation due to our ambient temperature being higher (23 – 33 ^{0}C) than those of European countries'.

The most prominent discovery through Zakaria's research is that the results suggested that biodiesel stored in high temperature is the main factor affecting the degradation rate in increasing the percentage of biodiesel. And through Komariah's research in 2017 regarding the storage material for biodiesel blend, the author used a biodiesel blend that was produced one year prior to the research. Therefore, the initial water content of the biodiesel at the beginning of the research might not be accurate since it is highly probable that during the one year of storage, the blend has accumulated water.

The major factor affecting the change of properties in B30 biodiesel during storage is oxidation. Uncontrollable oxidation, also known as self-oxidation or autoxidation, is inevitable in the event of storing a fuel, it gets increasingly worse in biodiesel since the fuel is blended with FAME. The chemical changes that occur in the degradation process during oxidation isn't very well known yet, therefore scientists haven't discovered a way to predict the ideal storage duration for biodiesel before it gets degraded and are still on the process of finding alternatives to avoid this event. The stability of fuel during storage highly depend on their chemical composition. The presence of heteroatoms of oxygen, sulfur, nitrogen, and traces of metal ions help catalyze the oxidation process. Storage conditions such as temperature, access of light, and possibility to absorb oxygen from the outside environment also affect the oxidation process in fuel (Czarnocka, Matuszewska, & Malgorzata, 2014). Oxidative stability is an important factor in biodiesel production, because the change in fuel stability may affect the performance during compression and ignition in engines. Due to this phenomenon, international regulatory agencies, biodiesel producers, engine manufacturing companies, research centers, and universities around the world are working together to solve this issue.

Oxidation rate could be slowed down by selecting storage materials that will have resistance towards oxidation, degradation, and corrosion. Using glass tank is found to be better among other polymeric materials to store biodiesel blends, the tanks could be modified to be set in a dark surface to protect the blend from harsh light exposure. The biggest disadvantage is that glass tanks are less versatile and less robust for industrial purposes. It is recommended to add additives in biodiesel blends if it were to be stored for more than a few months, and the oxidation stability is recommended to be measured monthly (U.S. Department of Energy, 2016).

According to Madiwale et al. (2017), poor cold weather flow properties of biodiesel can cause filter clogging. When the fuel clogs, it can eventually become so thick that it will not be able to be pumped from the fuel tank to the engine (U.S. Department of Energy, 2016). This causes a problem because HSD is commonly used in ships that do not require the presence of fuel heaters, therefore the gel-like form of B30 cannot be dissolved through heat before using. Moreover, when a ship sails to international waters during winter, the clogging could be a serious issue during voyage. In addition to clogging, biodiesel blends are more susceptible to microbial contamination. To deal with this problem, fuel storage tank housekeeping and monitoring have to be scheduled more often and water contact with the biodiesel blend needs to be minimized. Tanks are recommended to undergo microbial contamination test every 6 months (U.S. Department of Energy, 2016). Biodiesel that is bought for storing more than a few months should be stabilized with antioxidants to reduce the amount of oxidation and degradation to the fuel.

Blending techniques of biodiesel also play a part in determining the fuel's quality. B100 biodiesel has a specific gravity of 0.88, heavier than that of pure diesel fuel's. When not being blended properly, pure biodiesel may sink into the bottom of tanks. Overtime, the amount of pure biodiesel at the bottom of the tank may lead to filter plugging and formation of gel layer. Moreover, the short term effect biodiesel and pure diesel fuel fractionation is the solvent properties of pure biodiesel may start to dissolve sediments at the bottom of the tank, causing further filter clogging in warm conditions (U.S. Department of Energy, 2016).

There are many problems that are being faced by B30 biodiesel blends, but there isn't enough literature yet to concisely formulate the problems since the B30 blend has only been commercial for 6 months. Future researches are expected to look more into the long-term storage stability for B30 and higher biodiesel blends.

4.6. Design of Integrated Homogenizer Blending System

The use of an integrated homogenizer system on board a vessel to restore B30 fuel quality is initially proposed by PT Turbotech Indonesia. The three main components that make up this system are; a homogenizer, a separator, and gear pumps. These components are placed after the day tank so that the fuel that goes into the engine is the restored B30 biodiesel. For the prototype, the fuel that has been homogenized will be stored in another day tank.

4.6.1. Instruments in the Integrated Homogenizer System

a. Homogenizer

According to Aquametro Oil & Marine, homogenizer is a dynamic milling machine that is used in the fuel system on board ships. The purpose of the homogenizer is to achieve completely homogenized fuel. Homogenizers are designed to improve the fuel quality to improve its combustion process and reduce the amount of maintenance needed. Homogenizers are also aimed to reduce sludge in the case of fuel incompatibility and increases the amount of burnable fuel in case of bad fuel quality. The main benefits of the utilization of homogenizer onboard vessels are;

1. better fuel quality for combustion,
2. blend fuel improvement,
3. prevent sludge in case of fuel incompatibility,
4. increases amount of burnable fuel,
5. less wear and tear on engine components,
6. optimization of combustion process,
7. fuel treatment/conditioning,
8. less clogged filters (Aquametro OIl & Marine, 2018).

The homogenizer consists of specially constructed rotor-stator milling gear, the fast-spinning inner rotor with a stator as a stationary outer sheath homogenizes samples through mechanical tearing, shear fluid forces, and cavitation to improve the fuel quality as well as to allow sludge treatment on board of sea-going vessels.

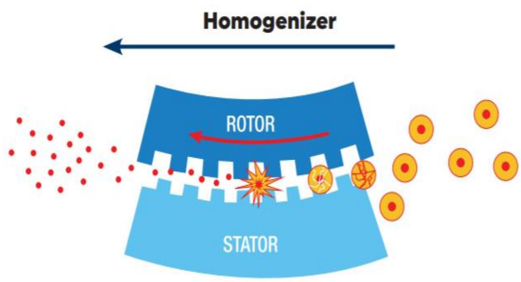


Figure 4- 17 Rotor-Stator Principle in Homogenizers

The rotor runs in the stator with high revolution. The gap between the stator and rotor will be very small therefore it will be possible for the equipment to reduce the size of the fuel oil droplets and produce a stable fuel-water emulsion. The specifications of the homogenizer used can be seen on the table below:

Table 4- 9 Specifications of SIT Homogenizer

Brand	**:**	S.I.T
Type	:	CD92^{TM} 140-M-MD

Flow capacity	:	< 120 m^3/h (IFO 380 @ 50 °C)
Design temperature	:	< 140 °C (fuel temperature)
Design pressure	:	< 12.0 bar (fuel pressure)
Electric drive	:	11.0/12.5 kW – 400/440 V 50/60 Hz

According to the manufacturer, this specific homogenizer balances the fuel's structure to particle sizes below 3 microns and it is said to provide the following benefits:

1. Fuel oil sludge reduction
2. Combustion improvement
3. Water-in-diesel emulsification
4. NOx reduction
5. Waste oil regeneration

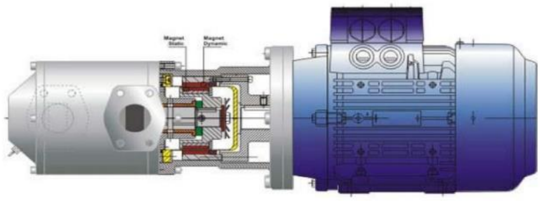


Figure 4- 18 SIT Homogenizer (2D) (Source: SIT Homogenizer Product Guide)

Figure 4- 19 SIT Homogenizer CD92TM 140-M-MD

Furthermore, S.I.T CD92™ Homogenizers already fulfill the International Maritime Organization (IMO) and International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) environmental requirements. The general piping and instrumentation diagram (P&ID) of the experiment scheme can be seen in the figure following up to this.

b. Separator

A separator in this case will operate as a purifier and clarifier. The purifying process will provide continuous purification of fuel oil from solid particles and water while the clarification process will provide continuous clarification of fuel oil from solid particles. The separator used has the following specifications:

Table 4- 10 Specification of Alfa Laval Separator

Brand	**:**	Alva Laval
Type	:	MAB 103B-24
Hydraulic capacity	:	Maximum 1.4m^3/h
Process capacity	:	Maximum oil flow at the maximum permissible oil density 991 kg/m^3 at 15 ^{o}C
Max. density of feed	:	991 kg/m^3
Flash point temp. of oil	:	Minimum 60 ^{o}C
Feed temperature	:	Minimum 0 ^{o}C Maximum +100 ^{o}C
Motor	:	4-pole 0.75 kW standard motor, 50 or 60 Hz, 3-phase, Direct on-line start

Figure 4- 20 Alfa Laval Separator MAB 103B-24

c. Gear Pump

Gear pump is a type of positive displacement pump. A gear pump moves a fluid by repeatedly enclosing a fixed volume using interlocking cogs or gears, transferring the fluid mechanically using a cyclic pumping action. Gear pumps are used to transfer high viscosity fluids such as fuels or lubricating oils. The specifications of the gear pumps chosen are as follow;

Table 4- 11 Specification of KCB Series Gear Pump

Brand	=	KCB Series
Type	=	YCB0.6-0.6, Y90S-6
Capacity	=	0.6 m^3/h
Discharge pressure	=	0.6 MPa
RPM	=	910 RPM
Power	=	0.75 kW | 1.005 HP

4.6.2. Piping and Instrumentation Diagram

In designing the integrated homogenizer blending system, the first step is to create the piping and instrumentation diagram (P&ID) of the system so that the working principle of the system could be understood. The system is centered around a homogenizer, and assisted by two gear pumps and a separator. The system's working principle will be explained below.

1. B30 will be stored in a day tank under ambient condition. The designated storage time for the B30 biodiesel sample will be for a month.
2. After the storage time has been complied, a sample of the B30 will be taken through the sampling valve for testing of its degraded properties.
3. Then the B30 will go through the system. The B30 will be pumped from the tank into the gear pump, where it will be forwarded to the homogenizer.
4. The B30 will be re-homogenized through the homogenizer with its milling gear. The objective of using the homogenizer is to re-blend the B30 which properties are assumed to be degraded due to the storage time it has went on.
5. Another sample of the B30 will be taken out after going through the homogenizer for properties testing through the sampling valve.
6. Then the remaining B30 biodiesel will be forwarded to the separator, where the sludge will go to the sludge tank and the remaining purified B30 will be forwarded to the final day tank.
7. Samples from the sludge tank as well as the final purified B30 will be taken for properties testing through the sampling valves.

Among the properties that will be tested for the degradation rate are: precipitation, acid value, density, kinematic viscosity, heating value, and water content. Other parameters that will be tested according to the availability of the laboratory are; biodiesel and diesel content after storage time, pH level, total suspended solid (TSS), and FAME chain length. The P&ID of the integrated homogenized blending system is attached in Figure 4-21.

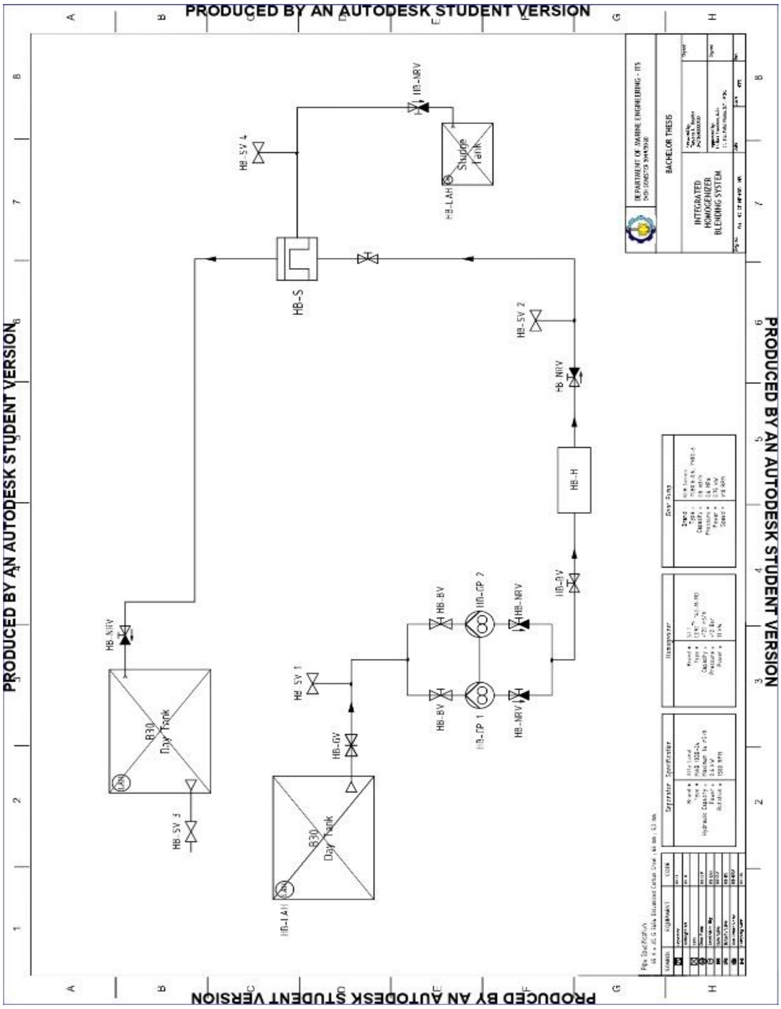


Figure 4- 21. P&ID of Integrated Homogenizer Blending System

4.6.3. Calculation of Integrated Homogenizer System

The technical calculation for the integrated homogenizer system is as the following:

a. Volume of B30 Tanks

The volume of day tanks used in the system are 120 liters or 0.12 m^3

b. Capacity and Pipe Diameter

Q = V/t

Where:

V:	Volume of tank	= 0.12 m^3
t:	Time to fill	= 0.5 hour/30 minutes

Q =	0.12/0,5	
=	0.24	m^3/h
v =	0.1	m/s
So, Q =	A x v	
D =	$(4Q/\pi \cdot V)^{0.5}$	
	0.06	m
	61.8	mm
	2.43	inch

The specification of the selected pipe for the integrated homogenizer system is chosen according to JIS 3454 with carbon steel as the material. This pipe was chosen because it is designated for pressure service and can stand operation at up to 350 °C.

Nominal Diameter:	65A		
Inside diameter (dm):	65.9	mm	2.59 inch
Thickness:	5.2	mm	0.20 inch
Outside diameter:	76.3	mm	3.00 inch
Material:	Carbon steel		
Schedule:	Sch 40		

c. Head Calculation

$$H = H_S + H_P + H_V + total\ head\ loss$$

Where:

- Head Static (H_S)

  Distance from suction at B30 day tank 1 to discharge at B30 day tank 2.

$$H_S = 2\ m$$

- Head Pressure (H_P)

  The working pressure in the suction and discharge side has the same value, so:

$$H_P = \frac{(P_{DISCHARGE} - P_{SUCTION})}{\rho g}$$

$$H_P = 0\ m$$

- Head Velocity (H_V)

  The designed diameter of the suction and discharge pipes are the same. Therefore, according to $Q = VA$ formula, the velocity in the suction and discharge side is the same due to the constant Q.

  $V_{DISCHARGE} = V_{SUCTION}$

  $$H_V = \frac{(Vdischarge^2 - Vsuction^2)}{\rho g}$$

  $H_V = 0\ m$

- Head Losses

  1. Head loss in suction line

     $$Re = \frac{D\ x\ V}{u}$$

     Where:

     $D = Inside\ diameter\ of\ main\ pipe = 65.90\ mm$

     $V = Flow\ velocity = 0.10\ m/s$

     $u = kinematic\ viscocity$

     $$= 0.000002 \frac{m^2}{s}\ at\ 40\ ^OC$$

     $$Re = \frac{(0.0650\ x\ 0.10)}{0.000003} = 2534.62$$

     $$= turbulent\ flow$$

     - Major Loss:

       $$\frac{\lambda\ x\ L\ x\ V^2}{D\ x\ 2g}$$

       Where:

       $\lambda = \frac{0.02 + 0.0005}{D} = 0.0276$

       $L = Length\ of\ suction\ side = 2\ m$

       $V = 0.10\ m/s$

       $D = Pipe\ diameter = 65.90\ mm$

       So,

$$H_{MAJ} = \frac{\lambda \; x \; L \; x \; V^2}{D \; x \; 2g}$$

$$H_{MAJ} = \frac{0.0276 \; x \; 2 \; x \; 0.10^2}{69.50 \; mm \; x \; (2 \; x \; 9.8)}$$

$$H_{MAJ} = 0.000427 \; m$$

- Minor Loss:

No	Types	n	k	n x k
1	Filter or strainer	0	2.5	0
2	Elbow 90	2	0.7	1.4
3	T-joint	1	1.14	1.14
4	Butterfly Valve	2	0.6	1.2
5	Gate Valve	1	0.15	0.15
	Total			3.89

$$Minor \; loss = \frac{(\Sigma nk) \; x \; V^2}{2 \; g}$$

$$Minor \; loss = \frac{(3.89) \; x \; 0.10^2}{2 \; x \; 9.8}$$

$$Minor \; loss = 0.0019847 \; m$$

Total head loss for suction side:

$$= Major \; head \; loss + Minor \; head \; loss$$

$$= \mathbf{0.0024119 \; m}$$

2. Head losses in discharge line
   - Major Loss:

$$\frac{\lambda \; x \; L \; x \; V^2}{D \; x \; 2g}$$

Where:

$$\lambda = \frac{0.02 + 0.0005}{D} = 0.0276$$

$$L = Length \; of \; suction \; side = 8 \; m$$

$$V = 0.10 \; m/s$$

$$D = Pipe \; diameter = 65.90 \; mm$$

So,

$$H_{MAJ} = \frac{\lambda \; x \; L \; x \; V^2}{D \; x \; 2g}$$

$$H_{MAJ} = \frac{0.0276\ x\ 8\ x\ 0.10^2}{69.50\ mm\ x\ (2\ x\ 9.8)}$$

$$H_{MAJ} = 0.001709\ m$$

- Minor Loss:

No	Types	n	k	n x k
1	Butterfly valve	1	0.6	0.6
2	Elbow 90	7	0.7	4.9
3	T-joint	1	1.14	1.14
4	Non-return valve	3	1.35	4.05
	Total			10.69

$$Minor\ loss = \frac{(\Sigma nk)\ x\ V^2}{2\ g}$$

$$Minor\ loss = \frac{(10.69)\ x\ 0.10^2}{2\ x\ 9.8}$$

$$Minor\ loss = 0.00545\ m$$

Total head loss for discharge side:

$$= Major\ head\ loss + Minor\ head\ loss$$

$$= \mathbf{0.0072\ m}$$

Total head:

$$= H_S + H_P + H_V$$

$$+ \Sigma\ \text{head losses in suction and discharge sides}$$

$$= \mathbf{4 + 0 + 0 + 0.003 + 0.01}$$

$$= 2.01\ m$$

3. Specification of pump chosen

Brand	=	KCB Series
Type	=	YCB0.6-0.6, Y90S-6
Capacity	=	0.6 m^3/h
Discharge pressure	=	0.6 MPa
RPM	=	910 RPM
Power	=	0.75 kW | 1.005 HP

4.6.4. 3D Design of Integrated Homogenizer System

The 3D design of the system was made to ease the visualization of the system. Individual components of the system are generated in Autdoesk Inventor and then assembled according to the P&ID that was created.

a. Homogenizer

The 3D image of the homogenizer is modelled after the S.I.T homogenizer type CD92TM 140-M-MD. The 3D model of the homogenizer looks as the following:

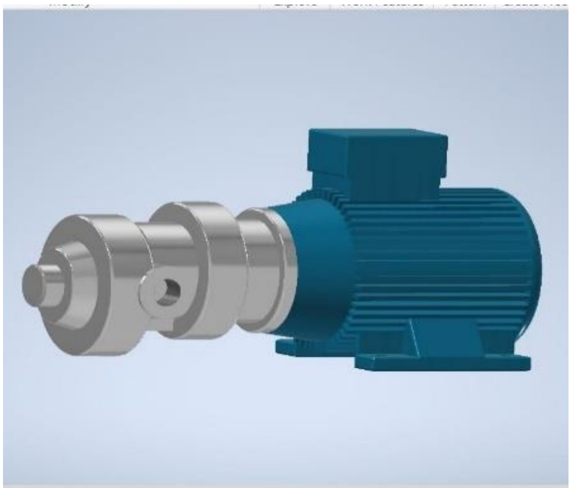


Figure 4- 23. 3D Model of S.I.T Homogenizer (1)

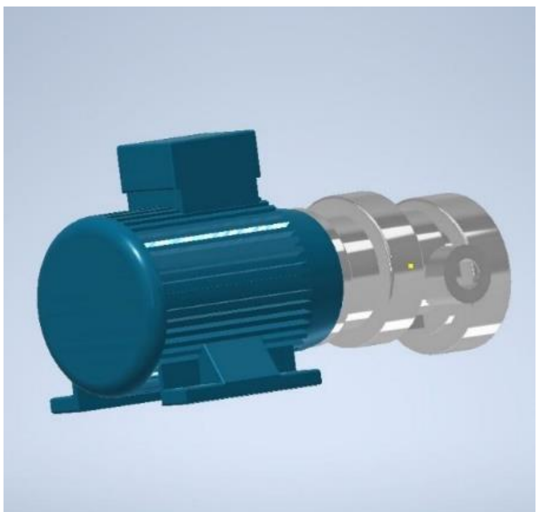


Figure 4- 24. 3D Model of S.I.T Homogenizer (2)

b. Separator

The 3D image of the separator is modelled after the Alfa Laval separator type MAB 103B-24. The 3D model of the separator looks as the following

Figure 4- 25. 3D Model of Alfa Laval Separator (1)

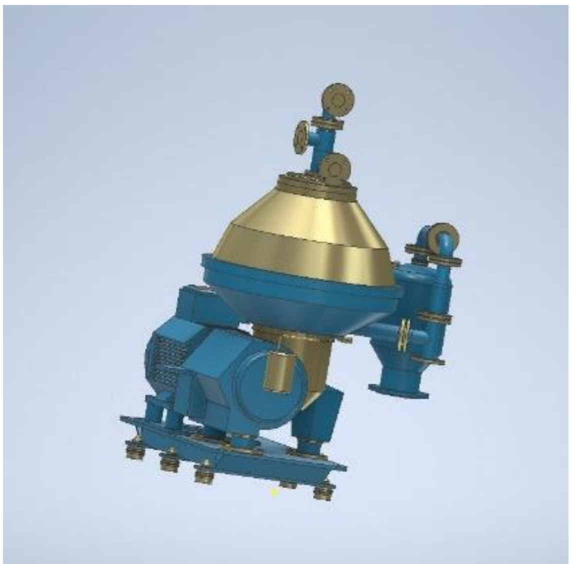


Figure 4- 26. 3D Model of Alfa Laval Separator (2)

c. Gear Pump
The 3D image of the gear pumps is modelled after the KCB Series gear pump type YCB0.6-0.6, Y90S-6. The 3D model of the gear pump looks as the following:

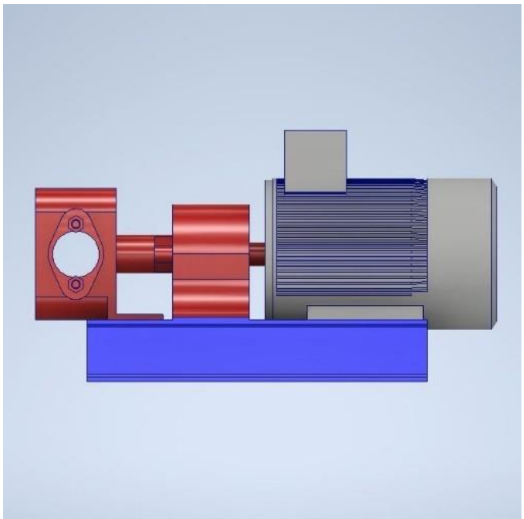


Figure 4- 27.3D Model of KCB Series Gear Pump (1)

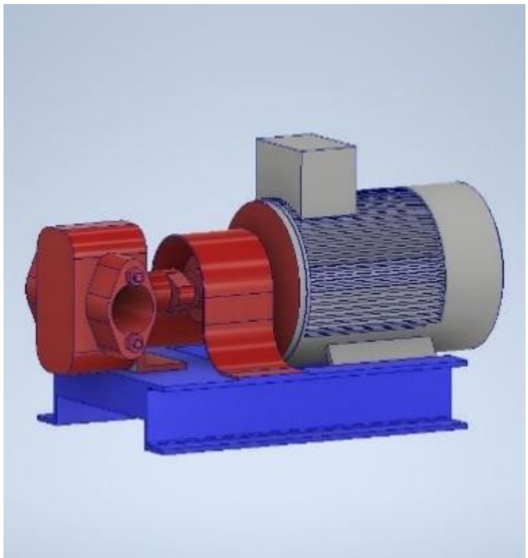


Figure 4- 28. 3D Model of KCB Series Gear Pump (1)

d. Design of 3D Integrated Homogenizer Blending System

All the 3D generated components in the system are assembled according to the designed P&ID along with their fittings. The assembled design is as the figure below:

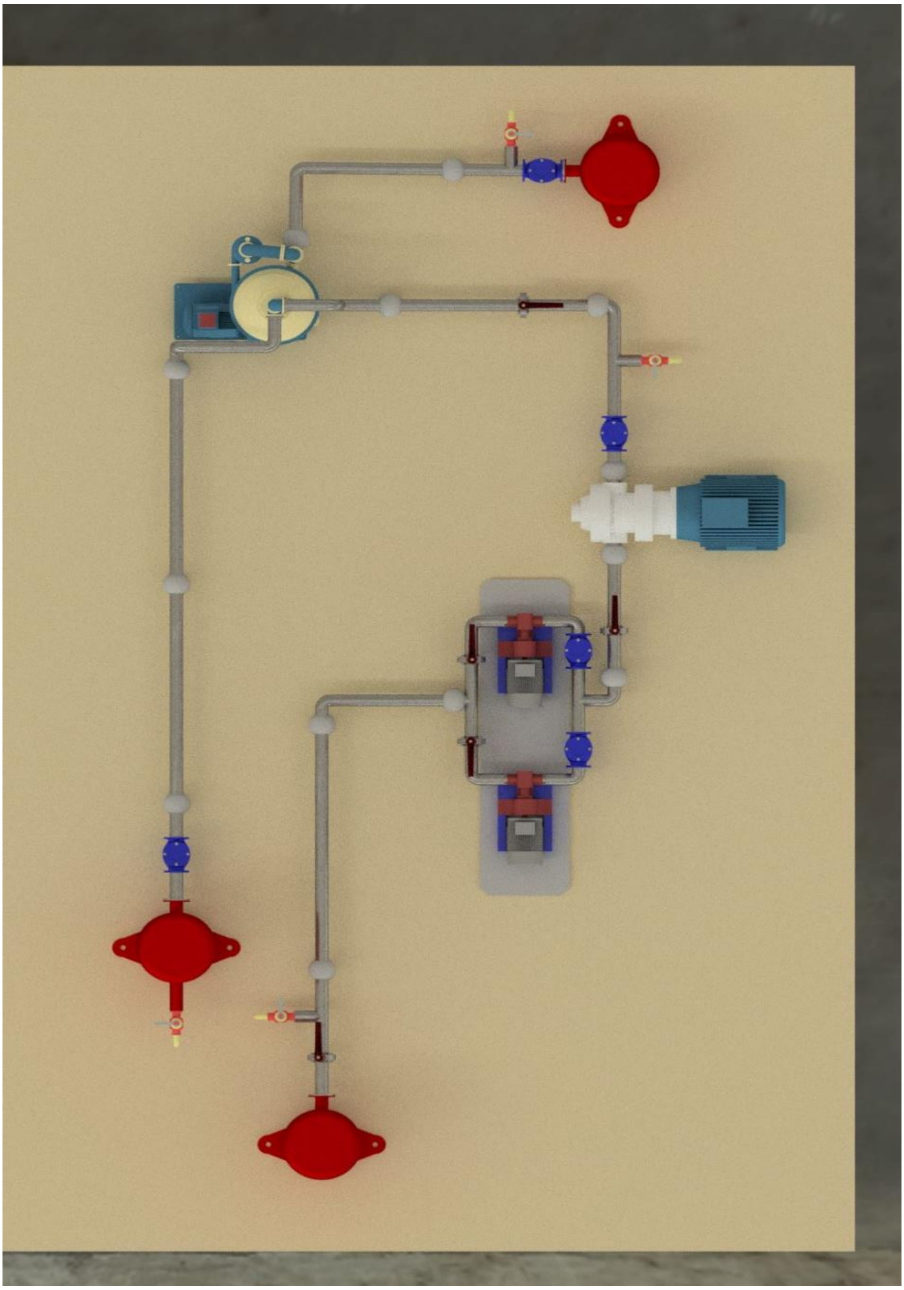


Figure 4- 29. Assembled 3D Design of Integrated Homogenizer Blending System

4.7. National Regulations for Biodiesel Utilization and Development

According to USAID, the energy policy in Indonesia has four main key policies and underlying objectives, which are;

1. energy diversification by expanding the use of coal, gas, and renewable energy sources to reduce dependence on oil,
2. rational energy pricing by eliminating unwanted subsidies,
3. energy sector reform to attract greater involvement and capital investment in energy sector, and
4. rural electrification.

These said objectives include the utilization of biofuel and the Mandatory Biodiesel Program (*Program Mandatori BBN* (*Bahan Bakar Nabati*)). Indonesia has had a long history of mandates regarding the utilization of biofuel since 2006, the mandates are added and revised for almost every year since the release of Presidential Regulation No. 5/2006. The national objectives of the implementation of the Mandatory Biodiesel Program are;

1. to fulfill the government commitment to reduce greenhouse gasses (GHGs) emission as much as 29% of the Business as Usual (BaU) scenario by 2030,
2. to increase national energy security and independence,
3. to stabilize the price of crude palm oil,
4. increase added value through downstream crude palm oil industry,
5. fulfil the 23% target of new and renewable energy (NRE) contribution in Indonesia's 2025 total energy mix,
6. reduce consumption and import of diesel fuel,
7. and to improve the trade balance deficit (Humas EBTKE, 2019).

These objectives are planned to be complied according to the national regulations regarding the matter. The following table will summarize the history of biofuel in Indonesia regarding government programs, financial incentives, and regulations of biofuel mix in the transportation sector in Indonesia (Silalahi & Simatupang, 2020).

Table 4- 12 Policy Documents on Biodiesel Development in Indonesia
(Source: Silalahi & Simatupang, 2020)

Year	Policy Document	Content
2006	Presidential Instruction No. 1	Provision and utilization of biofuel as another fuel
2006	Presidential Regulation No. 5	Biofuel target of 5% for the proportion of ethanol and biodiesel use within national energy consumption by 2025, seen on Figure 4-30
2007	Law No. 30 of 2007	The priority of supplying and utilizing new and renewable energy, one of which is biofuels

2008	Ministry of Energy and Mineral Resources regulation No. 32	Mandatory utilization of biofuel in the transportation, industrial, commercial and electricity generation sectors
2013	Ministry of Energy and Mineral Resources Regulation No. 25 of 2013, Ministry of Energy and Mineral Resources regulation No. 20 of 2005, Ministry of Energy and Mineral Resources Regulation No. 12 of 2015	The first, second, and third amendment to the regulation of the Minister of Energy and Mineral Resources No. 32 of 2008 about certain sector industry obligations/ mandatory to use biodiesel and bioethanol as a fuel mixture with certain mixtures from 2015 to 2025
2014	Government Regulation No. 79	The EBT target in 2025 is 23% of the national energy mix, and biofuel is targeted at 26% of the EBT target
2015	Decree of Ministry of Energy and Mineral Resource No. 0726K/12/MEM/2015	Determination of the market price index of biofuels mixed into certain types of fuels and special types of fuel
2015	Presidential Regulation No. 61	Establishment of Indonesian Oil Palm Estate Fund Agency (Badan Pengelola Dana Perkebunan Kelapa Sawit/BPDPKS)
2016	Ministry of Energy and Mineral Resources Regulation No. 41	Provision, utilization of biodiesel fuel under financing by the Indonesia Oil Palm Estate Fund
2018	Presidential Regulation No. 66	The collection and use of the palm oil plantation fund

The former president of Indonesia set out a Presidential Regulation No. 5/2006 on Indonesia's National Energy Policy to determine the national target for the optimal energy mix in 2025, the goals look as the following:

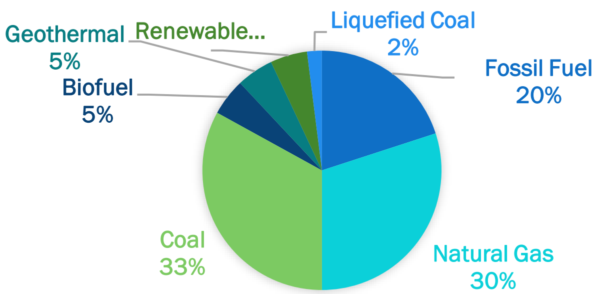


Figure 4- 30 National Optimal Energy Mix
(Source: Presidential Regulation No. 5/2006)

The National Energy Policy from Regulation No. 5/2006 set a target for energy diversification that includes 5% usage of biofuel in the country's total energy mix in 2025. Furthermore, In 2019, the Secretariat General National Energy Council formulated a modelling analysis framework of Indonesia's biodiesel usage projection through three scenarios, which are; Business as Usual Scenario (BaU), Sustainable Development Scenario (PB), and Low Carbon Scenario (RK). Each scenario has the following parameters:

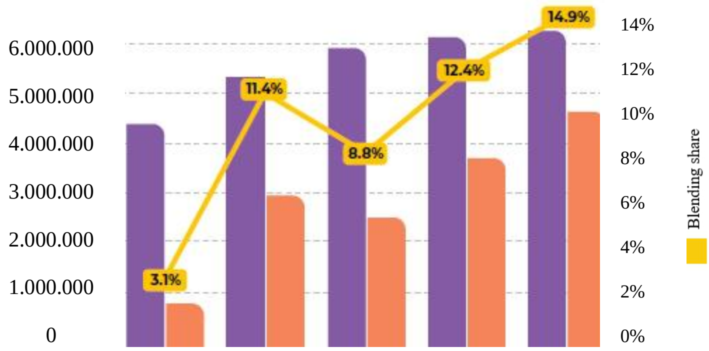
1. Business as Usual Scenario (BaU)
   BaU scenario uses targets in KEN and RUEN, RIPIN 2015-2035 and Renstra of each ministry, each of the targets is adjusted to the current realization.
2. Sustainable Development Scenario (PB)
   PB scenario uses RUEN assumptions, these assumptions are calculated with economic and population growth assumption in the BaU scenario. The sustainable development scenario considers the target of B30 biodiesel utilization by 2025 according to Minister of Energy and Mineral Resources Regulation (MEMR) No.12 of 2015. This target is assumed to reach B30 biodiesel in 2050.
3. Low Carbon Scenario (RK)
   The RK scenario demands that Indonesia contributes actively in the global effort based on the Paris Agreement to prevent the increase of Earth's temperature above 2 ^{0}C. In this scenario, the target for biodiesel utilization in 2025 is B30 while the target for 2015 is B100 (Secretariat General National Energy Council, 2019).

Table 4- 13 Scenario Assumptions of Biodiesel Target
(Source: Secretariat General National Energy Council, 2019)

Assumption	BaU	PB	RK
Biodiesel target	2025: 20%	2025: 30%	2025: 30%
	2050: 30%	2050: 30%	2050: 100%

4.8. Implementation and Progress of National Regulations

According to a report by Komisi XI DPR 2018, after a thorough investigation to Serikat Petani Kelapa Sawit, Indonesia's realization of biodiesel blending target is significantly higher than the consumption rate, the data is as the following graph;



		2015	2016	2017	2018	October 2019
Blending target		4.381.620	5.277.644	5.852.722	6.071.813	6.200.000
Biodiesel consumption		915.46	3.008.474	2.571.569	3.750.066	4.633.427

Figure 4- 31 Biodiesel Blending Target and Realization (million kL)
(Source: Commission XI DPR 2018 Work Visitation Report, SPKS (2019))

The biodiesel production in 2020 came to a bit of a halt due to the Coronavirus (Covid-19) pandemic. The Director of Bioenergy of the Directorate General of New and Renewable Energy and Energy Conservation of the MEMR stated that by May 26, 2020, the national biodiesel production for 2020 only reached 34,95% of the annual target (3.3 million kL out of 9.6 million kL target). This amount is a 15% deficit of what should have been reached by the month of May (Waseso, 2020).

In December 2019, Indonesia filed a lawsuit to the World Trade Organization (WTO) against the European Union (EU). Indonesia deemed the EU bloc's palm oil policy which is considered as discriminatory to the country's palm oil sector. The decision to file this lawsuit came after the European Commission adopted the directive which categorizes palm oil as an unsustainable product that supports deforestation. The EU also plans reduce the use of palm oil biofuel in 2024 and phase it out completely by 2030 (Iswara, 2019).

Indonesia's decision for this is made because the country is threatened that the EU's RED II policy would meddle with Indonesia's cooperation with European countries regarding the palm oil export, limiting the country's market access for palm oil products. Figure 4-32 shows the hefty amount of imported palm oil EU purchased from Indonesia from 2013 to 2017. Among the 15 countries that imported palm oil in 2019, the EU member states count as 5 of those countries, and most of their import of palm oil came from Indonesia (Workman, 2020). The Foreign Trade Director General of the Ministry of Trade Republic Indonesia, Indrasari Wisnu Wardhana, stated that EU's decision to end the use of palm oil will also impair the image of palm oil products in the global trade. In this case, Indonesia also plans to cooperate in this lawsuit with Malaysia as the world's second largest palm oil producer (Iswara, 2019).

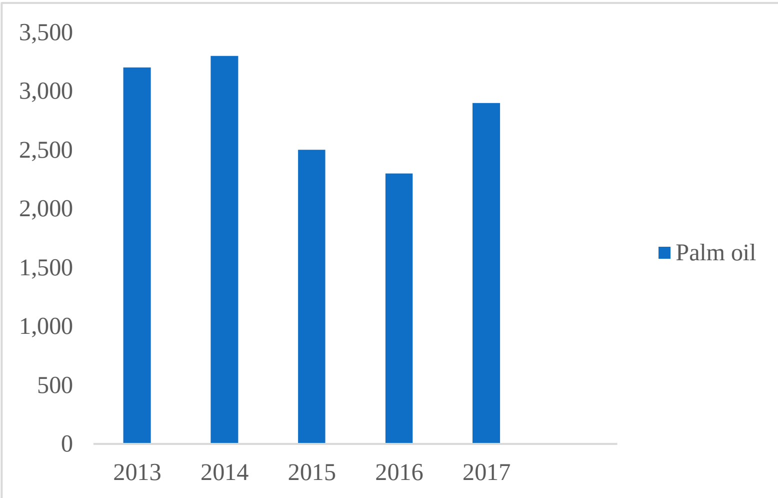


Figure 4- 32 EU Import of Palm Oil from Indonesia (in Million USD)
(Source: WITS, Eurostat, Copenhagen Economics)

The funding for palm oil plantation is managed by a certain organization, namely The Palm Oil Plantation Fund Management Agency (*Badan Pengelola Dana Perkebunan Kelapa Sawit* (*BPDPKS*)). They are a non-echelon organizational unit within the Ministry of Finance. It is governed under the Steering Committee, headed by the Coordinating Minister for Economic Affairs. The organizational unit was formed in 2015 to realize the goal of sustainable palm oil in accordance with Presidential Regulation 61/2015, Presidential Regulation 24/2016, and Presidential Regulation 6/2018. According to the law, the BPDPKS is aimed to reinvest in the industry for famer training, research and development, replanting trees which have aged with new productive trees, building infrastructure, and promoting palm oil. But on the contrary, BPDPKS have spent their money from mandatory export tariffs to subsidize producers and lowering the price of biodiesel at the pump to make it more competitive with regular diesel fuel. Since 2015 until 2019, BPDPKS managed to collect 47.2 trillion rupiah in revenue. About 71% of the revenue was given back to biodiesel producers, and less than 5% to small farmers for the replanting program (Jong, 2020).

According to the 2014 law that established BPDPKS, the funds of BPDPKS should be specifically used for the development of oil palm estate, including replanting, research, and empowering smallholder. In the law itself there was no mention of the use of funding towards biodiesel. Although in 2017, the BPDPKS showed indications of corrupt practices in the management due to the disbursement of funds that was largely proportioned towards subsidizing biodiesel producers. The next year, oil palm farmers came forward with a legal challenge against the BPDPKS use of funds. The national corruption agency, KPK, has taken notice, but ultimately the lawsuit was rejected (Jong, 2020).

4.9. Challenges in Biodiesel Program Implementation

In a wide lens, the national biofuel mandate has many benefits for= Indonesia. Among the benefits, the execution of the blending mandate resulted in a decrease in national diesel fuel imports. Albeit the benefits that the program give, the mandates of the biodiesel program possess some challenges that made the realization of the program difficult to execute, these challenges still persist and they are summarized as the following;

4.9.1. Crude Palm Oil as Raw Material

Since the biodiesel mandate increased the demand for crude palm oil as its blending material, more areas in Indonesia have been acquired as the palm oil plantation. The amount of land acquired for this purpose itself causes 6.5% of annual deforestation in Indonesia (Obidzinski, Andriani, Komarudin, & Andrianto, 2012), furthermore, the European Union (EU) believes that the acquiring of land for palm oil plantation contributed to 45% of deforestation in the country as a whole (Simangunsong, 2019). One study in Europe discovered that on average, biodiesel sourced from food crops emits 1.8 times more CO emission compared to using fossil fuels, because the process of clearing forests for farmland has to be taken into account when calculating the amount of emissions produced. For biodiesel from palm oil specifically, the emissions are calculated to be three times higher than for fossil fuels. (Jong, 2020).

Moreover, the feedstock to make the biodiesel blend, Crude Palm Oil (CPO), has a competition issue with other purposes of the material. The use of palm oil as the main material of biodiesel may contribute to compromising the national food security, since a hefty 47% of national production of palm oil is utilized to make highly-demanded cooking oil. Figure 4-33 explains regarding other purposes of FAME use apart from biodiesel production.

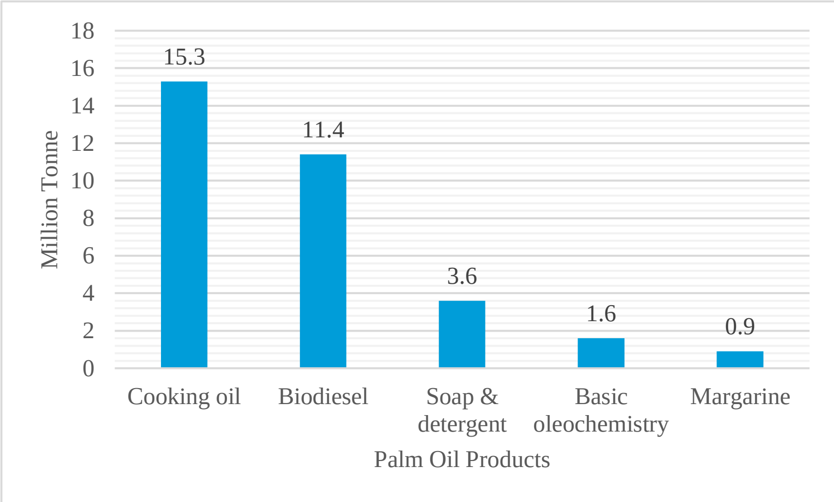


Figure 4- 33 CPO Consumption of Domestic Consumers
(Source: Gabungan Pengusaha Kelapa Sawit Indonesia, 2017)

4.9.2. Distribution of Biodiesel Blend

As seen in Figure 4-34 below, the map of the biodiesel blending facilities in Indonesia is heavily concentrated on the west side of the country. This fact supports a statement made by the former Managing Director of Pertamina who said that Indonesia had the most complex pattern of fuel oil distribution, this is due to the geographic nature of Indonesia archipelago country. The scattering of islands along the equator makes distribution for fuel very difficult (Rahman, 2014).

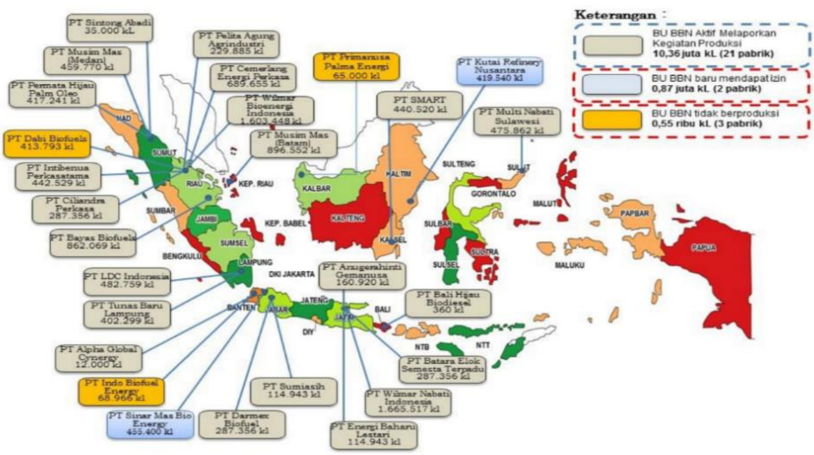


Figure 4- 34 Location of Biodiesel Blending Factories in Indonesia
(Source: MEMR, 2017)

Besides that fact that the geographic nature of the country makes the distribution fairly difficult, the transport vessels infrastructure to transport the blend are also in a limited number, creating an uneven distribution (IESR, 2019).

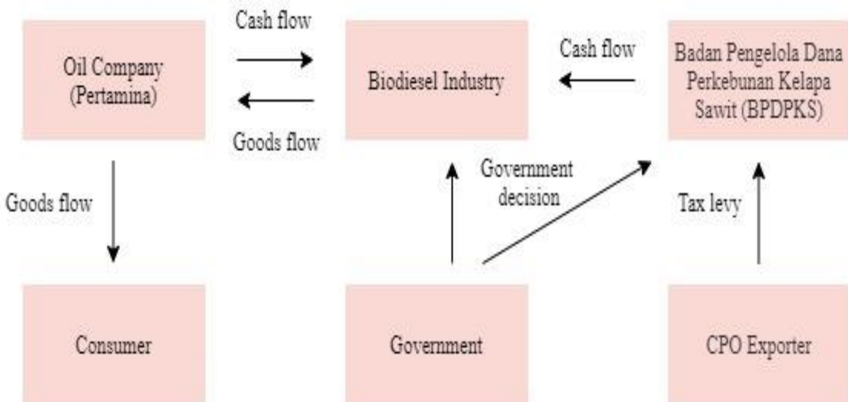


Figure 4- 35 Actors in the Indonesian Biodiesel Production and Distribution (Source: (Silalahi & Simatupang, 2020)*)*

In order to successfully implement the B30 mandate, collaboration synergy between involved actors is required. These said actors are consist the three parties; the suppliers of raw materials (individuals, private sector and state-owned enterprises); the biodiesel industry, which currently has 31 companies spread throughout Indonesia, and oil companies that will mix and distribute fuel to consumers. These commercial enterprises include: Pertamina, AKR, Shell and Total, although, the actor discussed in this study was Pertamina alone.

4.10. Future of National Biodiesel Outlook

According to Presidential Regulation No. 22/2017 regarding Rencana Umum Energi Nasional (RUEN), the Ministry of Energy and Mineral Resources (MEMR) has the target to produce 11.6 million kL of B30 on the year of 2025 and 54.2 million kL on the year of 2050 (Peraturan Presiden Republik Indonesia No. 22, 2017). While by the end of 2019, Indonesia only managed to produce 6 million kL of B30 biodiesel blend (IESR, 2019). Since 2015, Indonesia managed to increase their biodiesel production by 9.29% per year. If this trend continues, Indonesia will be able to produce 10.5 kL of biodiesel in 2015, around 9.5% short of the previously determined target according to the Presidential Regulation.

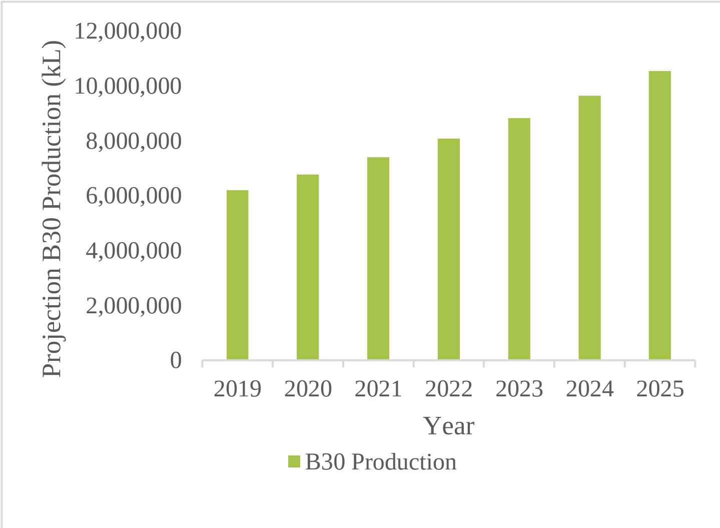


Figure 4- 36 Projection of National B30 Production (2020-2025)

The RUEN stated the Indonesian government intends to increase the biodiesel production and consumption up to year 2050, although the World Bank projected that CPO would cost 900 USD/tonne in 2030. If the case persists, Indonesia would only be able to follow through the blending mandate up to the year 2026. The IESR projects that the government would face a shortage of IDR 0.4 trillion in 2027.

In Figure 4-36 the International Council on Clean Transportation (ICCT) shows the prediction of global palm oil demand 2030. This prediction is done through extrapolating the historical linear increase of use in food and other non-biodiesel fuel from 2000-2017, in this prediction, Indonesia is assumed to reach the biodiesel blending target of 30% in 2019 (realistically, Indonesia reached this target in 2020). A few scenarios are included in the projection, these said scenarios are;

1. EU phase-out: The EU completely phases out the use of palm oil in biofuel by 2030. This scenario is created to anticipate the outcome of the current EU policy making process.
2. U.S. ends tariffs: In this scenario, the U.S. is assumed to recommence importing biodiesel at 2013–2016 levels without tariffs.
3. Indonesia B20: Indonesia is assumed to maintain its current biodiesel mandate at 20%, not increasing to 30% in 2019 or 2020.
4. No growth in Asia: Palm oil imports to non-palm producing countries in Asia remain flat at 2017 levels, for example, because of increasing tariffs (The International Council on Clean Transportation, 2019).

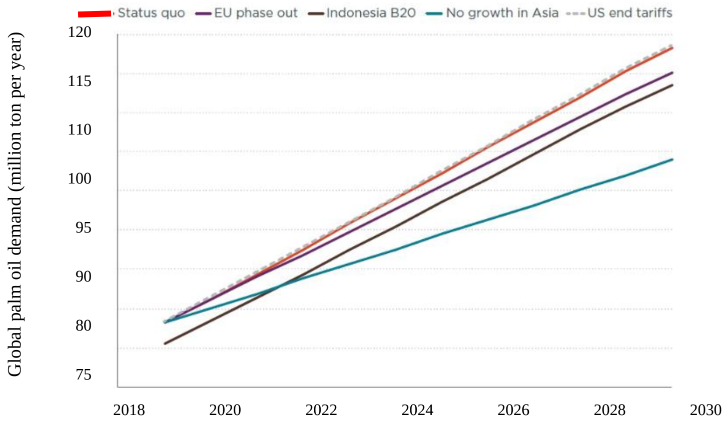


Figure 4- 37. Projection of Global Demand for Palm Oil in Various Scenarios

According to the projection, global palm oil demand is likely to rise over the next decade. In the status quo scenario by ICCT, the global demand for palm oil will increase close to 50% until 2030. ICCT's main takeaway is that none potential policy changes reviewed by ICCT are likely to reduce global palm oil demand by a notable amount. The EU policy could have a large impact to Indonesia, but not much in the global context of the palm oil market. If EU does proceed through with the biodiesel phase-out, the global palm oil demand will decrease by 3% compared to the status quo scenario.

Potential changes in policy decisions wouldn't have as big of an impact compared to potential market changes in Asia, since more than 50% of the global palm oil exports are sourced from Asia. If the demand for Asian palm oil were to decrease due to an economic downturn, the effect on the global demand will be three times larger than any policy changes from the EU, U.S., and Indonesian biodiesel policies (The International Council on Clean Transportation, 2019).

4.11. Review of National Biodiesel Regulations

The national regulation for the utilization of biodiesel blend has been created, added, and revised since 2016 until 2018, but there is still much room for improvement left. The government needs to figure out new incentive/subsidy schemes for biodiesel, if the particular plan is to increase the biodiesel blend to 30% or 50%, this to be taken seriously as to not only put a few forefront parties at advantage.

On the contrary, even though one of the objectives of following through with the B30 Mandatory Program is to reduce the amount of GHG emissions, at recent conditions it looks like if the government decides to follow through with the program, they are abandoning their own emission reduction commitment that they have made. The processes of producing FAME based biodiesel is explained as the figure below. As seen on the Figure 4-38 below, seven of the said processes of biodiesel production produces GHG emissions (Harsono, Prochnow, Grundman, Hansen, & Hallmann, 2012).

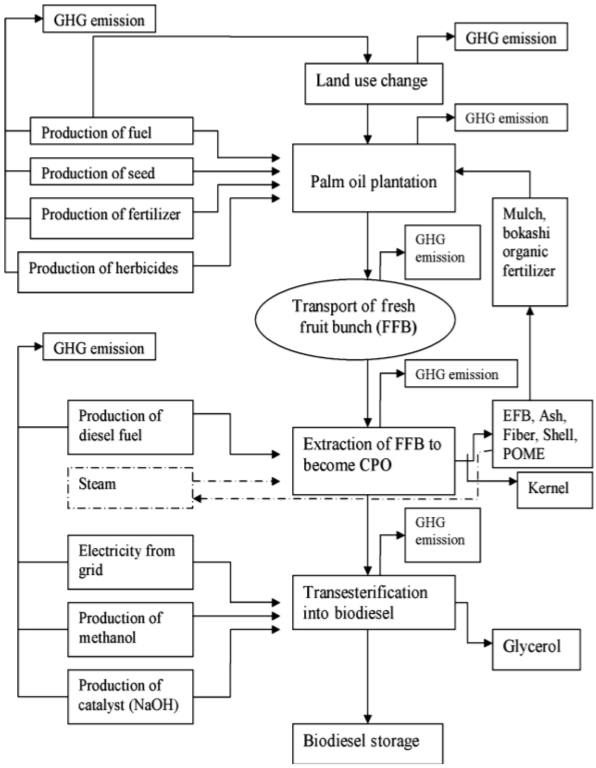


Figure 4- 38. System Overview of Stages Considered for Biodiesel Production from Palm Oil (Dashed Boxes and Line Indicate Internal Processes)

The greenhouse gas emissions from the production of FAME biodiesel is emitted through these processes:

1. Land-use change
   GHG from land-use change is counted from the results of converting forests into palm oil plantations.
2. Fertilizer
   Both organic and mineral fertilization emit GHG emissions.
3. Transportation
   The GHG emissions emitted from transportation is calculated from the transportation to plantation, transportation of fresh fruit bunches

to the mill, and transportation of CPO from the mill to the transesterification site.

4. Milling

   In this process, the GHG emissions is counted from the event of converting fresh fruit bunches to separated CPO, palm kernel oil, and their by-products. Power is required for these stages.

5. Transesterification

   The GHG in this event is calculated from the prechains of methanol and sodium hydroxide, also electricity generation (Harsono, Prochnow, Grundman, Hansen, & Hallmann, 2012).

After the thorough research from Harsono et al., it was discovered that the production of FAME biodiesel requires the largest energy input during its industrial phase. Among all the processes of FAME biodiesel production that emit GHG emissions, the largest GHG emissions are produced from the land-use change phase. Then followed by industrial phase, fertilizer production, agricultural production activities, milling, and transportation.

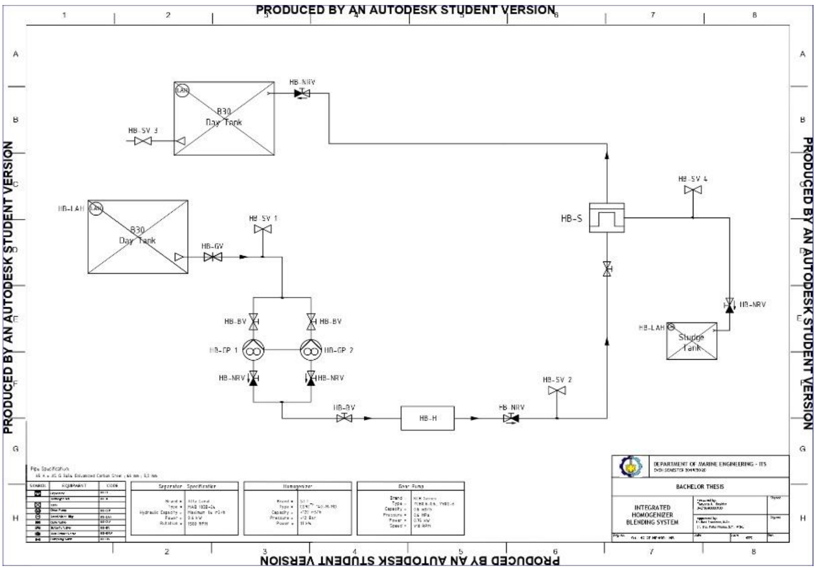
If the production of CPO biodiesel is seen as unsustainable, the government focus should be directed towards supporting the sustainable production of palm oil. This action includes identifying and transforming players that continue to work through unsustainable practices, both financially and technically. By putting only certain parties as priorities and putting them at the position of advantage, many people's livelihoods are at stake. This also makes the work counterproductive for millions of people in Indonesia.

Seeing Indonesia's plan to continue advancing with higher CPO blends in biodiesel, it was discovered through Zakaria's research that the sample with higher biodiesel ratio was more unstable compared to sample with lower ratio of biodiesel. This fact contrasts with Secretariat General National Energy Council's Low Carbon Scenario (RK) that intends to fully utilize B100 biodiesel by 2050. As during the development and utilization phase of B30, degradation issues were found in biodiesel blends that are stored for a long period of time due to fuel oxidation and biodeterioration. A thorough research and development still have to be done regarding the degradation issues in biodiesel blends before Indonesia can move forward with higher biodiesel to pure diesel fuel ratio.

CHAPTER V
CONCLUSION AND SUGGESTIONS

5.1. Conclusion

1. The main problem that contributes to creating the B30 storage issues is the inevitability of oxidation. The event of oxidation happens when the fuel blend is exposed to temperature, access of light, and oxygen from the outside environment. Oxidations lead to the event of fuel degradation and supporting the formation of crystals that will lead to the creation of precipitates and sludge on the bottom of the fuel tank. This event will result in filter clogging, incomplete combustion, and increase in emissions.
2. The design of the system consists of three main components; two gear pumps, a homogenizer, and a separator. The assembled system looks as the following:



3. The national regulation regarding biodiesel implementation has been created, added, and revised from 2006 to 2018. Indonesia aims to put 5% usage of biofuel in the country's total energy mix in 2025. Some of the challenges in the implementation of the mandatory biodiesel program are; crude palm oil as raw material and the distribution of biodiesel blend. Even though one of the objectives of the mandatory biodiesel program is to reduce emissions, the process of producing the biodiesel itself generates a hefty amount of emissions. Furthermore, due to the Covid-19 pandemic, the annual biodiesel

production for the year 2020 is coming to a bit of a halt. By May 26, 2020, the national biodiesel production for 2020 only reached 34,95% of the annual target (3.3 million kL out of 9.6 million kL target).

5.2. Suggestions

1. The proposed design of the integrated homogenizer system needs to be tested immediately as to confirm its effectivity in restoring the quality of stored biodiesel blend on board ships.
2. More research and tests regarding the national production of FAME biodiesel blends are needed to be done to discover regarding the national biodiesel performance and degradation during storage.
3. Research should be done to discover whether or not degraded biodiesel blends could be restored.

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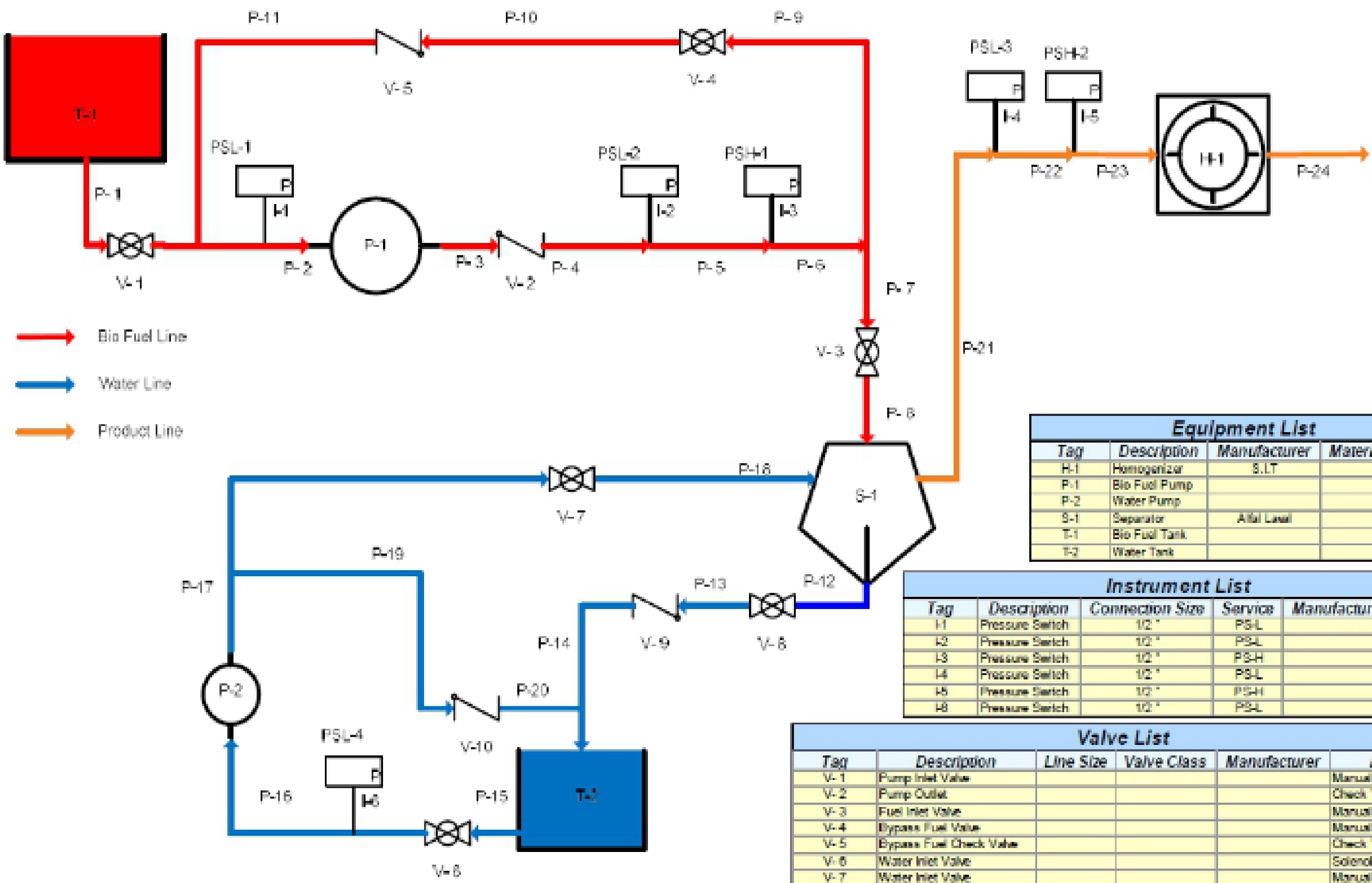
ATTACHMENTS

ATTACHMENT 1

INITIAL UNREVISED INTEGRATED HOMOGENIZER BLENDING DESIGN FROM PT X



Equipment List

Tag	Description	Manufacturer	Material	Model
H-1	Homogenizer	S.LT		
P-1	Bio Fuel Pump			
P-2	Water Pump			
S-1	Separator	Alfa Laval		MAB-103
T-1	Bio Fuel Tank			
T-2	Water Tank			

Instrument List

Tag	Description	Connection Size	Service	Manufacturer	Model
I-1	Pressure Switch	1/2 "	PSL		
I-2	Pressure Switch	1/2 "	PSL		
I-3	Pressure Switch	1/2 "	PSH		
I-4	Pressure Switch	1/2 "	PSL		
I-5	Pressure Switch	1/2 "	PSH		
I-6	Pressure Switch	1/2 "	PSL		

Valve List

Tag	Description	Line Size	Valve Class	Manufacturer	Model
V-1	Pump Inlet Valve				Manual Valve
V-2	Pump Outlet				Check Valve
V-3	Fuel Inlet Valve				Manual Valve
V-4	Bypass Fuel Valve				Manual Valve
V-5	Bypass Fuel Check Valve				Check Valve
V-6	Water Inlet Valve				Solenoid Valve / NC
V-7	Water Inlet Valve				Manual Valve
V-8	Water Outlet Valve				Manual Valve
V-9	Water Outlet Check Valve				Check Valve
V-10	Water Baypass				Check Valve

ATTACHMENT 2
SPECIFICATIONS OF ALVA LAVAL SEPARATOR

8.1 Technical data

Alfa Laval ref. 556001 rev. 0

Units according to ISO Standard.

The manufacturer reserves the right to change specifications without notice.

Product number	881145-09-01
Separator type	MAB 103B-24
Purpose	Continuous purification of heavy fuel oil or lubricating oil from solid particles and water. or Continuous clarification of heavy fuel oil or lubricating oil from solid particles. The flash point of the oil to be separated must be minimum 60 °C.
Hydraulic capacity	Maximum 1,4 m^3/h
Process capacity	Maximum oil flow at the maximum permissible oil density 991 kg/m^3 at 15 °C. The density is preferably measured at 50 °C according to ASTM method D 1298-80 and corrected to 15 °C according to ASTM tables D 1250-80.

Fuel oils, diesel engine

- Distillate: viscosity 1,5-5,5 cSt/40 °C — Maximum oil flow 1,15 m^3/h
- Marine Diesel Oil: viscosity 13 cSt/40 °C — Maximum oil flow 0,9 m^3/h

Lubricating oils, by-pass treatment, optimum

- R & O type: Crosshead diesel — Maximum oil flow 0,4 - 0,5 m^3/h
- Detergent: — Maximum oil flow
  Crosshead diesel — 0,3 - 0,4 m^3/h
  Trunk piston diesel — 0,2 - 0,3 m^3/h
- Steam turbine: — Maximum oil flow 0,8 m^3/h

Max. density of sediment 5000 kg/m^3

Max. density of feed 991 kg/m³, (mechanical safety max. 1100 kg/m³)

Feed temperature
Minimum 0 °C
Maximum +100 °C

Ambient temperature
Minimum+5°C
Maximum +55 °C

Motor
4-pole 0,75 kW standard motor, 50 or 60 Hz, 3-phase.
Direct on-line start.

If Y/D-start is used maximum 5 seconds in Y position.

Power consumption

idling	0,4 kW
running (at max. capacity)	0,6 kW
max. power consumption	0,6 kW (at starting-up)

Speed
The prescribed speed of the bowl spindle which must not be exceeded, is stamped on the name plate of the machine.

Gear ratio	40 : 7	43 : 9
Maximum speed of rotation, rpm	*50 Hz*	*60 Hz*
Motor shaft speed	1500	1800
Revolution counter speed	71 - 75	85 - 90
Bowl speed	8570	8600

Starting time 3 minutes

Stopping time

Running down with brake applied	min. 2 minutes max. 2,5 minutes
without brake	6 minutes (average)

Maximum running time without flow

empty bowl	480 minutes
filled bowl	480 minutes

Inlet pump, built-on	Capacity	50 Hz	60 Hz
	529209-82	1150 litres/h	1380 litres/h
	529209-83 (option)	580 litres/h	700 litres/h
	Suction lift Delivery head	Max. 4 m wg (manometric) Max. 15 m wg (manometric)	
Outlet pump, built-on	Capacity	50 Hz	60 Hz
	529209-82	1270 litres/h	1520 litres/h
	529209-83 (option)	640 litres/h	770 litres/h
	Delivery head	15 - 25 m wg (depending on flow and viscosity)	
Sludge and water space volume	0,56 litres		
Required water quality	Fresh water		
Lubrication	see "8.7.1 Lubrication chart, general" on page 131.		
Lubricating oil volume	0,8 litres		
Weight	Separator without motor	Net weight approx. 75 kg.	
	Motor	Approx. 13 kg.	
	Complete bowl	Approx. 13 kg.	
Shipping data	According to "Basic equipment"		
	Weight	100 kg (Net 85 kg)	
	Volume	0,30 m^3	
Sound power level	7,6 bel(A) ISO 3744, 1,2 m^3/h		
Sound pressure level	64 dB(A) ISO 3744, 1,2 m^3/h		
Vibration level	Max. for separator in use	9 mm/s (RMS)	
Materials	Bowl spindle, lock ring	steel	
	Frame, lower and upper parts	cast iron ("Centriblue" finish[1])	
	Collecting cover	silumin (grey finish[1])	
	Bowl body and hood, disc stack, gravity disc	stainless steel	
	Other bowl parts	brass	
	Other inlet and outlet parts	stainless steel, brass, cast iron	

1) An epoxy enamel

ATTACHMENT 3

S.I.T HOMOGENIZER BROSCHURE

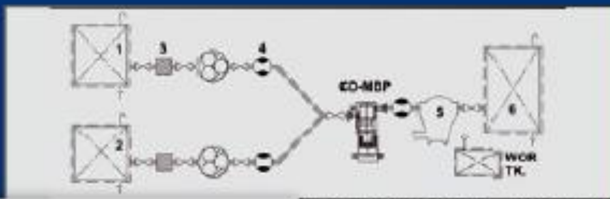
The CD92-MBP: "Micronizer Blending Processing System"

No experiments. Choose the Original.

Meet the permanent rising of Fuel costs!

Protect your budget! Ask for S.I.T CD92-Homogenizer!

Following see the potential of our CD92-System to reduce fuel costs.



CD-MBP

1: HFO-Settl. Tk 3: F. O. Filter 5: F. O. Separator
2: MDO-Serv. Tk 4: Flowmeter 6: F. O. Serv. Tk

Blending Operations

The oil phase in a stable residual fuel oil prevents the micelles from interacting and sticking together. Poor quality control at the manufacturing stage can render a fuel unstable. The blending process is the critical operation which will determine the stability of the finished fuel. The diluent use must be compatible with the residue. The mechanism of the blending process itself is equally important. The components must be completely homogenized and this is extremely difficult to achieve without suitable efficient blending equipment (in this respect: CD92-Mycronizer). The tank circulating process is blending these different types of fuel to one stable blended product. Even purification cannot separate the different types of fuel. In order to meet viscosity requirements, residual fuel oil is blended with a diluent, which is asphaltene free, and may originate from a variety of manufacturing processes. The type of diluent used will depend on the properties and concentrations of both the oil phase and asphaltenes in the residue.

Effects & Benefits…

- Stable blends HFO / MDO / DO
- Stable blends of Sulfur 1,0% limits.
- Stable medium (all types of fuel)
- No separation by purification.
- Reduced clogging of fine filter.
- Extended flushing intervals for F. O. Separator.

Only achievable with CD92-Mycronizer.

The Core of each CD92-system:
Different Application, same CD92-Homogenizer.

20 YEARS

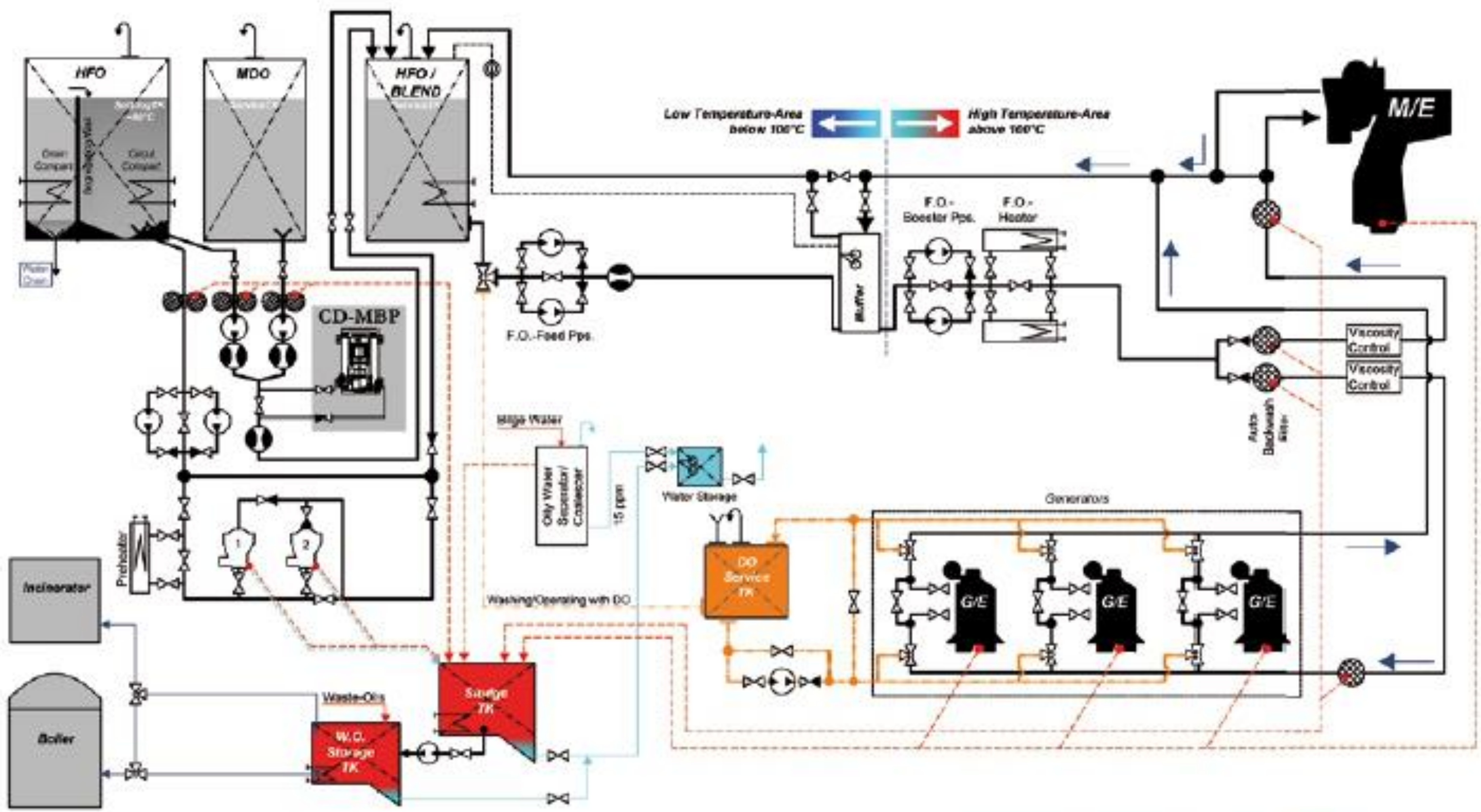
The effects of sludge formation in a residual fuel oil on board ship can result in choked centrifuges, filter blocking, heater fouling and, ultimately, engine shut down and damage. Stability is therefore a vital property of residual fuel oil. S.I.T establishes a new, improved technical standard in order to be able to continue to guarantee an economic and ecological use of heavy fuel oils in future.

S.I.T systems are approved by class societies ABS & LR and complying with Marpol 73/78, IMO 2000 requirements.

ABS Lloyd's Register MARPOL

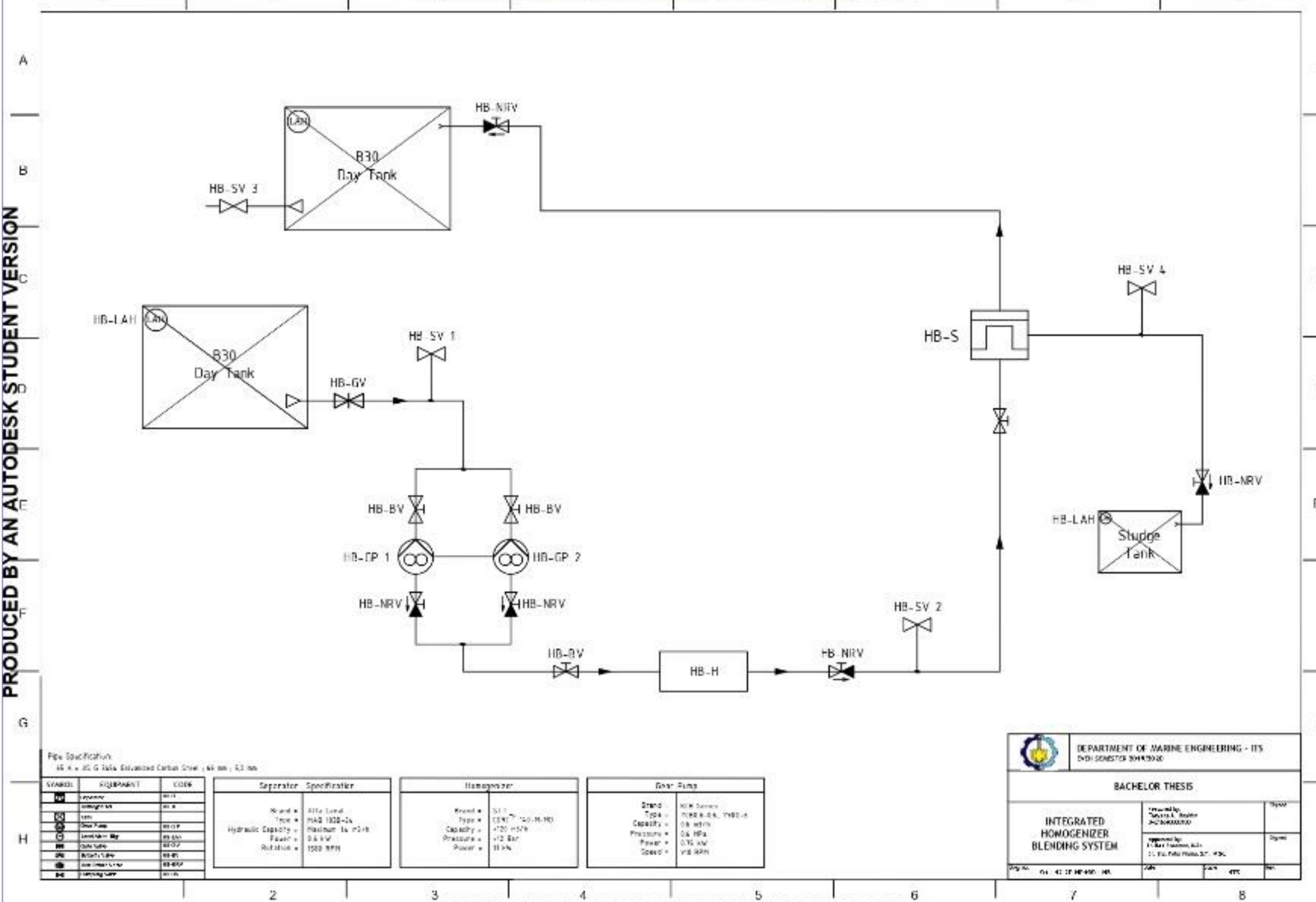
S.I.T

The CD92-MBP: "System-Description"



ATTACHMENT 4

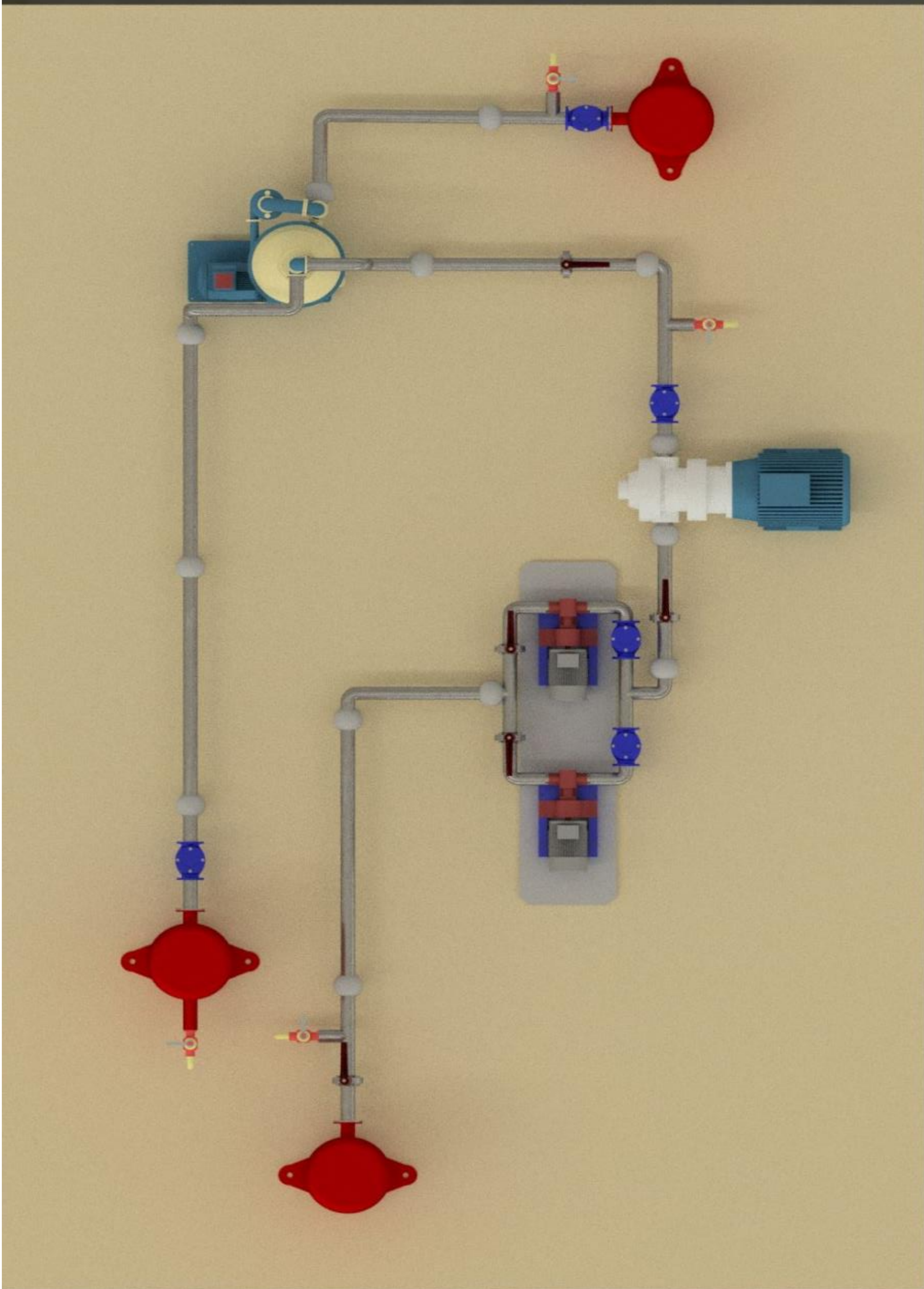
P&ID OF INTEGRATED HOMOGENIZER BLENDING SYSTEM



PRODUCED BY AN AUTODESK STUDENT VERSION
PRODUCED BY AN AUTODESK STUDENT VERSION
PRODUCED BY AN AUTODESK STUDENT VERSION

ATTACHMENT 5

3D GENERATED INTEGRATED HOMOGENIZER BLENDING SYSTEM



ATTACHMENT 6

SPECIFICATIONS OF CHOSEN GEAR PUMP

KCB SERIES GEAR PUMP

I. Applications

KCB series gear pumps apply to pumping non-corrosive lubricating oil or similar liquid without solid particles and fibres at temperature below 80 °C and with the viscosity of $5X10^{-6}$~$1.5X10^{-3}m^2/S$ (5-1500cSt).

It can be applied as delivering pump or booster pump in oil delivery system, as a fuel pump for delivery, pressurization and injection in fuel supply system and in all industry fields as lubricating oil pump.

II. Structure Features

KCB series gear pumps are mainly composed of gears, shafts, pump body, pump cap, safety valve and shaft-end seals etc. The heat-treated gears have the advantages of higher hardness and intensity, and rotate with the shaft inside the replaceable bearing sleeves. All of pump's parts can be lubricated by delivered liquid when working.

The pump is designed with logical leakage and return chute, which let the gears bear the least torque force and reduce bearings' load and abrasion, meanwhile raise pump's efficiency.

It is also designed with safety valve for protecting against overload. The full return flow pressure of the safety valve is1.5 times higher than the rated exhaust pressure of the pump. It can be also adjusted within the allowance of exhaust pressure range according to actual working condition. But please note the safety valve can't be applied as pressure-reducing valve for long time. You may install pressure-reducing valve separately on pipe-line if needed.

YCB Series Circular Gear Pump's Performance Parameter

Type	Capacity m^3/h	Speed r/min	Pressure MPa	(NPSH)r m	Efficiency η %	Motor		
						Hz	Power KW	Type
YCB0.6-0.6	0.6	910	0.6	5.5	60	50	0.75	Y90S-6
	1.0	1390				50	0.75	Y80L2-4
	0.7	1130				60	0.75	Y90S-6
	1.2	1710				60	0.75	Y80L2-4
YCB0.6-1.6	0.6	910	1.6	7.0	70	50	1.1	Y90L-6
	1.0	1400				50	1.5	Y90L-4
	0.7	1130				60	1.1	Y90L-6
	1.2	1710				60	1.1	Y90S-4
YCB1.6-0.6	1.6	910	0.6	5.5	63	50	0.75	Y90S-6
	2.5	1400				50	1.1	Y90S-4
	1.9	1130				60	1.1	Y90L-6
	3.0	1710				60	1.5	Y90S-4
YCB1.6-1.6	1.6	940	1.6	7.0	71	50	2.2	Y112M-6
	2.5	1440				50	4	Y112M-4
	1.9	1150				60	2.2	Y112M-6
	3.0	1750				60	4	Y112M-4
YCB3.3-0.6	3.3	940	0.6	5.0	60	50	1.5	Y100L-6
	5.0	1420				50	2.2	Y100L1-4
	4.0	1150				60	1.5	Y100L-6
	6.0	1730				60	2.2	Y100L1-4
YCB3.3-1.6	3.3	960	1.6	7.0	72	50	5.5	Y132M2-6
	5.0	1440				50	7.5	Y132M-4
	4.0	1170				60	4	Y132M1-6
	6.0	1750				60	7.5	Y132M-4
YCB4-0.6	4.0	940	0.6	5.0	60	50	1.5	Y100L-6
	6.0	1420				50	2.2	Y100L1-4
	4.8	1150				60	2.2	Y100M-6
	7.2	1730				60	3	Y100L2-4
YCB4-1.6	4.0	960	1.6	7.0	72	50	5.5	Y132M2-6
	6.0	1440				50	7.5	Y132M-4
	4.8	1170				60	5.5	Y132M1-6
	7.2	1750				60	7.5	Y132M-4
YCB8-0.6	8.0	960	0.6	5.0	61	50	3	Y132S-6
	12.0	1440				50	5.5	Y132S-4
	9.6	1170				60	4	Y132M1-6
	14.4	1750				60	5.5	Y132S-4
YCB8-1.6	8.0	970	1.6	7.0	75	50	11	Y160L-6
	12.0	1460				50	15	Y160L-4
	9.6	1170				60	11	Y160L-6
	14.4	1760				60	15	Y160L-4
YCB10-0.6	10.0	960	0.6	5.0	62	50	4	Y132M1-6
	15.0	1440				50	5.5	Y132S-4
	12.0	1170				60	5.5	Y132M2-6
	18.0	1750				60	7.5	Y132M-4
YCB10-1.6	10.0	970	1.6	7.0	76	50	11	Y160L-6
	15.0	1470				50	15	Y160L-4
	12.0	1170				60	11	Y160L-6
	18.0	1770				60	18.5	Y180M-4
YCB20-0.6	20.0	970	0.6	5.0	68	50	7.5	Y160M-6
	24.0	1170				60	7.5	Y160M-6
YCB25-0.6	25.0	970	0.6	5.5	69	50	11	Y160L-6
	30.0	1170				60	11	Y160L-6
YCB30-0.6	30.0	970	0.6	5.5	65	50	11	Y160L-6
	36.0	1170				60	11	Y160L-6

ATTACHMENT 7

S.I.T HOMOGENIZER TECHNICAL DATA

The CD92™

Fuel ConditioningDevice

... is the basic component of all S.I.T Fuel treatment plants, but also to be used solely.

In general to be used for refinement / conditioning of common fuels.

The CD92™ balances the fuels structure to particle sizes below 3 microns, what first leads to a remarkable FO-Sludge reduction from purification and filtration but also offers an optimized combustion process with less soot, dust and particulate emissions.

It also enables the production of longterm stable and resistant water-in-fuel emulsions, useful for reduced NOx-formation from the combustion process.

Applicable in all marine and industrial fuel systems. Supports all common fuel treatment systems like purifiers and filters.

Designed and manufactured according to valid regulations.
Now completely made of high grade steel for improved operation safety and easier handling.

The CD92™ 100-/130-/140-/160-/200-Mycronizer - MD - MagneticDrive Version.

Type 85-M-MD	Flow capacity:	< 1.5 m^3/h (IFO 380 @ 50°C)
	Design Temperature:	< 130°C (Fuel Temperature)
	Design Pressure:	< 10.0 bar (Fuel Pressure)
	Electric drive:	4.0/4.6 kW - 400/440 V - 50/60 Hz
	Pipe Connections:	DN 32 - PN 16
Type 100-M-MD	Flow capacity:	< 4.5 m^3/h (IFO 380 @ 50°C)
	Design Temperature:	< 140°C (Fuel Temperature)
	Design Pressure:	< 12.0 bar (Fuel Pressure)
	Electric drive:	7.5/8.6 kW - 400/440 V - 50/60 Hz
	Pipe Connections:	DN 40 - PN 16
Type 130-M-MD	Flow capacity:	< 9.0 m^3/h (IFO 380 @ 50°C)
	Design Temperature:	< 140°C (Fuel Temperature)
	Design Pressure:	< 12.0 bar (Fuel Pressure)
	Electric drive:	7.5/8.6 kW - 400/440 V - 50/60 Hz
	Pipe Connections:	DN 50 - PN 16
Type 140-M-MD	Flow capacity:	< 12.0 m^3/h (IFO 380 @ 50°C)
	Design Temperature:	< 140°C (Fuel Temperature)
	Design Pressure:	< 12.0 bar (Fuel Pressure)
	Electric drive:	11.0/12.5 kW - 400/440 V - 50/60 Hz
	Pipe Connections:	DN 65 - PN 16
Type 160-M-MD	Flow capacity:	< 20.0 m^3/h (IFO 380 @ 50°C)
	Design Temperature:	< 140°C (Fuel Temperature)
	Design Pressure:	< 16.0 bar (Fuel Pressure)
	Electric drive:	22.5/25.0 kW - 400/440 V - 50/60 Hz
	Pipe Connections:	DN 80 - PN 16
Type 200-M-MD	Flow capacity:	< 28.0 m^3/h (IFO 380 @ 50°C)
	Design Temperature:	< 160°C (Fuel Temperature)
	Design Pressure:	< 20.0 bar (Fuel Pressure)
	Electric drive:	22.5/25.0 kW - 400/440 V - 50/60 Hz
	Pipe Connections:	DN 100 - PN 16

Main applications:

- **FO-Sludge Reduction**
- **Combustion Improvement**
- **Water-in-Diesel-Emulsification**
- **NOx-Reduction**
- **Waste Oil Regeneration**

S.I.T Schiffs-&Industrie Technik (M) Sdn. Bhd
6, Kompleks Kilang SME Bank, Jalan PJU 3/38, Sunway Damansara
Technology Park, 47810 Petaling Jaya, Selangor Darul Ehsan, MALAYSIA.
–Tel: +603 7885 8663 –Fax: +603 7885 9663
-Email: info@sit-malaysia.com

Standards:
Material: - High grade steel
Drive: - Magnetic type
E-drive: - Siemens or ABB
(other upon request)

- **No Mechanical Seals**
- **No Ball Bearings**
- **Minimum Maintenance**
- **8.000 + Running Hours**

Manufacturing in Malaysia.
Design and production to highest possible technical standards. Accepted by: MARPOL, ABS, DNV, GL, LR, NK, RINA

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AUTHOR’S BIOGRAPHY

Tatyana Ibrahim pursued a bachelor’s degree in ITS Department of Marine Engineering from 2016 to 2020. During Tatyana’s journey in pursuing her degree in ITS, she was involved in Society of Petroleum Engineers ITS Student Chapter for three consecutive years. Her interest in the energy industry led her to participate in an international oil and gas related business case competition in ITB, where her team and she managed to win first place in the competition. Furthermore, her desire to get hands-on in the industry brought her to intern at Schlumberger as a Vacation Trainee in 2019 where she was assigned at Muara Badak, Kalimantan. She was also involved in ITS Model United Nations Club and became an ITS official delegate of Euro Model United Nations 2019 in Maastricht, Netherlands. In the same year, she was also appointed as an official Indonesian delegate for Hitachi Young Leaders Initiative program in Singapore, along with other official delegates from ASEAN countries + Japan. In her 5th semester, she was chosen as one of the awardees for the XL Future Leaders program, where she actively enhanced her soft skills. Since her participation on the program, she has spoken numerously at events as a keynote speaker and/or emcee. In her fourth year, she became a member of the Digital Marine Operation and Maintenance Laboratory, and took focus on biodiesel as her bachelor thesis topic. She looks forward to contribute on the renewable energy industry subsequent to earning her Bachelor in Engineering degree.

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