BACHELOR THESIS & COLLOQUIUM – ME-141502

CONCEPTUAL DESIGN OF 100 MW LNG MOBILE POWER PLANT

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Surabaya
2016

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APPROVAL SHEET

CONCEPTUAL DESIGN OF 100 MW LNG MOBILE POWER PLANT

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Submitted to Comply One of The Requirements to Obtain a Bachelor of Engineering Degree
in
Double Degree of Marine Engineering (DDME) Program
Department of Marine Engineering-Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember (ITS)
Department of Maritime Studies
Hochschule Wismar, University of Applied Sciences

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ABSTRACT

Energy is a key aspect to promotes various aspects. The presence of electrical energy in several area in Indonesia is very limited due to its facilities development limitation and access. Mobile power plant or known as power ship is a power plant which use ship as its vessel. In this thesis, dual-fuel type engine will be compared where it will utilize natural gas and diesel oil. The use of dual fuel engine is to reduce the emission since a combustion engine will produce amount of NOx and SOx and it can be reduced by using gas fuel because its low sulphur content.

By conducting calculation process to select engine along with its equipment, design, and arrangement the mobile power plant will be powered by 7 diesel engine of MAN18V51/60DF along with its auxiliary system were chosen among other diesel engines and gas turbines with total capacity of 3811,266 m3 of LNG to be operated

for 7,063 days at its average load. All of the system design, configuration and general arrangement of the mobile power plant designed with Germanischer Lloyd and engine’s project guide as guidelines to develop efficient, reliable, and safety system design and arrangement which comply with the standard

DESAIN KONSEP PEMBANGKIT LISTRIK BERGERAK.LNG 100 MW

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ABSTRACT

Energi adalah aspek untuk mendukung berbagai aspek lainya yang terkait. Kehadiran energi listrik di Indonesia sangatlah terbatas karena faktor pembangunan dan akses. Pembangkit listrik bergerak atau dikenal sebagai *powership* adalah pembangkit listrik yang menggunakan kapal sebagai wadah. Mesin *dual-fuel* yang memanfaatkan gas alam dan minyak diesel akan digunakan. Penggunaan *dual-fuel* ditujukan untuk mengurangi emisi NOx dan SOx, hal tersebut dapat dikurangi dengan penggunaan gas alam yang memiliki kandungan sulfur rendah. Dengan melakukan proses kalkulasi, desain dan pengaturan, Pembangkit listrik bergerak akan ditenagai oleh 7 mesin diesel MAN18V51/60DF bersama dengan system penunjangnya setelah dibandingkan dengan mesin diesel dan turbin gas lainya dengan kapasitas 3811,266 m3 LNG untuk dioperasikan 7,063 hari dengan beban

rata-rata. Seluruh desain sistem, konfigurasi dan rencana umum dari pembangkit listrik bergerak didesain dengan *Germanischer Lloyd* dan *Project Guide* sebagai acuan untuk menciptakan desain yang efisien, terpercaya, aman dan memenuhi standard.

PREFACE

This bachelor thesis is a gift for Indonesia and to fulfill the requirement to obtain Bachelor of Engineering Degree in Department of Marine Engineering, Sepuluh Nopember Institute of Technology and Hochschule Wismar.

Author is grateful to express gratitude for those who contribute and who give supports in accomplishing this bachelor thesis;

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This thesis proves that your supports have a big role.

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LIST OF SYMBOLS AND ABREVIATIONS

Symbol/Abb.		Description
L	=	Length
B	=	Breadth
D	=	Depth
H	=	Height
Cb	=	Block Coefficient
Cp	=	Prismatic Coefficient
Cm	=	Midship Coefficient
Cvp	=	Vertical Prismatic Coefficient
Cwp	=	Water Plane Area Coefficient
Δ	=	Mass Displacement
∇	=	Volume Displacement
LWT	=	Lightweight
DWT	=	Deadweight
ρ	=	Density
g	=	Gravity
KB	=	Keel to Centre of Buoyancy Distance
LCB	=	Longitudinal Centre of Buoyancy
CB	=	Centre of Buoyancy
KG	=	Keel to Centre of Gravity Distance
LCG	=	Longitudinal Location of Centre of Gravity
TCG	=	Transverse Location of Centre of Gravity
KM	=	Keel to Metacentric Distance
RPM	=	Revolution Per Minute
SGFC	=	Specific Gas Fuel Consumption
SFOC	=	Specific Fuel Oil Consumption
OC	=	Oil Consumption
LNG	=	Liquefied Natural Gas
NG	=	Natural Gas
STS	=	Ship-to-Ship Transfer
TTS	=	Truck-to-Ship Transfer
Wst	=	Weight of Steel

Wdh	=	Weight of Deckhouse
Wot	=	Weight of Outfitting
Wmdo	=	Weight of Marine Distillate Oil
Wlng	=	Weighr of Liquefied Natural Gas
Wlo	=	Weight of Lubricating Oil
Wfw	=	Weight of Freshwater
Wp	=	Weight of Provision
Wcp	=	Weight of Crew and Provision
Q	=	Capacity
P	=	Power
c	=	Specific Heat
BOG	=	Boil-off Gas
t	=	Duration
V	=	Volume
v	=	Velocity
m	=	Mass
A	=	Area
LMTD	=	Logarithmic Mean Temprature Difference
r	=	Radius

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CHAPTER I
INTRODUCTION

1.1. BACKGROUND

Indonesia is the largest archipelago or islands country where it consists of 17.508 islands scattered in an area of 1.904.569 km^2. The archipelago conditions complicate the development of technology, economy, and other aspects. Many islands in Indonesia are not evenly developed especially the East Indonesia even though some islands are very rich in natural resources and every Indonesian citizen deserve to entitled area development.

According to PT.PLN (Persero) 2014 database which shown by table 1.1, several East Indonesia Islands have peak load exceed the capacity of PLN installed power plant and to install a new power plant in East Indonesia requires high effort due to low manufacturing activity.

Table 1.1: Power (MW) Balance in several province

No.	Province	Installed Capacity (MW)	Peak Load (MW)
1	Papua	93.01	123.56
2	West Papua	54.17	81.17
3	North Sulawesi, Central Sulawesi, Gorontalo	453.25	574.12
4	South Sulawesi, South-East Sulawesi, West Sulawsi	575.39	890.53

Based on *Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2015-2024* in table 1.2 there are several area where PT PLN (Persero) will build an onshore power plant, the area is;

Table 1.2: PT PLN (Persero) Power Plant Plan

No.	Province	Capacity (MW)	Year
1	NTB (Lombok)	2 X 50	2018 - 2019
2	South Sulawesi (Punagaya)	2 X 100	2017 - 2018
3	South Sulawesi (Malea)	2 X 45	2020

Source: *Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2015-2024(2014)*

According to table 1.2, the 100 MW LNG Mobile Power Plant can be an optional solution for those area to substitute the onshore power plant with the mobile power plant considering the manufacturing process can be accelerated when it's built in well-developed area.

Power barge or power ship is a ship with a special purpose where a power plant is installed in its hull. Usually, a powerships are a converted ship with a propulsion, and an unmotorized powerships is called power barges. To develop an electricity, a power barge may use diesel engine or other engines to generate electricity. Power barge may become a solution to bridge the gap for local demand of power until certain of time until that local area able to supply their own power demand and power barge can be built faster than power ship since the absence of propulsion system.

Fossil fuel are highly consumed to produce energy. Its availability, calorific value, and stability made it very useful. In other hand, emission substance like CO_2, NO_x and SO_x discharged by fossil fuel are produced in significant amount. To minimize the amount of emission produced by ships, MARPOL Annex VI has been revised to create a new standard for ship's emission where NO_x and SO_x content must be reduced. A ship built after 1 January 2016 must comply with this MARPOL regulation, therefore to meet the new standard, LNG fuel is considered due to its level of cleanliness compared to other fossil fuel.

The need to have an electricity power plant in East Indonesia with low-emission generator is to be expected in the near future. Therefore, a mobile power plant can be used to overcome the demand of power with its mobility and low-emission requirement by using LNG as its main generator fuels. The power barge can be built in island with high manufacturing activities such as Java and Batam Islands and then transported to specific area in certain times.

1.2. STATEMENT OF PROBLEMS

Based on the description above the statement of problem of this thesis are;

1. How to choose the powering machinery for the 100 MW LNG Mobile Power Plant?
2. How to determine the auxiliary equipment for the 100 MW LNG Mobile Power Plant?
3. How to determine the fuel consumption and storage arrangement to operate the 100 MW LNG Mobile Power Plant?
4. How to design the General Arrangement of 100 MW LNG Mobile Power Plant refer to classification societies rules and other rules?
5. How to arrange the supporting system for the 100 MW LNG Mobile Power Plant Generator refer to classification societies and the engine requirements?

1.3. RESEARCH LIMITATIONS

The limititations of this thesis are;

1. This thesis is focusing on the general arrangement of 100 MW LNG Mobile Power Plant consist of these component; fuel storage, evaporator unit, engine, alternator, and the superstructure of power ship. Several equipment may be added.

2. The selection process will be conducted for dual-fuel diesel engine and gas turbine.
3. The engine use in this thesis is an engine which use snatural gas fuel and diesel oil as its fuel.
4. Electrical, operation aspects and shore facility shall be neglected.
5. Cost and economic factor are not included.
6. Safety factor, reliability design are not calculated.
7. General arrangement will be designed only for the chosen powering machinery.
8. The engine and other equipment will be determined and arranged regarding to ship trim, heel and buoyancy aspects.

1.4. RESEARCH OBJECTIVES

The objectives of this thesis are;

1. Determine the powering machinery for the 100 MW LNG Mobile Power Plant
2. Determine auxiliary equipment for the 100 MW LNG Mobile Power Plant
3. Determine the fuel consumption and the storage capacity to operate the 100 MW LNG Mobile Power Plant.
4. To design the General Arrangement of 100 MW LNG Mobile Power Plant refer to classification societies rules and other rules.
5. To arrange the supporting system for the the 100 MW LNG Mobile Power Plant Barge's Generator refer to classification societies and the engine requirements.

1.5. RESEARCH BENEFITS

1. Understand the requirement and regulation that should be implemented to design 100 MW LNG Mobile Power Plant.
2. Develop a conceptual design of the 100 MW LNG Mobile Power Plant.

CHAPTER II
LITERATURE REVIEW

2.1. Conceptual Design

Conceptual design is a part of the basic designas written in Ship Design and Construction (Taggart, 1980). Basic design includes ship dimension, hull form, power, preliminary arrangement of hull and machinery, and major structure. A basic design is consisted of both concept design and preliminary design where the result come from the basic design is a ship characteristic.

In the concept design, the mission requirements are translated into naval architecture and engineering characteristics. Usually, it contains some fundamentals of the ship like length, beam, depth, power, deadweight, lightweight, etc as it can be seen in figure 2.1. A conceptual design may have several scenario or alternatives which will be selected after several considerations. When the selected concept design is approved, preliminary design phase is initiated.

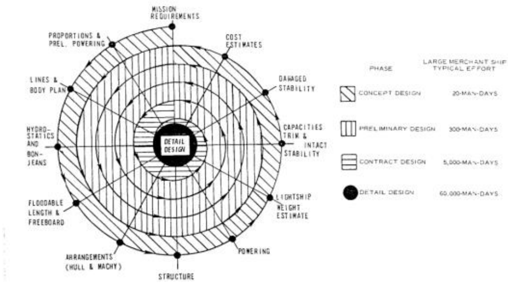

Figure 2.1 Design Spiral[1]

[1] Source: Ship Design and Construction (Taggart, 1980)

2.2. General Arrangement

General arrangement is a drawing of spaces for all the required machinery and access. The efficiency of ship's operation are depends on the proper arrangement where the design should be functionally with respect to another factor such as manpower. To design a general arrangement, several consideration and process are required as written in Ship Design and Construction (Taggart, 1980).

The problem and the approach to develop a general arrangement is determine and locating the main spaces. The spaces are:

1. Cargo spaces
2. Machinery spaces
3. Crew, passenger, and associated spaces
4. Tanks
5. Miscellaneous

Then, the general arrangement is gradually evolved by the process of trial, check and improvement. Several information is need to be gathered including;

1. Required volume of cargo spaces,
2. Method of stowing cargo and cargo handling system,
3. Required volume of machinery spaces,
4. Required volume of accommodation spaces,
5. Required volume of tank

(Taggart, 1980).

General Arrangement is a plan and should be the embodiment of everything the naval architect wants to achieve. Amount of detail is to be decided by draughtsman and a draughtman's skill and knowledge are not to be decried. Several things which is important for a general arrangement are the main purpose of the ship and how this purpose can be achieved. General arrangement must meet the deadweight, capacity, and speed requirements. in Practical Ship Design (Watson, 1998)

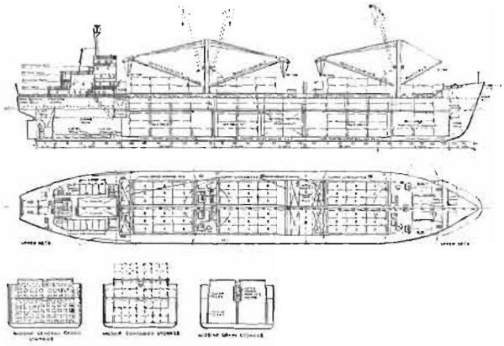

Figure 2.2 Example of General Arrangement[2]
Source: Watson, D.G.M., *Practical Ship Design.*(1998)

Based on figure 2.2, general arrangement may show the design from several views like top view, side view and sectional view for some area which need to have details drawings.

The general arrangement of the ship may consist the equipment inside onboard the ship, the arrangement of the equipment itself may affect the ship hydrostatic properties for trim, heel, and other motions.

2.2.1. Lightweight Calculation

Lightweight (LWT) is the weight of the ship during empty condition without cargo and consumable goods. Component inside LWT are structural weight, equipment, and machinery. To calculate LWT, an empirical formula from Ship Design for Efficiency and Economy (Schneekluth, 1998) and Chapter 11: Parametric Design (Parson, 2001), ther formula will be used particularly to estimate the weight of deckhouse and outfitting.

[2] Source: Practical Ship Design (Watson, 1998)

For equipment, it can be calculated one by one for each equipment by developing the system design, calculating the requirement, and determine the weight of the equipment using existing products.

2.2.2. Deadweight Calculation

Deadweight (DWT) is the weight of the ship consumable goods or moveable goods. Based on Chapter 11 Parametric Design (Parson, 2001), The deadweight are the sum of several component such as, fuel oil, lube oil, fresh water, crews weight, and other non-fixed object inside the ship. Empirical formula to estimate the weight of each aspect are provided. The other option to calculate the deadweight is by calculating each component one by one.

2.3. Gas Turbine

Gas turbine usage are very common in aviation world, for non-aviation, gas turbines is utilized as electric generator or ship's engine. Gas turbines output power vary from 0.05 MW to 240 MW depends on its size. Gas turbines have several advantages like;

1. Able to produce large amount of power for relatively small size and weight
2. Long mechanical life and relatively low maintenance cost due to its components only involve rotation (no reciprocating motion as in piston engine)
3. Wide variety of fuels can be used to operate gas engine. For land-based natural gas is commonly used.
4. Able to reach maximum operation condition faster than steam turbines.

Information above based on Introduction to Gas Turbines for Non-Engineers books (Langston, 1997)

Gas Turbine basic principle is utilizing the gas expansion inside the chambers. To promote a gas expansion, energy is added by injecting fuel and then ignited. The fuel combustion generates a high-temperature and high-pressure gas flow and enters the turbine where the gas expands and rotates the turbine.

There are several components to build the gas turbines such as;

1. Compressor
2. Combustion chamber
3. Turbines
4. Intercooler
5. Recuperator

Compressor in the gas turbine is to compressed air which enter the engine. To achieve large volume flows, gas turbine plants usually use an axial compressor because of the higher efficiency at larger volume flows.

Combustion chamber is the place where the temperature of the compressed air is increased through combustion of the atomized fuel. The burners inject a fine spray of fuel into the air by using pressure-jet atomizing, two-fluid atomizing, or rotational atomizing and then ignited using igniter.

Turbines is a component which utilize high-pressure and high-temperature gas from the combustion chamber. The gas will expand and increase pressure in the turbines then rotates the turbine's blade. The rotation from the turbine will be coupled to another device. Inside a turbine, every material is exposed to high temperature and require a cooling methods. There are several cooling methods like convection cooling (figure 3a), impingement cooling (figure 3b), film cooling (figure 3c) and transpiration cooling (figure 3d). Beside cooling, a high-temperature-resistant nickel or cobalt-based alloy are used as the blade material.

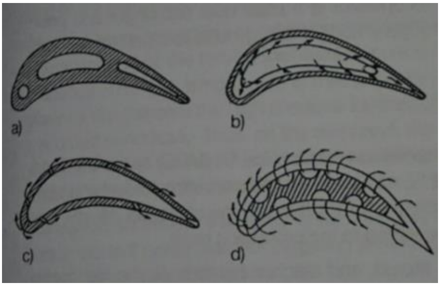

Figure 2.3 Gas Turbines Blade Cooling Methods[3]

Recuperator is a heater to increase the temperature of the compressed air. The effect of the recuperator are thermal efficiency increasing and reduction of the fuel consumption. Recuperator construction is made of plate heat exchanger and located above the power turbine.

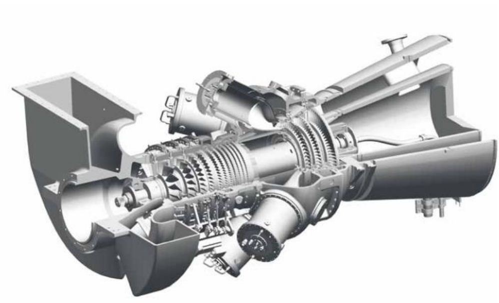

Figure 2.4 Gas Turbine Construction[4]
Source: MAN Industrial Gas Turbines Brochure

[3] Source: Compendium of Marine Engineering (Ackermann, 2009)
[4] Source: MAN Industrial Gas Turbines Brochure (

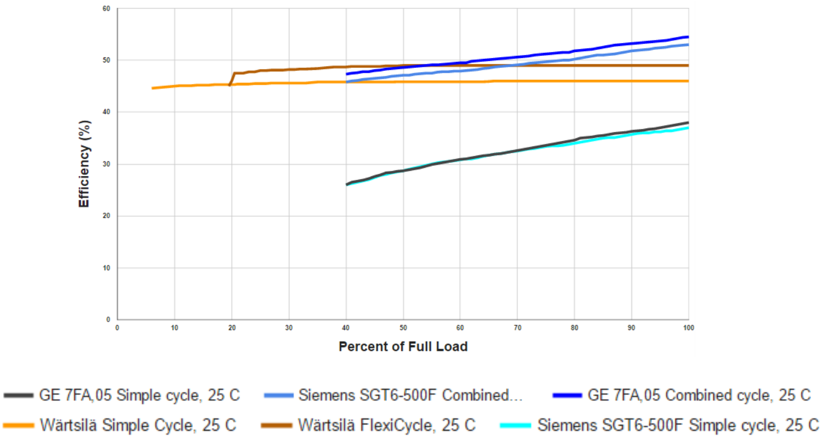

Figure 2.5 Gas Turbine and Diesel Comparison[5]

Based on the graph above, we could see that the comparison of Wartsila's diesel engine in simple cycle and flexicycle which is combined with steam turbine compared with General Electric's gas turbine, Siemens's gas turbine in simple cycle and combined cycle arrangement.

The gas turbine, whether is it in combined cycle arrangement or simple cycle arrangement have shorter operation range while diesel engine have wider operation range especially for the simple cycle. For the simple cycle diesel engine, it may operate from load under 10% while the gas turbine need to be operated only at 40% load or more.

For the performance itself, diesel engine have better efficiency in simple cycle which consume less space and have a little improvement when the diesel engine arranged at

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[5] Source: http://www.wartsila.com/energy/learning-center/technical-comparisons/combustion-engine-vs-gas-turbine-part-load-efficiency-and-flexibility

combined cycle. Difference with gas turbine, it has low efficiency when arranged in simple cycle and high efficiency when arranged in combined cycle (much higher than diesel engine) but as we know combined cycle require more spaces.

2.4. Dual-Fuel Diesel Engine

Dual-fuel diesel engine is an engine which capable to burn natural gas as fuel simultaneously with liquid (pilot) fuel and also have the capability of running on liquid fuel only based on Guide for Propulsion and Auxiliary Systems for Gas Fueled Ships (ABS, 2015)

The principle of dual-fuel diesel engine is the diesel started using diesel fuel on pilot and main injection, once the combustion process is stable, the engine switched to gas mode where most of the fuel is gas and liquid fuel is used as pilot fuel.

1. On the inlet stroke, gas is mixed with the inlet air.
2. On the compression process, air-gas mixture is being compressed but it will not ignite because gas fuel has a high self-ignition temperature.
3. As the piston reach TDC, small amount of diesel fuel is injected from pilot nozzle. The pilot fuel will be ignited by the high pressure and temperature inside the combustion chamber then ignite the air-gas mixture.

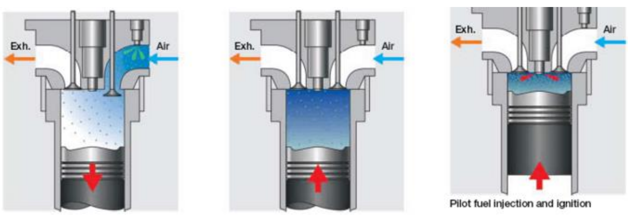

Figure 2.6 Dual Fuel Diesel Combustion Process[6]

[6] Source: [online] http://www.marinediesels.info/2_stroke_engine_parts/Other_info/dual_fuel.htm

Based on Germanischer Lloyd rules and guideline, there are several plans and specifications covering the ship like location and separation of spaces, access and openings, pipe design, gas supply in machinery spaces, gas fuel storage, bunkering and distribution outside machinery spaces.

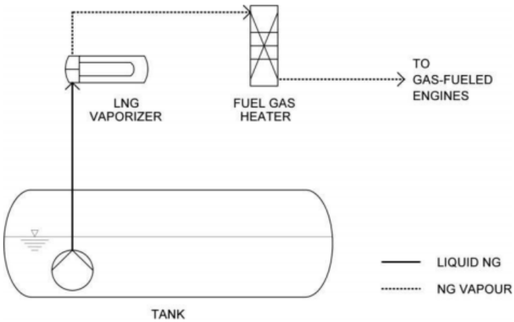

Figure 2.7 Basic Diagram of LNG Fuel Supply[7]

Since dual-fuel use two type of fuel which is gas fuel and liquid fuel, in this case marine diesel fuel (MDO) and liquefied natural gas (LNG), a storage for those fuel is required. To calculate the requirement of the storage, we could use engine projectguide specific fuel oil consumption to determine the liquid fuel volume requirement;

$$Vmdo = \frac{SFOC\left[\frac{g}{kWh}\right]\times Load[kW]\times Time[h]}{\rho\times 1000}$$

To calculate the NG volume required;

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[7] Source: [online] http://www.lngbunkering.org/sites/default/files/2013%20TGE%20Supply%2C%20storage%20and%20handling%20of%20LNG%20as%20ship%E2%80%99s%20fuel.pdf

$$NG\ consumption\ [kJ] = SFOC\ \left[\frac{kJ}{kWh}\right] \times Load\ [kW] \times Time\ [h]$$

In the equation 4, we could see that the calculation output is in kilojoule and need to be converted to volume unit. Based on Alberta Energy website, 1 gigajoule [GJ] of natural gas are equal with 26.84 cubic meters $[m^3]$ of natural gas.

$$Vng\ [m^3] = NG\ consumption\ [kJ] \times 26.84 \times 10^{-6}$$

The natural gas volume may be reduced $\frac{1}{600th}$ or 0.001667 from its original volume by liquefying the natural gas, then to convert the natural gas volume to liquefied natural gas volume we could use equation 6;

$$Vlng\ [m^3] = Vng[m^3] \times 0.001667$$

(Source: DOE Office of Fossil Energy)

Or using a table from Natural Gas Conversion Guide, International Gas Union (IGU)

$$1\ ft^3 = 1055\ kJ$$

Therefore, the specific storage volume can be calculated by determine how long the engine will work and the load the engine need to be produced. After the volume is calculated, the other equipment like heater, insulation, pump, etc can be determined too.

2.5. Fuel Storage

According to GL Rules and Guidelines VI-3-1 Guidelines for the Use of Gas as Fuel for Ships (Germanischer Lloyd, 2010). The storage used for liquefied gas should be an independent tank and must comply with GL Rules and Guidelines I-1-6 Liquefied Gas Carriers (Germanischer Lloyd, 2010). Independent tanks are self-supporting and it don’t form part of the ship’s hull and also not affecting the hull’s strength. There are several type of independent tank which is Type A, Type B, and Type C.

1. Type ‘A’ Tanks

Type ‘A’ independent tank is a prismatic tank which is adjustable to ship’s hull. This kind of tanks are space efficient but require high cost during construction. Type tank disadvantages are boil-off gas handling difficulties, and complex fuel system. The design of vapour pressure is to be less than 0.7 barg.

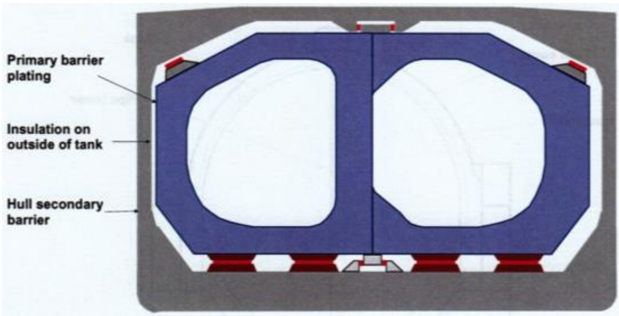

Figure 2.8 Type A Independent Tank[8]

Based on International Safety Guide for Inland Navigation Tank-Barges and Terminals (OCIMF, 2010) type ‘A’ tanks material is not crack propagation resistant. Therefore, there is a requirement to ensure the safety which is secondary containment or a secondary barrier. This type of tank must be able to prevent leakage of tank at least for 15 days period.

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[8] Source: [online] http://cmapspublic3.ihmc.us/rid=1HK92XSXR-CNTFND-SBK/contaiment%20tanks.cmap

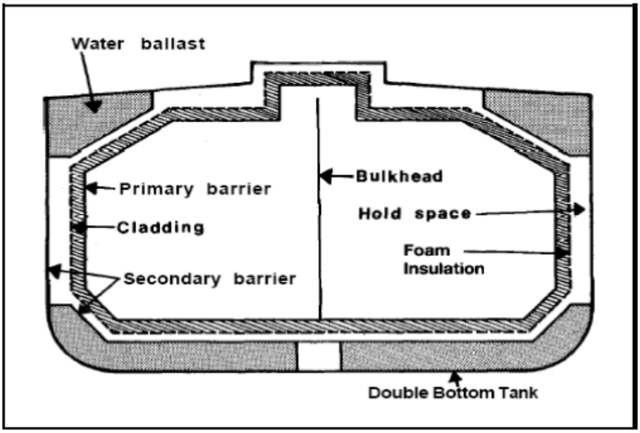

Figure 2.9 Type 'A' Tanks Secondary Barrier[9]

Secondary barrier may use the ship's hull only if the liquefied gas fuel temperature is not lower than −55℃, therefore LNG cargo tank need secondary barrier separated from its hull and protected by shield.

2. Type 'B' Tanks

Type B independent tank is a spherical tank. This kind of tanks are reliable due to its strength and capability to handle large amount of liquid, this tank is commonly used in LNG carriers. The disadvantages of this tanks are boil off gas handling difficulties. The tank dimension are designed using models test, analysis method to determine the stress level, fatigue and crack. For the vapor space pressure is, as for type 'B' tanks which is 0.7 barg.

[9] Source: International Safety Guide for Inland Navigation Tank-Barges and Terminals (OCIMF, 2010)

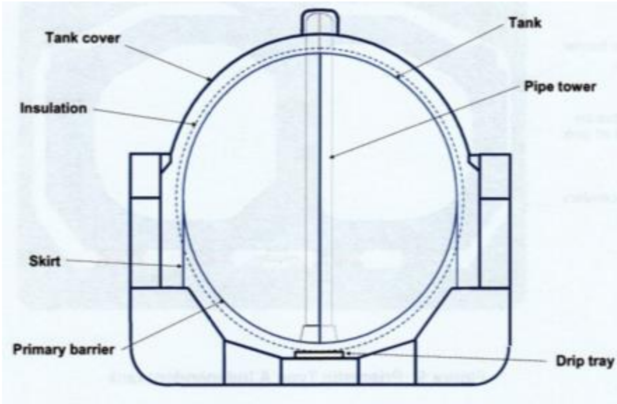

Figure 2.10 Independent Tank Type B[10]

Type 'B' tanks is not always form as a spherical structure. There is a prismatic type 'B' tanks, The benefit of type 'B' prismatic tank is to maximized the ship's spaces compared with the spherical type. (OCIMF, 2010)

3. Type 'C' Tanks

Type C independent tank is a pressured vessels or known as cylindrical. Type C tank allows an increase level of pressure higher than 4 barg but must be able to handle for fully pressurized 18barg as maximum working pressure. For semi pressureized, the tank are designed for a handling pressure of approximately 5 to 7 barg and 0.3 barg for the vacuum pressure. This tank is suitable for fuel storage due to its dimension, maintenance and easy to installation and usually installed vertically or horizontally. Type 'C' tanks does not require secondary barrier due to its material strength to overcome the cargo pressure.

[10] Source; [online] http://cmapspublic3.ihmc.us/rid=1HK92XSXR-CNTFND-SBK/contaiment%20tanks.cmap

The disadvantages of type ‘C’ tanks are poorly utilizing the hull’s space since the dimension of the tank is quite difference with the ship’s hull. (OCIMF, 2010)

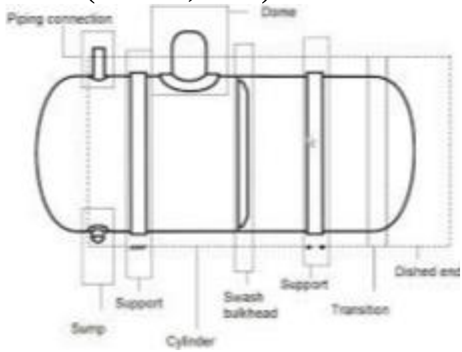

Figure 2.11 Type C Independent Tank[11]

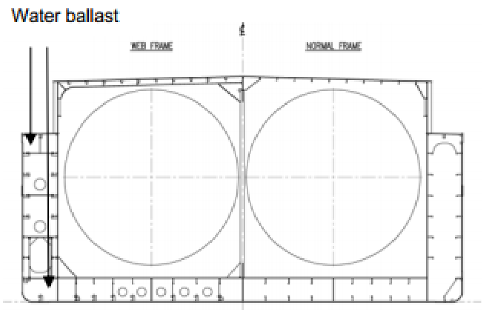

Figure 2.12 Type C Independent Tank Cross-Sectional View[12]

2.6. Regasification

To utilize LNG, the LNG must be converted to gas form by heating up the LNG from −161℃ back to natural gas at

[11] Source: Strength Analysis of Independent Type C Tanks (DNV Rules, 2013)

[12] Source: International Safey Guide for Inland Navigation Tank-Barges and Terminals (OCIMF, 2010)

atmospheric temperature. There are several methods to regasificate the LNG user can use according to LNG Vaporizer Selection Based on Site Ambient Condition Article (Patel, 2013) such as;

1. Open Rack Vaporizer (ORV)

Open rack vaporizer (ORV) is a vaporizer which use seawater as its heat source. The heat is distributed to LNG using heat exchanger. An ORV usually constructed with a material that able to work in extremely cold environment like alumunium alloy. For the seawater pipe, ORV panels are coated with zinc alloy to increase corrosion protection caused by seawater.

For large ORV plant, there are several considerations like seawater chemical content, seawater particles (e.g. sand, suspended solids) which have potential to damage the pipe, chlorination to slow down the marine growth, temperature, backup system, and environmental impact.

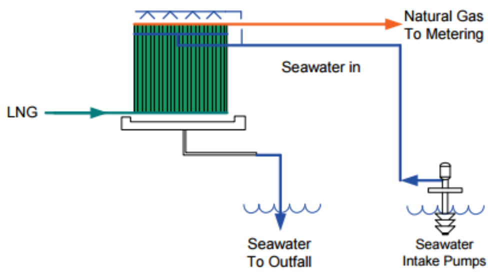

Figure 2.13 Open Rack Vaporizer Flow Scheme[13]

[13] Source: LNG Vaporizer Selecteion Based on Site Ambient Conditions (Dhirav, 2013)

2. **Submerged Combustion Vaporizers (SCV)**

   Submerged combustion vaporizer use fuel gas combustion as heat sources and usually used during winter times, fuel gas for SCV methods usually came from the LNG storage boil-off gas due to high cost of fuel.

   In SCV method, LNG flows through stainless steel tube coil which submerged in a water tank. The water tank is heated by hot-flue gas from submerged gas burner. The heat from the gas burner is transferred by water to the stainless steel tube coil. Due to its combustion process, SCV which submerged inside the waterbaths is vulnerable to corrosion by acid as the combustion gas products (CO_2) are condensed in the water.

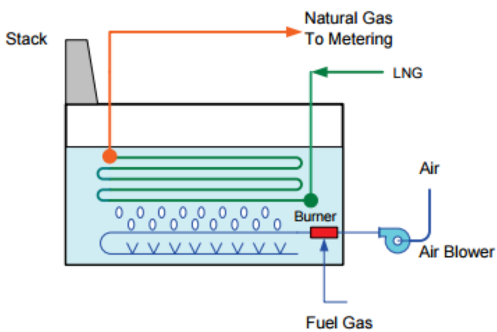

Figure 2.14 Submerged Combustion Vaporizers[14]

3. Ambient Air Vaporizers (AAV)

   Ambient air vaporizer use air as its heat source, air is a free and permit-free heat source, unlike SCVs which produce greenhouse gases and ORV which may damage the environment.

---

[14] Source: LNG Vaporizer Selecteion Based on Site Ambient Conditions (Dhirav, 2013)

Direct ambient air vaporizer use vertical heat exchanger where the LNG pipes is exposed to an open air. Due to low heat transfer, AAV usually use in smaller terminals and require more vaporizer to achieve same performance level with other regasification methods. In this method, Air is flowing from the upper side of the heat exchanger and flowing to the downside of the heat exchanger due to its density increasing as the air temperature decreasing.

AAV methods requires monitoring every 4-8 hours to clean the ice buildup on the LNG pipes, the ice buildup occurs because of the extreme temperature difference and create a condensation process, then condensed water frosted. The performance of AAV is very depend on the environment such as temperature, relative humidty, altitude, wind, solar radiation and its structure.

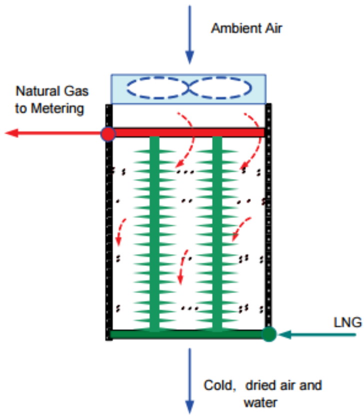

Figure 2.15 Ambient Air Vaporizer[15]

4. Intermediate Fluid Vaporizers (IFV)
An intermediate fluid vaporizer use heat transfer fluid (HTF) in a closed loop to vaporize the LNG, there are several type of

[15] Source: LNG Vaporizer Selecteion Based on Site Ambient Conditions (Dhirav, 2013)

heat transfer fluid can be utilized in this regasification method like Glycol-Water, Hydrocarbon Based Fluid, and Hot Water.

- Glycol-Water Intermediate Fluid Vaporizer
  This IFV method use ethylene glycol or propylene glycol as heat transfer media. The intermediate fluid flows in shell and tube exchanger where warm glycol-water flows to the vaporizer to rejects its heat.

  To warm the glycol-water, several heat source may be used like air heater, reverse cooling tower, seawater heater, and waste heat recovery system.

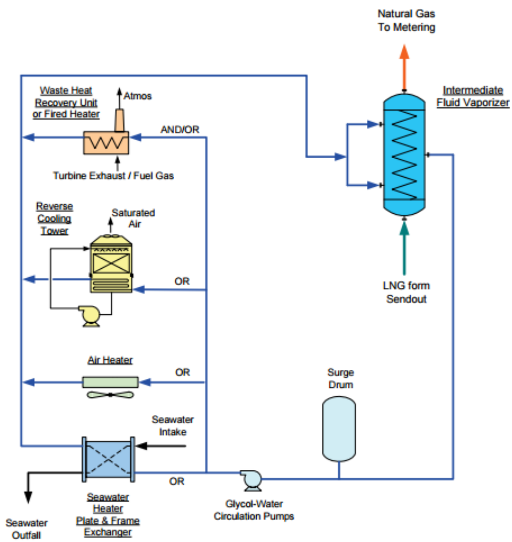

Figure 2.16 Glycol-Water Intermediate Fluid Vaporizer[16]

[16] Source: LNG Vaporizer Selecteion Based on Site Ambient Conditions (Dhirav, 2013)

- Intermediate Fluid (Hydrocarbon) in Rankine Cycle

  In intermediate fluid vaporizer which use hydrocarbon as heat transfer media, propane, butane or other hydrocarbon refrigerant may be used as heat transfer fluid (HTF).

  This type of vaporizer use 2 stage heat exchanger where the first stage, the LNG is heated partially using the propane, and the second heat exchanger is using seawater to heat the LNG. This method is reducing the amount of seawater used in ORV method and avoid sea water freezing since the seawater is exposed to the LNG at the second stage.

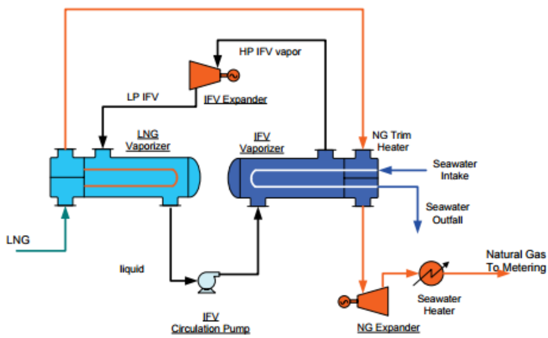

Figure 2.17 IFV LNG Vaporizer in Rankine Cycle[17]

2.7. Gas Valve Unit

The main function of gas valve unit (GVU) is to regulate the flow of natural gas to the engine. The other function of GVU is to ease the process of shutdown of the gas supply. Based on International Code of Safety for Ships Using Gas Fuels (IGF Code) statement that every gas consuming equipment need to be provided with set of “double block and bleed” valves.

[17] Source: LNG Vaporizer Selecteion Based on Site Ambient Conditions (Dhirav, 2013)

Double block and bleed valves is a valve consist of two quick acting closing valves and a vent valves between the quick acting closing valves. The block valves are arranged in series to create a redundant system as written in The Wartsila Gas Valve Unit Enclosed Design for Marine Application Publication (Karlsson, 2013).

2.8. Supporting System of the Engine

An engine is not simply converting chemical energy into mechanic energy where there is only fuel supply system to keep the engine running. Based on COMPENDIUM Marine Engineering (Bernhhardt eds., 2009) there are supply and disposal system like fresh water system, lubrication oil system, cooling water system, fuel system, compressed air system, etc.

2.8.1. Cooling Water System

Cooling water system is a system to keep the engine running in proper temperature. The task of cooling system is to dissipate heat from the engine coolers and other coolers.

Based on COMPENDIUM Marine Engineering (Bernhhardt eds., 2009) there are 2 types of common cooling systems which is decentralized cooling water systems, and centralized cooling water system.

Decentralized system is using seawater as a cooling media where the seawater directly flow into several cooler for each equipment while centralized system is connecting all equipment coolers in one closed-loop fresh water system and connected into one central cooler where seawater is only flowing through the central cooler.

The advantage of decentralized cooling system are simple temperature control operation and for centralized system, it has less maintenance due to isolated system from seawater. The disadvantages of decentralized system is, the system will consume more time for maintenance while for centralized system, the system are very prone to changing flow rate due to its low-quantity circulation. Figure 2.18 below illustrate the example of centralized engine cooling system from MAN Project Guide.

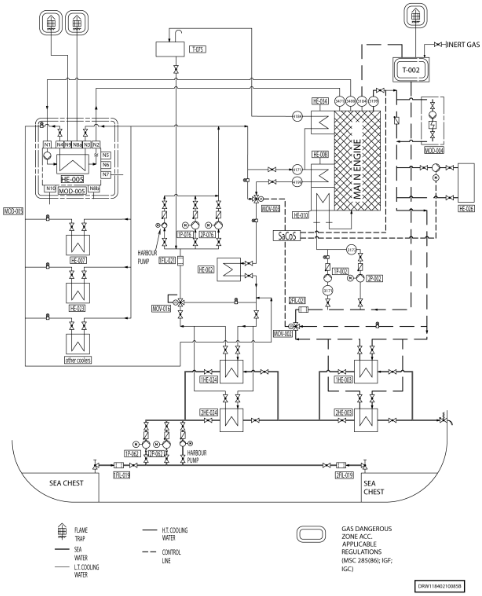

Figure 2.18 Cooling Water System Diagram[18]

2.8.2. Fuel Oil System

The fuel system of a ship encompasses procurement, storage, and the treatment of fuel and its supply systems based on COMPENDIUM Marine Engineering (Bernhhardt eds., 2009) where the major system is fuel treatment and fuel supply to the engine.

In the treatment system, foreign substance are eliminated from the fuel and the properties of the fuel such as viscosity is being regulated. While the supply system is mostly regulating the flow rate of the fuel which travels to the engine and its pressure so the engine can be operated at proper rate.

18 Source: MAN 51/60DF Project Guide

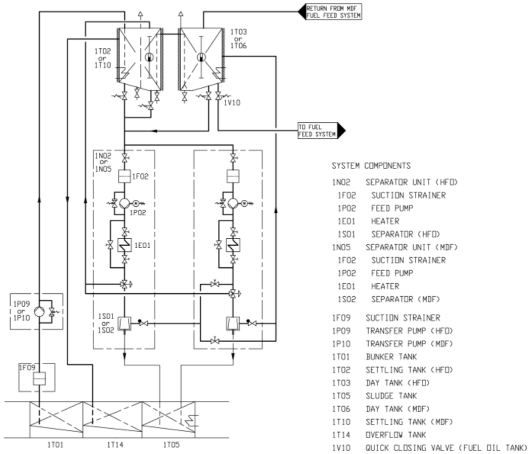

Figure 2.19 Fuel Oil System Diagram[19]

Figure 2.19 above illustrate the fuel treatment system from Wartsila diesel engine, based on several medium-speed diesel engine the treatment system are quite similar where the main components is the heater and separator to purify the fuel.

2.8.3. Lubrication Oil System

Lubrication system is a system that contain media to lubricate the engine during its operation. The function of the media is to reduce the friction between each moving parts inside the engine and also to dissipate the heat generated by friction.

Based on COMPENDIUM Marine Engineering (Bernhhardt eds., 2009) a forced circulatory lubrication is used to fulfilled the task of lubricating, cooling, and protect the parts from corrosion and it's usually applied in large engines where the lubrication oil system is a closed-loop circulation with specific lube oil as media.

[19] Source: Wartsila 32 Project Guide

The design of lube oil system may differ from each engine manufacturers such as the sump tank, type of lube oil, or the properties of lube oil.

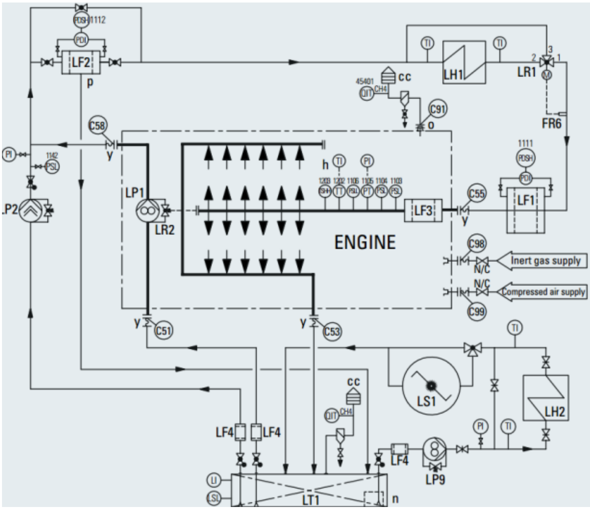

Figure 2.20 Lubricating Oil System Diagram[20]

Figure 2.19 may illustrate the general lube oil system configuration where lube oil are being pumped by the service pump which is engine driven or using stand-by pump (classification societies regulation) to the engine. The main components of the lube oil system is the preheater, lube oil cooler and the pump itself where the requirement of the equipment may differ from each engine.

2.8.4. Compressed Air System

To start an engine onboard ship, compressed air is more common used rather than electric motor due to the size of the engine and the power required to make an initial movement for the engine's parts.

---

[20] Source: CAT VM 46 DF Project Guide

Based on several project guides like MAN 51/60 DF, Wartsila 50DF, the size of the compressed air system is depends on the engine requirement, operation scenario, and classification societies regulation.

The key equipment in compressed air system is the service compressors or main compressor, stand-by compressors which has been classification societies regulation, and the size of air vessels. The size of air vessels are related to the engine operation and number of engine. Based on Germanischer Lloyd's Regulation, there are minimal capacity of air vessels for single -engine plant and also maximum capacity for multi-engine plant.

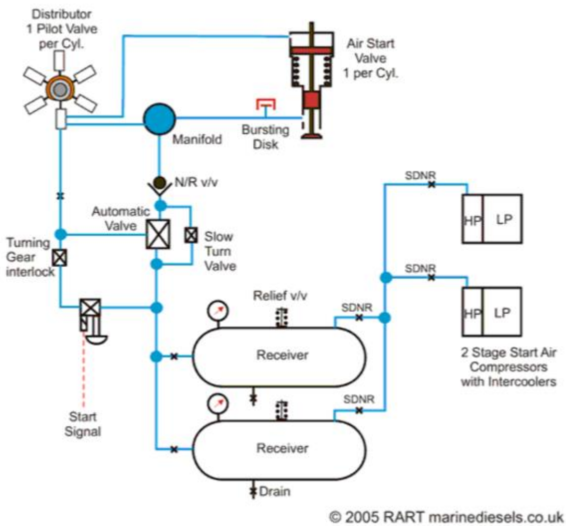

Figure 2.20 Compressed Air System Diagram[21]

Figure 2.20 illustrate a process diagram of the starting air system where the compressors fill the air vessels with compressed air. The compressed air inside the air vessels can

[21] Source: [online] http://www.marinediesels.co.uk

be distributed to each piston using manifold where the manifold will distribute the pressurized air into the piston with specific sequences. The pressurized air can be utilized for another system which required pressurized air such as horn, hydrophore, etc.

CHAPTER III
METHODOLOGY

To develop this report and to achieve the result, a proper methodology and analysis are required. In this chapter, the methodology of the research will be described step-by-step from early attempt to determine the engine until the general arrangement of the conceptual design ship is done.

3.1.Methodology Description

1. Statement of Problems
   This stage is an early stage to construct the thesis. In this stage, questions and problems are being prepared specifically in order to determine the specific objectives of this thesis. The content of the thesis is to overcome the statement of the problems mentioned earlier and it will be done by collect some information about the problems. Therefore, the purpose of this thesis can be understood in this stage.

2. Literature Study
   Right after the problems is raised, a literature study is performed. In this stage, literature will be use to connect the problems with existing theories and facts from various sources. Since this thesis is an implementation of many aspects disciplines, various literature topics is required to be constructed into one project. The study of literature is done by reading papers, journals, thesis, media and literature books that relates and able to support this thesis.

3. Collecting Data
   After literature study which support the thesis has been done, collecting data is being performed. Data collection is done by gather information to develop the conceptual design, most of data is available from the engine manufacturer, classification societies, countries regulation

and several conventions which provide statutory rules. The data which may support this thesis is the engine specification (diesel, turbine and generator), auxiliary unit specification, barge dimension, classification and convention regulation and engineering drawing of each equipment.

4. Determine the Powering Machinery
   This stage is conducted by study the data from engine manufacturer. By studying the engine power output without neglecting other aspects such as the weight and the dimension required by the engine the amount of engine and type of engine can be determined to reach the expected output power.

   The type of the engine also need to be determined. The consideration of those type of engine are fuel efficiency, power output and which one is the most suitable as powerplant.

5. Determine the auxiliary equipment
   This stage is required to create a system which able to support the operation of powering machinery, the most essentials equipment required to a gas fuelled engine is gas valve unit, regasification equipment, alternator, and several other system that may support the operation of the engine.

   The output of this stage is the required equipment that meet the requirement of the engine and the system configuration for each system where the system configuration will be arranged according the project guide recommendation and classification societies regulation.

6. Calculate the Fuel Consumption and Storage Arrangement
   In this stage, the engine specification for fuel consumption is considered. The fuel consumption is required to calculate the storage capacity to store the fuel for certain

time of operation. The fuel consumption of an engine is calculated by using the specific fuel oil consumption (SFOC) which is difference for every engine and the load of the engine.

Since duel fuel engine use two type of fuel which is the liquid fuel and the gas fuel, the amount of fuel need to be calculated by using equation 3 for liquid fuel;

$$V[m^3] = \frac{SFOC\left[\frac{g}{kWh}\right]\times Load[kW]\times Time[h]}{\rho\times 1000} \quad (3.1)$$

In equation 3, we could see that the volume of the fuel can be calculated by collecting the SFOC, load, time, and the density information. For the natural gas consumption, we could use equation 4;

$$NG\ consumption\ [kJ] = SFOC\ \left[\frac{kJ}{kWh}\right]\times Load\ [kW]\times Time\ [h] \quad (3.2)$$

In the equation 4, we could see that the calculation output is in kilojoule and need to be converted to volume unit. Based on Alberta Energy website, 1 gigajoule [GJ] of natural gas are equal with 26.84 cubic metres $[m^3]$ of natural gas.

$$Vng\ [m^3] = NG\ consumption\ [kJ]\times 26.84\times 10^{-6} \quad (3.3)$$

The natural gas volume may be reduced $\frac{1}{600th}$ or 0.001667 from its original volume by liquefying the natural gas, then to convert the natural gas volume to liquefied natural gas volume we could use equation 6;

$$Vlng\ [m^3] = Vng[m^3]\times 0.001667 \quad (3.4)$$

Or using a table from Natural Gas Conversion Guide, International Gas Union (IGU)

$1\ ft^3 = 1055\ kJ$

Calculate the Capacity of Pontoon’s Tanks for Fuel

A pontoon is built with several tank inside the hull, the tanks is dedicated for specific usage. Therefore, the capacity of the tank inside the pontoon need to be calculated and then compared with the fuel consumption of the LNG mobile power plant. If in this stage the capacity of pontoon’s tank is less than the required capacity of the engine fuel consumption, then we will back to the step before, especially design the stan-pontoon.

7. General Arrangement
   After every consideration is met the requirement, then the general arrangement can be drawn. General arrangement must use every consideration which has been calculated and determined before such as the powering machinery, auxiliary equipment, tank arrangement. In the general arrangement, an accommodation structure for ship’s crew and control system will be arranged.

3.2 METHODOLOGY FLOW CHART

The methodology flowchart of this report can be seen in figure 3.1 below.

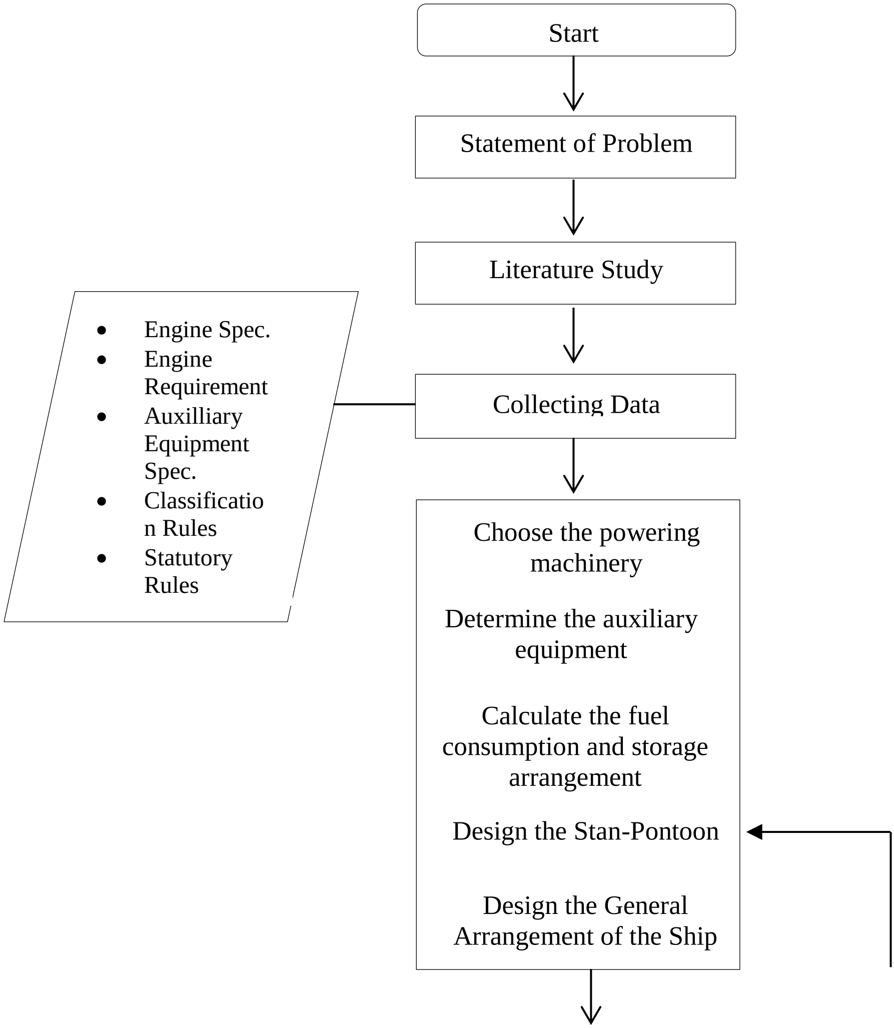

Figure 3.1 Methodology Flow Chart Diagram

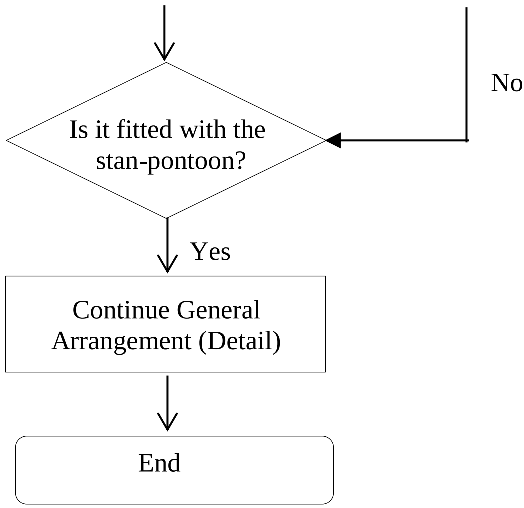

Figure 3.1 Methodology Flow Chart Diagram (Cont)

CHAPTER IV
ANALYSIS

In this chapter, the process to develop the ***Conceptual Design of 100 MW LNG Mobile Power Plant*** is explained. The description, summary of calculation, selected products / type of equipment are informed in this chapter while most of the detail calculation are written in the attachment. Every sub-chapter are related to the other chapter since every chapter may be done in parallel.

4.1. Engine Criteria

To determine the type of the engine, there are several aspects need to be considered by the designer in order to achieve the goal. In this thesis, the selection process carried out by considering some factors as below;

1. Engine maximum power output

   Each engine has their own power output depend on its design, arrangement and technology. The power output of the engine also related to the speed or torque during operation.

   The power output of the engine need to be considered because to achieve the required power output for the mobile power plant, several engines will be installed. The greater the power output of each engine means fewer engine will be installed but it also will affect other aspects such as dimension and performance.

2. Engine dimension and weight

   Since the project in this thesis is to develop a power plant built on a vessel which has a limitation in space and buoyancy, engine dimension and weight need to be considered. The chosen engine shall have the proper dimension and weight so it will fit in the vessel and also able to develop the required power output.

Engines with smaller power output tend to have smaller dimension and lighter weight while engines with greater power output usually have bigger dimension and also heavier. Therefore, smaller dimension of the engine doesn’t mean it’s better.

3. Fuel consumption

The fuel consumption of the engine is varying depend on the engine type and its operational load. For example, an engine will have different Specific Fuel Oil Consumption (SFOC) depend on its load percentage.

The fuel consumption of the engine need to be considered because it will lead to the fuel storage volume requirement and the arrangement of the fuel storage.

4.2. Choosing the Engine

Since the title of the project is ***Conceptual Design of 100 MW LNG Mobile Power Plant***, the requirement of the mobile power plant is to use an engine which produce 100 MW of power. To determine the engine, the several aspects listed in chapter 4.1 need to be considered.

a. Diesel Engine

At table 4.1, several engines are listed based on the data available on the market. In Table 4.2 the Specific Fuel Oil Consumption (SFOC) and Specific Gas Fuel Consumption (SGFC) is informed. The SFOC and SGFC in Table 4.2 are the result of the interpolation due to limited data available, the complete result of the SFOC and SGFC can be seen in **Attachment 1: SFOC and SGFC Calculation**

Table 4.1 Diesel Engine Dimension and Maximum Power Comparison

Manufacturer	Type	Technical Data				
		L mm	W mm	H mm	Weight T	BHP max kW
MaK	16VM46DF	11880	4016	6168	220	15440
Wartsila	16V46DF	12687	5174	5480	235	18320
Wartsila	18V50DF	14180	4730	5100	244	17550
MAN B&W	18V51/60DF	13544	4713	5517	265	18000

Table 4.2 Diesel Engine SFOC and SGFC Comparison

Manufacturer	Type	Technical Data	
		SFOC (at operation rate) $[{}^{g}/_{kW-h}]$	SFGC (at operation rate) $[{}^{kJ}/_{kW-h}]$
MaK	16VM46DF	1,295	7432,57
Wartsila	16V46DF	1,016	7431,07
Wartsila	18V50DF	1,224	7388,79
MAN B&W	18V51/60DF	2,434	7318,99

For dimension and weight aspects, it cannot be determined which one is better since this project doesn't use single engine, but multiple engine to achieve 100 MW of Electricity. Based on MAN Guidelines for Electric Plants, typical diesel electric plants will have 5.7% of losses (approximately) after frequency converter or before the consumer, the value of the losses is shown in Table 4.3 below. The value of losses may vary depend on the equipment efficiency itself. Assuming all of the engine will be operated with BHPscr of 90% BHPmcr, then the number of engine installed will be shown by table 4.4;

Table 4.3 Typical losses in Diesel-Electric Plants MAN 51-60DF

Equipment	Losses
Alternator	3% - 4%
Main Switchboard	0.2%
Supply Transformer	1%
Frequency Converter	1.5%
Consumer	Depend on the equipment

Table 4.4 Diesel Engine Electric Power Output and Required Engine Comparison

Manufacturer	**Type**	**Technical Data**				**No. of Engine**	**Load Rate [%]**
		BHPmcr [kW]	**BHPscr [kW] each**	**Eff %**	**E-Power Output [kW]**		
MaK	16VM46 DF	15440	13255,567	94,3	100000	8	85,85
Wartsila	16V46DF	18320	15149,220	94,3	100000	7	82,69
Wartsila	18V50DF	17550	15149,220	94,3	100000	7	86,32
MAN B&W	18V51/60 DF	18000	15149,220	94,3	100000	7	84,16

From the required engine, we may check the project guide to know the minimum space required for multiple-engine plant. The minimum space required and total weight is shown in Table 4.5 and being compared in chart in Figure 4.1 for area required, Figure 4.2 for total weight and Figure 4.3 for the engine load rate.

Table 4.5 Diesel Engine Total Weight of The Engine and Required Area Comparison

Manufacturer	**Type**	**Total Weight[1] [t]**	**Area Required[2] [m^2]**
MaK	16VM46DF	1760	546,7332
Wartsila	16V46DF	1645	671,9554
Wartsila	18V50DF	1708	651,7953
MAN B&W	18V51/60DF	1855	645,0654

(1) Total weight is the engine weight multiply by the number of the engine required to achieve 100MW of electricity

(2) Area required for the engine is calculated by sum up the dimension of the engine (without the alternator and other equipments) and the space required between each engine and for maintainability.

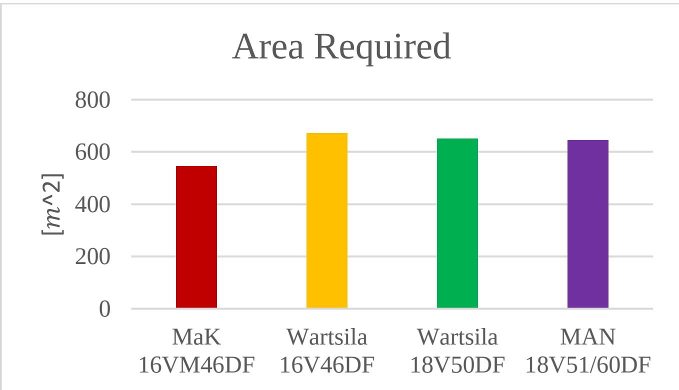

Figure 4.1 Engine Area Requirement Chart

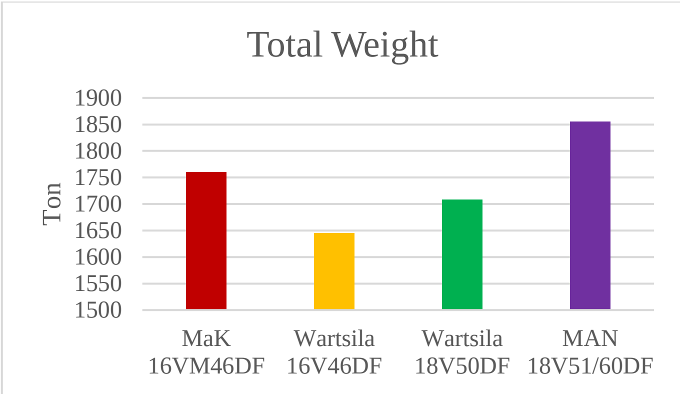

Figure 4.2 Engine Total Weight Chart

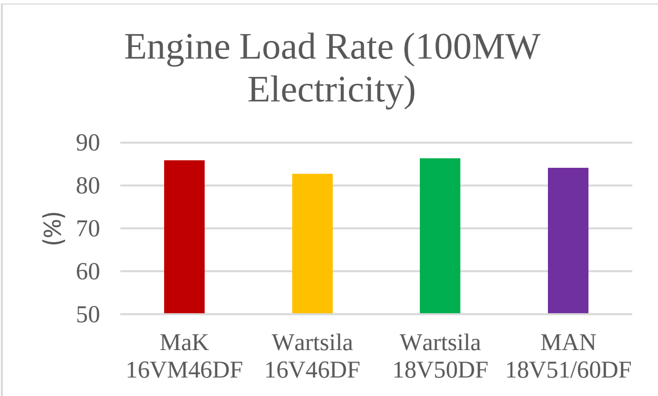

Figure 4.3 Engine Load Rate for 100 MW of Electricity Chart

Specific gas and fuel consumption of the diesel engine are related to the operational load of the engine itself. When the engine are operated at low load, the specific gas or fuel oil consumption may getting higher, the value of the specific gas fuel consumption (SGFC) and specific fuel oil consumption (SFOC) were given from the project guide/technical guide, so every engine may have difference specific fuel oil consumption or gas fuel consumption.

Assuming the plant will be operated at various load, which may affect the fuel consumption, Table 4.6 is created to inform the result of the calculation of the engine specific fuel consumption at various load. The behavior of the engine which is shown in Table 4.6 is projected into a graph in Figure 4.4.

Table 4.6 Diesel Engine SGFC and Load Rate at Various Electricity Load Comparison

Type	**Electricity Load**								
	100 MW			**90 MW**			**80 MW**		
	Load Rate	**Engine**	**SGFC** $kJ/_{kWh}$]	**Load Rate**	**Engine**	**SGFC** $kJ/_{kWh}$	**Load Rate**	**Engine**	**SGFC** $kJ/_{kWh}$
MaK 16VM46 DF	85,85	8	7407,309	88,30	7	7378,41	78,49	7	7507,58
Wartsila 16V46DF	82,69	7	7431,036	86,82	6	7376,37	77,17	6	7514,59
Wartsila 18V50DF	86,3	7	7388,789	77,68	7	7515,53	80,56	6	7469,48
MAN 18V51/60 DF	84,16	7	7318,989	88,37	6	7306,67	78,55	6	7346,64

Table 4.6 Diesel Engine SGFC and Load Rate at Various Electricity Load Comparison (Cont.)

Type	Electricity Load								
	70 MW			60 MW			50 MW		
	Load Rate	Engine	SGFC $kJ/_{kWh}$	Load Rate	Engine	SGFC $kJ/_{kWh}$	Load Rate	Engine	SGFC $kJ/_{kWh}$
MaK 16VM46 DF	80,12	6	7483,537	82,41	5	7451,56	85,85	4	7407,309
Wartsila 16V46DF	81,03	5	7454,823	86,82	4	7376,37	72,35	4	7597,727
Wartsila 18V50DF	84,59	5	7411,402	72,50	5	7608,01	75,53	4	7552,572
MAN 18V51/60 DF	82,47	5	7325,932	88,37	4	7306,67	73,64	4	7381,494

Table 4.7 Diesel Engine Fuel Consumption per Day to Produce 100 MW of Electricity Comparison

Type	SGFC(1) $kJ/_{kW-h}$	Total BHPscr [kW]	NG Consumption per Day $[m^3/_{day}]$
MaK 16VM46DF	7407,309	106044,538	505990,685
Wartsila 16V46DF	7431,036	106044,538	507611,468
Wartsila 18V50DF	7388,789	106044,538	504725,590
MAN 18V51/60DF	7318,989	106044,538	499957,577

Table 4.7 Diesel Engine Fuel Consumption per Day to Produce 100 MW of Electricity Comparison (Cont.)

Type	LNG Consumption per Day $[m^3/day]$	LNG Consumption per Day $[mmBTU/day]$	Oil Consumption per Day $[m^3/day]$	Oil Consumption per Day $[g/day]$
MaK 16VM46DF	843,3178094	17868,352	3,704	137373,4
Wartsila 16V46DF	846,0191145	17925,587	2,905	107745,1
Wartsila 18V50DF	841,2093182	17823,677	3,501	129803,3
MAN 18V51/60DF	833,2626289	17655,301	6,960	258116,7

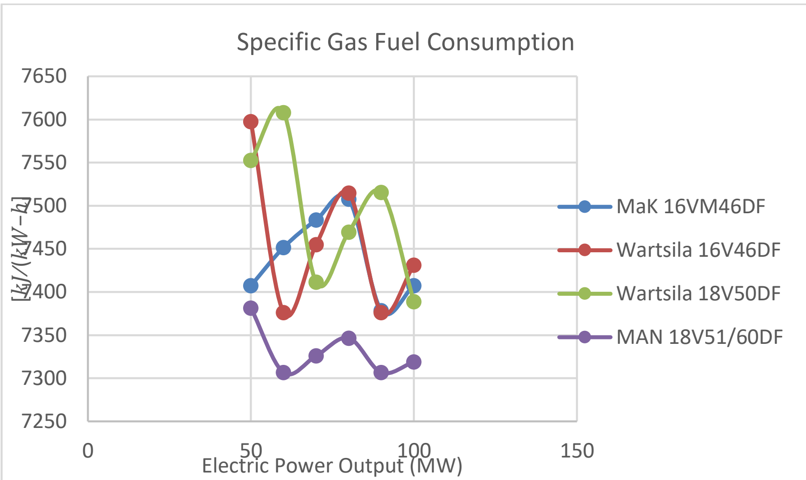

Figure 4.4 Engine SGFC - Electric Power Output Comparison Graph

Based on Figure 4.4, we may see that MAN 18V51/60 DF perform better compared to the other engine when operated at various load. Other engine tends to have superiority only in particular load.

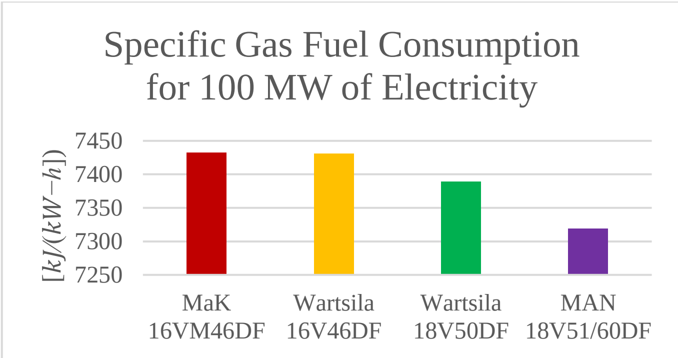

Figure 4.5 Engine SGFC for 100 MW of Electricity Chart

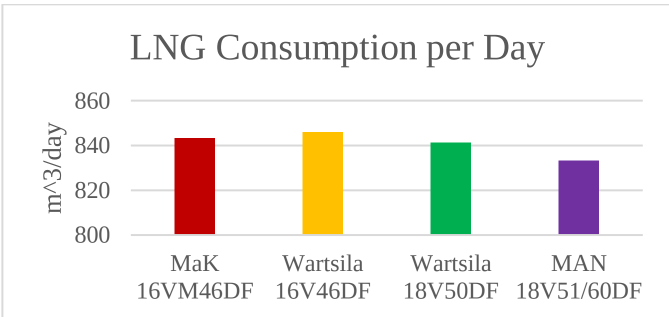

Figure 4.6 Engine LNG Consumption for 100 MW of Electricity Chart

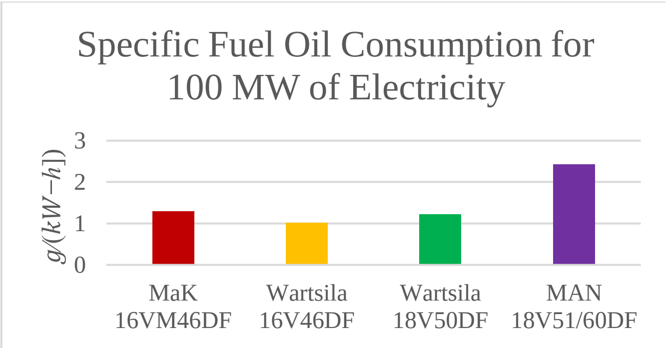

Figure 4.7 Engine SFOC for 100 MW of Electricity Chart

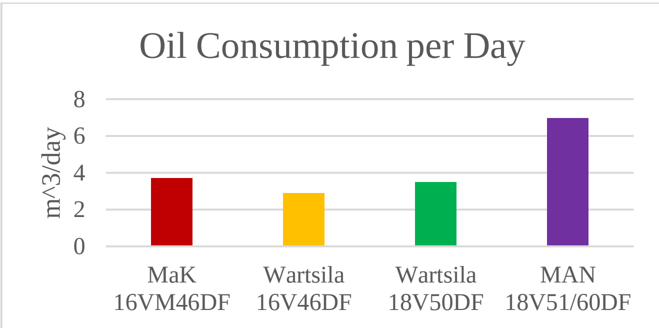

Figure 4.8 Engine Fuel Oil Consumption for 100 MW of Electricity Chart

The calculation for the Specific Gas Fuel Consumption (SGFC) at graph 4.4 and Specific Fuel Oil Consumption (SFOC) from graph 4.5 are in the attachment 1.

Based on the data, the Specific Gas Fuel Consumption (SGFC) to determine the engine since the gas fuel consumption will affect greatly the next step which is determine the auxiliary unit, and storage. Regarding the space required and the weight of the engine, there are no significant difference, therefore this aspect will be neglected.

MAN 18V51/60 DF has superiority in gas fuel consumption. This engine is chosen as the engine for the 100 MW LNG Mobile Power Plant for diesel engine type.

b. Gas Turbine

At table 4.8, several gas turbine is listed based on the data available on the market.

Table 4.8 Gas Turbine Dimension and Maximum Power Comparison

Manufacturer	Type	Technical Data					
		L[mm]	W[mm]	H[mm]	Weight [T]	Peak Load[kW]	Base Load [kW]
General Electric	HD 6B.03	12400	4100	4100	100	44000	37536
General Electric	TM2500	28025(1)	15594(1)	4020	61	30700	26190

(1) The dimension are included with intake filter, alternator, gas turbine, and switchgear

Due to the limited data, the specific fuel oil consumption and specific gas fuel consumption only available for the base load, the information is not available for various load. Therefore, the calculation for various load can't be conducted and for gas fuel consumption calculation, the base load's SGFC will be used.

Table 4.9 Gas Turbine SFOC and SGFC Comparison

Manufacturer	Type	Technical Data	
		SFOC(3) (at operation rate) $[{}^{g}/_{kW-h}]$	Est. $^{kJ}/_{kW-h}$' (LHV)
General Electric	HD 6B.03	-	10740(1)
General Electric	TM2500	-	10356(2)

1. Based on GE Power Play Insight PowerGen Tools
2. Based on data from PT.PP for MPP PLTG Lombok
3. SFOC for Pilot Fuel

Table 4.10 Gas Turbine Engine Electric Power Output and Required Engine Comparison

Manufacturer	Type	Technical Data			Engine Required [f/ 100MW]	Load Rate [%]
		Peak Load [kW]	Operated Load[kW]	E-Power Output [kW]		
General Electric	HD 6B.03	44000	33333,334	100000	3	75,76
General Electric	TM2500	30700	25000	100000	4	85,81

Table 4.11 Gas Turbine Total Weight of The Engine and Required Area Comparison

Manufacturer	Type	Total Weight[1] [t]	Area Required[m^2]
General Electric	HD 6B.03	300	1146,951[2]
General Electric	TM2500	244	2118,778[3]

(1) Total weight is the engine weight multiply by the number of the engine required to achieve 100MW of electricity

(2) Area required for the engine is calculated by sum up the dimension of the engine (without the alternator and other equipments) and the space required between each engine and for maintainability.

(3) Area required for the engine is calculated by sum up the dimension of the engine and all of its auxiliary system and the space required between each engine and for maintainabilty

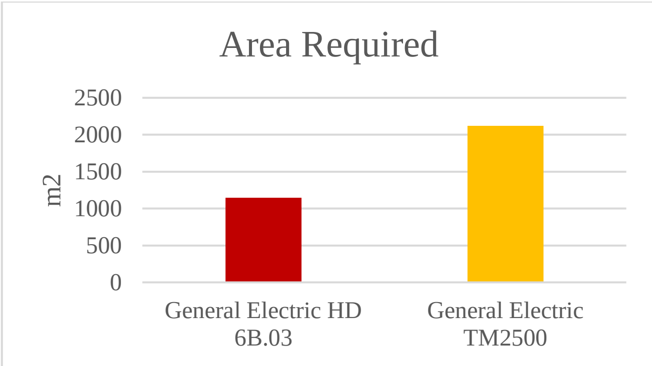

Figure 4.9 Gas Turbine Area Requirement Chart

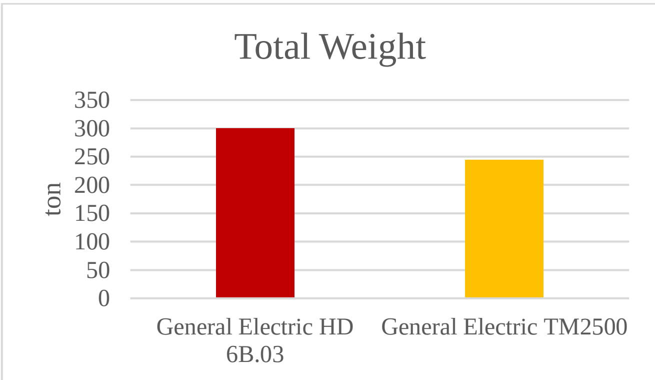

Figure 4.10 Gas Turbine Total Weight Chart

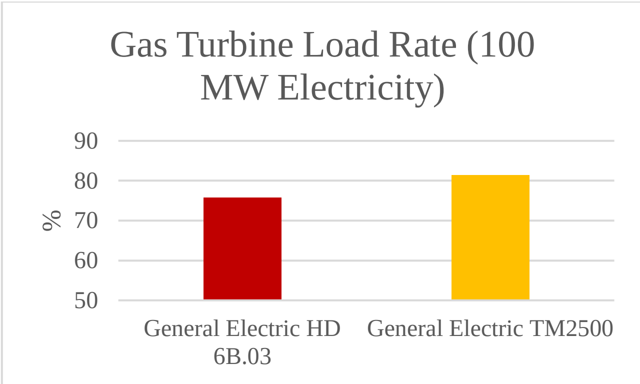

Figure 4.11 Gas Turbine Load Rate for 100 MW of Electricity Chart

To calculate the gas fuel consumption per day, Specific Gas Fuel Consumption (SGFC) that available from the manufacturer will be used. The result of the calculation is shown by table 4.12 and then visualized in the figure 4.12 and 4.13

Table 4.12 Gas Turbine Fuel Consumption per Day to Produce 100 MW of Electricity Comparison (Cont.)

Type	Est. kJ/kWh, LHV	Electricity Load kW	Gas Consumption GJ/day	NG Consumption per Day m^3/day	LNG Consumption per Day m^3/day	LNG Consumption per Day $mmBTU$
General Electric HD 6B.03	10740 (1)	100000	25776,0	691827,84	1153,046	24430,930
General Electric TM2500	10356 (2)	100000	24854,4	667092,096	1111,821	23557,422
1. Based on GE Power Play Insight PowerGen Tools 2. Based on data from PT.PP for MPP PLTG Lombok						

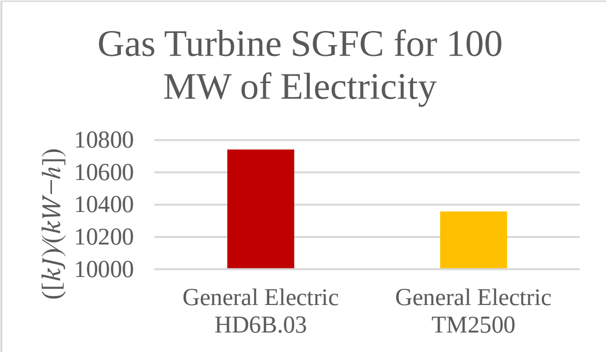

Figure 4.12 Gas Turbine SGFC for 100 MW of Electricity Chart

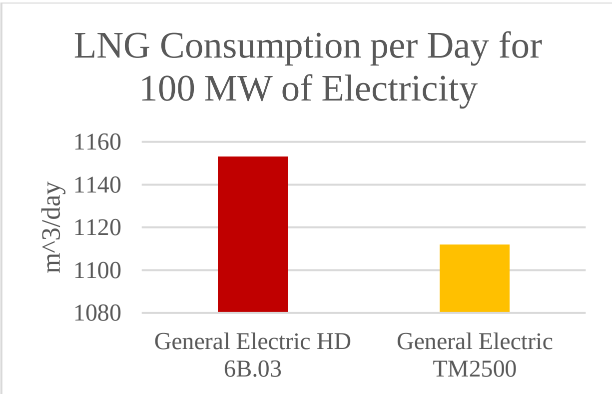

Figure 4.13 Gas Turbine LNG Consumption per Day for 100 MW of Electricity Chart

In gas turbine type, General Electric TM 2500 has superiority in several aspects, especially in gas consumption per day compared to General Electric HD 6B.03. The area required for the General Electric TM 2500 is slightly bigger than General Electric HD 6B.03 because it includes the auxiliary equipment.

The chosen engine for ***Conceptual Design of 100 MW LNG Mobile Power Plant*** is MAN 18V51/60 DF due to its superiority in gas fuel consumption per day. Compared to General Electric TM2500, MAN 18V51/60 DF still has better gas fuel consumption.

4.3. Auxiliary Equipment

Auxiliary equipments are an equipment that required to provide additional support to operate the mobile power plant. In this thesis, the auxiliary unit is focusing on engine supply system especially the fuel. In this sub-chapter, regasification unit, alternator, BOG compressor and condenser, LP-HP pump will be determined.

4.3.1. Electrical Equipment

a. Alternator

Alternator are type of electricity generator that produce alternating current by converting mechanical energy to electricity energy. Based on the information from MAN, to use MAN 18V51/60 DF as a generator or operated as GenSet, the engine may be coupled with ABB AMG 1600[22]. GensSet specification shown in table 4.13.

Tabel 4.13 Alternator Dimension, Specification, and Installation Design

Alternator	ABB AMG Generator	
Model	AMG 1600 Q DSEB	
Dimension		Measurement Unit
Height	4660	mm
Length	4465	mm
Width	4050	mm
Weight	67	ton
Specification		
Nominal output	20000	kVa
Power Factor	0,8	
Speed	500	RPM
Frequency	50 ±5%	Hz
Eff.	97	%

[22] MAN Document ***DRW 11745000697 Diesel Generator Set*** for type 18V 48/60, 51/60DF/G (2003). Drawn by J. Stroeher, Checked by Suhr.

Tabel 4.13 Alternator Dimension, Specification, and Installation Design (Cont.)

Installation Design		
No. of Alternator Required	7	Unit
Total Weight	134	ton

4.3.2. Gas Fuel Supply System and Equipment

Gas fuel supply system is system that designed to meet the requirement of the engine when it's operated at specific load. In this design, the calculations were done for static load which is the daily average load and full load.

The gas fuel supply system process begin at the LNG storage where the natural gas is in liquid phase. The LNG will be transported to the vaporizer using low pressure pump while the boil-off gas inside the storage will be compressed to the main gas fuel lines or to the gas combustion unit. The LNG inside the vaporizer will be heated by temperature-regulated fresh water, in the outlet of the vaporizer, the natural gas will have phase changed from liquid into gas phase.

The natural gas from the vaporizer will be received by the engine's gas-valve unit located on the main deck, near the engines. Where every connection in the open spaces will use a double pipes flowline.

All calculation to determine the requirement for gas fuel supply system are attached in the attachment 2. The following text are the result or an overview of the selected design.

a. Vaporizer

Based on the requirement of gas fuel per day of MAN 18V51/60 DF on previous chapter, the vaporizer can be determined. Table 4.14 shows the requirement of gas fuel to operate the Mobile Power Plant (MPP).

Table.4.14 Gas Fuel Consumption Requireminet of the Engine

Type	**NG Consumption per Day** $[m^3/day]$	**NG Consumption per Day** $[m^3/hr]$	**LNG Consumption per Day** $[m^3/day]$	**LNG Consumption per Day** $[m^3/hr]$
MAN 18V51/60DF	499957,577	20831,565	833,262	34,719

The vaporizer used in this Conceptual Design of 100 MW LNG Mobile Power Plant is
water heated vaporizer. The reason to use water heated vaporizer is because ambient air vaporizer required very large dimension while electric vaporizer has very small capacity.

The vaporizer capacity should be able to supply the gas fuel during maximum load. The chosen vaporizer is shown in table 4.15 where it has higher capacity to supply cluster 1, 2, and 3 while Table 4.16 shows cluster 4 vaporizer

Table 4.15 Vaporizer Cluster 1, 2 and 3 Dimension, Specification and Installation Design

Vaporizer Type	**Water Heated Vaporizer VWU Series**	**Cluster 1,2,3**
Model	**VWU - 182**	
Dimension		**Measurement Unit**
Height	915	mm
Length	3353	mm
Width	762	mm
Weight		
Inlet Connection	75	mm
Outlet Connection	100	mm
Specification		
Capacities	6572	Nm^3/hr
Shell Side Nozzle Size	150	mm
Flow rate @ 180F	1703	l/m

Table 4.15 Vaporizer Cluster 1, 2 and 3 Dimension, Specification and Installation Design (Cont.)

Installation Design		
No. of Vaporizer Required	3	Unit
Total Capacity	19716	$Nm^3/_{hr}$

Table 4.16 Vaporizer Cluster 4 Dimension, Specification and Installation Design

Vaporizer Type	**Water Heated Vaporizer VWU Series**	**Cluster 4**
Model	**VWU - 142**	
Dimension		**Measurement Unit**
Height	915	mm
Length	3353	mm
Width	661	mm
Weight		
Inlet Connection	50	mm
Outlet Connection	75	mm
Specification		
Capacities	3286	$Nm^3/_{hr}$
Shell Side Nozzle Size	100	mm
Flow rate @ 180F	852	l/m
Installation Design		
No. of Vaporizer Required	2	Unit
Total Capacity	19716	$Nm^3/_{hr}$

b. LP Pump

LP pump is a cryogenic pump that will be used to transfer the LNG from the storage tank to the vaporizer. In the design, there will be two configurations of the pump.

The first configuration was meant to be operated during full load where the demand of LNG flow rates were high, it is consist of one LNG pump which able to meet requirement of head and flow rates. The second configuration is to use 2 cryogenic pump, arranged in series in order to meet the head requirement but low flow rates. The second configuration are preferable during low demand of electricity where only part of the diesel engine will be used.

To increase the redundancy level, the second configuration were arranged to have stand-by pump. This configuration enable operation at low demand of electricity if the main second configuration breakdown. This configuration also enable operation at full load when the first configuration is breakdown by operating the main second configuration and the stand-by pump, so basically, it's utilizing 4 pumps to meet requirement when the first configuration isn't able to satisfy the demand.

Pilot fuel supply pump specification for first configuration can be seen in table 4.17 while for second configuration in table 4.18

Table 4.17 First Configuration LP Pump Dimension, Specification and Installation Design

Pump Type	**Cryogenic LP**	**Type A**
Model	**Vanzetti DSM L 230**	
Dimension		**Measurement Unit**
Height	425	mm
Length	891	mm
Width	318	mm
Weight	270	kg
Specification		
Capacities	5,4-72	m^3/hr
Power	15	kW
RPM	-	RPM
Installation Design		
No. of Pump Required	1	Unit
Power Required	15	kW

Table 4.18 Second Configuration LP Pump Dimension, Specification and Installation Design

Pump Type	**Cryogenic LP**	**Type B**
Model	**Vanzetti DSM L 185**	
Dimension		**Measurement Unit**
Height	308	mm
Length	816	mm
Width	318	mm
Weight	170	kg
Specification		
Capacities	1,2-24	m^3/hr
Power	11	kW
RPM	-	RPM
Installation Design		
No. of Pump Required	4	Unit
Power Required	44	kW

c. Compressors

The function of compressors in this design is to transport the BOG from the storage to the engine or Gas Combustion Unit (GCU). Boil-off gas generation is unavoidable while condenser using is considered as non-economical option, therefore combusting the boil-off gas or utilizing it as engine fuel is much more preferable.

The Boil-off Gas calculation are calculated in the attachment with specification related with Chapter 4.4 Fuel Consumption and Storages

The configuration consisted of 2 compressors where 1 compressor are in stand-by mode in case the main compressor outperformed. Table 4.19 shows the specification of the pump for the first configuration and second configuration.

Table 4.19 BOG Compressors Dimension, Specification and Installation Design

Compressor Type	**Cryogenic Compressors**	**All engine**
Model	**GEA HG44e/770-4 S HC**	
Dimension		**Measurement Unit**
Height	383	mm
Length	695	mm
Width	361	mm
Weight	171	kg
Specification		
Capacities	67-80,4	$m^3/_{hr}$
Power	5,05	kW
RPM	1450-1740	RPM
Installation Design		
No. of Compressors Required	2	Unit
Power Required	10,1	kW

d. Gas Combustion Unit (GCU)

The combustion unit, are a device to ignite the boil-off gas from the storage when it's not required to be utilized as engine fuel. The GCU capability to ignite natural gas need to be the same as boil-off gas generation per hour.

Table 4.20 shows the chosen GCU equipment that meet the minimum requirement.

Table 4.20 Gas Combustion Unit (GCU) Dimension, Specification and Installation Design

GCU	**Gas Combustion Unit**	
Model	**Cleaver Brooks LNV-25-1**	
Dimension		**Measurement Unit**
Height	539,75	mm
Length	946,15	mm
Width	711,2	mm
Weight	171	kg
Specification		
Capacities	2500000	$BTU/_{hr}$
Weight	-	Kg

Table 4.20 Gas Combustion Unit (GCU) Dimension, Specification and Installation Design (Cont.)

Installation Design		
No. of GCU Required	1	Unit

e. Economizer

Since the product guide of vaporizer demanding heated water as heat source, it's much more efficient if the heat content from the exhaust gas is utilized to heat the water into specific temperature. The parameter of choosing the economizer is the heat content of the exhaust gas (available energy to heat the water) and economizer capability. Table x shows the available and required energy to heat the water before entering the vaporizer and table 4.21 shows the specification of the chosen economizer for *Conceptual Design of 100 MW LNG Mobile Power Plant*

Table 4.21 Exhaust Gas Economizer Dimension, Specification and Installation Design

HeaterType	**Exhaust Gas Recovery**	**All engine**
Model	**Saacke Marine System EMB/EME VST**	
Dimension		**Measurement Unit**
Height	4800	mm
Length	2450	mm
Width	2450	mm
Weight	16000	kg
Specification		
Steam Capacities	2	t/hr
Water Content	5,5	m^3
Installation Design		
No. of Compressors Required	7	Unit
Utilized Heat	11042,0831	kW

f. Economizer Fresh Water Pumps

Beside specific temperature, the vaporizer also demand for specific flow rate of the heating media. The fresh water pumps for the heater circuit are differs based on the number of economizer connected directly to the pump.

Engine cluster for are connected to 1 economizer where the economizer will heat the water for vaporizer in cluster 4 (one engine). Therefore, the requirement of flow rate heat energy is lower compared to cluster 1, 2, and 3. Cluster 1, 2, and 3, each has 2 economizer connected and the heated water will be transferred into cluster 1, 2, and 3 vaporizer which demand higher flowrate, therefore higher capacity of pump is required. Table 4.22 shows the specification of Cluster 1, 2 and 3 fresh water pump and table 4.23 shows the specification of cluster 4 fresh water pump.

Table 4.22 Economizer Fresh Water Pumps Cluster 1, 2, and 3 Dimension, Specification and Installation Design

F/W Pump Type	**Centrifugal Pump**	**Cluster 1, Cluster 2, Cluster 3**
Model	**Herborner F-PM080**	
Dimension		**Measurement Unit**
Height	565	mm
Length	923	mm
Width	400	mm
Weight	284	kg
Specification		
Capacities	80-180	m^3/hr
Power	20	kW
RPM	3000	RPM
Installation Design		
No. of Pump Required	3	Unit
Power Required	60	kW

Table 4.23 Economizer Fresh Water Pumps Cluster 4 Dimension, Specification and Installation Design

F/W Pump Type	**Centrifugal Pump**	**Cluster 4**
Model	**Herborner F-PM050**	
Dimension		**Measurement Unit**
Height	400	mm
Length	513	mm
Width	320	mm
Weight	70	kg
Specification		
Capacities	22-64	m^3/hr
Power	8	kW
RPM	3000	RPM
Installation Design		
No. of Pump Required	1	Unit
Power Required	8	kW

g. System Drawings and Arrangement

The chosen equipment which has been calculated before need to be arranged where the configuration should enable the system to perform and support the main engine operation.

Fig 4.14 illustrate the process diagram of gas supply in for engine where the scope of the drawings is the engine room especially from gas valve unit to the engine. The drawings following the regulation of Germanischer Lloyd and recommendation of MAN Project Guide.

The LNG treatment system can be seen in fig 4.15 where the LNG is being heated by vaporizer so it'll reach gas phase by utilizing heat from exhaust gas. BOG treatment will be compressed by compressor and then delivered to the fuel supply line or directly to the gas combustion unit. The bunkering method of the storage tank can be seen in the next chapter which discuss about the bunkering scenario. Final version after optimization shown by figure 4.16.

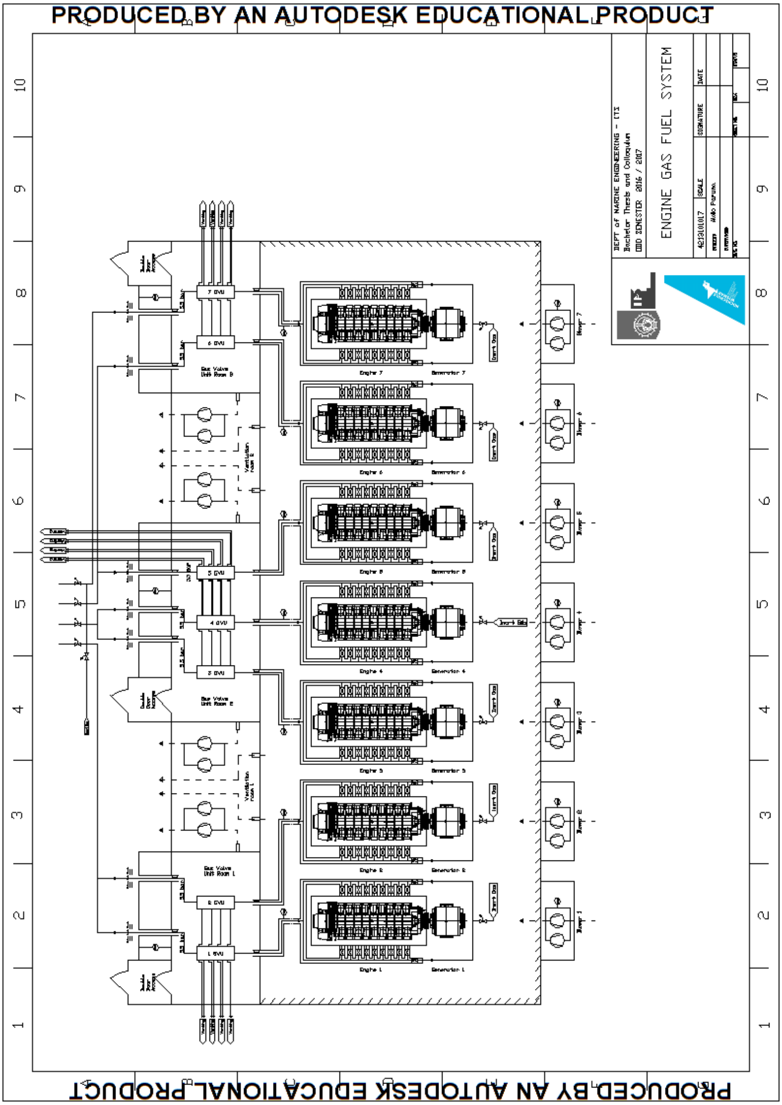

Figure 4.14 Engine Gas Fuel System

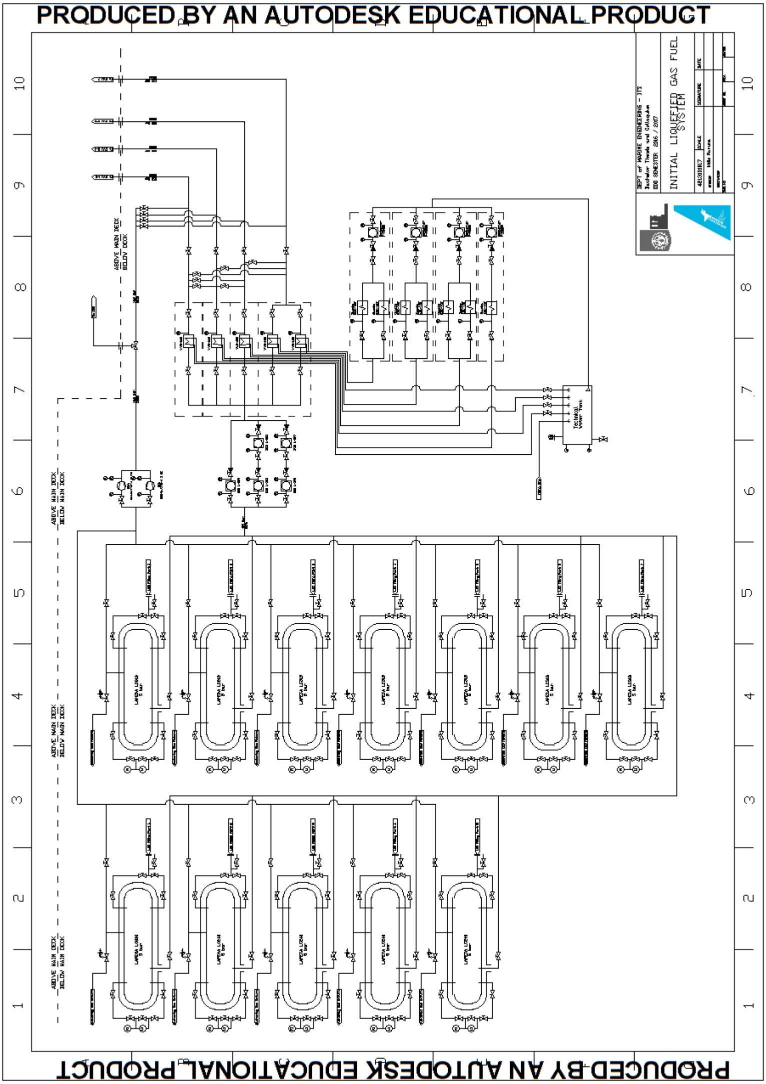

Figure 4.15 Initial Liquefied Gas Fuel System

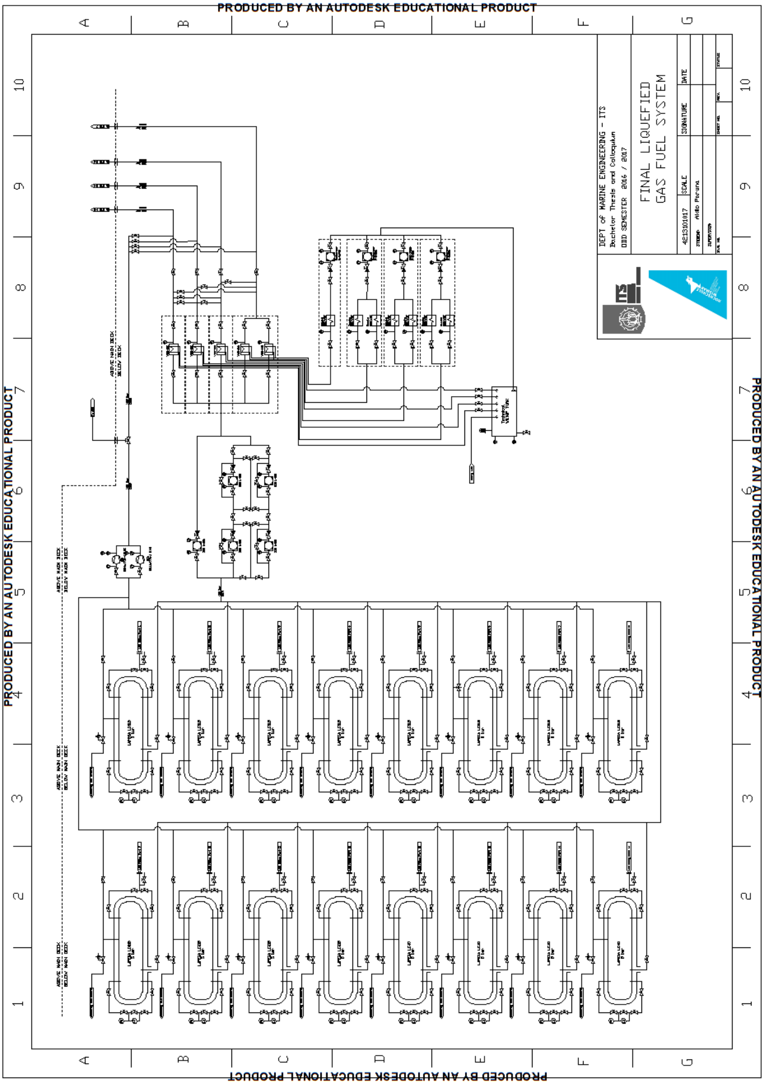

Figure 4.16 Final Liquefied Gas Fuel System

4.3.3. Liquid Fuel Supply System and Equipment

Liquid fuel supply system is an essential system to keep the engine running. The fuel system will supply the engine with the fuel so the engine may ignite the engine and convert the energy into mechanical energy which then will be used to rotate the alternator.

The designed system for liquid fuel supply is divided into 4 cluster where cluster 1, 2, and 3 are consist of two engine while cluster 4 only consist of 1 engine. This configuration will affect the calculation and the chosen equipment for each cluster.

Liquid fuel treatment system is a system that treat the liquid fuel before the fuel is injected to the engine. Fuel treatment are required because the fuel which is stored in the bunker isn’t in clean condition and it don’t meet required chemical properties, therefore the fuel will be transferred to treatment equipment in this system. It is designed is to supply all cluster, therefore all supply system will be connected into one fuel treatment system.

All detail calculations are attached in the Attachment 3: Liquid Fuel Supply System, the following text informs the chosen equipment and its specification.

a. Main Supply Pump
Based on MAN 51/60 Project guide, the duel fuel diesel engine must have a main supply pump which able to supply liquid fuel even if the engine is operated at 100% MCR.

Table 4.24 shows the chosen equipment for main supply pump for cluster 1,2 and 3 where the supply pump need to deliver fuel for 2 engines, while table 4.25 shows the supply pump for cluster 4 where this cluster only consists of 1 engine.

Table 4.24 Main Supply Pump Cluster 1, 2, and 3 Dimension, Specification and Installation Design

Suppy Pump Type	**Gear Pump**	**Cluster 1, Cluster 2, Cluster 3**
Model	**IMO Pump 3D 275E**	
Dimension		**Measurement Unit**
Height	283	mm
Length	831	mm
Width	280	mm
Weight	162	kg
Specification		
Capacities	51	m^3/hr
Power	0,46	kW
RPM	3500	RPM
Installation Design		
No. of Pump Required	6	Unit
Power Required	2,76	kW

Table 4.25 Main Supply Pump Cluster 4 Dimension, Specification and Installation Design

Supply Pump Type	**Gear Pump**	**Cluster 4**
Model	**IMO Pump 3D 218**	
Dimension		**Measurement Unit**
Height	229	mm
Length	742	mm
Width	229	mm
Weight	120	kg
Specification		
Capacities	28,62	m^3/hr
Power	0,24	kW
RPM	3500	RPM
Installation Design		
No. of Pump Required	2	Unit
Power Required	0,48	kW

b. Pilot Supply Pump

Based on MAN 51/60 Project guide, the duel fuel diesel engine must have a pilot supply pump where the function of the pilot supply pump is to deliver small amount of liquid fuel to the combustion chamber during dual-fuel mode. The function of pilot fuel is to ignite the gas fuel inside the combustion chamber.

Table 4.26 shows the chosen equipment for pilot supply pump for cluster 1,2 and 3 where the supply pump need satisfy pilot fuel requirement for 2 engines, while table 4.27 shows the pilot supply pump for cluster 4 where this cluster only consists of 1 engine.

Table 4.26 Pilot Supply Pump Cluster 1, 2, and 3 Dimension, Specification and Installation Design

Supply Pump Type	**Gear Pump**	**Cluster 1, Cluster 2, Cluster 3**
Model	**IMO Pump 87E**	
Dimension		**Measurement Unit**
Height	179,2	mm
Length	582	mm
Width	184,2	mm
Weight	35	kg
Specification		
Capacities	0,591	m^3/hr
Power	-	kW
RPM	2850	RPM
Installation Design		
No. of Pump Required	6	Unit
Power Required	-	kW

Table 4.27 Pilot Supply Pump Cluster 4 Dimension, Specification and Installation Design

Supply Pump Type	**Gear Pump**	**Cluster 4**
Model	**IMO Pump 87E**	
Dimension		**Measurement Unit**
Height	179,2	mm
Length	582	mm
Width	184,2	mm
Weight	35	kg
Specification		
Capacities	0,272	$m^3/_{hr}$
Power	-	kW
RPM	1425	RPM
Installation Design		
No. of Pump Required	2	Unit
Power Required	-	kW

c. MDO Separator

MDO separator is an equipment for separate water and impurities from the fuel during its travel from storage tank to service tank. MDO separator is one of the requirement for the engine based on the project guide for fuel treatment. The calculations are in the Attachment 3: Liquid Fuel Supply System.

Table 4.28 shows the chosen FO separator, the requirement of FO separator are calculated by using formula provided in MAN 51/60 DF where the formula is related with the supply pump capacity. Therefore, MDO separator specification shall satisfy the system requirement of liquid fuel.

Table 4.28 Fuel Oil Separator Dimension, Specification and Installation Design

Separator Type	Solids-retaining Centrifugal Separator	All Engines
Model	**MIB 303**	
Dimension		**Measurement Unit**
Height	370	mm
Length	610	mm
Width	510	mm
Weight	68	kg
Specification		
Capacities	0,76	m^3/hr
Feed Temprature	0-100	°C
Power	0,7	kW
Installation Design		
No. of Separator Required	2	Unit
Power Required	1,4	kW

d. Separator Heater

Before entering the separator, a liquid fuel need to be regulated first in order to achieve proper chemical properties. The separator heater function is to heat the liquid fuel from its original temperature to 40C, the purpose of heating the fuel is to achieve specific viscosity since the higher the temperature is, the less viscous the fluid will be.

Table 4.29 shows the chosen equipment for separator heater based on calculation, the selecting process were done by calculating the required power to heat the amount of the fluid.

Table 4.29 Fuel Oil Separator Separator Dimension, Specification and Installation Design

Separator Heater	Electric Heater	All Engines
Model	**Aalborg Vesta EH 15**	
Dimension		**Measurement Unit**
Height	404	mm
Length	864	mm
Width	270	mm
Weight	55	kg

Table 4.29 Fuel Oil Separator Separator Dimension, Specification and Installation Design (Cont)

Specification		
Capacity	5	kW
Installation Design		
No. of Heaters Required	2	Unit

e. Transfer Pump

To deliver the liquid fuel from the storage to the service tank, a transfer pump is required. The capacity of the transfer pump are designed to have the same capacity with the separator since in MAN 51/60 DF Project Guide, the formula provided is only for supply pump and separator, while the transfer capacity shall follow the capability of the separator itself.

Table 4.30 shows the chosen equipment for transfer pump. The transferred pump is considered as an equipment in liquid fuel treatment system and it's not directly related to the engine supply.

Table 4.30 Fuel Oil Separator Separator Dimension, Specification and Installation Design

Transfer Pump Type	**Gear Pump**	
Model	**Iron Pump ON 1**	
Dimension		**Measurement Unit**
Height	190	mm
Length	510	mm
Width	220	mm
Weight	45	kg
Specification		
Capacities	1,5	m^3/hr
Power	1,41	kW
RPM	850	RPM
Installation Design		
No. of Pump Required	2	Unit
Power Required	2,82	kW

f. Main MDO Cooler

During operation, main supply pump will continuously be transferred the liquid fuel to the engine and some amount of the liquid fuel is not being injected to the combustion chamber.

The amount of liquid fuel which has flow to the engine and not being injected faced temperature increase, this condition made the fuel oil cannot be transferred directly into the service tank to avoid temperature increase in the tank. Main MDO cooler function is to remove heat from the overflow liquid fuel from main liquid fuel supply circuit.

Table 4.31 shows the chosen main MDO cooler for cluster 1, 2, and 3 where it's consist of 2 engines, It means that the overflow flowrates of liquid fuel is higher than cluster 4 which only contain 1 engine. The specification for cluster 4 showm in table 4.32

Table 4.31 Main MDO Coolers Cluster 1, 2, and 3 Dimension Specification and Installation Design

Main MDO Coolers	**Plate Heat Exchanger**	**Cluster 1,2,3**
Model	**AlfaLaval M15 FM8**	
Dimension		**Measurement Unit**
Height	1815	mm
Length	1750	mm
Width	610	mm
Weight		kg
Specification		
Heating Surface	184	m^2
Installation Design		
No. of Coolers Required	3	Unit

Table 4.32 Main MDO Coolers Cluster 4 Dimension Specification and Installation Design

Main MDO Coolers	**Plate Heat Exchanger**	**Cluster 4**
Model	**AlfaLaval M10-FD ASME**	
Dimension		**Measurement Unit**
Height	1084	mm
Length	2400	mm
Width	470	mm
Weight		kg
Specification		
Heating Surface	105	m^2
Installation Design		
No. of Coolers Required	1	Unit

g. Pilot MDO Cooler

Pilot MDO coolers have the same function with main MDO coolers but pilot MDO coolers are specifically removes the heat from pilot fuel system circuit.

Table 4.33 shows the chosen pilot MDO cooler for cluster 1, 2, and 3 where it's consist of 2 engines, It means that the overflow flowrates of liquid fuel is higher than cluster 4 which only contain 1 engine. Specification for cluster can be seen in table 4.34.

Table 4.33 Pilot MDO Coolers Cluster 1, 2, and 3 Dimension Specification and Installation Design

Pilot MDO Coolers	**Shell and Tube Heat Exchanger**	**Cluster 1,2,3**
Model	**Aalborg MD20-1000**	
Dimension		**Measurement Unit**
Height	560	mm
Length	1432	mm
Width	340	mm
Weight		kg
Specification		
Heating Surface	4,8	m^2

Table 4.33 Pilot MDO Coolers Cluster 1, 2, and 3 Dimension Specification and Installation Design (Cont)

Installation Design		
No. of Coolers Required	3	Unit

Table 4.34 Pilot MDO Coolers Cluster 4 Dimension Specification and Installation Design

Pilot MDO Coolers	**Shell and Tube Heat Exchanger**	**Cluster 4**
Model	**Aalborg MD50-1000**	
Dimension		**Measurement Unit**
Height	470	mm
Length	1344	mm
Width	285	mm
Weight		kg
Specification		
Heating Surface	2,4	m^2
Installation Design		
No. of Coolers Required	1	Unit

h. System Drawings and Arrangement

The fuel treatment and the fuel supply system are connected where the treatment system should continuously supply the supply system with treated fuel.

Based on figure 4.17 the treatment system begins from the storage tank, to the separator and then ended at the service tank. The supply system begins from the service tank until the fuel reach the engine whether the fuel used as pilot fuel or main fuel. Figure 4.18 shows the fuel supply system for cluster 1 and 2 while figure 4.19 shows the fuel supply system for cluster 3 and 4.

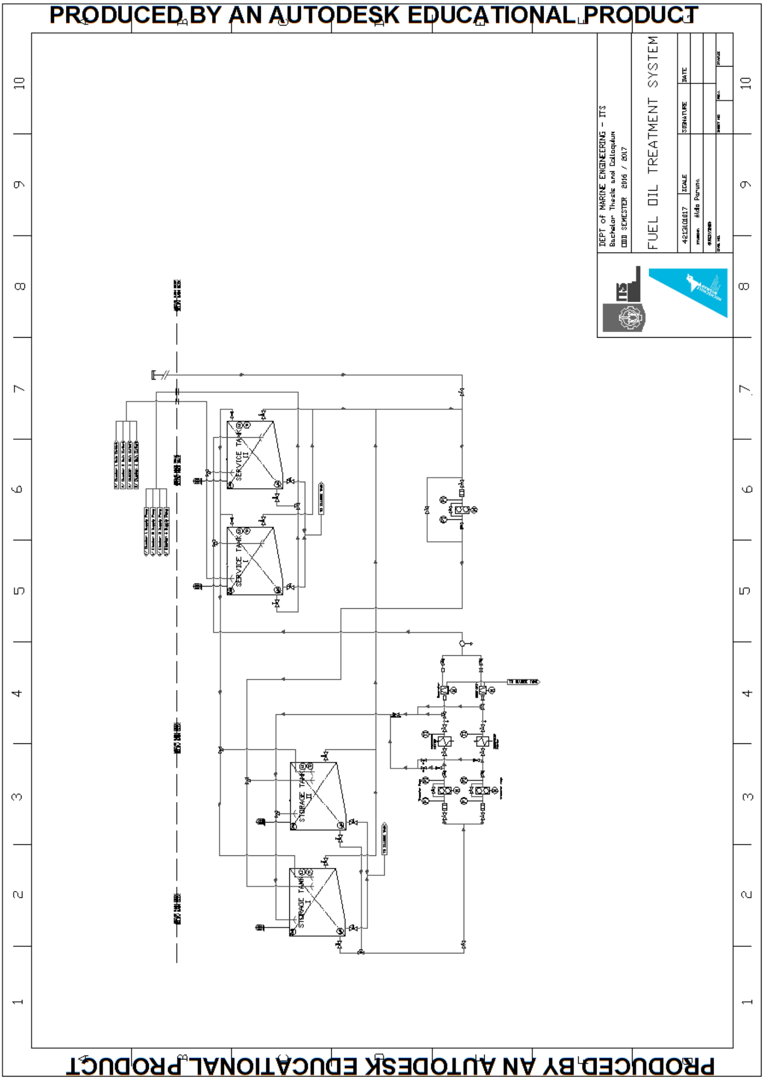

Figure 4.17 Fuel Oil Treatment System

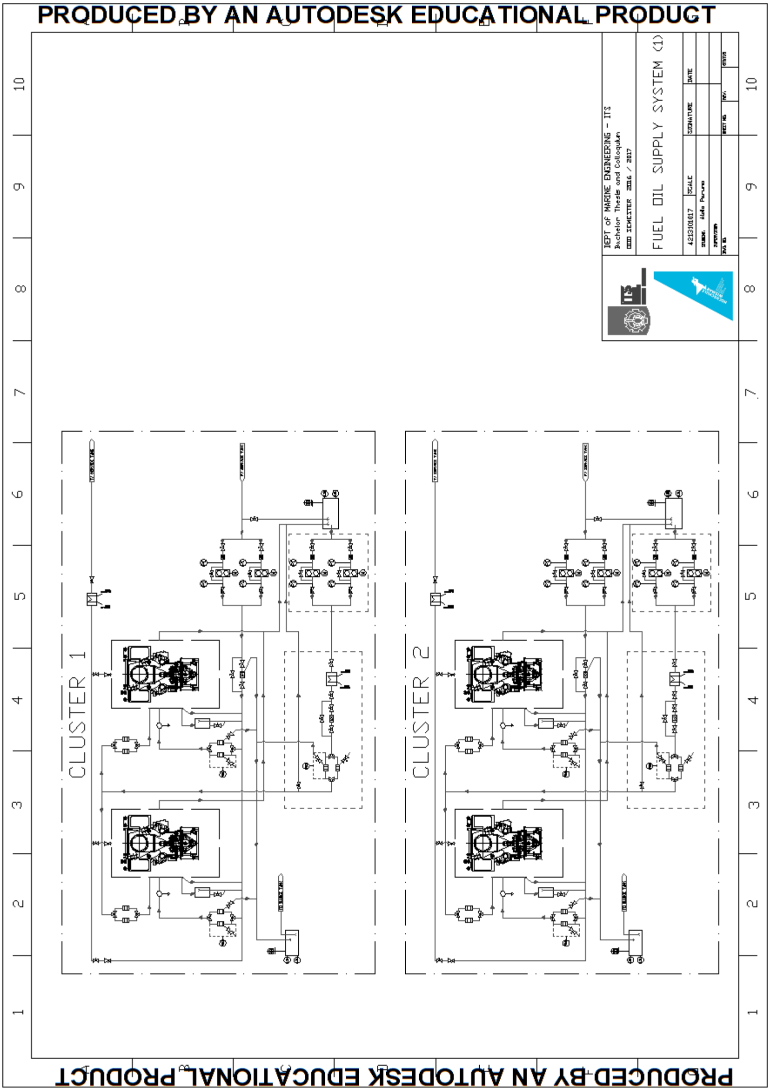

Figure 4.18 Fuel Oil Supply System for Cluster 1 and Cluster 2

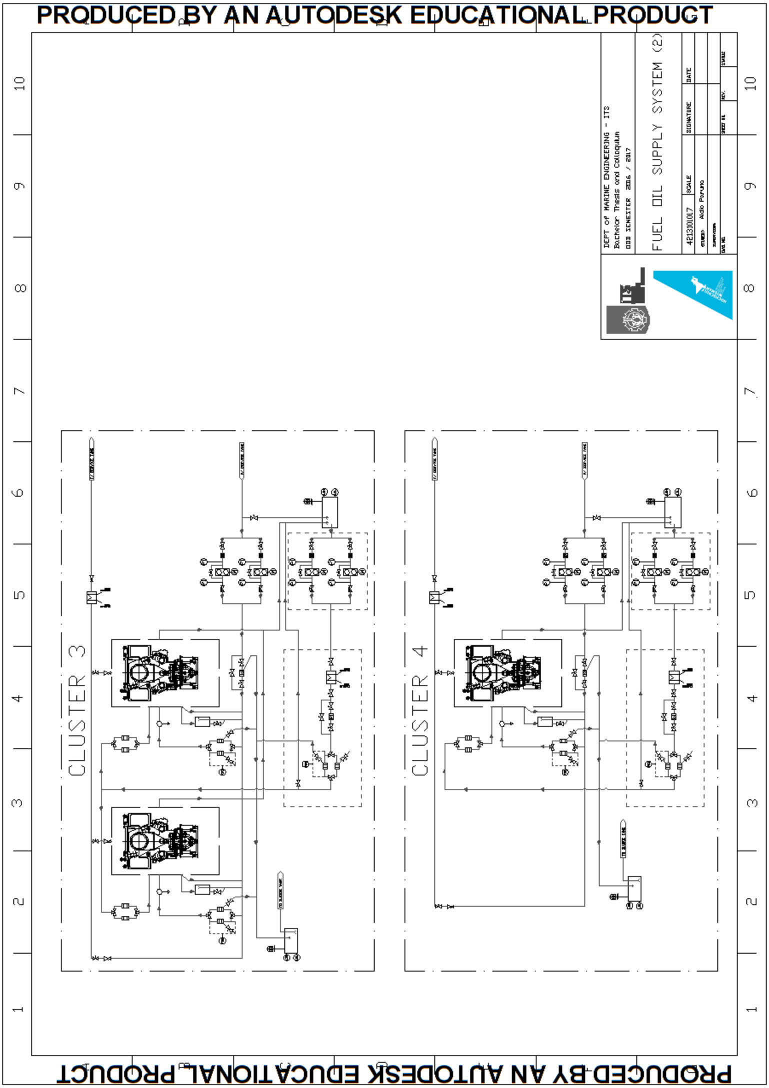

Figure 4.19 Fuel Oil Supply System for Cluster 3 and Cluster 4

4.3.4. Lubricating Oil (LO) Supply System and Equipment

Lubricating oil system is a system that supply lube oil to the engine. The system is required to remove the waste heat from the engine, reuce friction between every moving parts and also take roles as engine corrosion prevention.
In the calculation and technical specification of lube oil system, there is several aspect need to be determined such as lube oil specification, filter, separator requirement, and the pump head.

All calculation to determine the requirement for lubricating oil system are attached in the Attachment 4: Lubricating Oil Supply System. The following text are the result or an overview of the selected design.

a. LO Separator
LO separator is an equipment for separating the water and impurities from the lubricating oil in the service tank. LO separator is one of the requirement for the engine based on the project guide for LO treatment.

Based on table 4.35 and table 4.36 the separator in for LO system will use two type. The first type will be used for engine in Cluster 1, Cluster 2, and Cluster 3 where in this cluster there is two engines. While in the Cluster 4, there is only one engine, therefore, Cluster 4 doesn't require the same specification of LO Separator.

Table 4.35 Lube Oil Separator Cluster 1, 2, and 3 Dimension Specification and Installation Design

Separator Type	**Solids-retaining Centrifugal Separator**	**Cluster 1, Cluster 2, Cluster 3**
Model	**MAB 206**	
Dimension		**Measurement Unit**
Height	1430	mm
Length	1810	mm
Width	1055	mm
Weight	420	kg

Table 4.35 Lube Oil Separator Cluster 1, 2, and 3 Dimension Specification and Installation Design (Cont)

Specification		
Capacities	6,5	m^3/hr
Feed Temprature	0-100	℃
Power	5,5	kW
Installation Design		
No. of Separator Required	3	Unit
Power Required	16,5	kW

Table 4.36 Lube Oil Separator Cluster 4 Dimension Specification and Installation Design

Separator Type	**Solids-retaining Centrifugal Separator**	**Cluster 4**
Model	**MMB 305**	
Dimension		**Measurement Unit**
Height	935	mm
Length	795	mm
Width	465	mm
Weight	218	kg
Specification		
Capacities	3,5	m^3/hr
Feed Temprature	0-100	℃
Power	2,3	kW
Installation Design		
No. of Separator Required	1	Unit
Power Required	2,3	kW

b. Feed Pump

Feed pump are being used to transfer the LO from service tank to the LO Separator, therefore the capacity, and pipes specification for feed pump are the same with the separator.

The feed pump in LO system will use two type, both specification shown in table 4.37 for cluster 1, 2, and 3 while for cluster for in table 4.38. The first type will be used for engine in Cluster 1, Cluster 2, and Cluster 3 where in this cluster the separator have greater separator. While in the

Cluster 4, there is smaller LO Separator. The detail calculations are in the attachment.

Table 4.37 Lube Oil Feed Pump Cluster 1, 2, and 3 Dimension Specification and Installation Design

Feed Pump Type	**Gear Pump**	**Cluster 1, Cluster 2, Cluster 3**
Model	**Iron Pump ON-V: 4**	
Dimension		**Measurement Unit**
Height	800	mm
Length	340	mm
Width	340	mm
Weight	75	kg
Specification		
Capacities	6,5	$m^3/_{hr}$
Power	1,41	kW
RPM	1150	RPM
Installation Design		
No. of Pump Required	3	Unit
Power Required	4,23	kW

Table 4.38 Lube Oil Feed Pump Cluster 4 Dimension Specification and Installation Design

Feed Pump Type	**Gear Pump**	**Cluster 4**
Model	**Iron Pump ON 1**	
Dimension		**Measurement Unit**
Height	190	mm
Length	510	mm
Width	220	mm
Weight	45	kg
Specification		
Capacities	6,5	$m^3/_{hr}$
Power	1,41	kW
RPM	1450	RPM
Installation Design		
No. of Pump Required	1	Unit
Power Required	1,41	kW

c. Pre-lubrication Pump

Pre-lubrication pump are being used to transfer the LO from service tank to the engine in early operation when the LO system temperature are not meet the operation requirement. The capacity of the pre-lubrication pumps are designed with the same capacity with the attached service pump

The feed pump in LO system will use only one type since every engine will have 1 pre-lubrication pump, the specification of pre-lubrication pump can be seen in table 4.39.

Table 4.39 Pre-lubrication Pump Dimension Specification and Installation Design

Feed Pump Type	**Gear Pump**	**All Cluster**
Model	**Iron Pump ONT: 7/10**	
Dimension		**Measurement Unit**
Height	120	mm
Length	516	mm
Width	310	mm
Weight	35	kg
Specification		
Capacities	1,9	m^3/hr
Power	0,746	kW
RPM	950	RPM
Installation Design		
No. of Pump Required	7	Unit
Power Required	1,41	kW

d. Transfer Pump

Transfer pump are being used to transfer the LO from storage tank to the LO service tank. The design of the pump will follow the pipe size for separator for particular engine cluster.

The transfer in LO system will use two type. The first type will be used for engine in Cluster 1, Cluster 2, and Cluster 3 where in this cluster the pump may have greater capacity because it must able to supply 2 engines and the pipe diameter is larger, the equipment specification is listed in table 4.40. While in the Cluster 4, there is smaller LO transfer pump to supply one engine, therefore, Cluster 4 doesn't require the same specification of LO transfer pump, the equipment specification can be seen in table 4.41 . The detail calculations are in the attachment.

Table 4.40 Lube Oil Transfer Pump Cluster 1, 2, and 3 Dimension Specification and Installation Design

Feed Pump Type	**Gear Pump**	**Cluster 1, Cluster 2, Cluster 3**
Model	**Iron Pump ON-V: 4**	
Dimension		**Measurement Unit**
Height	800	mm
Length	340	mm
Width	340	mm
Weight	75	kg
Specification		
Capacities	8	$m^3/_{hr}$
Power	1,556	kW
RPM	1450	RPM
Installation Design		
No. of Pump Required	6	Unit
Power Required	9,396	kW

Table 4.41 Lube Oil Transfer Pump Cluster 4 Dimension Specification and Installation Design

Feed Pump Type	**Gear Pump**	**Cluster 4**
Model	**Iron Pump ON-V: 3**	
Dimension		**Measurement Unit**
Height	800	mm
Length	340	mm
Width	340	mm
Weight	75	kg
Specification		
Capacities	3,4	$m^3/_{hr}$
Power	0,821	kW
RPM	850	RPM

Table 4.41 Lube Oil Transfer Pump Cluster 4 Dimension Specification and Installation Design(Cont)

Installation Design		
No. of Pump Required	2	Unit
Power Required	1,642	kW

e. Lube Oil Cooler

Lube oil cooler is an equipment to dissipate the heat from the oil which just come out from the engine outlet. The engine inlet of lube oil should have lube oil supply in specific temperature which is in the range of 50-60 Celsius. Therefore, the coolers are required to achieve the temperature.

The amount of heat need to be dissipated are informed in the project guide. (MAN 51/60DF Project Guide P. 107) and calculated. The table 4.42 show the chosen equipment for lube oil cooler in cluster 1, 2, 3 and 4. The lube oil cooler for every cluster is the same because the cooler task is not to remove heat from 1 cluster, but only from 1 engine, therefore every engine are attached with one coolers.

Table 4.42 Lube Oil Cooler Dimension Specification and Installation Design

LO Coolers	Plate Heat Exchanger	All Engines
Model	AlfaLaval AlfaQ 14	
Dimension		Measurement Unit
Height	2920	mm
Length	5235	mm
Width	1190	mm
Weight		kg
Specification		
Heating Surface	1400	m^2
Installation Design		
No. of Coolers Required	7	Unit

f. Separator Heater

Separator heater is an equipment that should regulate the temperature of lube oil before entering the separator in order to achieve specific temperature and viscosity.

The separator heater in for LO system will use two type. The first type will be used for engine in Cluster 1, Cluster 2, and Cluster 3 where in this cluster there is two engines. The equipment for cluster 1, 2 and 3 can be seen in table 4.43, while for cluster 4 is in table 4.44.

Table 4.43 Lube Oil Separator Heater Cluster 1, 2, and 3 Dimension Specification and Installation Design

Separator Heater	**Electric Heater**	**Cluster 1, 2, and 3**
Model	**Aalborg Vesta EH 35**	
Dimension		**Measurement Unit**
Height	672	mm
Length	1907	mm
Width	460	mm
Weight	386	kg
Specification		
Capacity	78	*kW*
Installation Design		
No. of Coolers Required	3	Unit

Table 4.44 Lube Oil Separator Heater Cluster 4 Dimension Specification and Installation Design

Separator Heater	**Electric Heater**	**Cluster 4**
Model	**Aalborg Vesta EH 30**	
Dimension		**Measurement Unit**
Height	572	mm
Length	1384	mm
Width	425	mm
Weight	228	kg
Specification		
Capacity	40	*kW*
Installation Design		
No. of Coolers Required	2	Unit

i. System Drawings and Arrangement

The lube oil system are designed to have several task which is lubricate the engine to reduce the damage caused by friction, remove heat from the moving parts, and protect the metal parts from corrosion.

Lube oil in lubrication system came from the storage tank and transported into engine’s sump tank. From the sump tank, the lube oil need to be treated first by using heater to achieve specific temperature and viscosity so the performance of lube oil separator is at satisfying level. The lube oil from the separator will be transported back to the sump tank.

The lubrication system consisted of two pumps where the engine driven pump (attached) used as service pump which operated when the engine reach its specific load while the second pump is the pre-lubrication pump which is independent. The function of the pre-lubrication pump is to lubricate the engine when the engine at its beginning of operation.

Lubrication system for engines in cluster 1 and 2 can be seen in figure 4.20 while for engines which are located in cluster 3 and 4 can be seen in figure 4.21 (see next leaflet).

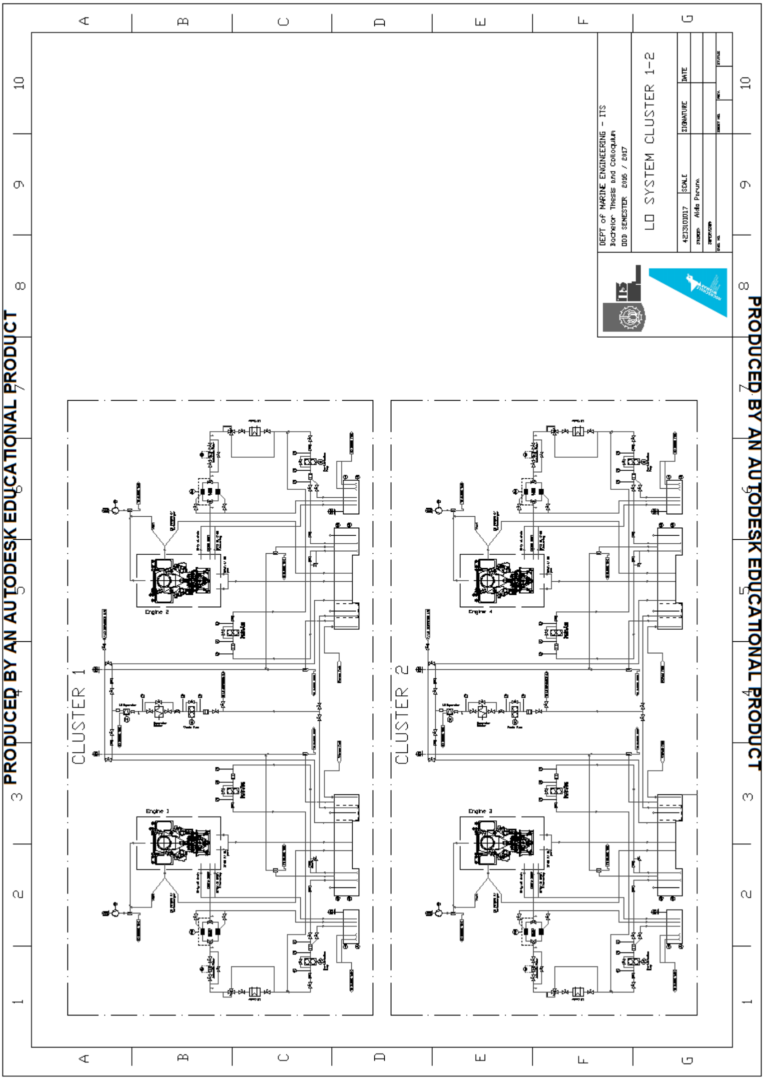

Figure 4.20 Lubricating Oil System for Cluster 1 and Cluster 2

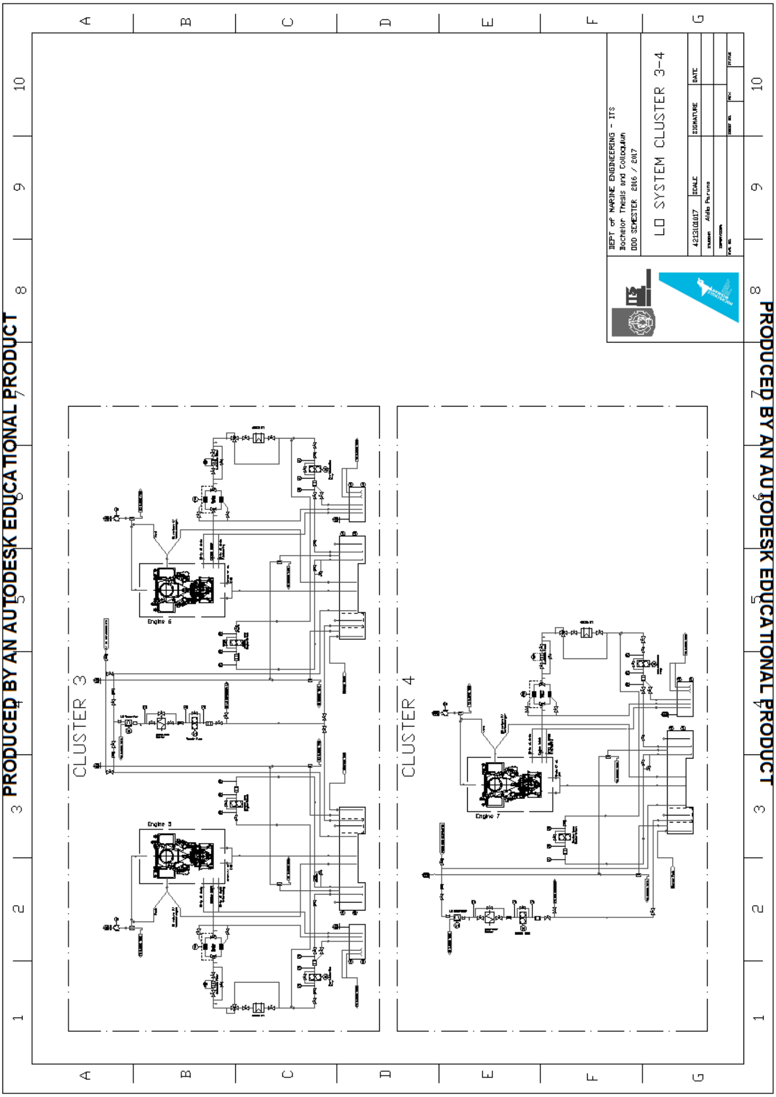

Figure 4.21 Lubricating Oil System for Cluster 3 and Cluster 4

4.3.5. Starting Air Supply System and Equipment

In the operation, compressed air is used to start an engine by providing an energy to move the piston. Operation using compressed air is regulated by the classification societies and the project guide of the engine to develop a safety and reliable system arrangement.

All calculation to determine the requirement for compressed air system are attached in the Attachment 5: Starting air Supply System. The following text are the result or an overview of the selected design.

a. Air Vessels

Air vessels is an equipment required to store the air which is compressed by the compressor. The capacity of air vessels need to comply with the project guide and classification societies regulation.

The air vessels in this system are designed to supply every engine without concerning the cluster, therefore, every engine will be connected to the main system of compressed air. The specification of the chosen air vessels can be seen in table 4.45.

Table 4.45 Air Vessels Dimension Specification and Installation Design

Air Vessels		**All Engine**
Model	**Kaeser**	
Dimension		**Measurement Unit**
Height	4400	mm
Length	1600	mm
Width	1600	mm
Weight	2350	kg
Specification		
Capacities	8000	m^3
Pressure	16	bar
Engine Start	18	Operation
Jet Assist	10 x 5	Operation
Slow Turn	0	Operation

Table 4.45 Air Vessels Dimension Specification and Installation Design (Cont)

Installation Design		
No. of Air Vessels Required	3	Unit

b. Air Compressor

Air compressor is an equipment required to compress air from the environment and store it in the air vessel. The capacity of air compressors need to comply with the project guide and classification societies regulation.

The air compressors in this system are designed to supply every engine without concerning the cluster classification. The specification of the air compressors for the mobile power plant can be seen in table 4.46.

Table 4.46 Air Compressors Dimension Specification and Installation Design

Air Compressor Type	**Air-cooled**	**All engine**
Model	**MacGregor HATLAPA L270 - 1150**	
Dimension		**Measurement Unit**
Height	1000	mm
Length	2005	mm
Width	900	mm
Weight	1000	kg
Specification		
Capacities	205	m^3/hr
Power	37	kW
RPM	1150	RPM
Installation Design		
No. of Compressors Required	3	Unit
Power Required	111	kW

c. System Drawings and Arrangement

All of the chosen equipment in the previous sub-chapter is arranged in specific configuration following the recommendation of the project guide and classification societies regulation. The detail drawings and design requirement can be seen in Attachment 5: Starting Air Supply System.

Based on figure 4.22 which illustrate the arrangement and the configuration of compressed air system where the system is connected to each engine and also connected to another system which may utilized compressed air. The arrangement and configuration of the system should comply with the project guide recommendation and the classification societies regulation to develop a redundant, efficient, and safety system.

The detail drawings and the design requirement of the system can be seen in the Attachment.

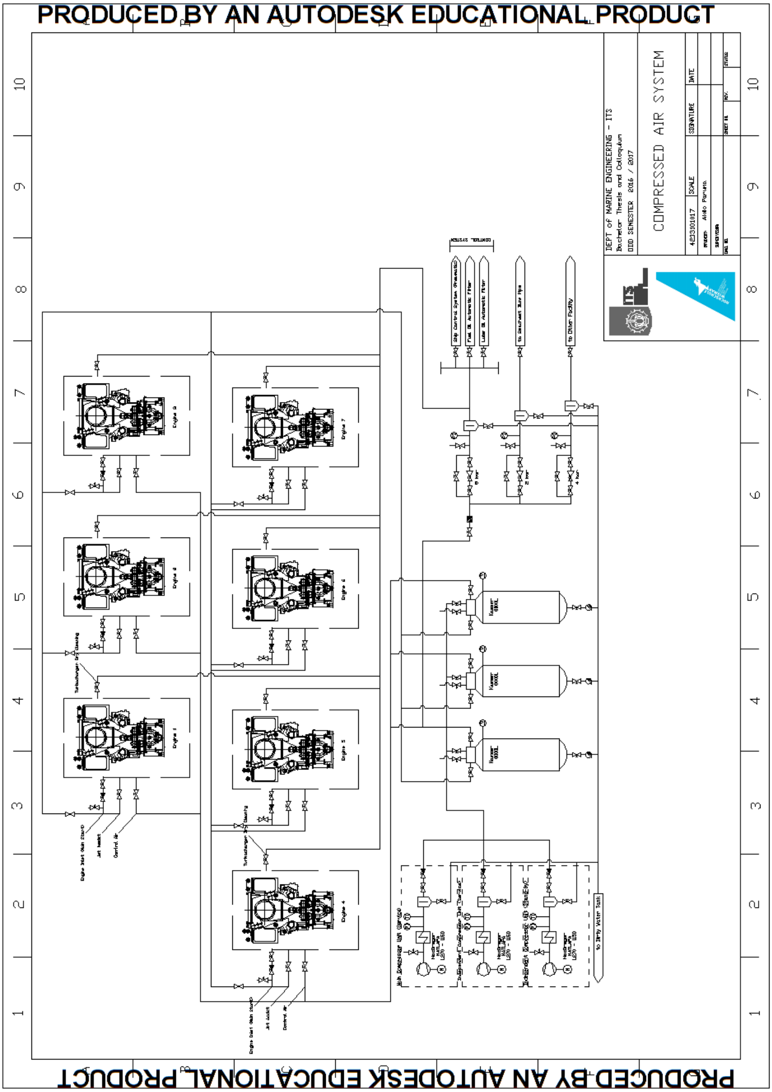

Figure 4.22 Compressed Air System

4.3.6. Cooling Water System and Equipment

Cooling system major task is to drain waste heat from ship machinery. Cooling water heat energy can be utilized for another process such as fresh water generator. But in this design, fresh water generator is removed by assuming all fresh water requirement will be supplied by the shore facility.

Cooling system in ship is using seawater and fresh water as heat transfer media, this type of cooling system are called close system. In fresh water cooling system, the water itself divided into a high temperature (HT) and low temperature (LT) system. HT water cools a high temperature objects such as cylinder liners, cylinder heads, etc. LT water cools the second stage of the charge air coolers, and lubricating oil system.

Cooling system of an engine recommendation is written in engine project guide and class societies. Engine project guide and class societies are recommending how to arranged the safest and the most efficient system.

The cooling system of the 100 MW LNG Mobile Power Plant are divided into 4 cluster, where cluster 1,2,3 are consist of twin-engine plant while cluster 4 consist of single-engine plant.

All calculation to determine the requirement for cooling system system are attached in the Attachment 6: Cooling Systems. The following text are the result or an overview of the selected design.

a. Tanks Capacity

In the cooling system, there are several tanks present such as LT expansion tank, HT expansion tank and drain tank. Each tank have different task but the main task is to collect the water from the system. The tanks capacity and quantity can be seen in table 4.47 for cluster 1, 2, and 3 while table 4.48 for cluster 4 below.

Table 4.47 Cooling Water Tank Cluster 1, 2, and 3 Volume and Quantity

Cooling Water Tank		**Cluster 1,2,3**
HT Expansion Tank		
Volume (each)	1,5	m^3
Quantity (in one cluster)	2	Tanks
LT Expansion Tank		
Volume (each)	3	m^3
Quantity (in one cluster)	1	Tanks
Drain Tank		
Volume	6	m^3

Table 4.48 Cooling Water Tank Cluster 4 Volume and Quantity

Cooling Water Tank		**Cluster 4**
HT Expansion Tank		
Volume (each)	1,5	m^3
Quantity (in one cluster)	1	Tanks
LT Expansion Tank		
Volume (each)	1	m^3
Quantity (in one cluster)	1	Tanks
Drain Tank		
Volume	2,5	m^3

b. LT Circuit Pump

LT circuit pump is a pump that circulate the cooling water inside the LT water system. Most of the LT water circuit task are to remove the heat from the coolers outside the engine where the temperature is much lower compared to HT.

The LT circuit pump are an arrangement of 2 pump where the first pump should be engine-driven (attached) and the second pumps is electrically-driven pump which take role as a stand-by pump. The engine-driven LT Circuit Pump specification are written in table 4.49 and for LT stand-by pump in table 4.50.

Table 4.49 LT Engine Drive Pump Dimension, Specification and Installation Design

LT Circuit Pump	Centrifugal Pump	All Engine
Model	**MAN Attached Pump**	
Dimension		**Measurement Unit**
Height	-	mm
Length	-	mm
Width	-	mm
Weight	-	kg
Specification		
Capacities	285	m^3/hr
Power	-	kW
RPM	-	RPM
Head	32,4	m
Installation Design		
No. of Pump Required	7	Unit
Power Required	-	kW

Table 4.50 LT Stand-by Pump Dimension, Specification and Installation Design

LT Stand-by Pump	Centrifugal Pump	All Engine
Model	**Herborner.X200-350A-5504H**	
Dimension		**Measurement Unit**
Height	1585	mm
Length	730	mm
Width	650	mm
Weight	797	kg
Specification		
Capacities	285	m^3/hr
Power	55	kW
RPM	1500	RPM
Head	32,4	m
Installation Design		
No. of Pump Required	7	Unit
Power Required	385	kW

c. LT Coolers

LT coolers are heat exchanger that dissipate the heat from LT system to the environment by using sea water as cooling media.

The LT Coolers for Cluster 1, 2, and 3 designed with 2 heat exchangers arranged in series arrangement to satisfy the heat surface area requirement. In Cluster 4, the LT coolers are only one due to its requirement are less than cluster 1, 2 and 3.

The flow rate in every cluster is same, therefore to dissipate the heat from different cluster, various heat exchanger size need to be determined. The chosen LT coolers or cluster 1, 2, and 3 are shown in table 4.51 and for cluster 4 in table 4.52

Table 4.51 LT Coolers Cluster 1, 2, and 3 Dimension, Specification and Installation Design

LT Coolers	**Plate Heat Exchanger**	**Cluster 1,2 and 3**
Model	**AlfaLaval AlfaQ 14L**	
Dimension		**Measurement Unit**
Height	3218	mm
Length	6420	mm
Width	1174	mm
Weight		kg
Specification		
Heating Surface	1700	m^2
Installation Design		
No. of Coolers Required	6	Unit
Arranged in Series W/		
LT Coolers	**Plate Heat Exchanger**	**Cluster 1,2 and 3**
Model	**AlfaLaval AlfaQ 8S**	
Dimension		**Measurement Unit**
Height	1435	mm
Length	2715	mm
Width	800	mm
Weight		kg

Table 4.51 LT Coolers Cluster 1, 2, and 3 Dimension, Specification and Installation Design (Cont)

Specification		
Heating Surface	85	m^2
Installation Design		
No. of Coolers Required	6	Unit

Table 4.52 LT Coolers Cluster 4 Dimension, Specification and Installation Design

LT Coolers	**Plate Heat Exchanger**	**Cluster 4**
Model	**AlfaLaval AlfaQ 10**	
Dimension		**Measurement Unit**
Height	3103	mm
Length	5185	mm
Width	940	mm
Weight		kg
Specification		
Heating Surface	940	m^2
Installation Design		
No. of Coolers Required	2	Unit

d. HT Circuit Pump

HT circuit pump is a pump that circulate the cooling water inside the HT water system. Most of the HT water circuit task are to remove the heat from the coolers inside the engine where the temperature is much higher compared to LT.

The HT circuit pump is an arrangement of 2 pump where the first pump should be engine-driven (attached) and the second pumps is electrically-driven pump which take role as a stand-by pump. The engine-driven HT Circuit Pump specification are written in table 4.53, and for HT stand-by pump in table 4.54.

Table 4.53 HT Engine Driven Pump Dimension, Specification and Installation Design

HT Circuit Pump	**Centrifugal Pump**	**All Engine**
Model	**MAN Attached Pump**	
Dimension		**Measurement Unit**
Height	-	mm
Length	-	mm
Width	-	mm
Weight	-	kg
Specification		
Capacities	200	$m^3/_{hr}$
Power	-	kW
RPM	-	RPM
Head	32,4	m
Installation Design		
No. of Pump Required	7	Unit
Power Required	-	kW

Table 4.54 HT Stand-by Pump Dimension, Specification and Installation Design

HT Stand-by Pump	**Centrifugal Pump**	**All Engine**
Model	**Herborner.X200-350A-4504H**	
Dimension		**Measurement Unit**
Height	1560	mm
Length	730	mm
Width	430	mm
Weight	652	kg
Specification		
Capacities	200	$m^3/_{hr}$
Power	45	kW
RPM	1500	RPM
Head	32,4	m
Installation Design		
No. of Pump Required	7	Unit
Power Required	315	kW

e. HT Coolers

HT coolers are heat exchanger that dissipate the heat from HT system to the environment by using sea water as cooling media.

The HT Coolers for Cluster 1, 2, and 3 designed with 2 heat exchangers arranged in series arrangement to satisfy the heat surface area requirement. Cluster for also arranged with 2 heat exchangers in series configuration but with different type of heat exchanger.

The flow rate in every cluster is same, therefore to dissipate the heat from different cluster, various heat exchanger size need to be determined. The chosen HT coolers or cluster 1, 2, and 3 are shown in table 4.55 and for cluster 4 in table 4.56.

Table 4.55 HT Coolers Cluster 1, 2, and 3 Dimension, Specification and Installation Design

HT Coolers	**Plate Heat Exchanger**	**Cluster 1,2 and 3**
Model	**AlfaLaval AlfaQ 20M**	
Dimension		**Measurement Unit**
Height	3951	mm
Length	7080	mm
Width	1550	mm
Weight		kg
Specification		
Heating Surface	2880	m^2
Installation Design		
No. of Coolers Required	6	Unit
Arranged in Series W/		
HT Coolers	**Plate Heat Exchanger**	**Cluster 1,2 and 3**
Model	**AlfaLaval AlfaQ 14L**	
Dimension		**Measurement Unit**
Height	3218	mm
Length	6420	mm
Width	1174	mm
Weight		kg

Table 4.55 HT Coolers Cluster 1, 2, and 3 Dimension, Specification and Installation Design (Cont)

Specification		
Heating Surface	1700	m^2
Installation Design		
No. of Coolers Required	6	Unit

Table 4.56 HT Coolers Cluster 4 Dimension, Specification and Installation Design

HT Coolers	**Plate Heat Exchanger**	**Cluster 1,2 and 3**
Model	**AlfaLaval AlfaQ 14L**	
Dimension		**Measurement Unit**
Height	3218	mm
Length	6420	mm
Width	1174	mm
Weight		kg
Specification		
Heating Surface	1700	m^2
Installation Design		
No. of Coolers Required	2	Unit
Arranged in Series W/		
HT Coolers	**Plate Heat Exchanger**	**Cluster 1,2 and 3**
Model	**AlfaLaval AlfaQ 6**	
Dimension		**Measurement Unit**
Height	2036	Mm
Length	3700	Mm
Width	650	Mm
Weight		Kg
Specification		
Heating Surface	390	m^2
Installation Design		
No. of Coolers Required	2	Unit

f. Seawater Pump

The seawater pump used to deliver seawater which act as cooling made for LT and HT coolers. The chosen equipment for seawater pump can be seen in table 4.57.

Table 4.57 Coolers Seawater pump Dimension, Specification and Installation Design

Seawater Pump	**Centrifugal Pump**	**All Engine**
Model	**Pompe Garbarino 250-400**	
Dimension		**Measurement Unit**
Height	602	Mm
Length	960	Mm
Width	1300	Mm
Weight	485	Kg
Specification		
Capacities	900	m^3/hr
Power	-	kW
RPM	1450	RPM
Head	46	M
Installation Design		
No. of Pump Required	3	Unit
Power Required	-	kW

g. System Drawings and Arrangement

All of the chosen equipment in the previous sub-chapter is arranged in specific configuration following the recommendation of the project guide and classification societies regulation. The detail drawings and design requirement can be seen in Attachment 6: Cooling System, general overview of the drawings can be seen in in figure 4.23 for cluster 1, cluster 2 in figure 4.24, cluster 3 in figure 4.25 and cluster 4 in figure 4.26.

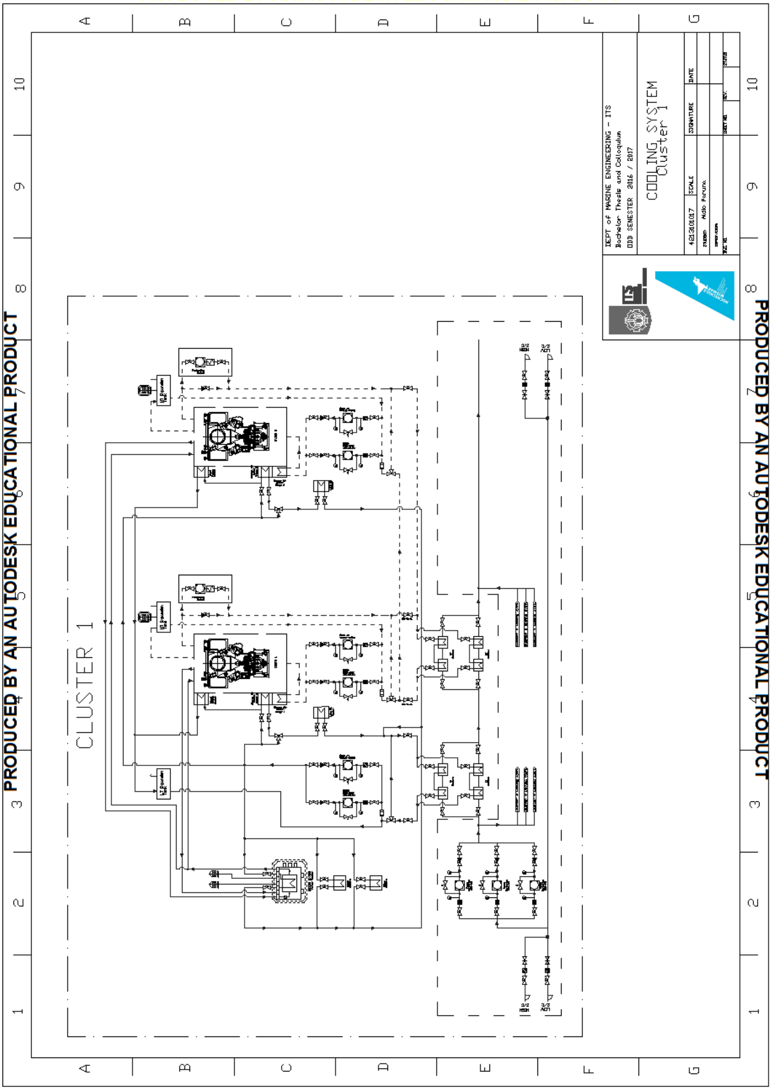

Figure 4.23 Cooling System for Cluster 1

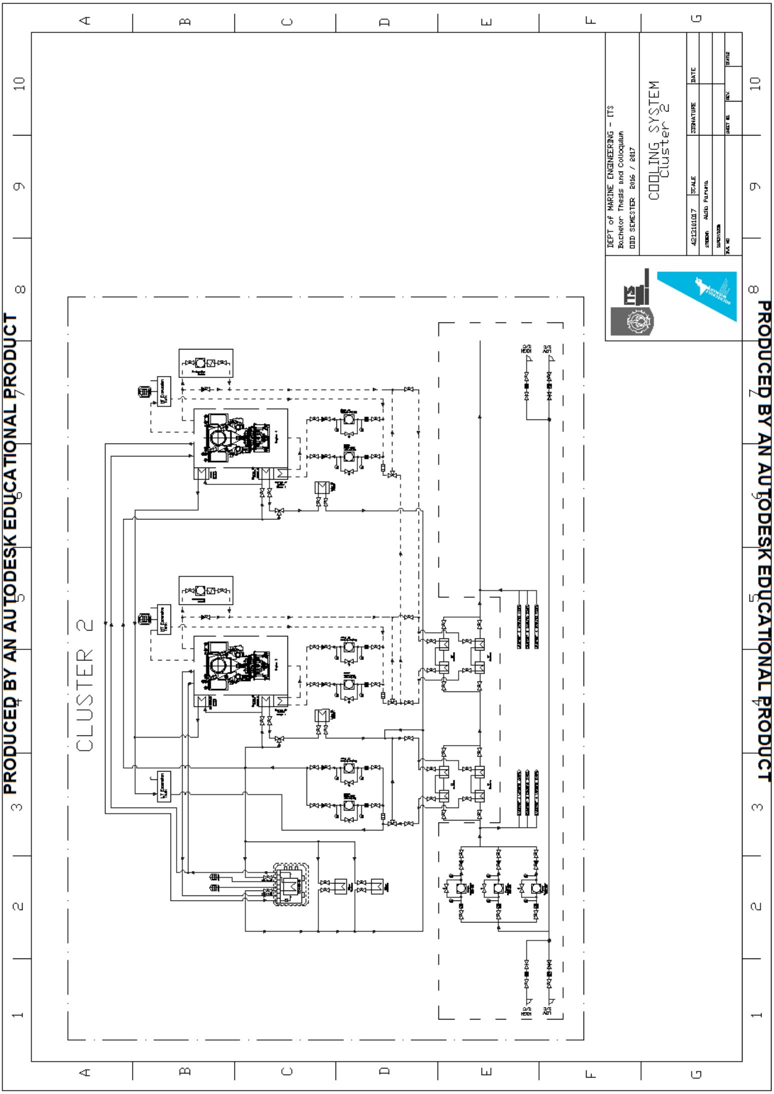

Figure 4.24 Cooling System for Cluster 2

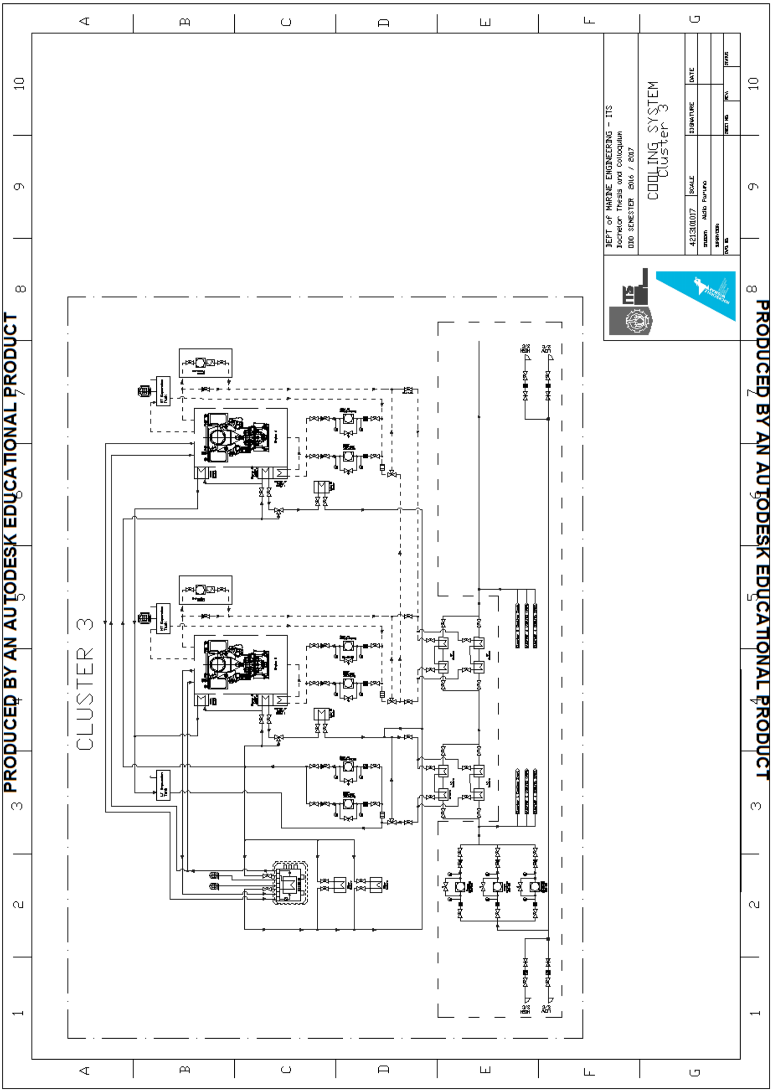

Figure 4.25 Cooling System for Cluster 3

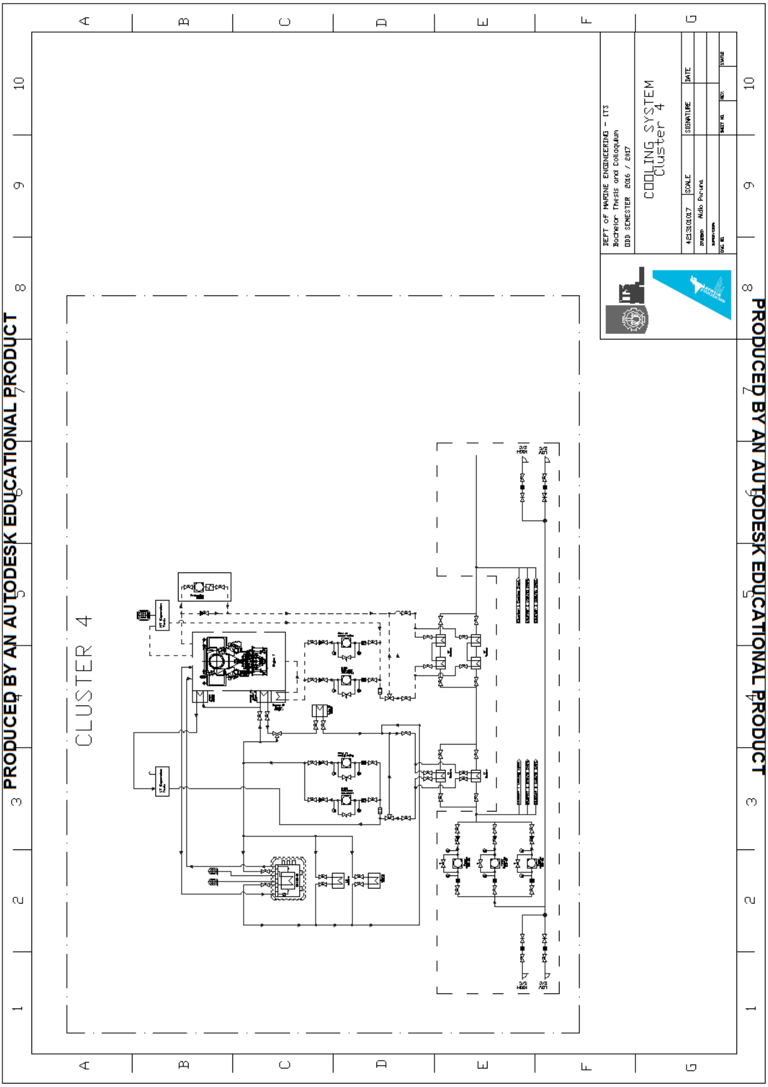

Figure 4.26 Cooling System for Cluster 4

4.4. Fuel Consumption and Storage

The concept of diesel engine is to convert chemical energy into mechanical energy, therefore, a continues supply of fuel is required if there is a demand to operate the power plant. Every diesel engine has difference fuel consumption which depends on its technology and design.

Since the power plant were meant to be built on a barge, the space available for fuel storage are also limited and requires a comparative process between several products and dimension.

In this chapter, the fuel consumption of the plant will be calculated, fuel storage will be determined, both information can be used to calculate the operation duration. Bunkering concept also will be discussed in this chapter.

4.4.1. Fuel Consumption

Fuel consumption of the engine will be calculated to determine the type of storage. When the storage is determined with an assumption the engine is running on maximum power for 24 hours.

To determine the safety stock of the 100 MW LNG Mobile Power Plant, the fuel consumption of existing 100 MW power plant with TM2500 as the generator will be used. The purpose of this calculation is to find the average load in 24 hours and to apply the load to calculate the fuel consumption for the chosen engine.

The fuel consumption and storage calculation is conducted with the gas turbine and the dual-fuel diesel engine to support the decision making of which engine should be used to power the 100 MW LNG Mobile Power Plant, the result can be seen in table 4.58.

Table 4.58 Fuel Consumption with Continuously 100 MW of Load per Day

Type	SGFC $[kJ/kWh]$	Engine Load [kW]	Gas Consumption kJ/day	Gas Consumption m^3/day
MAN 18V51/60DF	7318,989	106044,5	18627331495	499957,577
General Electric TM2500	10356	100000	24854400000	667092,096
LNG consumption m^3/day	**SFOC (1)**	**OC/d [g/d] (1)**	m^3/day (1)	
833,2626	2,434041	258116,7	0,290019	
1111,82016	-	-	-	

(1) SFOC for Pilot Fuel

4.4.2. Fuel Storages and Tanks

Fuel storages for *Conceptual Design of 100 MW LNG Mobile Power Plant* are very essential since every operation related to the mobile power plant requires a fuel, in this case a hydrocarbon fuel which is natural gas. Beside natural gas, a liquid fuel such as Medium Diesel Oil (MDO) is required as a pilot fuel or to promotes ignition of gas fuel inside the combustion chamber. Detail calculation and tank arrangement can be found at Attachment 7: Storage and Duration Calculations

a. Liquefied Natural Gas Storage
The fuel storage calculation process is done by choosing several types of Type C Pressurized Vessels that available on the market and then arrange it. By arranging the storage in the

available spaces, the number of storage vessels and its total capacity can be calculated. The draft of the arrangement and calculation for several type of storage vessels are in the Attachment 7: Storage and Duration Calculations.

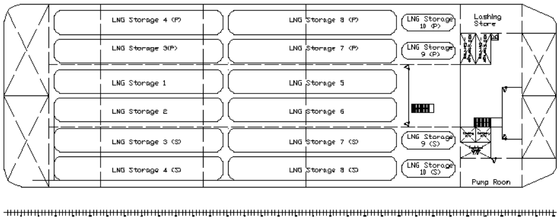

Fig 4.27. Arrangement of LNG Storage

The arrangement process is done by using the preliminary chosen barge which is Damen Stan Pontoon B32 SPo9832. The selected Type C Pressurized Vessels which has been shown by figure 4.27 is the combination of;

1. Lapesa 4200 H Type LC318

Capacity	304,825		m^3
Weight (Payload)	139		Ton
Tare Weight	70,3		Ton
Pressure	5		Barg
No. of tank	12		Unit
Dimension			
Length	**Height**	**Width**	
29700	4200	4200	mm
Total			
Total Capacity	3657,894		m^3
Total Weight	2511,6		Ton

2. Lapesa 3000 H Type LC40

Capacity	38,342		m^3
Weight (Payload)	104,9		Ton
Tare Weight	13,6		Ton
Pressure	5		Barg
No. of tank	4		Unit
Dimension			
Length	**Height**	**Width**	
9374	3000	3000	mm
Total			
Total Capacity	153,3711		m^3
Total Weight	124,3372		Ton

By combining the capacity and weight of the storage above, the result is as it can be seen in table 4.59;

Table 4.59 Total Capacity and Weight of LNG Tank

	Value		**Unit**
Total Capacity	3811,266		m^3
Total Weight	2635,937		Ton
LNG Weight	1737,937		Ton
Total Tare Weight	898		Ton

b. Diesel Oil Storage

Since the 100 MW LNG Mobile Power Plant may use dual-fuel diesel engine, diesel oil is required to support the combustion process where the diesel oil act as a pilot fuel. The required volume of MDO Storage is calculated based on the calculation in chapter 4.4.3 for the operation duration.

The detail of the calculations are attached in the attachment. The design parameters for the mobile power plant are as table 4.60 shows and table 4.61 shows the design of MDO Storage Tank Dimension and Capacity;

Table 4.60 Liquid Fuel Consumption for Tank Design Parameter

	Value	Unit
Pilot Fuel Consumption	0,29002	m^3/day
Low-load[(1)] duration	12	Hours
Low-load[(1)] fuel consumption	300	kg/h
1. Low-load operation cover operation fuel consumption during starting, shutting down, and idling		

Table 4.61 MDO Storage Tank Dimension and Capacity

Length	2,73		m
Width	5,5		m
Height	3		m
Quantity	2		unit
Capacity	45,045		m^3

The capacity of the MDO tanks is larger than required are because the tanks are utilizing the available space in the draft preliminary chosen barge which is Damen Stan Pontoon B32 SPo9832

c. Diesel Oil Service Tank

Based on the MAN 51/60 DF Project Guide, the minimum quantity of service tank is two. The minimum tank capacity of each tank should enable a full operation of minimum 8 operating hours under all condition. In this case, the service tank are built to supply the pilot fuel service tank and to enable liquid mode for several time.

Therefore;

$$Vmdost_{req} = 10{,}485\ m^3$$

The designed tank in the barge are based on the available space in the barge, the design specification of tank can be seen in table 4.62 below.

Table 4.62 MDO Storage Tank Dimension and Capacity

Length	2,73		m
Width	5,5		m
Height	1		m
Quantity	2		unit
Capacity	15,015		m^3

4.4.3. Operation Duration

The operation duration is the capability of the mobile power plant to operate in particular duration. The duration is determined by the capacity of the fuel and then divided by the consumption of the fuel per day, the result can be seen in table 4. 65.

$$Operation\ Duration = {capacity\ of\ fuel\ storage}/_{fuel\ consumption\ per\ day}$$

Table 4.63 LNG Consumption with Continously 100 MW Electricity Load

Engine	Gas Consumption ${m^3}/_{day}$	LNG consumption ${m^3}/_{day}$
MAN 18V51/60DF	499957,577	833,2626
General Electric TM2500	667092,096	1111,82016

Based on the data at table 4.63, the existing 100 MW power plant that using TM2500 as its engine is only consuming approximately 720 ${m^3}/_{day}$ of LNG. This consumption is difference from the calculation because it's related to the operation where the load is varying. By calculating the average load in one day from the fuel consumption, the average load of 100 MW power plant is at 64,759 MW at table 4.64.

$$Avg. Load = \left[720 \, \frac{m^3}{day} \Big/ 111{,}82016 \, \frac{m^3}{day} \right] \times 100 \; MW$$
$$= 64{,}759 \; MW$$

Table 4.64 LNG Consumption with Avg. Electricity Load of 64,759 MW

Engine	**Gas Consumption** m^3/day	**LNG consumption** m^3/day
MAN 18V51/60DF	323765,901	539,609
General Electric TM2500	432000	720

Tabel 4.65 Operation Duration with Available LNG Storage

MAN 18V51/60DF	**Gas Consumption** m^3/day	**LNG consumption** m^3/day	**Duration** *Days*
100 MW	499957,577	833,2626289	4,574
Avg. 64,759 MW	323765,901	539,609	7,063
General Electric TM25000	**Gas Consumption** m^3/day	**LNG consumption** m^3/day	**Duration** *Days*
100 MW	667092,096	1111,82016	3,428
Avg. 64,759 MW	432000	720	5,293

4.4.4. Bunkering Concept

Bunkering is the process of filling the fuel storage from external source, this process is required because the fuel storage for this concept design is not located onshore but inside its hull.

The bunkering concept for *Conceptual Design of 100 MW LNG Mobile Power Plant* were designed to have two option;

1. Ship-to-Ship Transfer (STS)
   Ship-to-ship may take place in various location such as along the quay, at anchoring area, or in the middle of the sea as long it's following the safe practice guidelines. The process of ship-to-ship transfer is animated in figure 4.28.

Figure 4.28 Animated Ship-to-Ship Transfer

Source: Swedish Marine Technology Forum

Ship-to-Ship method offer flexibility to perform bunkering with high capacity of transferred LNG in one operation. The drawbacks in STS method are high investment costs for bunker vessels, complex bunkering operation and complicated authorization from non-petroleum harbor.

Scenario

When the mobile power plant are planned to be settled in specific places with particular demand of electricity, the operation duration can be recalculated to achieve the proper operation duration.

Once the operation duration calculation completed, then scheduling supply from LNG ships can be done properly in order to maintain continues operation the mobile power plant.

The mobile power plant consists of 2 manifold located on starboard where each port has 1 LNG port and 1 gas return port. The LNG which has been transferred to the manifold will be distributed into specific tank by using multi selector valve. The process diagram illustrated by figure 4.29.

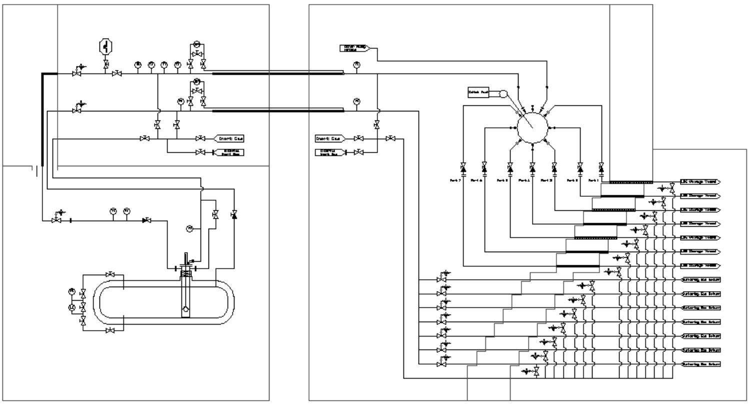

Figure 4.29 Bunkering Process Diagram (Detail, see Attachment 7)

Based on the figure, it can be seen that each LNG tank inside the mobile power plant has 2 connection which is for liquid fluid and gas return which will transferred into source ship. There is also another port that went to the starboard area for TTS Method.

2. Truck-to-Ship Transfer (TTS)

   Truck-to-Ship Transfer is a method which use truck to carry the LNG and then transfers it into the mobile power plant by using flexible hose.

The advantages of truck-to-ship transfer is low investment cost since the truck can be used for multi-purposes activities. The drawback of TTS are it's not suitable for large consumers since the truck has limited capability to carry the LNG.

Scenario

TTS method are preferably used as additional supply for prolonging the mobile power plant operation duration or a method that will be used if the power plant operated in light condition.

The port for TTS located on starboard area where the pipe will be connected to the pipe from the manifold which is located in the starboard area.

TTS will be done by using the truck's pump where the connection between the manifold and the truck will utilize flexible hose.

The figure 4.30. show the illustration of TTS where the ship is being filled up with LNG from the truck. As it can be seen the connection from the truck is using flexible hose.

Figure 4.30 Truck-to-Ship ansfer
Source: Gasnor

4.5. Approach to Calculate Weight, Design, and Barge Analysis Process

The state-of-art of ship design is to develop a design that enable a construction to float on the water. A vessel able to float due to its buoyancy while buoyancy itself depends on its dimension.

In this part of the thesis, existing barge design are chosen as a vessel to be loaded by the machinery and its supporting system. The pontoon selecting process are part of the analysis where the preliminary chosen barge need to be able loaded by the equipment. If the pontoon cannot be loaded, then the process should be started over from choosing the pontoon. The draught of the mobile power plant also will be calculated in this part of the thesis. The calculations for preliminary design are attached in the Attachment 8: Weight Estimation, and final arrangement at Attachment 11: Re-arranged Design and Specification (Optimization).

4.5.1. Stan Pontoon Weight

The pontoon design process is also the part of early process before the general arrangement drawing can be developed. As the mobile power plant are designed on a barge or pontoon, therefore the space, buoyancy and other aspect from the pontoon are essentials.

As mentioned before, the space and buoyance factor are very important to develop an ergonomic design which enable the safety at the working place during operation. Buoyancy also become an important aspect where the mobile power plant should able to float in its fully loaded condition.

For the early design process, author like to use the available stan-pontoon design to improve the reliability of the design. The stan-pontoon used for this process is Damen Stan Pontoon B32 SPo9832 with specification as below (table 4.65),

Table 4.65 Damen Stan-Pontoon B32 SPo9832 Dimension and Capacity

Damen Stan-Pontoon B32 SPo9832			
Dimension			
Length	97,5		M
Beam	32,2		M
Draft	6,2		M
Height	8,1		M
Principle Dimension			
Cb[(1)]	0,94		
LWT (barge only)	2720,6		Ton
DWT Max	16000		Ton
$\nabla^{(1)}$	18263,98		m^3
$\Delta^{(2)}$	18720,58		Ton

(1) The value are calculated using method of approach by using AutoCAD software
(2) Assumed the sea water density $\rho = 1{,}025\, {}^{ton}/_{m^3}$

The process achieves the Cb, LWT, volume displacement and mass displacement are done by using autocad. The processes were begun with creating lines plan then separate the lines plan into several segments. The next step is to calculate the area in each segment then calculate the volume by using Simpsons formula. The calculations are attached in the Attachment 8: Preliminary Weight Estimation.

Figure 4.31 show the general arrangement of Damen Stan-Pontoon B32 Series. The next phase of this project which is general arrangement drawing will be conduct with the pontoon above. The next phase is also part of the analysis process where the size of the pontoon will be analyzed is it fit to support the power plant or not.

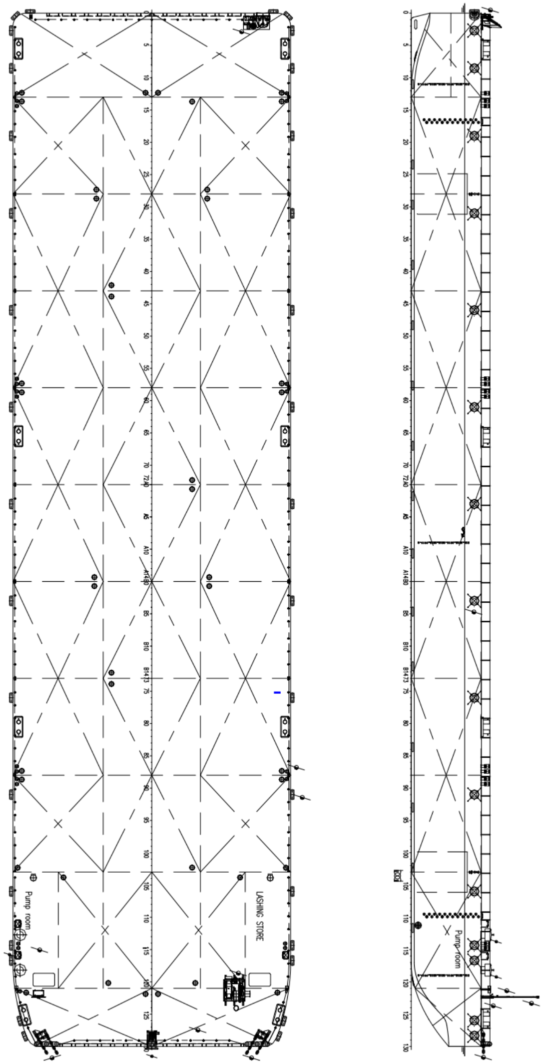

Figure 4.31 Damen Stan Pontoon B32 Series

4.5.2. Lightweight of the Ship

The lightweight of the ship is a mass of the ship itself without considering the moveable goods such as fuel, lube oil, water, etc. Every machinery that has been calculated and determined in chapter 4.3 and chapter 4.4 which located onboard ship will be part of the lightweight and also the deckhouse.

In this part of the thesis, weight estimation will be done by summing all of the determined equipment in the previous chapter rather than using empirical formula. A weight margin also will be added due to unmentioned minor equipment or any equipment outside the limitation of this thesis. While the system equipment can be estimated without a formula, the weight of the deckhouse which has been shown by figure 4.32 will be estimated by using formula from Ship Design for Efficiency and Economy *(H. Schneekluth,1998).*

$$Wst = (L \times B \times Da) \times Cs \qquad (4.1)$$

$$Cs = Cso + 0{,}064e^{-(0{,}5u+0{,}1u^{2{,}45})} \; where \; u = \log_{10}\frac{\Delta}{100} \qquad (4.2)$$

$Cso: Depend\ on\ the\ ship, assumed\ 0{,}064$

The deckhouses are separated into 4 part and can be seen in figure x., where each deck house has a weight of;

$WD_{h1} = 15m \times 24{,}6m \times 3m \times 0{,}107134 = 118{,}5979\ ton$

$WD_{h2} = 15m \times 24{,}6m \times 2{,}8m \times 0{,}107134 = 110{,}6913\ ton$

$WD_{h3} = 15m \times 24{,}6m \times 2{,}8m \times 0{,}107134 = 110{,}6913\ ton$

$WD_{h4} = 63{,}6m \times 26{,}6m \times 12{,}3m \times 0{,}107134 = 2236{,}222\ ton$

Total: 2576,202 ton

Outfitting for deckhouse 1,2 and 3 also done by using empirical formula which is;

$$Wot = L \times B \times K \text{ where } K = 0{,}35 \quad (4.3)$$

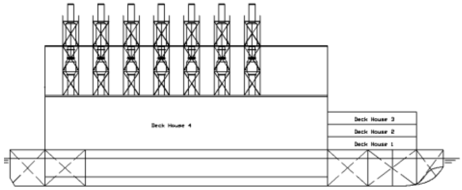

Figure 4.32 Deckhouse Arrangement

In table 4.66 present the total weight of the chosen equipment for the mobile power plant. All of the equipment weight are calculated related to the previous chapter where the equipments were determined.

Table 4.66 Lightweight Component of the Mobile Power Plant

No.	Object	Measurement Unit	Value
1	Engine related equipments(1)	Ton	2875,624
2	Deckhouse	Ton	2576,202
3	Outfitting	Ton	387,45
4	Gas Fuel System(2)	Ton	904,296
5	Liquid Fuel System	Ton	7,22
6	Lube Oil System	Ton	39,561
7	Cooling System	Ton	220,194
8	Compressed Air System	Ton	8,55
9	Manifold	Ton	11,6
10	Barge Weight	Ton	2720,6
Total			9751,3
(1) Diesel engine, exhaust pipe, economizer, silencer and alternator (2) GCU isn't included			

The type of heat exchanger in the weight estimation are difference, the type written in chapter 4 is only to estimate the dimension while for weight estimation and drawing, the current design was customized and the weight is an assumption based on the existing product. Details of each object in the table attached in the Attachment 8: Preliminary Weight Estimation for preliminary design and final design at Attachment 11: Re-arranged Design and Specification (Optimization).

4.5.3. Deadweight of the Ship

Consumable goods or deadweight are an object onboard ship which is moveable or deadweight, unlike lightweight which is permanently stayed onboard ship.

Consumable goods consist of liquid fuel, liquefied gas fuel, fresh water, lube oil, crew, provision, and etc. Therefore, to calculate the weight of each object, the requirement of each object need to be checked and then check the available tank/space in the design.

a. Weight of liquid fuel

Based on the previous chapter, the requirement of liquid fuel (MDO type) is 53,493 ton. But based on the available space, the content of liquid fuel that can be stored is 73,365 ton. The specifications of the tank are written in table 4.67.

Table 4.67 Liquid Fuel Tank Specification and Weight

L[m]	**B[m]**	**H[m]**
2,73	5,5	3,05
Volume[m^3]		45,795
Content Weight[ton] (1)		36,682
Total Weight[ton] (2 tanks)		73,365
(1) Density $\rho = 0{,}89 \frac{ton}{m^3}$, and filling volume 90%		

b. Weight of LNG
The tank and weight of LNG already determined in chapter 4.4 where number of tank, total weight of the LNG already calculated which is;

$$LNG\ weight = 1737{,}937\ ton$$

c. Weight of lube oil
Based on the previous chapter, the requirement of lube oil (Shell Gadinia AL40) in the storage to be able operated for the operation days is 4,924 ton. But based on the available space, the content of lube oil that can be stored is 7,577 ton. The specifications of the tank are written in table 4.68.

Table 4.68 Lube Oil Tank Specification and Weight

L[m]	**W[m]**	**H[m]**
1,28	1,28	6,1
Volume[m^3]		9,994
Content Weight[ton] (1)		8,914
Total Weight[ton] (storage + service tank content)		180,226
(1) Density $\rho = 0{,}892\frac{ton}{m^3}$, and filling volume 85%		

d. Weight of Crew and Provision
Based on previous research, the crew will be divided into 3 division which is deck department, production department and engineering department. And each division is consist of;

- Deck Department
  General Manager 1 Person
  Captain 1 Person
  Seaman 2 Person
- Production Department

Manager	1 Person
EPC of Fuel and Lube oil	2 Person
Logistic	1 Person

- Engineering Department

Manager	1 Person
Engineer for Electrical	6 Person
Engineer for Mechanical	6 Person
Operation and Maintenance	1 Person

The source of the ship manning are following the previous research done in “*Desain Power Plant Barge 20 MW Tenaga Gas Sebagai Unit Pembantu Wilayah Kabupaten Kepulauan Selayar Sulawesi Selatan”* (Hariyanto, 2014)

Assumed that crew mass is in average (75 kg) and brought 25 kg of their own belonging; therefore the total weight is;

$$Wcp = \frac{(22\times75)+(22\times25)}{1000} = 2{,}2\ ton \quad (4.4)$$

The provision for the crew assumed is 5 kg/pers.day, therefore the total of provision need to be stored for the previous operation duration is;

$$Wp = 0{,}68464\ ton$$

e. Weight of fresh water

The requirement of fresh water is divided into three categories (cooling water, consumable, technical water), whic in the storage to be able operated for the. Based on the available space, the total content of fresh water that can be stored is 166,0725 ton. The specifications of the tank are written in table 4.69.

The consumable water requirement are determine by multiplying the number of crew onboard with their assumed water consumption (10 kg/day for consumption and 80 kg/day for sanitary).

Table 4.69 Freshwater Tank Specification and Weight

Cooling Water Storage		
L[m]	**W[m]**	**H[m]**
2,75	2,75	6,1
Volume[m^3]		46,131
Content Weight[ton] (1)		41,518
Consumable Water Storage		
L[m]	**W[m]**	**L[m]**
2,75	2,75	6,1
Volume[m^3]		46,131
Content Weight[ton] (1)		41,518
Technical Water Storage		
L[m]	**W[m]**	**L[m]**
5,5	2,75	6,1
Volume[m^3]		92,2625
Content Weight[ton] (1)		83,03625
Total		
Total Weight[ton] (Cooling water, consumable, technical water)		166,0725
(1) Density $\rho = 1\frac{ton}{m^3}$, and filling volume 90%		

The total of the consumable goods or deadweight of the mobile power plant is presented in table 4.70.

Table 4.70 Consumable Goods Total Weight

No	Object	Measurement Unit	Value
1	Wmdo	Ton	73,364
2	Wlng	Ton	1737,937
3	Wlo	Ton	180,2226
4	Wfw	Ton	166,0725
5	Wp	Ton	0,684
6	Wcp	Ton	2,2
	Total	Ton	2160,481

4.5.4. Ballast Tank and Weight

A ship may have uneven weight distribution which may cause trim and roll due to the design. To avoid uneven weight distribution, the process need to be done in design phase, but if it's not possible or will sacrifice another aspect like ergonomic, then ballasting may become a suitable option to overcome this problem.

Ballasting also necessary to maintain the ship draught during full condition which may require less ballast water or in light condition which require more ballast water to maintain its draught. The basic of the stability itself related with the ship draught, therefore, ballasting will add more benefits to the ship stability.

Based on the available spaces, the designed tank meant for ballast is separated in several tanks, the arrangement illustrated in figure 4.33.

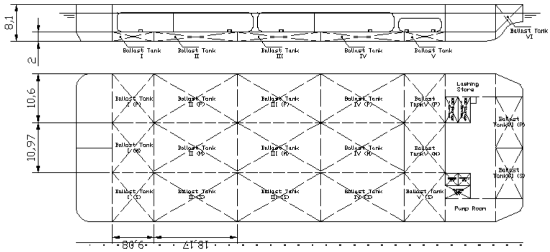

Figure 4.33 Ballast Tank Design

The specification, dimension, and capacity of the ballast tank are informed in table 4.71.

Table 4.71 Ballast Tank Dimension, Volume, and Mass

No	Object	$L \times W \times H$ $[m^3]$	Volume $[m^3]$	Mass [ton]
1	Ballast Tank 1 (P)	9,08 x 10,6 x 2	192,496	197,308
2	Ballast Tank 1 (M)	9,08 x 10,97 x 2	199,215	204,196
3	Ballast Tank 1 (S)	9,08 x 10,6 x 2	192,496	197,308
4	Ballast Tank 2 (P)	18,17 x 10,6 x 2	385,204	394,834
5	Ballast Tank 2 (M)	18,17 x 10,97 x 2	398,649	408,616
6	Ballast Tank 2 (S)	18,17 x 10,6 x 2	385,204	394,834
7	Ballast Tank 3 (P)	18,17 x 10,6 x 2	385,204	394,834
8	Ballast Tank 3 (M)	18,17 x 10,97 x 2	398,649	408,616
9	Ballast Tank 3 (S)	18,17 x 10,6 x 2	385,204	394,834
10	Ballast Tank 4 (P)	18,17 x 10,6 x 2	385,204	394,834
11	Ballast Tank 4 (M)	18,17 x 10,97 x 2	398,649	408,616
12	Ballast Tank 4 (S)	18,17 x 10,6 x 2	385,204	394,834
13	Ballast Tank 5 (P)	9,08 x 10,6 x 2	192,496	197,308
14	Ballast Tank 5 (M)	9,08 x 10,97 x 2	199,2152	204,195

Table 4.71 Ballast Tank Dimension, Volume and Mass (Cont)

No	Object	$L\times W\times H$ $[m^3]$	Volume $[m^3]$	Mass [ton]
15	Ballast Tank 5 (S)	9,08 x 10,6 x 2	192,496	197,308
16	Ballast Tank 6 (P)		344,854	353,475
17	Ballast Tank 6 (S)		344,854	353,475
Total			5365,296	5499,428

4.5.5. Draught Estimation

The draught of the ship may vary depends on its weight, basically the ship may inform the ship's draught at its fully loaded draught, and during light weight.

The following table 4.72 is the result of the estimated displacement at several water lines by using Simpson's Formula.

$$V = \frac{1}{3}\times\sum(A\times F)\times H \quad (4.5)$$

Then the volume result multiplied by the density of the seawater to achieve the mass displacement. Detail calculation of the Simpson's formula are attached in the Attachment 8: Preliminary Weight Estimation and Attachment 11: Re-arranged Design and Specification (Optimization) for final arrangement.

Table 4.72 Estimated Mobile Power Plant Displacement at Several Waterline

No	Waterline	$\nabla[m^3]$	$\Delta[ton]$
1	WL 1	2681,49	2748,53
2	WL 2	5394,62	5529,48
3	WL 3	8528,43	8741,64
4	WL 4	11429,8	11715,6
5	WL 5	14256,9	14613,3

The draught estimation were calculated by using fixed ballast due to previous calculation the mobile power plant shows tendency to have heeling position, therefore a fixed ballast is required as it can be seen in table 4.73.

Table 4.73 Mobile Power Plant Weight at 2 Conditions

No	Condition	Weight [ton]	Req. Ballast [ton]	Total [ton]
1	LWT	9751,3	311,489	10062,8
2	LWT + DWT	11911,8	209,354	12121,1

a. Lightweight's Draught

The light weight of the ship is 10062,8 ton which is in between of WL 4 and WL 3. Interpolation process was used to determine the waterline during lightweight.

$$D_{LWT+Ballast} = 4 - \frac{(11715{,}6-10062{,}8)}{(11715{,}6-8528{,}43)} \times (4-3) = 3{,}4425\ m \quad (4.6)$$

The result can be concluded that the ship will be on 3,3 m during light weight.

The ship dimension coefficients are as table 4.74 below;

Table 4.74 Mobile Power Plant Dimension Coefficient at LWT + Ballast

No	Coefficient	Symbol	Value
1	Block Coefficient	Cb	0,93689
2	Midship Coefficient	Cm	0,99889
3	Waterplane Coefficient	Cwp	0,96267
4	Prismatic Coefficient	Cp	0,93793
5	Vertical Prismatic Coefficient	Cvp	0,97322

b. Fully Loaded Draught

The fully loaded weight of the ship is 12121,1 ton which is in between of WL 4 and WL 5. Interpolation process was used to determine the waterline.

The result by summing the lightweight and deadweight of the ship is;

$$\Delta = LWT + DWT + Ballast \qquad (4.7)$$

$$\Delta = 12121{,}1\ ton$$

The total displacement of the ship when it's loaded is 12121,1 ton which is in between of WL4 and WL 5. Interpolation process was used to determine the waterline included with ballast water to prevent heeling.

$$D_{dwt+lwt+ballast} = 5 - \frac{(14613{,}3 - 12121{,}1)}{(14613{,}3 - 11715{,}6)} \times (5 - 4) = 4{,}1399\ m \qquad (4.8)$$

The ship dimension coefficients are as table 4.75 below;

Table 4.75 Mobile Power Plant Dimension Coefficient at LWT + DWT + Ballast

No	Coefficient	Symbol	Value
1	Block Coefficient	Cb	0,93842
2	Midship Coefficient	Cm	0,99908
3	Waterplane Coefficient	Cwp	0,97389
4	Prismatic Coefficient	Cp	0,93928
5	Vertical Prismatic Coefficient	Cvp	0,96358

4.5.6. General Arrangement

All of the chosen equipment and design consideration will be arranged to develop the general arrangement. The information contained by the general arrangement may differs from each designer, but the minimum information included in the drawings is the key aspects.

The general arrangement used to determine the initial stability, centre of gravity and buoyancy can be seen in figure 4.34. The process of design were done in 2 phase where there is Preliminary General Arrangement Drawing (see Attachment 9: Preliminary General Arrangement Design Philosophy and Drawings) and then continued with final general arrangement drawing (see Attachment 11: Re-arranged Design and Specification (Optimization)).

In figure 4.35 The 3D visualization of the 100 MW LNG Mobile Power Plant from South-East Isometric point of view can be seen. The detail 3D drawings from various point of view can be seen in the attachment.

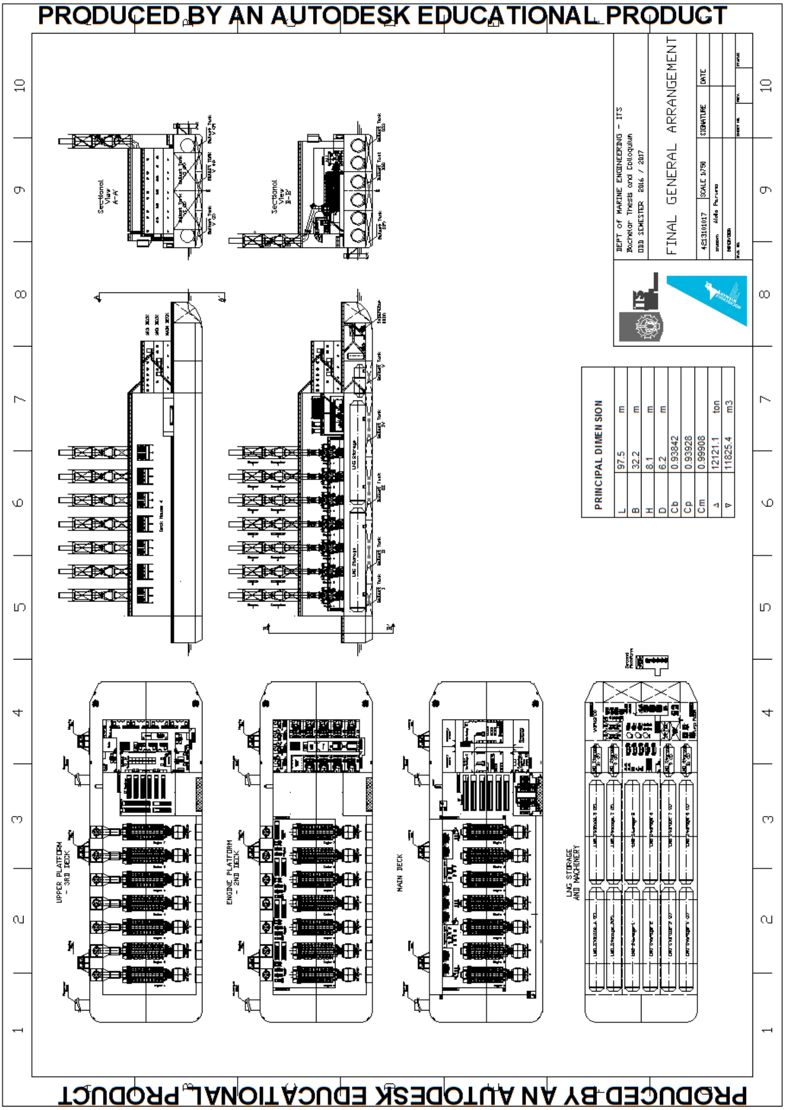

Figure 4.34 General Arrangement

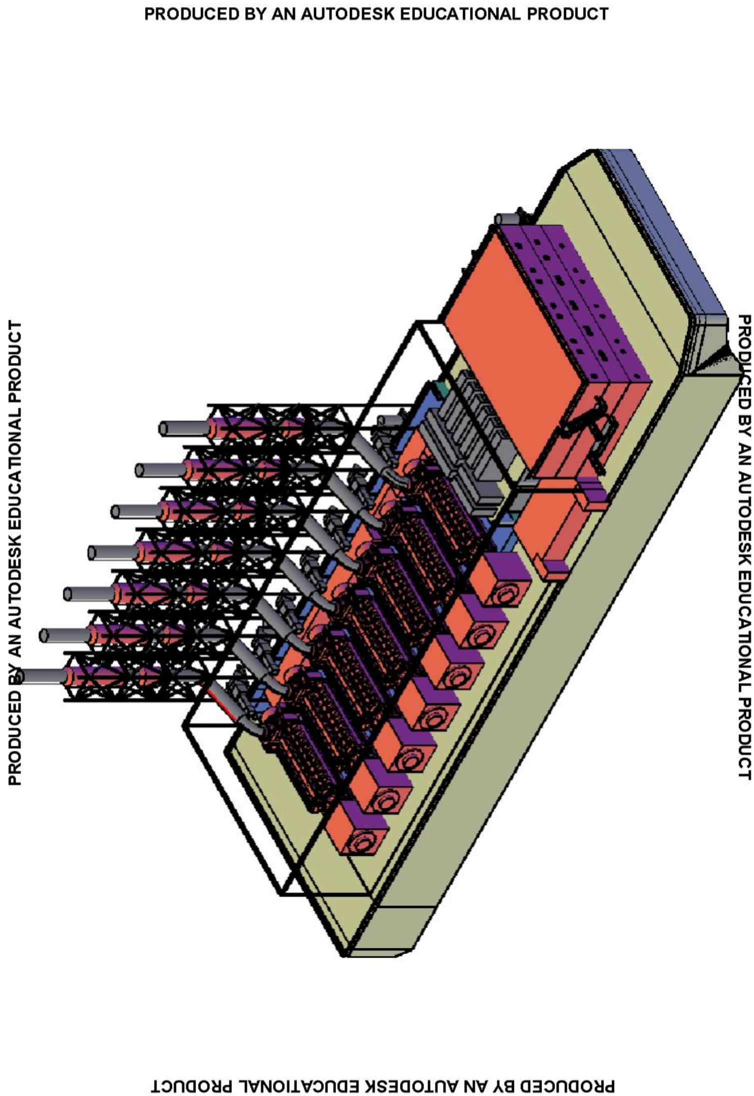

Figure 4.35 3D General Arrangement

4.5.7. Heel and Trim Condition

Heel and trim of the ship are related with the centre of gravity and its centre of buoyancy. In this chapter, some variables that may add an effects to the ship condition will be reported.

The following text was the result of the calculation of almost every equipment. Equipments in the previous chapter are illustrated into the general arrangement drawing then measured for its centre of gravity. Detail information and calculation for each equipment can be found in Attachment 10: Preliminary Centre of Gravity and Buoyancy for the preliminary design while Attachment 11: Re-arranged Design and Specification (Optimization) shows the final Heel and trim condition, the general arrangement used to determine the distance of each equipment was the final General Arrangement Drawing (see Attachment 11).

In table 4.76 the result of the calculation result during lightweight and fully loaded condition using formula can be seen;

$$KG\ Total = \frac{\sum(KG \times W)}{Wtotal} \tag{4.9}$$

$$LCG\ Total = \frac{\sum(LCG \times W)}{Wtotal} \tag{4.10}$$

$$TCG\ Total = \frac{\sum(TCG \times W)}{Wtotal} \tag{4.11}$$

Table 4.76 Mobile Power Plant KG, LCG and TCG at 2 Conditions

No	Condition	KG Total	LCG Total (1)	TCG Total (2)
1	LWT+ Ballast	8,417	-0,998	0
2	LWT+DWT+Ballast	7,747	-0,828	0

(1) ‘-‘ distance heading to stern, ‘+’ distance heading to bow
(2) ‘-‘ distance heading to starboard, ‘+’ distance heading to portside

To calculate the trim and heeling, several hydrostatic of the ship need to be determined first. The attempt to calculate the hydrostatic properties done by using existing empirical formula.

- Distance between keel and centre of buoyancy;

$$\frac{KB}{T} = 0{,}9 - 0{,}3Cm - 0{,}1Cb \qquad (4.12)$$

From Parametric Design (Parsons, 2001, p.11-19)

- Properties of Metacentric

a. Transverse:

$$BMt = It/\nabla \qquad (4.13)$$

Where;

$$It = \frac{Ci}{LB^3} \text{ with } Ci = 0{,}1216Cwp - 0{,}0410 \qquad (4.14)$$

And

$$GMt = KB + BMt - KG \qquad (4.15)$$

b. Longitudinal:

$$BMl = Il/\nabla \qquad (4.16)$$

Where;

$$Il = \frac{Cil}{LB^3} \text{ with } Cil = 0{,}350Cwp^2 - 0{,}405Cwp + 0{,}146 \qquad (4.17)$$

And

$$GMl = KB + BMl - KG \qquad (4.18)$$

From Parametric Design (Parsons, 2001, p.11-18, 11-19)

Then the trim and heel condition of the ship can be calculated by using formula;

$$trim = Ta - Tf = \frac{(LCG - LCB).L}{GMl} \qquad (4.19)$$

From Parametric Design (Parsons, 2001, p.11-27)

The following table 4.77 and calculations below shows the result of distance between keel and centre of buoyancy, properties of metacentric, trim and heel condition of the mobile power plant.

Table 4.77 Hydrostatic Properties of the Mobile Power Plant

No	Condition	KG	Transverse			Longitudinal			GMl	GMt
			BMt	It	Ci	BMl	Il	Cil		
1	LWT + Ballast	8,418	24,605	247592,486	0,076	238,68	2401836,179	0,08	232,011	17,93
2	LWT + DWT + Ballast	7,747	20,793	252030,783	0,077	205,68	2493125,998	0,084	200,034	15,14

a. LWT + Ballast Condition

$$trim = \frac{(0{,}46446)\times 97{,}5}{232{,}011} = 0{,}19518\ m \quad (4.20)$$

The ship will trim 0,19518 (0,229°) meters to bow.

$$heel = \frac{(0)\times 32{,}2}{17{,}93} = 0\ m \quad (4.21)$$

The ship will heel 0 (0°) meters.

b. LWT + DWT + Ballast Condition

$$trim = \frac{(0{,}63394)\times 97{,}5}{200{,}034} = 0{,}30899\ m \quad (4.22)$$

The ship will trim 0,30899 (0,363°) meters to bow.

$$heel = \frac{(0)\times 32{,}2}{15{,}14} = 0\ m \quad (4.23)$$

The ship will heel 0 (0°) meters.

c. Transverse Righting Arm

Righting arms are the length of the lever when the ship is rolled in some degree. Righting arm is the parameter of the ship's stability. Table 4.78 below shows the righting arm of the mobile power plant at several rolling angles where the righting arm (GZ) calculated by wall sided formula.

- For small angles;

  $$GZ = GM\times Sin\theta \quad (4.24)$$

  Barge Stability Guidelines (Maritime New Zealand, 2006, p. 04)

- For Wall-sided (large angles)
  $GZ = (GM + {}^{1}/_{2} \times BM \times \tan^2 \theta) \times Sin\theta$ (4.25)
  Basic Ship Theory (Rawson, 2001, p.103*)*

Table 4.78 Righting Arm of the Mobile Power Plant at 2 Conditions

No	**Angles [°]**	**GZ (LWT+Ballast) [m]**	**GZ (LWT+DWT+Ballast) [m]**
1	0	0	0
2	5	1,563	1,319
3	10	3,114	2,629
4	15	4,641	3,918
5	20	6,691	5,649
6	25	8,708	7,354
7	30	11,016	9,303
8	35	13,744	11,607
9	40	17,093	14,437

Based on the requirement from Germanischer Lloyd (I-1-1) as classification societies which adopt the regulation from IMO IS Code 2008. The result of ship hydrostatic properties compliance with the regulation is as table 4.79 below;

Table 4.79 Ship Hydrostatic and Stability Properties Compliance with the Standards

No	Regulation	Conditions
1	The righting lever GZ is to be at least 0.20 m at an angle of heel equal to or greater than 30°. (IS Code 2008 A,2.2.2)	Accepted

Table 4.79 Ship Hydrostatic and Stability Properties Compliance with the Standards (Cont)

No	Regulation	Conditions
2	The maximum righting arm is to occur at an angle of heel not less than 25 °. (IS Code 2008 A,2.2.3)	Accepted
3	The initial metacentric height GM_0 is not to be less than 0.15 m (IS Code 2008 A,2.2.3)	Accepted
4	The validity of such damage stability calculation is restricted to an operational trim of ±0.5% of the ship's length L. (0,4875 m). (MSC.Res216(82), Reg. 5-1.3, 7.2)	Accepted

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CHAPTER V
CONCLUSIONS

5.1. Conclusions

Based on the calculation, design, and drawing process of *Conceptual Design of 100 MW LNG Mobile Power Plant*, it can be concluded as below;

1. After several medium-speed diesel engines which have similar power output and 2 gas turbines have been compared, the chosen powering machinery for the 100 MW LNG Mobile Power Plant is MAN 18V51/60 DF Diesel with gas fuel consumption as priority parameter.

2. The result of calculations and chosen equipment for the 100 MW LNG Mobile Power Plant can be found at;
   a. Attachment 2: Gas Fuel Supply System
   b. Attachment 3: Liquid Fuel Supply System
   c. Attachment 4: Lubricating Oil Supply System
   d. Attachment 5: Starting Air Supply System
   e. Attachment 6: Cooling System

   In general, the system for the 100 MW LNG Mobile Power Plant is consist of 4 cluster where cluster 1, 2, and 3 consists of 2 diesel engines while cluster 4 consist of 1 diesel engine.

3. The fuel consumption of the 100 MW LNG Mobile Power Plant with MAN 18V51/60 DF as its powering machinery is as table 5.1;

Table 5.1 Fuel Consumption and Operation Duration of the Mobile Power Plant

MAN 18V51/60DF	Gas Consumption m^3/day	LNG consumption m^3/day	Operation Duration *Days*
Continuously 100 MW	499957,577	833,2626289	4,574
Avg. 64,759 MW	323765,901	539,609	7,063

The operation duration of the 100 MW LNG Mobile Power Plant is based on the total capacity of LNG the mobile power plant can store the result can be seen in table 5.2 below, the drawings of the final arrangement of LNG storage can be found in;

Attachment 11: Re-Arranged Design and Specification (Optimization)

Table 5.2 Total Capacity and Weight of the LNG Storage

	Value	**Unit**
Total Capacity	3811,266	m^3
Total Weight	2635,937	Ton
LNG Weight	1737,937	Ton
Total Tare Weight	898	Ton

4. The final general arrangement of *Conceptual Design of 100 MW LNG Mobile Power Plant* can be found in;

   a. Attachment 11: Re-Arranged Design and Specification (Optimization) for final drawings .

   b. Attachment 9: Preliminary General Arrangement Design Philosophy and Drawings for design requirements.

   c. Attachment 12: Material Requirement Planning (MRP) for the required materials and equipment.

   The result of the arrangement related principle dimension are as table 5.3 and its hydrostatic properties with the regulations at table table 5.4 shows;

Table 5.3 Principle Dimension of Conceptual Design of 100 MW LNG Mobile Power Plant

Principle Dimension			
No	**Object**	**Measurement Unit**	**Value**
1	L	m	97,500
2	B	m	32,200
3	D	m	4,139
4	H	m	8,100
5	Cb		0,93842
6	Cp		0,93928
7	Cm		0,99908
8	Δ	Ton	12121,1
9	∇	m^3	11825,4
10	LWT	Ton	9751,3
11	DWT	Ton	2160,5

Table 5.4 Compliance of Conceptual Design of 100 MW LNG Mobile Power Plant Stability and Trim with Regulations

Stability and Trim			
No	**Regulation**	**Existing Value**	**Accpetance**
1	The righting lever GZ is to be at least 0.20 m at an angle of heel equal to or greater than 30°. (IS Code 2008 A,2.2.2)	9,303 [m]	Accepted
2	The maximum righting arm is to occur at an angle of heel not less than 25 °. (IS Code 2008 A,2.2.3)	no	Accepted
3	The initial metacentric height GM0 is not to be less than 0.15 m (IS Code 2008 A,2.2.3)	15,14 [m]	Accepted
4	The validity of such damage stability calculation is restricted to an operational trim of ±0.5% of the ship's length L (0,4875 m). (MSC.Res216(82), Reg. 5-1.3, 7.2)	0,309 [m]	Accepted

5. The drawings result of supporting system arrangement included with the regulations for the 100 MW LNG Mobile Power Plant can be found at;
   a. Attachment 2: Gas Fuel Supply System
   b. Attachment 3: Liquid Fuel Supply System
   c. Attachment 4: Lubricating Oil Supply System
   d. Attachment 5: Starting Air Supply System
   e. Attachment 6: Cooling System

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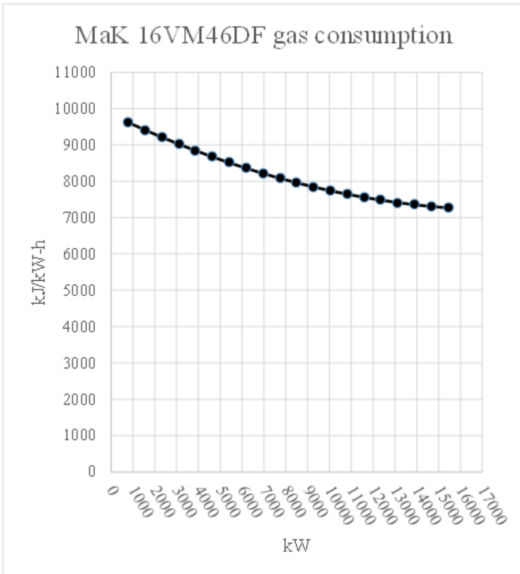
Attachment 1: SFOC and SGFC Calculation

SFOC and SGFC Graph

The data that used to develop the graph are by utilizing the provided data from the manufacturer and then tabulated to create a graph. From the graph, author may generate the function of the trendline, the function can be used to calculate the SGFC and SFOC from particular load which not informed by the manufacturer.

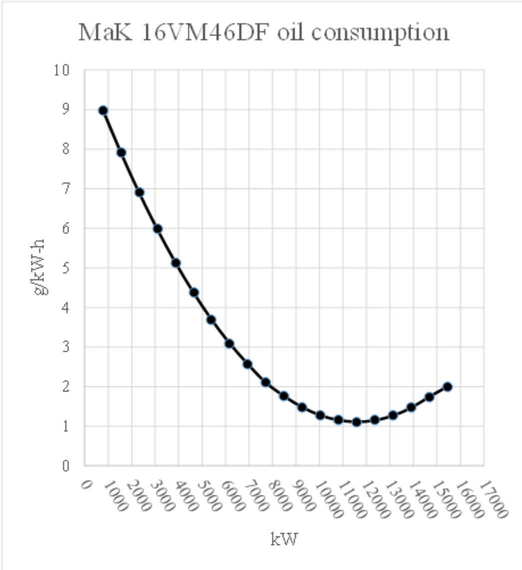
1. MaK 16VM46DF

Type	MaK 16VM46DF	
Power	15440	kW
Fuel Gas Consumption		
Load	Power [kW]	SGFC [kJ/kW-h]
0%	0,00	-
5%	772,00	9627,50
10%	1544,00	9418,81
15%	2316,00	9219,54
20%	3088,00	9029,67
25%	3860,00	8849,22
30%	4632,00	8678,18
35%	5404,00	8516,55
40%	6176,00	8364,33
45%	6948,00	8221,52
50%	7720,00	8088,00
55%	8492,00	7964,14
60%	9264,00	7849,57
65%	10036,00	7744,41
70%	10808,00	7648,66
75%	11580,00	7563,00
80%	12352,00	7485,39
85%	13124,00	7417,00
90%	13896,00	7359,77
95%	14668,00	7311,08
100%	15440,00	7272,00



= Data from MaK 16VM46DF Technical Guide

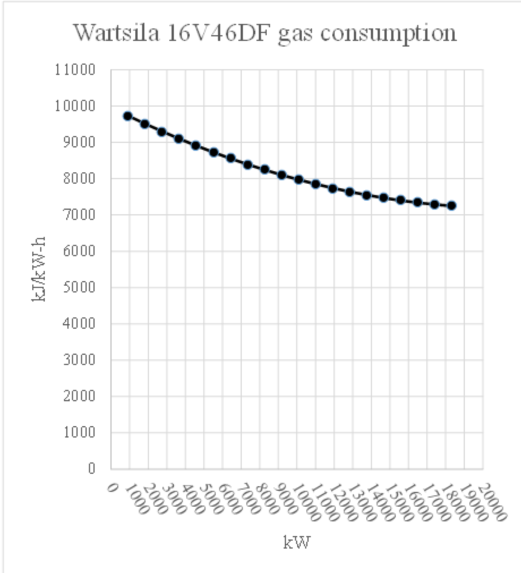
Type	MaK 16VM46DF	
Power	15440	kW
Fuel Oil Consumption		
Load	Power [kW]	SFOC [kJ/kW-h]
0%	0,00	-
5%	772,00	9627,50
10%	1544,00	9418,81
15%	2316,00	9219,54
20%	3088,00	9029,67
25%	3860,00	8849,22
30%	4632,00	8678,18
35%	5404,00	8516,55
40%	6176,00	8364,33
45%	6948,00	8221,52
50%	7720,00	8088,00
55%	8492,00	7964,14
60%	9264,00	7849,57
65%	10036,00	7744,41
70%	10808,00	7648,66
75%	11580,00	7563,00
80%	12352,00	7485,39
85%	13124,00	7417,00
90%	13896,00	7359,77
95%	14668,00	7311,08
100%	15440,00	7272,00



[yellow] = Data from MaK 16VM46DF Technical Guide

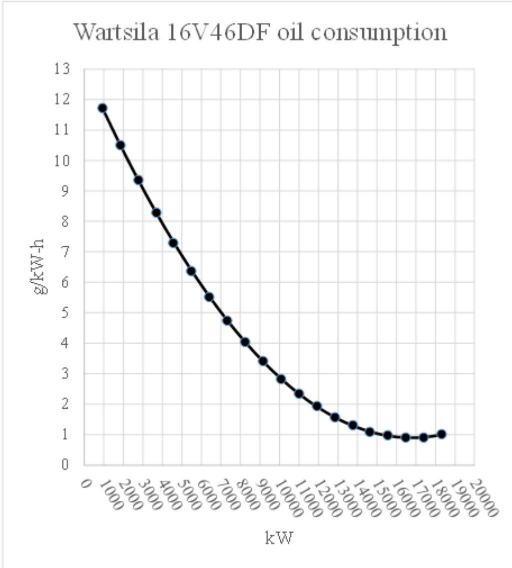
2. Wartsila 16V46DF

Type	Wartsila 16V46DF	
Power	18320	kW
Fuel Gas Consumption		
Load	Power [kW]	SGFC [kJ/kW-h]
0%	0,00	-
5%	916,00	9734,72
10%	1832,00	9513,48
15%	2748,00	9302,28
20%	3664,00	9101,12
25%	4580,00	8910,00
30%	5496,00	8728,92
35%	6412,00	8557,88
40%	7328,00	8396,88
45%	8244,00	8245,92
50%	9160,00	8105,00
55%	10076,00	7974,12
60%	10992,00	7853,28
65%	11908,00	7742,48
70%	12824,00	7641,72
75%	13740,00	7551,00
80%	14656,00	7470,32
85%	15572,00	7399,68
90%	16488,00	7339,08
95%	17404,00	7288,52
100%	18320,00	7248,00



(yellow) = Data from MaK Wartsila 16V46DF Technical Guide

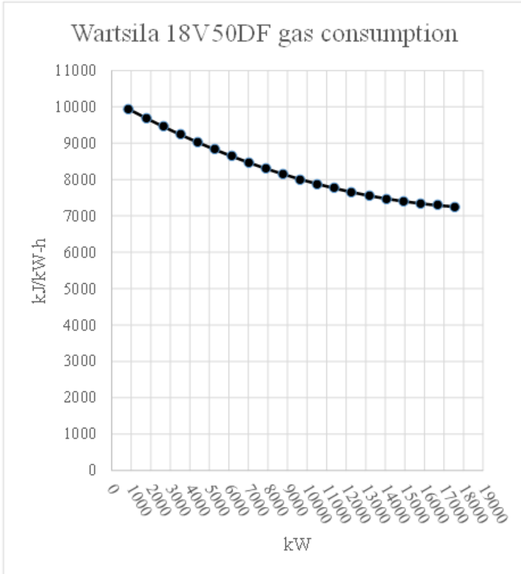
Type	Wartsila 16V46DF	
Power	18320	kW
Fuel Oil Consumption		
Load	Power [kW]	SFOC [kJ/kW-h]
0%	0,00	-
5%	916,00	11,72
10%	1832,00	10,50
15%	2748,00	9,36
20%	3664,00	8,30
25%	4580,00	7,30
30%	5496,00	6,38
35%	6412,00	5,52
40%	7328,00	4,74
45%	8244,00	4,04
50%	9160,00	3,40
55%	10076,00	2,84
60%	10992,00	2,34
65%	11908,00	1,92
70%	12824,00	1,58
75%	13740,00	1,30
80%	14656,00	1,10
85%	15572,00	0,96
90%	16488,00	0,90
95%	17404,00	0,92
100%	18320,00	1,00



(yellow) = Data from MaK 16VM46DF Technical Guide

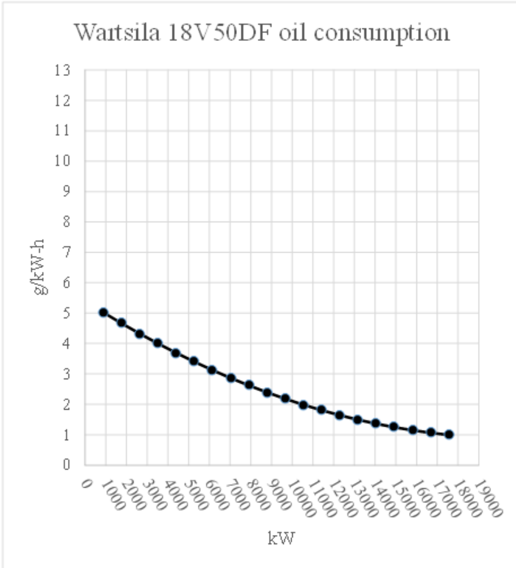
3. Wartsila 18V50DF

Type	Wartsila 18V50DF	
Power	18320	kW
Fuel Gas Consumption		
Load	Power [kW]	SGFC [kJ/kW-h]
0%	0,00	-
5%	877,50	9940,04
10%	1755,00	9695,56
15%	2632,50	9462,56
20%	3510,00	9241,04
25%	4387,50	9031,00
30%	5265,00	8832,44
35%	6142,50	8645,36
40%	7020,00	8469,76
45%	7897,50	8305,64
50%	8775,00	8153,00
55%	9652,50	8011,84
60%	10530,00	7882,16
65%	11407,50	7763,96
70%	12285,00	7657,24
75%	13162,50	7562,00
80%	14040,00	7478,24
85%	14917,50	7405,96
90%	15795,00	7345,16
95%	16672,50	7295,84
100%	17550,00	7258,00



(yellow) = Data from MaK Wartsila 16V46DF Technical Guide

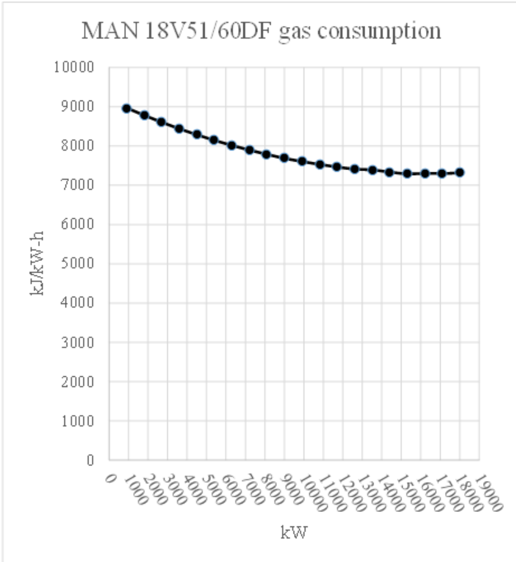
Type	Wartsila 18V50DF	
Power	18320	kW
Fuel Oil Consumption		
Load	Power [kW]	SFOC [kJ/kW-h]
0%	0,00	-
5%	877,50	5,03
10%	1755,00	4,67
15%	2632,50	4,33
20%	3510,00	4,01
25%	4387,50	3,70
30%	5265,00	3,41
35%	6142,50	3,13
40%	7020,00	2,87
45%	7897,50	2,63
50%	8775,00	2,40
55%	9652,50	2,19
60%	10530,00	1,99
65%	11407,50	1,81
70%	12285,00	1,65
75%	13162,50	1,50
80%	14040,00	1,37
85%	14917,50	1,25
90%	15795,00	1,15
95%	16672,50	1,07
100%	17550,00	1,00



= Data from MaK Wartsila 16V46DF Technical Guide

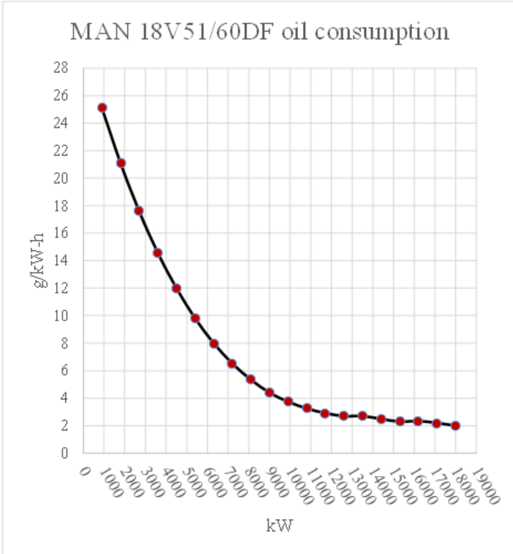
4. MAN 18V51/60DF

Type	MAN 18V51/60DF	
Power	18000	kW
Fuel Gas Consumption		
Load	Power [kW]	SGFC [kJ/kW-h]
0%	0,00	-
5%	900,00	8968,86
10%	1800,00	8780,67
15%	2700,00	8604,31
20%	3600,00	8439,68
25%	4500,00	8288,00
30%	5400,00	8145,15
35%	6300,00	8015,03
40%	7200,00	7896,19
45%	8100,00	7788,52
50%	9000,00	7685,00
55%	9900,00	7606,24
60%	10800,00	7531,42
65%	11700,00	7467,32
70%	12600,00	7413,83
75%	13500,00	7395,00
80%	14400,00	7338,27
85%	15300,00	7292,00
90%	16200,00	7303,83
95%	17100,00	7301,76
100%	18000,00	7315,00



(yellow) = Data from MaK Wartsila 16V46DF Technical Guide

Type	MAN 18V51/60DF	
Power	18000	kW
Fuel Oil Consumption		
Load	Power [kW]	SFOC [kJ/kW-h]
0%	0,00	-
5%	900,00	8968,86
10%	1800,00	8780,67
15%	2700,00	8604,31
20%	3600,00	8439,68
25%	4500,00	8288,00
30%	5400,00	8145,15
35%	6300,00	8015,03
40%	7200,00	7896,19
45%	8100,00	7788,52
50%	9000,00	7685,00
55%	9900,00	7606,24
60%	10800,00	7531,42
65%	11700,00	7467,32
70%	12600,00	7413,83
75%	13500,00	7395,00
80%	14400,00	7338,27
85%	15300,00	7292,00
90%	16200,00	7303,83
95%	17100,00	7301,76
100%	18000,00	7315,00



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Attachment 2: Gas Fuel Supply System

Design Requirement

Keyword	Reference	Design Requirement
Segregation of cargo area	GL I-1-6, Section 3, 3.1.1.	Hold spaces are to be segregated from machinery and boiler spaces, accommodation spaces, service spaces and control stations, chain lockers, drinking and domestic water tanks and from stores.
Cargo Pump and compressor room	GL I-1-6, Section 3, 3.3.1.2	When cargo pump rooms and cargo compressor rooms are permitted to be fitted above orbelow the weather deck at the after end of the aftermost hold space or at the forward end of the foremost hold space, the limits of the cargo area as defined in Section 1, C.1.6 are to be extended to include the cargo pump rooms and cargo compressor rooms for the full breadth and depth of the ship and deck areas above those spaces.
Cargo Control room	GL I-1-6, Section 3, 3.4.1	Any cargo control room is to be above the weather deck and may be located in the cargo area. The cargo control room may be located within the accommodation, service or control station spaces provided the following conditions
Cargo transfer methods	GL I-1-6, Section 3, 5.8.2	The procedure for transfer of cargo by gas pressurization must preclude lifting of the relief valves during such transfer. Gas pressurisation may be accepted as a means of transfer of cargo for those tanks so designed that the design factor of safety is not reduced under the conditions prevailing during the cargo transfer operation.

Filling Limit	GL I-1-6, Section 15, 15.1.1	No cargo tanks shall have a higher filling limit (FL) than 98 % at the reference temperature, except as permitted by 15.1.3.
Gas fuel Supply pipe	GL I-1-6, Section 16, 16.3	Gas fuel piping shall not pass through accommodation spaces, services spaces, or control stations.
Master gas valve	GL I-1-6, Section 16, 16.3.7	A master gas fuel valve that can be closed from within the machinery space is to be provided within the cargo area. The valve is to be arranged so as to close automatically if leakage of gas is detected, or loss of ventilation for the duct or casing or loss of pressurization of the double wall gas fuel piping occurs.
Location of gas make-up plant	GL I-1-6, Section 16, 16.4.1	All equipment (heaters, compressors, filters,etc.) for making-up the gas for its use as fuel, and the related storage tanks shall be located in the cargo area in accordance with paragraph 3.1.5.4. If the equipment is in an enclosed space the space shall be ventilated according to Section 12.1 and be equipped with a fixed fire extinguishing system according to Section 11.5 and with a gas detection system according to Section 13.6 as applicable.
Exhaust gas pipe for multi plant	GL I-1-6, Section 16, 16.6-0.6	The exhaust-gas pipes from multi-engine plants are to be arranged such as to lead to the open air separately. Combination of these pipes is not admissible.
Gas Compressor room	GL VI-3-1, Section 2, 2.3.2.1	Compressor rooms, if arranged, should belocated above freeboard deck, unless those rooms are arranged and fitted in accordance with the requirements of these guidelines for tank rooms.

Machinery spaces containing gas-fuelled engines	GL VI-3-1, Section 2, 2.3.3.1	When more than one machinery space is required for gas-fuelled engines and these spaces are separated by a single bulkhead, the arrangements should be such that the effects of a gas explosion in either space can be contained or vented without affecting the integrity of the adjacent space and equipment within that space
Access to compressor room	GL VI-3-1, Section 2, 2.4.2	If the compressor room is approved located below deck, the room should, as far as practicable, have an independent access direct from the open deck
Access to tank room	GL VI-3-1, Section 2, 2.4.4	Access to the tank room should as far as practicable be independent and direct from open deck.
Double pipe in machinery spaces	GL VI-3-1, Section 2, 2.7.1.1	Gas supply lines passing through enclosed spaces should be completely enclosed by a double pipe or ventilated duct. This double pipe or ventilated duct should fulfil one of the following: 2. The gas fuel piping should be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct should be equipped with mechanical under pressure ventilation having a capacity of at least 30 air changes per hour. This ventilation capacity may be reduced to 10 air changes per hour provided automatic filling of the duct with nitrogen upon detection of gas is arranged for. The fan motors should comply with the required explosion protection in the installation area. The ventilation outlet should be covered by a

		protection screen and placed in a position where no flammable gas-air mixture may be ignited.
Storage in enclosed spaces	GL VI-3-1, Section 2, 2.8.4.1	as in a liquid state may be stored in enclosed spaces, with a maximum acceptable working pressure of 10 bar. Storage of compressed gas in enclosed spaces and location of gas tanks with a higher pressure than 10 bar in enclosed spaces is normally not acceptable
Gas storage arrangement	GL VI-3-1, Section 2, 2.8.4.2	The gas storage tank(s) should be placed as close as possible to the centreline of the ship: **.1** minimum, the lesser of B/5 and 11,5 m from the ship side; **.2** minimum, the lesser of B/15 and 2 m from the bottom plating; **.3** not less than 760 mm from the shell plating. For ships other than passenger ships and multihulls, a tank location closer than B/5 from the ship side may be accepted.
Bunkering station location	GL VI-3-1, Section 2, 2.9.1.1	The bunkering station should be so located that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations should be subject to special consideration. The bunkering station should be physically separated or structurally shielded from accommodation, cargo/working deck and control stations. Connections and piping should be so positioned and arranged that any damage to the gas piping does not cause damage to the vessel's gas storage tank arrangement leading to uncontrolled gas discharge

Drip Tray	GL VI-3-1, Section 2, 2.9.1.2	Drip trays should be fitted below liquid gas bunkering connections and where leakage may occur. The drip trays should be made of stainless steel, and should be drained over the ship's side by a pipe that preferably leads down near the sea.
Return gas during bunkering	GL VI-3-1, Section 2, 2.9.2.1	The bunkering system should be so arranged that no gas is discharged to air during filling of storage tanks.
Inerting at bunkering lines	GL VI-3-1, Section 2, 2.9.2.6	Bunkering lines should be arranged for inerting and gas freeing. During operation of the vessel the bunkering pipes should be gas free
Start and stop for dual fuel engine	GL VI-3-1, Section 6, 6.3.1	Start and normal stop should be on oil fuel only. Gas injection should not be possible without a corresponding pilot oil injection. The amount of pilot fuel fed to each cylinder should be sufficient to ensure a positive ignition of the gas mixture.
Liquid mode only	GL VI-3-1, Section 6, 6.3.2	In case of shut-off of the gas fuel supply, the engines should be capable of continuous operation by oil fuel only.

Summary of Calculation

Object	Measurement Unit	Value
Vaporizer (Cluster 1,2,3)		
Manufacturer		Cryoquip
Type		VWU182
Q	$Nm^3/_h$	6572
Shell flowrate	$m^3/_h$	102,18
Weight		
Vaporizer (Cluster 4)		
Manufacturer		Cryoquip
Type		VWU142
Q	$Nm^3/_h$	3286
Shell flowrate	$m^3/_h$	51,12
Weight		
LP LNG Pump (A)		
Manufacturer		Vanzetti
Type		DSM L 185
Q min-max	$m^3/_h$	1,2 - 24
Head min – max	m	10 - 50
Power	kW	11
Weight	Kg	170

LP LNG Pump (B)		
Manufacturer		Vanzetti
Type		DSM L 230
Q min-max	$m^3/_h$	5,4 - 72
Head min – max	m	10 - 75
Power	kW	15
Weight	Kg	270
Fresh Water Pump (Cluster 1,2,3)		
Manufacturer		Herborner
Type		F-PM080
Qmax	$m^3/_h$	180
Head max	m	42
Rotation	RPM	3000
Power	kW	20
Weight	Kg	284
Fresh Water Pump (Cluster 4)		
Manufacturer		Herborner
Type		F-PM050
Qmax	$m^3/_h$	64
Head max	m	38
Rotation	RPM	3000
Power	kW	8

Weight	Kg	70
Exhaust gas Economizer		
Manufacturer		Saacke Marine System
Type		EMB/EME-VST
Design Pressure	Bar	10
Weight	Kg	16000
Water content	m^3	5,5
BOG Compressor		
Manufacturer		GEA
Type		HG44e/770-4 S HC
Q	$m^3/_h$	67-80,4
Pmax	bar	19
Rotation	RPM	1450-1740
Power	kW	5,05
Weight	Kg	171
Gas Combustion Unit		
Manufacturer		Cleaver Brooks
Type		LNV-25-1
Gas input	BTU/hr	2500000

1. CALCULATION OF VAPORIZER

To calculate the required vaporizer, the requirement of gas supply each cluster is needed.

- **Cluster 1,2,3**

Cluster 1,2, and 3 consist of 2 engines, the required gas consumption per hour is larger than cluster 4

Engine	Gas Consumption per hour $\boldsymbol{m^3/h}$
MAN 18V51/60DF	5951,876

The selected Vaporizer is;

Manufacturer		Cryoquip
Type		VWU182
Q	Nm^3/h	6572
Shell flowrate	m^3/h	102,18
Weight		

- **Cluster 4**

Cluster 4 consist of 1 engines, the required gas consumption per hour is less than cluster 1,2, and 3

Engine	Gas Consumption per hour $\boldsymbol{m^3/h}$
MAN 18V51/60DF	2975.938

The selected Vaporizer is;

Manufacturer		Cryoquip
Type		VWU142

Q	$Nm^3/_h$	3286
Shell flowrate	$m^3/_h$	51,12
Weight		

2. CALCULATION OF LP LNG PUMP

The LP LNG Pump design are consisting of 2 part where the first part consist of 1 pump which may supply the requirement of all engine fuel supply. The second part consist of 2 pumps arranged in series where the capacity of the pump able to supply engine requirement during lower load.

The series arrangement of second part pump is to achieve the required discharge pressure where in the GVU inlet, the pressure should be 5,5 bar. Therefore, the head of the pump shall be greater than the requirement considering the head loss during transferring the fluid.

- LP LNG Pump 1

Manufacturer		Vanzetti
Type		DSM L 185
Q min-max	$m^3/_h$	1,2 - 24
Head min – max	m	10 - 50
Power	kW	11
Weight	Kg	170
Quantity	unit	2

- LP LNG Pump 2

Manufacturer		Vanzetti
Type		DSM L 230
Q min-max	$m^3/_h$	5,4 - 72
Head min – max	m	10 - 75
Power	kW	15
Weight	Kg	270
Quantity	Unit	1

3. CALCULATION OF FRESH WATER PUMP

The fresh water will be used to heat the LNG since the type of vaporizer are heat exchanger. The calculation for water pump are following the requirement from the vaporizer flow rate ate tube side.

- **Cluster 1, 2, and 3**

$$Qreq = 102{,}18\, {m^3}/_h$$

- **Cluster 4**

$$Qreq = 51{,}12\, {m^3}/_h$$

4. CALCULATION OF FRESH WATER HEATER

The requirement from the vaporizer is fresh water with 82 C temperature, therefore the fresh water need to be heated before entering the vaporizer. The design are to utilize exhaust gas economizer as heat source.

- **Cluster 1, 2, and 3**

$P = m.c.\Delta T$

Where;

$P = power\ required$

$m = 102180\, kg/h$ (based on the fresh water pump flow rate, $\rho = 1000\ \ kg/m^3$)

$c = 4179\, j/kgK$ (specific heat of water)

$\Delta T = 62$ K (30℃ to 92℃)

Therefore, the result of the calculation is;

$P = 102180\, .\, 4179\, .62$

$P = 26474633640\, J/h$

$P = 7359{,}948\ kW$

- **Cluster 4**

$P = m.c.\Delta T$

Where;

$P = power\ required$

$m = 51120\, kg/h$ (based on the fresh water pump flow rate, $\rho = 1000\ \ kg/m^3$)

$c = 4179\, j/kgK$ (specific heat of water)

$\Delta T = 62$ K (30℃ to 92℃)

Therefore, the result of the calculation is;

$P = 51120\, .\, 4179\, .62$

$P = 13245089760\, J/h$

$P = 3682{,}135\ kW$

5. AVAILABLE HEAT FROM EXHAUST GAS

Based on MAN 51/60 DF Project guide P.101, Load specific values at ISO Conditions at gas mode, the mass flow, temperature and heat content of the engine may vary depend on the operation.

Exhaust gas data[4]					
Mass flow	kg/kWh	6.74	6.34	6.28	6.51
Temperature at turbine outlet	°C	309	346	366	420
Heat content (180 °C)	kJ/kWh	945	1,152	1,284	1,730

The engine are operated nearly around 85% load, therefore exhaust gas data that will be used is the data at 85%.

- **Cluster 1, 2, and 3**

$$Total\ heat\ cont. = Specific\ heat\ cont.\ \times P \times N$$

Where;

$Specific\ heat\ cont. = 1152\ {}^{kJ}/_{kWh}$

$P = 15149{,}22\ kW$ (Each engine)

$N = 2$ (no. of engine)

Therefore, the result of the calculation is;

$Total\ heat\ cont. = 1152\ .15149{,}22\ .2$

$Total\ heat\ cont. = 34903802{,}88\ {}^{kJ}/_{h}$

$Total\ heat\ cont. = 9703{,}257\ kW$ (satisfy the requirement)

- **Cluster 4**

$$Total\ heat\ cont. = Specific\ heat\ cont.\ \times P \times N$$

Where;

$Specific\ heat\ cont. = 1152\ {}^{kJ}/_{kWh}$

$P = 15149{,}22\ kW$ (Each engine)

$N = 1$ (no. of engine)

Therefore, the result of the calculation is;

$Total\ heat\ cont. = 1152\ .15149{,}22\ .1$

$Total\ heat\ cont. = 17451901{,}44\ {}^{kJ}/_{h}$

$Total\ heat\ cont. = 4851{,}6286\ kW$ (satisfy the requirement)

6. CALCULATION OF BOG RATE FOR COMPRESSOR AND GCU

Calculation of BOG Rate is using 0,08% referencing to……

The calculation of BOG rate is using formula as;

$BOG = BOG\ Rate \times Total\ capacity$

Where;

$BOG\ rate = 0{,}08\ \%$

$Total\ Capacity = 3358{,}77193\ m^3$

Therefore the result of the calculation is;

$BOG = 0{,}08\ \% \times 3358{,}77193$

$BOG\ lng = 2{,}687\ {m^3}/{day}$

Total capacity	m^3	3358,77193
BOG rate LNG	m^3	2,687
BOG rate NG	m^3	1612,211
BOG Normal Rate	Nm^3	67,175

The compressor should have minimal capacity as big as BOG normal rate with pressure more than 5,5 bar to be able merged with the gas fuel system.

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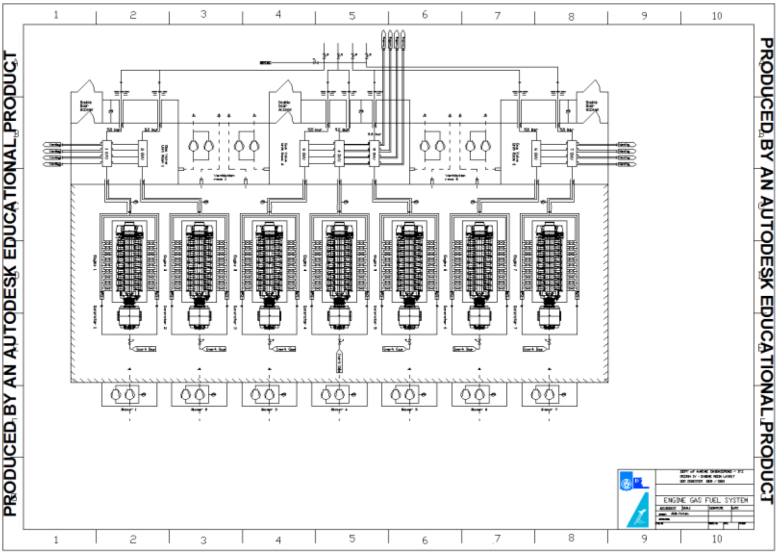
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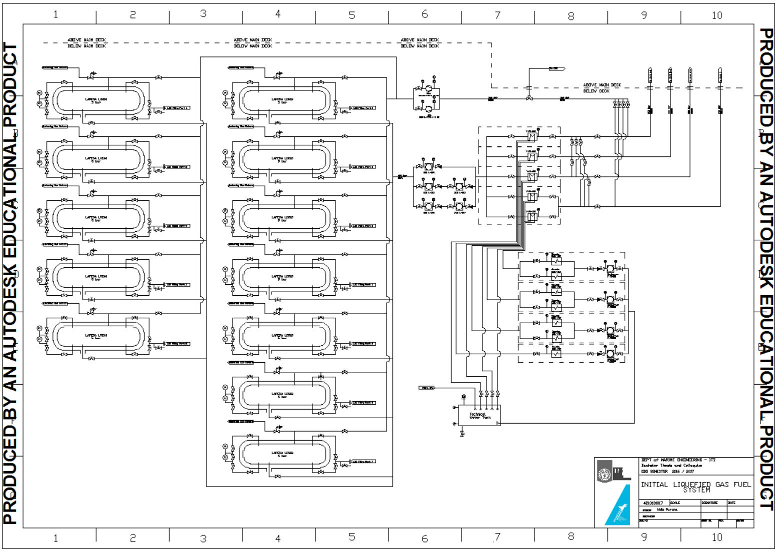
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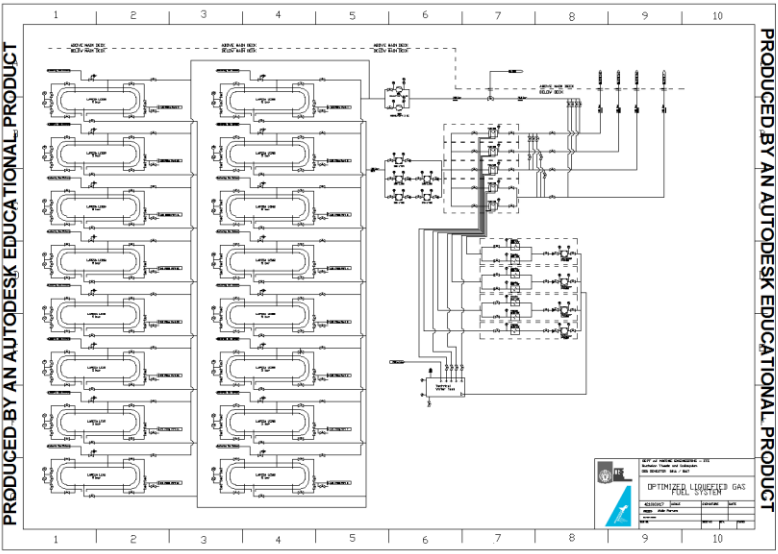
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OPTIMIZED LIQUEFIED GAS FUEL SYSTEM
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Attachment 3: Liquid Fuel Supply System

Design Requirement

Keyword	Reference	Design Requirement
General safety	GL I-1-2, Section 10, B.1.	Tanks and pipes are to be so located and equipped that fuel may not spread either inside the ship or on deck and may not be ignited by hot surfaces or electrical equipment. The tanks are to be fitted with air and overflow pipes as safeguards against overpressure, see Section 11, R
Distribution of fuel tanks	GL I-1-2, Section 10, B.2.1.1.	The fuel supply is to be stored in several tanks so that, even in the event of damage of one of the tanks, the fuel supply will not be lost entirely. On passenger ships and on cargo ships of 400 GT and over, no fuel tanks or tanks for the carriage offlammable liquids may be arranged forward of the collision bulkhead.
Location of fuel tanks	GL I-1-2, Section 10, B.2.1.3.	Fuel tanks are to be separated by cofferdams from tanks containing lubricating, hydraulic, thermal or edible oil as well as from tanks containing boiler feed water, condensate or drinking water. This does not apply to used lubricating oil which will not be used on board anymore
Location of fuel tanks	GL I-1-2, Section 10, B.2.1.5.	Fuel oil tanks adjacent to lubricating oil circulating tanks are not permitted.
Location of fuel tanks	GL I-1-2, Section 10, B.2.2.2.	Fuel tanks shall be an integral part of the ship's structure. If this is not practicable, the tanks shall be located adjacent to an engine room bulkhead and the tank top of the double bottom. The arrangement of fuel tanks adjacent to cofferdams required by MARPOL I Reg. 12A is acceptable. The arrangement of free-standing fuel tanks inside engine rooms is to be avoided. Tank arrangements which do not conform to the preceding rules require the approval of GL.

Tank gauges	GL I-1-2, Section 10, B.3.3.1.	The following tank gauges are permitted: sounding pipes oil-level indicating devices (type approved) oil-level gauges with flat glasses and self-closing shut-off valves at the connections to the tank and protected against external damage
Fastening of appliances	GL I-1-2, Section 10, B.4.2.	Valves and pipe connections are to be attached to doubler flanges welded to the tank wall. Holes for attachment bolts arenot to be drilled in the tank wall. Instead of doubler flanges, thick walled pipe stubs with flange connections may be welded into the tank walls.
Bunker lines	GL I-1-2, Section 11, G.1.	The bunkering of fuel oils is to be effected by means of permanently installed lines either from the open deck or from bunkering stations located below deck which are to be isolated from other spaces. Bunker stations are to be so arranged that the bunkering can be performed from both sides of the ship without danger. This requirement is considered to be fulfilled where the bunkering line is extended to both sides of the ship. The bunkering lines are to be fitted with blind flanges on deck.
Tank shutoff devices	GL I-1-2, Section 11, G.2.1.	Filling and suction lines from storage, settling and service tanks situated above the double bottom and from which in case of their damage fuel oil may leak, are to be fitted directly on the tanks with shut-off devices capable of being closed from a safe position outside the space concerned. In the case of deep tanks situated in shaft or pipe tunnel or similar spaces, shut-off devices are to be fitted on the tanks. The control in the event of fire may be effected by means of an additional shut-off device

		in the pipe outside the tunnel or similar space. If such additional shut-off device is fitted in the machinery space it is to be operated from a position outside this space.
Tank shutoff devices	GL I-1-2, Section 11, G.2.2.	Shut-off devices on fuel oil tanks having a capacity of less than 500 □need not be provided with remote control.
Filling lines	GL I-1-2, Section 11, G.2.3.	Filling lines are to extend to the bottom of the tank. Short filling lines directed to the side of the tank may be admissible. Storage tank suction lines may also be used as filling lines.
Inlet and drain lines	GL I-1-2, Section 11, G.2.6.	The inlet connections of suction lines are to be arranged far enough from the drains in the tank so that water and impurities which have settled out will not enter the suctions.
Pipe Layout	GL I-1-2, Section 11, G.3.1.	Fuel lines may not pass through tanks containing feed water, drinking water, lubricating oil or thermal oil.
Pipe below engine room	GL I-1-2, Section 11, G.4.5.	Pipes running below engine room floor need normally not to be screened.
Valve above floors	GL I-1-2, Section 11, G.3.5.	Shut-off valves in fuel lines in the machinery spaces are to be operable from above the floor plates
Pipe material	GL I-1-2, Section 11, G.3.6.	Glass and plastic components are not permitted in fuel systems. Sight glasses made of glass located in vertical overflow pipes may be permitted.
Shut off valves from pipe.	GL I-1-2, Section 11, G.3.7.	Fuel pumps are to be capable of being isolated from the piping system by shut-off valves.
Requirement of transfer pump	GL I-1-2, Section 11, G.4.2.	A fuel transfer pump is to be provided. Other service pumps may be used as back-up pump provided they are suitable for this purpose.

Two fuel oil transfer	GL I-1-2, Section 11, G.4.3.	At least two means of oil fuel transfer are to be provided for filling the service tanks.
Stand by pump	GL I-1-2, Section 11, G.4.4.	Where a feed or booster pump is required to supply fuel to main or auxiliary engines, stand-by pumps are to be provided. Where pumps are attached to the engines, stand-by pumps may be dispensed with for auxiliary engines. Fuel supply units of auxiliary diesel engine are to be designed such that the auxiliary engines start without aid from the emergency generator within 30 secafter black-out.
Stand by pump requirement	GL I-1-2, Section 11, G.4.5.	Fuel oil pumps referred to in G.4.4shall a) be suitable for marine fuels with a sulphur content not exceeding 0.1 % m/mand minimum viscosity of 2 cStat the required capacity for normal operation of the propulsion machinery or b) when fuel oil pumps as in a) need to be operated in parallel in order to achieve the required capacity for normal operation of propulsion machinery, one additional third fuel oil pump shall be provided. The additional pump shall, when operating in parallel with one of the pumps in a), be suitable for and capable of delivering marine fuels with a sulphur content not exceeding 0.1 % m/mand minimum viscosity of 2 cStat the required capacity for normal operation of the propulsion machinery. Where fuel oil pumps referred to in G.4.4 are not suitable for marine fuels with a sulphur content not exceeding 0.1 % m/m and minimum viscosity of 2 cStat the required capacity for normal operation of the propulsion machinery, two separate oil fuel pumps shall be provided, each capable and suitable for marine fuels with a sulphur

		content not exceeding 0.1% m/mand minimum viscosity of 2 cStat the required capacity for normal operation of the propulsion machinery. Note 1 If a marine distillate grade fuel with a different maximum sulphur content is specified by regulation for the area of operation of the ship (e.g., ECA, specific ports or local areas, etc.) then that maximum is to be applied. Note 2 Automatic start capability of standby pumps is required independent of the pump arrangement for vessels holding the class notation for unattended machinery space. Note 3 Where electrical power is required for the operation of propulsion machinery, the requirements are also applicable for machinery for power generation when such machinery is supplied by common fuel supply pumps.
Emergency Shut-down devices	GL I-1-2, Section 11, G.4.6.	For emergency shut-down devices, see Section 12, B.9
Shut off devices	GL I-1-2, Section 11, G.6.1.	On cargo ships of 500 GTor above and on all passenger ships for plants with more than one engine, shut-off devices for isolating the fuel supply and overproduction/recirculation lines to any engine from a common supply system are to be provided. These valves are to be operable from a position not rendered inaccessible by a fire on any of the engines

Fuel filters	GL I-1-2, Section 11, G.7.1.	Fuel oil filters are to be fitted in the delivery line of the fuel pumps.
Filters's mesh	GL I-1-2, Section 11, G.7.3.	Mesh size and filter capacity are to be in accordance with the requirements of the manufacturer of the engine.
Filter requirement	GL I-1-2, Section 11, G.7.4.	Uninterrupted supply of filtered fuel has to be ensured during cleaning of the filtering equipment. In case of automatic back-flushing filters it is to be ensured that a failure of the automatic backflushing will not lead to a total loss of filtration.
Filter back flush	GL I-1-2, Section 11, G.7.5.	Back-flushing intervals of automatic back-flushing filters provided for intermittent back-flushing are to be monitored.
Filter pressure monitoring	GL I-1-2, Section 11, G.7.6.	Fuel oil filters are to be fitted with differential pressure monitoring. On engines provided for operation with gas oil only, differential pressure monitoring may be dispensed with
Simplex filter	GL I-1-2, Section 11, G.7.8.	Fuel transfer units are to be fitted with a simplex filter on the suction side.
Fuel oil arrangements	GL I-1-2, Section 2, G.3.1.	Fuel and lubricating oil filters which are to be mounted directly on the engine are not to be located above rotating parts or in the immediate proximity of hot components.
Purifiers	GL I-1-2, Section 11, G.8.1.	Manufacturers of purifiers for cleaning fuel and lubricating oil are to be approved by GL.
Purifiers to sludge tank	GL I-1-2, Section 11, G.8.3.	The sludge tanks of purifiers are to be fitted with a level alarm which ensures that the level in the sludge tank cannot interfere with the operation of the purifier.

Oil firing equipment	GL I-1-2, Section 11, G.9.	Oil firing equipment is to be installed in accordance with Section 9. Pumps, pipelines and fittings are subject to the following requirements.
Service tanks	GL I-1-2, Section 11, G.10.1.	On cargo ships of 500 GTor above and all passenger ships two fuel oil service tanks for each type of fuel used on board necessary for propulsion and essential systems are to be provided. Equivalent arrangements may be permitted.
Service tanks capacity	GL I-1-2, Section 11, G.10.2.	Each service tank is to have a capacity of at least 8 hour at maximum continuous rating of the propulsion plant and normal operation load of the generator plant.
Separator Capacity	MAN 51/60DF Project Guide Page 325	$Qp = P1 \times Be/\rho$
Service Tank Capacity	MAN 51/60DF Project Guide Page 328	$V = \frac{Qp \times to \times ms}{3 \times 1000}$
Supply Pump	MAN 51/60DF Project Guide Page 329	$Qp = P1 \times Briso1 \times f3$
MDO Cooler	MAN 51/60DF Project Guide Page 331	$Pc = P1 \times Briso1 \times f1$ $Qc = P1 \times Briso1 \times f2$

Summary of Calculation

Object	Measurement Unit	Value
Fuel Oil's Weight		
Type		MDO DMB
Weight	Ton	53,493
Fuel Oil Tanks		
FO Storage req.	m^3	63,11
FO Service Tank req. (each)	m^3	5,292
Pilot Fuel Supply Pump (Cluster 1,2,3)		
Manufacturer		IMO Pump
Type		3E 87P
Q	m^3/h	0,591
Head	Bar	10
Rotation	RPM	2850
Weight	Kg	35
Pilot Fuel Supply Pump (Cluster 4)		
Manufacturer		IMO Pump
Type		3E 87P
Q	m^3/h	0,272
Head	Bar	10
Rotation	RPM	1425

Weight	Kg	35
Main Fuel Supply Pump (Cluster 1,2,3)		
Manufacturer		IMO Pump
Type		3D 275E
Q	$m^3/_h$	51
Head	bar	10
Rotation	RPM	3500
Weight(1)	Kg	162
Main Fuel Supply Pump (Cluster 4)		
Manufacturer		IMO Pump
Type		3D 218
Q	$m^3/_h$	28,62
Head	bar	10
Rotation	RPM	3500
Weight(1)	Kg	120
Transfer Pump		
Manufacturer		Iron Pump
Type		ON: 1
Q	$m^3/_h$	1,5
Head	m	20
Rotation	RPM	850
Weight	Kg	45

Fuel Oil Separator		
Manufacturer		Alfa Laval
Type		MIB 303
Quantity	Unit	2
Q	$m^3/_h$	0,76
Power	kW	0,7
Weight	Kg	68
Separator Heater		
Manufacturer		AlfaLaval
Type		Aalborg Vesta EH15
Capacity	kW	5
Weight	Kg	55
Main MDO Cooler (Cluster 1,2,3)		
Manufacturer		AlfaLaval
Type		M15 – FM8
Heat Surface	m^2	184
Weight	kg	
Main MDO Cooler (Cluster 4)		
Manufacturer		AlfaLaval
Type		M10 – FD ASME
Heat Surface	m^2	105

Weight	kg	
Pilot Fuel Cooler (Cluster 1,2,3)		
Manufacturer		AlfaLaval
Type		Aalborg MD20 – 1000
Heat Surface	m^2	4,8
Weight	kg	166
Pilot Fuel Cooler (Cluster 4)		
Manufacturer		AlfaLaval
Type		Aalborg MD15 – 1000
Heat Surface	m^2	4,8
Weight	kg	110

1. CALCULATION OF FUEL OIL'S WEIGHT

- Pilot Fuel

To calculate the fuel oil's weight, we could use basic formula;
$W\ MDO = BHP_{mcr} \times SFOC \times Endurance \times 10^{-6}\ [ton]$

Where;
$BHP = 106044{,}539\ kW$
$SFOC = 2{,}434\ g/(kw-h)$ MDO as a pilot fuel
$Endurance = 147{,}376\ hours\ or\ 6{,}224\ days$

Therefore, the result of the calculation is:
$W\ MDO = 106044{,}539 \times 2{,}434 \times 147{,}376 \times 10^{-6}\ [ton]$
$W\ MDO = 38{,}555\ [ton]$

- Reserve for low-load

To improve the reliability during operation, the calculation of fuel will also conduct with liquid only mode during starting, low-load operation, idling, and shut-down.

$$W\ MDO = t_o \times Low\ load\ consumption \times total\ \ operationduration\ [ton]$$

Where;
$t_o = 8\ hours\ per\ day$

$Consumption = 300\ kg/h$

$operation\ duration = 6{,}224\ days$

Therefore, the result of the calculation is:
$W\ MDO = 8 \times 300 \times 6{,}224\ [ton]$
$W\ MDO = 14{,}9376\ [ton]$

$W\ MDO\ total = Pilot\ fuel + Reserve\ for\ lowload\ [ton]$
$W\ MDO\ total = 38{,}555 + 14{,}9376\ \ [ton]$
$W\ MDO\ total = 53{,}493\ [ton]$

2. CALCULATION OF FUEL OIL STORAGE VOLUME

To calculate the fuel oil's volume, we could use the formula of density;
$V_{storage} = WMDO \times 1{,}05 / \rho MDO$

Where;
$WMDO = 53{,}493\ [ton]$
$\rho MDO = 0.89\ [ton/m^3]$

$margin\ for\ sludge = 1{,}05$

Therefore, the result of the calculation is:
$V_{storage} = 53{,}493 \times 1{,}05/\ 0.89$
$V_{storage} = 63{,}11\ [m^3]$

3. CALCULATION OF PILOT FUEL SUPPLY PUMP

Pilot fuel supply pump is the pump required to supply the pilot fuel system. The pilot fuel supply system will be operated frequently compared to the main fuel supply pump due to dual-fuel mode. The formula to calculate the supply pump is using the provided formula in MAN 51/60 Project Guide P. 329

- **Cluster 1, 2, and 3**

$Qp = P_1 \times br_{ISO1} \times f_3$

Where;

$P_1 = 36000\ kW\ (system\ output\ at\ 100\%\ MCR)$

$br_{ISO1} = 2g/(kw - h)$ (SFOC at 100% MCR)

$f_3 = 0{,}00375\ {}^{l}/_{g}$

Therefore the result of the calculation is;

$Qp = 36000 \times 2 \times 0{,}00375$

$Qp = 540\ {}^{l}/_{h}$

- **Cluster 4**

$Qp = P_1 \times br_{ISO1} \times f_3$

Where;

$P_1 = 18000\ kW\ (system\ output\ at\ 100\%\ MCR)$

$br_{ISO1} = 2g/(kw - h)$ (SFOC at 100% MCR)

$f_3 = 0{,}00375\ {}^{l}/_{g}$

Therefore the result of the calculation is;

$Qp = 18000 \times 2 \times 0{,}00375$

$Qp = 270\ {}^{l}/_{h}$

4. CALCULATION OF MAIN FUEL SUPPLY PUMP

Main fuel supply pump is the pump required to supply the engine fuel system. As the engine is dual fuel, it should be able to be operated even using MDO only. The formula to calculate the supply pump is using the provided formula in MAN 51/60 Project Guide P. 329

- **Cluster 1, 2, and 3**

$Qp = P_1 \times br_{ISO1} \times f_3$

Where;

$P_1 = 36000\ kW\ (system\ output\ at\ 100\%\ MCR)$

$br_{ISO1} = 178{,}1\ g/(kw - h)$ (SFOC at 100% MCR)

$f_3 = 0{,}00375\ {}^{l}/_{g}$

Therefore the result of the calculation is;

$Qp = 36000 \times 178{,}1 \times 0{,}00375$

$Qp = 48087\ {}^{l}/_{h}$

- **Cluster 4**

$Qp = P_1 \times br_{ISO1} \times f_3$

Where;
$P_1 = 18000\ kW\ (system\ output\ at\ 100\%\ MCR)$
$br_{ISO1} = 178{,}1\ g/(kw - h)$ (SFOC at 100% MCR)
$f_3 = 0{,}00375\ {}^{l}/_{g}$

Therefore the result of the calculation is;
$Qp = 18000 \times 178{,}1 \times 0{,}00375$
$Qp = 24043{,}5\ {}^{l}/_{h}$

5. CALCULATION OF SERVICE TANK CAPACITY

MDO Service Tank Capacity can be calculated by formula provided by MAN 51/60 Project Guide Page 328. The Q_p value that will be used is $Q_p$of pilot fuel supply pump because the system design was for dual-fuel mode and there is no scenario for liquid-mode only except during low load.
$V_{MDST} = Q_p \times t_o \times m_s\ /\ (3 \times 1000)$

Where;
$Q_p = 1890\ [l/h]$ (3 supply pump for cluster 1,2, and 3, and 1-
- supply pump for cluster 4)
$t_o = 8\ [h]$
$m_s\ = 1.05$

Therefore, the result of the calculation is:
$V_{MDST} = 1890\ \times 8 \times 1.05/\ (3 \times 1000)$
$Q_p = 5{,}292\ [m^3/h]$

Each service tank capacity is $5{,}292\ [m^3/h]$

6. CALCULATION OF SEPARATOR CAPACITY

Separator capacity can be calculated by using the formula provided by the MAN 51/60 Project Guide Page 325

$Q_p = \frac{P_1 \times b}{\rho}$

Where;
$P_1 = 106044{,}5387\ [kW]$
$b = 2{,}434\ [{}^{g}/_{kW-H}]$
$\rho = 870\ @\ separating\ temprature$

Therefore, the result of the calculation is:
$Q_p = \frac{106044{,}5387 \times 2{,}434}{0.87 \times 10^3} = 296{,}681\ l/h\ (minimum)$

7. CALCULATION OF TRANSFER PUMP

The capacity of the transfer pump are designed to satisfy the requirement of the separator so it able to be operated at proper operation. The pumps also should be electrically driven. (MAN 51/60 DF Project Guide P.325)

$Qmin = 296{,}681 \frac{l}{h}$ (minimum)

The value of Q is depend on the chosen separator.

8. CALCULATION OF SEPARATOR HEATER

Before the fluid enters the separator, the fluid need to be treated first, especially its temperature. Fluid temperature will affect its properties such as properties, in this case the separator may work efficiently if the fluid is in 40 ℃ with specific viscosity.
$P = m.c.\Delta T$

Where;
$P = power\ required$
$m = 258{,}1124\ kg/h$ (based on the separator flow rate, $\rho = 870\ \ kg/m^3$)
$c = 2008{,}32\ j/kg$℃ (specific heat of oil)
$\Delta T = 13$℃ (30℃ to 43℃)

Therefore, the result of the calculation is;

$P = 258{,}1124 \,.\, 2008{,}32 \,.13$

$P = 6738840 \; J/h$

$P = 1{,}8719 \; kW$

9. CALCULATION OF MAIN MDO COOLER

MDO Coolers are a cooler that reduce the temperature of main fuel outlet. To calculate main mdo cooler requirement, the formula from the project guide (MAN 51/60 DF P.331) will be used.

- **Cluster 1,2, and 3**

$P_c = P_1 \times br_{ISO1} \times f_1$

Where;

$Pc = heat\ to\ be\ dissipated$

$P_1 = 36000 \; kW$ (Cluster output at 100% MCR)

$br_{ISO1} = 178{,}1 \; g/kwh$ (SFOC at 100% MCR, Liquid mode)

$f_1 = 2{,}68 \times 10^{-5}$ (factor for heat dissipation)

Therefore, the result of the calculation is;

$P_c = 36000 \times 178{,}1 \times 2{,}68 \times 10^{-5}$

$P_c = 171{,}831 \; kW$

- **Cluster 4**

$P_c = P_1 \times br_{ISO1} \times f_1$

Where;

$Pc = heat\ to\ be\ dissipated$

$P_1 = 18000 \; kW$ (Cluster output at 100% MCR)

$br_{ISO1} = 178{,}1 \; g/kwh$ (SFOC at 100% MCR, Liquid mode)

$f_1 = 2{,}68 \times 10^{-5}$ (factor for heat dissipation)

Therefore, the result of the calculation is;

$P_c = 18000 \times 178{,}1 \times 2{,}68 \times 10^{-5}$

$P_c = 85{,}915 \; kW$

10. CALCULATION OF MAIN MDO COOLER HEAT SURFACE

To calculate the heating surface area, which is useful to select the proper heat exchanger or heater, we could use formula;
$LMTD = (\Delta Ta - \Delta Tb)/\log(\Delta Ta - \Delta Tb)$

Therefore, the result of the calculation is
$LMTD = (8)/\log(8)$
$LMTD = 8{,}858\ °C$

And then, we could calculate the surface area,

- **Cluster 1,2 and 3**

$A = H/(K - LMTD)$
Where;
$H = 147748\ [kcal/h]$
$K = 1000\ [{}^{kcal}/_{m^2 h°C}]$
$LMTD = 8{,}858\ °C$

Therefore, the result of the calculation is:
$A = 147748\ /(1000 - 8{,}858\ )$
$A = 149{,}0685\ m^2$

- **Cluster 4**

$A = H/(K - LMTD)$
Where;
$H = 73873{,}98\ [kcal/h]$
$K = 1000\ [{}^{kcal}/_{m^2 h°C}]$
$LMTD = 8{,}858\ °C$

Therefore, the result of the calculation is:
$A = 73873{,}98\ /(1000 - 8{,}858\ )$
$A = 74{,}534\ m^2$

11. CALCULATION OF PILOT FUEL MDO COOLER

MDO Coolers are a cooler that reduce the temperature of pilot fuel outlet. To calculate pilot fuel mdo cooler requirement, the standard from the project guide (MAN 51/60 DF P.351) will be used where the inlet of coolers is usually at 60 C while the outlet should reach temperature less than 45 C.

- **Cluster 1, 2, and 3**

$P = m.c.\Delta T$
Where;

$P = power\ required$
$m = 480{,}6\ kg/h$ (based on the pilot fuel feed pump flow rate, $\rho = 890\ \ kg/m^3$)
$c = 2008{,}32\ j/kg$℃ (specific heat of oil)
$\Delta T = 20$℃ (60℃ to 40℃)

Therefore, the result of the calculation is;
$P = 480{,}6\ .\ 2008{,}32\ .20$
$P = 19303972\ J/h$
$P = 5362{,}214\ kW$

- **Cluster 4**

$P = m.c.\Delta T$
Where;

$P = power\ required$
$m = 240{,}3\ kg/h$ (based on the pilot fuel feed pump flow rate, $\rho = 890\ \ kg/m^3$)
$c = 2008{,}32\ j/kg$℃ (specific heat of oil)
$\Delta T = 20$℃ (60℃ to 40℃)

Therefore, the result of the calculation is;
$P = 240{,}3\ .\ 2008{,}32\ .20$
$P = 9651985{,}92\ J/h$
$P = 2{,}681\ kW$

12. CALCULATION OF PILOT FUEL MDO COOLER HEAT SURFACE

To calculate the heating surface area, which is useful to select the proper heat exchanger or heater, we could use formula;
$LMTD = (\Delta Ta - \Delta Tb)/\log(\Delta Ta - \Delta Tb)$

Therefore, the result of the calculation is
$LMTD = (3)/\log(3)$
$LMTD = 6{,}287\,°C$

And then, we could calculate the surface area,

- **Cluster 1,2 and 3**
  $A = H/(K - LMTD)$
  Where;
  $H = 4610{,}674\ [kcal/h]$
  $K = 1000\ [{}^{kcal}/_{m^2 h °C}]$
  $LMTD = 6{,}287\ °C$

  Therefore, the result of the calculation is:
  $A = 4610{,}674\ /(1000 - 6{,}287)$
  $A = 4{,}639\ m^2$

- **Cluster 4**
  $A = H/(K - LMTD)$
  Where;
  $H = 2305{,}337\ [kcal/h]$
  $K = 1000\ [{}^{kcal}/_{m^2 h °C}]$
  $LMTD = 6{,}287\,°C$

  Therefore, the result of the calculation is:
  $A = 2305{,}337\ /(1000 - 6{,}287)$
  $A = 2{,}319\ m^2$

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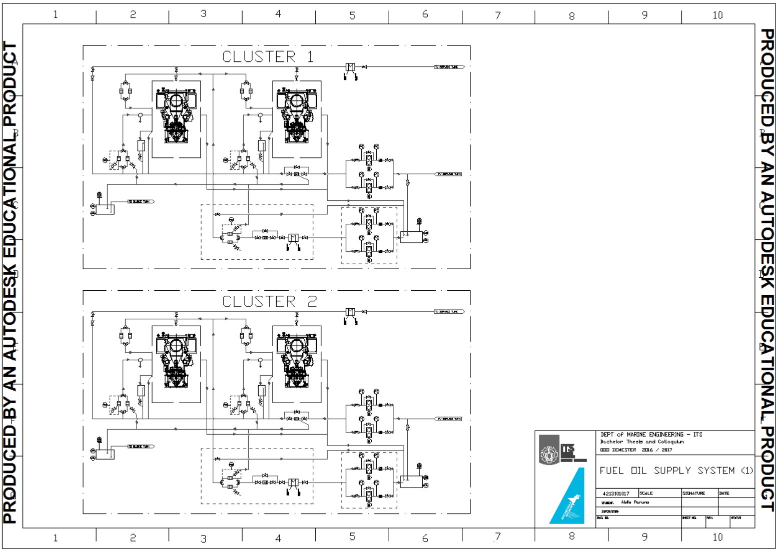
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CLUSTER 2
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ODD SEMESTER 2016 / 2017
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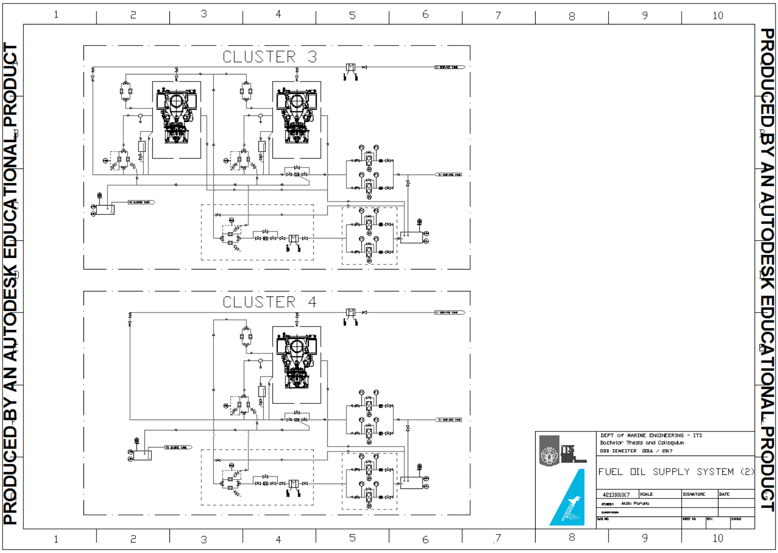
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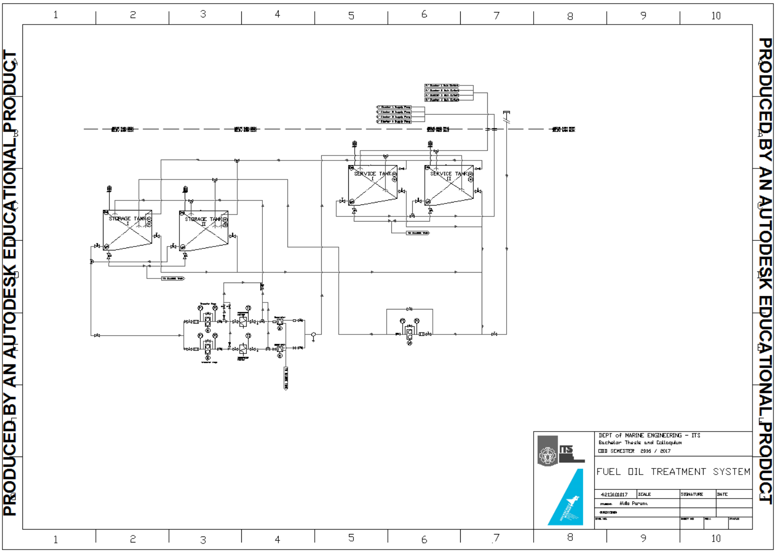
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STORAGE TANK II
SERVICE TANK I
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Attachment 4: Lubricating Oil Supply System

Design Requirement

Keyword	Reference	Design Requirement
Lube oil temp in double bottom	GL I-1-1, Section 27, C.3.3.1	In double bottom tanks, fuel oil may be carried, the flash point (closed cup test) of which exceeds 60°C.
Tank Gauges	GL I-1-2, Section 10, B.3.3.1	The following tank gauges are permitted: sounding pipes oil-level indicating devices (type approved) oil-level gauges with flat glasses and self-closing shut-off valves at the connections to the tank and protected against external damage
Sounding pipe	GL I-1-2, Section 10, B.3.3.5	Sounding pipes of fuel tanks may not terminate in accommodation or passenger spaces, nor shall they terminate in spaces where the risk of ignition of spillage from the sounding pipes consists.
Tank heating	GL I-1-2, Section 10, B.5.4	At tank outlets, heating coils are to be fitted with means of closing. Steam heating coils are to be provided with means for testing the condensate for oil between tank outlet and closing device. Heating coil connections in tanks normally are to be welded. The provision of detachable connections is permitted only in exceptional cases. Inside tanks, heating coils are to be supported in such a way that they are not subjected to impermissible stresses due to vibration, particularly at their points of clamping.
Lube oil circulating tank	GL I-1-2, Section 10, C.3.1	Lubricating oil circulation tanks are to be sufficiently dimensioned to ensure that the dwell time is long enough for settling out of air bubbles, residues, etc. With a maximum permissible filling level of about 85 %, the tanks are to be large enough to hold at least the lubricating oil contained in the entire

		circulation system including the contents of gravity tanks.
Vent	GL I-1-2, Section 10, C.3.3	Lubricating oil circulating tanks are to be equipped with sufficiently dimensioned vents.
Priming pumps	GL I-1-2, Section 11, H.1.2	Where necessary, priming pumps are to be provided for supplying lubricating oil to the engines.
Emergency lubrication	GL I-1-2, Section 11, H.1.3	A suitable emergency lubricating oil supply (e.g. gravity tank) is to be arranged for machinery which may bedamaged in case of interruption of lubricating oil supply.
Treatment equipment	GL I-1-2, Section 11, H.1.4.1	Equipment necessary for adequate treatment of lubricating oil is to be provided (purifiers, automatic back-flushing filters, filters, free-jet centrifuges)
Tanks	GL I-1-2, Section 11, H.2.1.2	For ships where a double bottom is required the minimum distance between shell and circluting tank shall be not less than 500 mm.
Tanks drain and suction	GL I-1-2, Section 11, H.2.1.3	The suction connections of lubricating oil pumps are to be located as far as possible from drain pipes.
Filling and suction lines	GL I-1-2, Section 11, H.2.2.1	Filling and suction lines of lubricating oil tanks with a capacity of 500 land more located above the double bottom and from which in case of their damage lubricating oil may leak, are to be fitted directly on the tanks with shut-off devices according to G.2.1.The remote operation of shut-off valves according to G.2.1may be dispensed with: - for valves which are kept closed during normal operation. - where an unintended operation of a quick closing valve would endanger the safe operation of the main propulsion plant or essential auxiliary machinery.

Pump filter	GL I-1-2, Section 11, H.2.3.1	Lubricating oil filters are to be fitted in the delivery line of the lubricating oil pumps.
Pump automatic filter	GL I-1-2, Section 11, H.2.3.3	Uninterrupted supply of filtered lubricating oil has to be ensured under cleaning conditions of the filter equipment. In case of automatic back-flushing filters it is to be ensured that a failure of the automatic back-flushing will not lead to a total loss of filtration.
Filter pressure indicator	GL I-1-2, Section 11, H.2.3.5	Main lubricating oil filters are to be fitted with differential pressure monitoring. On engines provided for operation with gas oil only, differential pressure monitoring may be dispensed with
Filter on pump suction side	GL I-1-2, Section 11, H.2.3.6	For protection of the lubricating oil pumps simplex filters may be installed on the suction side of the pumps if they have a minimum mesh size of 100 μ
Coolers	GL I-1-2, Section 11, H.2.4	It is recommended that turbine and large engine plants be provided with more than one oil cooler
Purifiers	GL I-1-2, Section 11, G.8.3	The sludge tanks of purifiers are to be fitted with a level alarm which ensures that the level in the sludge tank cannot interfere with the operation of the purifier.
Independent pumps	GL I-1-2, Section 11, H.3.1.1	**Main and independent stand-by pumps are to be arranged.** Main pumps driven by the main engines are to be so designed that the lubricating oil supply is ensured over the whole range of operation
Stand-by pump	GL I-1-2, Section 11, H.3.2.1	Main and independent stand-by lubricating oil pumps are to be provided.

Emergency lubrication	GL I-1-2, Section 11, H.3.2.2	The lubricating oil supply to the main turbine plant for cooling the bearings during the run-down period is to be assured in the event of failure of the power supply. By means of suitable arrangements such as gravity tanks the supply of oil is also to be assured during starting of the emergency lubrication system.
Reduction gear lubrication	GL I-1-2, Section 11, H.3.3.2	Where a reduction gear has been approved by GL to have adequate self-lubrication at 75 %of the torque of the propelling engine, a stand-by lubricating oil pump for the reduction gear may be dispensed with up to a power-speed ratio of P/n1[kW/min-1] < 3.0 n1: gear input revolution [min-1]
Diesel generator	GL I-1-2, Section 11, H.3.4.1	Where more than one diesel generator is available, stand-by pumps are not required. Where only one diesel generator is available (e.g. on turbine-driven vessels where the diesel generator is needed for start-up operations) a complete spare pump is to be carried on board.

Summary of Calculation

Object	Measurement Unit	Value
Lube Oil's Weight		
Type		Shell Gadinia AL 40
Weight (Storage + Service)	Ton	177,569
Lube Oil Tanks		
LO Storage	m^3	6,495
LO Service Tank (each)	m^3	25,882
Prelubrication Pump		
Manufacturer		Iron Pump
Type		ONT: 7/10
Q	$m^3/_h$	1,9
Rotation	RPM	950
Weight	Kg	35
Transfer Pump (Cluster 1,2,3)		
Manufacturer		Iron Pump
Type		ON-V: 4
Q	$m^3/_h$	8
Head	m	35
Rotation	RPM	1450

Weight	Kg	75
Transfer Pump (Cluster 4)		
Manufacturer		Iron Pump
Type		ON-V: 3
Q	$m^3/_h$	3,4
Head	m	34
Rotation	RPM	850
Weight	Kg	75
Service Pump (Engine Driven)		
Attached		
Separator Feed Pump (Cluster 1,2,3)		
Manufacturer		Iron Pump
Type		ON-V: 4
Q	$m^3/_h$	6,5
Head	m	15
Rotation	RPM	1150
Weight	Kg	75
Separator Feed Pump (Cluster 4)		
Manufacturer		Iron Pump
Type		ON 1
Q	$m^3/_h$	3,3
Head	m	25

Rotation	RPM	1450
Weight	Kg	45
Lube Oil Separator (Cluster 1,2,3)		
Manufacturer		Alfa Laval
Type		MAB 206
Quantity	Unit	3
Q	$m^3/_h$	6500
Power	kW	5,5
Lube Oil Separator (Cluster 4)		
Manufacturer		Alfa Laval
Type		MMB 305
Quantity	Unit	1
Q	$m^3/_h$	3500
Power	kW	2,3
Separator Heater (Cluster 1,2,3)		
Manufacturer		Aalborg
Type		Vesta EH 35
Capacity	kW	78
Weight	Kg	386
Separator Heater (Cluster 4)		
Manufacturer		Aalborg
Type		Vesta EH 30

Capacity	kW	40
Weight	Kg	228
Lube Oil Cooler (All Engines)		
Manufacturer		Alfalaval
Type		AlfaQ 14
Heat surface	m^2	1400

1. CALCULATION OF LUBE OIL'S WEIGHT

Main Engine

To calculate the lube oil's weight, we could use basic formula;

$W\ LO = BHP_{mcr} \times SLOC \times Endurance \times 10^{-6}\ [ton]$

Where there is two option, the option which has greater value will be designed;

- Option 1

$Engine\ Load$
$= 106044{,}54\ kW\ (100\ MW\ Electricity\ continuesly)$
$SLOC = 0.4\ g/(kw-h)$
$Duration = 96{,}744\ hours$

Therefore, the result of the calculation is:

$\boldsymbol{W\ LO = 106044{,}54 \times 0.4 \times 96{,}744 \times 10^{-6}\ [ton]}$
$\boldsymbol{W\ LO = 4{,}924\ [ton]}$

- Option 2

$Engine\ Load$
$= 68673{,}38\ kW\ (64{,}759\ MW\ Electricity\ average\ in\ 24\ hours)$
$SLOC = 0.4\ g/(kw-h)$
$Duration = 149{,}376\ hours$

Therefore, the result of the calculation is:

$W\ LO = 68673{,}38 \times 0.4 \times 149{,}376 \times 10^{-6}\ [ton]$
$W\ LO = 4{,}923\ [ton]$

The engine will be designed according the Option 1 which has greater Value

2. CALCULATION OF LUBE OIL'S VOLUME

To calculate the lube oil's volume, we could use the formula of density;

$V_{storage} = W\ LO/\ \rho\ LO$

Where;

$W\ LO\ M/E = 4{,}924\ [ton]$
$\rho\ LO = 0.892\ [ton/m^3]$

Therefore, the result of the calculation with 85% filling limit is:

$$V_{storage} = \frac{4{,}924}{0{,}892 * 0{,}85}$$

$$V_{storage} = 6{,}495\ [m^3]$$

3. CALCULATION OF LUBE OIL'S SERVICE TANK VOLUME

In the project guide, it's mention that the minimum effective lube oil in service tank is $22\,m^3$ while based on the classification societies GL I-1-2 Section 10, the maximum filling value is 85%, therefore;

$$Vlo\ service = \frac{22}{0{,}85} = 25{,}882 m^3$$

4. CALCULATION OF LUBE OIL SEPARATOR

To calculate the LO feed pump capacity, it must comply with the separator capacity

- **Cluster 1,2 and 3**

$$Q = \frac{1{,}0 \times P \times n}{24}$$

where

$1{,}0 = lube\ oil\ consumption\ (1\,{}^{L}/_{kW})$

$P = 30298{,}44\ (1\ Cluster\ total\ output\ power)$

$n = 5\ (gas + {}^{MDO}/_{MGO}\ for\ ignition)$

Therefore, the result of the calculation is:

$$Q = \frac{1{,}0 \times 30298{,}44 \times 5}{24}$$

$$Q = 6312{,}175\,{}^{l}/_{h}$$

- **Cluster 4**

$$Q = \frac{1{,}0 \times P \times n}{24}$$

where

$1{,}0 = lube\ oil\ consumption\ (1\,{}^{L}/_{kW})$

$P = 15149,22\ (1\ Cluster\ total\ output\ power)$
$n = 5\ (gas + {}^{MDO}/_{MGO}\ for\ ignition)$
Therefore, the result of the calculation is:

$$Q = \frac{1,0 \times 15149,22 \times 5}{24} = 3156,088\ {}^{l}/_{h}$$

5. LUBE OIL PIPE

Lube Oil Separator Pipe (Cluster 1,2 and 3)

Min. Inside Diameter:	38,57 [mm]
Min. Inside Diameter:	2 [mm]
Spec:	
Type:	40A
Outside Diameter:	48,6 [mm]
Thickness:	3,5 [mm]
Inside Diameter:	41,6 [mm]

Lube Oil Separator Pipe (Cluster 4)

Min. Inside Diameter:	27,274 [mm]
Min. Inside Diameter:	2 [mm]
Spec:	
Type:	25A
Outside Diameter:	34,0 [mm]
Thickness:	3,2 [mm]
Inside Diameter:	27,6 [mm]

Lube Oil Automatic Filter Pipe

Spec:	
Type:	20A
Outside Diameter:	27.2 [mm]
Thickness:	2.8 [mm]
Inside Diameter:	21.6 [mm]

Lube Oil Supply, Overflow, Outlet Pipe (Cluster 1,2 and 3)

Min. Inside Diameter:	38,57 [mm]

Min. Inside Diameter:	2 [mm]
Spec:	
Type:	40A
Outside Diameter:	34,0 [mm]
Thickness:	3.2 [mm]
Inside Diameter:	27,6 [mm]

Lube Oil Supply, Overflow, Outlet Pipe (Cluster 4)

Min. Inside Diameter:	27,274 [mm]
Min. Inside Diameter:	2 [mm]
Spec:	
Type:	25A
Outside Diameter:	48,6 [mm]
Thickness:	3,2 [mm]
Inside Diameter:	41,6 [mm]

Lube Oil By-Pass Filter Pipe

Spec:	
Type:	20A
Outside Diameter:	27.2 [mm]
Thickness:	2.8 [mm]
Inside Diameter:	21.6 [mm]

6. PUMPS

a. Pre-lubrication Pump

Pre-lubricating pump for the engine is electrically driven. The pump is gear pump type and able to self-priming. The specification of pre-lubrication pump is specified by the project guide.

Engine Type:	MAN 51/60 DF
Cylinder:	18
Pump Manufacture:	Iron Pump
Pump Type:	ONT: 7/10
Capacity:	1,9 $m^3/_h$

Rotation:	950 RPM
Power:	0,746 kW

b. Cylinder Oil Pump

Cylinder oil pump for the engine is attached. The pump is gear pump type and able to self priming. The specification of cylinder oil pump is specified by the project guide.

Engine Type:	MAN 51/60 DF
Pump Type:	Attached
Power:	~0,5 kW @380-420V/50Hz

c. Service Pump

Service pump for the engine is attached and engine driven. The pump is gear pump type and able to self priming. The specification of service pump is specified by the project guide.

Engine Type:	MAN 51/60 DF
Pump Type:	Attached

d. Feed Pump

The feed pump pipe is using the same pipe with separator system.

- **Cluster 1,2 and 3**

$Q = A \times v$

where

$Q = 6{,}312 \frac{m^3}{h} = 0{,}001753 \frac{m^3}{s}$ $(for\ Cluster\ 1, 2, 3)$

$v = 1{,}5\ m/s$

Therefore, the result of the calculation is:

$0{,}001753 = A \times 1{,}5$

$A = 1168{,}889\ mm^2$

$A = \pi \times r^2$

$r = 19{,}285\ mm$

- **Cluster 4**

$Q = A \times v$

where

$Q = 3156{,}088\frac{m^3}{h} = 0{,}000877\frac{m^3}{s}\ (for\ Cluster\ 4)$
$v = 1{,}5\ m/s$
Therefore, the result of the calculation is:
$0{,}000877 = A \times 1{,}5$
$A = 584{,}4606\ mm^2$
$A = \pi \times r^2$
$r = 13{,}637\ mm$

e. Transfer Pump

Transfer pump is a pump to transport the lube oil from the storage to the service tank. The pipe diameter is using same as the separator pipe

- **Cluster 1,2 and 3**

$Q = A \times v$
where
$v = 1{,}5\ \frac{m}{s} (Lube\ oil\ velocity\ ranged\ from\ 0.5 - 1.5)$
$A = 0{,}00136\ m^2$
Therefore, the result of the calculation is:
$Q = 0{,}00136 \times 1{,}5$
$Q = 7{,}342\ m^3/h$

- **Cluster 4**

$Q = A \times v$
where
$v = 1{,}5\ \frac{m}{s} (Lube\ oil\ velocity\ ranged\ from\ 0.5 - 1.5)$
$A = 0{,}000898\ m^2$
Therefore, the result of the calculation is:
$Q = 0{,}000898 \times 1{,}5$
$Q = 3{,}232\ m^3/h$

7. CALCULATION OF SEPARATOR HEATER

LO temperature should be heated to maintain the temperature is $\geq 40°\ C$

$\Delta \boldsymbol{T}$

The arrangement of heating coils temperature is;

$T\ of\ heating\ coils = 50°C$

$\Delta T = 50\ °C - 30\ °C$

$\Delta T = 20\ °C$

- **Cluster 1,2 and 3**

  $\boldsymbol{Heater\ Capacity\ (P)}$

  To calculate the heater capacity, we could use;

  $P = \frac{Q \times \Delta T}{1700}$

  Where:

  $Q = 6500\ l/h$

  $\Delta T = 20°\text{C}$

  Therefore, the result of the calculation is:

  $P = 6500 \times (20)/1700$

  $P = 76{,}47\ kW$

- **Cluster 4**

  $\boldsymbol{Heater\ Capacity\ (P)}$

  To calculate the heater capacity, we could use;

  $P = \frac{Q \times \Delta T}{1700}$

  Where:

  $Q = 3300\ l/h$

  $\Delta T = 20°\text{C}$

  Therefore, the result of the calculation is:

  $P = 3300 \times (20)/1700$

  $P = 38{,}824\ kW$

8. CALCULATION OF HEATING SURFACE AREA SEPARATOR HEATER

To calculate the heating surface area, which is useful to select the proper heat exchanger or heater, we could use formula;

$LMTD = (\Delta Ta - \Delta Tb)/\log(\Delta Ta - \Delta Tb)$

Therefore, the result of the calculation is

$LMTD = (20)/\log(20)$
$LMTD = 15{,}372\ °C$

And then, we could calculate the surface area,

- **Cluster 1,2 and 3**

$A = H/(K - LMTD)$
Where;
$H = 65752{,}36\ [kcal/h]$
$K = 1000\ [^{kcal}/_{m^2 h°C}]$
$LMTD = 15{,}372\ °C$

Therefore, the result of the calculation is:
$A = 65752{,}36\ /(1000 - 15{,}372)$
$A = 66{,}779\ m^2$

- **Cluster 4**

$A = H/(K - LMTD)$
Where;
$H = 33382{,}63\ [kcal/h]$
$K = 1000\ [^{kcal}/_{m^2 h°C}]$
$LMTD = 15{,}372\ °C$

Therefore, the result of the calculation is:
$A = 33382{,}63\ /(1000 - 15{,}372\ )$
$A = 33{,}904\ m^2$

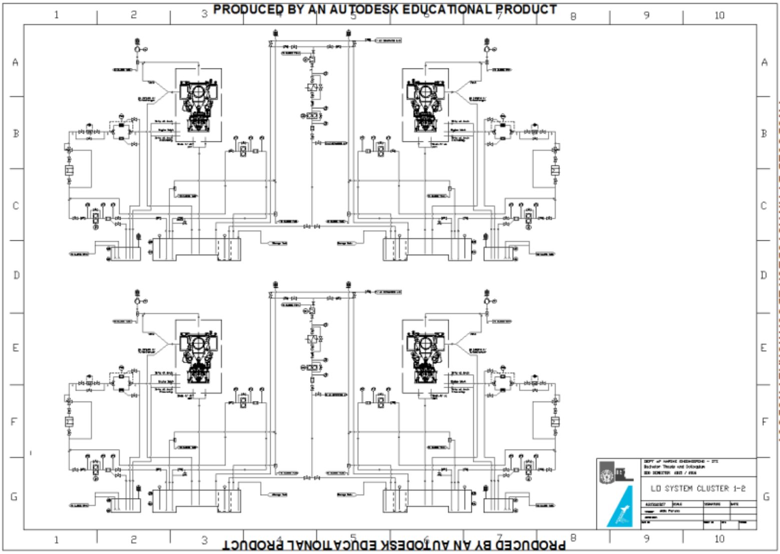
9. CALCULATION OF HEATING SURFACE AREA LUBE OIL COOLER

Based on the project guide, the heat need to be dissipated is 1440 kW per engine (MAN 51/60 DF Project Guide P.107)

$A = H/(K - LMTD)$
Where;
$H = 1238177\ [kcal/h]$
$K = 1000\ [^{kcal}/_{m^2 h°C}]$

$LMTD = 18{,}3749\ °C$

Therefore, the result of the calculation is:
$A = 1238177\ /(1000 - 18{,}3749)$
$A = 1261{,}354\ m^2$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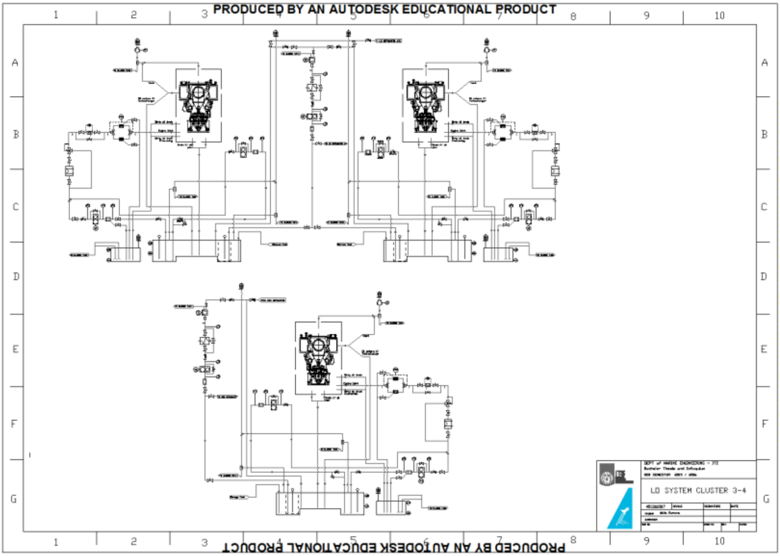
LO SYSTEM CLUSTER 1-2
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT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LO SYSTEM CLUSTER 3-4
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Attachment 5: Starting Air Supply System

Design Requirement

Keyword	Reference	Design Requirement
Compressor safety valve	GL I-1-2, Section 2, M.4.2.1	Every compressor stage shall be equipped with a suitable safety valve which cannot be blocked and which prevents the maximum permissible working pressure from being exceeded by more than 10 % even when the delivery line has been shut off. The setting of the safety valve shall be secured to prevent unauthorized alteration.
Compressor Pressure Gauge	GL I-1-2, Section 2, M.4.2.2	Each compressor stage shall be fitted with a suitable pressure gauge, the scale of which must indicate the relevant maximum permissible working pressure.
Compressed Air Temprature	GL I-1-2, Section 2, M.4.3.1	The compressed air temperature, measured directly at the discharge from the individual stages, may not exceed 160 °C for multi-stage compressors or 200 °C for single-stage compressors. For discharge pressures of up to 10 bar, temperatures may be higher by 20 °C.
Trap and Aftercooler	GL I-1-2, Section 2, M.4.3.3	After the final stage, all compressors are to be equipped with a water trap and an aftercooler.
Shut-off devices	GL I-1-2, Section 8, E.1	Shut-off devices must be fitted in pressure lines as close as possible to the pressure vessel. Where several pressure vessels are grouped together, it is not necessary that each vessel should be capable of being shut-off individually and means need only be provided for shutting off the group. In general, not more than three vessels should be grouped together. Starting air receivers and other pressure vessels which are opened in service must be

		capable of being shut-off individually. Devices incorporated in piping, (e.g. water and oil separators) do not require shut-off devices.
Pressure gauges	GL I-1-2, Section 8, E.2.1	Each pressure vessel which can be shut-off and every group of vessels with a shut-off device is to be equipped with a pressure gauge, also capable of being shut-off. The measuring range and calibration are to extend to the test pressure with a red mark to indicate the maximum allowable working pressure.
Safety valve set-point	GL I-1-2, Section 8, E.3.2	Safety valves are to be designed and set in such a way that the max. allowable working pressure cannot be exceeded by more than 10 %. Means shall be provided to prevent the unauthorized alteration of the safety valve setting. Valve cones are to be capable of being lifted at all times.
Filling lines	GL I-1-2, Section 11, L.1.3	Starting air lines may not be used as filling lines for air receivers.
Starting air line	GL I-1-2, Section 11, L.1.5	The starting air line to each engine is to be fitted with a non-return valve and a drain.
Pressure reducing valves	GL I-1-2, Section 11, L.1.7	A safety valve is to be fitted behind each pressure-reducing valve.
Seachest blowing	GL I-1-2, Section 11, I.1.5	Steam or compressed air connections are to be provided for clearing the sea chest gratings. The steam or compressed air lines are to be fitted with shut-off valves fitted directly to the sea chests. Compressed air for blowing through sea chest gratings may exceed 2 bar only if the sea chests are constructed for higher pressures.

Compressor capacity and quantity	GL I-1-2, Section 2, H.2.1	Starting air systems for main engines are to be equipped with at least two starting air compressors. At least one of the air compressors shall be driven independently of the main engine and shall supply at least 50 %of the total capacity required.
Starting air quantity	GL I-1-2, Section 2, H.2.3	If the main engine is started with compressed air, the available starting air is to be divided between at least two starting air receivers of approximately equal size which can be used independently of each other.
Air receiver capacity requirement	GL I-1-2, Section 2, H.2.4	The total capacity of air receivers is to be sufficient to provide, without their being replenished, not less than 12consecutive starts alternating between Ahead and Astern of each main engine of the reversible type, and not less than six starts of each main non-reversible type engine connected to a controllable pitch propeller or other device enabling the start without opposite torque.
Starting air capacity (reversible engine)	GL I-1-2, Section 2, H.2.10.1	The total capacity of air receivers is to be sufficient to provide, without their being replenished, not less than 12consecutive starts alternating between Ahead and Astern of each main engine of the reversible type, and not less than six starts of each main non-reversible type engine connected to a controllable pitch propeller or other device enabling the start without opposite torque.
Air receiver requirement	MAN 51/60DF Project Guide P.361	These are multi-stage compressor sets with safety valves, cooler for compressed air and condensate traps.The operational compressor is switched on by the pressure control at lowpressure then switched off when maximum service pressure is attained.A max. service pressure of 30 bar is required. The standard design

		pressureof the starting air vessels is 30 bar and the design temperature is 50 °C.
Identic Compressor	MAN 51/60DF Project Guide P.361	The service compressor is electrically driven, the auxiliary compressor may also be driven by a diesel engine. The capacity of both compressors (1C-001 and 2 C-001) is identical.
Air vessles pressure	MAN 51/60DF Project Guide P.365	Service pressure . . . . max. 30 bar Minimum starting air pressure . . . . .min. 10 bar
Air Compressor capacity		The total capacity of the starting air compressors has to be capable tocharge the air receivers from the atmospheric pressure to full pressure of 30bar within one hour.
Air Vessels Multiple Engine Plant	MAN 51/60DF Project Guide P.368	In this case the number of required starts is generally reduced. Three consecutive starts are required per engine. The total capacity must be sufficient for not less than 12 starts and need not exceed 18 starts.

Summary of Calculation

Object	Measurement Unit	Value
Air Vessels Capacity		
Manufacturer		Kaeser
Engine Start		18
Emergency Start		0
Jet Assist		10 x 5
Slow Turn Manoeuvres		0
Capacity	l	8000
Length	mm	4400
Diameter	mm	1600
Weight	Kg	2350
Compressor		
Manufacturer		MacGregor HATLAPA
Type		L270 - 1150
Q	$m^3/_h$	205
Rotation	RPM	1150
Power	kW	37
Weight	Kg	1000
Quantity	Unit	3
Height	mm	1000
Length	mm	2005
Width	mm	900

1. CALCULATION OF AIR VESSELS

To calculate the air vessels capacity, we could use the project guide recommendation table. In this case, multiple plant engine may have maximum 18 start, and the system are arranged to enable jet assist 10 times.

$$V = \frac{\left(Vst \times f_{drive} \times (Zst + Zsafe) + V_{jet} \times Z_{jet} + V_{sl} \times Z_{sl} \times f_{drive}\right)}{(P_{max} - P_{min})}$$

Where;

$V = Required\ vessel\ capacity\ [L]$
$Vst = Air\ consumption\ per\ nominal\ start\ [L]$
$fdrive = 1\ (diesel - mechanic)$
$Zst = Number\ of\ start$
$Zsafe = Emergency\ start$
$Vjet = Number\ of\ jet\ assist$
$Tjet = duration\ of\ jet\ assist$
$Vsl = Air\ consumption\ per\ slow\ turn$
$Zsl = Number\ of\ slow\ turn\ [L]$
$Pmax = Maximum\ starting\ air\ pressure\ [bar]$
$Pmin = Minimum\ starting\ air\ pressure\ [bar]$

Therefore the calculation is;

$V = \frac{(1600 \times 1 \times (18) + (11300 * 10) + 0)}{(16 - 10)}$
$V = 23633{,}333\ [L]$
$V = 23{,}633\ [m^3]$

2. CALCULATION OF COMPRESSOR

To calculate the air compressor capacity, we could use the project guide recommendation table above or we could use the formula which is the function of the required starting air. The formula is;

$P = \frac{V \cdot 16}{1000}$

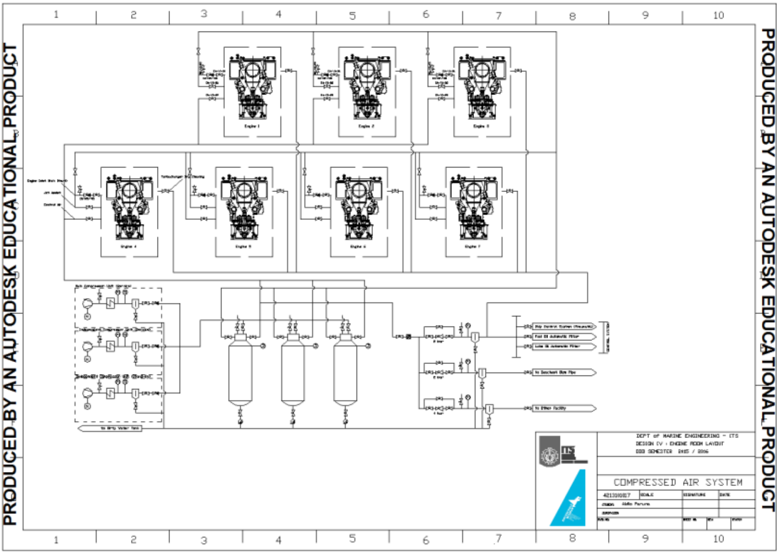
Where;

$V = 23633{,}333\ [L]$

Therefore the calculation is;

$$P = \frac{23633{,}333 \cdot 16}{1000}$$

$$P = 378{,}133\, {}^{m^3}\!/_{h}$$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DEPT of MARINE ENGINEERING - ITS
DESIGN IV : ENGINE ROOM LAYOUT
COMPRESSED AIR SYSTEM
SCALE
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Attachment 6: Cooling System

Design Requirement

Keyword	Reference	Design Requirement
Seachest	GL I-1-2, Section 11, I.1.1	At least two sea chests are to be provided. Wherever possible, the sea chests are to be arranged as low as possible on either side of the ship.
Shallow water seachest	GL I-1-2, Section 11, I.1.2	For service in shallow waters, it is recommended that an additional high seawater intake is provided.
Seawater supply	GL I-1-2, Section 11, I.1.3	It is to be ensured that the total seawater supply for the engines can be taken from only one seachest.
Seachest vent	GL I-1-2, Section 11, I.1.4	Each sea chest is to be provided with an effective vent. The following venting arrangements will be approved: an air pipe of at least 32 mm ID which can be shut off and which extends above the bulkhead deck adequately dimensioned ventilation slots in the shell plating.
Seachest grating	GL I-1-2, Section 11, I.1.5	team or compressed air connections are to be provided for clearing the sea chest gratings. The steam or compressed air lines are to be fitted with shut-off valves fitted directly to the sea chests. Compressed air for blowing through sea chest gratings may exceed 2 bar only if the sea chests are constructed for higher pressures.
Sea valves	GL I-1-2, Section 11, I.3.1	Sea valves are to be so arranged that they can be operated from above the floor plates.
Strainer	GL I-1-2, Section 11, I.4	The suction lines of the seawater pumps are to be fitted with strainers. The strainers are to be so arranged that they can be cleaned during service. Where

		cooling water is supplied by means of a scoop, strainers in the main seawater cooling line can be dispensed with
Freshwater cooling system	GL I-1-2, Section 11, K.1.1	Fresh water cooling systems are to be so arranged that the engines can be sufficiently cooled under all operating conditions.
Allowed System	GL I-1-2, Section 11, K.1.2	Depending on the requirements of the engine plant, the following fresh water cooling systems are allowed: a single cooling circuit for the entire plant separate cooling circuits for the main and auxiliary plant several independent cooling circuits for the main engine components which need cooling (e.g. cylinders, pistons and fuel valves) and for the auxiliary engines separate cooling circuits for various temperature ranges
Divided system	GL I-1-2, Section 11, K.1.3	The cooling circuits are to be so divided that, should one part of the system fail, operation of the auxiliary systems can be maintained. Change-over arrangements are to be provided for this purpose if necessary.
Shut-off valves	GL I-1-2, Section 11, K.1.6	Common engine cooling water systems for main and auxiliary plants are to be fitted with shutoff valves to enable repairs to be performed without taking the entire plant out of service.
H/E bypass line	GL I-1-2, Section 11, K.2.3	Heat exchangers for auxiliary equipment in the main cooling water circuit are to be provided with by-passes if in the event of a failure of the heat exchanger it is

		possible by these means to keep the system in operation
Maintained in operation	GL I-1-2, Section 11, K.2.4	It is to be ensured that auxiliary machinery can be maintained in operation while repairing the main coolers. If necessary, means are to be provided for changing over to other heat exchangers, machinery or equipment through which a temporary heat transfer can be achieved.
H/E shut-off valves	GL I-1-2, Section 11, K.2.5	Shut-off valves are to be provided at the inlet and outlet of all heat exchangers.
Vent and drain	GL I-1-2, Section 11, K.2.6	Every heat exchanger and cooler is to be provided with a vent and a drain.
Expansion tank arrangement	GL I-1-2, Section 11, K.3.1	Expansion tanks are to be arranged at sufficient height for every cooling water circuit. Different cooling circuits may only be connected to a common expansion tank if they do not interfere with each other. Care is to be taken here to ensure that damage to or faults in one system cannot affect the other system.
Expansion tank equipment	GL I-1-2, Section 11, K.3.2	Expansion tanks are to be fitted with filling connections, aeration/de-aeration devices, water level indicators and drains.
Main and stand-by pump	GL I-1-2, Section 11, K.4.1	Main and stand-by cooling water pumps are to be provided for each fresh water cooling system.
Engine driven pump	GL I-1-2, Section 11, K.4.2	Main cooling water pumps may be driven directly by the main or auxiliary engines which they

		are intended to cool provided that a sufficient supply of cooling water is assured under all operating conditions.
Stand-by Pump driver	GL I-1-2, Section 11, K.4.3	The drives of stand-by cooling water pumps are to be independent of the main engines
Stand-by pump capacity	GL I-1-2, Section 11, K.4.4	Stand-by cooling water pumps are to have the same capacity as main cooling water pumps
Pump quantity	GL I-1-2, Section 11, K.4.5	Main engines are to be fitted with at least one main and one stand-by cooling water pump. Where according to the construction of the engines more than one water cooling circuit is necessary, a stand-by pump is to be fitted for each main cooling water pump.
Pump quantity	GL I-1-2, Section 11, K.4.9	For plants with more than one main engine the requirements for sea cooling water pumps in I.5.3 may be applied -For plants with more than one engine and with separate cooling water systems, complete spare pumps stored on board may be accepted instead of stand-by pumps provided that the main seawater cooling pumps are so arranged that they can be replaced with the means available on board.
Temprature control	GL I-1-2, Section 11, K.5	Cooling water circuits are to be provided with temperature controls in accordance with the requirements. Control devices whose failure may impair the functional reliability of the engine are to be equipped for manual operation
Preheating of cooling water	GL I-1-2, Section 11, K.6	Means are to be provided for preheating cooling fresh water. Exceptions are to be approved by GL.

Summary of Calculation

Object	Measurement Unit	Value
Tank		
HT Expansion Tanks (Cluster 1,2,3)		
Volume (each)	m^3	1,5
Quantity (in one cluster)	Tanks	2
HT Expansion Tanks (Cluster 4)		
Volume (each)	m^3	1,5
Quantity (in one cluster)	Tanks	1
LT Expansion Tanks (Cluster 1,2,3)		
Volume (each)	m^3	3
Quantity (in one cluster)	Tanks	1
LT Expansion Tanks (Cluster 4)		
Volume (each)	m^3	1
Quantity (in one cluster)	Tanks	1
Drain Tank (Cluster 1,2,3)		
Volume	m^3	6
Drain Tank (Cluster 4)		
Volume	m^3	2,5
Pumps		
Engine-Drive LT Circuit Pump (All Engine)		
Attached		
Stand-by LT Circuit Pump (All Engine)		
Manufacturer		Herborner
Type		X200-350A-5504H
Q	$m^3/_h$	285
Head	m	32,4
Rotation	RPM	1500
Weight	Kg	797

Object	Measurement Unit	Value
Engine-Drive HT Circuit Pump (All Engine)		
Attached		
Stand-by HT Circuit Pump (All Engine)		
Manufacturer		Herborner
Type		X200-350A-4504H
Q	$m^3/_h$	200
Head	M	32,4
Rotation	RPM	1500
Weight	Kg	652
Sea Water Pumps		
Manufacturer		Pompe Garbarino
Type		250-400
Q	$m^3/_h$	900
Head	m	46
Rotation	RPM	1450
Weight	Kg	485
Arrangement		Parallel
LT Coolers (Cluster 1,2,3)		
Manufacturer		Alfalaval
Type		AlfaQ 14L
Heat surface	m^2	1700
Weight	Kg	
+ (series)		
Manufacturer		Alfalaval

Type		AlfaQ 8S
Heat surface	m^2	85
Weight	Kg	
LT Coolers (Cluster 4)		
Manufacturer		Alfalaval
Type		AlfaQ 10
Heat surface	m^2	940
Weight	Kg	
HT Coolers (Cluster 1,2,3)		
Manufacturer		Alfalaval
Type		AlfaQ 20M
Heat surface	m^2	2880
Weight	Kg	
+ series		
Manufacturer		Alfalaval
Type		AlfaQ 14L
Heat surface	m^2	1700
Weight	Kg	
HT Coolers (Cluster 4)		
Manufacturer		Alfalaval
Type		AlfaQ 14L
Heat surface	m^2	1700
Weight	Kg	
+ (series)		
Manufacturer		Alfalaval
Type		AlfaQ 6

Heat surface	m^2	390
Weight	Kg	
Preheaters		
Provided by MAN		

Calculation

1. CALCULATION OF HT EXPANSION TANK

The expansion tank compensate changes in system volume and losses due to leakages and located in the highest point of the system at any inclination. (MAN 51/60 DF P.307)
Cylinder, charge air cooler stage.

Service tanks	Installation height[1]	Minimum effective capacity							
	m	m^3							
No. of cylinders	-	6	7	8	9	12	14	16	18
Cooling water cylinder	6 ... 9	1.0				1.5			
Required diameter for expansion pipeline	-	≥ DN50 [2]							
Cooling water fuel nozzles	5 ... 8	0.5				0.75			

Service tank minimum effective capacity
(Source: Cooling water service tanks MAN 51/60 DF Project Guide P.122)

Therefore, the capacity of HT expansion tank for each engine is;
$V_{HT-Expansion} = 1.5\ [m^3]$

2. CALCULATION OF LT EXPANSION TANK

The effective tank capacity for twin-engine plants with common water system, the tank should be 50% higher than 2/3 of the content in the HT Expansion tank;

- **LT Expansion Tank Cluster 1,2 and 3**

$$V_{LT-Expansion} = \left(V_{HT-Expansion} \times 2 \times {}^{2}/_{3}\right) \times 150\%\ [m^3]$$

Where;
$V_{HT-Expansion} = 1.5[m^3]$
$2 = Number\ of\ the\ engine$
$150\% = requirement\ for\ twin-engine\ plant$

Therefore, the result is:

$V_{LT-Expansion} = \left(1.5 \times 2 \times {}^{2}/_{3}\right) \times 150\% \ [m^3]$

$V_{LT-Expansion} = 3 \ [m^3]$

- **LT Expansion Tank Cluster 4**

$V_{LT-Expansion} = \left(V_{HT-Expansion} \times 1 \times {}^{2}/_{3}\right) [m^3]$

Where;
$V_{HT-Expansion} = 1.5 [m^3]$
$1 = Number\ of\ the\ engine$

Therefore, the result of is:
$V_{LT-Expansion} = \left(1.5 \times 1 \times {}^{2}/_{3}\right) \ [m^3]$

$V_{LT-Expansion} = 1 \ [m^3]$

3. CALCULATION OF DRAIN TANK

According to the MAN 51/60 Section 5.3.4 P.309 project guide, the tank should be arranged to able all of the water content of the cylinder, turbocharge and nozzle cooling. In other word the drain tank should be able to collect LT-Water and HT-Water content;

Therefore, the result of is:

- **Drain Tank Cluster 1,2 and 3**

$V_{Drain\ tank} = V_{HT-Expansion} + V_{LT-Expansion}$
Where;
$V_{HT-Expansion}$
$= 1.5 \ [m^3] \times 2 \ (2\ expansion\ tank\ in\ clusster\ 1{,}2, and\ 3)$
$V_{LT-Expansion} = 3 \ [m^3]$
Then, the result is

$V_{Drain\ tank} = 6 \ [m^3]$
The drain tank will be located above the tank top at 6.5 m high.

- **Drain Tank Cluster 4**

$V_{Drain\ tank} = V_{HT-Expansion} + V_{LT-Expansion}$

Where;
$V_{HT-Expansion} = 1{,}5\ [m^3]$
$V_{LT-Expansion} = 1\ [m^3]$
Then, the result is
$V_{Drain\ tank} = 2{,}5\ [m^3]$
The drain tank will be located above the tank top at 6.5 m high.

4. SEAWATER PUMP

The seater pumps are separated from the attached pump. The capacity of the pumps is determined by the coolers and the amount of heat to be dissipated. In the design there is two seawater pump, it's arranged to prevent when the first pump is failed, there is another pump to coverage the role of the first pump. The specification of the seawater pump is written on the project guide

$$v = 1.5 \frac{m}{s} \left(MAN \frac{51}{60} DF\ Project\ Guide\ P.265\right)$$

$$Q\ fresh\ water = 285\ {m^3}/{h}\ (see\ point\ 6\ or\ project\ guide\ p.104)$$

The seawater pump capacity are not mentioned in the MAN 51/60 DF project guide, therefore to determine the capacity, author use similar engine which is Wartsila 50 DF where in the project guide it mention the seawater pump capacity should be around 1.5 times higher than the fresh water flow inside the coolers. Therefore;

$$Qseawater = 1.5 \times Qfresh\ water$$

$$Qseawater = 1.5 \times 285$$

$$Qseawater = 427{,}5\ {m^3}/{h}$$

The capacity in each cluster is $427{,}5\ {m^3}/{h}$, with the existing design which has 4 cluster, the total capacity should be;

$Qtotal = 427{,}5 \times 4 = 1710\, {m^3}/{h}$

The seawater pump head is is recommended by the project guide to have minimum working pressure at 4.5 bar which is

$1\ bar = 10{,}199\ m$

$H = 45{,}899\ m$

5. CALCULATION OF HEAT EXCHANGERS SURFACE AREA IN LT COOLERS

To calculate the heat exchangers surface area, which is useful to select the proper heat exchanger or heater, we could use formula;

- **Cluster 1,2, and 3**

$LMTD = (\Delta Ta - \Delta Tb)/\log(\Delta Ta - \Delta Tb)$

Therefore, the result of the calculation is

$LMTD = (19)/\log(19)$

$LMTD = 14{,}858\ °C$

And then, we could calculate the surface area,

$A = H/(K - LMTD)$

Where;

$H = 1730945\ [kcal/h]$(Heat to dissipated form the MAN 51/60DF project guide P.114 when operated at 15149,22 kW))

$K = 1000\ [{kcal}/{m^2 h °C}]$

$LMTD = 14{,}858\ °C$

Therefore, the result of the calculation is:

$A = 1757{,}052\ m^2$

- **Cluster 4**

$LMTD = (\Delta Ta - \Delta Tb)/\log(\Delta Ta - \Delta Tb)$

Therefore, the result of the calculation is

$LMTD = (19)/\log(19)$

$LMTD = 14{,}858\ °C$

And then, we could calculate the surface area,
$A = H/(K - LMTD)$

Where;
$H = 865472{,}4\ [kcal/h]$(Heat to dissipated form the MAN 51/60DF project guide P.114 when operated at 15149,22 kW)
$K = 1000\ [{}^{kcal}/_{m^2 h°C}]$
$LMTD = 14{,}858\ °C$

Therefore, the result of the calculation is:
$A = 878{,}525\ m^2$

6. LT SERVICE AND STAND-BY PUMPS

- **Service Pumps**

The capacity of attached LT Service pumps which are engine-driven are determined by using the project guide;

No. of cylinders	-	12V	14V	16V	18V
a) Attached					
HT CW service pump	m³/h	140	160	180	200
LT CW service pump		195	260	260	285
Lube oil service pump		408	436	504	504
b) Free-standing[4]					
HT CW stand-by pump	m³/h	140	160	180	200
LT CW stand-by pump		Depending on plant design			

Nominal Values for cooler specification
(Source: MAN 51/60 DF Project Guide P. 94)

$Q = 285\ {}^{m^3}/_{h}$ (Service and stand-by pump)

Minimum head of HT Cooling Pumps are regulated by the project guide (MAN 51/60 DF Project Guide P.118) ;

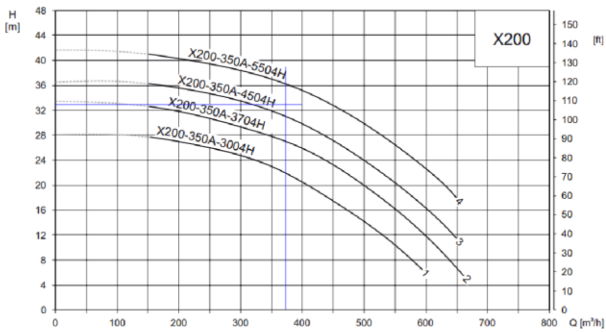
$H = 3{,}2\ bar = 32{,}64\ m$

- **Stand-by Pumps**

The stand-by pumps are designed to have the same head and capacity but with different driver. Based on the project guide and classification societies a stand-by pumps is not mandatory

(GL I-1-2 Section 11, K.4.9.), but as a precaution, author decide to determine the stand-by pump.

The capacity and the head of the LT stand-by pump are designed to have the same specification and can be seen in the table below.



LT Circuit Pump	**Centrifugal Pump**	**All Engine**
Model	**Herborner.X200-350A-5504H**	
Dimension		**Measurement Unit**
Height	1585	mm
Length	730	mm
Dimension		**Measurement Unit**
Width	650	mm
Weight	797	kg
Specification		
Capacities	285	m^3/hr
Power	55	kW
RPM	1500	RPM
Head	32,4	m

Installation Design		
No. of Pump Required	7	Unit
Power Required	385	kW

7. CALCULATION OF HEAT EXCHANGERS SURFACE AREA IN HT COOLERS

To calculate the heat exchangers surface area, which is useful to select the proper heat exchanger or heater, we could use formula;

- **Cluster 1,2 and 3**

$LMTD = (\Delta Ta - \Delta Tb)/\log(\Delta Ta - \Delta Tb)$

Therefore, the result of the calculation is

$LMTD = (19)/\log(19)$

$LMTD = 14{,}858\ °C$

And then, we could calculate the surface area,

$A = H/(K - LMTD)$

Where;

$H = 4106467\ [kcal/h]$ (Heat to dissipated form the MAN 51/60DF project guide P.114 when operated at 15149,22 kW)

$K = 1000\ [{}^{kcal}/_{m^2 h °C}]$

$LMTD = 14{,}858\ °C$

Therefore, the result of the calculation is:

$A = 4168{,}403\ m^2$

- **Cluster 4**

$LMTD = (\Delta Ta - \Delta Tb)/\log(\Delta Ta - \Delta Tb)$

Therefore, the result of the calculation is

$LMTD = (19)/\log(19)$

$LMTD = 14{,}858\ °C$

And then, we could calculate the surface area,

$A = H/(K - LMTD)$

Where;

$H = 2053234\ [kcal/h]$ (Heat to dissipated form the MAN 51/60DF project guide P.114 when operated at 15149,22 kW)
$K = 1000\ [{}^{kcal}/_{m^2 h°C}]$
$LMTD = 14{,}858\ °C$

Therefore, the result of the calculation is:
$A = 2084{,}201\ m^2$

8. HT SERVICE PUMPS

- **Service Pumps**
  The capacity of attached LT Service pumps which are engine-driven are determined by using the project guide;

No. of cylinders	-	12V	14V	16V	18V
a) Attached					
HT CW service pump	m^3/h	140	160	180	200
LT CW service pump		195	260	260	285
Lube oil service pump		408	436	504	504
b) Free-standing[4]					
HT CW stand-by pump	m^3/h	140	160	180	200
LT CW stand-by pump		Depending on plant design			

Nominal Values for cooler specification
(Source: MAN 51/60 DF Project Guide P. 94)

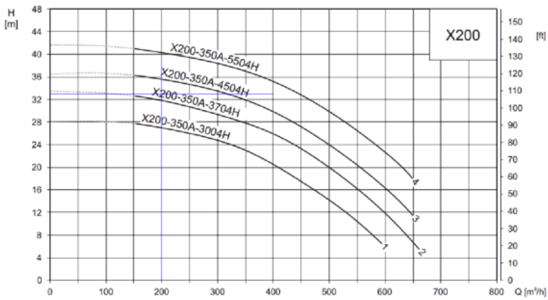
$Q = 200\ {}^{m^3}/_{h}$ (Service and stand-by pump)

Minimum head of HT Cooling Pumps are regulated by the project guide (MAN 51/60 DF Project Guide P.118) ;
$H = 3{,}2\ bar = 32{,}64\ m$

- **Stand-by Pumps**
  The stand-by pumps are designed to have the same head and capacity but with different driver. Based on the project guide and classification societies a stand-by pumps is not mandatory

(GL I-1-2 Section 11, K.4.9.), but as a precaution, author decide to determine the stand-by pump.

The capacity and the head of the HT stand-by pump are designed to have the same specification and can be seen in the table below.



HT Circuit Pump	**Centrifugal Pump**	**All Engine**
Model	**Herborner.X200-350A-4504H**	
Dimension		**Measurement Unit**
Height	1560	mm
Length	730	mm
Width	430	mm
Weight	652	kg
Specification		
Capacities	200	m^3/hr
Power	45	kW
RPM	1500	RPM
Head	32,4	m
Installation Design		
No. of Pump Required	7	Unit
Power Required	315	kW

9. CALCULATION OF HEAT EXCHANGERS SURFACE AREA IN PREHEATER

According to the project guide, the minimum power of the preheater should be 6 kW/Cylinder, and the heater should be able to increase the water temperature within 4 hours.

Engine type	L/V engine
Min. heating power (kW/cylinder)	14

Heating power of preheater
(Source: MAN 51/60 DF Project guide P.303)
Therefore the heater minimum power is;

$$P = 14 \times Number\ of\ Cylinder$$
$$P = 14 \times 18$$
$$P = 252\ kW$$

According to the project guide, the minimum capacity of the preheater should refer to the project guide recommendation, and the preheater must be used in pre-heating and post-cooling process.

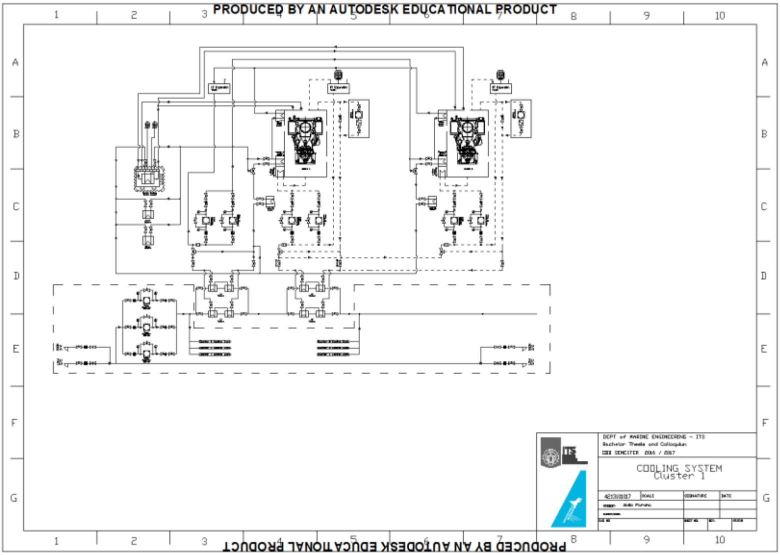
No. of cylinders	Minimum flow rate required during preheating and post-cooling
	m^3/h
6L	14
7L	16
8L	18
9L	20
12V	28
14V	30
16V	30
18V	30

Minimum flow rate during preheating and post-cooling
Source: MAN 51/60 DF Project Guide P. 303

Therefore the capacity is;

$$Q = 30 \ {m^3}/{h}$$

The preheater and the pump will use the available module provided by MAN, therefore, calculation of the pump head, and surface area are not necessary.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Cluster 1
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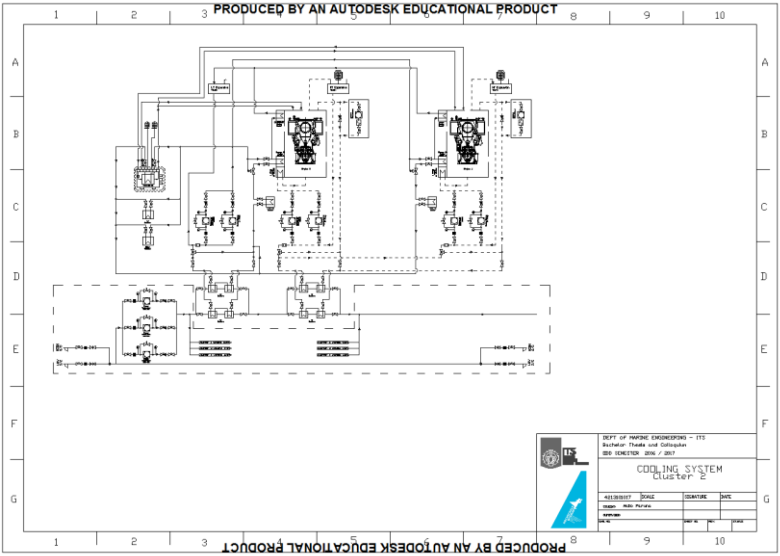
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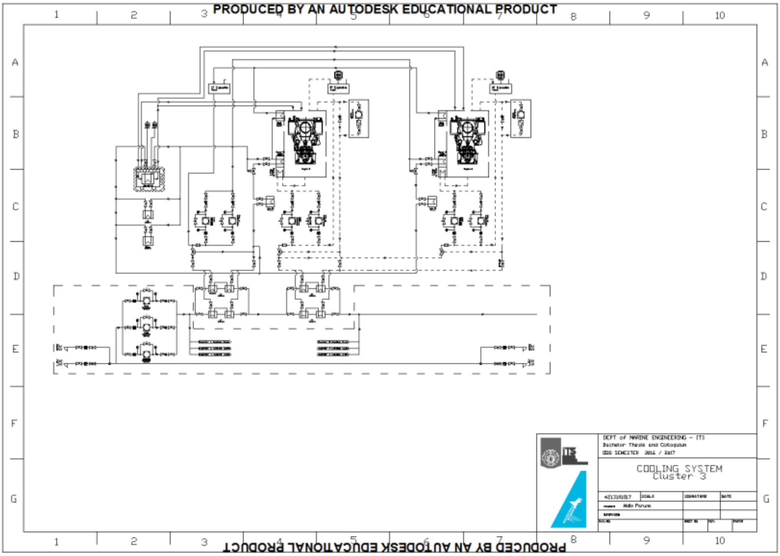
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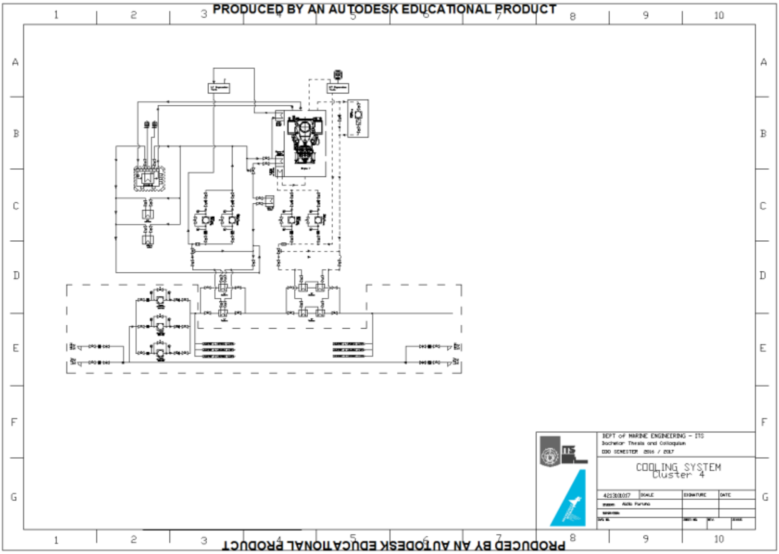
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Attachment 7: Preliminary Storage and Duration Calculation

1. LNG Storage

To determine the LNG Storage, several products which have various capacity is being compared and arranged. The parameter to determine the type of the storage is the quantity of the storage required and the total capacity of the storage based on the arrangement.

The LNG Storage used in the comparison process is Type C Vessels.

1. ISO VAC - 40ft LNG

Capacity	41,325		m^3
Weight (Payload)	139		Ton
Tare Weight	70,3		Ton
Pressure	5		Barg
No. of tank	8		Unit

Dimension

Length	Height	Width	
29700	4200	4200	mm

Total

Total Capacity	2438,596		m^3
Total Weight	1674,4		Ton

2. ISISAN 95000

Capacity	90,250		m^3
Weight (Payload)	41,154		Ton
Tare Weight	25		Ton
Pressure	5		Barg
No. of tank	21		Unit

Dimension

Length	Height	Width	
15350	3850	3350	mm

Total

Total Capacity	1895,250		m^3
Total Weight	1389,234		Ton

3. ISISAN 60000

Capacity	57		m^3
Weight (Payload)	25,992		Ton
Tare Weight	17		Ton
Pressure	5		Barg
No. of tank	56		Unit

Dimension

Length	Height	Width	
10600	2830	3920	mm

Total

Total Capacity	3192,000		m^3
Total Weight	2407,552		Ton

4. Worthington 25000

Capacity	95,635		m^3
Weight (Payload)	43,134		Ton
Tare Weight	32,885		Ton
Pressure	10		Barg
No. of tank	20		Unit

Dimension

Length	Height	Width	
17068	3658	3658	mm

Total

Total Capacity	1892,7		m^3
Total Weight	1520,771		Ton

5. Worthington 80000

Capacity	288,0698		m^3
Weight (Payload)	131,359		Ton
Tare Weight	75,296		Ton
Pressure	10		Barg
No. of tank	10		Unit

Dimension

Length	Height	Width	
24384	5151,12	5151,12	mm

Total

Total Capacity	2880,698		m^3
Total Weight	2066,558		Ton

6. Worthington 65000

Capacity	237,345		m^3
Weight (Payload)	108,229		Ton
Tare Weight	60,554		Ton
Pressure	10		Barg
No. of tank	6		Unit

Dimension

Length	Height	Width	
20726,4	5151,12	5151,12	mm

Total

Total Capacity	1424,07		m^3

Total Weight	1012,7		Ton

7. Lapesa 4200H LC318

Capacity	304,825		m^3
Weight (Payload)	139		Ton
Tare Weight	70,3		Ton
Pressure	5		Barg
No. of tank	8		Unit

Dimension

Length	Height	Width	
29700	4200	4200	mm

Total

Total Capacity	2438,596		m^3
Total Weight	1674,4		Ton

8. Lapesa 4200H LC240

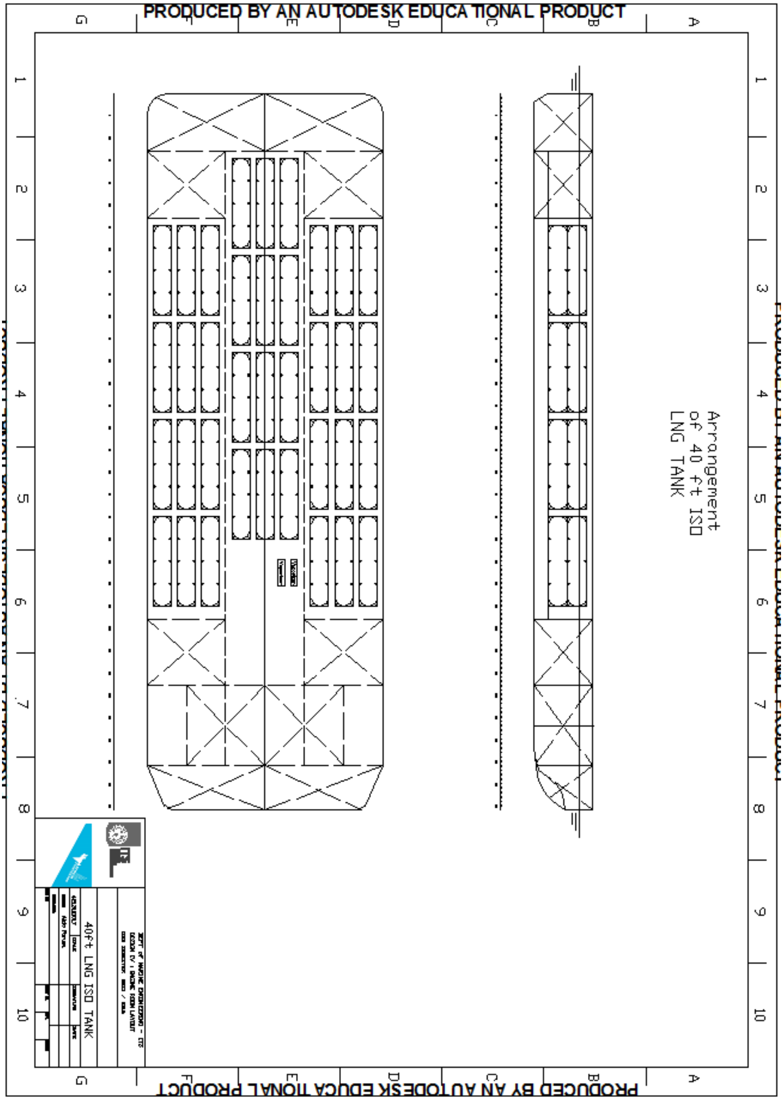
Capacity	230,044		m^3
Weight (Payload)	104,9		Ton
Tare Weight	54,9		Ton
Pressure	5		Barg
No. of tank	14		Unit

Dimension

Length	Height	Width	
22700	4200	4200	mm

Total

Total Capacity	3220,614		m^3
Total Weight	2237,2		Ton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Arrangement of 40 ft ISO LNG TANK
40ft LNG ISO TANK
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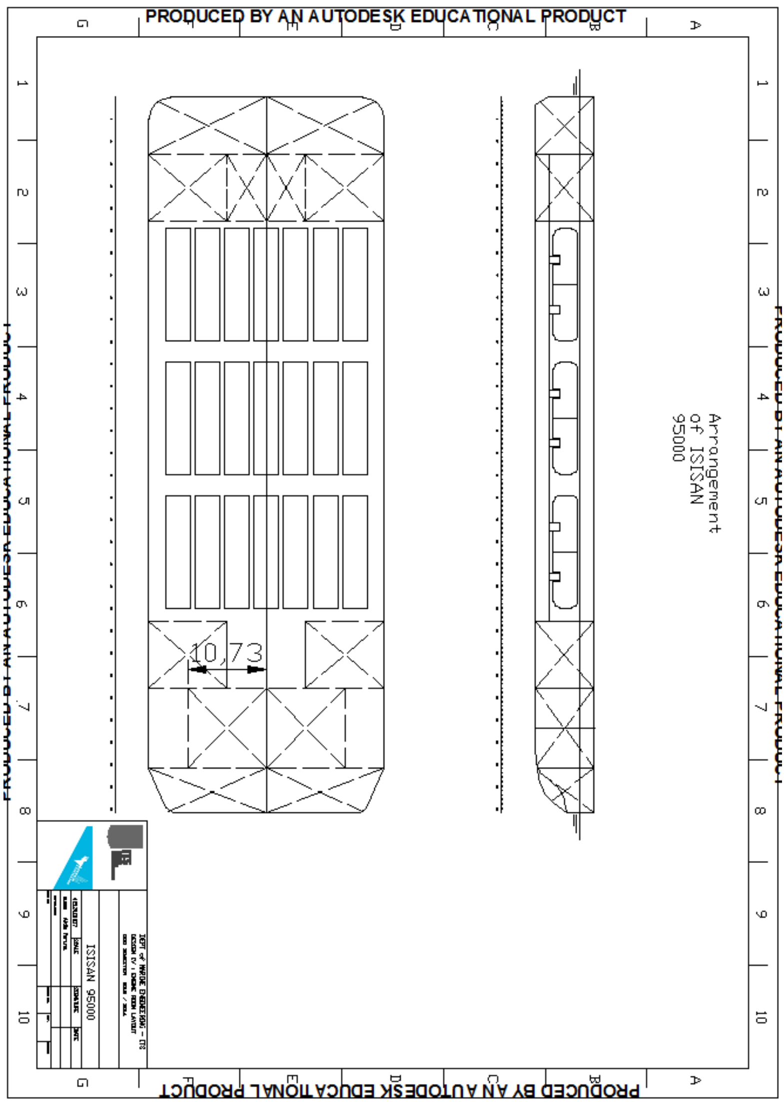
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of ISISAN
95000
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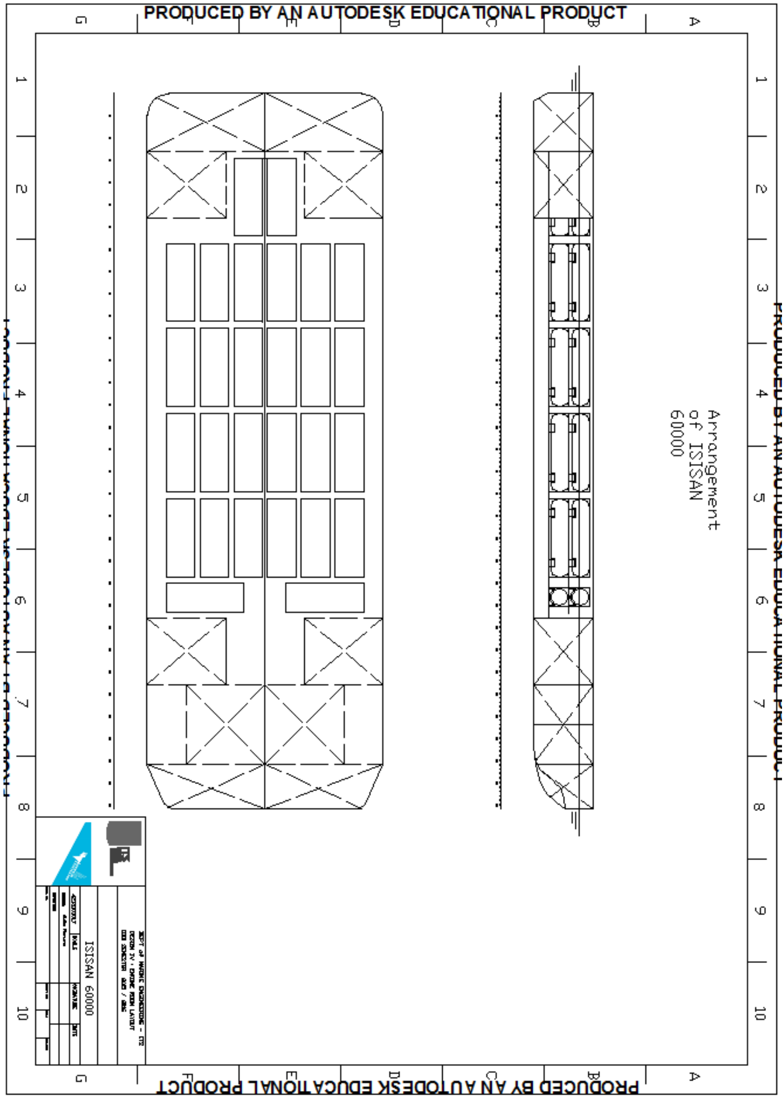
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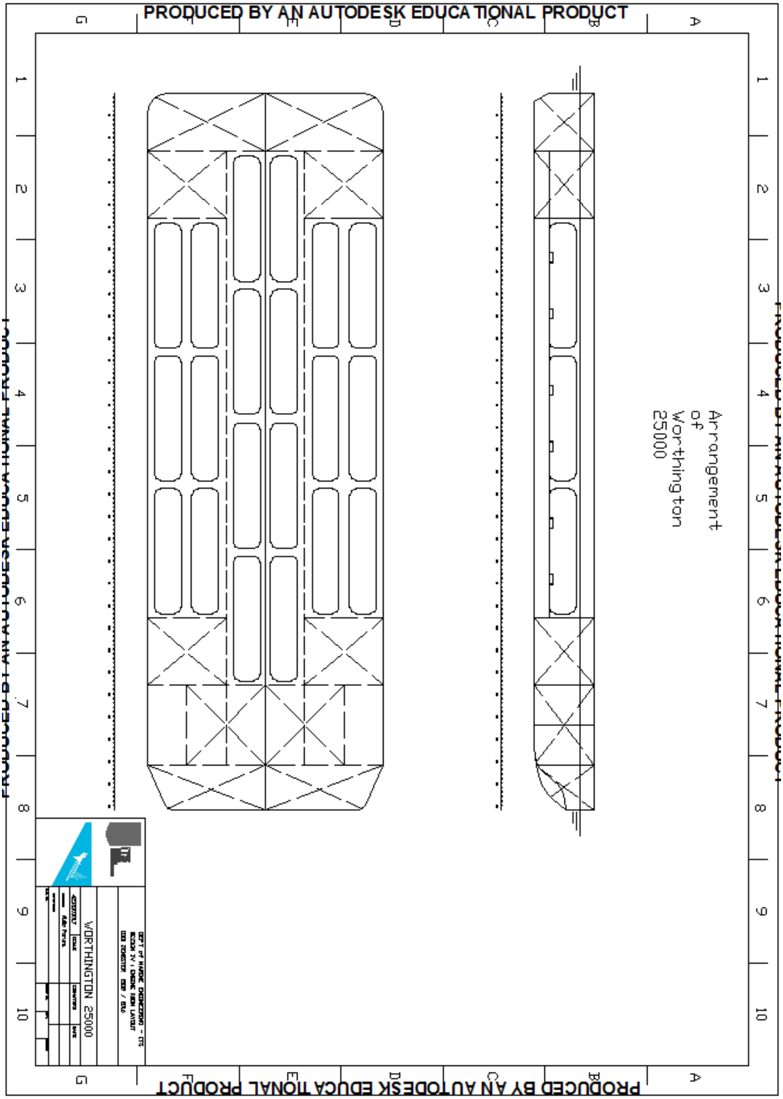
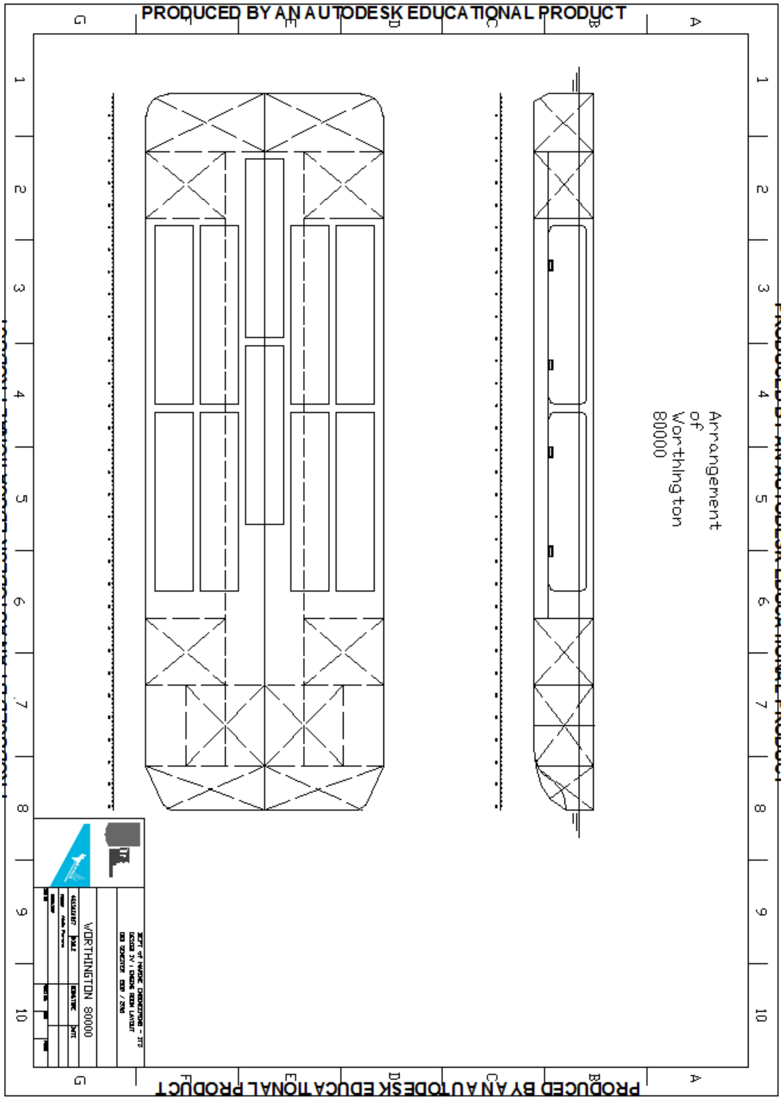
Arrangement of ISISAN 60000
ISISAN 60000


PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
Arrangement of Worthington 25000
WORTHINGTON 25000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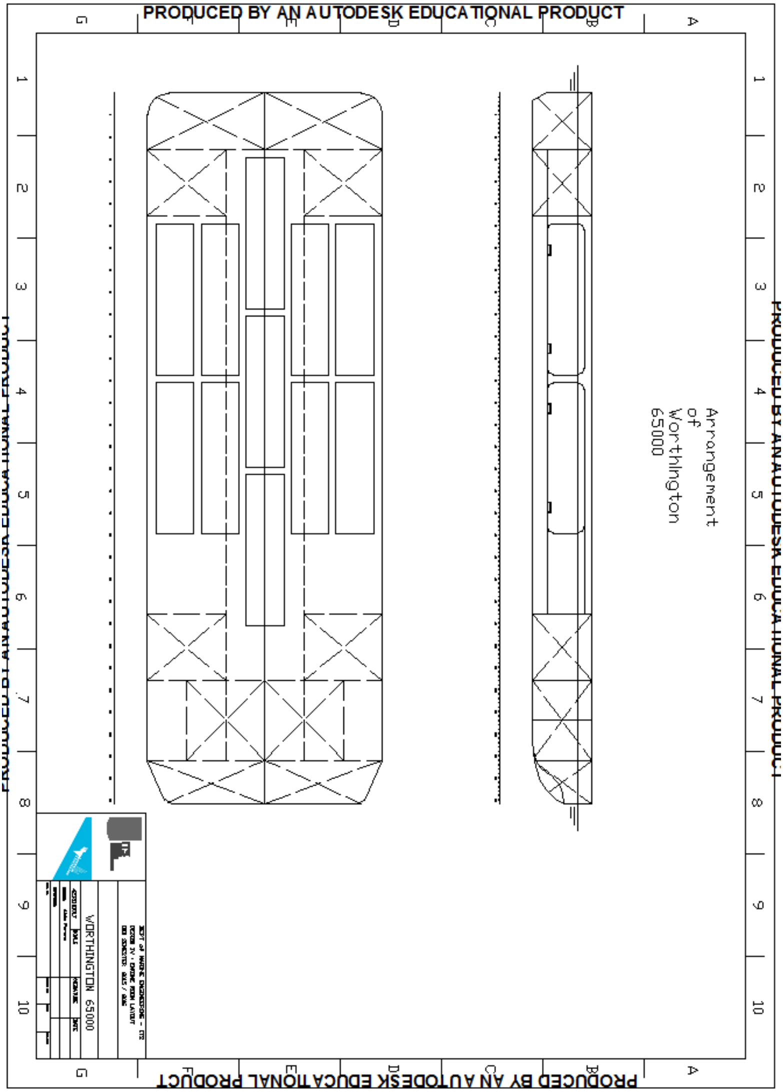
Arrangement
of
Worthington
80000
WORTHINGTON 80000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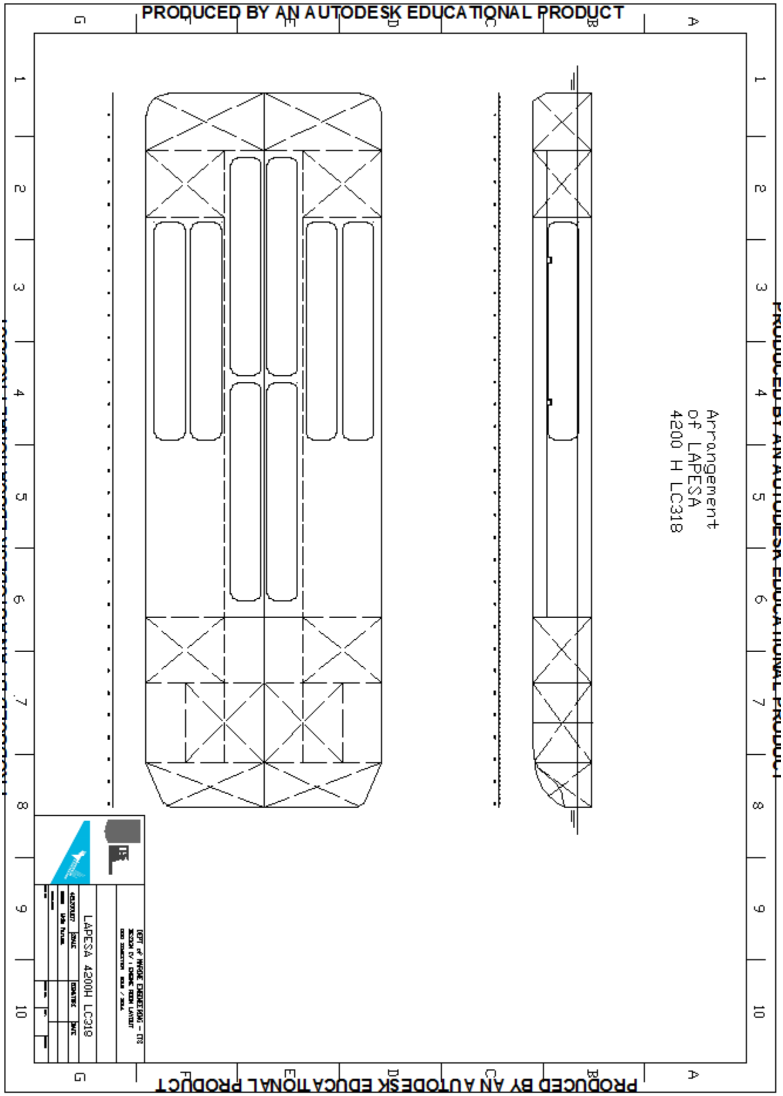
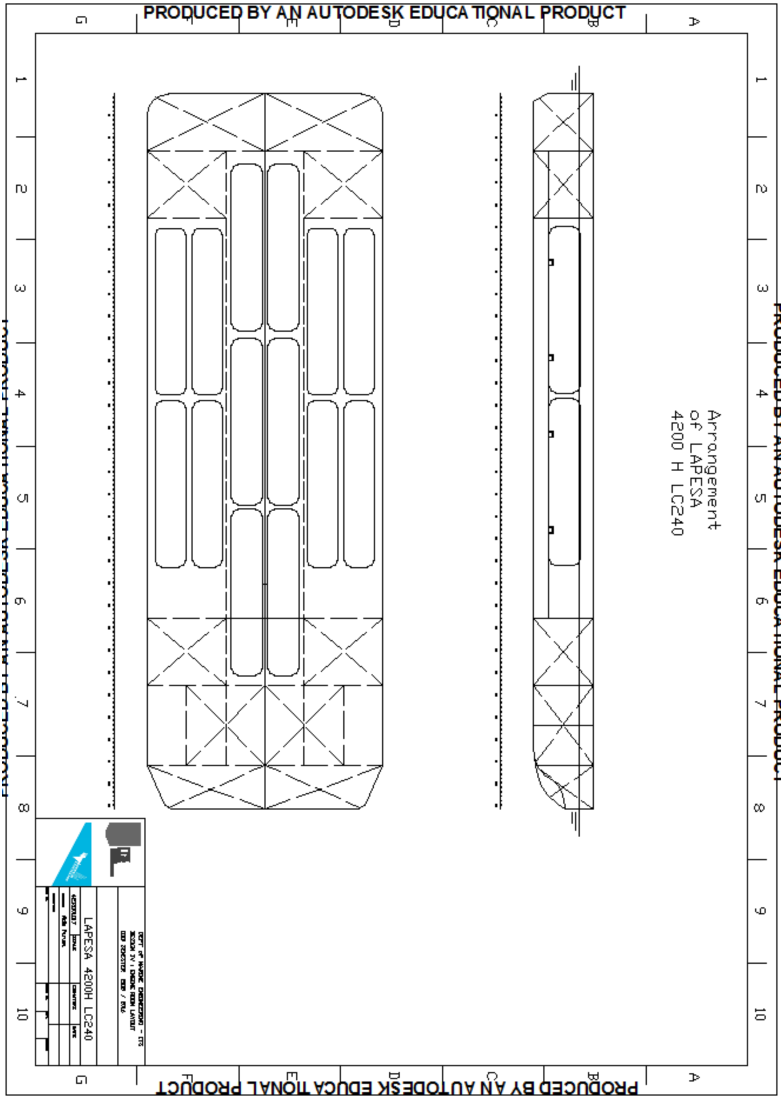
Arrangement of Worthington 65000
WORTHINGTON 65000


PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
Arrangement
of LAPESA
4200 H LC318
LAPESA 4200H LC319


PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
Arrangement
of LAPESA
4200 H LC240
LAPESA 4200H LC240

2. Operation Duration Capability

The arrangement of storage will result to the total capacity of LNG that can be stored inside the stan-pontoon. Since the engine is already determined, then the total duration of the mobile power plant can be calculated.

To calculate the duration of the specific arrangement may use the formula of;

$$Duration = \frac{Total\ Capacity}{LNG\ Consumption/day}$$

The total capacity data is available at point 1, attachment 4.

Type	Gas Consumption kj/day	Gas Consumption m3/day	LNG consumption m3/day
MAN 18V51/60DF	18627331495	499957,5773	833,2626289

Storage Type	Operation Duration [days]	Quantity [unit]
ISO VAC 40 ft LNG	3,571	72
ISISAN 60000	3,831	56
ISISAN 95000	2,274	21
Worthington 25000	2,271	20
Worthington 65000	1,709	6
Worthington 80000	3,457	10
Lapesa 4200H LC240	3,865	14
Lapesa 4200H LC318	2,926	8

3. Preliminary LNG Storage Selected Arrangement

Based on the data in point 1 and point 2, attachment 4. The arrangement of the storage will be a combination of Lapesa 4200H LC318 and Lapesa 4200H LC240.

Lapesa 4200 H Type LC318

Capacity	304,825		m^3
Weight (Payload)	139		Ton
Tare Weight	70,3		Ton
Pressure	5		Barg
No. of tank	8		Unit

Dimension

Length	Height	Width	
29700	4200	4200	mm

Total

Total Capacity	2438,596		m^3
Total Weight	1674,4		Ton

Lapesa 4200 H Type LC240

Capacity	230,044		m^3
Weight (Payload)	104,9		Ton
Tare Weight	54,9		Ton
Pressure	5		Barg
No. of tank	4		Unit

Dimension

Length	Height	Width	
22700	4200	4200	mm

Total

Total Capacity	920,175		m^3
Total Weight	639,2		Ton

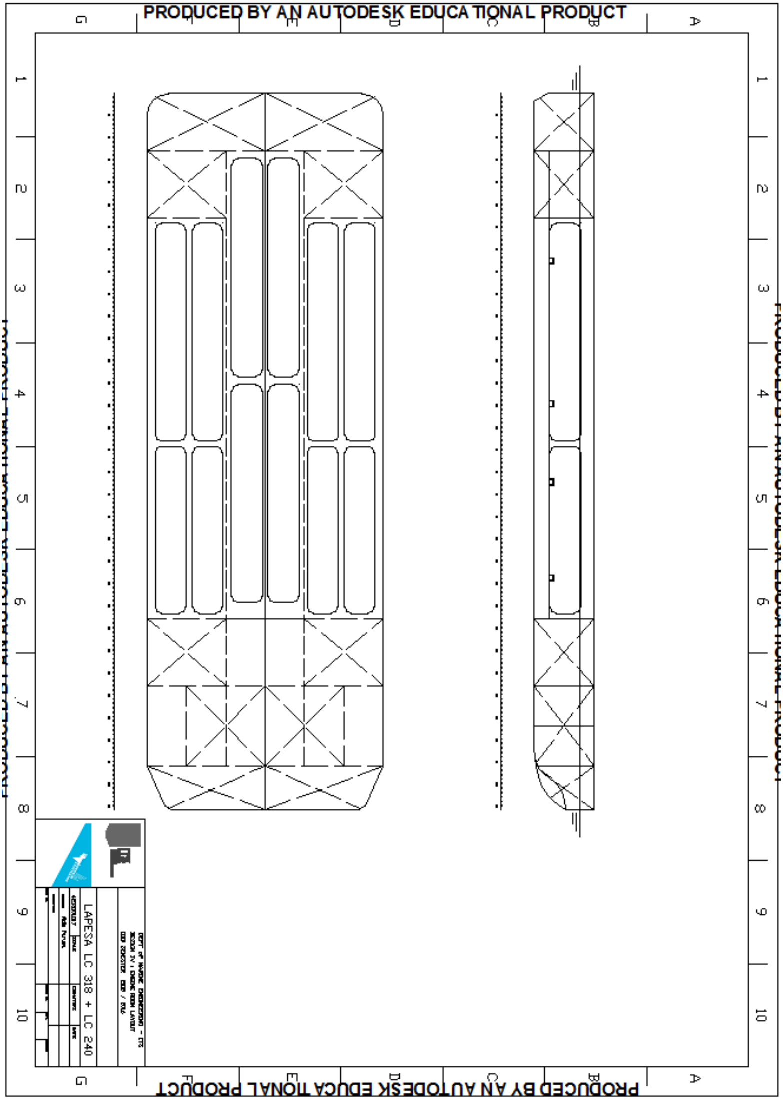
The combination of the storage may have total capacity of;

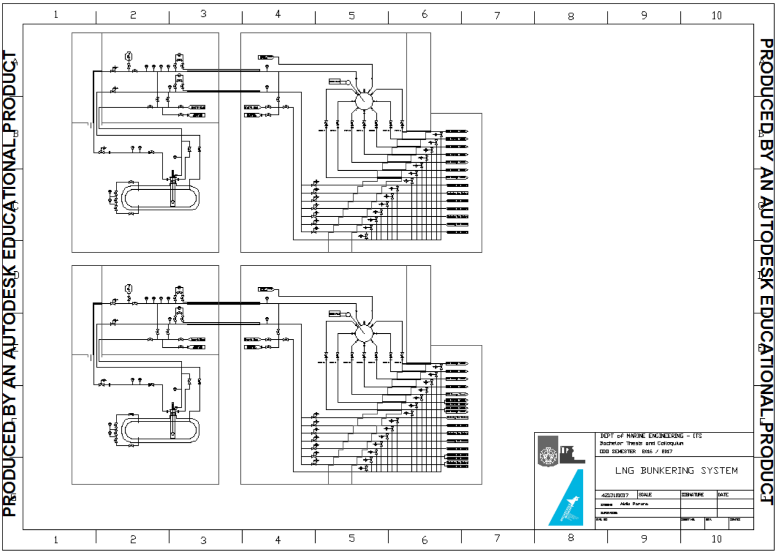
Total Capacity	3358,772	m^3
Total Weight	2313,6	Ton
Total Tare Weight	782	Ton

The combination of the storage may have total operation duration of;

Engine	**Gas Consumption** m^3/day	**LNG consumption** m^3/day	**Duration** $Days$
MAN 18V51/60DF	499957,577	833,2626	4,031

The arrangement draft of LNG storage and bunkering diagram are available on the next page.


PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
LAPESA LC 318 + LC 240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Bachelor Thesis and Colloquium
ODD SEMESTER 2016 / 2017
LNG BUNKERING SYSTEM
SCALE
SIGNATURE
DATE
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Attachment 8: Preliminary Weight Estimation

- Barge Weight

L	97,5	m
B	32,2	m
T	6,2	m
Capacity	16000	t
∇	18263,9796	m3
Δ	18720,6	t
Cb	0,93830328	
LWT	2720,6	t
ρ	1,025	t/m3

Calculated by using simpson's formula and autocad where the linesplan of the barge is being divided into several segments.

$$V = \frac{1}{3} \times \sum (A \times F) \times H$$

WL	Area	f	A x F
WL 0	2459,231	1	2459,231
WL 1	2687,642	4	10750,57
WL 2	2974,053	2	5948,106
WL 3	3018,513	4	12074,05
WL 4	3057,528	2	6115,055
WL 5	3115,165	4	12460,66
WL 6	3115,165	1,1	3426,682
WL 6.1	3115,165	0,4	1246,066
WL 6.2	3115,165	0,1	311,5165
		total	54791,94
		∇	18263,98
		Δ	18720,58

- Ship's Lightweight

The ship's lightweight are determined by summing all of the required equipment with some exception due to the limited data. The calculation done by summing the weight of each system, and then being combined, table below shows the total weight and weight in each system.

a. Barge structure weight

- Calculated in previous page

Structure weight: 2720,6 ton

b. Deckhouse weight

Deckhouse 1

L [m]	W [m]	H [m]	Volume	
19,98	24,6	3	**1474,524**	m3

Deckhouse 2

L [m]	W [m]	H [m]	Volume	
19,98	24,6	2,8	**1376,222**	m3

Deckhouse 3

L [m]	W [m]	H [m]	Volume	
19,98	24,6	2,8	**1376,222**	m3

Deckhouse 4

L [m]	W [m]	H [m]	Volume	
63,59	26,6	12,34	**1376,222**	m3

$Wst = (L \times B \times Da) \times Cs$

$Cs = Cso + 0{,}064e^{-(0{,}5u+0{,}1u^{2{,}45})}\ where\ u = \log_{10} \frac{\Delta}{100}$

$Cso: Depend\ on\ the\ ship, assumed\ 0{,}064$

$Cs = 0{,}107134\ ton/m3$

The result of the calculation is

$WD_{h1} = 15m \times 24{,}6m \times 3m \times 0{,}107134 = 118{,}5979\ ton$

$WD_{h2} = 15m \times 24{,}6m \times 2{,}8m \times 0{,}107134 = 110{,}6913\ ton$

$WD_{h3} = 15m \times 24{,}6m \times 2{,}8m \times 0{,}107134 = 110{,}6913\ ton$

$WD_{h4} = 63{,}6m \times 26{,}6m \times 12{,}3m \times 0{,}107134 = 2236{,}222\ ton$

Total: 2689,08 ton

c. Outfitting weight

The outfitting weight only calculated in deck house 1, 2, and 3 while for deckhouse 4, most of the equipment are already calculated.

$Wot = L \times B \times K$ where $K = 0{,}35\ ton/m2$

The result of the calculation is

$Wot_{h1} = 15m \times 24{,}6m \times 0{,}35 = 129{,}15\ ton$

$Wot_{h2} = 15m \times 24{,}6m \times 0{,}35 = 129{,}15\ ton$

$Wot_{h3} = 15m \times 24{,}6m \times 0{,}35 = 129{,}15\ ton$

d. Engine related equipment weight

No.	Equipment	Weight [ton]	Category
1	MAN 18V51/60 DF 1	293,8	Diesel Engine
2	MAN 18V51/60 DF 2	293,8	
3	MAN 18V51/60 DF 3	293,8	
4	MAN 18V51/60 DF 4	293,8	
5	MAN 18V51/60 DF 5	293,8	
6	MAN 18V51/60 DF 6	293,8	
7	MAN 18V51/60 DF 7	293,8	
8	ABB AMG 1600 Q DSEB 1	67	Alternator / Generator
9	ABB AMG 1600 Q DSEB 2	67	
10	ABB AMG 1600 Q DSEB 3	67	
11	ABB AMG 1600 Q DSEB 4	67	
12	ABB AMG 1600 Q DSEB 5	67	
13	ABB AMG 1600 Q DSEB 6	67	
14	ABB AMG 1600 Q DSEB 7	67	
15	Coupling 1	4,6	Coupling
16	Coupling 2	4,6	
17	Coupling 3	4,6	
18	Coupling 4	4,6	
19	Coupling 5	4,6	
20	Coupling 6	4,6	
21	Coupling 7	4,6	
22	Saacke EMB/EME-VST 1	16	Economizer
23	Saacke EMB/EME-VST 2	16	
24	Saacke EMB/EME-VST 3	16	
25	Saacke EMB/EME-VST 4	16	
26	Saacke EMB/EME-VST 5	16	
27	Saacke EMB/EME-VST 6	16	

No.	Equipment	Weight [ton]	Category
28	Saacke EMB/EME-VST 7	16	Economizer
29	Miratech CS JCE-20-100084 1	1,232	Silencer
30	Miratech CS JCE-20-100084 2	1,232	
31	Miratech CS JCE-20-100084 3	1,232	
32	Miratech CS JCE-20-100084 4	1,232	
33	Miratech CS JCE-20-100084 5	1,232	
34	Miratech CS JCE-20-100084 6	1,232	
35	Miratech CS JCE-20-100084 7	1,232	
36	19,48m Exhaust Gas Pipe 1	9,6	Exhaust Gas Pipes
37	19,48m Exhaust Gas Pipe 2	9,6	
38	19,48m Exhaust Gas Pipe 3	9,6	
39	19,48m Exhaust Gas Pipe 4	9,6	
40	19,48m Exhaust Gas Pipe 5	9,6	
41	19,48m Exhaust Gas Pipe 6	9,6	
42	19,48m Exhaust Gas Pipe 7	9,6	
43	Engine Access stage	130	Engine access stage
	Total	**2875,624**	

e. Gas fuel system weight

No.	Equipment	Weight [ton]	Category
1	Lapesa 4200H LC318 1	70,3	LNG Storage
2	Lapesa 4200H LC318 2	70,3	
3	Lapesa 4200H LC318 3	70,3	
4	Lapesa 4200H LC318 4	70,3	
5	Lapesa 4200H LC318 5	70,3	
6	Lapesa 4200H LC318 6	70,3	
7	Lapesa 4200H LC318 7	70,3	

No.	Equipment	Weight [ton]	Category
8	Lapesa 4200H LC318 8	70,3	LNG Storage
9	Lapesa 4200H LC240 1	54,9	
10	Lapesa 4200H LC240 2	54,9	
11	Lapesa 4200H LC240 3	54,9	
12	Lapesa 4200H LC240 4	54,9	
13	Vaporizer VWU 182 1	0,942	Vaporizer
14	Vaporizer VWU 182 2	0,942	
15	Vaporizer VWU 182 3	0,942	
16	Vaporizer VWU 142 1	0,628	
17	Vaporizer VWU 142 2	0,628	
18	Vanzetti DSM L185 1	0,17	LP Pump
19	Vanzetti DSM L185 2	0,17	
20	Vanzetti DSM L185 3	0,17	
21	Vanzetti DSM L185 4	0,17	
22	Vanzetti DSM L230 1	0,27	
23	Herborner F-PM080 1	0,284	SW Pump
24	Herborner F-PM080 2	0,284	
25	Herborner F-PM080 3	0,284	
26	Herborner F-PM050 1	0,07	
27	GEA HG44e/770-4S HC 1	0,171	Compressor
28	GEA HG44e/770-4S HC 2	0,171	
29	GCU Cleaver Brooks LNV-25-1	-	
	Total	**788,296**	

f. Liquid Fuel System

No.	Equipment	Weight [ton]	Category
1	Pilot IMO Pump 3E 87P 1	0,035	Pilot pump
2	Pilot IMO Pump 3E 87P 2	0,035	

No.	Equipment	Weight [ton]	Category
3	Pilot IMO Pump 3E 87P 3	0,035	Pilot Pump
4	Pilot IMO Pump 3E 87P 4	0,035	
5	Pilot IMO Pump 3E 87P 5	0,035	
6	Pilot IMO Pump 3E 87P 6	0,035	
7	Pilot IMO Pump 3E 87P 7	0,035	
8	Pilot IMO Pump 3E 87P 8	0,035	
9	Main IMO Pump 3D 275E 1	0,162	Main Pump
10	Main IMO Pump 3D 275E 2	0,162	
11	Main IMO Pump 3D 275E 3	0,162	
12	Main IMO Pump 3D 275E 4	0,162	
13	Main IMO Pump 3D 275E 5	0,162	
14	Main IMO Pump 3D 275E 6	0,162	
15	Main IMO Pump 3D 218 1	0,12	
16	Main IMO Pump 3D 218 2	0,12	
17	Iron Pump ON: 1 1	0,045	Seperator Pump
18	Iron Pump ON: 1 2	0,045	
19	Alfa Laval MIB 303 1	0,068	FO Separator
20	Alfa Laval MIB 303 2	0,068	
21	Aalborg Vesta EH15 1	0,055	Sep. Heater
22	Aalborg Vesta EH15 2	0,055	
23	M. Cooler Alfa Laval M15-FM8 1	1,365	Main fuel cooler
24	M. Cooler Alfa Laval M15-FM8 2	1,365	
25	M. Cooler Alfa Laval M15-FM8 3	1,365	
26	M. Cooler Alfa Laval M10-FD ASME	0,689	
27	P. Cooler Aalborg MD20 - 1000 1	0,166	Pilot fuel cooler
28	P. Cooler Aalborg MD20 - 1000 2	0,166	
29	P. Cooler Aalborg MD20 - 1000 3	0,166	
30	P. Cooler Aalborg MD15 - 1000 1	0,11	

No.	Equipment	Weight [ton]	Category
	Filling Pump	-	
		7,22	

g. Lube Oil System weight

No.	Equipment	Weight [ton]	Category
1	Iron Pump ONT: 7/10 1	0,035	prelub
2	Iron Pump ONT: 7/10 2	0,035	
3	Iron Pump ONT: 7/10 3	0,035	
4	Iron Pump ONT: 7/10 4	0,035	
5	Iron Pump ONT: 7/10 5	0,035	
6	Iron Pump ONT: 7/10 6	0,035	
7	Iron Pump ONT: 7/10 7	0,035	
8	Iron Pump ON-V: 4 1	0,075	Feed
9	Iron Pump ON-V: 4 2	0,075	
10	Iron Pump ON-V: 4 3	0,075	
11	Iron Pump ON 1 1	0,045	
12	Alfa Laval MAB 206 1	0,42	Separator
13	Alfa Laval MAB 206 2	0,42	
14	Alfa Laval MAB 206 3	0,42	
15	Alfa Laval MMB 305 1	0,218	
16	Vesta EH 35 1	0,386	Preheater
17	Vesta EH 35 2	0,386	
18	Vesta EH 35 3	0,386	
19	Vesta EH 30 1	0,228	
20	Alfa Laval AlfaQ 14 1	5,126	LO Cooler
21	Alfa Laval AlfaQ 14 2	5,126	
22	Alfa Laval AlfaQ 14 3	5,126	
23	Alfa Laval AlfaQ 14 4	5,126	

No.	Equipment	Weight [ton]	Category
24	Alfa Laval AlfaQ 14 5	5,126	LO Cooler
25	Alfa Laval AlfaQ 14 6	5,126	
26	Alfa Laval AlfaQ 14 7	5,126	
27	Iron Pump ON-V: 4 1	0,075	Transfer Pump
28	Iron Pump ON-V: 4 2	0,075	
29	Iron Pump ON-V: 4 3	0,075	
30	Iron Pump ON-V: 3 4	0,075	
	Total	**39,561**	

h. Cooling System weight

The type of heat exchanger in the weight estimation are difference, the type written in chapter 4 is only to estimate the dimension while for weight estimation and drawing, the current design was customized and the weight is an assumption based on the existing product.

No.	Equipment	Weight [ton]	Category
1	Herborner X200-350A-5504H 1	0,797	LT Circuit
2	Herborner X200-350A-5504H 2	0,797	
3	Herborner X200-350A-5504H 3	0,797	
4	Herborner X200-350A-5504H 4	0,797	
5	Herborner X200-350A-5504H 5	0,797	
6	Herborner X200-350A-5504H 6	0,797	
7	Herborner X200-350A-5504H 7	0,797	
8	LT Coolers 1 AlfaQ 14L	8,879	LT Coolers
9	LT Coolers 2 AlfaQ 14L	8,879	
10	LT Coolers 3 AlfaQ 14L	8,879	
11	LT Coolers 4 AlfaQ 14L	8,879	
12	LT Coolers 5 AlfaQ 14L	8,879	

No.	Equipment	Weight [ton]	
13	LT Coolers 6 AlfaQ 14L	8,879	LT Coolers
14	LT Coolers 1 AlfaQ 10	5,435	
151	LT Coolers 2 AlfaQ 10	5,435	
16	Herborner X200-350A-4504H 1	0,652	HT Circuit
17	Herborner X200-350A-4504H 2	0,652	
18	Herborner X200-350A-4504H 3	0,652	
19	Herborner X200-350A-4504H 4	0,652	
20	Herborner X200-350A-4504H 5	0,652	
21	Herborner X200-350A-4504H 6	0,652	
22	Herborner X200-350A-4504H 7	0,652	
23	HT Coolers 1 AlfaQ 20M	20,354	HT Coolers
24	HT Coolers 2 AlfaQ 20M	20,354	
25	HT Coolers 3 AlfaQ 20M	20,354	
26	HT Coolers 4 AlfaQ 20M	20,354	
27	HT Coolers 5 AlfaQ 20M	20,354	
28	HT Coolers 6 AlfaQ 20M	20,354	
29	HT Coolers 1 AlfaQ 14L	9,964	
30	HT Coolers 2 AlfaQ 14L	9,964	
31	Pompe Garbarino 250-400 1	0,485	S/W Pump
32	Pompe Garbarino 250-400 2	0,485	
33	Pompe Garbarino 250-400 3	0,485	
34	trf pump	0,6	Transfer Pump
35	trf pump	0,6	
36	trf pump	0,6	
37	trf pump	0,6	
	total	**220,194**	

i. Compressed Air system

No.	Equipment	Weight [ton]	Category
1	Air Vessel Kaeser 8000 1	1,85	Air Vessel
2	Air Vessel Kaeser 8000 2	1,85	
3	Air Vessel Kaeser 8000 3	1,85	
4	HATLAPA 170-1150 1	1	Compressor
5	HATLAPA 170-1150 2	1	
6	HATLAPA 170-1150 3	1	
	total	**8,55**	

j. Export and Import device

No.	Equipment	Weight [ton]	Category
1	Manifold	5,8	Manifold
2	Manifold	5,8	
3	Transformer	-	Transformer
4	Transformer	-	
	total	**11,6**	

k. Total

No.	Object	Measurement Unit	Value
1	Engine related equipments(1)	Ton	2875,624
2	Deckhouse	Ton	2576,202
3	Outfitting	Ton	387,45
4	Gas Fuel System(2)	Ton	788,296
5	Liquid Fuel System	Ton	7,22

No.	Object	Measurement Unit	Value
6	Lube Oil System	Ton	39,561
7	Cooling System	Ton	220,194
8	Compressed Air System	Ton	8,55
9	Manifold	Ton	11,6
10	Barge Weight	Ton	2720,6
Total			**9635,3**
(3) Diesel engine, exhaust pipe, economizer, silencer and alternator (4) GCU isn't included			

- Draught Estimation in Lightweight condition

Lightweight of ship: 9635,3 ton

Using Simpson's Formula and autocad software to calculate the volume in each waterline. The calculation below using $\rho = 1{,}025\ ton/m3$

WL1	Area	f	A x F
WL 0	2459,231	1	2459,231
WL 0.5	2735,515	4	10942,06
Wl 1	2687,642	1	2687,642
		total	16088,93
		Volume	2681,489 m3
		M Displ	2748,526 ton

WL2	Area	f	A x F
WL 0	2459,231	1	2459,231
WL 1	2687,642	4	10750,57
WL 2	2974,053	1	2974,053
		total	16183,85
		Volume	5394,617 m3
		M Displ	5529,483 ton

WL3	Area	f	A x F
WL 0	2459,231	1	2459,231
WL 0.5	2735,515	4	10942,06
Wl 1	2687,642	2	5375,284
Wl 1.5	2862,076	4	11448,31
WL 2	2974,053	2	5948,106

WL3	Area	f	A x F
WL 2.5	2994,776	4	11979,1
WL 3	3018,513	1	3018,513
		Total	51170,6
		Volume	8528,434 m3
		M Displ	8741,645 ton

WL4	Area	F	A x F
WL 0	2459,231	1	2459,231
WL 1	2687,642	4	10750,57
WL 2	2974,053	2	5948,106
WL 3	3018,513	4	12074,05
WL 4	3057,528	1	3057,528
		Total	34289,49
		Volume	11429,83 m3
		M Displ	11715,57 ton

WL 5	Area	F	A x F
WL 0	2459,231	1	2459,231
WL 0.5	2735,515	4	10942,06
Wl 1	2687,642	2	5375,284
Wl 1.5	2862,076	4	11448,31
WL 2	2974,053	2	5948,106
WL 2.5	2994,776	4	11979,1
WL 3	3018,513	2	6037,027
WL 3.5	3030,092	4	12120,37
WL 4	3057,528	2	6115,055
WL 4.5	3115,165	4	12460,66
WL 5	3115,165	1	3115,165

WL 5	Area	F	A x F
		total	85541,14
		Volume	14256,86 m3
		M Displ	14613,28 ton

The light weight of the ship is 9635,3 ton which is in between of WL 3 and WL 4. Interpolation process was used to determine the waterline during lightweight.

$$D_{LWT} = 4 - \frac{(11715,6 - 9635,3)}{(11715,6 - 8528,43)} \times (4 - 3) = 3,3\ m$$

The result can be concluded that the ship will be on 3,3 m during light weight.

Attachment 9: Preliminary General Arrangement Design Philosophy and Drawings

Design Philosophy

- LNG Storage Room

  The storage room for LNG are specified only to store the LNG tank. It’s located inside the hull of the barge. Every equipment for importing or exporting are located outside the room (separated room) which is also located inside the barge’s hull.

  The LNG storage room consist of 12 type C vessels with 8 of it are Lapesa 4200H LC318 and 4 of it are Lapesa 4200H LC 240. The arrangement of the tanks was designed to satisfy the Germanischer Lloyd regulation, especially about the minimum distance from bottom plating and side plating. Therefore the LNG storage tanks were settled on a floor which has specific distance from the bottom plating.

- Cold-room

  The cold-room substitute the function of cold-box in common dual-fuel propulsion ships. Inside the cold-room, every machinery are dealing with cryogenic flammable fluid, therefore a ventilation is required (not included in the drawings). Machinery inside the cold-room are compressors, LP LNG Pump, and vaporizer.

  Compressors function is to handle the BOG from the storage tank and transferred it to the engine supply or the combustion unit. LP LNG Pump function is to deliver the LNG from the storage to the vaporizer. The vaporizer itself change the phase of the natural gas from liquid phase into gas phase.

Based on the Germanischer Lloyd's regulation, a cold-room must have a specific entrance where it's not connected with another room.

- Machinery room

  The machinery room is a room inside the ship's hull that contain an equipment to process non-cryogenic fluid. In this case the room is consist of several system's equipment such as, fuel oil system, compressed air system, lube oil system, cooling water system and also technical fresh water pump for heating the vaporizer. Inside the machinery, several tanks that belong to lube oil system, fuel oil system, and cooling water system were designed in this room. Machinery room are designed to have different entrance from the cold-room.

- Pump room

  The pump room which is located at starboard area, next to the machinery room is specifically created for ballast pump and other general system which may be added in future development of this *Conceptual Design of 100 MW LNG Mobile Power Plant*.

- Equipment Store

  Equipment store are located in the portside of the ships, beside the machinery room. The store room was designed to store spare-part and some equipment, it's located near the machinery room to ease the process of maintenance and changing the equipment.

- Deck Houses

  In the design, the deckhouses were divided into 4 segment. The first 3 deck houses are arranged as maintenance area in deckhouse 1, control area and office in deckhouse 2, and accommodation in deckhouse 3.

  The 4th deckhouse are designed to covers the engine from the external environment, therefore the size of the 4th deckhouse is massive. The 4th deckhouse also considered as the engine room.

- Engine Room (4th Deckhouse)
  The engine room is consisted of 4 cluster of engine where the cluster 1, 2, and 3 consist of 2 engine while the 4th cluster is consist of 1 engine, in total, the engine room has 7 engine.

  To improve the ventilation, the engine room were designed to have forced circulation where there are a set of air intake fan at the starboard area and set of exhaust fan in the portside of the barge.

  a. Engine Arrangement and Spaces
     The engine were arranged to has satisfying distance between each engine's centreline (the requirement of the distance are informed in MAN 51/60 DF Project Guide). To improve the ergonomic level, an engine steps with 1,38 m height is added. The function of steps is to ease the process of monitoring at the bottom level and also as an approach to increase the aesthetic level where the sump tank of the engine is located below the steps. Beside engine steps, a second platform also designed to ease the process of monitoring and maintenance of the upper part of the engine.

b. Arrangement of Exhaust Gas Pipes and Alternator
The engine flywheel arranged to face portside of the ships where the flywheel will be coupled with ABB AMG 1600 Q alternator.

The exhaust gas pipe are located on portside of the ship where along the exhaust gas pipes there is a series arrangement of economizer and silencer. Another reason to design the exhaust gas pipe facing the shore is to reduce the risk during ship-to-ship transfer where the LNG ship may be exposed to the heat from the exhaust gas pipes if the pipes were designed in the starboard.

c. Heat Exchanger Area
Due to the limited space in the machinery room, the heat exchanger, especially for cooling system are located in the 4th deck or the engine room. The area design is to have 2 level, where the first level consist of HT Coolers for cluster 1, 2, and 3 while in the second level, there is LT Coolers for Cluster 1, 2, 3, 4 and HT Coolers for Cluster 4.

d. GVU Room and Engine's Machinery Area
The area for GVU and engine machinery such as supply pump, lube oil stand-by pump was designed beside the engine (portside), below the exhaust gas pipes. The arrangement was utilizing the available area under the exhaust gas pipes rather than adding more platform above the engine.

Since the GVU is dealing with flammable gas, MAN 51/60 DF Project Guide and Germanischer Lloyd demand for separated room for GVU where there should be sufficient ventilation to avoid gas hydrocarbon gasses build-up inside the GVU room (GVU room connected to forced ventilation system).

Design Requirement

Keyword	Reference	Design Requirement
Collision Bulkhead	GL I-1-1, Section 27, B.3.2	A collision bulkhead is to be fitted which is to be watertight up to the bulkhead deck. This bulkhead is to be located at a distance from the forward perpendicular of not less than 0.05 · **L**c or 10 m, whichever is the less, and, except as may be permitted by the Administration, not more than 0.08 · **L**c or 0.05 · **L**c + 3m, whichever is the greater.
Collision Bulkhead Height	GL I-1-1, Section 27, B.3.4	The collision bulkhead is to extend watertight up to the bulkhead deck. The bulkhead may have steps or recesses provided they are within the limits prescribed in B.3.1
Collision Bulkhead Opening	GL I-1-1, Section 27, B.3.5	No doors, manholes, access openings, ventilation ducts or any other openings are permitted in the collision bulkhead below the bulkhead deck.
Piping Through Collision Bulkhead	GL I-1-1, Section 27, B.3.6	Except as provided in B.3.7 the collision bulkhead may be pierced below the bulkhead deck by not more than one pipe for dealing with fluid in the forepeak tank, provided that the pipe is fitted with a screw-down valve capable of being operated from above the bulkhead deck, the valve chest being secured inside the forepeak to the collision bulkhead. The Administration may, however, authorize the fitting of this valve on the after side of the collision bulkhead provided that the valve is readily accessible under all service conditions and the space in which it is located is not a cargo space. All valves are to be of steel, bronze or other approved ductile material. Valves

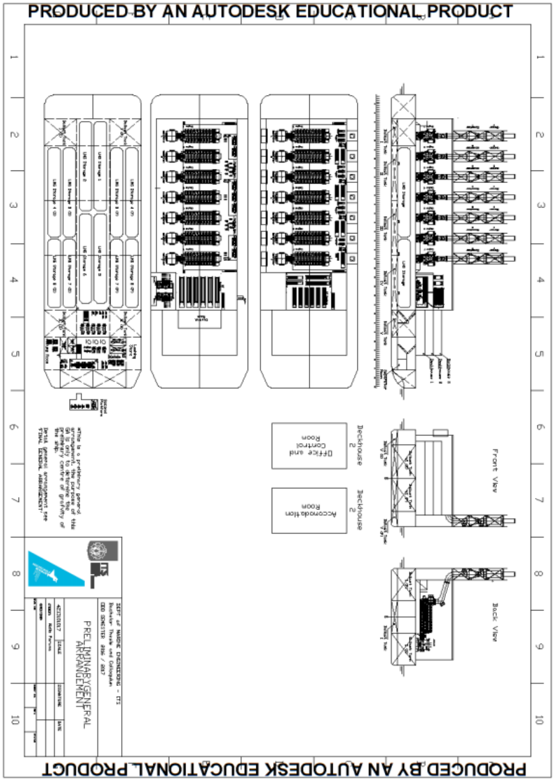
		of ordinary cast iron or similar material are not acceptable.
Double Bottom	GL I-1-1, Section 27, C.2.2	A double bottom is to be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.
Double Bottom Height	GL I-1-1, Section 27, C.2.3	Where a double bottom is required to be fitted the inner bottom is to be continued out to the ship's sides in such a manner as to protect the bottom to the turn of the bilge. Such protection will be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, as calculated by the formula: $h / 20 = \mathbf{B}$ However, in no case is the value of h to be less than 760 mm, and need not be taken as more than 2 000 mm.
Fuel Oil Tanks	GL I-1-1, Section 27, C.3.1.1.3	Fuel oil, lubrication oil and other flammable oils are not to be carried in forepeak tanks
Oil tanks separation	GL I-1-1, Section 27, C.3.2.1	Oil fuel tanks are to be separated from tanks for lubricating oil, hydraulic oil, thermal oil, vegetable oil, feedwater, condensate water and potable water by cofferdams.
General Accessibility	GL I-1-1, Section 27, D.1	**D.1.1** All parts of the hull are to be accessible for survey and maintenance. **D.1.2** Spaces, which are to be accessible for the service of the ship, hold spaces and accommodation spaces are to be gastight against each other. **D.1.3** The design appraisal and testing of accesses to ships (accommodation

		ladders, gangways) are not part of Classification.
LNG Room	GL I-1-6, Section 3, 3.2	No accommodation space, service space or control station is to be located within the cargo area. The bulkhead of accommodation spaces, service spaces or control stations which face the cargo area is to be located so as to avoid the entry of gas from the hold space to such spaces through a single failure of a deck or bulkhead on a ship having a containment system requiring a secondary barrier.
Airlocks	GL I-1-6, Section 3, 3.2.3	Access through doors, gastight or otherwise, is not permitted from a gas safe space to a gas dangerous space, except for access to service spaces forward of the cargo area through airlocks as permitted by 3.6.1 when accommodation spaces are aft
Cargo Pump Rooms and Compressors Rooms	GL I-1-6, Section 3, 3.3.3	Arrangements of cargo pump rooms and cargo compressor rooms are to be such as to ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. All valves necessary for cargo handling are to be readily accessible to personnel wearing protective clothing. Suitable arrangements shall be made to deal with drainage of pump and compressor rooms.
Gas Compressors Room	GL VI-3-1, Section 2, 2.3.2	Compressor rooms, if arranged, should be located above freeboard deck, unless those rooms are arranged and fitted in accordance with the requirements of these guidelines for tank rooms.

Gas Compressors Room Exception	GL VI-3-1, Section 2, 2.4.2	If the compressor room is approved located below deck, the room should, as far as practicable, have an independent access direct from the open deck. Where a separate access from deck is not practicable, an air lock which complies with the requirements of GL Rules, Liquefied Gas Carriers (I-1-6), Section 3, 3.6 (2-7) should be provided.
Cargo Control Rooms	GL I-1-6, Section 3, 3.4.1	Any cargo control room is to be above the weather deck and may be located in the cargo area. The cargo control room may be located within the accommodation, service or control station spaces provided the following conditions are complied with: **.1** the cargo control room is a gas safe space; and **.2.1** if the entrance complies with 3.2.4, the control room may have access to the spaces described above; **.2.2** if the entrance does not comply with 3.2.4, the control room shall have no access to the spaces described above and the boundaries to such spaces shall be insulated to "A-60" standard.
Storage Arrangement	GL I-1-6, Section 2, 2.8.4.2	The gas storage tank(s) should be placed as close as possible to the centreline of the ship: **.1** minimum, the lesser of B/5 and 11,5 m from the ship side; **.2** minimum, the lesser of B/15 and 2 m from the bottom plating; **.3** not less than 760 mm from the shell plating. For ships other than passenger ships and multihulls, a tank location closer than B/5 from the ship side may be accepted.

Fuel Bunkering Location	GL I-1-6, Section 2, 2.9.1.1	The bunkering station should be so located that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations should be subject to special consideration. The bunkering station should be physically separated or structurally shielded from accommodation, cargo/working deck and control stations. Connections and piping should be so positioned and arranged that any damage to the gas piping does not cause damage to the vessel's gas storage tank arrangement leading to uncontrolled gas discharge.
Drip Trays	GL I-1-6, Section 2, 2.9.1.2	Drip trays should be fitted below liquid gas bunkering connections and where leakage may occur. The drip trays should be made of stainless steel, and should be drained over the ship's side by a pipe that preferably leads down near the sea. This pipe could be temporarily fitted for bunkering operations. The surrounding hull or deck structures should not be exposed to unacceptable cooling, in case of leakage of liquid gas. For compressed gas bunkering stations, low temperature steel shielding should be provided to prevent the possible escape of cold jets impinging on surrounding hull structure.
Bunkering Control Room	GL I-1-6, Section 2, 2.9.1.3	Control of the bunkering should be possible from a safe location in regard to bunkering operations. At this location tank pressure and tank level should be monitored. Overfill alarm and automatic shutdown should also be indicated at this location.
Gas Fuel Supply System	-	See Attachment 2: Gas Fuel Supply System, Design Requirement

Liquid Fuel Supply System	-	See Attachment 3: Liquid Fuel Supply System, Design Requirement
Lubricating System	-	See Attachment 4: Lubricating Oil Supply System, Design Requirement
Starting Air System	-	See Attachment 5: Starting Air System. Design Requirement
Cooling System	-	See Attachment 6: Cooling System, Design Requirement
Preliminary Design of Storage	-	See Attachment 7: Storage and Duration Calculation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Front View
Back View
PRELIMINARY GENERAL ARRANGEMENT
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Attachment 10: Preliminary Centre of Gravity and Buoyancy

List of Equipment's Weight at Lightweight

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
1	Lapesa 4200H LC318 1	70,3	4,2	295,26	-25,03	-105,126	2,6	182,78
2	Lapesa 4200H LC318 2	70,3	4,2	295,26	-25,03	-105,126	-2,6	-182,78
3	Lapesa 4200H LC318 3	70,3	4,2	295,26	5,67	23,814	2,6	182,78
4	Lapesa 4200H LC318 4	70,3	4,2	295,26	5,67	23,814	-2,6	-182,78
5	Lapesa 4200H LC318 5	70,3	4,2	295,26	-16,25	-68,250	7,85	551,855
6	Lapesa 4200H LC318 6	70,3	4,2	295,26	-16,25	-68,250	-7,85	-551,855
7	Lapesa 4200H LC318 7	70,3	4,2	295,26	-16,25	-68,250	12,83	901,949
8	Lapesa 4200H LC318 8	70,3	4,2	295,26	-16,25	-68,250	-12,83	-901,949
9	Lapesa 4200H LC240 1	54,9	4,2	230,58	10,65	44,730	7,85	430,965
10	Lapesa 4200H LC240 2	54,9	4,2	230,58	10,65	44,730	-7,85	-430,965
11	Lapesa 4200H LC240 3	54,9	4,2	230,58	10,65	44,730	12,83	704,367
12	Lapesa 4200H LC240 4	54,9	4,2	230,58	10,65	44,730	-12,83	-704,367
13	Vaporizer VWU 182 1	0,94 2	2,98 8	2,814696	29,06	86,831	3,86	3,63612
14	Vaporizer VWU 182 2	0,94 2	2,98 8	2,814696	29,06	86,831	2,03	1,91226
15	Vaporizer VWU 182 3	0,94 2	2,98 8	2,814696	29,06	86,831	0,21	0,19782

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
16	Vaporizer VWU 142 1	0,628	2,858	1,794824	29,06	83,053	-1,62	-1,01736
17	Vaporizer VWU 142 2	0,628	2,858	1,794824	29,06	83,053	-3,45	-2,1666
18	Vanzetti DSM L185 1	0,17	2,16	0,3672	23,77	51,343	4,44	0,7548
19	Vanzetti DSM L185 2	0,17	2,16	0,3672	24,89	53,762	4,44	0,7548
20	Vanzetti DSM L185 3	0,17	2,16	0,3672	23,77	51,343	3,48	0,5916
21	Vanzetti DSM L185 4	0,17	2,16	0,3672	24,89	53,762	3,48	0,5916
22	Vanzetti DSM L230 1	0,27	2,16	0,5832	23,77	51,343	2,48	0,6696
23	Herborner F-PM080 1	0,284	2,75	0,781	39,88	109,670	-8,746	-2,48386
24	Herborner F-PM080 2	0,284	2,75	0,781	39,88	109,670	-9,96	-2,82864
25	Herborner F-PM080 3	0,284	2,75	0,781	41,58	114,345	-9,96	-2,82864
26	Herborner F-PM050 1	0,07	2,68	0,1876	41,58	111,434	-8,746	-0,61222
27	GEA HG44e/770-4S HC 1	0,171	2,155	0,368505	23,71	51,095	1,29	0,22059
28	GEA HG44e/770-4S HC 2	0,171	2,155	0,368505	23,71	51,095	0,14	0,02394
29	GCU Cleaver Brooks LNV-25-1			0	-4,24	0,000		0
30	Air Vessel Kaeser 8000 1	1,85	4,2	7,77	33,29	139,818	3,47	6,4195
31	Air Vessel Kaeser 8000 2	1,85	4,2	7,77	33,29	139,818	1,07	1,9795

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
32	Air Vessel Kaeser 8000 3	1,85	4,2	7,77	33,29	139,818	-1,33	-2,4605
33	HATLAPA 170-1150 1	1	2,5	2,5	35,83	89,575	3,82	3,82
34	HATLAPA 170-1150 2	1	2,5	2,5	35,83	89,575	2,12	2,12
35	HATLAPA 170-1150 3	1	2,5	2,5	35,83	89,575	0,42	0,42
36	Pilot IMO Pump 3E 87P 1	0,035	12,0696	0,422436	-32,4	-391,055	11,32	0,3962
37	Pilot IMO Pump 3E 87P 2	0,035	12,0696	0,422436	-31,64	-381,882	11,32	0,3962
38	Pilot IMO Pump 3E 87P 3	0,035	12,0696	0,422436	-20,41	-246,341	11,32	0,3962
39	Pilot IMO Pump 3E 87P 4	0,035	12,0696	0,422436	-19,65	-237,168	11,32	0,3962
40	Pilot IMO Pump 3E 87P 5	0,035	12,0696	0,422436	-8,42	-101,626	11,32	0,3962
41	Pilot IMO Pump 3E 87P 6	0,035	12,0696	0,422436	-7,67	-92,574	11,32	0,3962
42	Pilot IMO Pump 3E 87P 7	0,035	12,0696	0,422436	2,09	25,225	11,32	0,3962
43	Pilot IMO Pump 3E 87P 8	0,035	12,0696	0,422436	2,84	34,278	11,32	0,3962
44	Main IMO Pump 3D 275E 1	0,162	12,1215	1,963683	-35,26	-427,404	10,38	1,68156
45	Main IMO Pump 3D 275E 2	0,162	12,1215	1,963683	-33,67	-408,131	10,38	1,68156
46	Main IMO Pump 3D 275E 3	0,162	12,1215	1,963683	-23,27	-282,067	10,38	1,68156
47	Main IMO Pump 3D 275E 4	0,162	12,1215	1,963683	-21,68	-262,794	10,38	1,68156

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
48	Main IMO Pump 3D 275E 5	0,162	12,1215	1,963683	-11,29	-136,852	10,38	1,68156
49	Main IMO Pump 3D 275E 6	0,162	12,1215	1,963683	-9,7	-117,579	10,38	1,68156
50	Main IMO Pump 3D 218 1	0,12	12,0945	1,45134	-0,58	-7,015	10,38	1,2456
51	Main IMO Pump 3D 218 2	0,12	12,0945	1,45134	0,88	10,643	10,38	1,2456
52	Iron Pump ON: 1 1	0,045	2,19	0,09855	40,47	88,629	4,53	0,20385
53	Iron Pump ON: 1 2	0,045	2,19	0,09855	40,47	88,629	3,45	0,15525
54	Alfa Laval MIB 303 1	0,068	2,25	0,153	40,33	90,743	0,34	0,02312
55	Alfa Laval MIB 303 2	0,068	2,25	0,153	41,59	93,578	0,34	0,02312
56	Aalborg Vesta EH15 1	0,055	2,234	0,12287	41,72	93,202	4,53	0,24915
57	Aalborg Vesta EH15 2	0,055	2,234	0,12287	41,72	93,202	3,45	0,18975
58	M. Cooler Alfa Laval M15-FM8 1	1,365	12,95	17,67675	-36,71	-475,395	10,83	14,78295
59	M. Cooler Alfa Laval M15-FM8 2	1,365	12,95	17,67675	-24,71	-319,995	10,83	14,78295
60	M. Cooler Alfa Laval M15-FM8 3	1,365	12,95	17,67675	-12,72	-164,724	10,83	14,78295
61	M. Cooler Alfa Laval M10-FD ASME	0,689	12,52	8,62628	4,97	62,224	9,58	6,60062
62	P. Cooler Aalborg MD20 - 1000 1	0,166	12,305	2,04263	-32,08	-394,744	10,05	1,6683
63	P. Cooler Aalborg	0,166	12,305	2,04263	-20,1	-247,331	10,05	1,6683

	MD20 - 1000 2							
No.	**Equipment**	**W ton**	**KG m**	**KGxW**	**LCG[m]**	**LCGxW**	**TCG[m]**	**TCGxW**
64	P. Cooler Aalborg MD20 - 1000 3	0,166	12,305	2,04263	-8,11	-99,794	10,05	1,6683
65	P. Cooler Aalborg MD15 - 1000 1	0,11	12,25	1,3475	2,47	30,258	10,05	1,1055
66	Filling Pump			0	-4,24	0,000		0
67	Iron Pump ONT: 7/10 1	0,035	9,6	0,336	-33,96	-326,016	8,61	0,30135
68	Iron Pump ONT: 7/10 2	0,035	9,6	0,336	-33,22	-318,912	8,61	0,30135
69	Iron Pump ONT: 7/10 3	0,035	9,6	0,336	-15,42	-148,032	8,61	0,30135
70	Iron Pump ONT: 7/10 4	0,035	9,6	0,336	-14,68	-140,928	8,61	0,30135
71	Iron Pump ONT: 7/10 5	0,035	9,6	0,336	-13,95	-133,920	8,61	0,30135
72	Iron Pump ONT: 7/10 6	0,035	9,6	0,336	3,85	36,960	8,61	0,30135
73	Iron Pump ONT: 7/10 7	0,035	9,6	0,336	4,59	44,064	8,61	0,30135
74	Iron Pump ON-V: 4 1	0,075	2,4	0,18	38,32	91,968	8,73	0,65475
75	Iron Pump ON-V: 4 2	0,075	2,4	0,18	38,32	91,968	7,68	0,576
76	Iron Pump ON-V: 4 3	0,075	2,4	0,18	38,32	91,968	6,63	0,49725
77	Iron Pump ON 1 1	0,045	2,19	0,09855	38,32	83,921	5,68	0,2556
78	Alfa Laval MAB 206 1	0,42	2,5	1,05	41,03	102,575	-1,2	-0,504
79	Alfa Laval MAB 206 2	0,42	2,5	1,05	41,03	102,575	-3,1	-1,302

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
80	Alfa Laval MAB 206 3	0,42	2,5	1,05	41,03	102,575	-5	-2,1
81	Alfa Laval MMB 305 1	0,218	2,45	0,5341	41,03	100,524	-6,8	-1,4824
82	Vesta EH 35 1	0,386	2,372	0,915592	40,34	95,686	9,85	3,8021
83	Vesta EH 35 2	0,386	2,372	0,915592	40,34	95,686	8,43	3,25398
84	Vesta EH 35 3	0,386	2,372	0,915592	40,34	95,686	7,02	2,70972
85	Vesta EH 30 1	0,228	2,322	0,529416	40,06	93,019	5,69	1,29732
86	Alfa Laval AlfaQ 14 1	5,126	13,44	68,89344	-28,13	-378,067	11,11	56,94986
87	Alfa Laval AlfaQ 14 2	5,126	13,44	68,89344	-28,13	-378,067	9,22	47,26172
88	Alfa Laval AlfaQ 14 3	5,126	13,44	68,89344	-16,14	-216,922	11,11	56,94986
89	Alfa Laval AlfaQ 14 4	5,126	13,44	68,89344	-16,14	-216,922	9,22	47,26172
90	Alfa Laval AlfaQ 14 5	5,126	13,44	68,89344	-4,15	-55,776	11,11	56,94986
91	Alfa Laval AlfaQ 14 6	5,126	13,44	68,89344	-4,15	-55,776	9,22	47,26172
92	Alfa Laval AlfaQ 14 7	5,126	13,44	68,89344	6,36	85,478	11,11	56,94986
93	Iron Pump ON-V: 4 1	0,075	2,4	0,18	35,13	84,312	-1,02	-0,0765
94	Iron Pump ON-V: 4 2	0,075	2,4	0,18	35,13	84,312	-2,07	-0,15525
95	Iron Pump ON-V: 4 3	0,075	2,4	0,18	36,36	87,264	-1,02	-0,0765
96	Iron Pump ON-V: 3 4	0,075	2,4	0,18	36,36	87,264	-2,07	-0,15525
97	Herborner X200-350A-5504H 1	0,797	10,106	8,054482	-26,53	-268,112	10,4	8,2888

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
98	Herborner X200-350A-5504H 2	0,797	10,106	8,054482	-25,18	-254,469	10,4	8,2888
99	Herborner X200-350A-5504H 3	0,797	10,106	8,054482	-23,84	-240,927	10,4	8,2888
100	Herborner X200-350A-5504H 4	0,797	10,106	8,054482	-22,5	-227,385	10,4	8,2888
101	Herborner X200-350A-5504H 5	0,797	10,106	8,054482	-6,74	-68,114	10,4	8,2888
102	Herborner X200-350A-5504H 6	0,797	10,106	8,054482	-5,39	-54,471	10,4	8,2888
103	Herborner X200-350A-5504H 7	0,797	10,106	8,054482	-4,05	-40,929	10,4	8,2888
104	LT Coolers 1 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	4,94	43,86226
105	LT Coolers 2 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	2,96	26,28184
106	LT Coolers 3 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	0,99	8,79021
107	LT Coolers 4 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	-0,99	-8,79021
108	LT Coolers 5 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	-2,96	-26,2818
109	LT Coolers 6 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	-4,94	-43,8623
110	LT Coolers 1 AlfaQ 10	5,435	15,45	83,97075	11,96	184,782	-4,6	-25,001

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
111	LT Coolers 2 AlfaQ 10	5,435	15,45	83,97075	11,96	184,782	-4,6	-25,001
112	Herborner X200-350A-4504H 1	0,652	10,106	6,589112	-25,85	-261,240	8,94	5,82888
113	Herborner X200-350A-4504H 2	0,652	10,106	6,589112	-24,51	-247,698	8,94	5,82888
114	Herborner X200-350A-4504H 3	0,652	10,106	6,589112	-23,17	-234,156	8,94	5,82888
115	Herborner X200-350A-4504H 4	0,652	10,106	6,589112	-21,83	-220,614	8,94	5,82888
116	Herborner X200-350A-4504H 5	0,652	10,106	6,589112	-7,38	-74,582	8,94	5,82888
117	Herborner X200-350A-4504H 6	0,652	10,106	6,589112	-6,04	-61,040	8,94	5,82888
118	Herborner X200-350A-4504H 7	0,652	10,106	6,589112	-4,7	-47,498	8,94	5,82888
119	HT Coolers 1 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	5,88	119,6815
120	HT Coolers 2 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	3,53	71,84962
121	HT Coolers 3 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	1,18	24,01772
122	HT Coolers 4 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	-1,18	-24,0177
123	HT Coolers 5 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	-3,53	-71,8496

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
124	HT Coolers 6 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	-5,88	-119,682
125	HT Coolers 1 AlfaQ 14L	9,964	15,635	155,7871	11,96	186,995	2,77	27,60028
126	HT Coolers 2 AlfaQ 14L	9,964	15,635	155,7871	11,96	186,995	2,77	27,60028
127	Pompe Garbarino 250-400 1	0,485	3	1,455	33,37	100,110	-12,44	-6,0334
128	Pompe Garbarino 250-400 2	0,485	3	1,455	35,81	107,430	-12,44	-6,0334
129	Pompe Garbarino 250-400 3	0,485	3	1,455	33,37	100,110	-14,5	-7,0325
130	trf pump	0,6	5,706	3,4236	41,49	236,742	-3,05	-1,83
131	trf pump	0,6	5,706	3,4236	41,49	236,742	-4,25	-2,55
132	trf pump	0,6	5,706	3,4236	41,49	236,742	-5,44	-3,264
133	trf pump	0,6	5,706	3,4236	41,49	236,742	-6,64	-3,984
134	MAN 18V51/60 DF 1	293,8	11,9	3496,22	-35,08	-417,452	0	0
135	MAN 18V51/60 DF 2	293,8	11,9	3496,22	-28,28	-336,532	0	0
136	MAN 18V51/60 DF 3	293,8	11,9	3496,22	-21,48	-255,612	0	0
137	MAN 18V51/60 DF 4	293,8	11,9	3496,22	-14,68	-174,692	0	0
138	MAN 18V51/60 DF 5	293,8	11,9	3496,22	-7,88	-93,772	0	0

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
139	MAN 18V51/60 DF 6	293, 8	11,9	3496,22	-1,08	-12,852	0	0
140	MAN 18V51/60 DF 7	293, 8	11,9	3496,22	5,72	68,068	0	0
141	ABB AMG 1600 Q DSEB 1	67	10,4	696,8	-35,08	-364,832	-9,08	-608,36
142	ABB AMG 1600 Q DSEB 2	67	10,4	696,8	-28,28	-294,112	-9,08	-608,36
143	ABB AMG 1600 Q DSEB 3	67	10,4	696,8	-21,48	-223,392	-9,08	-608,36
144	ABB AMG 1600 Q DSEB 4	67	10,4	696,8	-14,68	-152,672	-9,08	-608,36
145	ABB AMG 1600 Q DSEB 5	67	10,4	696,8	-7,88	-81,952	-9,08	-608,36
146	ABB AMG 1600 Q DSEB 6	67	10,4	696,8	-1,08	-11,232	-9,08	-608,36
147	ABB AMG 1600 Q DSEB 7	67	10,4	696,8	5,72	59,488	-9,08	-608,36
148	Coupling 1	4,6	10,4	47,84	-35,08	-364,832	-6,52	-29,992
149	Coupling 2	4,6	10,4	47,84	-28,28	-294,112	-6,52	-29,992
150	Coupling 3	4,6	10,4	47,84	-21,48	-223,392	-6,52	-29,992
151	Coupling 4	4,6	10,4	47,84	-14,68	-152,672	-6,52	-29,992
152	Coupling 5	4,6	10,4	47,84	-7,88	-81,952	-6,52	-29,992
153	Coupling 6	4,6	10,4	47,84	-1,08	-11,232	-6,52	-29,992
154	Coupling 7	4,6	10,4	47,84	5,72	59,488	-6,52	-29,992
155	Saacke EMB/EME-VST 1	16	26,8 351	429,3616	-35,08	-941,375	14,24	227,84
156	Saacke EMB/EME-VST 2	16	26,8 351	429,3616	-28,28	-758,897	14,24	227,84

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
157	Saacke EMB/EME-VST 3	16	26,8351	429,3616	-21,48	-576,418	14,24	227,84
158	Saacke EMB/EME-VST 4	16	26,8351	429,3616	-14,68	-393,939	14,24	227,84
159	Saacke EMB/EME-VST 5	16	26,8351	429,3616	-7,88	-211,461	14,24	227,84
160	Saacke EMB/EME-VST 6	16	26,8351	429,3616	-1,08	-28,982	14,24	227,84
161	Saacke EMB/EME-VST 7	16	26,8351	429,3616	5,72	153,497	14,24	227,84
162	Miratech CS JCE-20-100084 1	1,232	34,041	41,93851	-35,08	-1194,158	14,24	17,54368
163	Miratech CS JCE-20-100084 2	1,232	34,041	41,93851	-28,28	-962,679	14,24	17,54368
164	Miratech CS JCE-20-100084 3	1,232	34,041	41,93851	-21,48	-731,201	14,24	17,54368
165	Miratech CS JCE-20-100084 4	1,232	34,041	41,93851	-14,68	-499,722	14,24	17,54368
166	Miratech CS JCE-20-100084 5	1,232	34,041	41,93851	-7,88	-268,243	14,24	17,54368
167	Miratech CS JCE-20-100084 6	1,232	34,041	41,93851	-1,08	-36,764	14,24	17,54368
168	Miratech CS JCE-20-100084 7	1,232	34,041	41,93851	5,72	194,715	14,24	17,54368
169	19,48m Exhaust Gas Pipe 1	9,6	33,57	322,272	-35,08	-1177,636	11,97	114,912
170	19,48m Exhaust Gas Pipe 2	9,6	33,57	322,272	-28,28	-949,360	11,97	114,912
171	19,48m Exhaust Gas Pipe 3	9,6	33,57	322,272	-21,48	-721,084	11,97	114,912

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
172	19,48m Exhaust Gas Pipe 4	9,6	33,57	322,272	-14,68	-492,808	11,97	114,912
173	19,48m Exhaust Gas Pipe 5	9,6	33,57	322,272	-7,88	-264,532	11,97	114,912
174	19,48m Exhaust Gas Pipe 6	9,6	33,57	322,272	-1,08	-36,256	11,97	114,912
175	19,48m Exhaust Gas Pipe 7	9,6	33,57	322,272	5,72	192,020	11,97	114,912
176	Engine Access stage	130	8,79	1142,7	-14,68	-129,037	3,36	436,8
176	Structure	2720,6	0	0	-4,24	0,000	0	0
176	Deckhouse 1	118,597863	9,5	1126,68	32,7	310,650	0	0
176	Deckhouse 2	110,691339	12,4	1372,573	32,7	405,480	0	0
176	Deckhouse 3	110,691339	15,06	1667,012	32,7	492,462	0	0
176	Deckhouse 4	2236,22174	14,27	31910,88	-9,09	-129,714	-1	-2236,22
176	Outfitting	387,45	12,4	4804,38	32,7	405,480	0	0
176	Manifold 1	5,8	8,45	49,01	14,33	121,089	-12,94	-75,052
177	Manifold 2	5,8	8,45	49,01	18,26	154,297	-12,94	-75,052
Total	9635,297 ton			83941,98		-11825		-3360,37

$$KG\ Total = \frac{\sum(KG \times W)}{Wtotal} = \frac{83941,98}{9635,297} = 8,712\ m$$

$$LCG\ Total = \frac{\sum(LCG \times W)}{Wtotal} = \frac{-11825}{9635{,}297} = -1{,}227\ m$$

$$TCG\ Total = \frac{\sum(LCG \times W)}{Wtotal} = \frac{-3360{,}37}{9635{,}297} = -0{,}3487\ m$$

List of Equipment's LWT+DWT

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
1	Lapesa 4200H LC318 1	209,3	4,2	879,06	-25,03	-105,126	2,6	544,18
2	Lapesa 4200H LC318 2	209,3	4,2	879,06	-25,03	-105,126	-2,6	-544,18
3	Lapesa 4200H LC318 3	209,3	4,2	879,06	5,67	23,814	2,6	544,18
4	Lapesa 4200H LC318 4	209,3	4,2	879,06	5,67	23,814	-2,6	-544,18
5	Lapesa 4200H LC318 5	209,3	4,2	879,06	-16,25	-68,250	7,85	1643,005
6	Lapesa 4200H LC318 6	209,3	4,2	879,06	-16,25	-68,250	-7,85	-1643,01
7	Lapesa 4200H LC318 7	209,3	4,2	879,06	-16,25	-68,250	12,83	2685,319
8	Lapesa 4200H LC318 8	209,3	4,2	879,06	-16,25	-68,250	-12,83	-2685,32
9	Lapesa 4200H LC240 1	159,8	4,2	671,16	10,65	44,730	7,85	1254,43
10	Lapesa 4200H LC240 2	159,8	4,2	671,16	10,65	44,730	-7,85	-1254,43
11	Lapesa 4200H LC240 3	159,8	4,2	671,16	10,65	44,730	12,83	2050,234
12	Lapesa 4200H LC240 4	159,8	4,2	671,16	10,65	44,730	-12,83	-2050,23
13	Vaporizer VWU 182 1	0,942	2,988	2,814696	29,06	86,831	3,86	3,63612
14	Vaporizer VWU 182 2	0,942	2,988	2,814696	29,06	86,831	2,03	1,91226
15	Vaporizer VWU 182 3	0,942	2,988	2,814696	29,06	86,831	0,21	0,19782

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
16	Vaporizer VWU 142 1	0,628	2,858	1,794824	29,06	83,053	-1,62	-1,01736
17	Vaporizer VWU 142 2	0,628	2,858	1,794824	29,06	83,053	-3,45	-2,1666
18	Vanzetti DSM L185 1	0,17	2,16	0,3672	23,77	51,343	4,44	0,7548
19	Vanzetti DSM L185 2	0,17	2,16	0,3672	24,89	53,762	4,44	0,7548
20	Vanzetti DSM L185 3	0,17	2,16	0,3672	23,77	51,343	3,48	0,5916
21	Vanzetti DSM L185 4	0,17	2,16	0,3672	24,89	53,762	3,48	0,5916
22	Vanzetti DSM L230 1	0,27	2,16	0,5832	23,77	51,343	2,48	0,6696
23	Herborner F-PM080 1	0,284	2,75	0,781	39,88	109,670	-8,746	-2,48386
24	Herborner F-PM080 2	0,284	2,75	0,781	39,88	109,670	-9,96	-2,82864
25	Herborner F-PM080 3	0,284	2,75	0,781	41,58	114,345	-9,96	-2,82864
26	Herborner F-PM050 1	0,07	2,68	0,1876	41,58	111,434	-8,746	-0,61222
27	GEA HG44e/770-4S HC 1	0,171	2,155	0,368505	23,71	51,095	1,29	0,22059
28	GEA HG44e/770-4S HC 2	0,171	2,155	0,368505	23,71	51,095	0,14	0,02394
29	GCU Cleaver Brooks LNV-25-1			0	-4,24	0,000		0
30	Air Vessel Kaeser 8000 1	1,85	4,2	7,77	33,29	139,818	3,47	6,4195

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
31	Air Vessel Kaeser 8000 2	1,85	4,2	7,77	33,29	139,818	1,07	1,9795
32	Air Vessel Kaeser 8000 3	1,85	4,2	7,77	33,29	139,818	-1,33	-2,4605
33	HATLAPA 170-1150 1	1	2,5	2,5	35,83	89,575	3,82	3,82
34	HATLAPA 170-1150 2	1	2,5	2,5	35,83	89,575	2,12	2,12
35	HATLAPA 170-1150 3	1	2,5	2,5	35,83	89,575	0,42	0,42
36	Pilot IMO Pump 3E 87P 1	0,035	12,0696	0,422436	-32,4	-391,055	11,32	0,3962
37	Pilot IMO Pump 3E 87P 2	0,035	12,0696	0,422436	-31,64	-381,882	11,32	0,3962
38	Pilot IMO Pump 3E 87P 3	0,035	12,0696	0,422436	-20,41	-246,341	11,32	0,3962
39	Pilot IMO Pump 3E 87P 4	0,035	12,0696	0,422436	-19,65	-237,168	11,32	0,3962
40	Pilot IMO Pump 3E 87P 5	0,035	12,0696	0,422436	-8,42	-101,626	11,32	0,3962
41	Pilot IMO Pump 3E 87P 6	0,035	12,0696	0,422436	-7,67	-92,574	11,32	0,3962
42	Pilot IMO Pump 3E 87P 7	0,035	12,0696	0,422436	2,09	25,225	11,32	0,3962
43	Pilot IMO Pump 3E 87P 8	0,035	12,0696	0,422436	2,84	34,278	11,32	0,3962
44	Main IMO Pump 3D 275E 1	0,162	12,1215	1,963683	-35,26	-427,404	10,38	1,68156
45	Main IMO Pump 3D 275E 2	0,162	12,1215	1,963683	-33,67	-408,131	10,38	1,68156
46	Main IMO Pump 3D 275E 3	0,162	12,1215	1,963683	-23,27	-282,067	10,38	1,68156

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
47	Main IMO Pump 3D 275E 4	0,162	12,1215	1,963683	-21,68	-262,794	10,38	1,68156
48	Main IMO Pump 3D 275E 5	0,162	12,1215	1,963683	-11,29	-136,852	10,38	1,68156
49	Main IMO Pump 3D 275E 6	0,162	12,1215	1,963683	-9,7	-117,579	10,38	1,68156
50	Main IMO Pump 3D 218 1	0,12	12,0945	1,45134	-0,58	-7,015	10,38	1,2456
51	Main IMO Pump 3D 218 2	0,12	12,0945	1,45134	0,88	10,643	10,38	1,2456
52	Iron Pump ON: 1 1	0,045	2,19	0,09855	40,47	88,629	4,53	0,20385
53	Iron Pump ON: 1 2	0,045	2,19	0,09855	40,47	88,629	3,45	0,15525
54	Alfa Laval MIB 303 1	0,068	2,25	0,153	40,33	90,743	0,34	0,02312
55	Alfa Laval MIB 303 2	0,068	2,25	0,153	41,59	93,578	0,34	0,02312
56	Aalborg Vesta EH15 1	0,055	2,234	0,12287	41,72	93,202	4,53	0,24915
57	Aalborg Vesta EH15 2	0,055	2,234	0,12287	41,72	93,202	3,45	0,18975
58	M. Cooler Alfa Laval M15-FM8 1	1,365	12,95	17,67675	-36,71	-475,395	10,83	14,78295
59	M. Cooler Alfa Laval M15-FM8 2	1,365	12,95	17,67675	-24,71	-319,995	10,83	14,78295
60	M. Cooler Alfa Laval M15-FM8 3	1,365	12,95	17,67675	-12,72	-164,724	10,83	14,78295
61	M. Cooler Alfa Laval M10-FD ASME	0,689	12,52	8,62628	4,97	62,224	9,58	6,60062

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
62	P. Cooler Aalborg MD20 - 1000 1	0,166	12,305	2,04263	-32,08	-394,744	10,05	1,6683
63	P. Cooler Aalborg MD20 - 1000 2	0,166	12,305	2,04263	-20,1	-247,331	10,05	1,6683
64	P. Cooler Aalborg MD20 - 1000 3	0,166	12,305	2,04263	-8,11	-99,794	10,05	1,6683
65	P. Cooler Aalborg MD15 - 1000 1	0,11	12,25	1,3475	2,47	30,258	10,05	1,1055
66	Filling Pump			0	-4,24	0,000		0
67	Iron Pump ONT: 7/10 1	0,035	9,6	0,336	-33,96	-326,016	8,61	0,30135
68	Iron Pump ONT: 7/10 2	0,035	9,6	0,336	-33,22	-318,912	8,61	0,30135
69	Iron Pump ONT: 7/10 3	0,035	9,6	0,336	-15,42	-148,032	8,61	0,30135
70	Iron Pump ONT: 7/10 4	0,035	9,6	0,336	-14,68	-140,928	8,61	0,30135
71	Iron Pump ONT: 7/10 5	0,035	9,6	0,336	-13,95	-133,920	8,61	0,30135
72	Iron Pump ONT: 7/10 6	0,035	9,6	0,336	3,85	36,960	8,61	0,30135
73	Iron Pump ONT: 7/10 7	0,035	9,6	0,336	4,59	44,064	8,61	0,30135
74	Iron Pump ON-V: 4 1	0,075	2,4	0,18	38,32	91,968	8,73	0,65475
75	Iron Pump ON-V: 4 2	0,075	2,4	0,18	38,32	91,968	7,68	0,576

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
76	Iron Pump ON-V: 4 3	0,075	2,4	0,18	38,32	91,968	6,63	0,49725
77	Iron Pump ON 1 1	0,045	2,19	0,09855	38,32	83,921	5,68	0,2556
78	Alfa Laval MAB 206 1	0,42	2,5	1,05	41,03	102,575	-1,2	-0,504
79	Alfa Laval MAB 206 2	0,42	2,5	1,05	41,03	102,575	-3,1	-1,302
80	Alfa Laval MAB 206 3	0,42	2,5	1,05	41,03	102,575	-5	-2,1
81	Alfa Laval MMB 305 1	0,218	2,45	0,5341	41,03	100,524	-6,8	-1,4824
82	Vesta EH 35 1	0,386	2,372	0,915592	40,34	95,686	9,85	3,8021
83	Vesta EH 35 2	0,386	2,372	0,915592	40,34	95,686	8,43	3,25398
84	Vesta EH 35 3	0,386	2,372	0,915592	40,34	95,686	7,02	2,70972
85	Vesta EH 30 1	0,228	2,322	0,529416	40,06	93,019	5,69	1,29732
86	Alfa Laval AlfaQ 14 1	5,126	13,44	68,89344	-28,13	-378,067	11,11	56,94986
87	Alfa Laval AlfaQ 14 2	5,126	13,44	68,89344	-28,13	-378,067	9,22	47,26172
88	Alfa Laval AlfaQ 14 3	5,126	13,44	68,89344	-16,14	-216,922	11,11	56,94986
89	Alfa Laval AlfaQ 14 4	5,126	13,44	68,89344	-16,14	-216,922	9,22	47,26172
90	Alfa Laval AlfaQ 14 5	5,126	13,44	68,89344	-4,15	-55,776	11,11	56,94986
91	Alfa Laval AlfaQ 14 6	5,126	13,44	68,89344	-4,15	-55,776	9,22	47,26172
92	Alfa Laval AlfaQ 14 7	5,126	13,44	68,89344	6,36	85,478	11,11	56,94986

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
93	Iron Pump ON-V: 4 1	0,075	2,4	0,18	35,13	84,312	-1,02	-0,0765
94	Iron Pump ON-V: 4 2	0,075	2,4	0,18	35,13	84,312	-2,07	-0,15525
95	Iron Pump ON-V: 4 3	0,075	2,4	0,18	36,36	87,264	-1,02	-0,0765
96	Iron Pump ON-V: 3 4	0,075	2,4	0,18	36,36	87,264	-2,07	-0,15525
97	Herborner X200-350A-5504H 1	0,797	10,106	8,054482	-26,53	-268,112	10,4	8,2888
98	Herborner X200-350A-5504H 2	0,797	10,106	8,054482	-25,18	-254,469	10,4	8,2888
99	Herborner X200-350A-5504H 3	0,797	10,106	8,054482	-23,84	-240,927	10,4	8,2888
100	Herborner X200-350A-5504H 4	0,797	10,106	8,054482	-22,5	-227,385	10,4	8,2888
101	Herborner X200-350A-5504H 5	0,797	10,106	8,054482	-6,74	-68,114	10,4	8,2888
102	Herborner X200-350A-5504H 6	0,797	10,106	8,054482	-5,39	-54,471	10,4	8,2888
103	Herborner X200-350A-5504H 7	0,797	10,106	8,054482	-4,05	-40,929	10,4	8,2888
104	LT Coolers 1 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	4,94	43,86226
105	LT Coolers 2 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	2,96	26,28184

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
106	LT Coolers 3 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	0,99	8,79021
107	LT Coolers 4 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	-0,99	-8,79021
108	LT Coolers 5 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	-2,96	-26,2818
109	LT Coolers 6 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	-4,94	-43,8623
110	LT Coolers 1 AlfaQ 10	5,435	15,45	83,97075	11,96	184,782	-4,6	-25,001
111	LT Coolers 2 AlfaQ 10	5,435	15,45	83,97075	11,96	184,782	-4,6	-25,001
112	Herborner X200-350A-4504H 1	0,652	10,106	6,589112	-25,85	-261,240	8,94	5,82888
113	Herborner X200-350A-4504H 2	0,652	10,106	6,589112	-24,51	-247,698	8,94	5,82888
114	Herborner X200-350A-4504H 3	0,652	10,106	6,589112	-23,17	-234,156	8,94	5,82888
115	Herborner X200-350A-4504H 4	0,652	10,106	6,589112	-21,83	-220,614	8,94	5,82888
116	Herborner X200-350A-4504H 5	0,652	10,106	6,589112	-7,38	-74,582	8,94	5,82888
117	Herborner X200-350A-4504H 6	0,652	10,106	6,589112	-6,04	-61,040	8,94	5,82888
118	Herborner X200-350A-4504H 7	0,652	10,106	6,589112	-4,7	-47,498	8,94	5,82888

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
119	HT Coolers 1 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	5,88	119,6815
120	HT Coolers 2 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	3,53	71,84962
121	HT Coolers 3 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	1,18	24,01772
122	HT Coolers 4 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	-1,18	-24,0177
123	HT Coolers 5 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	-3,53	-71,8496
124	HT Coolers 6 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	-5,88	-119,682
125	HT Coolers 1 AlfaQ 14L	9,964	15,635	155,7871	11,96	186,995	2,77	27,60028
126	HT Coolers 2 AlfaQ 14L	9,964	15,635	155,7871	11,96	186,995	2,77	27,60028
127	Pompe Garbarino 250-400 1	0,485	3	1,455	33,37	100,110	-12,44	-6,0334
128	Pompe Garbarino 250-400 2	0,485	3	1,455	35,81	107,430	-12,44	-6,0334
129	Pompe Garbarino 250-400 3	0,485	3	1,455	33,37	100,110	-14,5	-7,0325
130	trf pump	0,6	5,706	3,4236	41,49	236,742	-3,05	-1,83
131	trf pump	0,6	5,706	3,4236	41,49	236,742	-4,25	-2,55
132	trf pump	0,6	5,706	3,4236	41,49	236,742	-5,44	-3,264
133	trf pump	0,6	5,706	3,4236	41,49	236,742	-6,64	-3,984

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
134	MAN 18V51/60 DF 1	293, 8	11,9	3496,22	-35,08	-417,452	0	0
135	MAN 18V51/60 DF 2	293, 8	11,9	3496,22	-28,28	-336,532	0	0
136	MAN 18V51/60 DF 3	293, 8	11,9	3496,22	-21,48	-255,612	0	0
137	MAN 18V51/60 DF 4	293, 8	11,9	3496,22	-14,68	-174,692	0	0
138	MAN 18V51/60 DF 5	293, 8	11,9	3496,22	-7,88	-93,772	0	0
139	MAN 18V51/60 DF 6	293, 8	11,9	3496,22	-1,08	-12,852	0	0
140	MAN 18V51/60 DF 7	293, 8	11,9	3496,22	5,72	68,068	0	0
141	ABB AMG 1600 Q DSEB 1	67	10,4	696,8	-35,08	-364,832	-9,08	-608,36
142	ABB AMG 1600 Q DSEB 2	67	10,4	696,8	-28,28	-294,112	-9,08	-608,36
143	ABB AMG 1600 Q DSEB 3	67	10,4	696,8	-21,48	-223,392	-9,08	-608,36
144	ABB AMG 1600 Q DSEB 4	67	10,4	696,8	-14,68	-152,672	-9,08	-608,36
145	ABB AMG 1600 Q DSEB 5	67	10,4	696,8	-7,88	-81,952	-9,08	-608,36
146	ABB AMG 1600 Q DSEB 6	67	10,4	696,8	-1,08	-11,232	-9,08	-608,36
147	ABB AMG 1600 Q DSEB 7	67	10,4	696,8	5,72	59,488	-9,08	-608,36
148	Coupling 1	4,6	10,4	47,84	-35,08	-364,832	-6,52	-29,992
149	Coupling 2	4,6	10,4	47,84	-28,28	-294,112	-6,52	-29,992

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
150	Coupling 3	4,6	10,4	47,84	-21,48	-223,392	-6,52	-29,992
151	Coupling 4	4,6	10,4	47,84	-14,68	-152,672	-6,52	-29,992
152	Coupling 5	4,6	10,4	47,84	-7,88	-81,952	-6,52	-29,992
153	Coupling 6	4,6	10,4	47,84	-1,08	-11,232	-6,52	-29,992
154	Coupling 7	4,6	10,4	47,84	5,72	59,488	-6,52	-29,992
155	Saacke EMB/EME-VST 1	16	26,8 351	429,3616	-35,08	-941,375	14,24	227,84
156	Saacke EMB/EME-VST 2	16	26,8 351	429,3616	-28,28	-758,897	14,24	227,84
157	Saacke EMB/EME-VST 3	16	26,8 351	429,3616	-21,48	-576,418	14,24	227,84
158	Saacke EMB/EME-VST 4	16	26,8 351	429,3616	-14,68	-393,939	14,24	227,84
159	Saacke EMB/EME-VST 5	16	26,8 351	429,3616	-7,88	-211,461	14,24	227,84
160	Saacke EMB/EME-VST 6	16	26,8 351	429,3616	-1,08	-28,982	14,24	227,84
161	Saacke EMB/EME-VST 7	16	26,8 351	429,3616	5,72	153,497	14,24	227,84
162	Miratech CS JCE-20-100084 1	1,23 2	34,0 41	41,93851	-35,08	- 1194,158	14,24	17,54368
163	Miratech CS JCE-20-100084 2	1,23 2	34,0 41	41,93851	-28,28	-962,679	14,24	17,54368
164	Miratech CS JCE-20-100084 3	1,23 2	34,0 41	41,93851	-21,48	-731,201	14,24	17,54368
165	Miratech CS JCE-20-100084 4	1,23 2	34,0 41	41,93851	-14,68	-499,722	14,24	17,54368
166	Miratech CS JCE-20-100084 5	1,23 2	34,0 41	41,93851	-7,88	-268,243	14,24	17,54368

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
167	Miratech CS JCE-20-100084 6	1,232	34,041	41,93851	-1,08	-36,764	14,24	17,54368
168	Miratech CS JCE-20-100084 7	1,232	34,041	41,93851	5,72	194,715	14,24	17,54368
169	19,48m Exhaust Gas Pipe 1	9,6	33,57	322,272	-35,08	-1177,636	11,97	114,912
170	19,48m Exhaust Gas Pipe 2	9,6	33,57	322,272	-28,28	-949,360	11,97	114,912
171	19,48m Exhaust Gas Pipe 3	9,6	33,57	322,272	-21,48	-721,084	11,97	114,912
172	19,48m Exhaust Gas Pipe 4	9,6	33,57	322,272	-14,68	-492,808	11,97	114,912
173	19,48m Exhaust Gas Pipe 5	9,6	33,57	322,272	-7,88	-264,532	11,97	114,912
174	19,48m Exhaust Gas Pipe 6	9,6	33,57	322,272	-1,08	-36,256	11,97	114,912
175	19,48m Exhaust Gas Pipe 7	9,6	33,57	322,272	5,72	192,020	11,97	114,912
176	Engine Access stage	130	8,79	1142,7	-14,68	-129,037	3,36	436,8
176	Structure	2720,6	0	0	-4,24	0,000	0	0
176	Deckhouse 1	118,5979	9,5	1126,68	32,7	310,650	0	0
176	Deckhouse 2	110,6913	12,4	1372,573	32,7	405,480	0	0
176	Deckhouse 3	110,6913	15,06	1667,012	32,7	492,462	0	0
176	Deckhouse 4	2236,222	14,27	31910,88	-9,09	-129,714	-1	-2236,22

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
176	Outfitting	387,45	12,4	4804,38	32,7	405,480	0	0
176	Manifold 1	5,8	8,45	49,01	14,33	121,089	-12,94	-75,052
177	Manifold 2	5,8	8,45	49,01	18,26	154,297	-12,94	-75,052
178	MDO Tank	73,364	3,525	258,6109	34,52	121,683	8,25	605,2595
179	LO Tank	180,222	5,05	910,1241	37,88	191,294	10,36	1867,106
180	FW Technical Tank	83,036	5,05	419,3331	34,52	174,326	-9,63	-799,639
181	FW Consumable Tank	41,518	5,05	209,6665	35,88	181,194	-6,88	-285,645
182	FW Cooling Tank	41,518	5,05	209,6665	33,15	167,408	-6,88	-285,645
183	Provision Weight	0,684	12,4	8,4816	32,7	405,480	0	0
184	Crew Weight	2,2	12,4	27,28	31,8	394,320	0	0
Total	11589,44 ton			92417,87		-10189,3		-2258,93

$$KG\ Total = \frac{\sum(KG \times W)}{Wtotal} = \frac{92417,87}{11589,44} = 7,9743\ m$$

$$LCG\ Total = \frac{\sum(LCG \times W)}{Wtotal} = \frac{-10189,3}{11589,44} = -0,87919\ m$$

$$TCG\ Total = \frac{\sum(LCG \times W)}{Wtotal} = \frac{-2258,93}{11589,44} = -0,1949\ m$$

Ship Condition

No	Condition	KG	Transverse			Longitudinal			GMl	GMt
			BMt	It	Ci	BMl	Il	Cil		
1	LWT	8,712	26,282	247055,298	0,076	254,35	2390965,134	0,08	247,311	19,24
2	LWT+DWT	7,974	22,29	252030,783	0,077	220,5	2493125,998	0,084	214,53	16,32

a. Lightweight Condition

$$trim = \frac{(-0{,}3527034) \times 97{,}5}{247{,}311} = -0{,}1390502\, m$$

The ship will trim 0,1390502 meters to stern.

$$heel = \frac{(-0{,}3527034) \times 32{,}2}{19{,}242} = -0{,}5836144\, m$$

The ship will trim 0,5836144 meters to starboard.

b. LWT+DWT Condition

$$trim = \frac{(-0{,}13434) \times 97{,}5}{214{,}530} = -0{,}06106\, m$$

The ship will trim 0,06106 meters to stern.

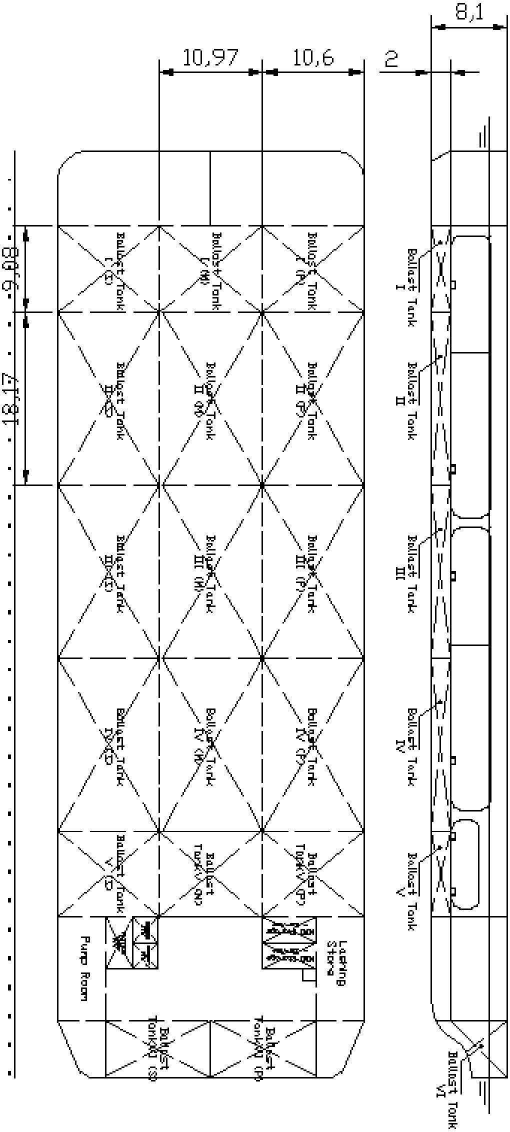
$$heel = \frac{(-0{,}19491) \times 32{,}2}{16.3203} = -0{,}38456\, m$$

The ship will trim 0,38456 meters to starboard.

Attachment 11: Re-arranged Design and Specification (Optimization)

- **Re-arranged Ballast Tank**

No	Object	$L \times W \times H$ $[m^3]$	Volume $[m^3]$	Mass [ton]
1	Ballast Tank 1 (P)	9,08 x 10,6 x 2	192,496	197,3084
2	Ballast Tank 1 (M)	9,08 x 10,97 x 2	199,2152	204,1956
3	Ballast Tank 1 (S)	9,08 x 10,6 x 2	192,496	197,3084
4	Ballast Tank 2 (P)	18,17 x 10,6 x 2	385,204	394,8341
5	Ballast Tank 2 (M)	18,17 x 10,97 x 2	398,6498	408,616
6	Ballast Tank 2 (S)	18,17 x 10,6 x 2	385,204	394,8341
7	Ballast Tank 3 (P)	18,17 x 10,6 x 2	385,204	394,8341
8	Ballast Tank 3 (M)	18,17 x 10,97 x 2	398,6498	408,616
9	Ballast Tank 3 (S)	18,17 x 10,6 x 2	385,204	394,8341
10	Ballast Tank 4 (P)	18,17 x 10,6 x 2	385,204	394,8341
11	Ballast Tank 4 (M)	18,17 x 10,97 x 2	398,6498	408,616
12	Ballast Tank 4 (S)	18,17 x 10,6 x 2	385,204	394,8341
13	Ballast Tank 5 (P)	9,08 x 10,6 x 2	192,496	197,3084
14	Ballast Tank 5 (M)	9,08 x 10,97 x 2	199,2152	204,1956
15	Ballast Tank 5 (S)	9,08 x 10,6 x 2	192,496	197,3084
16	Ballast Tank 6 (P)		344,854	353,4754
17	Ballast Tank 6 (S)		344,854	353,4754
Total			5365,296	5499,428


8,1
10,97
10,6
2
9,08
18,17
Pump Room
Lashing Store

- **Re-arranged LNG Storage Tank**

1. Lapesa 4200 H Type LC318

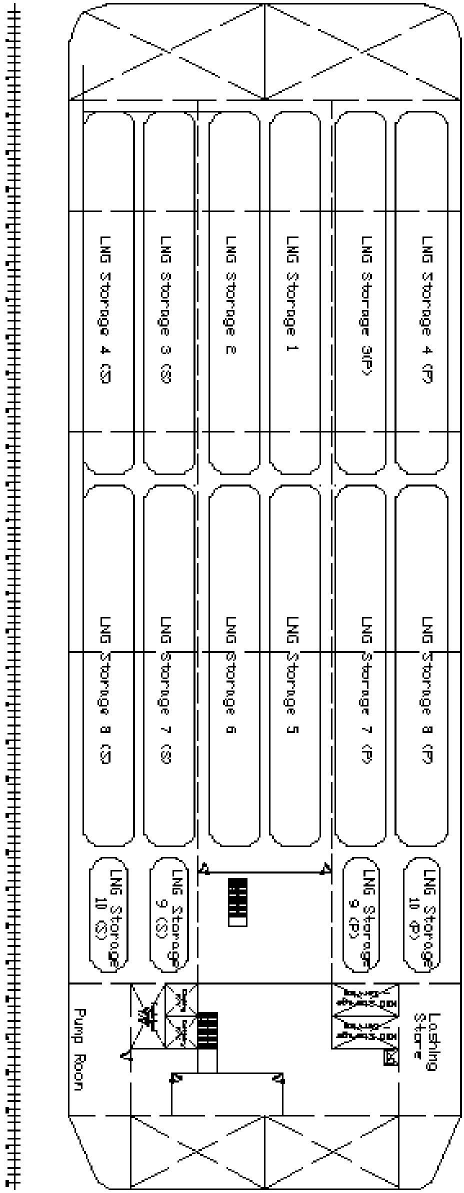
Capacity	304,825		m^3
Weight (Payload)	139		Ton
Tare Weight	70,3		Ton
Pressure	5		Barg
No. of tank	12		Unit
Dimension			
Length	**Height**	**Width**	
29700	4200	4200	mm
Total			
Total Capacity	3657,894		m^3
Total Weight	2511,6		Ton

2. Lapesa 3000 H Type LC40

Capacity	38,342		m^3
Weight (Payload)	104,9		Ton
Tare Weight	13,6		Ton
Pressure	5		Barg
No. of tank	4		Unit
Dimension			
Length	**Height**	**Width**	
9374	3000	3000	mm
Total			
Total Capacity	153,3711		m^3
Total Weight	124,3372		Ton

Total Capacity	3811,266		m^3
Total Weight	2635,937		Ton
LNG Weight	1737,937		Ton
Total Tare Weight	898		Ton

$$Duration = \frac{Total\ Capacity}{LNG\ Consumption/day}$$


LNG Storage 4 (S)
LNG Storage 3 (S)
LNG Storage 2
LNG Storage 1
LNG Storage 3(P)
LNG Storage 4 (P)
LNG Storage 8 (S)
LNG Storage 7 (S)
LNG Storage 6
LNG Storage 5
LNG Storage 7 (P)
LNG Storage 8 (P)
LNG Storage 10 (S)
LNG Storage 9 (S)
LNG Storage 9 (P)
LNG Storage 10 (P)
Pump Room
Lashing Store

- **Weight and Centre of Gravity at LWT + Ballast**

	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
1	Lapesa 4200H LC318 1	70,3	4,2	295,26	-25,03	-105,126	2,49	175,047
2	Lapesa 4200H LC318 2	70,3	4,2	295,26	-25,03	-105,126	-2,49	-175,047
3	Lapesa 4200H LC318 3 (S)	70,3	4,2	295,26	-25,03	-105,126	-7,85	-551,855
4	Lapesa 4200H LC318 4 (S)	70,3	4,2	295,26	-25,03	-105,126	-12,83	-901,949
5	Lapesa 4200H LC318 3 (P)	70,3	4,2	295,26	-25,03	-105,126	7,85	551,855
6	Lapesa 4200H LC318 4 (P)	70,3	4,2	295,26	-25,03	-105,126	12,83	901,949
7	Lapesa 4200H LC318 5	70,3	4,2	295,26	5,67	23,814	2,49	175,047
8	Lapesa 4200H LC318 6	70,3	4,2	295,26	5,67	23,814	-2,49	-175,047
9	Lapesa 4200H LC318 7 (S)	70,3	4,2	295,26	5,67	23,814	-7,85	-551,855
10	Lapesa 4200H LC318 8 (S)	70,3	4,2	295,26	5,67	23,814	-12,83	-901,949
11	Lapesa 4200H LC318 7 (P)	70,3	4,2	295,26	5,67	23,814	7,85	551,855

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
12	Lapesa 4200H LC318 8 (P)	70,3	4,2	295,26	5,67	23,814	12,83	901,949
13	Lapesa 3000H LC40 9 (S)	13,6	3,6	48,96	26,21	94,356	-7,85	-106,76
14	Lapesa 3000H LC40 10 (S)	13,6	3,6	48,96	26,21	94,356	-12,83	-174,488
15	Lapesa 3000H LC40 9 (P)	13,6	3,6	48,96	26,21	94,356	7,85	106,76
16	Lapesa 3000H LC40 10 (P)	13,6	3,6	48,96	26,21	94,356	12,83	174,488
17	Vaporizer VWU 182 1	0,942	2,988	2,814696	29,06	86,831	3,86	3,63612
18	Vaporizer VWU 182 2	0,942	2,988	2,814696	29,06	86,831	2,03	1,91226
19	Vaporizer VWU 182 3	0,942	2,988	2,814696	29,06	86,831	0,21	0,19782
20	Vaporizer VWU 142 1	0,628	2,858	1,794824	29,06	83,053	-1,62	-1,01736
21	Vaporizer VWU 142 2	0,628	2,858	1,794824	29,06	83,053	-3,45	-2,1666
22	Vanzetti DSM L185 1	0,17	2,16	0,3672	23,77	51,343	4,44	0,7548
23	Vanzetti DSM L185 2	0,17	2,16	0,3672	24,89	53,762	4,44	0,7548
24	Vanzetti DSM L185 3	0,17	2,16	0,3672	23,77	51,343	3,48	0,5916

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
25	Vanzetti DSM L185 4	0,17	2,16	0,3672	24,89	53,762	3,48	0,5916
26	Vanzetti DSM L230 1	0,27	2,16	0,5832	23,77	51,343	2,48	0,6696
27	Herborner F-PM080 1	0,28 4	2,75	0,781	39,88	109,670	-8,746	-2,48386
28	Herborner F-PM080 2	0,28 4	2,75	0,781	39,88	109,670	-9,96	-2,82864
29	Herborner F-PM080 3	0,28 4	2,75	0,781	41,58	114,345	-9,96	-2,82864
30	Herborner F-PM050 1	0,07	2,68	0,1876	41,58	111,434	-8,746	-0,61222
31	GEA HG44e/770-4S HC 1	0,17 1	2,15 5	0,368505	23,71	51,095	1,29	0,22059
32	GEA HG44e/770-4S HC 2	0,17 1	2,15 5	0,368505	23,71	51,095	0,14	0,02394
33	GCU Cleaver Brooks LNV-25-1			0	-4,24	0,000		0
34	Air Vessel Kaeser 8000 1	1,85	4,2	7,77	33,29	139,818	3,47	6,4195
35	Air Vessel Kaeser 8000 2	1,85	4,2	7,77	33,29	139,818	1,07	1,9795
36	Air Vessel Kaeser 8000 3	1,85	4,2	7,77	33,29	139,818	-1,33	-2,4605
37	HATLAPA 170-1150 1	1	2,5	2,5	35,83	89,575	3,82	3,82

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
38	HATLAPA 170-1150 2	1	2,5	2,5	35,83	89,575	2,12	2,12
39	HATLAPA 170-1150 3	1	2,5	2,5	35,83	89,575	0,42	0,42
40	Pilot IMO Pump 3E 87P 1	0,035	12,0696	0,422436	-32,4	-391,055	11,32	0,3962
41	Pilot IMO Pump 3E 87P 2	0,035	12,0696	0,422436	-31,64	-381,882	11,32	0,3962
42	Pilot IMO Pump 3E 87P 3	0,035	12,0696	0,422436	-20,41	-246,341	11,32	0,3962
43	Pilot IMO Pump 3E 87P 4	0,035	12,0696	0,422436	-19,65	-237,168	11,32	0,3962
44	Pilot IMO Pump 3E 87P 5	0,035	12,0696	0,422436	-8,42	-101,626	11,32	0,3962
45	Pilot IMO Pump 3E 87P 6	0,035	12,0696	0,422436	-7,67	-92,574	11,32	0,3962
46	Pilot IMO Pump 3E 87P 7	0,035	12,0696	0,422436	2,09	25,225	11,32	0,3962
47	Pilot IMO Pump 3E 87P 8	0,035	12,0696	0,422436	2,84	34,278	11,32	0,3962
48	Main IMO Pump 3D 275E 1	0,162	12,1215	1,963683	-35,26	-427,404	10,38	1,68156
49	Main IMO Pump 3D 275E 2	0,162	12,1215	1,963683	-33,67	-408,131	10,38	1,68156
50	Main IMO Pump 3D 275E 3	0,162	12,1215	1,963683	-23,27	-282,067	10,38	1,68156

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
51	Main IMO Pump 3D 275E 4	0,16 2	12,1 215	1,963683	-21,68	-262,794	10,38	1,68156
52	Main IMO Pump 3D 275E 5	0,16 2	12,1 215	1,963683	-11,29	-136,852	10,38	1,68156
53	Main IMO Pump 3D 275E 6	0,16 2	12,1 215	1,963683	-9,7	-117,579	10,38	1,68156
54	Main IMO Pump 3D 218 1	0,12	12,0 945	1,45134	-0,58	-7,015	10,38	1,2456
55	Main IMO Pump 3D 218 2	0,12	12,0 945	1,45134	0,88	10,643	10,38	1,2456
56	Iron Pump ON: 1 1	0,04 5	2,19	0,09855	40,47	88,629	4,53	0,20385
57	Iron Pump ON: 1 2	0,04 5	2,19	0,09855	40,47	88,629	3,45	0,15525
58	Alfa Laval MIB 303 1	0,06 8	2,25	0,153	40,33	90,743	0,34	0,02312
59	Alfa Laval MIB 303 2	0,06 8	2,25	0,153	41,59	93,578	0,34	0,02312
60	Aalborg Vesta EH15 1	0,05 5	2,23 4	0,12287	41,72	93,202	4,53	0,24915
61	Aalborg Vesta EH15 2	0,05 5	2,23 4	0,12287	41,72	93,202	3,45	0,18975
62	M. Cooler Alfa Laval M15-FM8 1	1,36 5	12,9 5	17,67675	-36,71	-475,395	10,83	14,78295
63	M. Cooler Alfa Laval M15-FM8 2	1,36 5	12,9 5	17,67675	-24,71	-319,995	10,83	14,78295

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
64	M. Cooler Alfa Laval M15-FM8 3	1,365	12,95	17,67675	-12,72	-164,724	10,83	14,78295
65	M. Cooler Alfa Laval M10-FD ASME	0,689	12,52	8,62628	4,97	62,224	9,58	6,60062
66	P. Cooler Aalborg MD20 - 1000 1	0,166	12,305	2,04263	-32,08	-394,744	10,05	1,6683
67	P. Cooler Aalborg MD20 - 1000 2	0,166	12,305	2,04263	-20,1	-247,331	10,05	1,6683
68	P. Cooler Aalborg MD20 - 1000 3	0,166	12,305	2,04263	-8,11	-99,794	10,05	1,6683
69	P. Cooler Aalborg MD15 - 1000 1	0,11	12,25	1,3475	2,47	30,258	10,05	1,1055
70	Filling Pump			0	-4,24	0,000		0
71	Iron Pump ONT: 7/10 1	0,035	9,6	0,336	-33,96	-326,016	8,61	0,30135
72	Iron Pump ONT: 7/10 2	0,035	9,6	0,336	-33,22	-318,912	8,61	0,30135
73	Iron Pump ONT: 7/10 3	0,035	9,6	0,336	-15,42	-148,032	8,61	0,30135
74	Iron Pump ONT: 7/10 4	0,035	9,6	0,336	-14,68	-140,928	8,61	0,30135

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
75	Iron Pump ONT: 7/10 5	0,035	9,6	0,336	-13,95	-133,920	8,61	0,30135
76	Iron Pump ONT: 7/10 6	0,035	9,6	0,336	3,85	36,960	8,61	0,30135
77	Iron Pump ONT: 7/10 7	0,035	9,6	0,336	4,59	44,064	8,61	0,30135
78	Iron Pump ON-V: 4 1	0,075	2,4	0,18	38,32	91,968	8,73	0,65475
79	Iron Pump ON-V: 4 2	0,075	2,4	0,18	38,32	91,968	7,68	0,576
80	Iron Pump ON-V: 4 3	0,075	2,4	0,18	38,32	91,968	6,63	0,49725
81	Iron Pump ON 1 1	0,045	2,19	0,09855	38,32	83,921	5,68	0,2556
82	Alfa Laval MAB 206 1	0,42	2,5	1,05	41,03	102,575	-1,2	-0,504
83	Alfa Laval MAB 206 2	0,42	2,5	1,05	41,03	102,575	-3,1	-1,302
84	Alfa Laval MAB 206 3	0,42	2,5	1,05	41,03	102,575	-5	-2,1
85	Alfa Laval MMB 305 1	0,218	2,45	0,5341	41,03	100,524	-6,8	-1,4824
86	Vesta EH 35 1	0,386	2,372	0,915592	40,34	95,686	9,85	3,8021
87	Vesta EH 35 2	0,386	2,372	0,915592	40,34	95,686	8,43	3,25398
88	Vesta EH 35 3	0,386	2,372	0,915592	40,34	95,686	7,02	2,70972
89	Vesta EH 30 1	0,228	2,322	0,529416	40,06	93,019	5,69	1,29732
90	Alfa Laval AlfaQ 14 1	5,126	13,44	68,89344	-28,13	-378,067	11,11	56,94986

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
91	Alfa Laval AlfaQ 14 2	5,126	13,44	68,89344	-28,13	-378,067	9,22	47,26172
92	Alfa Laval AlfaQ 14 3	5,126	13,44	68,89344	-16,14	-216,922	11,11	56,94986
93	Alfa Laval AlfaQ 14 4	5,126	13,44	68,89344	-16,14	-216,922	9,22	47,26172
94	Alfa Laval AlfaQ 14 5	5,126	13,44	68,89344	-4,15	-55,776	11,11	56,94986
95	Alfa Laval AlfaQ 14 6	5,126	13,44	68,89344	-4,15	-55,776	9,22	47,26172
96	Alfa Laval AlfaQ 14 7	5,126	13,44	68,89344	6,36	85,478	11,11	56,94986
97	Iron Pump ON-V: 4 1	0,075	2,4	0,18	35,13	84,312	-1,02	-0,0765
98	Iron Pump ON-V: 4 2	0,075	2,4	0,18	35,13	84,312	-2,07	-0,15525
99	Iron Pump ON-V: 4 3	0,075	2,4	0,18	36,36	87,264	-1,02	-0,0765
100	Iron Pump ON-V: 3 4	0,075	2,4	0,18	36,36	87,264	-2,07	-0,15525
101	Herborner X200-350A-5504H 1	0,797	10,106	8,054482	-26,53	-268,112	10,4	8,2888
102	Herborner X200-350A-5504H 2	0,797	10,106	8,054482	-25,18	-254,469	10,4	8,2888
103	Herborner X200-350A-5504H 3	0,797	10,106	8,054482	-23,84	-240,927	10,4	8,2888
104	Herborner X200-350A-5504H 4	0,797	10,106	8,054482	-22,5	-227,385	10,4	8,2888

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
105	Herborner X200-350A-5504H 5	0,797	10,106	8,054482	-6,74	-68,114	10,4	8,2888
106	Herborner X200-350A-5504H 6	0,797	10,106	8,054482	-5,39	-54,471	10,4	8,2888
107	Herborner X200-350A-5504H 7	0,797	10,106	8,054482	-4,05	-40,929	10,4	8,2888
108	LT Coolers 1 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	4,94	43,86226
109	LT Coolers 2 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	2,96	26,28184
110	LT Coolers 3 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	0,99	8,79021
111	LT Coolers 4 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	-0,99	-8,79021
112	LT Coolers 5 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	-2,96	-26,2818
113	LT Coolers 6 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	-4,94	-43,8623
114	LT Coolers 1 AlfaQ 10	5,435	15,45	83,97075	11,96	184,782	-4,6	-25,001
115	LT Coolers 2 AlfaQ 10	5,435	15,45	83,97075	11,96	184,782	-4,6	-25,001
116	Herborner X200-350A-4504H 1	0,652	10,106	6,589112	-25,85	-261,240	8,94	5,82888

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
117	Herborner X200-350A-4504H 2	0,652	10,106	6,589112	-24,51	-247,698	8,94	5,82888
118	Herborner X200-350A-4504H 3	0,652	10,106	6,589112	-23,17	-234,156	8,94	5,82888
119	Herborner X200-350A-4504H 4	0,652	10,106	6,589112	-21,83	-220,614	8,94	5,82888
120	Herborner X200-350A-4504H 5	0,652	10,106	6,589112	-7,38	-74,582	8,94	5,82888
121	Herborner X200-350A-4504H 6	0,652	10,106	6,589112	-6,04	-61,040	8,94	5,82888
122	Herborner X200-350A-4504H 7	0,652	10,106	6,589112	-4,7	-47,498	8,94	5,82888
123	HT Coolers 1 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	5,88	119,6815
124	HT Coolers 2 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	3,53	71,84962
125	HT Coolers 3 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	1,18	24,01772
126	HT Coolers 4 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	-1,18	-24,0177

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
127	HT Coolers 5 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	-3,53	-71,8496
128	HT Coolers 6 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	-5,88	-119,682
129	HT Coolers 1 AlfaQ 14L	9,964	15,635	155,7871	11,96	186,995	2,77	27,60028
130	HT Coolers 2 AlfaQ 14L	9,964	15,635	155,7871	11,96	186,995	2,77	27,60028
131	Pompe Garbarino 250-400 1	0,485	3	1,455	33,37	100,110	-12,44	-6,0334
132	Pompe Garbarino 250-400 2	0,485	3	1,455	35,81	107,430	-12,44	-6,0334
133	Pompe Garbarino 250-400 3	0,485	3	1,455	33,37	100,110	-14,5	-7,0325
134	trf pump	0,6	5,706	3,4236	41,49	236,742	-3,05	-1,83
135	trf pump	0,6	5,706	3,4236	41,49	236,742	-4,25	-2,55
136	trf pump	0,6	5,706	3,4236	41,49	236,742	-5,44	-3,264
137	trf pump	0,6	5,706	3,4236	41,49	236,742	-6,64	-3,984
138	MAN 18V51/60 DF 1	293,8	11,9	3496,22	-35,08	-417,452	0	0
139	MAN 18V51/60 DF 2	293,8	11,9	3496,22	-28,28	-336,532	0	0

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
140	MAN 18V51/60 DF 3	293,8	11,9	3496,22	-21,48	-255,612	0	0
141	MAN 18V51/60 DF 4	293,8	11,9	3496,22	-14,68	-174,692	0	0
142	MAN 18V51/60 DF 5	293,8	11,9	3496,22	-7,88	-93,772	0	0
143	MAN 18V51/60 DF 6	293,8	11,9	3496,22	-1,08	-12,852	0	0
144	MAN 18V51/60 DF 7	293,8	11,9	3496,22	5,72	68,068	0	0
145	ABB AMG 1600 Q DSEB 1	67	10,4	696,8	-35,08	-364,832	-9,08	-608,36
146	ABB AMG 1600 Q DSEB 2	67	10,4	696,8	-28,28	-294,112	-9,08	-608,36
147	ABB AMG 1600 Q DSEB 3	67	10,4	696,8	-21,48	-223,392	-9,08	-608,36
148	ABB AMG 1600 Q DSEB 4	67	10,4	696,8	-14,68	-152,672	-9,08	-608,36
149	ABB AMG 1600 Q DSEB 5	67	10,4	696,8	-7,88	-81,952	-9,08	-608,36
150	ABB AMG 1600 Q DSEB 6	67	10,4	696,8	-1,08	-11,232	-9,08	-608,36
151	ABB AMG 1600 Q DSEB 7	67	10,4	696,8	5,72	59,488	-9,08	-608,36
152	Coupling 1	4,6	10,4	47,84	-35,08	-364,832	-6,52	-29,992

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
153	Coupling 2	4,6	10,4	47,84	-28,28	-294,112	-6,52	-29,992
154	Coupling 3	4,6	10,4	47,84	-21,48	-223,392	-6,52	-29,992
155	Coupling 4	4,6	10,4	47,84	-14,68	-152,672	-6,52	-29,992
156	Coupling 5	4,6	10,4	47,84	-7,88	-81,952	-6,52	-29,992
157	Coupling 6	4,6	10,4	47,84	-1,08	-11,232	-6,52	-29,992
158	Coupling 7	4,6	10,4	47,84	5,72	59,488	-6,52	-29,992
159	Saacke EMB/EME-VST 1	16	26,8 351	429,3616	-35,08	-941,375	14,24	227,84
160	Saacke EMB/EME-VST 2	16	26,8 351	429,3616	-28,28	-758,897	14,24	227,84
161	Saacke EMB/EME-VST 3	16	26,8 351	429,3616	-21,48	-576,418	14,24	227,84
162	Saacke EMB/EME-VST 4	16	26,8 351	429,3616	-14,68	-393,939	14,24	227,84
163	Saacke EMB/EME-VST 5	16	26,8 351	429,3616	-7,88	-211,461	14,24	227,84
164	Saacke EMB/EME-VST 6	16	26,8 351	429,3616	-1,08	-28,982	14,24	227,84
165	Saacke EMB/EME-VST 7	16	26,8 351	429,3616	5,72	153,497	14,24	227,84
166	Miratech CS JCE-20-100084 1	1,23 2	34,0 41	41,93851	-35,08	- 1194,158	14,24	17,54368
167	Miratech CS JCE-20-100084 2	1,23 2	34,0 41	41,93851	-28,28	-962,679	14,24	17,54368

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
168	Miratech CS JCE-20-100084 3	1,232	34,041	41,93851	-21,48	-731,201	14,24	17,54368
169	Miratech CS JCE-20-100084 4	1,232	34,041	41,93851	-14,68	-499,722	14,24	17,54368
170	Miratech CS JCE-20-100084 5	1,232	34,041	41,93851	-7,88	-268,243	14,24	17,54368
171	Miratech CS JCE-20-100084 6	1,232	34,041	41,93851	-1,08	-36,764	14,24	17,54368
172	Miratech CS JCE-20-100084 7	1,232	34,041	41,93851	5,72	194,715	14,24	17,54368
173	19,48m Exhaust Gas Pipe 1	9,6	33,57	322,272	-35,08	-1177,636	11,97	114,912
174	19,48m Exhaust Gas Pipe 2	9,6	33,57	322,272	-28,28	-949,360	11,97	114,912
175	19,48m Exhaust Gas Pipe 3	9,6	33,57	322,272	-21,48	-721,084	11,97	114,912
176	19,48m Exhaust Gas Pipe 4	9,6	33,57	322,272	-14,68	-492,808	11,97	114,912
177	19,48m Exhaust Gas Pipe 5	9,6	33,57	322,272	-7,88	-264,532	11,97	114,912
178	19,48m Exhaust Gas Pipe 6	9,6	33,57	322,272	-1,08	-36,256	11,97	114,912
179	19,48m Exhaust Gas Pipe 7	9,6	33,57	322,272	5,72	192,020	11,97	114,912

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
180	Engine Access stage	130	8,79	1142,7	-14,68	-129,037	3,36	436,8
181	Structure	2720 ,6	0	0	-4,24	0,000	0	0
182	Deckhouse 1	118, 5979	9,5	1126,68	32,7	310,650	0	0
183	Deckhouse 2	110, 6913	12,4	1372,573	32,7	405,480	0	0
184	Deckhouse 3	110, 6913	15,0 6	1667,012	32,7	492,462	0	0
185	Deckhouse 4	2236 ,222	14,2 7	31910,88	-9,09	-129,714	-1	-2236,22
186	Outfitting	387, 45	12,4	4804,38	32,7	405,480	0	0
187	Manifold 1	5,8	8,45	49,01	14,33	121,089	-12,94	-75,052
188	Manifold 2	5,8	8,45	49,01	18,26	154,297	-12,94	-75,052
189	Ballast Tank III (P)	311, 489	1	311,489	4,54	4,540	10,79	3360,97
Total	10062,8 ton			84708		0,5988		- 10043,05 7

$$KG\ Total = \frac{\sum(KG \times W)}{Wtotal} = \frac{84708}{10062,8} = 8,418\ m$$

$$LCG\ Total = \frac{\sum(LCG \times W)}{Wtotal} = \frac{-10043,057}{10062,8} = -0,998\ m$$

$$TCG\ Total = \frac{\sum(LCG \times W)}{Wtotal} = \frac{-10043,057}{10062,8} = 0,000m$$

- **Weight and Centre of Gravity at LWT + DWT + Ballast**

	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
1	Lapesa 4200H LC318 1	209,3	4,2	879,06	-25,03	-105,126	2,49	521,157
2	Lapesa 4200H LC318 2	209,3	4,2	879,06	-25,03	-105,126	-2,49	-521,157
3	Lapesa 4200H LC318 3 (S)	209,3	4,2	879,06	-25,03	-105,126	-7,85	-1643,01
4	Lapesa 4200H LC318 4 (S)	209,3	4,2	879,06	-25,03	-105,126	-12,83	-2685,32
5	Lapesa 4200H LC318 3 (P)	209,3	4,2	879,06	-25,03	-105,126	7,85	1643,005
6	Lapesa 4200H LC318 4 (P)	209,3	4,2	879,06	-25,03	-105,126	12,83	2685,319
7	Lapesa 4200H LC318 5	209,3	4,2	879,06	5,67	23,814	2,49	521,157
8	Lapesa 4200H LC318 6	209,3	4,2	879,06	5,67	23,814	-2,49	-521,157
9	Lapesa 4200H LC318 7 (S)	209,3	4,2	879,06	5,67	23,814	-7,85	-1643,01
10	Lapesa 4200H LC318 8 (S)	209,3	4,2	879,06	5,67	23,814	-12,83	-2685,32
11	Lapesa 4200H LC318 7 (P)	209,3	4,2	879,06	5,67	23,814	7,85	1643,005

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
12	Lapesa 4200H LC318 8 (P)	209,3	4,2	879,06	5,67	23,814	12,83	2685,319
13	Lapesa 3000H LC40 9 (S)	31,0843	3,6	111,9035	26,21	94,356	-7,85	-244,012
14	Lapesa 3000H LC40 10 (S)	31,0843	3,6	111,9035	26,21	94,356	-12,83	-398,812
15	Lapesa 3000H LC40 9 (P)	31,0843	3,6	111,9035	26,21	94,356	7,85	244,0118
16	Lapesa 3000H LC40 10 (P)	31,0843	3,6	111,9035	26,21	94,356	12,83	398,8116
17	Vaporizer VWU 182 1	0,942	2,988	2,814696	29,06	86,831	3,86	3,63612
18	Vaporizer VWU 182 2	0,942	2,988	2,814696	29,06	86,831	2,03	1,91226
19	Vaporizer VWU 182 3	0,942	2,988	2,814696	29,06	86,831	0,21	0,19782
20	Vaporizer VWU 142 1	0,628	2,858	1,794824	29,06	83,053	-1,62	-1,01736
21	Vaporizer VWU 142 2	0,628	2,858	1,794824	29,06	83,053	-3,45	-2,1666
22	Vanzetti DSM L185 1	0,17	2,16	0,3672	23,77	51,343	4,44	0,7548
23	Vanzetti DSM L185 2	0,17	2,16	0,3672	24,89	53,762	4,44	0,7548
24	Vanzetti DSM L185 3	0,17	2,16	0,3672	23,77	51,343	3,48	0,5916

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
25	Vanzetti DSM L185 4	0,17	2,16	0,3672	24,89	53,762	3,48	0,5916
26	Vanzetti DSM L230 1	0,27	2,16	0,5832	23,77	51,343	2,48	0,6696
27	Herborner F-PM080 1	0,284	2,75	0,781	39,88	109,670	-8,746	-2,48386
28	Herborner F-PM080 2	0,284	2,75	0,781	39,88	109,670	-9,96	-2,82864
29	Herborner F-PM080 3	0,284	2,75	0,781	41,58	114,345	-9,96	-2,82864
30	Herborner F-PM050 1	0,07	2,68	0,1876	41,58	111,434	-8,746	-0,61222
31	GEA HG44e/770-4S HC 1	0,171	2,155	0,368505	23,71	51,095	1,29	0,22059
32	GEA HG44e/770-4S HC 2	0,171	2,155	0,368505	23,71	51,095	0,14	0,02394
33	GCU Cleaver Brooks LNV-25-1			0	-4,24	0,000		0
34	Air Vessel Kaeser 8000 1	1,85	4,2	7,77	33,29	139,818	3,47	6,4195
35	Air Vessel Kaeser 8000 2	1,85	4,2	7,77	33,29	139,818	1,07	1,9795
36	Air Vessel Kaeser 8000 3	1,85	4,2	7,77	33,29	139,818	-1,33	-2,4605
37	HATLAPA 170-1150 1	1	2,5	2,5	35,83	89,575	3,82	3,82

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
38	HATLAPA 170-1150 2	1	2,5	2,5	35,83	89,575	2,12	2,12
39	HATLAPA 170-1150 3	1	2,5	2,5	35,83	89,575	0,42	0,42
40	Pilot IMO Pump 3E 87P 1	0,035	12,0696	0,422436	-32,4	-391,055	11,32	0,3962
41	Pilot IMO Pump 3E 87P 2	0,035	12,0696	0,422436	-31,64	-381,882	11,32	0,3962
42	Pilot IMO Pump 3E 87P 3	0,035	12,0696	0,422436	-20,41	-246,341	11,32	0,3962
43	Pilot IMO Pump 3E 87P 4	0,035	12,0696	0,422436	-19,65	-237,168	11,32	0,3962
44	Pilot IMO Pump 3E 87P 5	0,035	12,0696	0,422436	-8,42	-101,626	11,32	0,3962
45	Pilot IMO Pump 3E 87P 6	0,035	12,0696	0,422436	-7,67	-92,574	11,32	0,3962
46	Pilot IMO Pump 3E 87P 7	0,035	12,0696	0,422436	2,09	25,225	11,32	0,3962
47	Pilot IMO Pump 3E 87P 8	0,035	12,0696	0,422436	2,84	34,278	11,32	0,3962
48	Main IMO Pump 3D 275E 1	0,162	12,1215	1,963683	-35,26	-427,404	10,38	1,68156
49	Main IMO Pump 3D 275E 2	0,162	12,1215	1,963683	-33,67	-408,131	10,38	1,68156
50	Main IMO Pump 3D 275E 3	0,162	12,1215	1,963683	-23,27	-282,067	10,38	1,68156

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
51	Main IMO Pump 3D 275E 4	0,162	12,1215	1,963683	-21,68	-262,794	10,38	1,68156
52	Main IMO Pump 3D 275E 5	0,162	12,1215	1,963683	-11,29	-136,852	10,38	1,68156
53	Main IMO Pump 3D 275E 6	0,162	12,1215	1,963683	-9,7	-117,579	10,38	1,68156
54	Main IMO Pump 3D 218 1	0,12	12,0945	1,45134	-0,58	-7,015	10,38	1,2456
55	Main IMO Pump 3D 218 2	0,12	12,0945	1,45134	0,88	10,643	10,38	1,2456
56	Iron Pump ON: 1 1	0,045	2,19	0,09855	40,47	88,629	4,53	0,20385
57	Iron Pump ON: 1 2	0,045	2,19	0,09855	40,47	88,629	3,45	0,15525
58	Alfa Laval MIB 303 1	0,068	2,25	0,153	40,33	90,743	0,34	0,02312
59	Alfa Laval MIB 303 2	0,068	2,25	0,153	41,59	93,578	0,34	0,02312
60	Aalborg Vesta EH15 1	0,055	2,234	0,12287	41,72	93,202	4,53	0,24915
61	Aalborg Vesta EH15 2	0,055	2,234	0,12287	41,72	93,202	3,45	0,18975
62	M. Cooler Alfa Laval M15-FM8 1	1,365	12,95	17,67675	-36,71	-475,395	10,83	14,78295
63	M. Cooler Alfa Laval M15-FM8 2	1,365	12,95	17,67675	-24,71	-319,995	10,83	14,78295

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
64	M. Cooler Alfa Laval M15-FM8 3	1,365	12,95	17,67675	-12,72	-164,724	10,83	14,78295
65	M. Cooler Alfa Laval M10-FD ASME	0,689	12,52	8,62628	4,97	62,224	9,58	6,60062
66	P. Cooler Aalborg MD20 - 1000 1	0,166	12,305	2,04263	-32,08	-394,744	10,05	1,6683
67	P. Cooler Aalborg MD20 - 1000 2	0,166	12,305	2,04263	-20,1	-247,331	10,05	1,6683
68	P. Cooler Aalborg MD20 - 1000 3	0,166	12,305	2,04263	-8,11	-99,794	10,05	1,6683
69	P. Cooler Aalborg MD15 - 1000 1	0,11	12,25	1,3475	2,47	30,258	10,05	1,1055
70	Filling Pump			0	-4,24	0,000		0
71	Iron Pump ONT: 7/10 1	0,035	9,6	0,336	-33,96	-326,016	8,61	0,30135
72	Iron Pump ONT: 7/10 2	0,035	9,6	0,336	-33,22	-318,912	8,61	0,30135
73	Iron Pump ONT: 7/10 3	0,035	9,6	0,336	-15,42	-148,032	8,61	0,30135
74	Iron Pump ONT: 7/10 4	0,035	9,6	0,336	-14,68	-140,928	8,61	0,30135

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
75	Iron Pump ONT: 7/10 5	0,035	9,6	0,336	-13,95	-133,920	8,61	0,30135
76	Iron Pump ONT: 7/10 6	0,035	9,6	0,336	3,85	36,960	8,61	0,30135
77	Iron Pump ONT: 7/10 7	0,035	9,6	0,336	4,59	44,064	8,61	0,30135
78	Iron Pump ON-V: 4 1	0,075	2,4	0,18	38,32	91,968	8,73	0,65475
79	Iron Pump ON-V: 4 2	0,075	2,4	0,18	38,32	91,968	7,68	0,576
80	Iron Pump ON-V: 4 3	0,075	2,4	0,18	38,32	91,968	6,63	0,49725
81	Iron Pump ON 1 1	0,045	2,19	0,09855	38,32	83,921	5,68	0,2556
82	Alfa Laval MAB 206 1	0,42	2,5	1,05	41,03	102,575	-1,2	-0,504
83	Alfa Laval MAB 206 2	0,42	2,5	1,05	41,03	102,575	-3,1	-1,302
84	Alfa Laval MAB 206 3	0,42	2,5	1,05	41,03	102,575	-5	-2,1
85	Alfa Laval MMB 305 1	0,218	2,45	0,5341	41,03	100,524	-6,8	-1,4824
86	Vesta EH 35 1	0,386	2,372	0,915592	40,34	95,686	9,85	3,8021
87	Vesta EH 35 2	0,386	2,372	0,915592	40,34	95,686	8,43	3,25398
88	Vesta EH 35 3	0,386	2,372	0,915592	40,34	95,686	7,02	2,70972
89	Vesta EH 30 1	0,228	2,322	0,529416	40,06	93,019	5,69	1,29732

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
90	Alfa Laval AlfaQ 14 1	5,126	13,44	68,89344	-28,13	-378,067	11,11	56,94986
91	Alfa Laval AlfaQ 14 2	5,126	13,44	68,89344	-28,13	-378,067	9,22	47,26172
92	Alfa Laval AlfaQ 14 3	5,126	13,44	68,89344	-16,14	-216,922	11,11	56,94986
93	Alfa Laval AlfaQ 14 4	5,126	13,44	68,89344	-16,14	-216,922	9,22	47,26172
94	Alfa Laval AlfaQ 14 5	5,126	13,44	68,89344	-4,15	-55,776	11,11	56,94986
95	Alfa Laval AlfaQ 14 6	5,126	13,44	68,89344	-4,15	-55,776	9,22	47,26172
96	Alfa Laval AlfaQ 14 7	5,126	13,44	68,89344	6,36	85,478	11,11	56,94986
97	Iron Pump ON-V: 4 1	0,075	2,4	0,18	35,13	84,312	-1,02	-0,0765
98	Iron Pump ON-V: 4 2	0,075	2,4	0,18	35,13	84,312	-2,07	-0,15525
99	Iron Pump ON-V: 4 3	0,075	2,4	0,18	36,36	87,264	-1,02	-0,0765
100	Iron Pump ON-V: 3 4	0,075	2,4	0,18	36,36	87,264	-2,07	-0,15525
101	Herborner X200-350A-5504H 1	0,797	10,106	8,054482	-26,53	-268,112	10,4	8,2888
102	Herborner X200-350A-5504H 2	0,797	10,106	8,054482	-25,18	-254,469	10,4	8,2888
103	Herborner X200-	0,797	10,106	8,054482	-23,84	-240,927	10,4	8,2888

	350A-5504H 3							
No.	**Equipment**	**W ton**	**KG m**	**KGxW**	**LCG[m]**	**LCGxW**	**TCG[m]**	**TCGxW**
104	Herborner X200-350A-5504H 4	0,797	10,106	8,054482	-22,5	-227,385	10,4	8,2888
105	Herborner X200-350A-5504H 5	0,797	10,106	8,054482	-6,74	-68,114	10,4	8,2888
106	Herborner X200-350A-5504H 6	0,797	10,106	8,054482	-5,39	-54,471	10,4	8,2888
107	Herborner X200-350A-5504H 7	0,797	10,106	8,054482	-4,05	-40,929	10,4	8,2888
108	LT Coolers 1 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	4,94	43,86226
109	LT Coolers 2 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	2,96	26,28184
110	LT Coolers 3 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	0,99	8,79021
111	LT Coolers 4 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	-0,99	-8,79021
112	LT Coolers 5 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	-2,96	-26,2818
113	LT Coolers 6 AlfaQ 14L	8,879	15,6355	138,8276	18,68	292,071	-4,94	-43,8623

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
114	LT Coolers 1 AlfaQ 10	5,435	15,45	83,97075	11,96	184,782	-4,6	-25,001
115	LT Coolers 2 AlfaQ 10	5,435	15,45	83,97075	11,96	184,782	-4,6	-25,001
116	Herborner X200-350A-4504H 1	0,652	10,106	6,589112	-25,85	-261,240	8,94	5,82888
117	Herborner X200-350A-4504H 2	0,652	10,106	6,589112	-24,51	-247,698	8,94	5,82888
118	Herborner X200-350A-4504H 3	0,652	10,106	6,589112	-23,17	-234,156	8,94	5,82888
119	Herborner X200-350A-4504H 4	0,652	10,106	6,589112	-21,83	-220,614	8,94	5,82888
120	Herborner X200-350A-4504H 5	0,652	10,106	6,589112	-7,38	-74,582	8,94	5,82888
121	Herborner X200-350A-4504H 6	0,652	10,106	6,589112	-6,04	-61,040	8,94	5,82888
122	Herborner X200-350A-4504H 7	0,652	10,106	6,589112	-4,7	-47,498	8,94	5,82888
123	HT Coolers 1 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	5,88	119,6815
124	HT Coolers 2 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	3,53	71,84962

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
125	HT Coolers 3 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	1,18	24,01772
126	HT Coolers 4 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	-1,18	-24,0177
127	HT Coolers 5 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	-3,53	-71,8496
128	HT Coolers 6 AlfaQ 20M	20,354	10,09	205,3719	21,29	214,816	-5,88	-119,682
129	HT Coolers 1 AlfaQ 14L	9,964	15,635	155,7871	11,96	186,995	2,77	27,60028
130	HT Coolers 2 AlfaQ 14L	9,964	15,635	155,7871	11,96	186,995	2,77	27,60028
131	Pompe Garbarino 250-400 1	0,485	3	1,455	33,37	100,110	-12,44	-6,0334
132	Pompe Garbarino 250-400 2	0,485	3	1,455	35,81	107,430	-12,44	-6,0334
133	Pompe Garbarino 250-400 3	0,485	3	1,455	33,37	100,110	-14,5	-7,0325
134	trf pump	0,6	5,706	3,4236	41,49	236,742	-3,05	-1,83
135	trf pump	0,6	5,706	3,4236	41,49	236,742	-4,25	-2,55
136	trf pump	0,6	5,706	3,4236	41,49	236,742	-5,44	-3,264
137	trf pump	0,6	5,706	3,4236	41,49	236,742	-6,64	-3,984

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
138	MAN 18V51/60 DF 1	293,8	11,9	3496,22	-35,08	-417,452	0	0
139	MAN 18V51/60 DF 2	293,8	11,9	3496,22	-28,28	-336,532	0	0
140	MAN 18V51/60 DF 3	293,8	11,9	3496,22	-21,48	-255,612	0	0
141	MAN 18V51/60 DF 4	293,8	11,9	3496,22	-14,68	-174,692	0	0
142	MAN 18V51/60 DF 5	293,8	11,9	3496,22	-7,88	-93,772	0	0
143	MAN 18V51/60 DF 6	293,8	11,9	3496,22	-1,08	-12,852	0	0
144	MAN 18V51/60 DF 7	293,8	11,9	3496,22	5,72	68,068	0	0
145	ABB AMG 1600 Q DSEB 1	67	10,4	696,8	-35,08	-364,832	-9,08	-608,36
146	ABB AMG 1600 Q DSEB 2	67	10,4	696,8	-28,28	-294,112	-9,08	-608,36
147	ABB AMG 1600 Q DSEB 3	67	10,4	696,8	-21,48	-223,392	-9,08	-608,36
148	ABB AMG 1600 Q DSEB 4	67	10,4	696,8	-14,68	-152,672	-9,08	-608,36
149	ABB AMG 1600 Q DSEB 5	67	10,4	696,8	-7,88	-81,952	-9,08	-608,36

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
150	ABB AMG 1600 Q DSEB 6	67	10,4	696,8	-1,08	-11,232	-9,08	-608,36
151	ABB AMG 1600 Q DSEB 7	67	10,4	696,8	5,72	59,488	-9,08	-608,36
152	Coupling 1	4,6	10,4	47,84	-35,08	-364,832	-6,52	-29,992
153	Coupling 2	4,6	10,4	47,84	-28,28	-294,112	-6,52	-29,992
154	Coupling 3	4,6	10,4	47,84	-21,48	-223,392	-6,52	-29,992
155	Coupling 4	4,6	10,4	47,84	-14,68	-152,672	-6,52	-29,992
156	Coupling 5	4,6	10,4	47,84	-7,88	-81,952	-6,52	-29,992
157	Coupling 6	4,6	10,4	47,84	-1,08	-11,232	-6,52	-29,992
158	Coupling 7	4,6	10,4	47,84	5,72	59,488	-6,52	-29,992
159	Saacke EMB/EME-VST 1	16	26,8 351	429,3616	-35,08	-941,375	14,24	227,84
160	Saacke EMB/EME-VST 2	16	26,8 351	429,3616	-28,28	-758,897	14,24	227,84
161	Saacke EMB/EME-VST 3	16	26,8 351	429,3616	-21,48	-576,418	14,24	227,84
162	Saacke EMB/EME-VST 4	16	26,8 351	429,3616	-14,68	-393,939	14,24	227,84
163	Saacke EMB/EME-VST 5	16	26,8 351	429,3616	-7,88	-211,461	14,24	227,84
164	Saacke EMB/EME-VST 6	16	26,8 351	429,3616	-1,08	-28,982	14,24	227,84
165	Saacke EMB/EME-VST 7	16	26,8 351	429,3616	5,72	153,497	14,24	227,84

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
166	Miratech CS JCE-20-100084 1	1,232	34,041	41,93851	-35,08	-1194,158	14,24	17,54368
167	Miratech CS JCE-20-100084 2	1,232	34,041	41,93851	-28,28	-962,679	14,24	17,54368
168	Miratech CS JCE-20-100084 3	1,232	34,041	41,93851	-21,48	-731,201	14,24	17,54368
169	Miratech CS JCE-20-100084 4	1,232	34,041	41,93851	-14,68	-499,722	14,24	17,54368
170	Miratech CS JCE-20-100084 5	1,232	34,041	41,93851	-7,88	-268,243	14,24	17,54368
171	Miratech CS JCE-20-100084 6	1,232	34,041	41,93851	-1,08	-36,764	14,24	17,54368
172	Miratech CS JCE-20-100084 7	1,232	34,041	41,93851	5,72	194,715	14,24	17,54368
173	19,48m Exhaust Gas Pipe 1	9,6	33,57	322,272	-35,08	-1177,636	11,97	114,912
174	19,48m Exhaust Gas Pipe 2	9,6	33,57	322,272	-28,28	-949,360	11,97	114,912
175	19,48m Exhaust Gas Pipe 3	9,6	33,57	322,272	-21,48	-721,084	11,97	114,912
176	19,48m Exhaust Gas Pipe 4	9,6	33,57	322,272	-14,68	-492,808	11,97	114,912
177	19,48m Exhaust Gas Pipe 5	9,6	33,57	322,272	-7,88	-264,532	11,97	114,912

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
178	19,48m Exhaust Gas Pipe 6	9,6	33,57	322,272	-1,08	-36,256	11,97	114,912
179	19,48m Exhaust Gas Pipe 7	9,6	33,57	322,272	5,72	192,020	11,97	114,912
180	Engine Access stage	130	8,79	1142,7	-14,68	-129,037	3,36	436,8
181	Structure	2720,6	0	0	-4,24	0,000	0	0
182	Deckhouse 1	118,5979	9,5	1126,68	32,7	310,650	0	0
183	Deckhouse 2	110,6913	12,4	1372,573	32,7	405,480	0	0
184	Deckhouse 3	110,6913	15,06	1667,012	32,7	492,462	0	0
185	Deckhouse 4	2236,222	14,27	31910,88	-9,09	-129,714	-1	-2236,22
186	Outfitting	387,45	12,4	4804,38	32,7	405,480	0	0
187	Manifold 1	5,8	8,45	49,01	14,33	121,089	-12,94	-75,052
188	Manifold 2	5,8	8,45	49,01	18,26	154,297	-12,94	-75,052
189	MDO Tank	73,36479		258,6109	34,52	121,683	8,25	605,2595
190	LO Tank	180,2226		910,1241	37,88	191,294	10,36	1867,106

No.	Equipment	W ton	KG m	KGxW	LCG[m]	LCGxW	TCG[m]	TCGxW
191	FW Technical Tank	83,0 362 5		419,3331	34,52	174,326	-9,63	-799,639
192	FW Consumable Tank	41,5 181 3		209,6665	35,88	181,194	-6,88	-285,645
193	FW Cooling Tank	41,5 181 3		209,6665	33,15	167,408	-6,88	-285,645
194	Provision Weight	0,68 4		8,4816	32,7	405,480	0	0
195	Crew and Provision Weight	2,2		27,28	31,8	394,320	0	0
196	Ballast Tank III (P)	209, 354	1	209,354	4,54	4,540	10,79	2258,93
Total	12121,1 ton			93906,4		-10043,05 7		-0,00067

$$KG\ Total = \frac{\sum(KG \times W)}{Wtotal} = \frac{93906,4}{12121,1} = 7,747\ m$$

$$LCG\ Total = \frac{\sum(LCG \times W)}{Wtotal} = \frac{-10043,057}{12121,1} = -0,828\ m$$

$$TCG\ Total = \frac{\sum(LCG \times W)}{Wtotal} = \frac{-10043,057}{12121,1} = 0,000m$$

Ship Condition

No	Condition	KG	Transverse			Longitudinal			GMl	GMt
			BMt	It	Ci	BMl	Il	Cil		
1	LWT + Ballast	8,418	24,605	247592,486	0,076	238,68	2401836,179	0,08	232,011	17,93
2	LWT + DWT + Ballast	7,747	20,793	252030,783	0,077	205,68	2493125,998	0,084	200,034	15,14

a. LWT + Ballast Condition

$$trim = \frac{(0{,}46446)\times 97{,}5}{232{,}011} = 0{,}19518\ m$$

The ship will trim 0,19518 meters to bow.

$$heel = \frac{(0)\times 32{,}2}{17{,}93} = 0\ m$$

The ship will heel 0 meters.

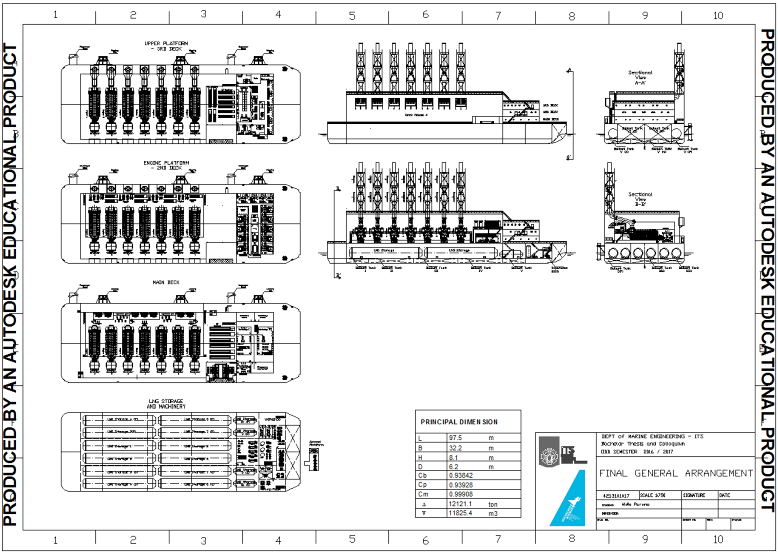
b. LWT + DWT + Ballast Condition

$$trim = \frac{(0{,}63394)\times 97{,}5}{200{,}034} = 0{,}30899\ m$$

The ship will trim 0,30899 meters to bow.

$$heel = \frac{(0)\times 32{,}2}{15{,}14} = 0\ m$$

The ship will heel 0 meters.


PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
UPPER PLATFORM - 3RD DECK
ENGINE PLATFORM - 2ND DECK
MAIN DECK
LNG STORAGE AND MACHINERY
Sectional View A-A'
Sectional View B-B'
PRINCIPAL DIMENSION
L 97.5 m
B 32.2 m
H 8.1 m
D 6.2 m
Cb 0.93842
Cp 0.93928
Cm 0.99908
Δ 12121.1 ton
∇ 11825.4 m3
DEPT of MARINE ENGINEERING - ITS
Bachelor Thesis and Colloquium
ODD SEMESTER 2016 / 2017
FINAL GENERAL ARRANGEMENT
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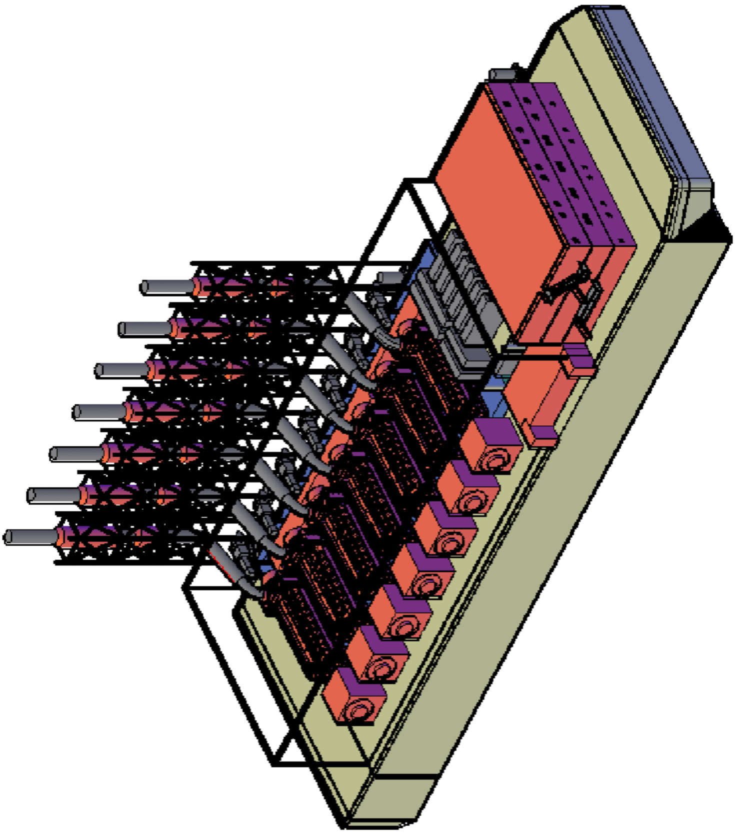

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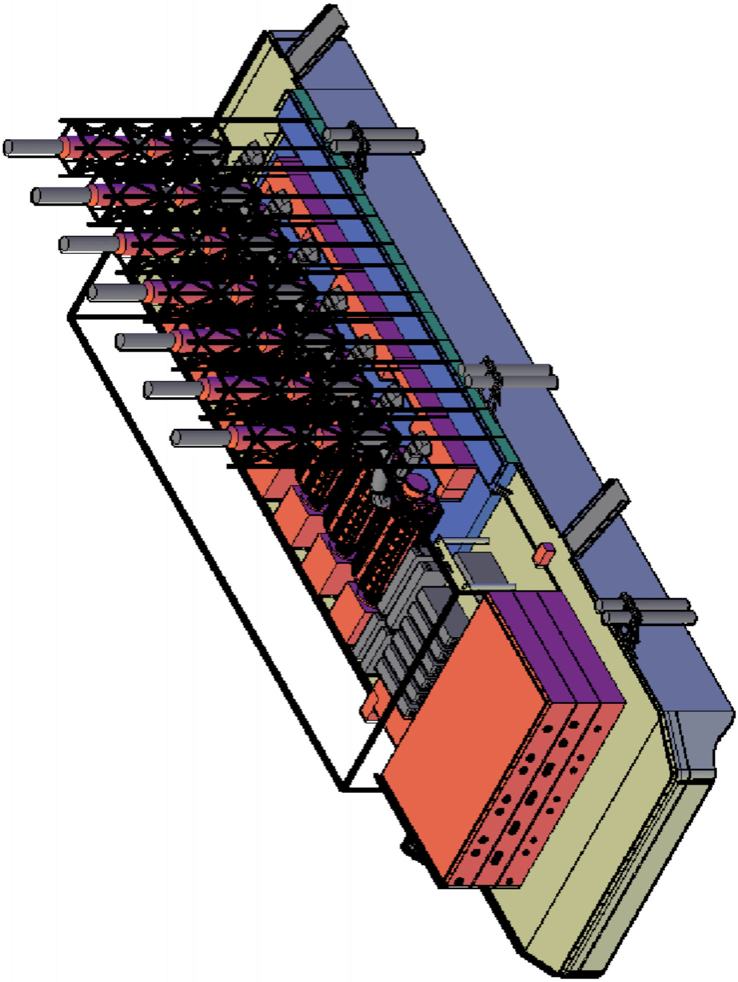

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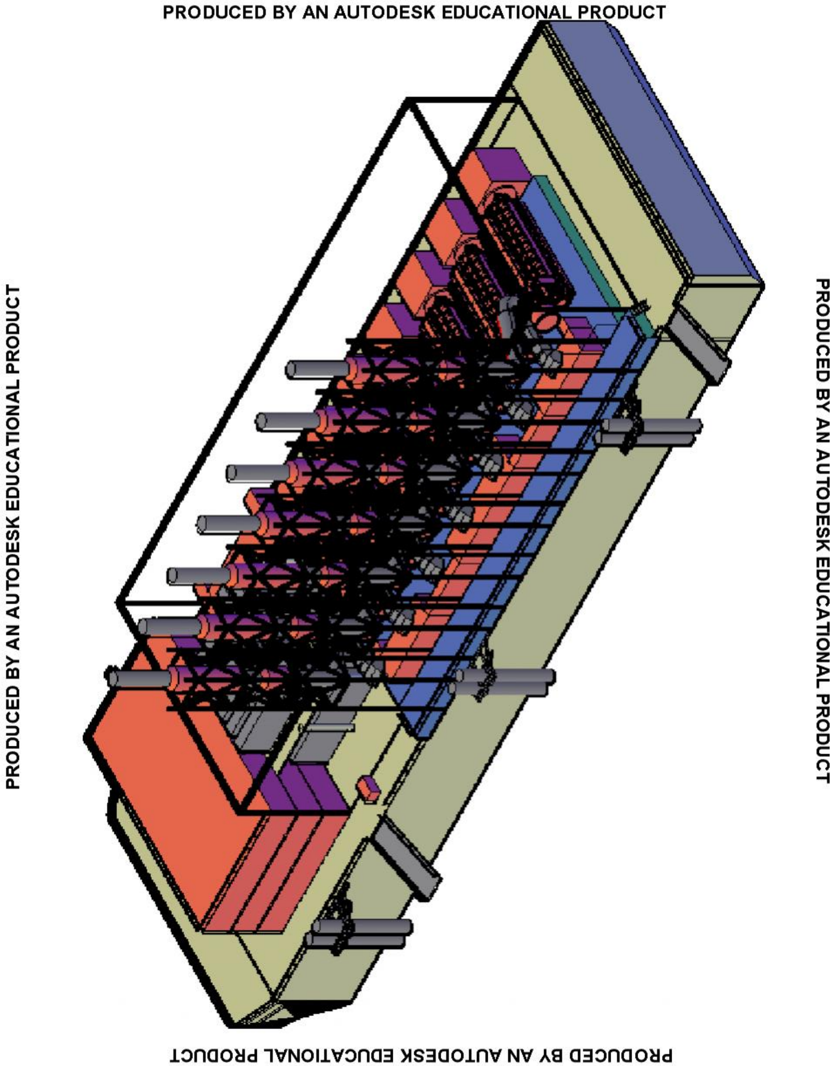
NE



NW

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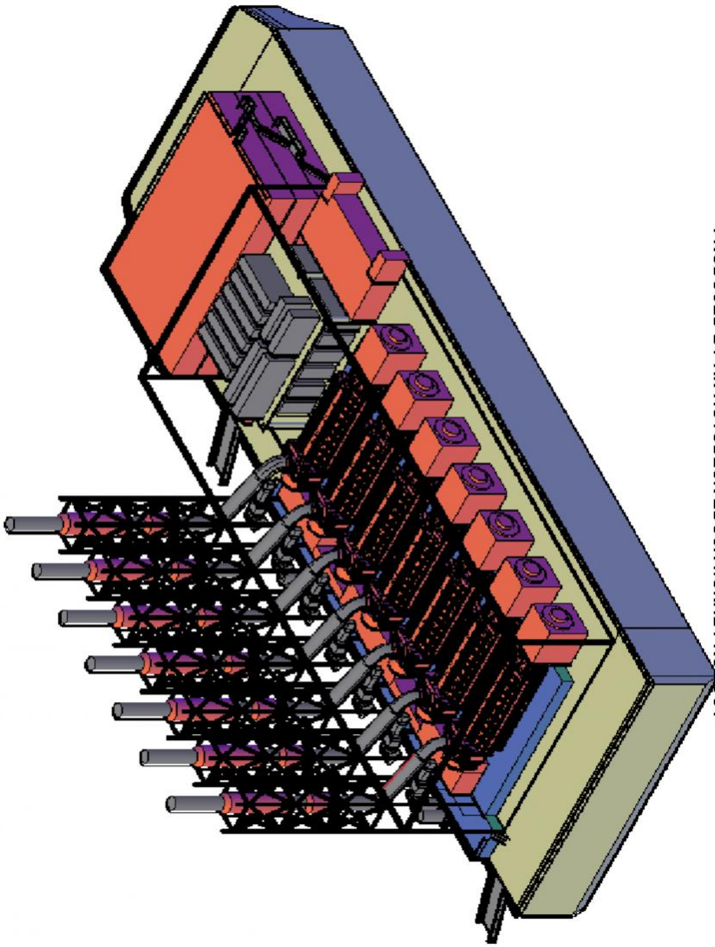

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SW

Attachment 12: MRP (Material Requirements Planning)

The following tables shows the MRP or Material Requirements Planning to develop the *Conceptual Design of 100 MW LNG Mobile Power Plant* which has been calculated in the previous attachment. The equipment below exclude the general system equipment, piping, electrical, accommodation, and office equipment.

No.	Equipment	Amount
1	MAN 18V51/60 DF	7
2	ABB AMG 1600 Q DSEB	7
3	Coupling	7
4	Saacke EMB/EME-VST	7
5	Miratech CS JCE-20-100084	7
6	19,48m Exhaust Gas Pipe	7
7	Engine Access stage	1
8	Lapesa 4200H LC318	12
9	Lapesa 4200H LC40	4
10	Vaporizer VWU 182	3
11	Vaporizer VWU 142	2
12	Vanzetti DSM L185	4
13	Vanzetti DSM L230	1
14	Herborner F-PM080	3
15	Herborner F-PM050	1
16	GEA HG44e/770-4S HC 1	2
17	GCU Cleaver Brooks LNV-25-1	1
18	Pilot Fuel IMO Pump 3E 87P	8

No.	Equipment	Amount
19	Main Fuel IMO Pump 3D 275E 1	6
20	Main Fuel IMO Pump 3D 218 2	2
21	Iron Pump ON: 1	3
22	Alfa Laval MIB 303	2
23	Aalborg Vesta EH15	2
24	M. Cooler Alfa Laval M15-FM8	3
25	M. Cooler Alfa Laval M10-FD ASME	1
26	P. Cooler Aalborg MD20 - 1000	3
27	P. Cooler Aalborg MD15 - 1000 1	1
28	Iron Pump ONT: 7/10	7
29	Iron Pump ON-V: 4	3
30	Alfa Laval MAB 206	3
31	Alfa Laval MMB 305	1
32	Vesta EH 35 1	3
33	Vesta EH 30 1	1
34	Alfa Laval AlfaQ 14	7
35	Iron Pump ON-V: 4	3
36	Iron Pump ON-V: 3	1
37	Herborner X200-350A-5504H 1	7
38	LT Coolers 1 AlfaQ 14L	6
39	LT Coolers AlfaQ 10	2
40	Herborner X200-350A-4504H 1	7
41	HT Coolers AlfaQ 20M	6

No	Equipment	Amount
42	HT Coolers AlfaQ 14L	2
43	Pompe Garbarino 250-400 1	3
44	LO TRF PUMP	4
45	Air Vessel Kaeser 8000 1	3
46	HATLAPA 170-1150 1	3
47	Manifold	2
48	Transformer	2

Attachment 13: Equipment and Products Documents

- **CAT VM 46 DF**

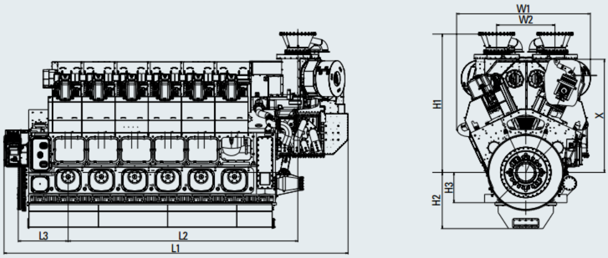


Fig. 2-1 Turbocharger at free end – B-side

Type	Dimensions [mm]								Weight
	L1	L2	L3	H1	H2	H3	W1	W2	[t]
12 M 46 DF	9,930	6,628	1,440	4,000	1,625	875	3,860	1,685	160.0
16 M 46 DF	11,850	9,974	1,440	3,975	1,625	875	3,997	1,670	220.0

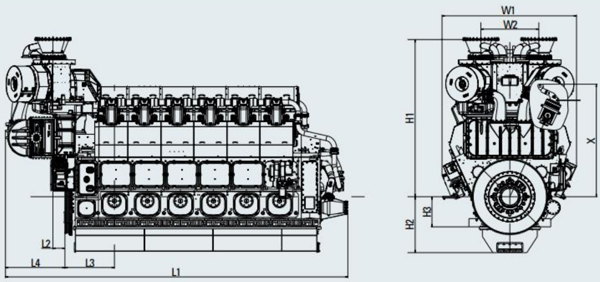


Fig. 2-2 Turbocharger at driving end – B-side

Type	Dimensions [mm]									Weight
	L1	L2	L3	L4	H1	H2	H3	W1	W2	[t]
12 M 46 DF	9,960	348	1,440	1,729	4,568	1,625	875	3,912	1,685	160.0
16 M 46 DF	11,880	333	1,440	1,729	4,543	1,625	875	4,016	1,670	220.0

Performance data			
Maximum continuous rating acc. ISO 3046/1	[kW]	10,800	14,400
Speed	[rpm]	500/514	500/514
Minimum speed	[rpm]	300	300
Brake mean effective presure	[bar]	21.3/20.7	21.3/20.7
Charge air pressure	[bar]	3.55	3.55
Firing pressure (max. allowed, tolerance +/- 3%)	[bar]	190	190
Combustion air demand (ta=20°C)	[m³/h]	64,100	86,700
Max. load acceptance	[kW/s]	66	90
Specific fuel oil consumption diesel/gas			
n = const [1] 100 %	[g/kWh] [kJ/kWh]	186/7,272	186/7,272
85 %	[g/kWh] [kJ/kWh]	185/7,417	185/7,417
75 %	[g/kWh] [kJ/kWh]	187/7,563	187/7,563
50 %	[g/kWh] [kJ/kWh]	192/8,088	192/8,088
Lube oil consumption [2]	[g/kWh]	0.6	0.6
NO_x-emission (diesel) [6]	[g/kWh]	10.0	10.0
NO_x-emission (gas) [6]	[g/kWh]	2.6	2.6
Methane slip, sp. pilot oil injection			
100 %	[% kJ/kWh]	2.0/72	2.0/72
50 %	[% kJ/kWh]	2.1/96	2.1/96
15 %	[% kJ/kWh]	6.9/272	6.9/272
CO_2 100% (diesel/gas)	[%]	5.4/4.5	5.4/4.5
Turbocharger type		2 x ABB TPL71	2 x ABB TPL76

Fuel			
Engine driven booster pump	[m³/h] [bar]	–/–	–/–
Stand-by booster pump	[m³/h] [bar]	8.4/5	11.2/5
Mesh size MDO fine filter	[mm]	0.025	0.025
Mesh size HFO automatic filter	[mm]	0.010	0.010
Mesh size HFO fine filter	[mm]	0.034	0.034

Lube oil			
Engine driven pump	[m³/h] [bar]	250/10	400/10
Independent pump	[m³/h] [bar]	200/10	270/10
Working pressure on engine inlet	[bar]	4 - 5	4 - 5
Engine driven suction pump	[m³/h] [bar]	–/–	–/–
Independent suction pump	[m³/h] [bar]	350/3	470/3
Priming pump	[m³/h] [bar]	30/5	40/5
Lube oil circulating tank / dry sump content	[m³]	16.3	21.8
Temperature at engine inlet	[°C]	60 - 65	60 - 65
Temperature controller NB	[mm]	200	200
Double filter NB	[mm]	200	200
Mesh size double filter	[mm]	0.08	0.08
Mesh size automatic filter	[mm]	0.03	0.03
Fresh water cooling			
Engine content	[m³]	2.8	4.0
Pressure at engine inlet min/max	[bar]	4.5/6.0	4.5/6.0
Header tank capacity	[m³]	1.5	2.0
Temperature at engine outlet	[°C]	80 - 90	80 - 90
Two circuit system			
Engine driven pump HT	[m³/h] [bar]	200/4.7	350/4.7
Independent pump HT	[m³/h] [bar]	200/3	350/3
HT-controller NB	[mm]	200	200
Water demand LT-charge air cooler	[m³/h]	100	130
Temperature LT-charge air cooler inlet	[°C]	38	38

Heat dissipation [*)]			
Specific jacket water heat	[kJ/kWh]	496	496
Specific lube oil heat	[kJ/kWh]	500	500
Lube oil cooler	[kW]	1,495	1,995
Jacket water	[kW]	1,490	1,985
Charge air cooler [3)]	[kW]	–/–	–/–
Charge air cooler (HT-stage) [3)]	[kW]	3,540	4,715
Charge air cooler (LT-stage) [3)] (HT-stage before engine)	[kW]	1,000	1,330
Heat radiation engine	[kW]	510	670

Output 900 kW/Cyl. (HFO and MDO)		12 M 46 DF	16 M 46 DF
Exhaust gas			
Silencer / spark arrestor NB	[mm]	1,200	1,500
Pipe diameter NB after turbine	[mm]	2 x 900	2 x 1,000
Exhaust gas temperature after turbine (intake air 25 °C, diesel) [5]	[°C)	345	335
Exhaust gas mass flow (intake air 25 °C, diesel) [5]	[kg/h]	79,025	105,360
Exhaust gas temperature after turbine (intake air 25 °C, gas) [5]	[°C]	385	375
Exhaust gas mass flow (intake air 25 °C, gas) [5]	[kg/h]	67,154	90,600
Maximum exhaust gas back pressure	[bar]	0.03	0.03
Starting air			
Maximum starting air pressure	[bar]	30	30
Minimum starting air pressure	[bar]	14	14
Air consumption per start [4]	[Nm^3]	3.0	3.5
Air consumption per slow turn maneuver [4]	[Nm^3]	6.0	7.0
Max. allowed crankcase pressure, ND ventilation pipe	[mmWs/mm]	15/200	15/200

- **Wartsila 46DF**

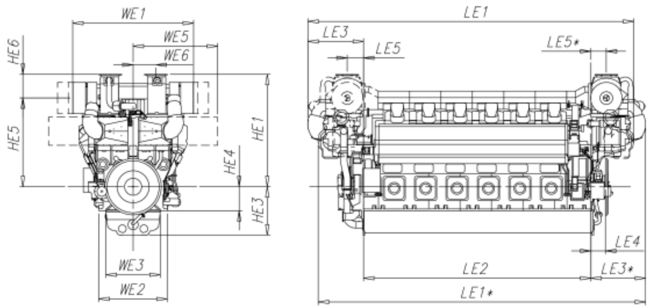


Fig 1.5.2 V-engines (DAAR038992)

Engine	LE1*	LE1	LE2	LE3*	LE3	LE4	LE5*	LE5	HE1	HE3
12V46DF*	11036	-	7600	1921	-	460	430	-	3670	1620
12V46DF	-	10375	7600	-	2043	485	-	684	3670	1620
14V46DF	-	11425	8650	-	2043	485	-	684	3670	1620
16V46DF	-	12687	9700	-	2347	485	-	689	3860	1620

Engine	HE4	HE5	HE6	WE1	WE2	WE3	WE5	WE6	Weight [ton]
12V46DF*	800	3020	650	4555	2290	1820	3225	781	184
12V46DF	800	3020	650	4555	2290	1820	3225	781	184
14V46DF	800	3020	650	4555	2290	1820	3225	781	223
16V46DF	800	3110	750	5174	2290	1820	3225	858	235

Wärtsilä 16V46DF		ME		DE	
		Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**1145**		**1145**	
Engine speed	**rpm**	**600**		**600**	
Engine output	kW	18320		18320	
Mean effective pressure	MPa	2.38		2.38	
Combustion air system (Note 1)					
Flow at 100% load	kg/s	29.5	32.8	29.5	32.8
Temperature at turbocharger intake, max.	°C	45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50
Exhaust gas system (Note 2)					
Flow at 100% load	kg/s	30.2	33.8	30.2	33.8
Flow at 75% load	kg/s	23.2	26.4	22.9	27.5
Flow at 50% load	kg/s	-	19.0	-	23.7
Temperature after turbocharger at 100% load (TE 517)	°C	354	354	354	354
Temperature after turbocharger at 75% load (TE 517)	°C	373	399	405	377
Temperature after turbocharger at 50% load (TE 517)	°C	-	345	-	320
Backpressure, max.	kPa	4		4	
Calculated exhaust diameter for 35 m/s	mm	1394	1473	1394	1473

Heat balance at 100% load (Note 3)					
Jacket water, HT-circuit	kW	1856	2944	1840	2944
Charge air, HT-circuit	kW	4016	4896	4016	4896
Charge air, LT-circuit	kW	1616	1840	1616	1840
Lubricating oil, LT-circuit	kW	1248	2208	1248	2208
Radiation	kW	528	541	528	541
Fuel consumption (Note 4)					
Total energy consumption at 100% load	kJ/kWh	7290	-	7290	-
Total energy consumption at 75% load	kJ/kWh	7450	-	7610	-
Total energy consumption at 50% load	kJ/kWh	7910	-	8250	-
Fuel gas consumption at 100% load	kJ/kWh	7248	-	7248	-
Fuel gas consumption at 75% load	kJ/kWh	7387	-	7551	-
Fuel gas consumption at 50% load	kJ/kWh	7776	-	8105	-
Fuel oil consumption at 100% load	g/kWh	1.0	186	1.0	185
Fuel oil consumption at 75% load	g/kWh	1.3	193	1.3	198
Fuel oil consumption 50% load	g/kWh	3.2	196	3.4	204
Fuel gas system (Note 5)					
Gas pressure at engine inlet, min (PT901)	kPa (a)	517	-	517	-
Gas pressure to Gas Valve unit, min	kPa (a)	517	-	517	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-

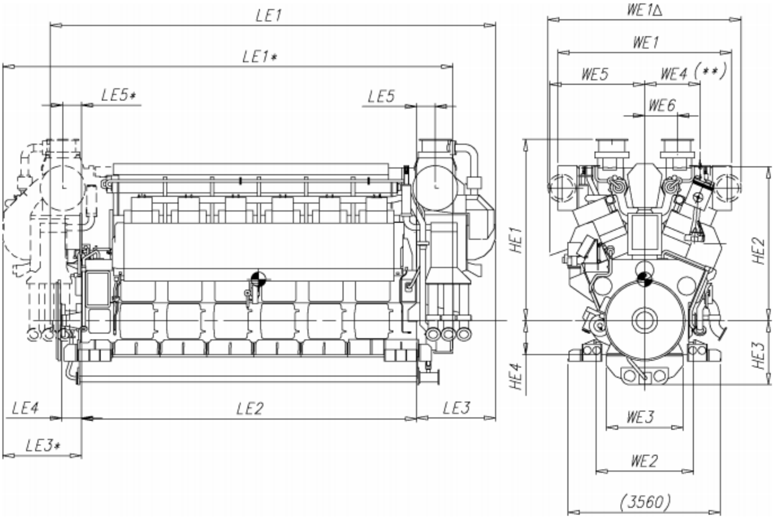
Fuel oil system					
Pressure before injection pumps (PT 101)	kPa	800±0		800±0	
Fuel oil flow to engine, approx	m^3/h	19.2		19.1	
HFO viscosity before the engine	cSt	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	40		40	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	12.0	-	12.0
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	31.1	60.0		60.0
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa	400...800		400...800	
Pilot fuel pressure drop after engine, max	kPa	150		150	
Pilot fuel return flow at 100% load	kg/h	317		317	

Lubricating oil system			
Pressure before bearings, nom. (PT 201)	kPa	450	450
Pressure after pump, max.	kPa	800	800
Suction ability, including pipe loss, max.	kPa	40	40
Priming pressure, nom. (PT 201)	kPa	80	80
Temperature before bearings, nom. (TE 201)	°C	56	56
Temperature after engine, approx.	°C	75	75
Pump capacity (main), engine driven	m^3/h	335	335
Pump capacity (main), electrically driven	m^3/h	331	331
Oil flow through engine	m^3/h	250	250
Priming pump capacity (50/60Hz)	m^3/h	80.0 / 80.0	80.0 / 80.0
Oil volume in separate system oil tank	m^3	30	30
Oil consumption at 100% load, approx.	g/kWh	0.7	0.7
Crankcase ventilation flow rate at full load	l/min	4520	4520
Crankcase volume	m^3	4.2	4.2
Crankcase ventilation backpressure, max.	Pa	300	300
Oil volume in turning device	l	68.0...70.0	68.0...70.0
Oil volume in speed governor	l	7.1	7.1

HT cooling water system			
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	530	530
Temperature before cylinders, approx. (TE 401)	°C	74	74
Temperature after charge air cooler, nom.	°C	91	91
Capacity of engine driven pump, nom.	m^3/h	340	340
Pressure drop over engine, total	kPa	100	100
Pressure drop in external system, max.	kPa	150	150
Pressure from expansion tank	kPa	70...150	70...150

LT cooling water system			
Pressure at engine, after pump, nom. (PT 471)	kPa	250+ static	250+ static
Pressure at engine, after pump, max. (PT 471)	kPa	530	530
Temperature before engine, max. (TE 471)	°C	38	38
Temperature before engine, min. (TE 471)	°C	25	25
Capacity of engine driven pump, nom.	m^3/h	340	340
Pressure drop over charge air cooler	kPa	50	50
Pressure drop in external system, max.	kPa	200	200
Pressure from expansion tank	kPa	70...150	70...150
Starting air system (Note 6)			
Pressure, nom. (PT 301)	kPa	3000	3000
Pressure at engine during start, min. (20 °C)	kPa	1500	1500
Pressure, max. (PT 301)	kPa	3000	3000
Low pressure limit in starting air vessel	kPa	1800	1800
Consumption per start at 20 °C (successful start)	Nm^3	16.0	16.0
Consumption per start at 20 °C (with slowturn)	Nm^3	19.0	19.0

- **Wartsila 50DF**



Engine	TC	LE1	LE1*	LE2	LE3	LE3*	LE4	LE5	LE5*	HE1	HE2	HE3	HE4
W 12V50DF	NA357	10410	10540	7850	1840	1840	460	500	500	4055	3600	1500	800
	TPL71	10425	10540	7850	1840	1840	460	435	435	4240	3600	1500	800
W 16V50DF	TPL76	13830	13200	10050	2300	2300	460	680	680	4400	3600	1500	800
W 18V50DF	TPL76	14180	-	11150	2300	-	460	680	-	4400	3600	1500	800

Engine	TC	HE5	HE6	WE1	WE1Δ	WE2	WE3	WE4	WE4**	WE5	WE6	Weight
W 12V50DF	NA357	3080	925	3810	4520	2290	1800	1495	1300	2220	765	175
	TPL71	3100	1140	4055	4525	2290	1800	1495	1300	2220	770	175
W 16V50DF	TPL76	3300	1100	4730	5325	2290	1800	1495	1300	2220	930	224
W 18V50DF	TPL76	3300	1100	4730	5325	2290	1800	1495	1300	2220	930	244

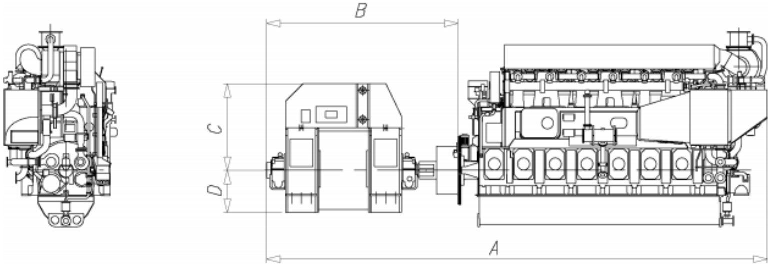
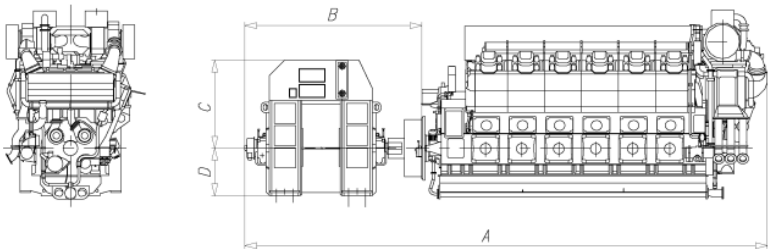


Figure 1.6 Example of total installation lengths, V-engines (DAAE000489)



Engine	A	B	C	D	Genset weight [ton]
W 6L50DF	12940	4940	2235	1090	138
W 8L50DF	15060	5060	2825	1020	171
W 9L50DF	15910	5060	2825	1020	185
W 12V50DF	15475	5253	2593	1365	239
W 16V50DF	17540	4690	2050	1590	288
W 18V50DF	18500	4690	2050	1590	315

Values are indicative only and are based on Wärtsilä 50DF engine with built-on pumps and turbocharger at free end of the engine.

Generator make and type will effect width, length, height and weight.

[All dimensions are in mm]

Wärtsilä 18V50DF		DE IMO Tier 2		DE IMO Tier 2	
		Gas mode	Diesel mode	Gas mode	Diesel mode
Cylinder output	**kW**	**950**		**975**	
Engine speed	**rpm**	**500**		**514**	
Engine output	kW	17100		17550	
Mean effective pressure	MPa	2.0		2.0	
Combustion air system (Note 1)					
Flow at 100% load	kg/s	27.5	33.8	27.5	33.7
Temperature at turbocharger intake, max.	°C	45		45	
Temperature after air cooler, nom. (TE 601)	°C	45	50	45	50
Exhaust gas system					
Flow at 100% load	kg/s	28.2	34.7	28.2	34.7
Flow at 75% load	kg/s	21.3	26.9	21.3	26.9
Flow at 50% load	kg/s	16.2	19.0	16.2	19.0
Temperature after turbocharger at 100% load (TE 517)	°C	373	343	373	343
Temperature after turbocharger at 75% load (TE 517)	°C	424	351	424	351
Temperature after turbocharger at 50% load (TE 517)	°C	426	385	426	385
Backpressure, max.	kPa	4		4	
Calculated exhaust diameter for 35 m/s	mm	1366	1480	1366	1480
Heat balance at 100% load (Note 2)					
Jacket water, HT-circuit	kW	1980	3120	1980	3120
Charge air, HT-circuit	kW	2520	3780	2520	3780
Charge air, LT-circuit	kW	1500	1890	1500	1890
Lubricating oil, LT-circuit	kW	1410	2340	1410	2340
Radiation	kW	480	540	480	540
Fuel consumption (Note 3)					
Total energy consumption at 100% load	kJ/kWh	7300	-	7300	-
Total energy consumption at 75% load	kJ/kWh	7620	-	7620	-
Total energy consumption at 50% load	kJ/kWh	8260	-	8260	-
Fuel gas consumption at 100% load	kJ/kWh	7258	-	7258	-
Fuel gas consumption at 75% load	kJ/kWh	7562	-	7562	-
Fuel gas consumption at 50% load	kJ/kWh	8153	-	8153	-
Fuel oil consumption at 100% load	g/kWh	1.0	189	1.0	189
Fuel oil consumption at 75% load	g/kWh	1.5	192	1.5	192
Fuel oil consumption 50% load	g/kWh	2.4	204	2.4	204
Fuel gas system (Note 4)					
Gas pressure at engine inlet, min (PT901)	kPa (a)	472	-	472	-
Gas pressure to Gas Valve unit, min	kPa (a)	592	-	592	-
Gas temperature before Gas Valve Unit	°C	0...60	-	0...60	-

Fuel oil system					
Pressure before injection pumps (PT 101)	kPa	800±50		800±50	
Fuel oil flow to engine, approx	m³/h	18.2		18.7	
HFO viscosity before the engine	cSt	-	16...24	-	16...24
Max. HFO temperature before engine (TE 101)	°C	-	140	-	140
MDF viscosity, min.	cSt	2.0		2.0	
Max. MDF temperature before engine (TE 101)	°C	45		45	
Leak fuel quantity (HFO), clean fuel at 100% load	kg/h	-	13.6	-	13.6
Leak fuel quantity (MDF), clean fuel at 100% load	kg/h	36.1	68.0	36.1	68.0
Pilot fuel (MDF) viscosity before the engine	cSt	2...11		2...11	
Pilot fuel pressure at engine inlet (PT 112)	kPa	400...800		400...800	
Pilot fuel pressure drop after engine, max	kPa	150		150	
Pilot fuel return flow at 100% load	kg/h	325		325	
Lubricating oil system (Note 5)					
Pressure before bearings, nom. (PT 201)	kPa	400		400	
Pressure after pump, max.	kPa	800		800	
Suction ability, including pipe loss, max.	kPa	40		40	
Priming pressure, nom. (PT 201)	kPa	80		80	
Temperature before bearings, nom. (TE 201)	°C	63		63	
Temperature after engine, approx.	°C	78		78	
Pump capacity (main), engine driven	m³/h	335		345	

Pump capacity (main), electrically driven	m³/h	335	335
Oil flow through engine	m³/h	260	260
Priming pump capacity (50/60Hz)	m³/h	100.0 / 100.0	100.0 / 100.0
Oil volume in separate system oil tank	m³	25	25
Oil consumption at 100% load, approx.	g/kWh	0.5	0.5
Crankcase ventilation flow rate at full load	l/min	4200	4200
Crankcase volume	m³	44.3	44.3
Crankcase ventilation backpressure, max.	Pa	500	500
Oil volume in turning device	l	68.0...70.0	68.0...70.0
Oil volume in speed governor	l	6.2	6.2

HT cooling water system			
Pressure at engine, after pump, nom. (PT 401)	kPa	250 + static	250 + static
Pressure at engine, after pump, max. (PT 401)	kPa	480	480
Temperature before cylinders, approx. (TE 401)	°C	74	74
Temperature after charge air cooler, nom.	°C	91	91
Capacity of engine driven pump, nom.	m³/h	400	400
Pressure drop over engine, total	kPa	50	50
Pressure drop in external system, max.	kPa	150	150
Pressure from expansion tank	kPa	70...150	70...150
Water volume in engine	m³	2.6	2.6

LT cooling water system			
Pressure at engine, after pump, nom. (PT 471)	kPa	250+ static	250+ static
Pressure at engine, after pump, max. (PT 471)	kPa	440	440
Temperature before engine, max. (TE 471)	°C	45	45
Temperature before engine, min. (TE 471)	°C	25	25
Capacity of engine driven pump, nom.	m^3/h	400	200
Pressure drop over charge air cooler	kPa	30	30
Pressure drop in external system, max.	kPa	200	200
Pressure from expansion tank	kPa	70...150	70...150

Starting air system (Note 6)			
Pressure, nom. (PT 301)	kPa	3000	3000
Pressure at engine during start, min. (20 °C)	kPa	1000	1000
Pressure, max. (PT 301)	kPa	3000	3000
Low pressure limit in starting air vessel	kPa	1800	1800
Consumption per start at 20 °C (successful start)	Nm^3	9.0	9.0
Consumption per start at 20 °C (with slowturn)	Nm^3	10.8	10.8

- **MAN 51/60 DF**

V engine – Mechanical propulsion

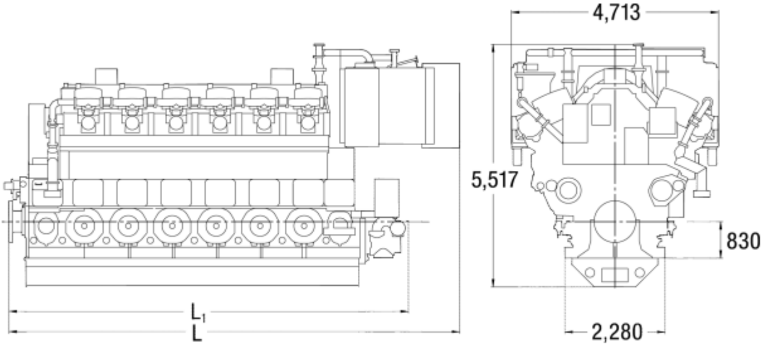


Figure 11: Main dimensions and weights – V engine

No. of cylinders	L	L_1	W	Weight without flywheel
	mm			tons
12V	10,254	9,088	4,713	187
14V	11,254	10,088		213
16V	12,254	11,088		240
18V	13,644	12,088		265
The dimensions and weights are given for guidance only.				

Engine 51/60DF – Electric propulsion/auxiliary GenSet (speed = constant)

975 kW/cyl., 500 rpm or 1,000 kW/cyl., 514 rpm

		L engine					V engine				
% Load		100	85	75	50	25	100	85	75	50	25
Spec. fuel consumption in gas mode without attached pumps[1) 2) 3)]											
a) Natural gas	kJ/kWh	7,275	7,252	7,365	7,662	8,288	7,315	7,292	7,395	7,682	8,288
b) Pilot fuel	g/kWh	2.0	2.3	2.7	4.4	12.0	2.0	2.3	2.7	4.4	12.0
	kJ/kWh	85	98	115	188	512	85	98	115	188	512
c) Total =a + b[4)]	kJ/kWh	7,360	7,350 [5)]	7,480	7,850	8,800	7,400	7,390 [5)]	7,510	7,870	8,800

[1)] Based on reference conditions, see table Reference conditions for fuel consumption, Page 86.

[2)] Tolerance +5 %.

Note! The additions to fuel consumption must be considered before the tolerance for warranty is taken into account.

[3)] Relevant for engine´s certification for compliance with the NO_x limits according E2 test cycle (constant-speed electric propulsion) respectively D2 (constant speed auxiliary engine application).

[4)] Gas operation (including pilot fuel).

[5)] Warranted fuel consumption at 85 % MCR.

	Total lube oil consumption [kg/h][1]							
No. of cylinders	**6L**	**7L**	**8L**	**9L**	**12V**	**14V**	**16V**	**18V**
Speed 500/514 rpm	2.4	2.8	3.2	3.6	4.8	5.6	6.4	7.2
[1] Tolerance for warranty +20 %.								

No. of cylinders		**6L**	**7L**	**8L**	**9L**	**12V**	**14V**	**16V**	**18V**
Swept volume of engine	litre	651	760	868	977	1,303	1,520	1,737	1,955
Control air consumption	Nm^3 [2]	The control air consumption depends highly on the specific engine operation and is less than 1 % of the engine´s air consumption per start.							
Air consumption per start[1]	Nm^3 [2]	2.8	3.2	3.5	3.8	4.8	5.5	6.0	6.7
Air consumption per Jet Assist activation[3]	Nm^3 [2]	4.0	4.0	5.5	5.5	7.9	7.9	7.9	11.3

No. of cylinders		**6L**	**7L**	**8L**	**9L**	**12V**	**14V**	**16V**	**18V**
Air consumption per slow turn manoeuvre[1] [4]	Nm^3 [2]	5.6	6.4	7.0	7.6	9.6	11.0	12.0	13.4

[1] The air consumption per starting manoeuvre/slow turn activation depends on the inertia moment of the unit. The stated air consumption refers only to the engine. For the electric propulsion an higher air consumption needs to be considered due to the additional inertia moment of the generator (approximately 50 % increased).

[2] Nm^3 corresponds to one cubic meter of gas at 0 °C and 101.32 kPa.

[3] The above-mentioned air consumption per Jet Assist activation is valid for a jet duration of 5 seconds. The jet duration may vary between 3 sec. and 10 sec., depending on the loading (average jet duration 5 sec.).

[4] Required for plants with Power Management System demanding automatic engine start. The air consumption per slow turn activation depends on the inertia moment of the unit. This value does not include the needed air consumption for the automically activated engine start after end of the slow turn manoeuvre.

HT cooling water – Engine

	Min.	**Max.**
HT cooling water temperature engine outlet[1]	90 °C[2]	95 °C[3]
HT cooling water temperature engine inlet – preheated before start	60 °C	90 °C
HT cooling water pressure engine inlet[4]	3 bar	4 bar
Pressure loss engine (total, for nominal flow rate)	-	1.3 bar
Only for information:		
+ Pressure loss engine (without charge air cooler)	0.3 bar	0.5 bar
+ Pressure loss HT piping engine	0.2 bar	0.4 bar
+ Pressure loss charge air cooler (HT stage)	0.2 bar	0.4 bar
Pressure rise attached HT cooling water pump (optional)	3.2 bar	3.8 bar

[1] $SaCoS_{one}$ measuring point is outlet cylinder cooling of the engine.

[2] Regulated temperature.

[3] Operation at alarm level.

[4] $SaCoS_{one}$ measuring point is inlet cylinder cooling of the engine.

HT cooling water – Plant

	Min.	Max.
Maximum allowed pressure loss of external HT system (plant)	-	1.9 bar
Needed minimum pressure rise free-standing HT cooling water stand-by pump (plant)	3.2 bar	-
Cooling water expansion tank + Pre-pressure due to expansion tank at suction side of cooling water pump + Pressure loss from expansion tank to suction side of cooling water pump	 0.6 bar -	 0.9 bar 0.1 bar

LT cooling water – Engine

	Min.	Max.
LT cooling water temperature charge air cooler inlet (LT stage)	32 °C[1]	38 °C[2]
LT cooling water pressure charge air cooler inlet (LT stage)	2 bar	4 bar
Pressure loss charge air cooler (LT stage, for nominal flow rate) Only for information: + pressure loss LT piping engine + pressure loss charge air cooler (LT stage)	- - -	0.8 bar 0.3 bar 0.5 bar
Pressure rise attached LT cooling water pump (optional)	3.2 bar	3.8 bar

[1] Regulated temperature.

[2] In accordance with power definition. A reduction in power is required at higher temperatures/lower pressures.

LT cooling water – Plant

	Min.	Max.
Maximum allowed pressure loss of external LT system (plant)	-	2.4 bar
Needed minimum pressure rise free-standing LT cooling water stand-by pump (plant)	3.2 bar	-
Cooling water expansion tank + Pre-pressure due to expansion tank at suction side of cooling water pump + Pressure loss from expansion tank to suction side of cooling water pump	 0.6 bar -	 0.9 bar 0.1 bar

Lube oil

	Min.	Max.
Lube oil temperature engine inlet	50 °C[1]	60 °C[2]
Lube oil temperature engine inlet - preheated before start	40 °C	50 °C[3]
Lube oil pressure (during engine operation) – Engine inlet L engine V engine – Turbocharger inlet	 4 bar 5 bar 1.5 bar	 5 bar 5.5 bar 1.7 bar
Prelubrication/postlubrication (duration ≤ 10 min) lube oil pressure – Engine inlet L engine V engine – Turbocharger inlet	 0.3 bar[4] 0.3 bar[4] 0.2 bar	 5 bar 5.5 bar 1.7 bar
Prelubrication/postlubrication (duration > 10 min) lube oil pressure – Engine inlet – Turbocharger inlet	 0.3 bar[4] 0.2 bar	 0.6 bar 0.6 bar

Fuel – Main fuel

	Min.	Max.
Fuel temperature engine inlet – MGO (DMA, DMZ) and MDO (DMB) according ISO 8217-2010 – HFO according ISO 8217-2010	 –10 °C[1] -	 45 °C[2] 150 °C[3]
Fuel viscosity engine inlet – MGO (DMA, DMZ) and MDO (DMB) according ISO 8217-2010 – HFO according ISO 8217-2010, recommended viscosity	 1.9 cSt 12.0 cSt	 14.0 cSt 14.0 cSt
Fuel pressure engine inlet	6.0 bar	8.0 bar
Fuel pressure engine inlet in case of black out (only engine start idling)	0.6 bar	-
Differential pressure (engine inlet/engine outlet)	1.0 bar	-
Fuel return, fuel pressure engine outlet	2.0 bar	-
Maximum pressure variation at engine inlet	-	± 0.5 bar
HFO supply system + Needed minimum pressure rise free-standing HFO supply pump (plant) + Needed minimum pressure rise free-standing HFO circulating pump (booster pumps, plant) + Needed minimum absolute design pressure free-standing HFO circulating pump (booster pumps, plant)	 7.0 bar 7.0 bar 10.0 bar	 - - -
MDO/MGO supply system + Needed minimum pressure rise free-standing MDO/MGO supply pump (plant)	 7.0 bar	 -
Fuel temperature within HFO day tank (preheating)	75 °C	X[3]

[1] Maximum viscosity not to be exceeded. "Pour point" and "Cold filter plugging point" have to be observed.
[2] Not allowed to fall below minimum viscosity.
[3] Temperature at which viscosity of 12 cSt will be reached.

Fuel – Pilot fuel

	Min.	Max.
Fuel temperature engine inlet – MGO (DMA, DMZ) and MDO (DMB) according ISO 8217-2010	 –10 °C[1]	 45 °C[2]
Fuel viscosity engine inlet – MGO (DMA, DMZ) and MDO (DMB) according ISO 8217-2010	 1.9 cSt	 11.0 cSt
Pilot fuel pressure engine inlet	5.0 bar	9.0 bar
Pilot fuel return, fuel pressure engine outlet	0.2 bar	0.4 bar

[1] Maximum viscosity not to be exceeded. "Pour point" and "Cold filter plugging point" have to be observed.
[2] Not allowed to fall below minimum viscosity.

Water Heated Vaporizer
VWU Series

Description

Cryoquip Water-Heated VWU series Vaporizers are fully engineered shell and tube heat exchange units for vaporizing and superheating cryogenic liquids: O_2, N_2, Ar, He, H_2, LNG, CO_2 and others. The shell side utilizes cooling water, seawater, Glycol mix, or other heat transfer fluids. Shell and tube vaporizers can reduce the strain on cooling towers by providing a convenient source of cooling duty while also achieving vaporization of the cryogen. This form of process heat integration reduces plant utility cost. Performance of the unit is solely dependent on the shell side fluid temperature and flow-rate, which allows for simplified operation. The addition of the SPIRO-VANE® enhancement virtually eliminates film boiling in the vaporizing zone contributing to higher heat transfer rates, prevention of liquid slugging and highly efficient performance. Uses include process, back-up, fueling, energy and disposal stream applications. The VWU series is also an excellent choice for Shipboard LNG fueling and mobile / transportation rail / truck LNG vaporizer fueling applications.

Feature

- Stainless steel process bundle material is standard, carbon steel shell
- Tube bundle is easily removed for inspection or cleaning. U-tube hairpin bundle allows for free thermal expansion and contraction of all tubes eliminating thermal stress
- The tube bundle and shell are certified to Section VIII, Div. 1 of the ASME pressure vessel code as standard

Options Available

- Variety of highly corrosion-resistant materials options for highly corrosive environments: AL-6XN, 254-SMO, Monel, Inconel.
- If desired, multiple vaporizers and/or pressure building circuits can be built into a single shell, with multiple inlet and outlet nozzles on the tube side for a more compact all-in-one design.
- Pressure vessel codes – PED, SQL/SELO, KGSC, CRN
- Low water flow, Low water temperature and Low process discharge temperature alarm controls
- Weatherproof shell insulation with aluminum or stainless steel jacketing
- High pressures to 6000 psig (414 Barg) and higher
- Railcar, trailer and transport mounting designs for onboard Energy and fueling options such as LNG/CNG
- Maritime approvals available for shipboard installations: DNV, USCG, ABS

Water Heated Vaporizer
VWU Series

Common Models And Dimension

Model	Dimension						Process Connection			
	Height		Length		width		Inlet		Outlet	
	Inches	mm	Inches	mm	Inches	mm	Inches	mm	Inches	mm
VWU-102	36	915	126	3,200	22	559	1.5	38	2	50
VWU-142	36	915	132	3,353	26	661	2	50	3	75
VWU-162	36	915	132	3,353	28	712	3	75	4	100
VWU-182	36	915	132	3,353	30	762	3	75	4	100
VWU-202	48	1,220	132	3,353	32	813	4	100	6	150
VWU-222	48	1,220	132	3,353	34	864	4	100	6	150
VWU-242	48	1,220	144	3,658	36	915	6	150	8	200
VWU-302	48	1,220	228	5,792	42	1,067	6	150	8	200

Flowrate Capacities for Water and Process Fluids

Model	LOX/LIN/LAR		LNG		Shell Side Nozzle Size		Flow Rate at 180°F	
	SCFH	Nm^3/hr	SCFH	Nm^3/hr	Inches	mm	GPM	Liter/min
VWU-102	100,000	2,629	50,000	1,314	3	75	100	379
VWU-142	250,000	6,572	125,000	3,286	4	100	225	852
VWU-162	350,000	9,200	175,000	4,600	4	100	350	1,325
VWU-182	500,000	13,144	250,000	6,572	6	150	450	1,703
VWU-202	650,000	17,087	300,000	7,886	6	150	600	2,271
VWU-222	750,000	19,716	375,000	9,858	6	150	675	2,555
VWU-242	1,000,000	26,288	500,000	13,144	8	200	900	3,407
VWU-302	1,500,000	39,432	750,000	19,716	8	200	1,250	4,731

Larger sizes are available. Consult the Cryoquip Application Engineering Department for total surface area recommendation on specific applications to vaporize any low temperature fluid.

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VANZETTI®
CRYOGENIC TECHNOLOGY

CRYOGENIC CENTRIFUGAL PUMPS

DSM L SERIES

for ***LIQUEFIED NATURAL GAS (LNG)***

Technical features

- Direct power transmission
- Mechanical seal in rulon
- Inducer to minimize required NPSH
- Low noise emission (< 80 dB)

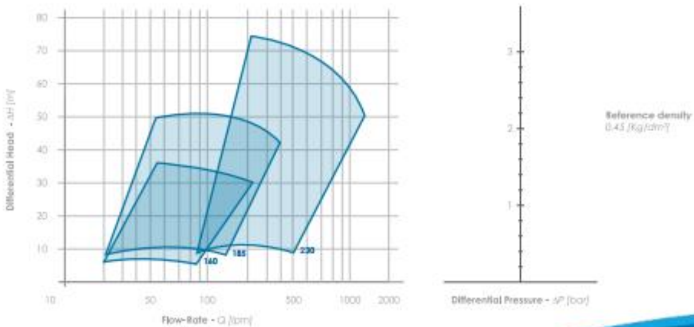
Applications

- Road trailers unloading, storage/iso-containers loading/unloading
- Bunkering
- Process and back-up operations, petrochemical industry applications

Transferred fluids

- LNG

PERFORMANCE			
Model	**DSM 160**	**DSM 185**	**DSM 230**
Transmission		Direct	
Min - max flow rate [lpm]	20 - 215	25 - 315	85 - 1250
Min - max differential head [m]	5,4 - 37	7,6 - 50	8,5 - 74
Max suction pressure [bar]		5	
Maximum allowable pressure [bar]	30	35	28



Optional

- Filter
- Flexible hose for suction, return and by-pass lines
- Leakage detection by temperature sensor
- Flushing system with nitrogen gas
- Temperature sensor for cooling down
- Electical control panel
- Motor suitable for VFD
- Customized electrical control panel available on demand
- Completely automated systems available on demand
- Mobile skid available on demand

Test and controls

- Dimensional control of each mechanical component before assembly
- Running test of each pump with LIN before delivery

Standards

Designed according to:

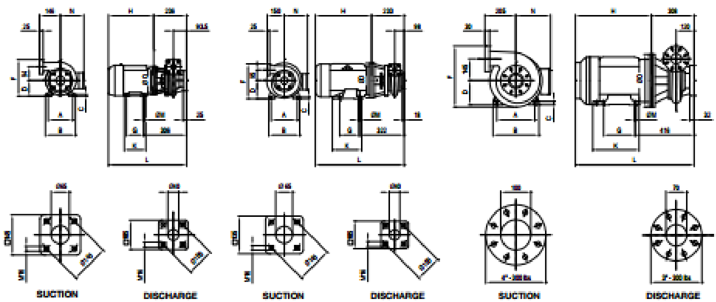
- European Directive 2006/42/CE Machinery
- European Directive PED 97/23/CE
- European Directive 94/9/CE ATEX*
- EIGA/IGC/CGA guidelines

*DSM Centrifugal Pumps are ATEX certified for "zone 1".

II 2G ck IIB T4

GENERAL DIMENSIONS

DSM 160 | DSM 185 | DSM 230



DSM 160 L

Available motor power [kW]	Motor size	A	B	C	D	F	G	H	K	L	M	O	Weight [Kg]
4	112M	190	235	12	112	259	140	415	175	648	12	250	70

DSM 185 L

Available motor power [kW]	Motor size	A	B	C	D	F	G	H	K	L	M	O	Weight [Kg]
5.5	132S	216	272	13	132	280	140	425	222	658	12	300	120
11	160M	254	318	15	160	308	210	583	305	816	14	350	170
15													

DSM 230 L

Available motor power [kW]	Motor size	A	B	C	D	F	G	H	K	L	M	O	Weight [Kg]
11	160M	254	318	15	160	425	210	583	305	891	14	350	220
15													270
18.5	160L	254	318	15	160	425	254	583	305	891	14	350	270

Data can be subjected to change

ISO 9001

Certified quality management system

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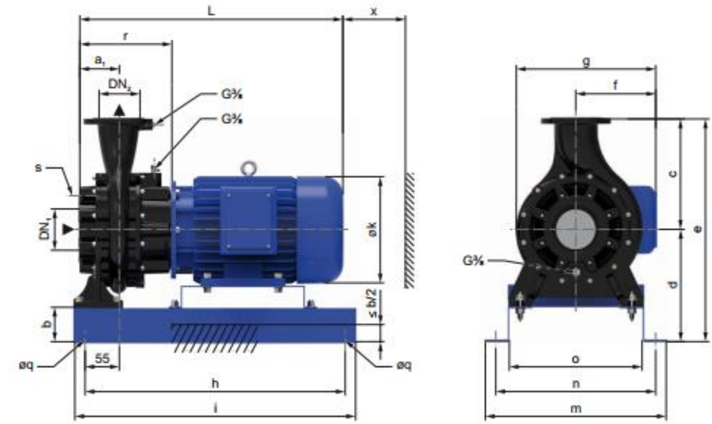
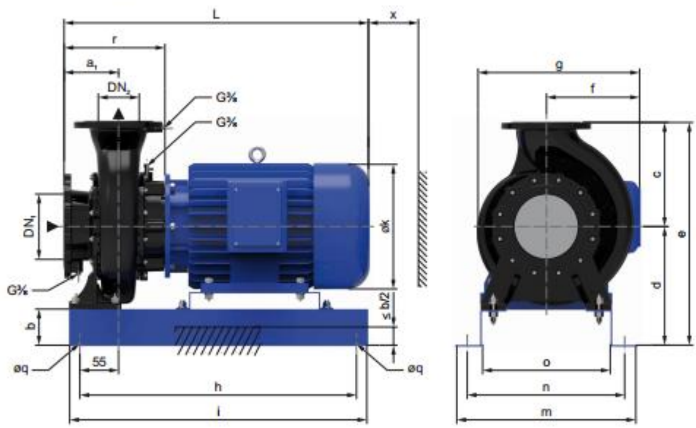
herborner.F-PM Dimensions • Weights

Version with blind hole thread and base rail (≥ 37 kW)



Version with flange and base rail (≥ 37 kW)

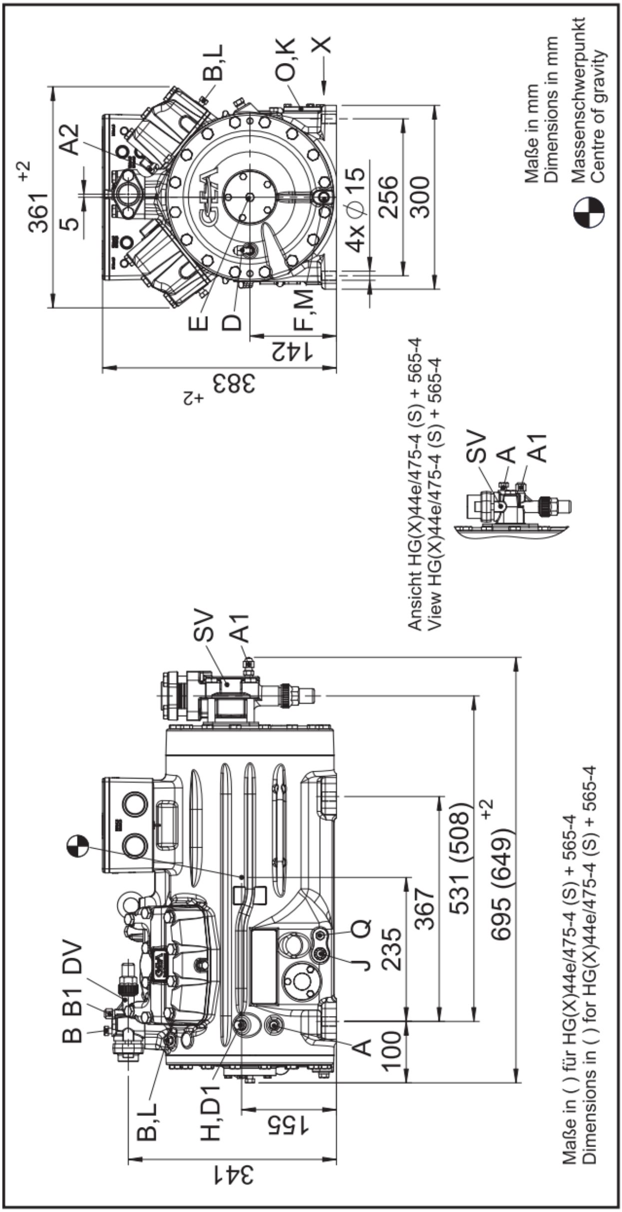


Flange connection dimensions according to DIN 2501 PN 10

Dimensions with frequency converter for direct installation on request.

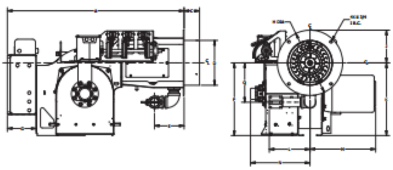
Model	P_2 [kW]	DN_2	DN_1	L	a_1	a_2	b	c	d	e	F	g	h	i	øk	m	n	o	q	r	s	x_{min}	m[1] [kg]
F025-160A[2]	0.37	25	50	380	80	35	12	160	132	292	122	229	70	100	138	240	190	140	15	168	4xM16	150	31
F032-160A[2]	0.37	32	50	380	80	35	12	160	132	292	122	229	70	100	138	240	190	140	15	168	4xM16	150	32
F032-200A[2]	0.55	32	50	402	80	39	13	180	160	340	135	260	70	100	139	240	190	140	15	161	4xM16	150	38
F032-200A[2]	0.75	32	50	402	80	39	13	180	160	340	135	260	70	100	139	240	190	140	15	161	4xM16	150	39
F032-200A[2]	1.1	32	50	430	80	39	13	180	160	340	135	260	70	100	157	240	190	140	15	166	4xM16	150	43
F032-250A[2]	1.5	32	50	438	100	46	15	225	180	405	155	260	95	125	192	320	250	190	15	147	4xM16	150	58
F032-250A[2]	2.2	32	50	502	100	46	15	225	180	405	155	305	95	125	192	320	250	190	15	186	4xM16	150	67
F032-250B[2]	2.2	32	50	502	100	46	15	225	180	405	155	305	95	125	192	320	250	190	15	186	4xM16	150	68
F040-160A[2]	0.37	40	65	380	80	33	12	160	132	292	122	232	70	100	138	240	190	140	15	168	4xM16	150	31
F040-160A[2]	0.55	40	65	409	80	33	12	160	132	292	120	230	70	100	139	240	190	140	15	168	4xM16	150	33
F040-160A[2]	0.75	40	65	409	80	33	12	160	132	292	120	230	70	100	139	240	190	140	15	168	4xM16	150	34
F040-220A[2]	1.1	40	65	458	100	55	13	200	160	360	157	295	70	100	157	265	212	165	15	194	4xM16	150	54
F040-220A[2]	1.5	40	65	485	100	55	13	200	160	360	157	295	70	100	176	265	212	165	15	194	4xM16	150	56
F040-270A[2]	2.2	40	65	504	100	52	13	200	180	380	157	295	70	100	177	265	212	165	15	188	4xM16	150	71
F040-270A[2]	3	40	65	513	100	52	13	234	180	414	178	340	95	125	196	320	250	190	15	197	4xM16	150	79
F040-270A[2]	4	40	65	573	100	52	13	234	180	414	178	340	95	125	196	320	250	190	15	197	4xM16	150	86
F040-270A[2]	5.5	40	65	606	100	52	13	234	180	414	178	340	95	125	220	320	250	190	15	200	4xM16	150	90
F050-140A[2]	0.55	50	65	458	128	80	17	160	132	292	130	245	95	139	157	240	190	140	15	217	4xM16	150	48
F050-140A[2]	0.75	50	65	458	128	80	17	160	132	292	130	245	95	139	157	240	190	140	15	217	4xM16	150	49
F050-140A[2]	1.1	50	65	489	128	80	17	160	132	292	130	245	65	157	177	240	190	140	15	225	4xM16	150	53
F050-160A[2]	0.75	50	65	429	100	54	17	180	160	340	132	248	70	100	139	265	212	165	15	188	4xM16	150	40
F050-160A[2]	1.1	50	65	461	100	54	17	180	160	340	132	248	70	100	157	265	212	165	15	197	4xM16	150	45
F050-190A[2]	1.5	50	65	485	100	54	16	200	160	360	150	278	70	100	176	265	212	165	15	194	4xM16	150	51
F050-190A[2]	2.2	50	65	510	100	54	16	200	160	360	150	278	70	100	177	265	212	165	15	194	4xM16	150	55
F050-190A[2]	3	50	65	510	100	54	16	200	160	360	150	278	70	100	196	265	212	165	15	194	4xM16	150	62
F050-190B[2]	2.2	50	65	510	100	54	16	200	160	360	150	278	70	100	177	265	212	165	15	194	4xM16	150	55
F050-240A[2]	1.5	50	65	478	100	58	17	220	180	400	170	320	95	125	176	320	250	190	15	187	4xM16	150	57
F050-240A[2]	2.2	50	65	503	100	58	17	220	180	400	170	320	95	125	177	320	250	190	15	187	4xM16	150	62
F050-240A[2]	3	50	65	513	100	58	17	220	180	400	170	320	95	125	196	320	250	190	15	197	4xM16	150	70
F065-200A[2]	1.1	65	80	472	100	34	17	225	180	405	150	285	95	125	157	320	250	170	15	208	4xM16	150	58
F065-200A[2]	1.5	65	80	499	100	34	17	225	180	405	150	285	95	125	176	320	250	170	15	208	4xM16	150	61
F065-200A[2]	2.2	65	80	515	100	34	17	225	180	405	150	285	95	125	177	320	250	170	15	199	4xM16	150	65
F065-220A[2]	2.2	65	80	510	100	50	15	250	180	430	170	316	95	125	177	320	250	190	15	194	4xM16	150	66
F065-220A[2]	3	65	80	510	100	50	15	250	180	430	170	316	95	125	196	320	250	190	15	194	4xM16	150	73
F065-220A[2]	4	65	80	570	100	50	15	250	180	430	170	316	95	125	196	320	250	190	15	194	4xM16	150	80
F065-240A[2]	3	65	80	516	100	54	17	250	200	450	184	340	120	160	196	360	280	200	19	200	4xM16	150	80
F065-240A[2]	4	65	80	576	100	54	17	250	200	450	184	340	120	160	196	360	280	200	19	200	4xM16	150	87
F065-270A[2]	4	65	80	574	100	52	17	240	200	440	184	345	120	160	196	360	280	200	19	198	4xM16	150	93
F065-270A[2]	5.5	65	80	604	100	52	17	240	200	440	184	345	120	160	220	360	280	200	19	198	4xM16	150	97
F065-270C[2]	5.5	65	80	607	100	57	17	250	200	450	192	365	120	160	220	360	280	200	19	201	4xM16	150	99
F065-300B[2]	7.5	65	80	662	125	62	15	275	225	500	211	402	120	160	258	400	315	240	19	233	4xM16	150	142
F065-300B[2]	11	65	80	746	125	62	15	275	225	500	211	402	120	160	260	400	315	240	19	236	4xM16	150	163
F080-170A[3]	1.1	80	100	499	140	80	19	225	180	405	165	302	120	160	157	320	250	190	19	235	-	150	56
F080-170A[3]	1.5	80	100	526	140	80	19	225	180	405	165	302	120	160	176	320	250	190	19	235	-	150	59
F080-170A[3]	2.2	80	100	566	140	80	19	225	180	405	165	302	120	160	177	320	250	190	19	250	-	150	65
F080-210A[2]	4	80	100	600	125	69	19	250	190	440	188	348	95	125	196	345	280	215	15	224	8xM16	150	86
F080-210A[2]	5.5	80	100	630	125	69	19	250	190	440	188	348	95	125	220	345	280	215	15	224	8xM16	150	93
F080-255A[2]	3	80	100	537	125	68	17	280	200	480	190	357	120	160	196	400	315	240	19	221	8xM16	150	91
F080-255A[2]	4	80	100	597	125	68	17	280	200	480	190	357	120	160	196	400	315	240	19	221	8xM16	150	98
F080-255A[2]	5.5	80	100	627	125	68	17	280	200	480	190	357	120	160	220	400	315	240	19	221	8xM16	150	102
F080-330A[2]	11	80	100	757	125	54	15	315	250	565	248	462	120	160	260	400	315	240	19	247	8xM16	150	186
F080-330A[2]	15	80	100	794	125	54	15	315	250	565	248	462	120	160	313	400	315	240	19	247	8xM16	150	214
F080-330A[2]	18.5	80	100	897	125	54	15	315	250	565	253	467	120	160	315	400	315	240	19	301	8xM16	150	259
F080-330A[2]	22	80	100	923	125	54	15	315	250	565	270	477	120	160	350	400	315	240	19	301	8xM16	150	284

- BOG Compressor

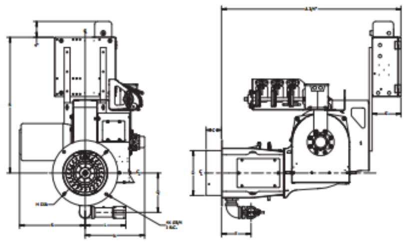


Standard Dimensions
V Series

VG - VL - VLG: Gas, #2 Oil, Gas/Oil Configuration



Standard Configuration



Inverted Configuration

	DIM	Burner Frame Size Size 1	Size 2	Size 3	Size 4
Length in inches					
Overall length	A	37 1/4	40 3/8	45 1/4	51 1/8
Width in inches					
Center line to right side (Standard)	M	14	13 5/8	16 7/8	21 7/8
Center line to left side (Standard)	N	12 7/16	13 7/8	15 1/4	15 1/4
Center line to right side (Inverted)	N	12 7/16	13 7/8	15 1/4	15 1/4
Center line to left side (Inverted)	S	14	13 5/8	16 7/8	21 7/8
Height in inches					
Center line to top (Standard)	J	9 1/2	9 1/8	8 3/8	9 3/4
Center line to bottom (Standard)	K	11 3/4	14 7/16	18 5/8	19 1/4
Center line to burner support (Standard)	P	11 3/4	14 7/16	18 5/8	19 1/4
Center line to top (Inverted)	R	28	30 5/8	34 3/4	35 1/2
Center line to center line of main gas inlet (Inverted)	Q	6 7/8	8 7/8	10 1/8	11 3/4
Blast tube dimensions in inches					
Extension (Standard)	C STD	4	4	4	5
Extension (Maximum)	C MAX	5	5	5	6
Diameter	D STD	8 1/4	10	11 1/2	13 5/8
Panel box depth in inches					
Panel box depth	G	7 3/8	7 3/8	7 3/8	7 3/8
Mounting flange dimensions in inches					
Diameter	H	12 7/8	15	16 3/4	17 1/2
Bolt circle diameter	I	11 1/4	13 1/4	15 1/4	15 3/8
Gas inlet measurement in inches					
Center line to main gas inlet	L	9 5/8	9 5/8	10 1/2	11
Mounting flange to main gas inlet	E	6 7/8	7 1/4	7 5/8	9 1/2

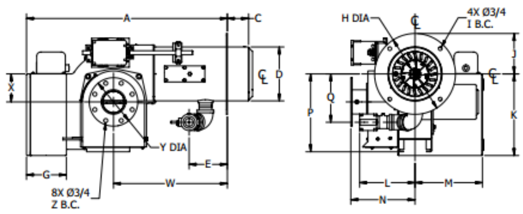
Accompanying dimensions, while sufficiently accurate for layout purposes, must be confirmed for construction.

Standard Ratings
V Series

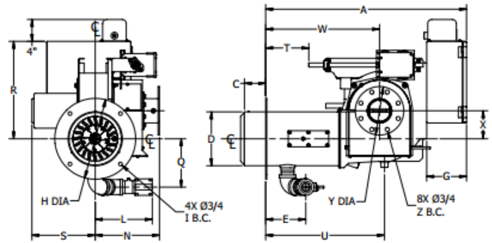
VG - VL - VLG: Gas, #2 Oil, Gas/Oil Configuration

Model No. & Frame Size	Gas Input MBH	Oil Input GPH	BHP @ 80% Eff.	Blower Motor HP[1]	Blower Motor HP[2]	Remote Oil Pump Motor HP[3]	Furnace Pressure ("w.c.)	Standard Gas Train Pipe Size (in.)	Min. Gas Pressure ("w.c.)[6]	Voltage
V-13-1	1,300	9.3	31	1/2	3/4	1/2	0.4	1	8.6/9.2[5]	115 / 230 / 1
V-15-1	1.500	10.7	36	1/2	3/4	1/2	0.5	1	11.4/11.7[5]	
V-17-1	1.700	12.1	40	1/2	3/4	1/2	0.7	1	14.3/14.7[5]	
V-20-1	2,000	14.3	48	3/4	1	1/2	0.9	1	19.7/20.2[5]	
V-21-1	2,100	15.0	50	3/4	1	1/2	1.0	1	21.5/22.1[5]	
V-25-1	2,500	17.9	60	3/4	1	1/2	1.2	1 1/2	9.6/10.4[5]	
V-30-1	3,000	21.4	71	3/4	1	1/2	1.4	2	8.7	
V-34-1	3,400	24.3	81	3/4	1	1/2	1.8	2	10.3	
V-35-2	3,500	25.0	83	1	1 1/2	1/2	1.9	2	8.1	
V-40-2	4,000	28.6	95	1	1 1/2	1/2	1.2	2	10.4	
V-42-2	4,200	30.0	100	1 1/2[4]	2	1/2	1.3	2	11.5	208 / 230 / 460 / 3
V-45-2	4,500	32.1	107	2	2	1/2	1.4	2	10.8	
V-50-2	5,000	35.7	119	2	3	3/4	1.8	2	13.6	
V-54-2	5,400	38.6	129	3	3	3/4	2.1	2	19.2	
V-55-2	5,500	39.3	131	3	3	3/4	2.2	2	19.7	
V-60-3	6,000	42.9	143	5	-	3/4	2.7	2	17.6	
V-63-3	6,300	45.0	150	5	-	3/4	1.8	2	19.3	
V-70-3	7,000	50.0	167	5	-	3/4	2.2	2 1/2	15.7	
V-80-3	8,000	57.1	190	5	-	1	2.8	2 1/2	14.8	
V-84-3	8,400	60.0	200	7 1/2	-	1	3.1	2 1/2	15.2	460 / 3
V-90-3	9,000	64.3	214	7 1/2	-	1 1/2	3.5	2 1/2	17.4	
V-100-3	10,000	71.4	238	10	-	1 1/2	2.7	2 1/2	20.5	
V-105-3	10,500	75.0	250	10	-	1 1/2	2.8	2 1/2	44.7	
V-110-3	11,000	78.6	262	10	-	1 1/2	3.0	2 1/2	48.7	
V-120-4	12,000	85.7	286	15	-	1 1/2	3.6	2 1/2	34.2	
V-126-4	12,600	90.0	300	15	-	1 1/2	4.3	2	49.1	
V-147-4	14,700	105.0	350	15	-	1 1/2	4.3	2	2.5 PSI	
V-168-4	16,800	120.0	400	15	-	1 1/2	1.0	2	3.1 PSI	

Standard equipment:	Combustion Control System options:	Fuel options:
3450 RPM motor, panel signal lights (Power On, Main Fuel, Ignition, Flame Failure), combustion air proving switch, safety shutoff valves, 120/1/60 control circuit, burner mounted panel with standard or inverted configuration, and a shipped loose gas train (where applicable).	Parallel Positioning Combustion Control System with O_2 Trim and Variable Frequency Drive (VFD)	Main Fuel: Natural gas (VG), #2 oil - pressure atomized (VL) or Combination gas/ #2 oil - pressure atomized (VLG). Igniter Fuel: Natural gas and/or propane. Fuel Changeover Switch: Combination gas/oil units only (VLG).



CB STANDARD CONFIGURATION



CB INVERTED CONFIGURATION

BURNER MODEL	A	C STD	C MAX	D STD*	D FIRE*	E	G	H	I	J	K	L	M	N	P	Q	R	S	T	U	W	X	Y	Z
SIZE-1	32 3/4	4	5	8 1/4	7 1/2	6 1/2	7 3/8	12 7/8	11 1/4	6 1/2	14 3/8	9 3/4	13	11 3/8	11 3/4	7 1/4	18 1/4	11 1/4	7 1/8	16 3/4	18 1/4	4	9	7 1/2
SIZE-2	37 1/4	4	5	10	9 3/4	7 1/8	7 3/8	15	13 1/4	7 1/2	15 1/8	10 1/4	12 1/2	12	14 1/2	9	18 1/4	11 3/4	8	22	21 1/8	5 1/4	9	7 1/2
SIZE-3	44 1/4	4	5	11 1/2	10 3/4	8	7 3/8	16 3/4	15 1/4	8 3/8	17 3/8	12 1/8	12 1/2	14 1/2	18 5/8	10 1/4	19 3/4	15 1/4	8 3/8	26 1/2	25 3/8	7 7/8	9	7 1/2
SIZE-4	50 1/4	5	6	13 5/8	12 1/8	8 1/4	7 3/8	17 1/2	15 3/8	8 3/4	20 1/8	12 1/8	12 1/2	17	19 1/4	12 1/2	19 1/2	21 3/4	8 1/2	31 1/2	30 1/4	7 1/8	11	9 1/2

NOTES

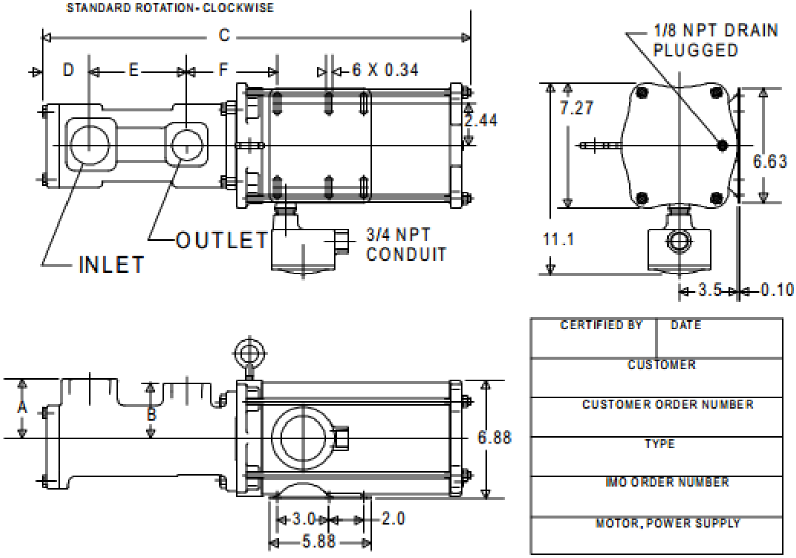
1 - "D STD" COLUMN TO BE USED FOR (WATERTUBE, CAST IRON, FIREBOX) APPLICATIONS
"D FIRE" COLUMN TO BE USED FOR (FIRETUBE) APPLICATIONS

656-00037

- Pilot Fuel Pump

MODEL 3E CAST IRON CANNED MOTOR PUMPS

ALL DIMENSIONS IN INCHES
STANDARD ROTATION- CLOCKWISE



MODEL NUMBER	INLET#	OUTLET#	A	B	C	D	E	F	WEIGHT-LBS.
W0*003E087SPCV	1	1	2.63	2.63	19.94	1.56	2.13	4.86	9 + MOTOR**
W0*003E087SCCV	1	1	2.63	2.63	19.94	1.56	2.13	4.86	9 + MOTOR**
W0*003E095SCCV	1	1	2.63	2.63	19.94	1.56	2.13	4.86	9 + MOTOR**
W0*003E118SPCV	1-1/2	1	3.26	3.26	22.04	1.86	3.88	4.85	27 + MOTOR**
W0*003E118SCCV	1-1/2	1	3.26	3.26	22.04	1.86	3.88	4.85	27 + MOTOR**
W0*003E143SJCV	2	1-1/2	3.63	3.38	24.81	2.74	5.63	5.22	38 + MOTOR**
W0*003E143SCCV	2	1-1/2	3.63	3.38	24.81	2.74	5.63	5.22	38 + MOTOR**
W0*003E162SCCV	2	1-1/2	3.63	3.38	24.81	2.74	5.63	5.22	38 + MOTOR**
W0*003E187SCCV	2-1/2	2	4.5	4.5	28.69	3.75	5.81	7.66	92 + MOTOR**
W0*003E200SCCV	2-1/2	2	4.5	4.5	28.69	3.75	5.81	7.66	92 + MOTOR**

* DIMENSIONS APPLY TO MOTOR SIZES 02, 03, 05, AND 06.
** MOTOR WEIGHTS: 02 = 68 LBS.; 03 = 71 LBS.; 05 = 74 LBS.; 06 = 77 LBS.
# INLET AND OUTLET ARE NPT THREADED.
PUMP MAY BE ROTATED IN 90 DEGREE INCREMENTS RELATIVE TO THE PLANE OF THE MOTOR FOOT.
INLET HEAD ON SIZES 187 & 200 MAY BE ROTATED IN 90 DEGREE INCREMENTS RELATIVE TO THE PUMP OUTLET.

IMO PUMP, MONROE, NC 28111-5020, USA

SERIES 3E

Pump Rotor Size 87P — Speed 3450 RPM (60 Hz 2-pole)

	Viscosity SSU	Differential Pressure PSID 25	50	100	150	NIPr PSI*
GPM	33	4.9	4.3	3.4	2.8	
	65	5.3	4.9	4.3	3.8	
	100	5.5	5.2	4.7	4.3	
	650	6.0	5.9	5.7	5.6	
	1000	6.1	6.0	5.8	5.7	
	1500	6.2	6.1	5.9	5.8	
BHP	150	0.26	0.36	0.57	0.78	4.3
	650	0.49	0.60	0.80	1.0	4.4
	1000	0.61	0.71	0.92	1.1	4.5
	1500	0.75	0.86	1.1	1.3	4.6

Pump Rotor Size 87 — Speed 3450 RPM (60 Hz 2-pole)

	Viscosity SSU	Differential Pressure PSID 25	50	100	150	NIPr PSI*
GPM	33	6.7	6.1	5.2	4.6	
	65	7.1	6.7	6.1	5.6	
	100	7.3	7.0	6.5	6.1	
	650	7.8	7.7	7.5	7.4	
	1000	7.9	7.8	7.6	7.5	
	1500	8.0	7.8	7.7	7.6	
BHP	150	0.29	0.42	0.68	0.94	4.6
	650	0.52	0.65	0.91	1.2	4.8
	1000	0.64	0.76	1.0	1.3	4.9
	1500	0.78	0.91	1.2	1.4	5.1

Pump Rotor Size 87P — Speed 2850 RPM (50 Hz 2-pole)

	Viscosity SSU	Differential Pressure PSID 25	50	100	150	NIPr PSI*
GPM	33	3.7	3.0	N/A	N/A	
	65	4.1	3.6	3.0	2.6	
	100	4.3	3.9	3.5	3.1	
	650	4.8	4.7	4.5	4.3	
	1000	4.9	4.8	4.6	4.5	
	1500	4.9	4.8	4.7	4.6	
BHP	150	0.19	0.28	0.45	0.62	4.1
	650	0.35	0.44	0.61	0.78	4.2
	1000	0.43	0.52	0.69	0.86	4.2
	1500	0.53	0.62	0.79	0.96	4.3

Pump Rotor Size 87 — Speed 2850 RPM (50 Hz 2-pole)

	Viscosity SSU	Differential Pressure PSID 25	50	100	150	NIPr PSI*
GPM	33	5.2	4.5	3.7	N/A	
	65	5.6	5.1	4.5	4.0	
	100	5.8	5.4	4.9	4.6	
	650	6.3	6.2	6.0	5.8	
	1000	6.4	6.2	6.1	6.0	
	1500	6.4	6.3	6.2	6.1	
BHP	150	0.21	0.32	0.54	0.75	4.3
	650	0.37	0.48	0.70	0.91	4.4
	1000	0.45	0.56	0.78	0.99	4.5
	1500	0.55	0.66	0.88	1.1	4.6

Pump Rotor Size 87P — Speed 1725 RPM (60 Hz 4-pole)

	Viscosity SSU	Differential Pressure PSID 25	50	100	150	NIPr PSI*
GPM	33	N/A	N/A	N/A	N/A	
	65	1.8	N/A	N/A	N/A	
	100	2.0	N/A	N/A	N/A	
	650	2.5	2.4	2.2	2.0	
	1000	2.6	2.4	2.3	2.2	
	1500	2.6	2.5	2.4	2.3	
BHP	150	0.09	N/A	N/A	N/A	3.7
	650	0.15	0.20	0.31	0.41	3.8
	1000	0.18	0.23	0.34	0.44	3.8
	1500	0.22	0.27	0.37	0.48	3.8

Pump Rotor Size 87 — Speed 1725 RPM (60 Hz 4-pole)

	Viscosity SSU	Differential Pressure PSID 25	50	100	150	NIPr PSI*
GPM	33	N/A	N/A	N/A	N/A	
	65	2.7	2.2	N/A	N/A	
	100	2.9	2.5	N/A	N/A	
	650	3.4	3.2	3.0	2.9	
	1000	3.4	3.3	3.2	3.1	
	1500	3.5	3.4	3.3	3.2	
BHP	150	0.10	0.16	N/A	N/A	3.8
	650	0.16	0.23	0.36	0.49	3.9
	1000	0.19	0.26	0.39	0.52	3.9
	1500	0.23	0.30	0.43	0.56	4.0

Pump Rotor Size 87P — Speed 1425 RPM (50 Hz 4-pole)

	Viscosity SSU	Differential Pressure PSID 25	50	100	150	NIPr PSI*
GPM	33	N/A	N/A	N/A	N/A	
	65	N/A	N/A	N/A	N/A	
	100	1.4	N/A	N/A	N/A	
	650	1.9	1.7	1.5	1.4	
	1000	1.9	1.8	1.7	1.5	
	1500	2.0	1.9	1.8	1.7	
BHP	150	0.07	N/A	N/A	N/A	3.6
	650	0.11	0.15	0.24	0.33	3.7
	1000	0.13	0.17	0.26	0.35	3.7
	1500	0.16	0.20	0.29	0.37	3.7

Pump Rotor Size 87 — Speed 1425 RPM (50 Hz 4-pole)

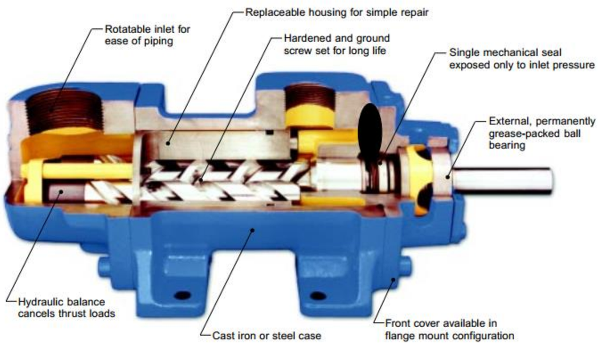
	Viscosity SSU	Differential Pressure PSID 25	50	100	150	NIPr PSI*
GPM	33	N/A	N/A	N/A	N/A	
	65	1.9	N/A	N/A	N/A	
	100	2.1	N/A	N/A	N/A	
	650	2.6	2.5	2.3	2.1	
	1000	2.7	2.6	2.4	2.3	
	1500	2.7	2.6	2.5	2.4	
BHP	150	0.08	N/A	N/A	N/A	3.7
	650	0.12	0.18	0.28	0.39	3.8
	1000	0.14	0.20	0.30	0.41	3.8
	1500	0.17	0.22	0.33	0.44	3.8

(shaded) indicates exceeds current motor size availability N/A=not applicable

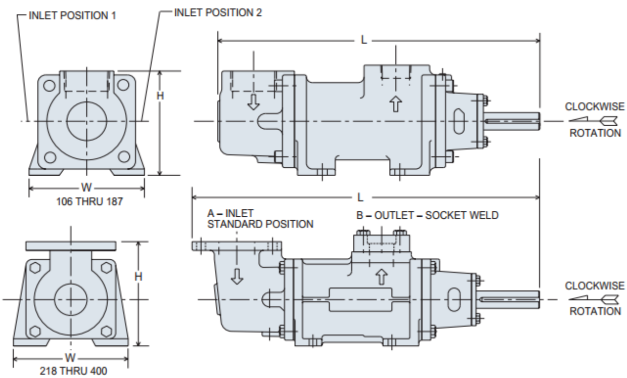
* Net inlet pressure required is the minimum pressure above vapor pressure at pump inlet to prevent cavitation assuming liquid is air and gas free.

- Main Fuel Pump

Imo Series 3D Pump



Shown Above: G3DB-187 foot mounted pump typical of sizes 106 through 187 with iron casing



Size	A		B		H		L		W		WEIGHT	
	INCH	MM	INCH	MM	INCH	MM	INCH	MM	INCH	MM	LBS	KG
106	1	25.4	1	25.4	5 5/8	143	14 7/16	367	6	153	41	18.6
118	1 1/2	38.1	1	25.4	5 7/8	150	15 1/4	388	6 1/4	159	44	20
137	1 1/2	38.1	1	25.4	6 1/8	156	16 11/16	424	6 1/2	166	50	22.7
156	2	50.8	1 1/2	38.1	6 1/2	166	18 5/8	474	7	178	66	30
187, Y, M	2 1/2	63.5	1 1/2	38.1	6 3/4	172	20 5/16	516	7 1/2	191	82	37.3
218,L	3	76.2	2	50.8	9	229	29 3/16	742	9	229	154	70
250,P	4	101.6	2 1/2	63.5	10 3/4	273	32 1/4	820	10	254	202	91.8
275,E	4	101.6	3	76.2	11 1/8	283	32 11/16	831	11	280	246	112
312,P	4	101.6	3	76.2	11 3/4	299	35 1/4	896	12	305	281	128
337,350	5	127	4	101.6	13 1/4	337	38 9/16	980	13	331	410	186
400,P	6	152.4	4	101.6	16	407	41 5/8	1058	14	356	601	273

Type ON

Horizontal Gear Pumps

Specification

Pump body and covers:
Hard fine-grained cast iron

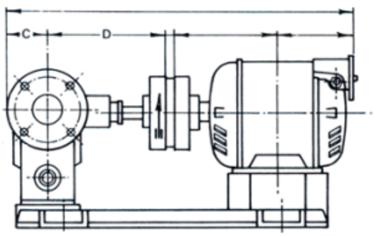
Shafts:
Steel or alloy steel, heat treated and ground to the exact size.

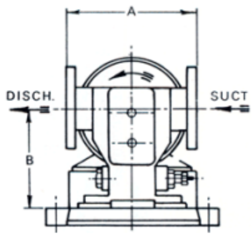
Gears:
Helical teeth in heat treated steel, keyed to the shafts and held in place by lock nuts and washers.

Bearings:
Of ample size and standard manufacture.

Base plate:
Cast iron.

Coupling:
Flexible.





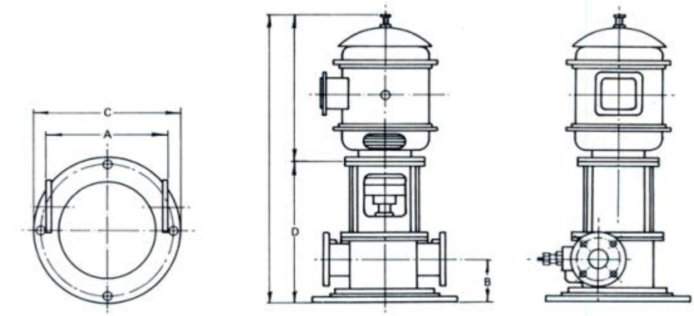
The pump can be furnished right or left hand.

Arrangement

Type:	A	B	C	D	Pipesize	Nozzles			Veight without motor -kg
						O. D. flange	B.C.	Bolt - holes	
ON: 1–2	220	190	65	190	25–1″	115	85	4–15ø	45
ON: 3–4	240	175	75	205	40–1 1/2″	150	110	4–18ø	75
ON: 5–6–7	300	220	90	270	70–2 3/4″	185	145	4–18ø	105
ON: 8–9–10	300	245	135	310	90–3 1/2″	210	170	8–18ø	135
ON: 35/10	360	270	180	348	100–4″	220	180	8–18ø	220
ON: 50/10	400	291	220	398	125–5″	250	210	8–18ø	290
ON: 80/10	450	340	325	530	150–6″	285	240	8–23ø	430
ON: 100/10	450	340	325	530	150–6″	285	240	8–23ø	540

Type ONV

Vertical Gear Pumps



Arrangement

Type:	A	B	C	D	Pipesize	Nozzles O. D. flange	Nozzles B.C.	Nozzles Bolt - holes	Veight without motor -kg
ONV: 3–4	300	112	340	400	40–1½"	150	110	4–18ø	75
ONV: 5–6–7	420	166	500	450	70–2¾"	185	145	4–18ø	105
ONV: 8–9–10	450	170	500	535	90–3½"	210	170	8–18ø	135
ONV: 35/10	440	170	550	685	100–4"	220	180	8–18ø	220
ONV: 50/10	440	210	550	765	125–5"	250	210	8–18ø	290
ONV: 80/10	450	315	540	980	150–6"	285	240	8–23ø	430
ONV: 100/10	450	315	540	980	150–6"	285	240	8–23ø	540

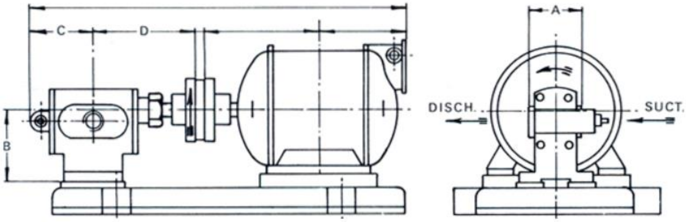
Ratings for ON and ONV

Type:	n = 1150 R.P.M. 15 m Head m³/h	HP	30 m Head m³/h	HP	45 m Head m³/h	HP
ON: 1	2,7	0,4	2,5	0,7	2,3	1,0
ON: 2	4,0	0.8	3,7	1,1	3,4	1,6
ON–V: 3	5,5	1,2	5,2	1,7	4,9	2,3
ON–V: 4	6,5	1,9	6,2	2,4	5,9	3,1
ON–V: 5	13,0	2,7	12,5	3,4	12,0	4,2
ON–V: 6	15,3	3,0	14,7	3,9	14,1	4,9
ON–V: 7	19,0	3,4	18,5	4,3	18,0	5,6
ON–V: 8	25,5	3,8	24,5	5,0	23,5	6,5
ON–V: 9	32,0	4,3	30,5	5,7	29,0	7,5
ON–V: 10	38,0	4,9	36,5	6,5	35,0	8,7
ON–V: 35/10	45,0	9,5	44,0	11,0	43,0	13,0
ON–V: 35–50/10	68,0	12,7	67,0	14,6	66,0	17,0
ON–V: 50/10	70,0	14,8	69,0	17,0	68,0	19,6

Type:	n = 1450 R.P.M. 15 m Head m³/h	HP	25 m Head m³/h	HP	35 m Head m³/h	HP
ON: 1	3,3	0,6	3,2	0,7	3,1	0,9
ON: 2	5,0	0,9	4,8	1,0	4,6	1,2
ON–V: 3	7,2	1,4	6,8	1,5	6,4	1,8
ON–V: 4	9,0	1,7	8,5	1,9	8,0	2,1
ON–V: 5	16,3	2,5	15,8	3,0	15,3	3,7
ON–V: 6	19,8	3,2	19,3	3,9	18,8	4,7
ON–V: 7	25,2	4,2	24,5	4,9	23,8	5,7
ON–V: 8	32,6	5,5	31,8	6,2	31,0	7,1
ON–V: 9	41,0	6,4	39,9	7,3	38,8	8,3
ON–V: 10	46,6	7,2	45,2	8,3	43,8	9,6
ON–V: 35/10	53,0	10,5	51,5	12,0	50,0	13,7
ON–V: 35–50/10	71,0	13,0	69,5	15,0	68,0	17,5

Type ON

Specification:
The same as for type ON except for the bearings which for this type are slidebearings.



Arrangement

Type:	A	B	C	D	Pipesize	Veight without motor-kg
ONT: 5/10	80	112	98	160	3/4P.T.	35
ONT: 7/10	155	120	112	215	1 1/4P.T.	35

Ratings

Type:	n = 950 R.P.M.			
	15 m Head		30 m Head	
	m³/h	HP	m³/h	HP
ONT: 5/10	1,0	0,3	0,9	0,5
ONT: 7/10	1,9	0,6	1,8	1,0

Type:	n = 1150 R.P.M.			
	15 m Head		30 m Head	
	m³/h	HP	m³/h	HP
ONT: 5/10	1,3	0,4	1,2	0,7
ONT: 7/10	2,1	0,6	1,9	1,1

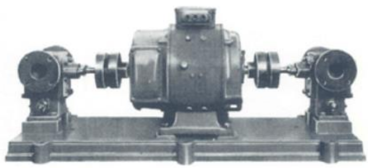
Type:	n = 1450 m R.P.M.			
	15 m Head		30 m Head	
	m³/h	HP	m³/h	HP
ONT: 5/10	1,5	0,5	1,4	0,8
ONT: 7/10	2,7	0,8	2,5	1,4

Type ON + ON

Horizontal twin Gear Pumps

Specification: the same as for type ON:

Twin gear pumps can be executed as shown to the right, driven by one motor with two shaft ends. Pumps can be of same or different size and both can have flexible couplings or one or both can be fitted with a coupling handle to uncouple the pump, which is not wanted in operation.



MIB 303

Solids-retaining centrifugal separator

Application
The MIB 303 separation system is designed for centrifugal separation of sludge and water from mineral oil.

The separator is designed for oils with a maximum density of 920 kg/m³ at 15°C. The maximum separation temperature for gas oil and marine diesel oil is +40°C, and for lubricating oil +70°C, since this is the max. separation temperature for the separator.

Mineral oil
The MIB 303 separator in a cleaning system for distillate and marine diesel oil should be operated as a purifier. For cleaning of lubricating oil, MIB 303 purifier or clarifier can be used.

Concept
The MIB 303 separator features a special design concept for solid-bowl separators. Advanced manufacturing, design and drive technologies have contributed to a separator more compact and lightweight than conventional solid-bowl models.

Features
- No lock ring. Requires only small mechanical force on opening/assembling of the bowl.
- The design allows the bowl wall to be taken out and cleaned with the disc stack still in place.
- Lightweight materials in bowl and discs.
- Direct drive with motor speed controlled by a frequency converter eliminates gears or belts.
- Requires no lubrication.
- The cleaned oil is discharged under pressure, due to the built-in paring disc pump.
- Frequency converter with built-in voltage protector.

Benefits
- Easy to install, operate and maintain. No special training required.
- Small dimensions allow installation in narrow spaces.
- Removal of solid impurities extends intervals between filter replacements, which saves filter costs and reduces filter disposal handling.
- Removal of water from mineral oil improves the reliability of the oil system. It also reduces the risk of bacterial growth in tanks that could clog the filters.
- Electronics protected from voltage variations.

Throughput capacity
The MIB 303 separator has a throughput capacity of max. 760 litres per hour of diesel/gas oil and max. 460 litres per hour of steam turbine lube oil.

Standard equipment
Separator with drive, funnel for water supply with connections and starter for both separator and feed pump.

Ancillary equipment
Necessary for operation are: feed pump, collecting tank with water seal alarm, strainer, valves and fittings.

Available models
The MIB 303 separator is available as a purifier or a clarifier in stand-alone and module versions. There is also a choice between 230 V AC and 110 V AC. In the module version the ancillary equipment mentioned above is built together with the separator to form a compact unit.

Power consumption
700 W ±10%.

Weight of module
68 kg.

Purifier operation
Separation takes place in the rotating solid-wall bowl. The uncleaned oil is fed into the bowl where the centrifugal force makes water and solid particles move out towards the periphery of the bowl, while the clean oil flows inwards.

To establish a water seal during start-up of the separator, water is added to the bowl before the oil feed is started. The water collects in the water seal which drains into the water channel below the bowl.

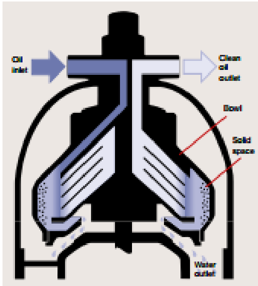
The solids accumulate on the bowl wall and are removed periodically by hand.

The cleaned oil flows towards the centre of the bowl and up to the paring disc. Since the oil is rotating, the stationary paring disc acts as a pump which forces the oil out through the outlet under pressure.

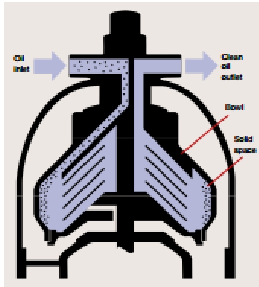
Clarifier operation
In clarifier mode the oil normally does not contain any free water. The separation principle is similar to that of the purifier, although there is no water seal and no water outlet in the bowl and the water handling capacity is limited.

Technical documentation
Complete information and documentation is provided in the instruction book accompanying each MIB 303 separator.

After sales support
Replacement part kits for preventive maintenance at one and two years intervals are available.



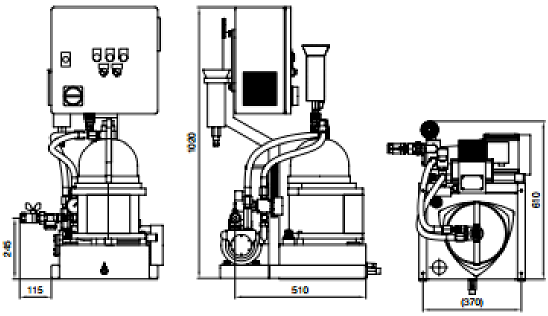
Functional principle of the MIB 303 purifier.



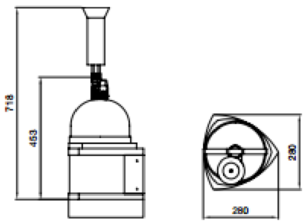
Functional principle of the MIB 303 clarifier.

Dimensions, mm

Module version



Stand-alone version



MMB

Solids-retaining centrifugal separators

MMB 305 solids-retaining separator.

Application

Purification or clarification (optional) of mineral oils used in marine installations and power stations:

- Distillates
- Marine Diesel Oils MDO up to 13 cSt at 40°C
- Lubricating oils for trunk diesel engines operating on distillates and light MDO
- Lubricating oils for steam and gas turbines
- Lubricating and hydraulic oils for hydroelectric power stations

Concept

The MMB series of solids-retaining separators is available in two models, the MMB 304 and MMB 305.

Each MMB separation system comprises:

- An MMB separator
- Ancillary equipment consisting of connections and valve assembly

Optional equipment

- Independent oil feed pump
- Oil heating system, steam or electric
- Water seal alarm MAWA-40

Water seal alarm MAWA-40.

Features and benefits

The unique features of the system are:

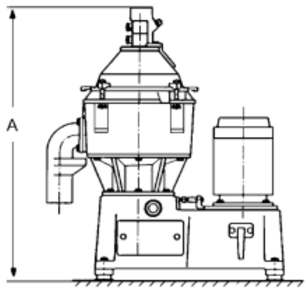
- Compact, robust design
- Internal paring disc for discharge of clean oil
- Large sludge space
- Belt-driven

The major benefits are:

- Easy to install.
  Requires limited space.
- Pressurised discharge of clean oil.
  No need for downstream pump.
- Fewer service manhours.
  Larger sludge space extends operating period between manual cleaning.
- Lower maintenance and spare parts costs.

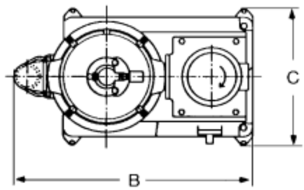
Technical data in brief

	MMB 304	MMB 305
Input voltage supply:	220/230, 380/400, 415, 440 V AC (50/60 Hz)	
Power consumption at max. rec. flow for gas oil:	1.4 kW	2.3 kW



Shipping data

	Dimensions (mm)	
	MMB 304	MMB 305
A	910	935
B	795	795
C	465	465



	Weight (kg)	
Type of equipment	Net	Gross
Separator MMB 304		
– without motor	185	235
– with motor	201	251
Separator MMB 305		
– without motor	190	240
– with motor	218	268

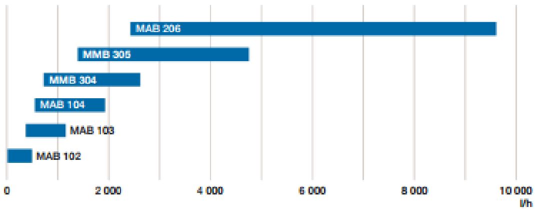
Technical documentation
Complete information and documentation accompany each separator system.

After Sales support
Alfa Laval's Preventive Maintenance Program is available for the MMB 300 series. Alfa Laval service engineers are available to assist you with all types of maintenance and repair, and to help you train your personnel.

The use of genuine Alfa Laval spare parts reduces down-time and repair costs. Spare parts kits can be ordered from Alfa Laval Marine Service Centers and stocked as single units.

Intermediate service kits for routine bowl maintenance and major service kits for bowl overhaul are available.

All service kits include detailed service instructions.



Throughput capacities
The blue bars indicate range from minimum economical throughput on detergent type lubricating oil for trunk diesel engines to a maximum recommended throughput on distillate fuel (1.5–6 cSt/40°C). Detailed information on throughput capacities is provided on separate data sheets for each model.

For more detailed information see the separate data sheet of each model.

MAB 206

Solids-retaining Centrifugal Separator

Efficiant oil cleaning

Clean oil is crucial for the safe, reliable and economical running of virtually all kinds of equipment that uses oils for either fuel, lubrication or in hydraulic systems. Clean oil reduces wear and corrosion on all equipment installed downstream, thus helping avoid breakdowns and cutting back on downtime throughout a plant or installation.

The impact of contaminants in oil

Contaminants in lubricating and hydraulic oils have serious effects on system performance, operating costs and durability.

For example, the presence of solid particles:

- abrades metal surfaces
- increases friction
- clogs filters

Similarly, if water is present in the oil, this:

- causes corrosion
- reacts with additives
- forms oil/water emulsions
- causes significant deterioration in the performance of the oil.
- eliminates or reduces corrosion by removing any waterpresent in the oil

Standard equipment

The separator is working either with two or three phases and could easaly be changed between the two diffrent versions clarifier and purifier.

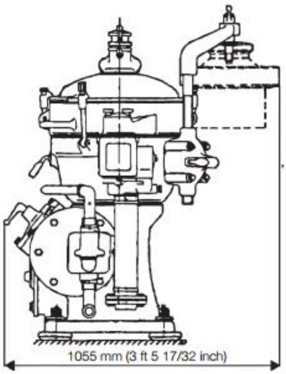
MAB 206 complete with motor

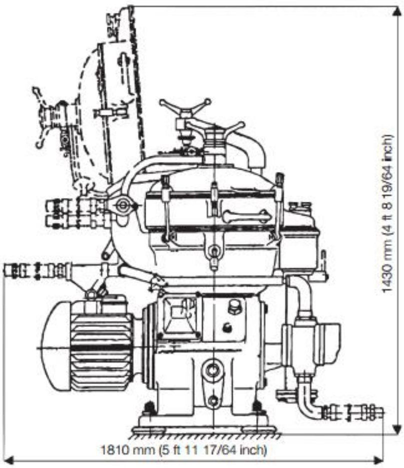
Features and benifits

Compact and robust design with the following benefits:

- Simple installation, operation and maintenance
- Internal paring disc for discharge of clean oil
- Large sludge space
- Sludge basket for easy removal of sludge
- Flexibility: the bowl may be used either as purifier or clarifier
- Extremely reliable, ensuring long service life eliminates or reduces corrosion by removing any waterpresent in the oil

Dimensions





Clarifier
1. Oil inlet
2. Clean oil outlet
3. Sludge

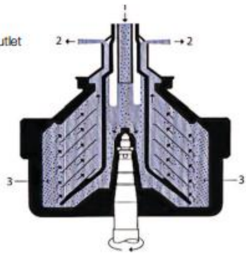


Fig 2 MAB bowl arranged as a **clarifier** for separating oils containing sludge and a very small quantity of water.

Purifier
1. Oil inlet
2. Clean oil outlet
3. Sludge
4. Oil/water interface
5. Water outlet

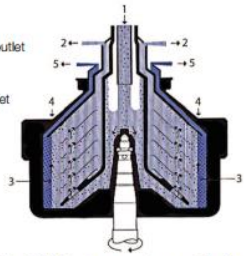


Fig 3 MAB bowl arranged as a **purifier** for separating oils containing sludge and an appreciable quantity of water.

Shipping data (approximate)

Net weight	420 kg (926 lbs)
Gross weight	525 kg (1 157 lbs)
Volume	2.1 m³

Technical specifications

Max. throughput capacity	10.6 m³/h [1]
Sludge and water space	3.4 l
Feed temperature range	0 - 100 °C
Installed motor power	5.5 / 12 kW [2]
Sound pressure	75 dB(A) [3]

[1] Actual capacity depends on composition of feed and separation demands.
[2] Without built-on pump 5.5 kW
With built-on pump 12 kW
[3] According to ISO 3744 or 3746

Utilities consumption

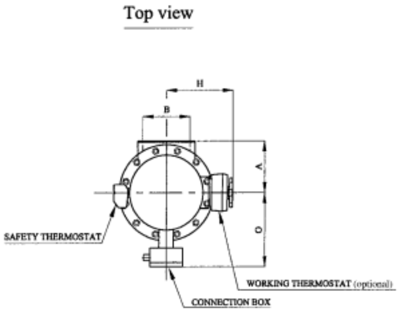
Electric power	3.3 – 8 kW [4]

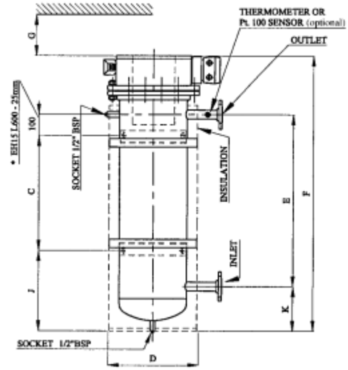
[4] Actual consumption depends on throughput capacity, feed characteristics.

AALBORG INDUSTRIES

Versatile booster, auxiliary oil and water heater

VESTA™ EH ELECTRICAL HEATER





Electric power supply terminals (110-690 V AC/DC), safety thermostat and the optional control thermostat are located on the top hood.

Design pressure: 16 bar (EH40-15 bar)
Design temperature: 160°C
Flanges: PN 16 DIN 86030/JIS-16K

Mounting style:
Vertically or horizontally
Dimensions in mm
Weights in kg

Accessories (optional):
Safety valve
Drain valve

Manometer
Thermometer
Pt. 100 sensor (optional)

Surface loads:

Lubrication oil	1 W/cm²
Heavy fuel oil	1.4 W/cm²
Water	3 W/cm²

STANDARD PRODUCT RANGE

Capacity and dimensions

TYPE	15			20			25			
Capacity kW Lub. oil	5	7	8.5	12	14	17	21	23	26	29
Capacity kW Fuel oil	7	10	12	17	20	24	30	33	36	40
Capacity kW Water	15	21	26	36	42	51	64	70	77	85
Element length	600	850	1000	850	850	1000	850	850	1000	1000
No. of elements	9			15	18	18	27	30	27	30
A	170			250			250			
B	130			220			220			
C	300	430	580	430	430	580	430	430	580	580
D	270			325			380			
E	420	670	820	670	670	820	670	670	820	820
F	864	1114	1264	1174	1174	1324	1209	1209	1359	1359
G	580	820	980	820	820	980	820	820	980	980
H	253			280			307			
J	265	310	310	320			340			
K	170			180			200			
O	234			262			294			
Flange size, DN	32			32			40			
Net weight	55	65	71	102	109	112	137	140	163	166

TYPE	30					35					40				
Capacity kW Lub. oil	33	37	40	45	48	51	59	63	74	78	96	100	111	116	121
Capacity kW Fuel oil	47	52	56	63	68	72	83	88	104	110	135	141	156	164	171
Capacity kW Water	101	111	120	135	146	154	178	188	223	235	See special data sheet				
Element length	850	1000	1000	1200	1200	1000	1200	1200	1500	1500	1500	1500	1800	1800	1800
No. of elements	42	39	42	39	42	54	51	54	51	54	66	69	63	66	69
A	250					300					300				
B	220					300					300				
C	430	580	580	780	780	580	780	780	1080	1080	1060	1060	1360	1360	1360
D	425					460					510				
E	670	820	820	1020	1020	820	1020	1020	1320	1320	1300	1300	1600	1600	1600
F	1234	1384	1384	1584	1584	1407	1607	1607	1907	1907	1932	1932	2232	2232	2232
G	820	980	980	1180	1180	980	1180	1180	1480	1480	1480	1480	1780	1780	1780
H	333					350					375				
J	360					377					407				
K	220					237					267				
O	322					372					402				
Flange size, DN	50					50					65				
Net weight	206	225	228	254	258	294	327	331	381	386	486	495	555	560	565

M15

Plate heat exchanger

M15B-FM

Applications
General heating and cooling duties.

Standard design
The plate heat exchanger consists of a pack of corrugated metal plates with portholes for the passage of the two fluids between which heat transfer will take place.

The plate pack is assembled betweeen a fix frame plate and a movable pressure plate and compressed by tightening bolts. The plates are fitted with a gasket which seals the interplate channel and directs the fluids into alternate channels. The number of plates is determined by the flow rate, physical properties of the fluids, pressure drop and temperature program. The plate corrugations promote fluid turbulence and support the plates against differential pressure.

The plate and the pressure plate are suspended from an upper carrying bar and located by a lower guiding bar, both of which are fixed to a support column.

Connections are located in the frame plate or, if either or both fluids make more than a single pass within the unit, in the frame and pressure plates.

Typical capacities

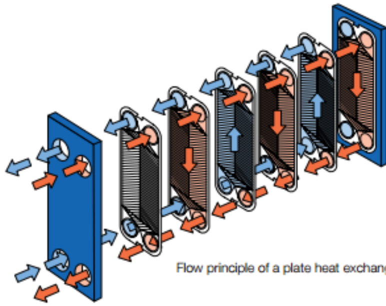
Liquid flow rate
Up to 80 kg/s, depending on media, permitted pressue drop and temperture program.

Plate types
M15B, M15E and M15M

Frame types
FM, FG, FD and FML

Working principle

Channels are formed between the plates and the corner ports are arranged so that the two media flow through alternate channels. The heat is transferred through the plate between the channels, and complete counter-current flow is created for highest possible efficiency. The corrugation of the plates provides the passage between the plates, supports each plate against the adjacent one and enhances the turbulence, resulting in efficient heat transfer.



Flow principle of a plate heat exchanger

Standard materials

Frame plate
Mild steel, Epoxy painted

Nozzles
Carbon steel
Lined: Stainless steel, Rubber lined, Titanium

Plates
Stainless steel: AISI 304, AISI 316
Titanium
Alloy C-276
Alloy 254 SMO

Gaskets (Clip-on/Tape-on, Glued)

Nitrile	Nitrile hydrogenated
EPDM	Viton® G
AL-EPDM	

Connections

FML	Size 150 mm	DIN 2501 PN10
FM8	Size 150 mm	DIN 2501 PN10 or ANSI 150
FG8	Size 150 mm	DIN 2501 PN16 or ANSI 150
FD8	Size 150 mm	DIN 2501 PN40 or ANSI 300
FD10	Size 150 mm	DIN ANSI 400

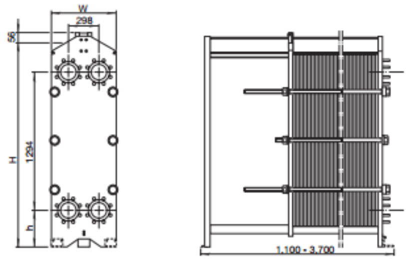
Technical data

Max. working pressure

FML/FM8	10 bar over pressure
FG8	16 bar over pressure
FD8	30 bar over pressure
FD10	400 psi over pressure

Maximum heat transfer surface
390 m² (4,200 sq. ft)

Dimensions



Measurements (mm)

Type	H	W	h
M15-FML	1,815	610	275
M15-FM8	1,815	610	275
M15-FG8	1,815	650	275
M15-FD8	1,980	650	370
M15-FD10	1,980	650	370

The number of tightening bolts may vary depending on pressure rating.

Particulars required for quotation

- Flow rates or heat load
- Temperature program
- Physical properties of liquids in question (if not water)
- Desired working pressure
- Maximum permitted pressure drop
- Available steam pressure

M10

Plate heat exchanger

Applications
General heating and cooling duties. Heating by means of steam.

Standard design
The plate heat exchanger consists of a pack of corrugated metal plates with portholes for the passage of the two fluids between which heat transfer will take place.

The plate pack is assembled betweeen a fix frame plate and a movable pressure plate and compressed by tightening bolts. The plates are fitted with a gasket which seals the interplate channel and directs the fluids into alternate channels. The number of plates is determined by the flow rate, physical properties of the fluids, pressure drop and temperature program. The plate corrugations promote fluid turbulence and support the plates against differential pressure.

The plate and the pressure plate are suspended from an upper carrying bar and located by a lower guiding bar, both of which are fixed to a support column.

Connections are located in the frame plate or, if either or both fluids make more than a single pass within the unit, in the frame and pressure plates.

M10-BFG

Typical capacities

Liquid flow rate
Up to 50 kg/s, depending on media, permitted pressue drop and temperture program.

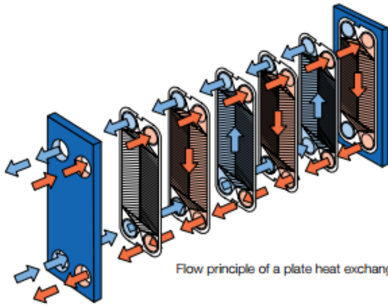
Water heating by steam
0.7 to 3.0 MW

Plate types
M10B, M10M and M10MD

Frame types
FM, FG and FD

Working principle

Channels are formed between the plates and the corner ports are arranged so that the two media flow through alternate channels. The heat is transferred through the plate between the channels, and complete counter-current flow is created for highest possible efficiency. The corrugation of the plates provides the passage between the plates, supports each plate against the adjacent one and enhances the turbulence, resulting in efficient heat transfer.



Flow principle of a plate heat exchanger

Standard materials

Frame plate
Mild steel, Epoxy painted

Nozzles
Carbon steel
Lined: Stainless steel, Rubber, Titanium

Plates
Stainless steel AISI 316, Titanium, Alloy 20/18/6

Gaskets
M10B Nitrile, EPDM
M10M Nitrile, EPDM, HeatSeal F™, HNBR, EPDM-FDA, Viton®G

Connections

FM – Size 100 mm	DIN 2501 PN10 or ANSI 150
FG – Size 100 mm	DIN 2501 PN16 or ANSI 150
FD – Size 100 mm	DIN 2501 PN25 or ANSI 150
FD – Size 100 mm	DIN 2501 PN25 or ANSI 300 (ASME)

Technical data

Mechanical design pressure (g) / temperature

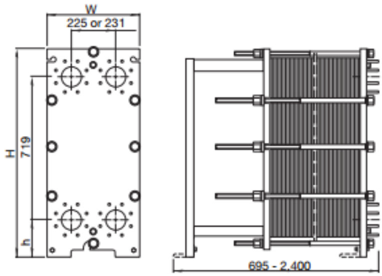
FM	1.0 MPa / 160°C
FG	1.6 MPa / 180°C *)
FG ASME	150 psig / 350°F
FD	2.5 MPa / 160°C
FD ASME	300 psig / 320°F

*) Frame FG also approved for 1.2 MPa / 200°C to allow use in steam systems without safety valves.

Maximum heat transfer surface

M10B 105 m² (1126 sq. ft)
M10M 62 m² (1126 sq. ft)

Dimensions



Measurements (mm)

Type	H	W	h
M10-FM	1,084	470	215
M10-FG	1,084	470	215
M10-FD	981	470	131
M10-FD ASME	1,084	470	215

The number of tightening bolts may vary depending on pressure rating.

Particulars required for quotation

- Flow rates or heat load
- Temperature program
- Physical properties of liquids in question (if not water)
- Desired working pressure
- Maximum permitted pressure drop
- Available steam pressure

AQ14

AlfaQ™ AHRI-certified plate heat exchanger

Applications
General heating and cooling duties.

Standard design
The plate heat exchanger consists of a pack of corrugated metal plates with portholes for the passage of the two fluids between which heat transfer will take place.

The plate pack is assembled between a fix frame plate and a movable pressure plate and compressed by tightening bolts. The plates are fitted with a gasket, which seals the interplate channel and directs the fluids into alternate channels. The number of plates is determined by the flow rate, physical properties of the fluids, pressure drop and temperature program. The plate corrugations promote fluid turbulence and support the plates against differential pressure.

The plate and the pressure plate are suspended from an upper carrying bar and located by a lower guiding bar, both of which are fixed to a support column.

Connections are located in the frame plate or, if either or both fluids make more than a single pass within the unit, in the frame and pressure plates.

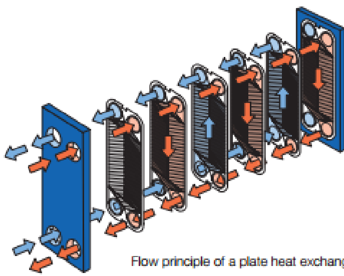
Typical capacities
Liquid flow rate
Up to 650 kg/s (10400 gpm), depending on media, permitted pressure drop and temperature program.

Plate types
AQ14

Frame types
FM, FG and FD

Working principle
Channels are formed between the plates and the corner ports are arranged so that the two media flow through alternate channels. The heat is transferred through the plate between the channels, and complete counter-current flow is created for highest possible efficiency. The corrugation of the plates provides the passage between the plates, supports each plate against the adjacent one and enhances the turbulence, resulting in efficient heat transfer.

AQ14-FG



Flow principle of a plate heat exchanger

STANDARD MATERIALS

Frame plate
Mild steel, painted

Nozzles
Carbon steel
Metal lined: Stainless steel, Titanium

Plates
Stainless steel Alloy 304, Alloy 316 or Titanium

Gaskets
Nitrile or EPDM

CONNECTIONS

FM pvcALS™	Size 300/350 mm	DIN PN10, ASME Cl. 150, JIS 10K
FM PED	Size 300/350 mm	DIN PN10
FM ASME	Size 12"/14"	ASME Cl. 150
FG pvcALS™	Size 300/350 mm	DIN PN16, ASME Cl. 150, JIS 16K
FG PED	Size 300/350 mm	DIN PN16
FG ASME	Size 12"/14"	ASME Cl. 150
FD pvcALS™	Size 300/350 mm	DIN PN25, ASME Cl. 150, ASME Cl. 300, JIS 20K
FD PED	Size 300/350 mm	DIN PN25
FD ASME	Size 12"/14"	ASME Cl. 300

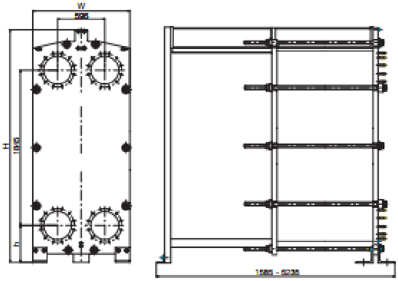
TECHNICAL DATA

Mechanical design pressure (g) / temperature

FM PED, pvcALS™	1.0 MPa / 190°C
FG PED, pvcALS™	1.6 MPa / 180°C
FG ASME	150 psig / 320°F
FD PED, pvcALS™	2.5 MPa / 190°C
FD ASME	300 psig / 320°F

Maximum heat transfer surface
1400 m² (14,980 sq. ft)

Dimensions



Measurements (mm)

Type	H*	W	h
AQ14-FM	2882 (113.5")	1150 (45.3")	470 (18.5")
AQ14-FG	2882 (113.5")	1170 (46.1")	470 (18.5")
AQ14-FD	2920 (115")	1190 (46.9")	506 (19.9")

* +200 mm for carrying bars > 3600 mm
The number of tightening bolts may vary depending on the pressure rating.

Particulars required for quotation
- Flow rates or heat load
- Temperature program
- Desired working pressure
- Maximum permitted pressure drop

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AHRI Standard 400

AQ14L

AlfaQ™ AHRI-certified plate heat exchanger

Applications
General heating and cooling duties.

Standard design
The plate heat exchanger consists of a pack of corrugated metal plates with portholes for the passage of the two fluids between which heat transfer will take place.

The plate pack is assembled between a fix frame plate and a movable pressure plate and compressed by tightening bolts. The plates are fitted with a gasket, which seals the inter-plate channel and directs the fluids into alternate channels. The number of plates is determined by the flow rate, physical properties of the fluids, pressure drop and temperature program. The plate corrugations promote fluid turbulence and support the plates against differential pressure.

The frame plate is stationary, while the pressure plate is movable along the upper carrying bar, which also holds the plate pack. The pressure plate and the plate pack are located by the lower guiding bar. The carrying bar is supported by the frame at one end and a support column at the other which are bolted to the foundation.

Connections are located in the frame plate or, if either or both fluids make more than a single pass within the unit, in the frame and pressure plates.

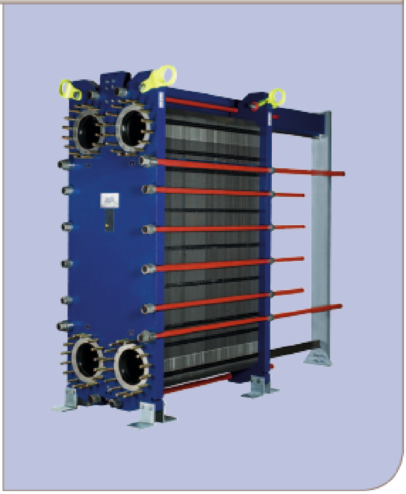
Typical capacities

Liquid flow rate
Up to 650 kg/s (10400 gpm), depending on media, permitted pressure drop and temperature program.

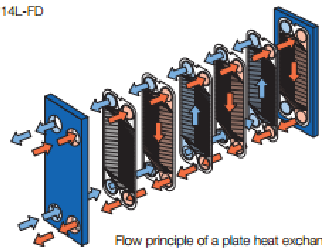
Plate types
AQ14L plates

Frame types
FM, FG, FD and FS

Working principle
Channels are formed between the plates and the corner ports are arranged so that the two media flow through alternate channels. The heat is transferred through the plate between the channels, and complete counter-current flow is created for highest possible efficiency. The corrugation of the plates provides the passage between the plates, supports each plate against the adjacent one and enhances the turbulence, resulting in efficient heat transfer.



AQ14L-FD



Flow principle of a plate heat exchanger

STANDARD MATERIALS

Frame plate
Mild steel, painted

Nozzles
Carbon steel
Metal lined: Stainless steel, Titanium

Plates
Stainless steel Alloy 316 / Alloy 304 / Titanium

Gaskets
Nitrile, EPDM

TECHNICAL DATA

Pressure vessel codes, PED, ASME, pvcALS™

Mechanical design pressure (g) / temperature

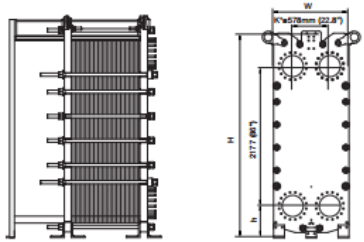
FM	PED / pvcALS™	1.0 MPa / 180°C
FM	ASME	100 psig / 350°F
FG	PED / pvcALS™	1.6 MPa / 180°C
FG	ASME	150psig / 350°F
FD	PED	2.5 MPa / 180°C
FD	ALS	2.5 MPa / 160°C
FD	ASME	300 psig / 350°F
FS	PED	3.0 MPa / 180°C
FS	ASME	400 psig / 350°F

CONNECTIONS

FM	pvcALS™	Size 300 or 350 mm DIN PN10 ASME Cl.150, JIS 10K
FM	PED	Size 300 or 350 mm DIN PN10 ASME Cl. 150
FM	ASME	Size 12 or 14" ASME Cl. 150
FG	pvcALS™	Size 300 or 350 mm DIN PN16 ASME Cl. 150, JIS 16K
FG	PED	Size 300 or 350 mm DIN PN16, ASME Cl. 150
FG	ASME	Size 12 or 14" ASME Cl. 150
FD	PED	Size 300 or 350 mm DIN PN25, ASME Cl. 300
FD	ALS	Size 300 or 350 mm DIN PN25, ASME Cl. 300, JIS 20K
FD	ASME	Size 12 or 14" ASME Cl. 300
FS	PED	Size 300 or 350 mm DIN PN40, ASME Cl. 400
FS	ASME	Size 12 or 14" ASME Cl. 400

Maximum heat transfer surface
1700 m² (18000 sq.ft)

Dimensions



Measurements mm (inch)

Type	H	W	h	C_{min}	C_{max}
AQ14L-FM	3210 (126.4")	1154 (45.4")	488 (19.2")	2190 (86")	6360 (250")
AQ14L-FG	3210 (126.4")	1154 (45.4")	488 (19.2")	2205 (89")	6375 (251")
AQ14L-FD	3218 (126.7")	1174 (46.2")	496 (19.5")	2230 (88")	6400 (252")
AQ14L-FS	3218 (126.7")	1174 (46.2")	496 (19.5")	2245 (88")	6420 (253")

The number of tightening bolts may vary depending on pressure rating.
Max no. of plates AQ14L= 1000

K* = 578 mm (22.8 inches) except following cases

584 (23.0") FS	PED	Size 350DN PN40
589 (23.2") FD	PED/pvcALS™ ASME	Size 14" ASME Cl.300
589 (23.2") FS	PED/ASME	Size 14" ASME Cl 300 or 400

Particulars required for quotation

- Flow rates or heat load
- Temperature program
- Desired working pressure
- Maximum permitted pressure drop

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AQ10

AlfaQ™ AHRI-certified plate heat exchanger

AQ10-FG

Applications
Plate heat exchanger for general heating and cooling duties.

Standard design
The plate heat exchanger consists of a pack of corrugated metal plates with portholes for the passage of the two fluids between which heat transfer will take place.

The plate pack is assembled between a fix frame plate and a movable pressure plate and compressed by tightening bolts. The plates are fitted with a gasket, which seals the interplate channel and directs the fluids into alternate channels. The number of plates is determined by the flow rate, physical properties of the fluids, pressure drop and temperature program. The plate corrugations promote fluid turbulence and support the plates against differential pressure.

The plate and the pressure plate are suspended from an upper carrying bar and located by a lower guiding bar, both of which are fixed to a support column.

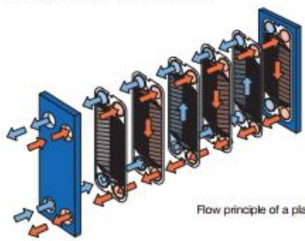
Connections are located in the frame plate or, if either or both fluids make more than a single pass within the unit, in the frame and pressure plates.

Typical capacities
Liquid flow rate.
Up to 350 kg/s (5600 gpm), depending on media, permitted pressure drop and temperature program.

Plate types
AQ10, AQ10M

Frame types
FMS, FGS, FG, FD and FS

Working principle
Channels are formed between the plates and the corner ports are arranged so that the two media flow through alternate channels. The heat is transferred through the plate between the channels, and complete counter-current flow is created for highest possible efficiency. The corrugation of the plates provides the passage between the plates, supports each plate against the adjacent one and enhances the turbulence, resulting in efficient heat transfer.



Flow principle of a plate heat exchanger

STANDARD MATERIALS

Frame plate
Mild steel, painted

Nozzles
Carbon steel
Metal lined: Stainless steel, Titanium
Rubber lined: Nitrile, EPDM

Plates
Stainless steel Alloy 316 or Titanium

Gaskets
Nitrile or EPDM

TECHNICAL DATA

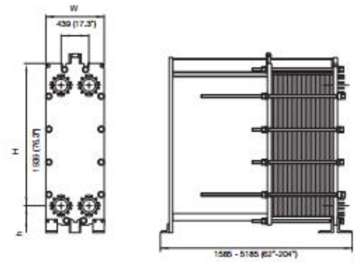
Pressure vessel codes PED, ASME, pvcALS™
Mechanical design pressure (g) / temperature

FMS PED, pvcALS™	1.0 MPa / 180°C
FGS PED, pvcALS™	1.6 MPa / 180°C
FGS ASME	150 psig / 350°F
FG PED, pvcALS™	1.6 MPa / 200°C
FG ASME	150 psig / 350°F
FD PED, pvcALS™	2.5 MPa / 210°C
FD ASME	300 psig / 350°F
FS ASME	400 psig / 350°F

CONNECTIONS

FMS PED	Size 200/250 mm	DIN 2501 PN10, ASME Cl. 150
FMS pvcALS™	Size 200/250 mm	DIN 2501 PN10, ASME Cl. 150, JIS 10K
FGS PED	Size 200 mm	DIN 2501 PN16, ASME Cl. 150
FGS pvcALS™	Size 200/250 mm	DIN 2501 PN16, ASME Cl. 150, JIS 10K/16K
FGS ASME	Size 8"	ASME Cl. 150
FG PED	Size 200/250 mm	DIN 2501 PN16, ASME Cl. 150
FG pvcALS™	Size 200/250 mm	DIN 2501 PN16, ASME Cl. 150, JIS 10K/16K
FG ASME	Size 8"/10"	ASME Cl.150
FD PED	Size 200/250 mm	DIN 2501 PN25, ASME Cl. 300
FD pvcALS™	Size 200/250 mm	DIN 2501 PN25 ASME Cl. 300, JIS 20K
FD ASME	Size 8"/10"	ASME Cl. 300
FS ASME	Size 8"/10"	ASME Cl. 400

Dimensions



Measurements mm (inch)

Type	H	W	h
AQ10-FMS	2595 (102")	920 (36.2")	325 (12.8")
AQ10-FGS	2595 (102")	920 (36.2")	325 (12.8")
AQ10-FG	max 3103 (122.2")	920 (36.2")	435 (17.1")
AQ10-FD	max 3103 (122.2")	940 (37")	435 (17.1")
AQ10-FS	max 3103 (122.2")	940 (37")	435 (17.1")

The number of tightening bolts may vary depending on the pressure rating

Maximum heat transfer surface
940 m² (10.000 sq. ft)

Particulars required for quotation
- Flow rates or heat load
- Temperature program
- Desired working pressure
- Maximum permitted pressure drop

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AQ20M

AlfaQ™ AHRI-certified plate heat exchanger

Applications
General heating and cooling duties.

Standard design
The plate heat exchanger consists of a pack of corrugated metal plates with portholes for the passage of the two fluids between which heat transfer will take place.

The plate pack is assembled between a fix frame plate and a movable pressure plate and compressed by tightening bolts. The plates are fitted with a gasket which seals the interplate channel and directs the fluids into alternate channels. The number of plates is determined by the flow rate, physical properties of the fluids, pressure drop and temperature program. The plate corrugations promote fluid turbulence and support the plates against differential pressure.

The frame plate and the pressure plate are suspended from an upper carrying bar and located by a lower guiding bar, both of which are fixed to a support column.

Connections are located in the frame plate or, if either or both fluids make more than a single pass within the unit, in the frame and pressure plates.

Typical capacities

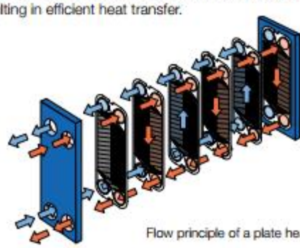
Liquid flow rate
Up to 1300 kg/s (20800 gpm), depending on media, permitted pressure drop and temperature program.

Plate types
AQ20M

Frame types
FG and FD

Working principle
Channels are formed between the plates and the corner ports are arranged so that the two media flow through alternate channels. The heat is transferred through the plate between the channels, and complete counter-current flow is created for highest possible efficiency. The corrugation of the plates provides the passage between the plates, supports each plate against the adjacent one and enhances the turbulence, resulting in efficient heat transfer.

AQ20M



Flow principle of a plate heat exchanger

STANDARD MATERIALS

Frame plate
Mild steel, painted

Nozzles
Metal lined: Stainless steel, Titanium

Plates
Stainless steel: Alloy 316 or Titanium

Gaskets
Nitrile or EPDM

TECHNICAL DATA

Mechanical design pressure (g) / temperature

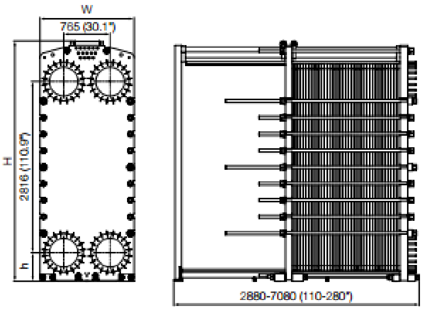
FG	PED	1.6 MPa / 180°C
FG	ASME	150 psig / 350°F
FD	PED	2.5 MPa / 180°C
FD	ASME	300 psig / 350°F

CONNECTIONS

FG	PED	Size 500 mm	DIN PN16
FG	ASME	Size 20"	ASME Cl. 150
FD	PED	Size 500 mm	DIN PN25
FS	ASME	Size 20"	ASME Cl. 300

Maximum heat transfer surface
2880 m² (31018 sq. ft)

Dimensions



Measurements mm (inch)

Type	H	W	h
AQ20M-MFG	3951 (155 9/16")	1550 (61")	467 (18 3/8")
AQ20M-MFD	3951 (155 9/16")	1550 (61")	467 (18 3/8")

The number of tightening bolts may vary depending on pressure rating.

Particulars required for quotation
– Flow rates or heat load
– Temperature program
– Desired working pressure
– Maximum permitted pressure drop

AHRI CERTIFIED™
www.ahridirectory.org
Liquid to Liquid Heat Exchangers
AHRI Standard 400

AQ6

AlfaQ™ AHRI-certified plate heat exchanger

Applications
General heating and cooling duties.

Standard design
The plate heat exchanger consists of a pack of corrugated metal plates with portholes for the passage of the two fluids between which heat transfer will take place.

The plate pack is assembled between a fix frame plate and a movable pressure plate and compressed by tightening bolts. The plates are fitted with a gasket which seals the interplate channel and directs the fluids into alternate channels. The number of plates is determined by the flow rate, physical properties of the fluids, pressure drop and temperature program. The plate corrugations promote fluid turbulence and support the plates against differential pressure.

The plate and the pressure plate are suspended from an upper carrying bar and located by a lower guiding bar, both of which are fixed to a support column.

Connections are located in the frame plate or, if either or both fluids make more than a single pass within the unit, in the frame and pressure plates.

AQ6-FM

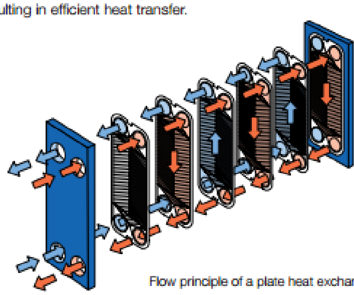
Typical capacities

Liquid flow rate
Up to 80 kg/s (1300 gpm), depending on media, permitted pressure drop and temperature program.

Plate types
AQ6, AQ6M, AQ6D - double wall plates

Frame types
FM, FG and FD

Working principle
Channels are formed between the plates and the corner ports are arranged so that the two media flow through alternate channels. The heat is transferred through the plate between the channels, and complete counter-current flow is created for highest possible efficiency. The corrugation of the plates provides the passage between the plates, supports each plate against the adjacent one and enhances the turbulence, resulting in efficient heat transfer.



Flow principle of a plate heat exchanger

STANDARD MATERIALS

Frame plate
Mild steel, painted

Nozzles
Carbon steel
Metal lined: Stainless steel, Titanium
Rubber lined: Nitrile, EPDM

Plates
Stainless steel: Alloy 304, Alloy 316
Titanium

Gaskets
Nitrile, EPDM

TECHNICAL DATA

Pressure vessel codes, PED, ASME, pvcALS™
Mechanical design pressure (g) / temperature

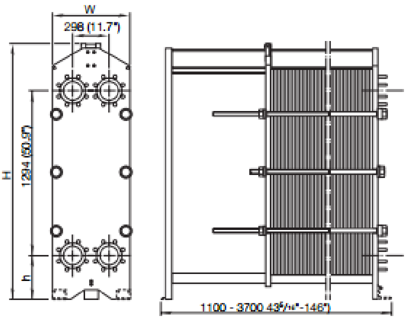
FM	PED, pvcALS™	1.0 MPa / 180°C
FG	PED, pvcALS™	1.6 MPa / 180°C
FG	ASME	150 psig / 482°F
FD	PED, pvcALS™	3.0 MPa / 180°C
FD	ASME	300 psig / 356°F

CONNECTIONS

FM	PED	Size 150 mm	DIN PN 10 ASME Cl. 150
FM	pvcALS™	Size 150 mm	DIN/GB/GOST PN10, ASME Cl. 150, JIS 10K
FG	PED	Size 150 mm	DIN PN16, ASME Cl. 150
FG	pvcALS™	Size 150 mm	DIN/GB/GOST PN16, ASME Cl. 150, JIS 10/16K
FG	ASME	Size 6"	ASME Cl. 150
FD	PED	Size 150 mm	DIN PN25, ASME Cl. 300
FD	ASME	Size 6"	ASME Cl. 300

Maximum heat transfer surface
390 m² (4200 sq. ft)

Dimensions



Measurements mm (inch)

Type	H	W	h
AQ6-FM	max. 1941 (76 ½")	610 (24")	275 (10 ¾")
AQ6-FG	max. 1941 (76 ½")	650 (25 ½")	275 (10 ¾")
AQ6-FD	max. 2036 (80")	650 (25 ½")	370 (14 ½")

The number of tightening bolts may vary depending on pressure rating.

Particulars required for quotation
– Flow rates or heat load
– Temperature program
– Desired working pressure
– Maximum permitted pressure drop

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AHRI Standard 400

Aalborg MD

Multi-purpose heat exchanger in noble materials

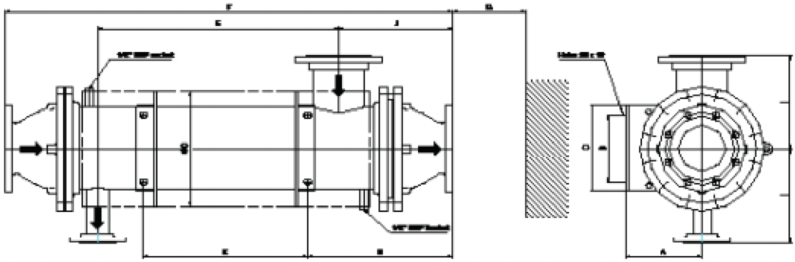
Aalborg MD coolers and condensers are shell and tube heat exchangers applicable as dump condensers, drain coolers or oil coolers. The straight tube design condenser in extremely durable materials is available in designs for either atmospheric or pressurized operation (up to 16 bar(g)).

Description

The Aalborg MD tank washing heat exchanger is designed for horizontal installation and an operating pressure og 16 bar(g) and eliminates the need for sacrificial anodes.

The externally sealed floating head tube sheet of the straight tube coolers/condensers compensates for thermal expansion. The design conditions for the shell and tube side are 16 bar(g)/ 204°C and 16 bar(g)/100°C respectively.

The capacity range of the Aalborg MD cooler is 400 – 6,000 kg/h steam at 3 bar(g)/157°C is subcooled to 80°C with 32°C seawater.



Standard product range

Capacity and dimensions

Type	A	B	C	ØD	E	F	G	H	I	J	K
MD15	200	220	270	270	L - 275	L + 233	L - 100	360	254	281	Acc. to dimension dwg
MD20	250	220	280	325	L - 290	L + 285	L - 100	400	280	319	Acc. to dimension dwg
MD25	250	220	280	380	L - 314	L + 363	L - 100	475	307	374	Acc. to dimension dwg
MD30	250	220	280	425	L - 349	L + 385	L - 100	540	332	411	Acc. to dimension dwg
MD40	350	300	300	610	1555	1940	2100		375	635	1200
MD50	450	350	300	715	2470	4260	3100		425	820	193

L is the length of straight tubes

	Nozzles	MD15	MD20	MD25	MD30	
Sea water inlet	N1	DN100	DN125	DN150	DN200	Fixed size
Sea water outlet	N2	DN100	DN125	DN150	DN200	Fixed size
Steam inlet	N3	DN100	DN125	DN150	DN200	Max. size
Condensate outlet	N4	DN40	DN40	DN50	DN65	Max. size
Inlet for drain cooling (optional)	N5	DN100	DN125	DN150	DN200	Max. size

Standard programme – weights in kg

Type/Length	600	750	850	1000	1200	1500	1800	2000
MD15	93	99	104	110	119	132	143	151
MD20	137	148	155	166	180	202	220	234
MD25	209	226	238	255	279	314	339	360
MD30	277	302	319	343	377	426	461	480

Design pressure shell/tubeside: 16/16 bar(g)
Design temperature shell/tubeside: 204/100°C
Flanges: JIS-16K/EN1092-1 PN16
Mounting style: Horizontally or vertically

KAESER COMPRESSORS

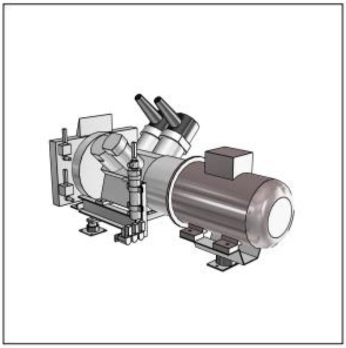
Air receiver volume	Max. permitted working pressure	Available versions		Vertical version				Horizontal version			
Litres	bar	Vertical	Horizontal	Height mm	Ø mm	Inlet/outlet connections	Weight kg	Length mm	Ø mm	Inlet/outlet connections	Weight kg
90	11 45	Yes	–	1160 1154	350	2 x G ½ rear	37 88	–	–	–	–
150	11 16	Yes	Yes	1190	450	2 x G ¾ rear	60 67	1050 1346	450 400	2 x G 2	55 75
250	11 16	Yes	Yes	1540 1545	500	2 x G ¾ rear	84 100	1410 1410	500	2 x G 2	84 100
	45		–	1600	500	2 x G 1 rear	270	–	–	–	–
350	11 16	Yes	Yes	1810	550	2 x G 1 rear	100 150	1630 1640	550	2 x G 2	101 164
500	11 16	Yes	Yes	1925 1918	600	2 x G 1 rear	130 210	1780	600	2 x G 2	130 208
	45		–	1925			420	–	–	–	–
900	11	Yes	–	2170	800	2 x G 2; 2 x G 1½	238	–	–	–	–
1000	11 16	Yes	Yes	2265 2255	800	2 x G 1½; 2 x G 2	244 356	2150 2160	800	G 2; 1 x G 1½	240 360
	45			2255		4 x G 1½	500	–	–	–	–
2000	11 16	Yes	Yes	2375 2360	1150 1150	4 x G 2½	470 500	2180	1150	2 x G 2	470 600
	50		–	2430	1100	4 x DN 80	1600	–	–	–	–
3000	11 16	Yes	Yes	2705 2845	1250	4 x G 2½	680 850	2610 3040	1250 1150	2 x G 2½ 2 x G 2	680 810
5000	11 16	Yes	Yes	3570	1400	4 x DN 100	1400 1430	3470 3700	1400	4 x DN 100	1100 1800
8000	11 16	Yes	Yes	4400	1600	4 x DN 200	1850 2350	4440 4400	1600	4 x DN 200	1850 2350
10000	11 16	Yes	Yes	5415	1600	4 x DN 200	2260 2540	5400 5440	1600	4 x DN 200	2200 2650

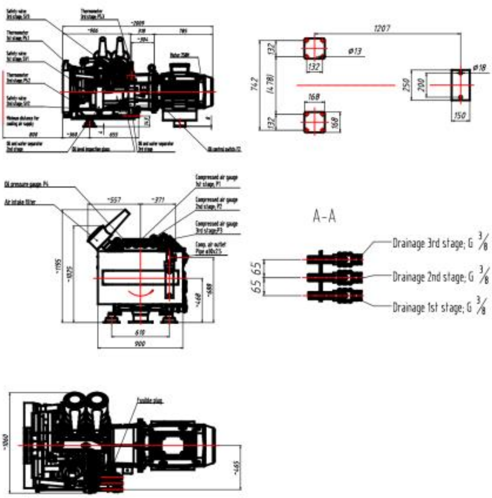
Air Cooled Compressor
L270

PDF DATASHEET

Last Modification (geometry): 17/04/2014 06:47

Datasheet creation date: 29/10/2016 10:24





Air Cooled Compressor
L270

PDF DATASHEET

Last Modification (geometry): 17/04/2014 06:47

Datasheet creation date: 29/10/2016 10:24

TYPE (type)	L270
INFO1 (data sheet)	PDF
INFO2 (installation drawing)	PDF
CY (Cylinders)	4
S (stages)	3
SP (speed / rpm)	1150
FAD (F.A.D. @ 30 barg / m3/h)	205
P (power / kW)	37
WEIGHT (approx. weight / kg)	1000
LENGTH (approx. length / mm)	2005
WIDTH (approx. width / mm)	900
HEIGHT (approx. height / mm)	1000

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AUTHOR BIOGRAPHY

Author was born in Bandung, 5th September 1995 as a son of cardiologist and dentist. Author completed his formal education in Yahya Christian School in Bandung since primary school until high school.

In 2013, author enrolled in Double Degree Program of Marine Engineering in ITS Surabaya – Hochschule Wismar with student number (NRP) 4213101017.

During his study in Department of Marine Engineering, author took Fluid Machinery Laboratory (MMS) and active in several activities held by the institute. Author received awards from BKI-RINA Award in recognition of academic excellence and 2 awards from Hochschule Wismar for social commitment and best student.

In 2015 author participate in OJT program which held in PT. DKB Jakarta, Indonesia and 2nd OJT program (2016) which held in MEDCO LLC Muscat, Sultanate of Oman.