BACHELOR THESIS - (ME 141502)

RISK AND ECONOMICAL ASSESSMENT OF PASSENGER SHIP RETROFITTED WITH DUAL FUEL ENGINE

ANDIKA CANDRA PRABANA
NRP. 04211441000018

Supervisor
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DOUBLE DEGREE PROGRAM
MARINE ENGINEERING DEPARTMENT
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SKRIPSI - (ME 141502)

PENILAIAN RESIKO DAN EKONOMI PADA KAPAL PENUMPANG DENGAN MENGGUNAKAN MESIN DUAL FUEL

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2018

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APPROVAL FORM

RISK AND ECONOMICAL ASSESSMENT OF PASSENGER SHIP RETROFITTED WITH DUAL FUEL ENGINE

BACHELOR THESIS

Proposed to Fulfill One of the Requirements for Obtaining a Bachelor Engineering Degree
On
Reliability, Availability, Management and Safety (RAMS) Laboratory
Study Program Bachelor Double Degree of Marine Engineering Department
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember

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SURABAYA

July, 2018

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DECLARATION OF HONOUR

I hereby who signed below declare that:

This final project has been written and developed independently without any plagiarism act. All contents and ideas drawn directly from internal and external sources are indicated such as cited sources, literatures, and other professional sources.

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Bachelor Thesis Title	:	Risk and Economical Assessment of Passenger Ship Retrofitted with Dual Fuel Engine
Department	:	Double Degree Marine Engineering

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Surabaya, July 2018

Andika Candra Prabana

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RISK AND ECONOMICAL ASSESSMENT OF PASSENGER SHIP RETROFITTED WITH DUAL FUEL ENGINE

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Abstract

Indonesia produces about twice amount of natural gas consumed. In 2016, Indonesia has 144 TSCF (Trillion of Standard Cubic Feet) of natural gas reserves that consist of 101.2 TSCF proven gas reserves and 42.8 TSCF of potential gas reserves. LNG offers huge advantages, especially to obey IMO regulation adopted a revised Annex VI about the International Convention for the Prevention of Pollution from ships (MARPOL). Annex VI contains regulations for the prevention of air pollution. all industrial components, manufacturing industry, and shipping industries in Indonesia are highly dependent on fuel oil. This is one reason for runs out of indonesia's oil supplies. This condition also affects in shipping sector because oil consumption is quite large as the fuel of ship. In addition, the occurrence fluctuations in the price of petroleum to make industry players go to use alternative fuels. safety record of LNG carriers is extremely good. Even though most of the principles remain the same, using LNG as fuel for conventional ships introduces new systems on board together with their associated risks. To located LNG tank also need many consideration for safety reason and economical aspect. In order to design, build and operate a gas-fuelled vessel in a safe and sustainable way, the risks will have to be thoroughly investigated and minimized. This thesis will analysis about risk and economical aspect of placement LNG tank inside and outside compartement.

Keyword : Dual Fuel, Passenger Ship, Fuel System, HAZOP, LNG, Risk Assesment, Economical Assesment

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Abstrak

Pada tahun 2016, Indonesia memiliki cadangan gas alam sebesar 144 TSCF (Trillion of Standard Cubic Feet) yang terdiri dari 101,2 cadangan gas terbukti TSCF dan 42,8 TSCF cadangan gas potensial. . LNG menawarkan keuntungan yang sangat besar, terutama untuk mematuhi peraturan IMO yang mengadopsi Lampiran VI revisi tentang Konvensi Internasional untuk Pencegahan Pencemaran dari kapal (MARPOL). Lampiran VI berisi peraturan untuk pencegahan pencemaran udara. Semua komponen industri, manufaktur, dan industri pelayaran di Indonesia sangat bergantung for bahan bakar minyak. Inilah salah satu alasan mahalnya pasokan minyak di indonesia. Kondisi ini juga berdampak for sektor pelayaran karena konsumsi minyak cukup besar seperti bahan bakar kapal. Selain itu, terjadinya fluktuasi harga minyak bumi membuat pelaku industri menggunakan bahan bakar alternatif. Meskipun sebagian besar prinsipnya tetap sama, menggunakan LNG sebagai bahan bakar untuk kapal konvensional memperkenalkan sistem baru di kapal beserta risiko yang terkait dengannya. Dalam peletakan tangki LNG membutuhkan banyak pertimbangan secara keamanan dan ekonomi. Dalam mendesain, membangun dan mengoperasikan kapal berbahan bakar gas dengan aman, maka resikonya harus bisa di invertigasi dan di perkecil. Thesis ini akan menganalisa aspek resiko dan ekonomi dalam peletakan tangki LNG di dalam dan diluar kompartemen tempat cargo

Keyword : Dual Fuel, Kapal Penumpang, Sistem Bahan Bakar, HAZOP, LNG, Analisa Resiko, Analisa Ekonomi

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PREFACE

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

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

1. Author's parent and sister. (Budi Sarwono, Illa Ariyani, Adinda Lintang Pambayun)
2. A.A.B Dinariyana DP, S.T., MES, Ph.D and Dr. Dhimas Widhi Handani, S.T., M.Sc. as supervisor
3. All part who gave access to technical data, design, and recommendation.
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5. Ramadhana as my best friend who always spent time in my hard time until i can standing here today.
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7. Every person who spent more than 2 hours with me at least once in a lifetime to discuss particular topic.
8. Whoever you are that ever come in my life and leave traces in my heart.

This thesis proves that your supports have a big role.

Surabaya, July 2018

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CHAPTER 1
INTRODUCTION

I.1 Background

Indonesia has huge natural gas reserves and largest gas reserves in the Asia Pacific region (after Australia and the People's Republic of China), contributes 1.5% of the world's total gas reserves. (BP Statistical Review of World Energy 2015). The biggest ones are:

1. Blok Arun, Aceh Sumatera
2. Bontang, East Kalimantan
3. Tangguh, Papua
4. Natuna Island

Figure 1.1 Location of Indonesia Gas Production Center
(source : http://www.indonesia-investments.com/id/bisnis/komoditas/gas-alam/item184?)

Indonesia produces about twice amount of natural gas that consumed. In 2016, Indonesia has natural gas reserves of 144 TSCF (Trillion of Standard Cubic Feet) consisting of 101.2 TSCF proven gas reserves and 42.8 TSCF of potential gas reserves.

Table 1.1 Indonesia's Gas Reserves Last 5 Years

Year	Potential	Proven
2016	42,80	101,20
2015	53,34	97,99
2014	49,00	100,30
2013	48,90	101,50
2012	47,40	103,30

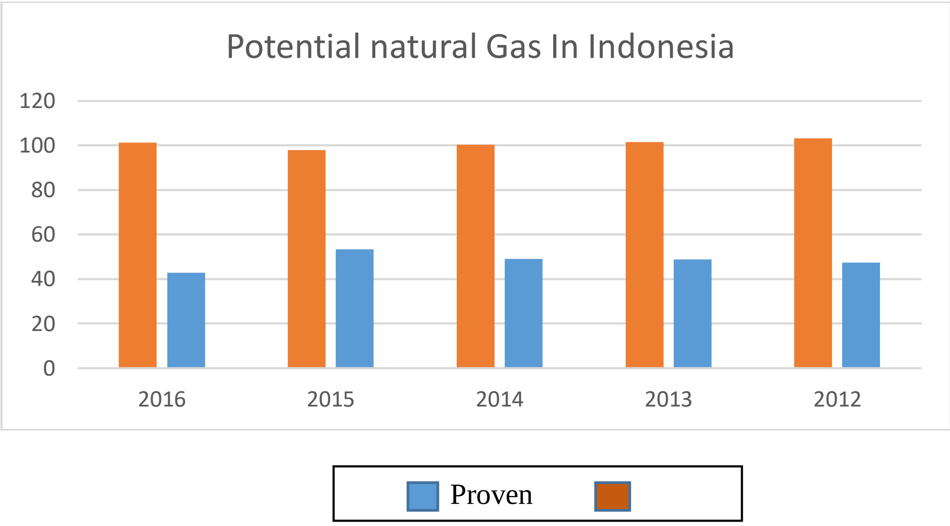


Figure 1.2 Resource Energy in 5 years in Indonesia
(Source : http://statistik.migas.esdm.go.id/index.php?r=cadanganGasBumi/index)

LNG as a fuel is proven and available for commercial solution. One of the main reason that makes LNG become the preferable fuel is the lower price compared to Heavy Fuel Oil (HFO), Marine Diesel Oil (MDO) and Low Sulphur Heavy Fuel Oil (LSHFO). DNV GL was made fuel price scenario for the basic assumption. Starting year 2010 for the fuel price scenario is 650 $/t (=15.3 $/mmBTU) for HFO and 900 $/t (=21.2 $/mmBTU) for MGO. LNG is set at 13 $/mmBTU which includes small-scale distribution costs of 4 $/mmBTU. (leonardo,2017)

LNG offers huge advantages, especially to obey regulation of IMO adopted a revised Annex VI about International Convention for the Prevention of Pollution form ships (MARPOL) and Presidential Decree no.12 of 2012 on pollution prevention regulations air from the ship. Annex VI contains regulations for the prevention of air pollution. The main emission product from a diesel engine are NOx, SOx , CO2 and particulate matter (PM). These emissions can increasing the temperature on earth, affect the air quality, global warming and other health problems that can impact the environmental. The use of LNG as marine fuel is the proven solution and will contribute to a reduction of these emissions. These reductions will have significant environmental benefits such as improved local air quality, reduced acid rain and contribute to limit global warming.

Indonesian shipping industry has to take this challenge to adjust its vessels to comply with the regulation. Passenger ships operated by PELNI is still using high speed diesel (HSD) oil as their fuel. Although HSD produces less emission than the heavy fuel oil (HFO), its sulfur is found to be 0.25% m/m on the HSD oil that distributed in Indonesia. (Ariana,2017)

Last research compair passenger ships of PT. Pelni with dynamic analysis method. determinant variable is based on variables about OPEX (Operational Expenditure) and CAPEX (Capital Expendicture) variables.

Table 1.2 Specification age of ship and DWT

No.	Ship	Age of Ship	DWT
1.	KM. Gunung Dempo	9 Year	4.018 Ton
2.	KM. Labobar	14 Year	3.482 Ton
3.	KM. Dobonsolo	24 Year	3.500 Ton

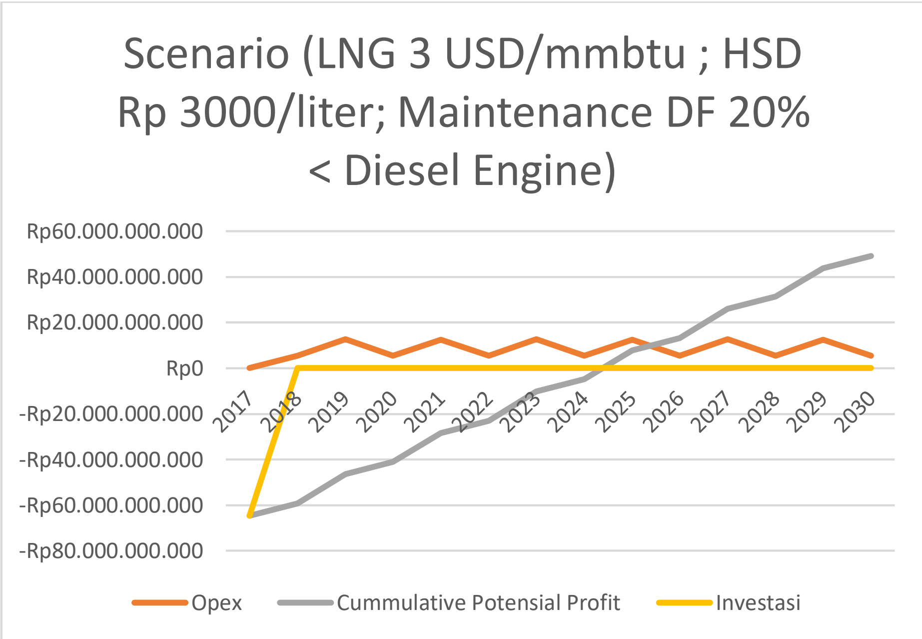


Figure 1.3 Scenario Graph Feasibility KM. Gunung Dempo Variation Price LNG 3 USD and HSD Rp 3.000/liter with Maintenance DF20%<Diesel Engine

In all industrial components, manufacturing industry, and shipping industries in the world are highly dependent on fuel oil. This is the strongest reason for the deplection of world oil supplies . This condition also affects in shipping sector because oil consumption is quite large as the fuel of ship. In addition, the occurrence fluctuations in the price of petroleum to make industry players began to use alternative fuels. Some industry players have managed to commercialize engines into machines that can use 2 types of fuel or which can be called dual fuel by combining fuel oil and LNG.

The safety record of LNG carriers is extremely good. Even though most of the principles remain the same, using LNG as fuel for conventional ships introduces new systems on board together with their associated risks. To located LNG tank also need many consideration for safety reason and economical aspect. In order to design, build and operate a gas-fuelled vessel in a safe and sustainable way, these risks will have to be thoroughly investigated and minimised

1.2 STATEMENT OF PROBLEMS

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

1. How to design tank LNG inside and outside compartement for dual fuel system in passenger ship?
2. Which is more economically profitable for location of LNG tanks inside and outside compartement?
3. What are risks and failures that can be generate for LNG tank inside and outside compartement on fuel system that uses natural gas?

1.3 RESEARCH LIMITATION

1. The ship that will be design is KM Gunung Dempo whiches especially in fuel system with LNG tank inside and outside compartement.
2. Data that are not listed in detail, such as P&ID, will be assumed to follow project guide from the machine manufacture and class regulation which used by ship.
3. The feasibility economic analysis only focuses on the most profitable design LNG tank.

1.4 RESEARCH OBJECTIVES

The objectives of this thesis are:

1. To design LNG tank inside and outside compartement of KM Gunung Dempo.
2. To Analysis economical aspect on comparing profit of LNG tank inside and outside compartement.
3. To risk assessment on the fuel system that uses natural gas as fuel.
4. To propose mitigation if risk is not acceptable.

1.5 RESEARCH BENEFITS

The final result of this thesis is Design alternative fuel system inside and outside LNG tank of KM Gunung Dempo based in risk assessment and economic analysis.

CHAPTER II
BASIC THEORY

2.1 PT. Pelayaran Nasional Indonesia (PELNI)

PT. Pelayaran Nasional Indonesia (PT PELNI) is a national shipping company providing marine transportation services, passenger and inter-island freight services. The ship that was used as design for P&ID design of Fuel system using Dual Fuel Diesel Engine is KM Gunung Dempo.

Figure 2. 1 KM. GunungDempo
(Sumber:www.marinetraffic.com/en/ais/details/ships/vessel:GUNUNG_DEMP)

Table2. 1 Information KM Gunung Dempo

Ship Name	KM. Gunung Dempo
Dock Building	Jos L. Mayer, Papaenburg, Germany
Year Built	2008
IMO Number	9401324
Call Sign	YBMG
Type	2000 Pax
Loa	147,00 m
Lpp	130,00 m
Breadth	23,40 m
Draught	5,90 m
Gros Tonnage	14,017 GT
DWT	4.018 Ton
Service Speed	17 Knot
Main Engine	2 Unit MAK Catterpillar 6M43 Spec 6000 KW/ 500 Rpm
Auxilliary Engine	4 Unit Yanmar 6N21L-EV Spec. 750 KW/ 750 Rpm

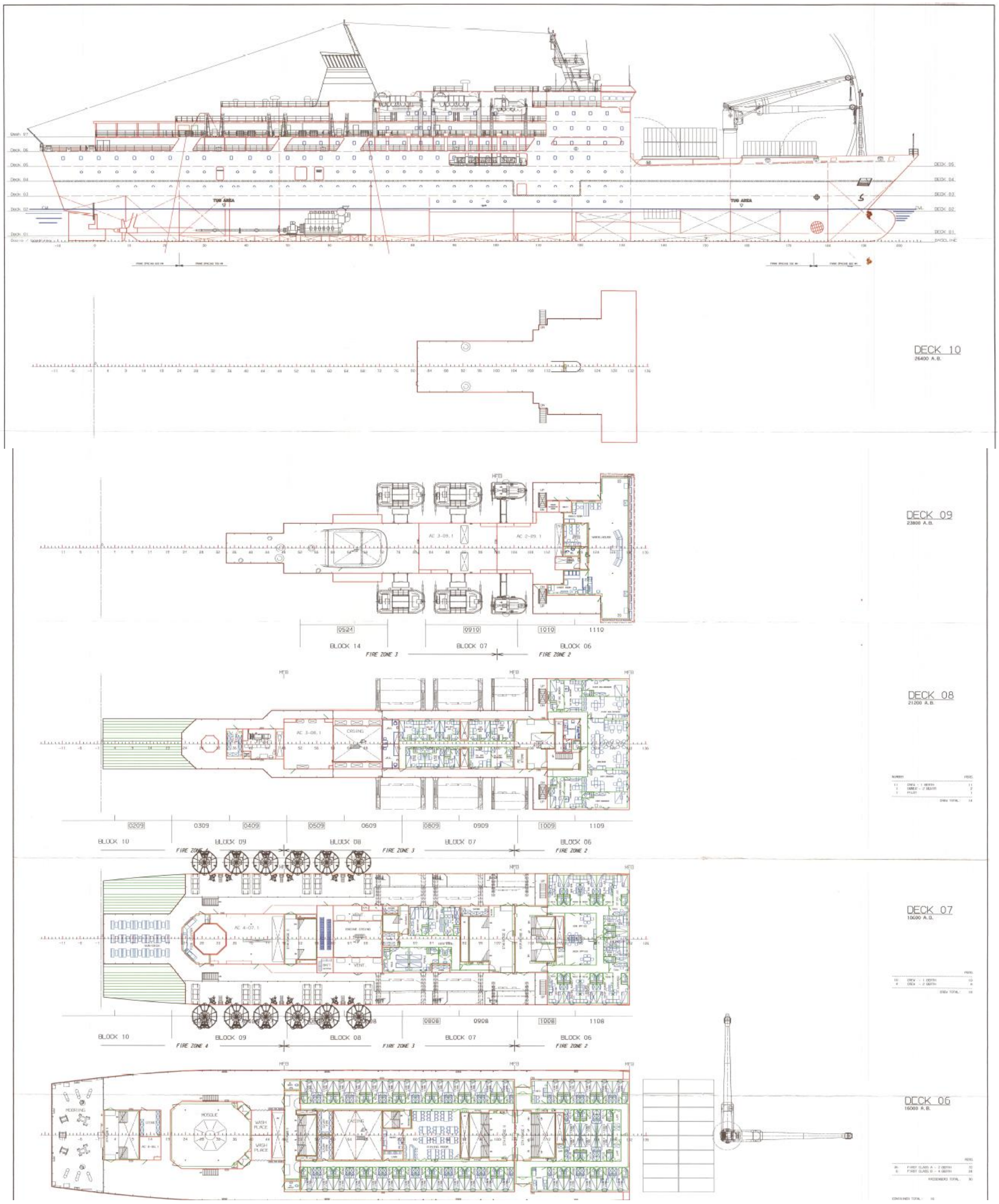


Figure 2. 2 General Arrangement KM. Gunung Dempo

2.2 The Feasibility Study for Determining Age of Passenger Ship Conversion Into a Dual Fuel Engine Diesel Engine with System Dynamics Method

In the study of feasibility studies on determining the life of passenger ships can be known that the variable - the determinant variable is based on variables about OPEX (Operational Expenditure) and CAPEX (Capital Expendicture) variables. On OPEX and CAPEX will affect the Potential Cummulative Profit that determines the eligibility of the vessel. Operational Expendicture variable consist of variable of Fuel, Lubricant variable, maintenance cost variable, overhaul variable and weight difference variable. While at variable of Capital Expendicture consist of docking cost variable, LNG tank cost variable and variable purchase cost of dual fuel engine based on power used. The most influential cost effect is on the difference in the cost of LNG fuel and the cost of fuel oil. At the cost of fuel is very influential in the change of determination of eligibility.

Modeling on determining the life of passenger ships is illustrated through causal loop diagram which is a big picture modeling that will be done in more detail through the model image on each variable.

2.3 Liquified Natural Gases

Liquified natural gas is a liquid substance, a mixture of light hydrocarbons primarily composed of methane (CH_4, 85-98% by volume), with smaller quantities of ethane (C_2H_6), propane (C_3H_8), higher hydrocarbons (C4+) and nitrogen as an inert component. The composition of LNG depends on the traits of the natural gas source and treatment of gas at the liquefaction facility. It can also vary with storage conditions and customer requirements (Benito, 2009; British Petrol and International Gas Union, 2011). LNG producers determine the quality of their LNG based on composition of field gas and more importantly, market demand. Liquefied natural gas is a colourless, odourless, non-corrosive and non-toxic liquid, lighter than water. Typical thermo-physical properties of LNG are presented in Table 2.3.

Table 2.3 Thermo – physical properties of LNG

Parameter	**Value**
Boiling point	-160°C do - 162°C
Molecular weight	16 – 19 g/mol
Density	425 - 485 kg/m^3
Specific heat capacity	2,2 – 3,7 kJ/kg/°C
Viscosity	0,11 – 0,18 mPa•s
Higher heat value	38 - 44 MJ/m^3

Table 2.4 Classification of LNG

Composition (%)	**LNG Light**	**LNG Medium**	**LNG Heavy**
Methane	98.00	92.00	87.00
Propane	1.40	6.00	9.50
Propane	0.40	1.00	2.50
Butane	0.1	0.00	0.50
Nitrogen	0.10	1.00	0.50
Density (kg/m3)	427.74	445.69	464.83

LNG may be classified in accordance with several criteria: Density, Heat Value, Methane or Nitrogen amount, etc. The parameter most commonly used for classification is density. Accordingly, we differentiate between heavy, medium or light LNG's. The typical composition and density of three typical LNG qualities are depicted in Table 2.3.

The produced LNG is stored in cryogenic tanks below the boiling point at the pressure of 0.05-0.2 bar until an LNG tanker arrives to transport product. Upon the arrival of tanker, LNG from storage tank is loaded from the loading plant into LNG tanker, which will transport gas to the receiving terminal. For safety reasons, storage tanks at loading and receiving terminals in which liquefied gas is stored usually consist of two tanks designed to be fully loaded. The inside of the container in which liquefied gas is stored usually made of stainless steel resistant to low temperatures. The outer tank is made of pre-stressed concrete and designed to fully contain LNG in case of spillage and fully loaded in the event of damage to inner tank. Apart from safety aspects, LNG tanks are also designed to minimise ingress of heat into tanks to prevent the boiling (evaporation) of a fraction of the LNG. The usual tank volumes range from 80.000 to 160.000 m.

2.4 Boil of Gas

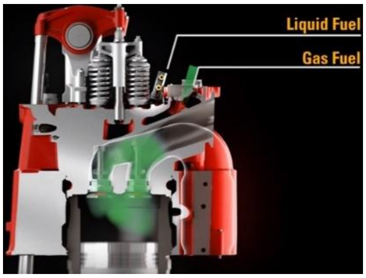
Liquefied natural gas is stored and transported in a tank with a cryogenic material (liquid brittle), as a liquid at a temperature below the boiling point. As with other liquids, LNG (Liquefied Natural Gas) evaporates at temperatures above its boiling point by producing BOG (Boil Off Gas). The formation of BOG with the inclusion of heat into the LNG tank during storage, delivery and loading and unloading operations and also by the existence of sloshing or movement on the ship while sailing. The number of BOGs depends on the design and operational conditions of LNG tank usage. An increase in the number of BOGs can increase the pressure in the LNG tank. Given the increased pressure in the tank it can be bad condition to excess pressure and there may be an explosion. Therefore there is a need for maintenance to maintain the BOG with a certain amount. In the LNG supply chain, BOGs can be safely guarded in a way that can be utilized for fuel or re-melted into liquid by descending. (Dobrota Dorde, 2013)

2.5 Dual Fuel Engine Concept

In this research with comparison of machining system which in pure air Engine gas which is inhaled will be mixed with LNG gas so that only LNG gas is needed for explosion. Operation with gas mode This engine can reduce nitrogen oxide (NOx) emissions approaching 85%. In addition, when operating with natural gas and low sulfur fuel, gas - fueled diesel motors produce SOx levels almost zero. (ABS, 2014). The working principle on gas Engine is actually not much different from conventional engine working system (diesel engine). Gas Engine currently mostly uses 4 steps, namely (Eribson, 2016):

a. Suction Step

At this step, the air is mixed with the gas before the inlet valve and the mixture is compressed into the combustion chamber during the compressing phase. At the time of this suction step, the gas will also be atomized into the combustion chamber



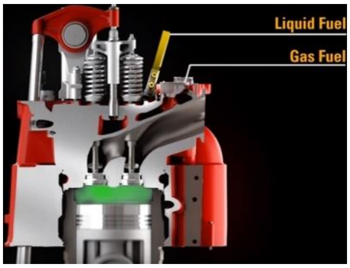


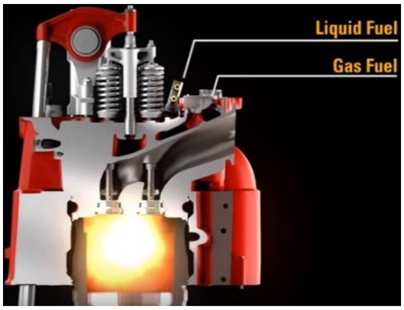
Figure 2. 3 step suction of Dual Fuel   Figure 2. 4 Compresion Step of Dual Fuel
(Sumber: https://www.youtube.com/watch?v=6oj3_fO-_L8&t=142s)

b. Compression Step

The compression step of the piston moves from the TMB (bottom dead point) to the TMA (the top dead point). The inlet and outlet valve positions are closed so that air or gas in the combustion chamber is compressed shortly before the piston reaches the TMA position (top dead point). The purpose of this compression step is to increase the temperature so that the mixture of air and gas fuel (LNG) can collaborate.

c. Burning Steps

This step begins by turning on the spark plug which causes the burning of fuel (a mixture of air and fuel gas LNG). The combustion process will cause an explosion that will push the piston down (crankshaft).



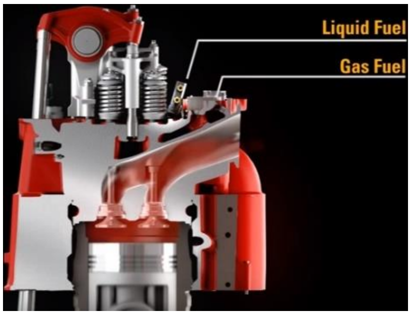


Figure 2.5 Combustion Steps   Figure 2.6 Dispose Step of Dual Fuel
(Sumber: https://www.youtube.com/watch?v=6oj3_fO-_L8&t=142s)

d. Dispose Step

In this step the piston will move up to TMA and push the exhaust gas out through the open exhaust valve. At the end of the fresh air exhaust step and the gas fuel mix (LNG), it will enter and push the remaining exhaust gas out and the next work process will begin. In this step, the exhaust valve opens and the inlet valve is closed.

Utilization of Diesel Engine as main engine in the vessel due to high thermal efficiency achieved (up to 48%) and the low emission of NOx (up to 3 Kg / kWh). Dual Fuel Diesel Engine (DFDE) utilizes gas as fuel based on the concept of otto cycle and diesel oil based on the concept of diesel - cycle. Gas fuel used here as main fuel, while diesel oil is used as a pilot fuel (fuel at the beginning of diesel engine operation). Utilization of this type of diesel engine as marine application becomes better considering low gas supply pressure needed (about 5 bar) and excellent safety characteristics. This type of diesel can not be categorized as a gas engine that only uses gas as a fuel for diesel. Furthermore, this application allows LNG vessel to operate even when the ship does not carry cargo at all. (Soegiono & Artana, 2006)

Since dual-fuel uses 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 project guide 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;

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

In the equation 4, we could see that the calculation output is in kilojoule and needs to be converted to volume unit. Based on Alberta Energy website, 1 gigajoule [GJ] of natural gas is 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 determining how long the engine will work and the load the engine needs to be produced. After the volume is calculated, the other equipment like heater, insulation, pump, etc can be determined too.

2.6 Regasification

To utilize LNG, the LNG must be converted to gas form by heating up the LNG from $\mathbf{-161}$℃ back to natural gas at atmospheric temperature. There are several methods to regasification, the LNG user can use according to LNG Vaporizer Selection Based on Site Ambient Condition Article (Patel, 2013) such as;

2.6.1 Open Rack Vaporizer (ORV)

Open rack vaporizer (ORV) is a vaporizer which uses seawater as its heat source. The heat is distributed to LNG using heat exchanger. An ORV is usually constructed with a material that is able to work in extremely cold environment like aluminium 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.

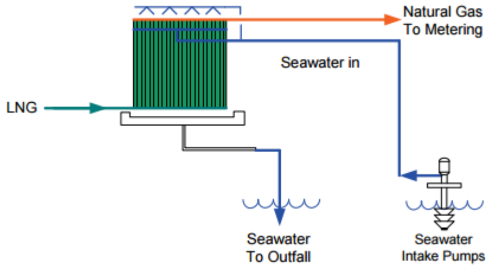


Figure 2.7 Open Rack Vaporizer Flow Scheme[1]

2.6.2 Submerged Combustion Vaporizers (SCV)

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

In SCV method, LNG flows through stainless steel tube coil 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 submerged inside the water baths is vulnerable to corrosion by acid as the combustion gas products (CO_2) that are condensed in the water.

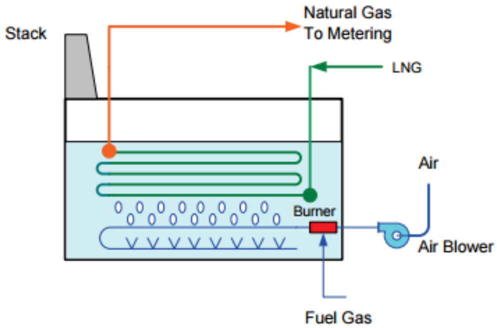


Figure 2.8 Submerged Combustion Vaporizers[2]

2.6.3 Ambient Air Vaporizers (AAV)

Ambient air vaporizer uses 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.

Direct ambient air vaporizer uses vertical heat exchanger where the LNG pipes is exposed to an open air. Due to low heat transfer, AAV is usually used in smaller terminals and requires more vaporizers to achieve the same performance level with other regasification methods. In this method, air is flowing from the upper side of the heat

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exchanger and flowing to the downside of the heat exchanger due to its increasing density as the decreasing air temperature.

AAV methods require monitoring every 4-8 hours to clean the ice build-up on the LNG pipes, the ice build-up occurs because of the extreme temperature difference and creates a condensation process, then condenses water frosted. The performance of AAV is highly depending on the environment such as temperature, relative humidity, altitude, wind, solar radiation and its structure.

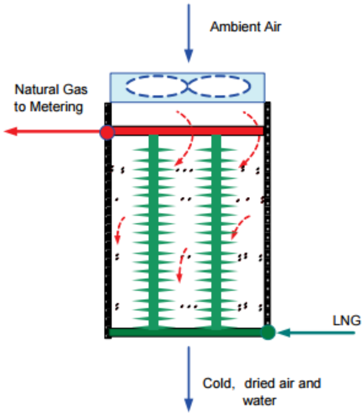


Figure 2.9 Ambient Air Vaporizer[3]

2.6.4 Intermediate Fluid Vaporizers (IFV)

An intermediate fluid vaporizer uses heat transfer fluid (HTF) in a closed loop to vaporize the LNG, there are several types of heat transfer fluid which can be utilized in this regasification method like Glycol-Water, Hydrocarbon Based Fluid, and Hot Water.

2.7.4.1 Glycol-Water Intermediate Fluid Vaporizer

This IFV method uses 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 reject its heat.

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

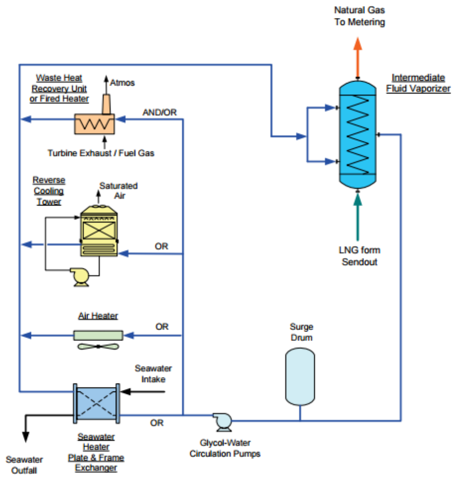


Figure 2.10 Glycol-Water Intermediate Fluid Vaporizer[4]

2.6.4.2 Intermediate Fluid (Hydrocarbon) in Rankine Cycle

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

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

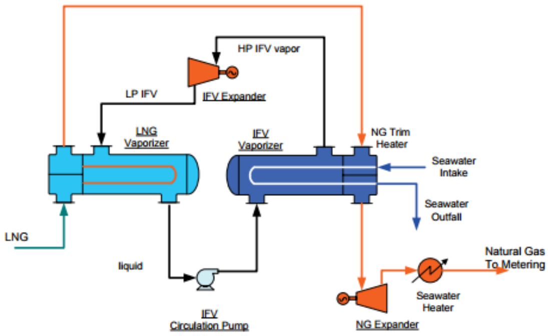


Figure 2.11 IFV LNG Vaporizer in Rankine Cycle[5]

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 needs to be provided with aset of “double block and bleed” valves.

Double block and bleed valves are a valve consisting 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 Risk assessment

Risk assesment can be facilitated through several formal techniques. These different methods may contain similar approaches to answer the basic risk assessment questions; however, some techniques may be more appropriate than others for risk analysis depending on the situation.

Risk assessment techniques develop processes for identifying risk that can assist in decision making about the system. The logic of modeling the interaction of a system’s components can be divided into two general categories: induction and deduction.

Induction provides the reasoning of a general conclusion from individual cases. Inductive analysis answers the question, “what are the system state(s) due to some event?” In reliability and risk studies this “event” is often some fault in the system. Deductive approaches provide reasoning for a specific conclusion from general conditions. This technique attempts to identify what modes of a system/ subsystem/component failure can be used to contribute to the failure of the system. Deductive logic answers the question, “how can a system state occur?”. (Wilcox, Burrows, Ghosh, & Ayyub, 2000)

2.8.1 Hazop Method

Hazard and Operability or HAZOP is an analysis technique which used to exam safety factor on new system or modification to knowing the potential failure on their operability. The HAZOP study should preferably be carried out as early in the design phase as possible - to have influence on the design.

HAZOP studies may also be used more extensively, including:

- At the initial concept stage when design drawings are available.
- When the final piping and instrumentation diagrams (P&ID) are available.
- During construction and installation to ensure that recommendations are implemented.
- During commissioning.
- During operation to ensure that plant emergency and operating procedures are regularly reviewed and updated as required/

The basis of HAZOP is a “guide word examination” which is a deliberate search for deviations from the design intent. To facilitate the examination, a system is divided into parts in such a way that the design intent for each part can be adequately defined. The size of the part chosen is likely to depend on the complexity of the system and the severity of the hazard. In complex systems or those which present a high hazard the parts are likely to be small.

The design intent for a given part of a system is expressed in terms of elements which convey the essential features of the part and which represent natural divisions of the part. The selection of elements to be examined is to some extent a subjective decision in that there may be several combinations which will achieve the required purpose and the choice may also depend upon the particular application. Elements may be discrete steps or stages in a procedure, individual signals and equipment items in a control system, equipment or components in a process or electronic system, etc.

The identification of deviations from the design intent is achieved by a questioning process using predetermined “guide words”. The role of the guide word is to stimulate imaginative thinking, to focus the study and elicit ideas and discussion, thereby maximizing the chances of study completeness.

Table 2.5 Basic Guide Words and Meanings

Guide Word	Meaning
NO or NOT	Complete negation of the design intent
MORE	Quantitative increase
LESS	Quantitative decrease
AS WELL AS	Qualitative modification/ increase
PART OF	Qualitative modification/ decrease
REVERSE	Logical opposite of the design intent
OTHER THAN	Complete substitution

Table 2.6 Guide Words relating to Clock Time and Order or Sequence

Guide Word	Meaning
EARLY	Relative to the clock time
LATE	Relative to the clock time
BEFORE	Relating to order and sequence
AFTER	Relating to order and sequence

Some examples of combinations of guide-words and parameters:

- NO FLOW

Wrong flow path - blockage - incorrect slip plate – incorrectly fitted return valve - burst pipe - large leak - equipment failure- incorrect pressure differential - isolation in error.

- MORE FLOW

Increase pumping capacity - increased suction pressure - reduced delivery head - greater fluid density - exchanger tube leaks - cross connection of systems - control faults.

The technical process of HAZOP assessment is to list the critical coponents that lead into potential hazard and what kind of guide words to lead into the deviations as seen in Table 2.2 is the typical british standard form that will be used in this thesis.

Table 2.7 Example of HAZOP Assessment

STUDY TITLE: PROCESS EXAMPLE								**SHEET: 1 of 4**	
Drawing No.:			**REV. No.:**					**DATE:** December 17, 1998	
TEAM COMPOSITION:			LB, DH, EK, NE, MG, JK					**MEETING DATE:** December 15, 1998	
PART CONSIDERED:			**Transfer line from supply tank A to reactor**						
DESIGN INTENT:			**Material:** A **Source:** Tank for A	**Activity:** Transfer continuously at a rate greater than B **Destination:** Reactor					
No.	**Guide word**	**Element**	**Deviation**	**Possible causes**	**Consequences**	**Safeguards**	**Comments**	**Actions required**	**Action allocated to**
1	NO	Material A	No Material A	Supply Tank A is empty	No flow of A into reactor Explosion	None shown	Situation not acceptable	Consider installation on tank A of a low-level alarm plus a low/low-level trip to stop pump B	MG
2	NO	Transfer A (at a rate >B)	No transfer of A takes place	Pump A stopped, line blocked	Explosion	None shown	Situation not acceptable	Measurement of flow rate for material A plus a low flow alarm and a low flow which trips pump B	JK
3	MORE	Material A	More material A: supply tank over full	Filling of tank from tanker when insufficient capacity exists	Tank will overflow into bounded area	None shown	Remark: This would have been identified during examination of the tank	Consider high-level alarm if not previously identified	EK

2.8.2 Fault Tree Analysis (FTA)

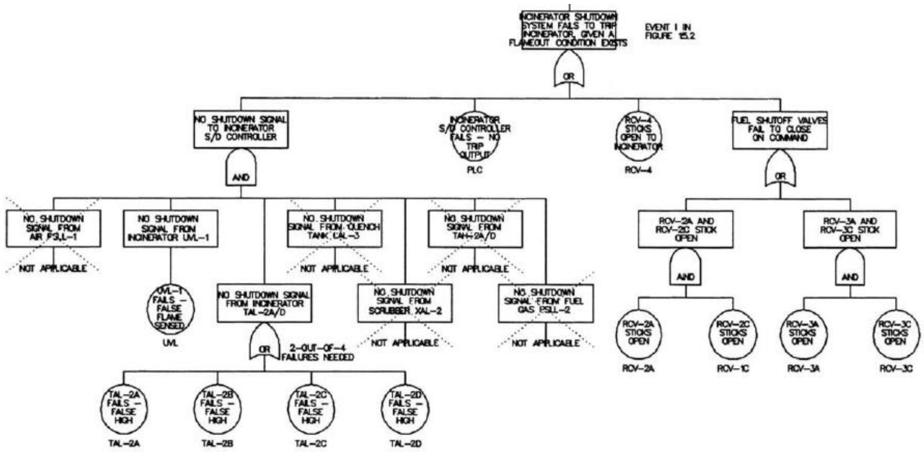


Figure 2.12 FTA Applications

Fault Tree Analysis (FTA) is a method to determining cause of specific top event incident that caused by several basics cause, using logical Figure depiction that called Bolean Logic Gate. The fault tree is a Figureal model that displays the various combinations of equipment failures and human errors that can result in the main system failure of interest (called the Top event). The purpose of an FTA is to identify combinations of equipment failures and human errors that can result in an accident.

2.8.3 Event Tree Analysis (ETA)

Event Tree Analysis is a method to predict the posible outcomes by showing it into graphs that show the probability of various scenarios and the consequences. The results of the Event Tree Analysis are accident sequences; that is, sets of failures or errors that lead to an accident.

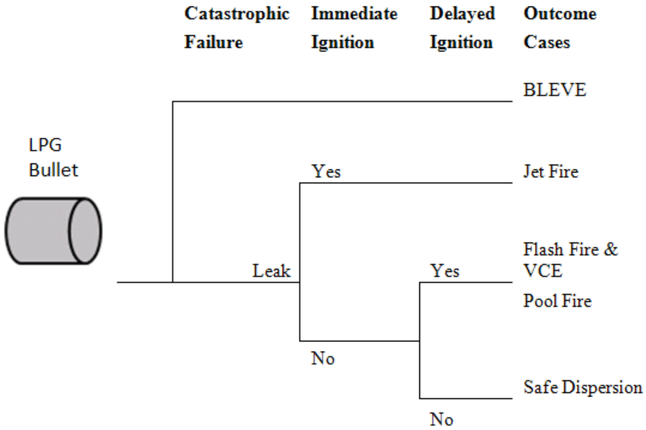


Figure 2.13 ETA Applications

2.8.4 Consequences Modelling Using Process Hazard Analysis Software Tools

Consequences modelling is one of the method to numerical and computational based modelling to predict what an accident can affect and what its physical outcome to surrounding, and also show what its potential impact to people, assets or safety function.

There are several approaching method to do consequences modelling they are: release approach, dispersion in air and water approach, fire and thermal radiation, explosion approach, smoke and gas ingress approach, and toxicity approach. All the approaches are making consequences modelling has a lot of aspect to explore, but also for the same reason the various approach that exist make it are quite hard to cover all the approach in one hit. It makes the tools (e.g. Software) to do an approach is have their own boundaries/limits to calculation. For example for certain software which concerning about thermal and radiation approach are cannot to be used in smoke or toxicity approach. This limitation make the approach to overcome an event are have to be specifically determined and chosen to do such an analysis.

Process Hazard Analysis Software Tools is one of most comprehensive hazard analysis software for all stages including process industry, design, and operation will be very comply with the problem above, since Process Hazard Analysis Software Tools is can analyze the present potential hazard that may occur accurately and also provide clear illustration of the outcomes that may results from the modelling process. Process Hazard Analysis Software Tools is also in compliance with the safety regulations that is strictly monitored in oil and gas industry.

2.8.5 ALOHA

ALOHA is a software that use to make plan and respon hazard condition from chemical substance, for example methane. This software can detect threat zone from hazard. ALOHA simulate hazard potency from toxic vapour, BLEEVE, pool fire, and vapour cloud expansions.

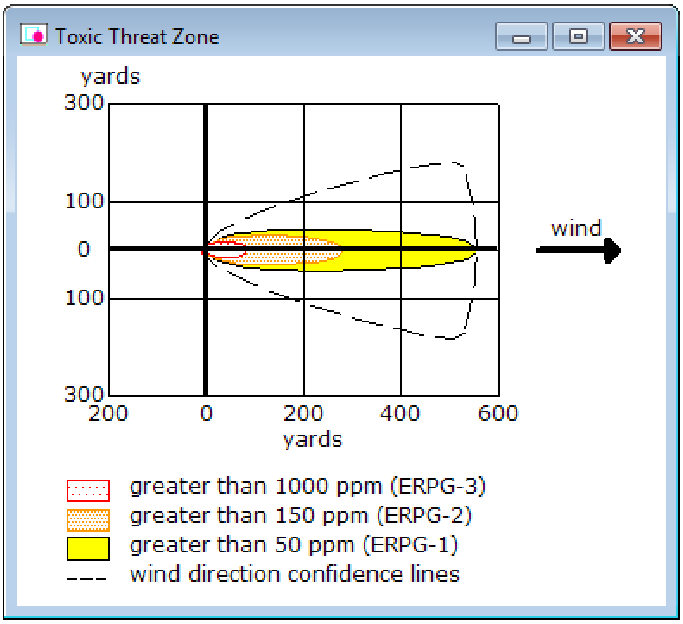


Figure 2.14 Aloha Software

Red zone is the worst area, yellow zone and orange zone show decresing of hazard.

2.8.6 Risk Evaluation

Risk Evaluation can do by many way, for example by risk matrix, F-N cuve, risk profile and etc. Some of them can chose for risk evaluation.

2.8.7 F-N Curve

F-N curve is a method risk representative which form of Figure.

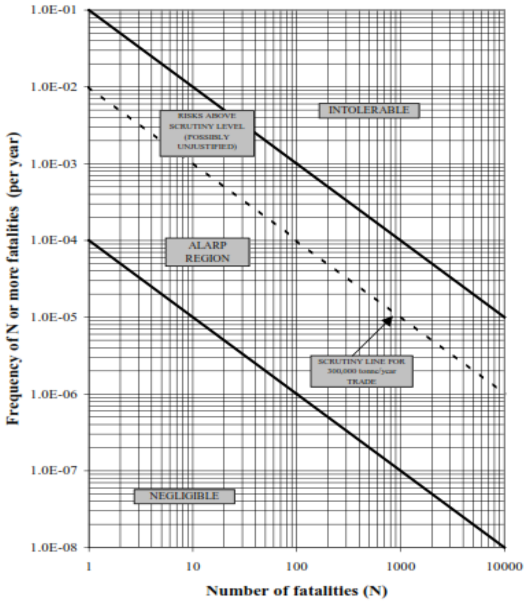


Figure 2.15 F-N Curve ACDS Tolerability of Transport Risk Framework (DNV, 2013)

Figure 2.15 above is a F-N Curve owned by Advisory Committee on Dangerous Substances (ACDS). Where the x-axis axis shows a representation of death rate. While y-axix strategy shows frequency of hazards that appear within a year. The F-N Standard Curve is chosen because it can be applied to special transport areas for the transport of dangerous goods.

2.8.8 Layer Of Protection (LOPA)

LOPA is a method that used to perform risk mitigation. Risk mitigation is an action to reduce value of frequency or value of consequences an unacceptable or tolerant risk. Risk mitigation using LOPA there are several ways that can be done such as adding components to process diagram in order to reduce frequency of risk or in other words provide redundancy on the system. Addition of safety components such as relief valve, safety valve, and others. Provide independent protection or so-called independent protection layer (IPL) such as gas detector, flamebale detector, smoke detector, pressure alarm, temperature and others.

In this study will be used addition of IPL to reduce the frequency value if risk is not acceptable. The value of IPL frequency is obtained from Geun Woong Yun's thesis entitled "Bayesian-LOPA methodology For Risk Assessment Of An LNG Importation Terminal". (Geun Woong Yun)

2.9 Economical Analysis

Economical study is feasibility of investing whether conversion made a favorable outcome or not. Some of techniques used in this economic assessment are Net Present Value (NPV), Internal Rate Return (IRR) and to know return period of an investment using Payback.

2.9.1 Net Present Value

Net Present Value (NPV) is a method of assessment an investment that will be done by focusing on present value (Present Value) and expenditure will be compared with present value (Present Value) income / acceptance. NPV shows the net benefits received from a given business period at a certain discount rate rate. Often the term discount rate is also called the Minimum Attractive Rate of Return (MARR).

If t NPV value is more than 0, the investment can be said profitable. If NPV value is equal to 0, it can be said that the investment can be returned exactly the same. But if NPV is less than 0, then project is said not to do.

2.9.2 Internal Rate Return

IRR is used to calculate the interest rate at the NPV value is equal to 0. The IRR is useful to know the interest rate of some fixed investments giving profit.

2.9.3 Payback Period

Payback Periods is period required to recover all costs incurred in the investment of a project.

2.9.4 Feasibility of Conversion Project

Financial feasibility of a ship project can be determined by determining what parameters used as a reference in assessing project feasible to run or not. A common term used in assessing financial feasibility of a project is with a feasibility study. Project feasibility study steps from financial aspect is first to prepare project cash flow by determining CAPEX and OPEX of a project, where CAPEX is initial investment of a project and amount of CAPEX is the amount of operational costs incurred in a project. OPEX includes operational costs, shipping costs or voyage costs as well as cash flow terminals, for further explanation will be explained in explanation below. (Soeharto, 2001)

2.9.5 Cash Flow

Cash flow during age of vessel investment is a model to be analyzed in order to assess the financial feasibility. Broadly speaking, cash flow is divided into three main sections, namely initial cash flow, operational cash flow and cash flow terminal. A more detailed explanation of t parts of cash flow arrangement is as follows (Stopford, 2009):

A. Capital Expenditure

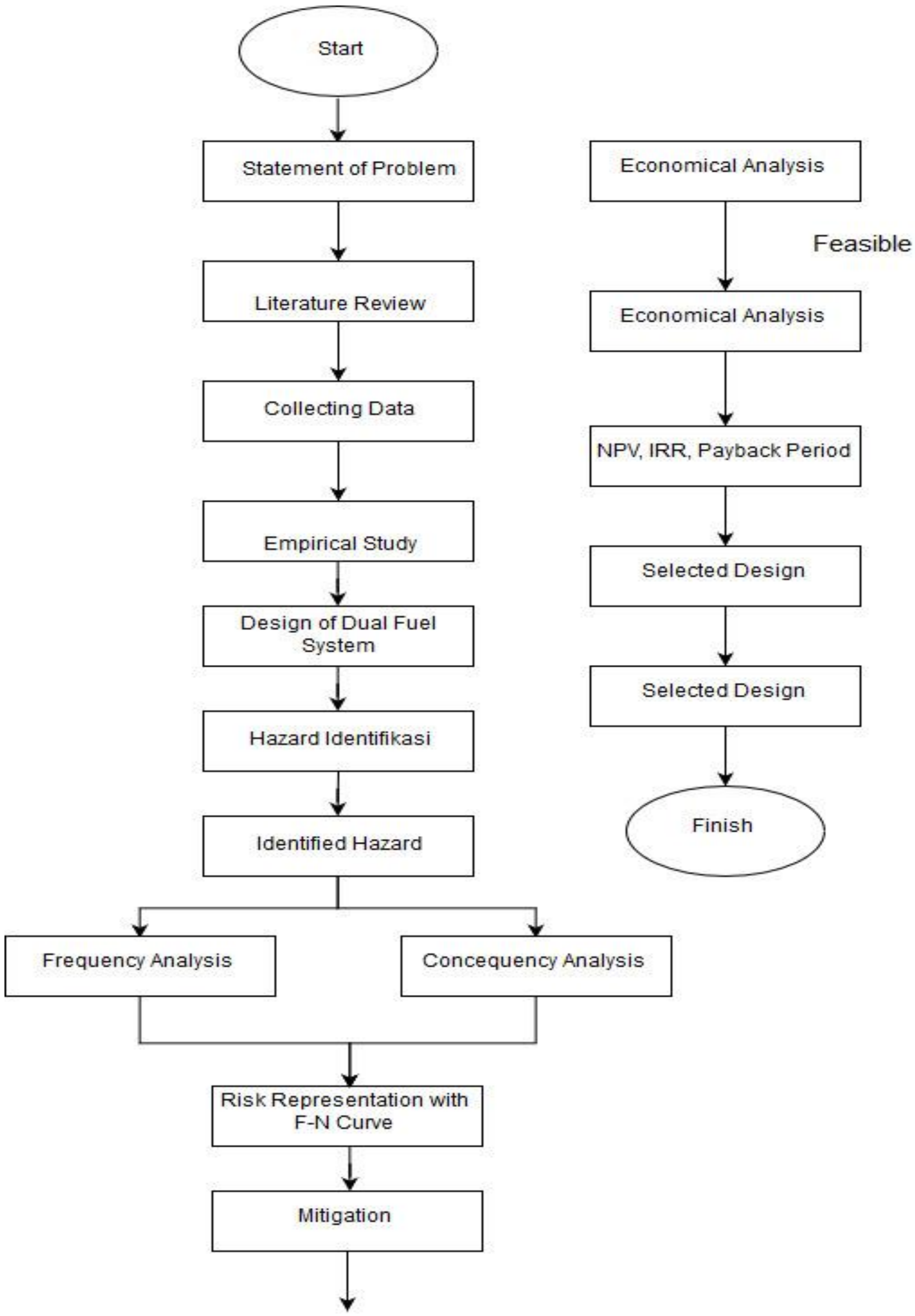
The initial cash flow will involve Capital Expenditure calculations (CAPEX), costs to be incurred for investment, interest (interest) and project costs. One of the considerations is from where the vessel's investment capital is obtained, whether by own capital or loan. Surely this will affect the financial sustainability of the project forward.

B. Operational Expendicture

In the operating cash flow will be taken into account the cash inflows from income and cash flow out of opperating expenditure (OPEX) as well as taxes. Revenue will be highly dependent on load capacity, productivity and freight rate. While operating expenditure (OPEX) that is borne by ship owner will be related to ship charter type. Charges for voyage charter types include operational costs and voyage costs.

CHAPTER 3

RESEARCH METHODOLOGY



In order to solve the problem above, that will be used dataanalysis from literatures.

1. **Statement of Problems**

   Identifying the problems is to determine what problem formulation to be taken. Formulation of the problem is an early stage in the implementation of the final project. This stage is a very important stage, which at this stage is why there is a problem that must be solved so worthy to be used as ingredients in the final work. Problem formulation is done by digging information about problems that occur at this time. From this stage, the purpose of why this thesis done is knowable. In this thesis, the problem to be addressed in conceptual of dual fuel engine and risk assesment.

2. **Literatur Review**

   Once a problem is already known, the next step is to collect reference materials related to the final project from any resources. The references of this thesis are received from books, journals, thesis report, and informations from internet.

3. **Data Collection**

   To support the thesis, we need to collect some data such as: ship size, engine data, lng data, and other data. The collected data shall cover general plan drawings.

4. **Design of Dual Fuel System**

   The data that have we collect, then we draw in autocad. The design in here is kind of conceptual design.

5. **Economical Analysis**

   The methods for analysis the profit of each design of inside and outside LNG Tank. The analysis using method of benefit cost analysis

6. **Hazard Identification**

   Potential cause of failure describes how a processfailure could occur, in terms of something that can be controlled or correccted. The goal is to describes direct relationship that exist between cause and resulting process failure mode.

7. **Frequency Analysis and Concequence Analysis**

   Analysis of the data in order to determine thelevels of risk. By using FTA for frequency analysis and ALOHA for concequence analysis

8. **Risk Representation**

   This stage willbe determined whether the risk are acceptableor not, the decision are made based on risk matrix

9. **Mitigation**

   Make conclution based on the result obtainedand sugestion for further research development

CHAPTER 4
DATA ANALYSIS AND FINDINGS

4.1 Data Analysis

On this chapter will be discussed further on about all data that required. Analyze data will be appropriated to the scope of problems which had determined.

4.1.1 Ships data

The ship that was used as design for P&ID design of Fuel system using Dual Fuel Diesel Engine is KM Gunung Dempo.

Figure 4. 1 KM. Gunung Dempo
(Sumber:www.marinetraffic.com/en/ais/details/ships/vessel:GUNUNG_DEMP)

Table4. 1 Information KM Gunung Dempo

Ship Name	KM. Gunung Dempo
Dock Building	Jos L. Mayer, Papaenburg, Germany
Year Built	2008
IMO Number	9401324
Call Sign	YBMG
Type	2000 Pax
Loa	147,00 m
Lpp	130,00 m
Breadth	23,40 m
Draught	5,90 m
Gros Tonnage	14,017 GT
DWT	4.018 Ton
Service Speed	17 Knot
Main Engine	2 Unit MAK Catterpillar 6M43 Spec 6000 KW/ 500 Rpm
Auxilliary Engine	4 Unit Yanmar 6N21L-EV Spec. 750 KW/ 750 Rpm

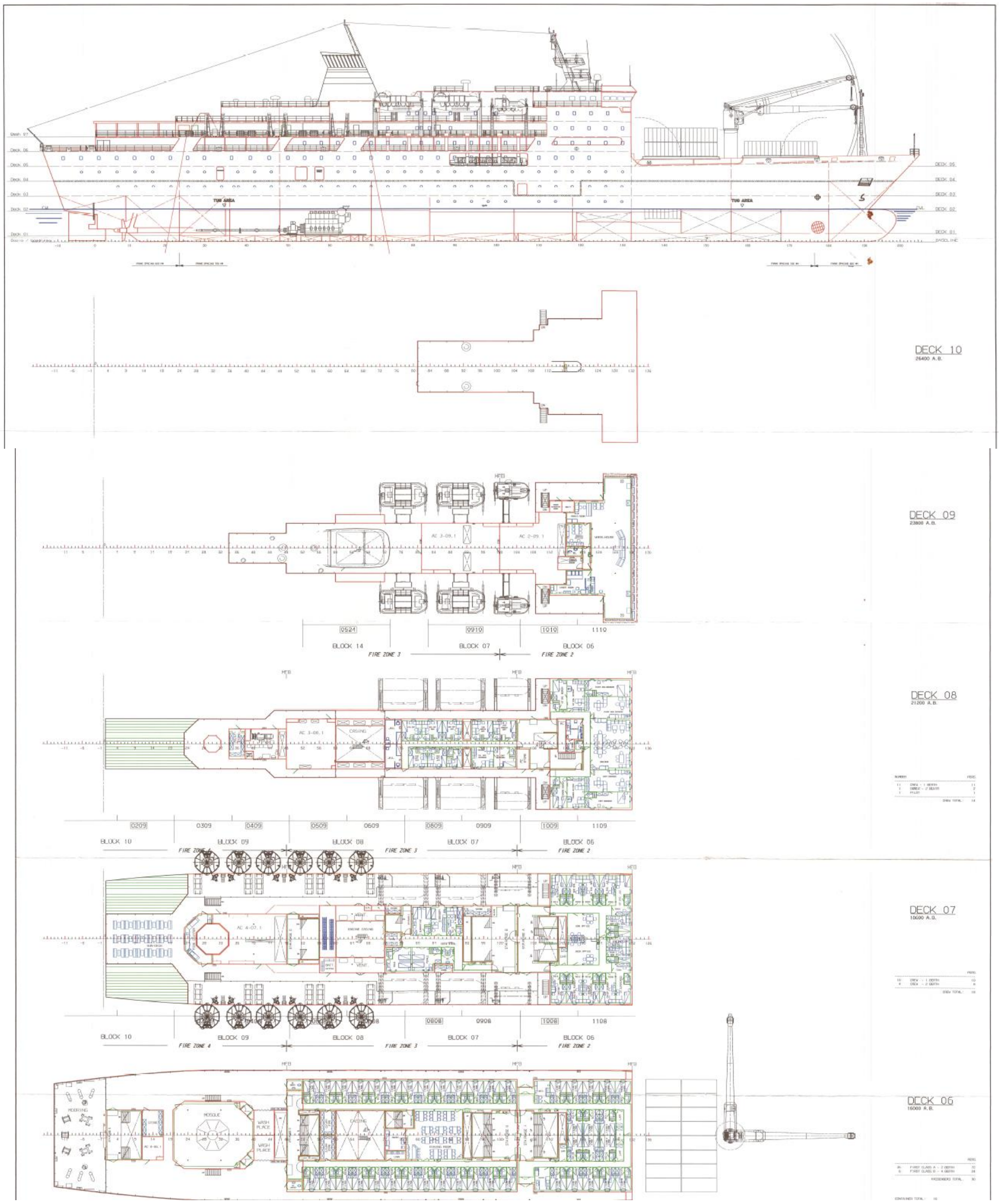


Figure 4. 2 General Arrangement KM. Gunung Dempo

4 P&ID

To convert fuel system to be dual fuel engine needs P&ID design of fuel system in KM. Gunung Dempo that consist :

- P&ID of Gas Storage and Supply System

- P&ID of lng tank inside and outside compartment

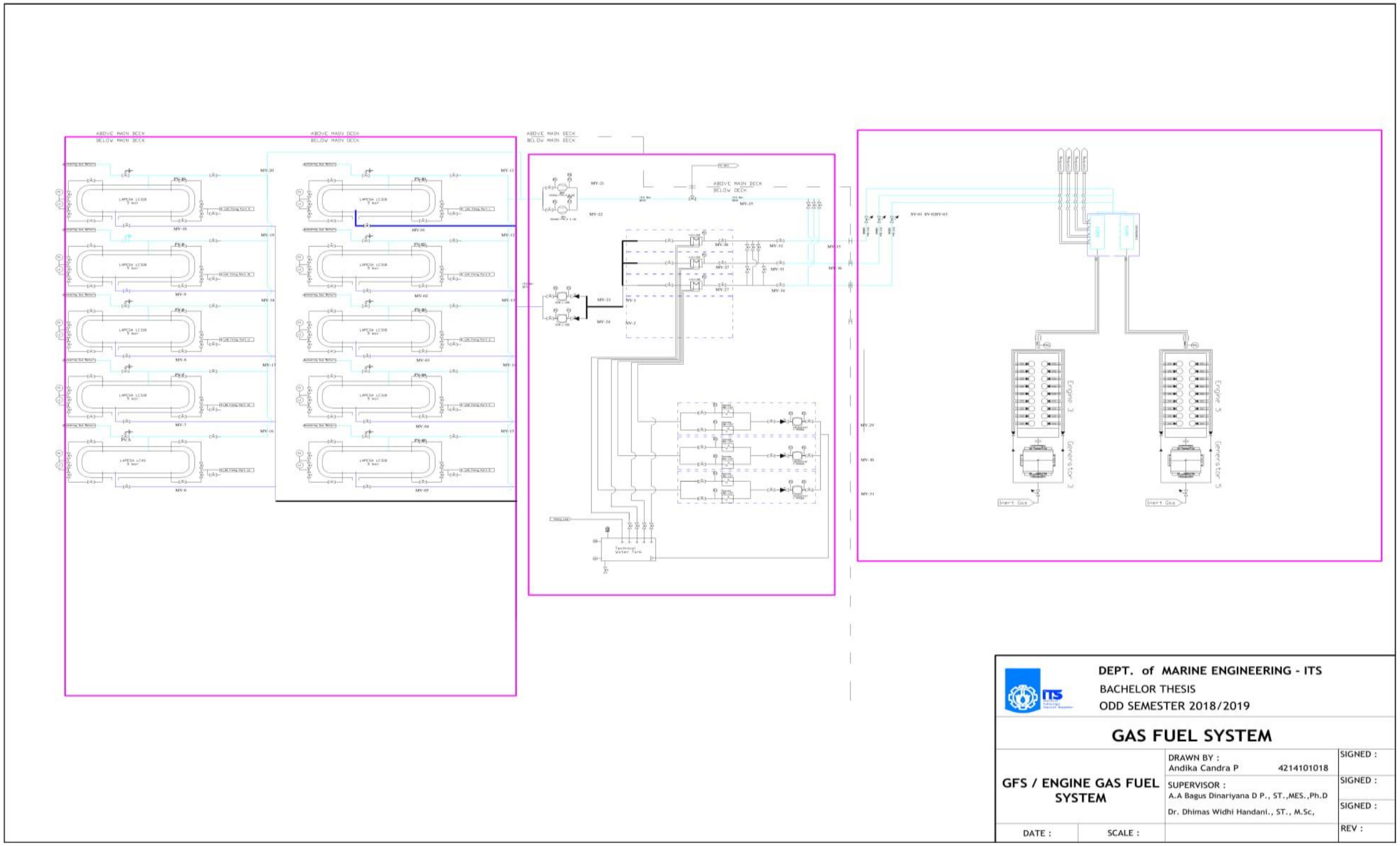


Figure 4.3 LNG Fuel System

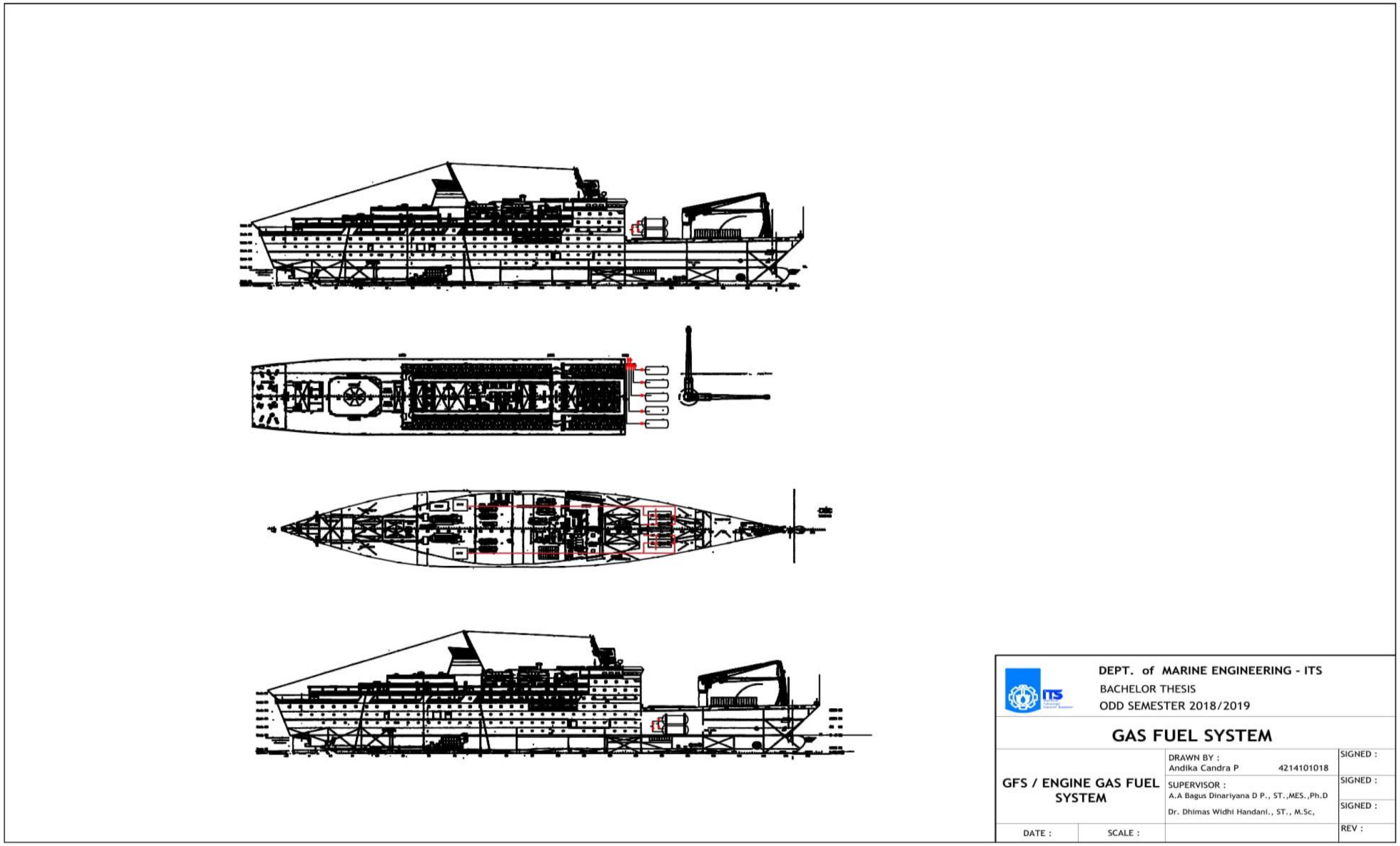


Figure 4.4 P&ID LNG tank inside and outside comparemet

From the figure design of P&ID above explain about how gas fuel can generate to main engine which through Vaporizing process. First step LNG will transfer from LNG bunkering with manifold in compartement LNG tank. After transfer finish, boil of gas from LNG tank will transfer with compresor to GVU before enter engine. LNG with form of liquid will pump to regasification process with vaporizer, then enter in GVU system before enter engine. All LNG must be form of gas when enter in engine.

4.1.2 Fuel System

The system that has been designed need calculation for chosing component of fuel system. Fuel supply system is a designed system to match the requirement of the engine when operated at specific load. In this design, the calculations are done for static load which is the daily average load.

The gas fuel supply system process begins 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 vaporizer will be heated by temperature-regulated fresh water, in the outlet of vaporizer, 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 pipe flow line.

All calculation to determine the requirement for fuel supply system is below.

4.1.2.1 Calculation Liquid Fuel Oil

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;
   $BHP = 6300$
   $SFOC = 2{,}2\ g/(kw - h)$ MDO as a pilot fuel
   $Endurance = 282\ hours\ or\ 13\ days$

   Therefore, the result of the calculation is:
   $W\ MDO = 6300 \times 179{,}5 \times 282 \times 10^{-6}\ [ton]$
   $W\ MDO = 318{,}9\ [ton]$

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;
   $WMDO = 318{,}9\ [ton]$
   $\rho MDO = 0.89\ [ton/m^3]$

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

Therefore, the result of the calculation is:
$V_{storage} = 318{,}9\ \times 1{,}05/\ 0.89$
$V_{storage} = 376{,}2\ [m^3]$

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 supply pump is using the provided formula in MAN 51/60 Project Guide P. 370

- **Cluster 1**

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

Where;

$P_1 = 6300\ kW\ (system\ output\ at\ 100\%\ MCR)$

$br_{ISO1} = 1{,}8\ g/(kw - h)$ (SFOC at 100% MCR)
$f_3 = 0{,}00375\ {}^{l}/_{g}$
Therefore the result of the calculation is;
$Qp = 6300 \times 1{,}8\ \times 0{,}00375$

$Qp = 47\ {}^{l}/_{h}$

- **Cluster 2**

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

Where;

$P_1 = 6300kW\ (system\ output\ at\ 100\%\ MCR)$
$br_{ISO1} = 1{,}8\ g/(kw - h)$ (SFOC at 100% MCR)

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

Therefore the result of the calculation is;

$Qp = 6300 \times 1{,}8\ \times 0{,}00375$

$Qp = 47\ {}^{l}/_{h}$

Table 4. 2 Information Pilot Fuel Supply

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

4. CALCULATION OF MAIN FUEL SUPPLY PUMP

Main fuel supply pump is required pump to supply the engine fuel system. As 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**

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

Where;
$P_1 = 6300\ kW\ (system\ output\ at\ 100\%\ MCR)$
$br_{ISO1} = 178{,}1\ g/(kw-h)$ (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 2**

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

Where;
$P_1 = 6300\ kW\ (system\ output\ at\ 100\%\ MCR)$
$br_{ISO1} = 178{,}1\ g/(kw-h)$ (SFOC at 100% MCR)
$f_3 = 0{,}00375\ {}^{l}/_{g}$

Therefore the result of the calculation is;
$Qp = 36000 \times 178{,}1 \times 0{,}00375$
$Qp = 48087\ {}^{l}/_{h}$

Table 4. 3 Information Main Fuel Supply

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

5. CALCULATION OF SERVICE TANK CAPACITY

MDO Service Tank Capacity can be calculated by formula provided by MAN 51/60 Project Guide. 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;

$P_1 = 6300 \ [kW]$

$b = 2{,}2 \ [{}^{g}/_{kW - H}]$

$\rho = 870 \ @ \ separating \ temprature$

Therefore, the result of the calculation is:

$Q_p = \frac{6300 \times 2,2}{0.87 \times 10^3} = 296,681\ l/h\ (minimum)$

Table 4. 4 Information Fuel oil Separator

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

7. CALCULATION OF SEPARATOR HEATER

Before fluid enters separator, the fluid need to be treated first, especially the temperature. Fluid temperature will affect its properties such as properties, in this case separator will work efficiently if the fluid is temperature 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;
$P = 258,1124\ .2008,32\ .13$
$P = 6738840\ J/h$
$P = 1,8719\ kW$

Table 4. 5 Information Separator Heater

Separator Heater		
Manufacturer		AlfaLaval
Type		Aalborg Vesta EH15
Capacity	kW	5
Weight	Kg	55

8. 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**

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

Where;
$Pc = heat\ to\ be\ dissipated$
$P_1 = 6300\ kW$ (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;
$P_c = 6300 \times 178{,}1 \times 2{,}68 \times 10^{-5}$
$P_c = 171{,}831\ kW$

- **Cluster 2**

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

Where;
$Pc = heat\ to\ be\ dissipated$
$P_1 = 6300\ kW$ (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;
$P_c = 6300 \times 178{,}1 \times 2{,}68 \times 10^{-5}$
$P_c = 171{,}831\ kW$

Table 4. 6 Information Main MDO Cooler

Main MDO Cooler (Cluster 1,2,3)		
Manufacturer		AlfaLaval
Type		M15 – FM8
Heat Surface	kw	184
Weight	kg	

4.1.2.2 Calculation Gas Fuel Oil

1. **CALCULATION OF VAPORIZER**

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

   - **Cluster 1**

Engine	**Gas Consumption per hour** $\boldsymbol{m^3/h}$
MAN 6L51/60DF	562,71

The selected Vaporizer is;

Table4. 7 Information Vaporizer

Manufacturer		Cryoquip
Type		VWU104
Q	Nm^3/h	1314

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 GVU inlet, the pressure should be 5,5 bar. Therefore, the head of pump shall be greater than the requirement considering head loss during transferring fluid.

   - LP LNG Pump 1

Table 4. 8 LP pump

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

Table 4. 9 LP 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 LNG with type of vaporizer are heat exchanger. The calculation for water pump are following requirement from the vaporizer flow rate.

Table 4. 10 FW pump

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

4. CALCULATION OF FRESH WATER HEATER

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

- **Cluster 1**
- $P = m.c.\Delta T$

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 2**

$P = m.c.\Delta T$

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°C to 92°C)

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**

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

Where;
$Specific\ heat\ cont. = 1152\ {}^{kJ}/_{kWh}$
$P = 6300\ \ kW$ (Each engine)
$N = 2$ (no. of engine)

Therefore, the result of the calculation is;
$Total\ heat\ cont. = 1152\ \ .6300\ .2$
$Total\ heat\ cont. = 34903802{,}88\ {}^{kJ}/_{h}$
$Total\ heat\ cont. = 9703{,}257\ kW$ (satisfy the requirement)

- **Cluster 2**

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

Where;
$Specific\ heat\ cont. = 1152\ {}^{kJ}/_{kWh}$
$P = 5800\ kW$ (Each engine)
$N = 1$ (no. of engine)

Therefore, the result of the calculation is;
$Total\ heat\ cont. = 1152\ .5800\ .1$
$Total\ heat\ cont. = 17451901{,}44\ {}^{kJ}/_{h}$
$Total\ heat\ cont. = 4851{,}6286\ kW$ (satisfy the requirement)

Table 4. 10 Exhaust gas economizer

Exhaust gas Economizer		
Manufacturer		Saacke Marine System
Type		EMB/EME-VST
Design Pressure	Bar	10
Weight	Kg	16000
Water content	m^3	5,5

6. CALCULATION OF BOG RATE FOR COMPRESSOR AND GCU

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.

Table 4. 11 BOG Compresor

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

4.1.3 LNG Tank

The tank that design in P&ID need to calculate for knowing the total LNG tank in KM. Gunung Dempo. When calculate LNG tank also need to observe weight of engine that has been converted. KM Gunung Dempo has heavy components such as fuel weight, MAN engine weight, Compressor Casing, Silincer MAN, SCR Control Cabinet and other systems. The weight calculation for total system of MAN 51 - 60 DF engine that will be used at KM Gunung Dempo is 262,963 Ton. Weight of fuel is not yet include LNG tank that needs to be used on the ship KM. Gunung Dempo. Scenario of filling LNG fuel are in 3 location, Sorong, Jayapura and Makasar. In that 3 location there will be LNG terminal that build by Pelindo Energy and Bachelor thesis plan of Satrio Nurahman. So, the duration of filling LNG is 72 Hours.

FC_{Gas}

= BHP x SFGC x Endurance

= 5.355 kW x 7.106 kJ/KWH x 72 H

= 2.739.789 x 10^6 Joule
Change in mmbtu (1 mmbtu = 9,47086 x 10^{-10} Joule)
Then get,

FC_{Gas}

= 2.739.789 x 10^6 Joule x 9,47086 x 10^{-10} mmbtu/Joule

= 2.594,816 mmbtu
Convert to volume (1 m^3 LNG = 21,2 mmbtu), then get,

V_{Gas}

= 2.594,816 mmbtu : 21,2 mmbtu/m^3

= 122,397 m^3 (Ditambah 15%)

= 140,756
Tank capacity ISO LNG 40 Feet is 33,4 m^3, then found the LNG needs,

TankLNG

= V_{gas} : 33,4 m^3/Tanki LNG

= 122,397 m^3 : 33,4 m^3/Tanki LNG

= 4,21 (because more then 4, take more tank)

= 5 Tanki ISO LNG 40 Feet

CHAPTER 5
RISK ASSESSMENT

5.1 Risk Analysis

The object discussed in this risk assessment is dual fuel KM Gunung Dempo system, where the P & ID design of dual fuel system can be seen in Figure 5.1. LNG used to supply duel fuel diesel engine is planned to be supplied by an LNG bunkering vessel. LNG bunkering vessel supplies LNG to the LNG tank which is placed in KM Gunung Dempo compartment. After transfer of LNG to the LNG tank is completed, the next process is BOG that occurs in the LNG tank will be transferred using the compressor to GVU before being injected into the engine. While LNG in liquid form will be converted in the form of gas through vaporizer. LNG in the form of gas after going through the vaporizer will be passed to the GVU before being injected into the engine.

5.2 Hazard Identification

Hazard is an object which has potential of safety danger. If hazard identification is process of hazard identified that probably happen in a system and effect from the hazard. There are some failure that can occur in dual fuel engine system like leakage which can triger effect of explosion, BLEEVE, flash fire, etc. In this study will asses the risk of transfer gas from LNG tank to dual fuel engine.

5.3 Hazard and Operability Study (HAZOP)

Hazard and Operability (HAZOP) study giving the detailed assessment of the potential hazard which may occur. Basic concept of HAZOP study is to take a full description of the process and to question every part of it to discover what deviations from design can occur and what the causes and consequences of these deviations might be. Based on BS IEC 61882:2001 process of HAZOP study are include in determining the nodes, deviations, safeguards, and another criteria to support the study.

5.3.1 Node Classification

The LNG fuel system facility consist of various system that divided into main division: storage tank of LNG, pump and vaporizer system, and main engine. The main division still consist of several subsystem that support the terminal activity based on P&ID classification eventhough certain process need to be separeted due to different flow direction and different operational intent. The node classification is ease us to assess the HAZOP study since every subsystem are consist of various components and also different operational intent.

The technical description of the node classification above are:

1. Node 1
   This Node are concerned in LNG tank that transfer by pump. The specification of liquid line are mentioned below:
   - Operational Press : 5,5 bar
   - Operational Temp. : -162^{o}C
2. Node 2
   The concern of this node are the system of BOG compresor. The system consist with many valve that can have effect to failure

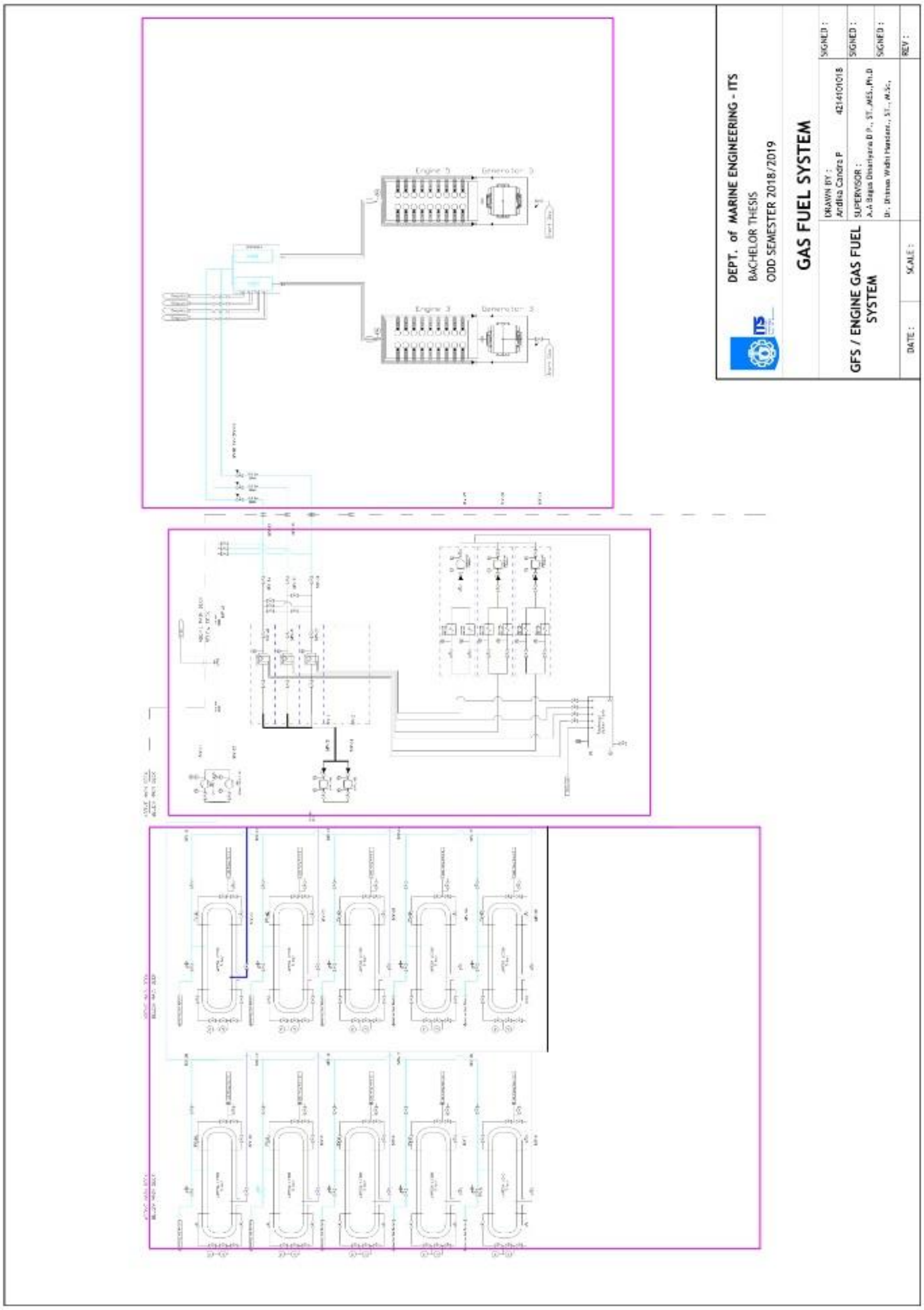


Figure 5.1 LNG Fuel Gas System

3. Node 3
   The concern of this node are the system of liquid fuel system. The system consist with many valve that can have effect to failure
4. Node 4
   The fuel system will finish in main engine, and before main angine it will pass GVU. In GVU will have possibility of failure.

After dividing some node, continue with HAZOP worksheet that will contain of node, keywords, safeguard and safe prevention that must do. The HAZOP worksheet can view below and others node located in attachment.

5.3.2 Systems Deviation Determination

The Process of system deviation is to choose the guide word that comply with the design. Based on BS IEC 61882:2001 the list of deviation are already provided as seen in Table 5.2. The guide word then combined with the type of deviation. The variables of deviation can be determined based on the type of system that need to be assess. For the purpose of design and operational intent in this thesis are LNG Fuel system the concerned are variables that can lead into rise of flow and temperature since that kind of deviation can lead into rupture of components and further caused the release of the LNG.

Table 5.1 HAZOP Guide Word

Guide Word	**Meaning**
NO OR NOT	Complete negation of the design intent
MORE	Quintative increase
LESS	Quantitative decrease
AS WELL AS	Qualitative modification/increase
PART OF	Qualitative modification/decrease
REVERSE	Logical opposite of the design intent
OTHER THAN	Complete substitution

(Source: BS IEC 61882:2001)

5.3.3 Causes and Consequences Determination

The causes and consequences are variables that occur caused by the deviation implementation on the system. The detailed causes and consequences shall be determine so that the possible cause can be reduced and and the consequences can be mitigated. The operator and expertise point of view during the causes and consequences examination are something need to be considered, but the simple principle and basic knowledge due to the deviation occured are also one thing that can help the process of examination.

5.3.4 Safeguard Determination

The safeguard on the assessment are the existing facility that by the design intent it designed to overcome the consequences caused by deviation. The existing safeguard are including the indicator that shows the parameters and automatic alarm that warn the operator when certain parameters are not in safe range.

5.3.5 Action Required Determination

The action need to be taken in case certain hazard occur are the recommendation that the examiners suggest so that the consequences or the effect can be reduced. The action required olso need to be examined so that any potential hazard due to failure of any safeguard can be covered and the overcome planning are determined.

5.3.6 List of Abbreviations

In Hazard and Operability (HAZOP) study the components listed in assessment are following the original identification as follows in system P&ID identification system. To ease the identification the complete defintion of each components listed are explained in Table 4.11 below.

Table 5.2 List of Abbreviations

No	Abbreviation	Definition
1	MV	Manual Valve
2	SV	Safety Valve
3	SDV	Shutdown Valve
4	BV	Butterfly Valve
5	PSV	Pressure Safety Valve
6	PI	Pressure Indicator
7	TI	Temperature Indicator

Table 5.3 HAZOP Node 1 Storage System

Study Title: Node 1							Sheet: 1 of 3	
Drawing No :	GFS 01/ P&ID ENGINE GAS FUEL SYSTEM						Date:	
Part Considered:	Discharge System							
Design Intent:	Material: LNG Source: Manifold Receiving Vessel		Destination: Receiving Storage Tank		Design Pressure : 5 Bar Operating Pressure : 3.5 Bar		Temprature : -162 C	
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated To
1	NO	NO FLOW (LNG)	Valve MV-01,MV-02, MV-03, MV-04, MV-05, MV-06, MV-07, MV-08, MV-09, MV-10, MV-11, MV-12, MV-13, MV-14, MV-15, MV-16 blocked	No lng supply	Flow Meter	Situation is not acceptable	condition check before operate LNG discharging	Discharging pipeline and valve on LNG storage tank
2	NO	NO FLOW (GAS RETURN)	Valve PV-01, PV-02, PV-03, PV-04, PV-05, PV-06, PV-07, PV-08, PV-09, PV-10, PV-11, PV-12, PV-13, PV-14, PV-15, PV-16 blocked	No Gas return and LNG supply interrupt		Situation is not acceptable	Visual and condition check before operate LNG discharging	Discharging on LNG storage tank
3	NO	NO FLOW (BOG)	Valve MV-17, MV-18, MV-19, MV-20, MV-21, MV-22, MV-23, MV-24, MV-25, MV,-26, MV-27, MV-28, MV-29, MV-30, MV-31, MV-32 Blocked	ME Shutdown	Pressure Indicator	Situation is not acceptable	check BOG compresor	
4	MORE	MORE TEMPRATURE	External Heat	liquid will be change to gas phase	Insert the safety valve, pressure indicator and pressure transmitter, and insert gas detector	Situation is not acceptable	check the things that can affect external heat and system especially routine check the PI and PT	
5	NO	NO FLOW (BOG Compressor)	MV-21 Blocked	No supply BOG, ME Shutdown	Pressure indicator, Pressure Transmittter	Situation is not acceptable	Recheck prosedure and equipment before begin operation	BOG Compressor

Table 5.4 HAZOP node 2 Fuel System

Study Title: Node 2							Sheet: 1 of 3	
Drawing No :	GFS 02/ P&ID ENGINE LNG FUEL SYSTEM						Date:	
Part Considered:	Discharge System							
Design Intent:	Material: LNG Source: LNG Pump		Destination: Receiving Storage Tank		Design Pressure : 5 Bar Operating Pressure : 3.5 Bar		Temprature :	
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated To
1	NO	NO FLOW (FEED PUMP LNG)	MV-34 Blocked	No supply LNG, ME Shutdown Pump Failure and LNG Flowrate to vaporizer is decrease	Pressure indicator instal feed pump more than 1 set as a redundancy system to increase flowrate	Situation is not acceptable	Recheck prosedure and equipment before begin operation	LNG Feed Pump
2	MORE	MORE PRESSUR	LNG feed pump failu	Presure built up at LNG Feed Pump lead to pump	change to second pump	Situation is not acceptable	Recheck prosedure and equipment before begin	LNG Feed Pump
3	MORE	MORE PRESSURE (AT LNG FEED PUMP)	Pressure built up at LNG Feed Pump DSML-185	Pump Damaged	instal feed pump more than 1	Situation is not acceptable	Recheck prosedure and equipment before begin operation	LNG Feed Pump
5	REVERSE	REVERSE FLOW	Valve NV-02 Failure	Back flow and lead to pump damaged	close MV before pump	Situation is not acceptable	Recheck prosedure and equipment before begin operation	LNG Feed Pump

Table 5.4 HAZOP node 3 Gas Fuel System

Study Title: Node 3							Sheet: 2 of 3	
Drawing No :	GFS 02/ P&ID ENGINE GAS FUEL SYSTEM						Date:	
Part Considered:	Discharge System							
Design Intent:	Material: LNG Source: LNG STORAGE TANK		Destination: Receiving Storage Tank		Design Pressure : 5 Bar Operating Pressure : 3.5 Bar		Temprature :	
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated To
6	OTHER THAN	OTHER THAN DESTINATION	Valve MV-27 Failure close	BOG supply decrease to engine, lead pipe rupture and make enviromental effect and lead the explosions	Flow Transmitter , Pressure Indicator	Situation is not acceptable	Recheck prosedure and equipment before begin operation	Vaporizer
7	NO	NO FLOW (Vaporizer)	Valve MV-24 Blocked Vaporizer 1 perfomance degradation (plugging, fouling,	LNG cant supply to vaporizer Natural Gas supply decrease	change to Vaporizer 2	Situation is not acceptable	Recheck prosedure and equipment before begin operation	Vaporizer
8	NO	NO FLOW (Vaporizer)	Vaporizer tube rupture (Gas)	Gas supply loss, fire and explosion risk in stream	Insert safety valve	Situation is not acceptable	Visual Check all equipment and recheck the prosedure before begin operation	Vaporizer
9	NO	LESS FLOW(BOG COMPRESSOR)	BOG Compressor degradation	BOG supply decrease	second pump	Situation is not acceptable	Recheck prosedure and equipment before begin operation	BOG Compressor
10	NO	NO FLOW (ECONOMIZER)	Feed Pump Damage Valve MV-34 blocked	No supply fresh water to economizer fresh water pump	use Economizer 2	Situation is not acceptable	Visual Check all equipment and recheck the prosedure before begin operation	Economizers

Table 5.5 HAZOP node 4 GVU System

Study Title: Node 4							Sheet: 2 of 3	
Drawing No :	GFS 02/ P&ID ENGINE GAS FUEL SYSTEM						Date:	
Part Considered:	Discharge System							
Design Intent:	Material: LNG Source: GVU		Destination: Pump Cryogenic		Design Pressure : 5 Bar Operating Pressure : 3.5 Bar		Temprature :	
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated To
1	NO	NO FLOW	Valve SV-02 blocked	No NG Supply	Flow meter, Pressure Inidcator	Situation is not acceptable	recheck the prosedure before begin operation	
2	LESS	LESS PRESSURE	GVU Valve Close, SV - 1 blocked	Decrease needs the flow NG in engine		Situation is not acceptable	recheck the prosedure before begin operation	
3	LESS	LESS PRESSURE	SV-01 Close	Decrease needs the flow NG in engine No NG Supply	use another vaporizer flow	Situation is not acceptable	recheck the prosedure before begin operation	
4	MORE	MORE TEMPRATURE	Flow rate increase too high	Valve will be blocked and lead to pipe rupture because of overpressure and it will trigger the occurance like jet fire, flash fire, gas dispersion, explosion	safety valve	Situation is not acceptable	Visual Check all equipment and recheck the prosedure before begin operation	
				GVU Leakage	Make the GVU room with Double Door room access with venting	Situation is not acceptable	recheck the prosedure before begin operation	

5.4 Frequency Analysis

From the result of hazard identification which use HAZOP method, there are 4 node that need to do frequency analysis to know how huge the risk may accur. The analysis do by use fault tree analysis method and event tree analysis method. Data that use in frequency failure rate an component is using DNV GL.

5.4.1 Fault Tree Analysis

FTA use to identified the failure of system that form of gas release frequency. The result calculation of FTA can use if the cause of system failure more than one (not only gas release). This calculation have 3 scenario :

Scenario 1 : pipe hole which has leakage diameter 1 – 3 mm
Scenario 2 : pipe hole which has leakage diameter 3 – 10 mm
Scenario 3 : pipe hole which has leakage diameter 10 – 50 mm

Table 5.6 Component Leak Frequency Based on DNV GL

Nomor	Name of Component	Scenario	Leak Frequency
1	MV	1-3 mm	5,26E-05
		3-10 mm	2,28E-05
		10-50 mm	1,48E-05
2	SV	1-3 mm	5,43E-04
		3-10 mm	1,68E-04
		10-50 mm	7,03E-05
3	HE	1-3 mm	1,18E-02
		3-10 mm	9,85E-04
		10-50 mm	8,88E-04
4	Pipe	1-3 mm	2,85E-04
		3-10 mm	9,98E-05
		10-50 mm	4,51E-04

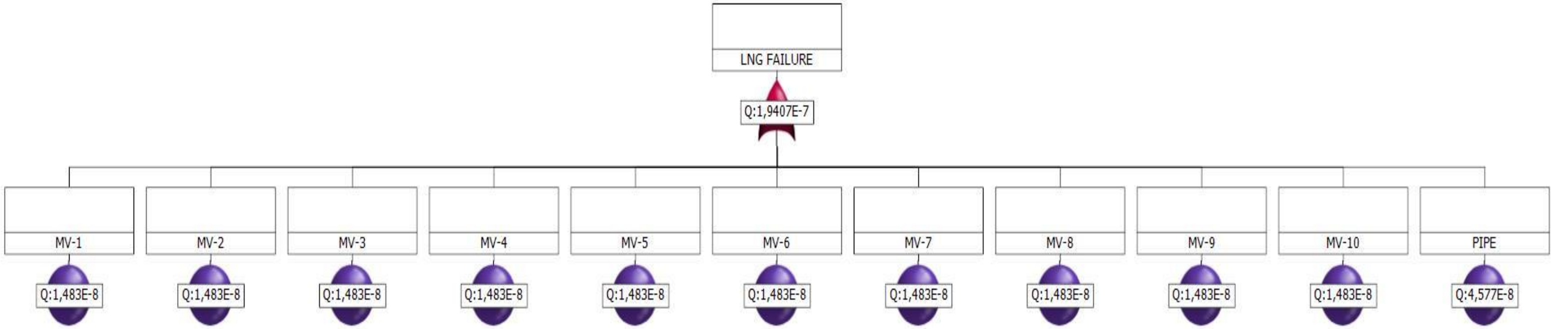


Figure 5.2 FTA Storage System bore 1-3 mm

Figure 5.2 shows FTA of LNG storage system due to presence components leaked. The relationship of each component with top event gas release is OR. Where one component leaks then gas will release out of the system. By performing calculations using Relex 2009 obtained results according to the following table

Table 5.7 Gas Release Frequency Fuel Supply System

	fuel supply System Gas Release		
1	Small (1-3 mm)	Medium (3-10 mm)	Large (10-50 mm)
	5,85E-06	3,12E-06	2,77E-06

Table5.8 Gas Release Frequency Storage System

	Storage System Gas Release		
2	Small (1-3 mm)	Medium (3-10 mm)	Large (10-50 mm)
	0,0000000010	0,00000000066	0,00068620

Table 5.9 Gas Release Frequency BOG System

	BOG System		
3	Small (1-3 mm)	Medium (3-10 mm)	Large (10-50 mm)
	1,13E-05	0,00000468	0,00000263

Table 5.10 Gas Release Frequency GVU System

	GVU		
4	Small (1-3 mm)	Medium (3-10 mm)	Large (10-50 mm)
	0,01628100	0,00000000	0,00000021

Analysis using FTA only calculate until gas release happen. For calculate more risk like jet fire, flash fire, gas dispersion must do analysis using ETA.

5.4.2 Event Tree Analysis

Event tree analysis use to calculate value of component frecuency that have potency generate fire. ETA can detect frequency of flash fire, pool fire, explossion, gas dispersion and jet fire. This frequency value base on bore of pipe leakage. The data needed is to know the value of the ignition probability. The probability of ignition can be determined by calculating flow release and then mapping flow release into the probability ignition table in OGP Risk Assessment Data Directory 2010 about ignition probability.
To calculate flow release using UK-HSE formula for flow release calculations for low pressure gas. Formula is as follows:

$$m = Cd.\rho.area\sqrt{2.\frac{P1-P}{\rho}} + g.\,h \text{........................}(5.4)$$

Where:

m : Mass (kg/s)
Cd : Koefisien (0,6 for gas)
ρ : Density (kg/m^3)
Area : leakage hole (m^2)
P1 : Presure (Pa)
P : ambient Presure (Pa)
g : Gravity acceleration (m/s^2)
h : head statis (m)

Table 5.11 Flow Release and Ignition Probability Fuel System Gas Release

Fuel System Gas Release	Small	Medium	Large
Hole Area (m^2)	0,000007065	0,0000785	0,0019625
Flow release	0,004229660	0,046996224	1,174905606
Ignition Probablity	0,001000000	0,001000000	0,002200000

Table 5.12 Flow Release and Ignition Probability Storage System

Storage System	Small	Medium	Large
Hole Area (m^2)	0,000007065	0,0000785	0,0019625
Flow release	0,006344415	0,070493497	1,762337420
Ignition Probablity	0,001000000	0,001000000	0,002200000

Table 5.13 Flow Release and Ignition Probability BOG system

BOG system	Small	Medium	Large
Hole Area (m^2)	0,000007065	0,0000785	0,0019625
Flow release	0,008190573	0,091006366	2,275159155
Ignition Probablity	0,001000000	0,001000000	0,021300000

Table 5.14 Flow Release and Ignition Probability GVU

GVU	Small	Medium	Large
Hole Area (m^2)	0,000007065	0,0000785	0,0019625
Flow release	0,000027695	0,000307720	0,007693000
Ignition Probablity	0,001000000	0,001000000	0,002200000

From the calculation of flow release based on the formula of UK-HSE will be plotted to determine the value of ignition probability using OGP 2010 about ignition probability. The table ignition probability as below.

Tabel 5. 15 Ignition Probability

Release Rate (kg/s)	Ignition Probability
0.1	0.0010
0.2	0.0013
0.5	0.0019
1	0.0025
2	0.0074
5	0.0204
10	0.0339
20	0.0564
50	0.1107
100	0.1842
200	0.3065
500	0.6000

From calculation ploted to find probability of ignition. After find all ignition probability, ETA can make to find hazard frequency that become the effect of gas release.

Type process of ETA here made base on paper "A model for estimating the impact of the domino effect on accident frequencies in QRA of storage facilities".

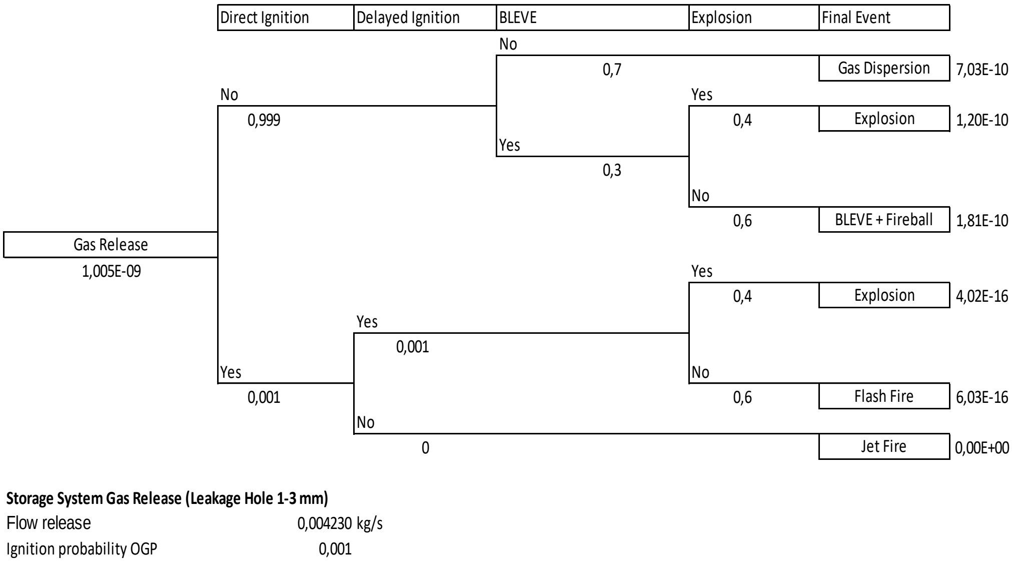


Figure 5.3 ETA for Storage Tank bore 1-3 mm

From gas release can become cause of fire source or ignition source. There are two types of ignition, direct ignition and delayed ignition. If after gas release give effect in direct ignition, then will follow by hazard of jet fire. But if ignition not direct happen (delayed ignition), so effect that will happen are flash fire, jet fire. When gas release happen and there is no ignition final effect, it will become BLEEVE. BLEEVE happen when LNG in liquid form disperse out change in gas phase. The result of ETA from storage tank bore 1-3 mm show in tabel below.

Tabel 5. 16 Result ETA Storage System bore 1-3 mm

Storage System	BLEVE/ Fireball	1.81E-10
	Explosion	1.20E-10
	Flash Fire	1.11E-13
	Jet Fire	1.45E-05
	Gas Dispersion	1.63E-02

Tabel above show frequency from hazard that probably happen because gas release in GVU System. For BOG system, fuel system, storage system will show in attachment.

5.4.3 Consequence Analysis

Consequences is impact from hazard that happen. Consequences analysis in here form by calculate how many passenger or crew that dead because of gas release. For knowing level of consequences use fire modelling with aloha software.

Aloha is a simulation software uses for mapping hazard impact explosion, fire and gas disperse. In this simulation using aloha 5.4.6. Some data that must be complete for simulation are coordinate instalation place, time, wind direction, wind velocity, type of gas or fluid and some other data.

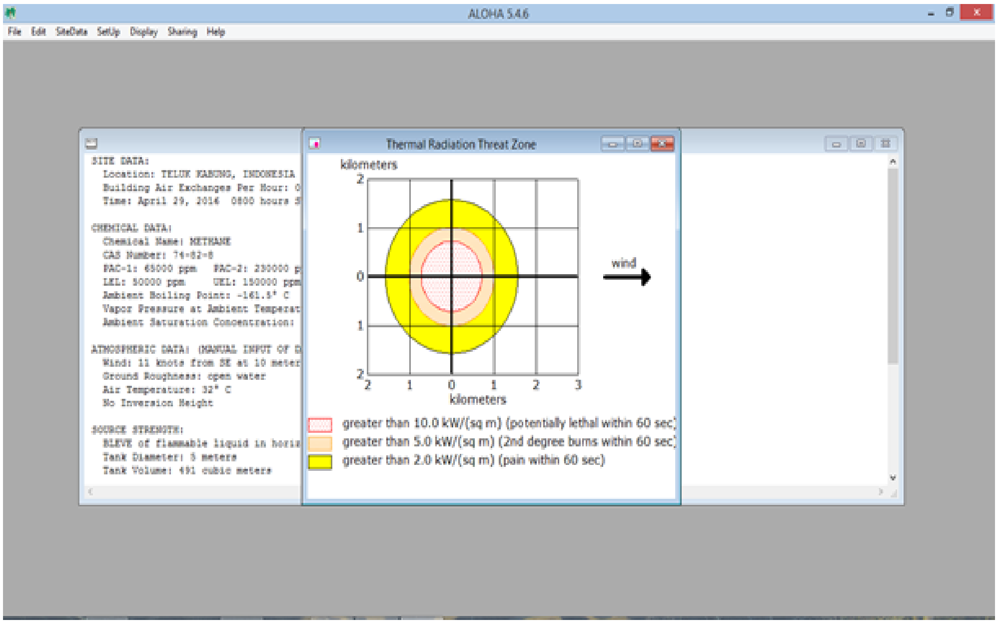


Figure 5.4 Result of aloha simulation

From figure above, threat zone show the impact BLEEVE in LNG tank that have gas release with diameter 3-10 mm. For calculate crew affected impact, resut from aloha will draw in layout dual fuel system using autocad.

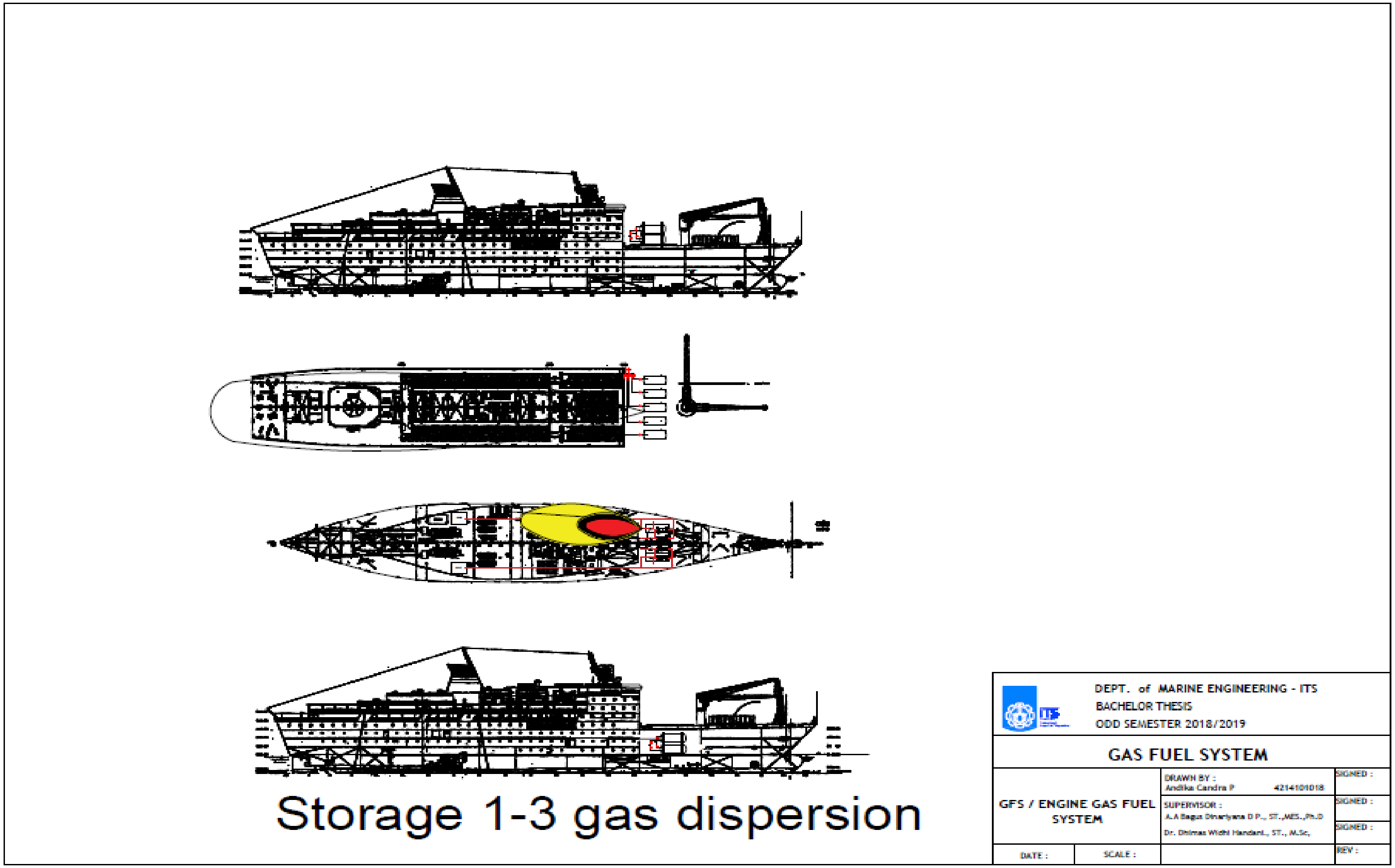


Figure 5.5 Threat Zone Storage Tank bore 1-3 mm with Hazard Gas Dispersion

Tabel 5.17 Result of ALOHA

Gas Dispersion Skenario 1-3 mm									
No.	System	Location	Total	Protective Action Criteria (Jumlah orang terdampak/Jangkauan/Waktu)				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	< 2900	-
		deck 2	418	-	-	-	-	< 2900	
		deck 3	257	-	-	-	-	< 2900	-
		deck 4	431	-	-	-	-	< 2900	-
		deck 5	490	15/10/60s	-	-	-	> 17000	15
		deck 6	96	-	-	-	-	< 2900	-
		deck 7	18	-	-	-	-	< 2900	-
		deck 8	14	-	-	-	-	< 2900	-
Total									15

5.4.4 Risk Representation

Risk representative is a limit measure a risk that can accept or not. For knowing risk acceptable or not is using F-N curve ACDS tolerability of transport risk frame work. The frequency and consequency hazard of BLEEVE, explosion, flash fire, gas dispersion that has been calculate before, will become data to make F-N curve by enter calculation in standard F-N curve that used. The result will acceptable or not is depend of dot location in F-N curve. If result show in acceptable zone, no need mitigation to do. But, if the result not acceptable will continue with mitigation. Layer of protection (LOPA) will be method of mitigation From risk representative get result for hazard BLEEVE, explosion, flash fire, jet fire and gas dispersion scenario bore hole 1-3

Table 5.18 BLEEVE Scenario bore 1-3 mm

BLEEVE Scenario bore 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	0	0,00E+00	0,00E+00
2	Fuel system	0	0,00E+00	0,00E+00
3	GVU System	0	0,00E+00	0,00E+00
4	storage	85	1,80719E-10	

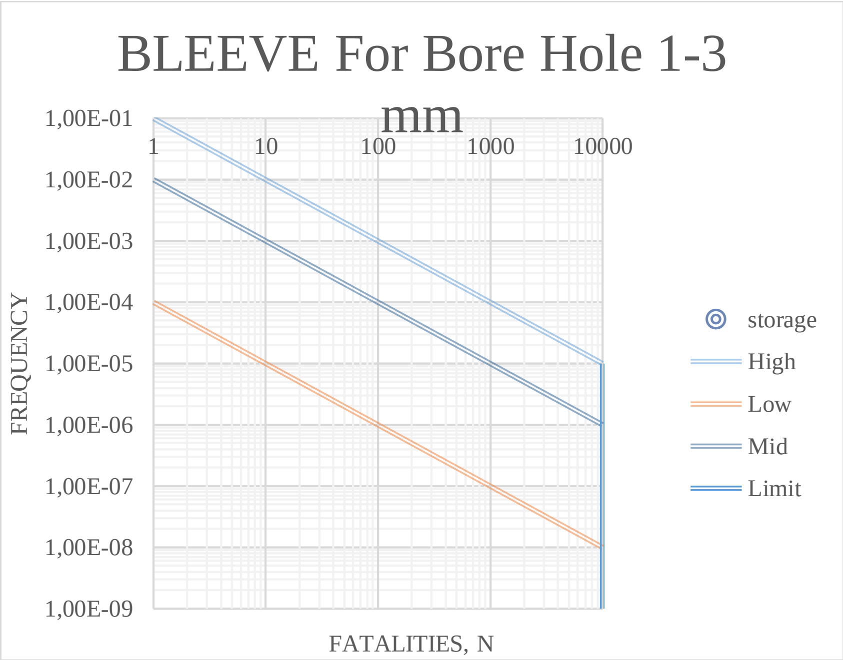


Figure 5.6 BLEEVE Bore 1-3 mm

Figure 5.6 show that risk of BLEEVE in fuel system locate in acceptable zone. For BOG, Fuel system, GVU cannot show because the concecuences value is 0. In level ALARP, risk is acceptable and allow to mitigate or not.

Table 5.19 Explosion Bore Hole 1-3 mm

Skenario Explosion in Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	0	0,00E+00	0,00E+00
2	Fuel System	0	0,00E+00	0,00E+00
3	GVU System	0	0,00E+00	0,00E+00
4	storage	32	1,2E-10	

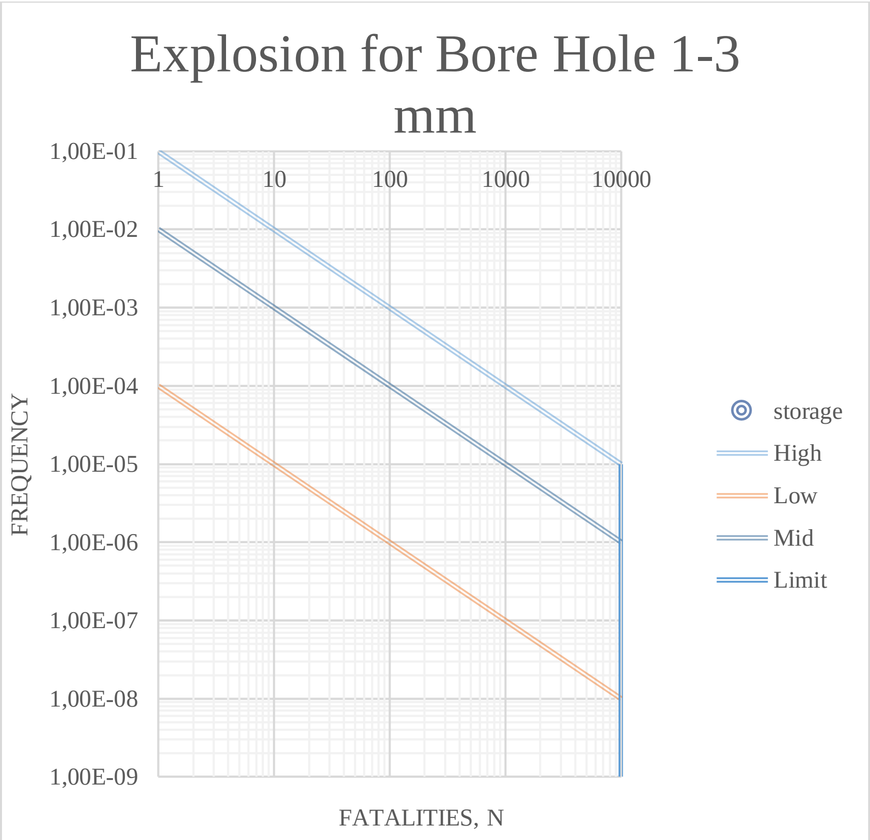


Figure 5.7 Explosion Bore 1-3 mm

Figure 5.7 show that risk of explosion in fuel system locate in acceptable level. For BOG, Fuel system, GVU cannot show because the concecuences value is 0. In level ALARP, risk is acceptable and allow to mitigate or not.

Table 5.20 Scenario Flash Fire Bore 1-3

Skenario Flash Fire for Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,89E-10	2,89E-10
2	Fuel System	5	6,43E-10	9,33E-10
3	GVU System	2	4,91E-24	9,33E-10
4	storage	2	6,03E-16	9,33E-10

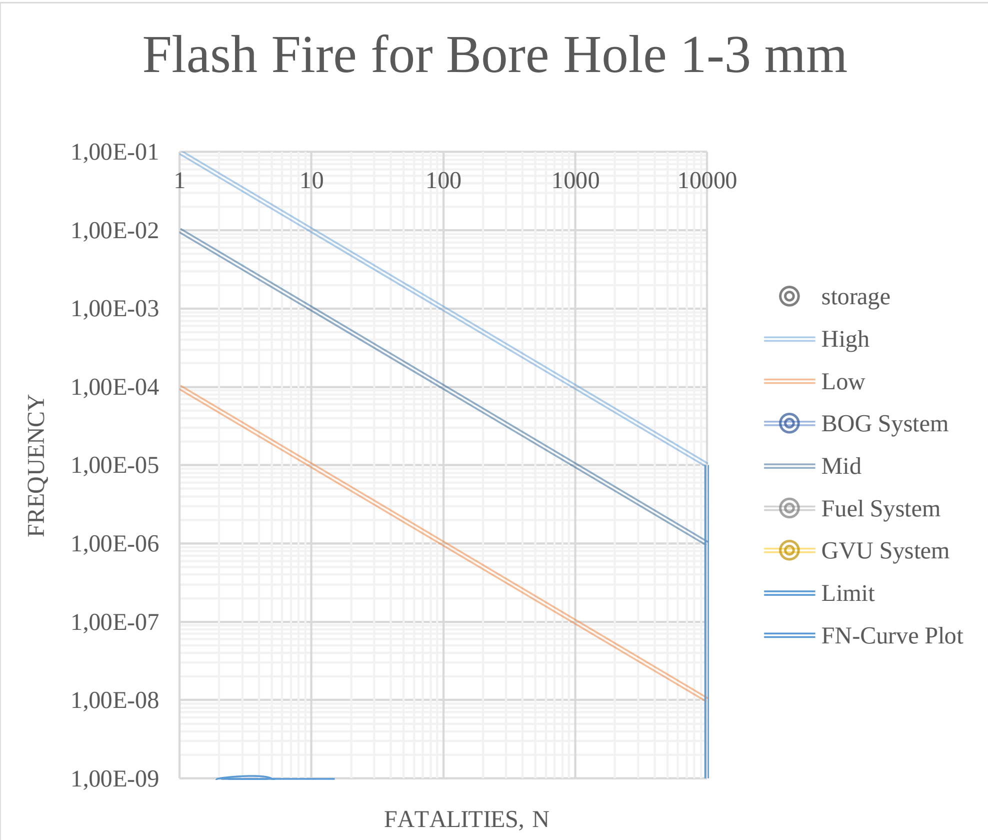


Figure 5.8 Flash Fire Bore 1-3 mm

Figure 5.8 show that risk of flash fire in fuel system locate in acceptable level. . For BOG, Fuel system, GVU cannot show because risk frequency to small not exceds than 1,00-09. In level ALARP, risk is acceptable and allow to mitigate or not.

Table 5.21 Scenario Jet Fire Bore 1-3

Skenario Jet Fire For Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,34E-09	2,34E-09
2	Fuel Sytem	5	5,21E-09	7,55E-09
3	GVU System	5	3,97E-23	7,55E-09
4	storage	24	0	7,55E-09

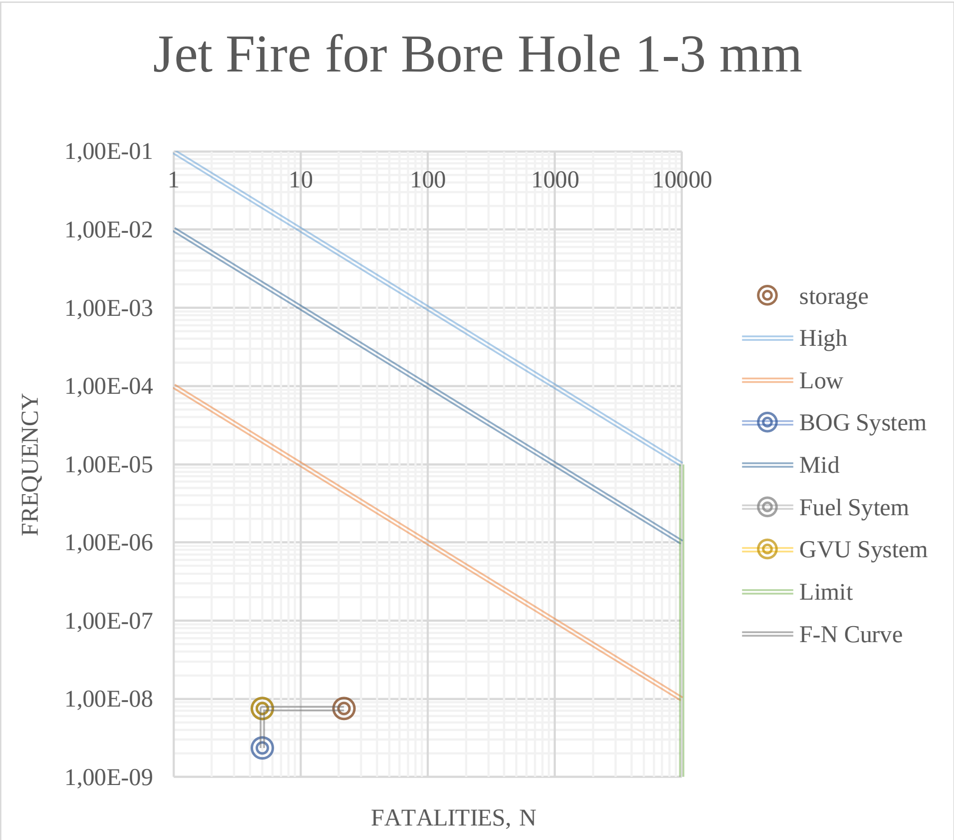


Figure 5.9 Jet Fire Bore 1-3 mm

Figure 5.9 show that risk of jet fire in fuel system locate in acceptable. In level ALARP, risk is acceptable and allow to mitigate or not.

Table 5.22 Scenario Gas Dispersion Fire Bore 1-3

Skenario Gas Dispersion For Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,63E-06	2,63E-06
2	Fuel Sytem	5	5,84E-06	8,47E-06
3	GVU System	2	4,46E-20	8,47E-06
4	storage	2	7,03E-10	8,47E-06

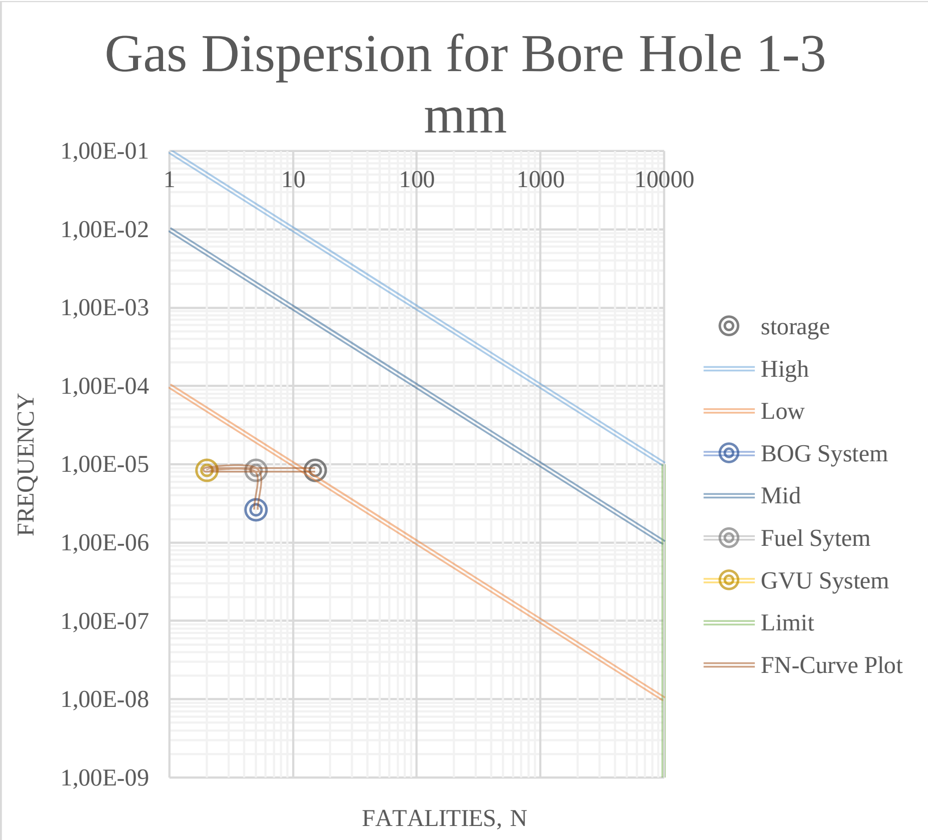


Figure 5.10 Gas Dispersion Bore 1-3 mm

Figure 5.10 show that risk of gas dispersion in fuel system locate in acceptable level. In level ALARP, risk is acceptable and allow to mitigate or not.

All result F-N Curve above show result of LNG tank outside compartement. Then figure below will show F-N Curve result of LNG inside compartement.

Table 5.23 Scenario BLEEVE Fire Bore 1-3

Skenario BLEEVE For Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	0	0,00E+00	0,00E+00
2	Fuel System	0	0,00E+00	0,00E+00
3	GVU System	0	0,00E+00	0,00E+00
4	storage	32	1,81E-10	

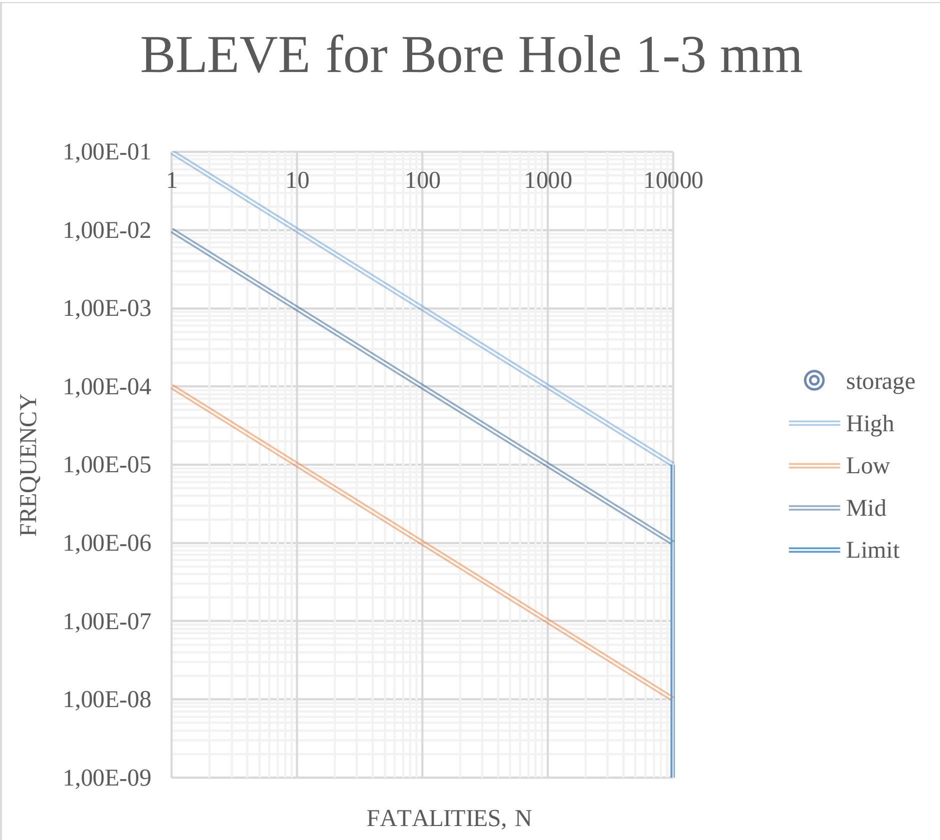


Figure 5.11 BLEEVE Bore 1-3 mm

Figure 5.11 show that risk of BLEEVE in fuel system locate in acceptable level. For BOG, Fuel system, GVU cannot show because the concecuences value is 0. In level ALARP, risk is acceptable and allow to mitigate or not

Table 5.24 Scenario Explosion Fire Bore 1-3

Skenario Explosion For Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	0	0,00E+00	0,00E+00
2	Fuel System	0	0,00E+00	0,00E+00
3	GVU System	0	0,00E+00	0,00E+00
4	storage	32	1,2E-10	

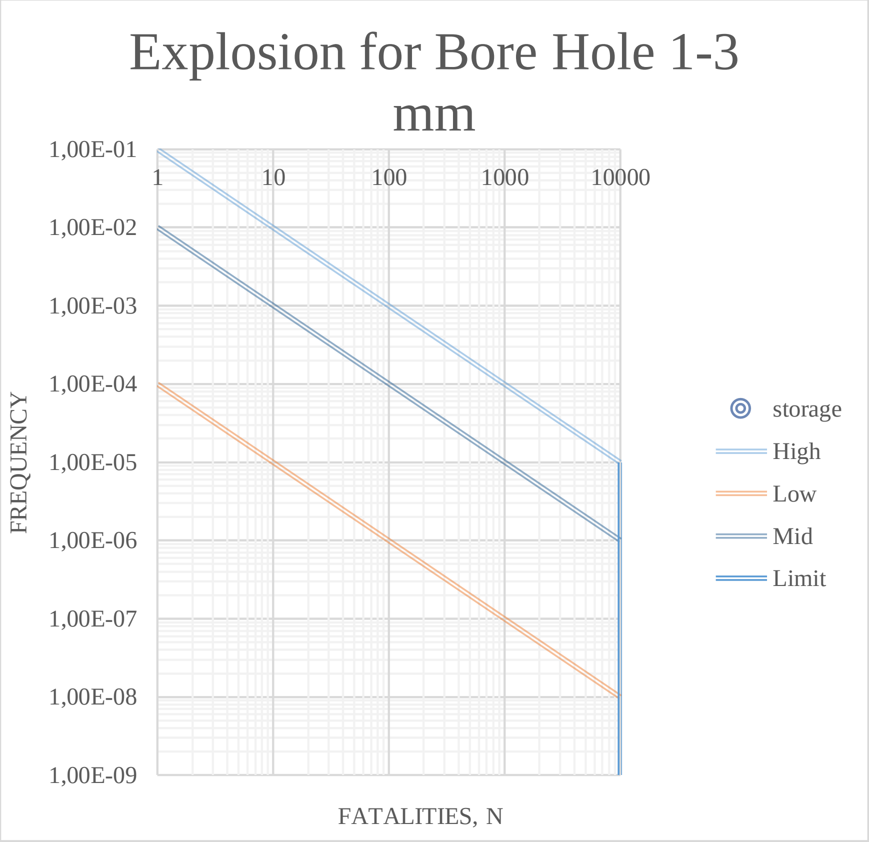


Figure 5.12 Explosion Bore 1-3 mm

Figure 5.12 show that risk of explosion in fuel system locate in acceptable level. For BOG, Fuel system, GVU cannot show because the concecuences value is 0. In level ALARP, risk is acceptable and allow to mitigate or not.

Table 5.24 Scenario Flash Fire Bore 1-3

Skenario Flash Fire For Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,89E-10	2,89E-10
2	Fuel System	5	6,43E-10	9,33E-10
3	GVU System	2	4,91E-24	9,33E-10
4	storage	2	6,03E-16	9,33E-10

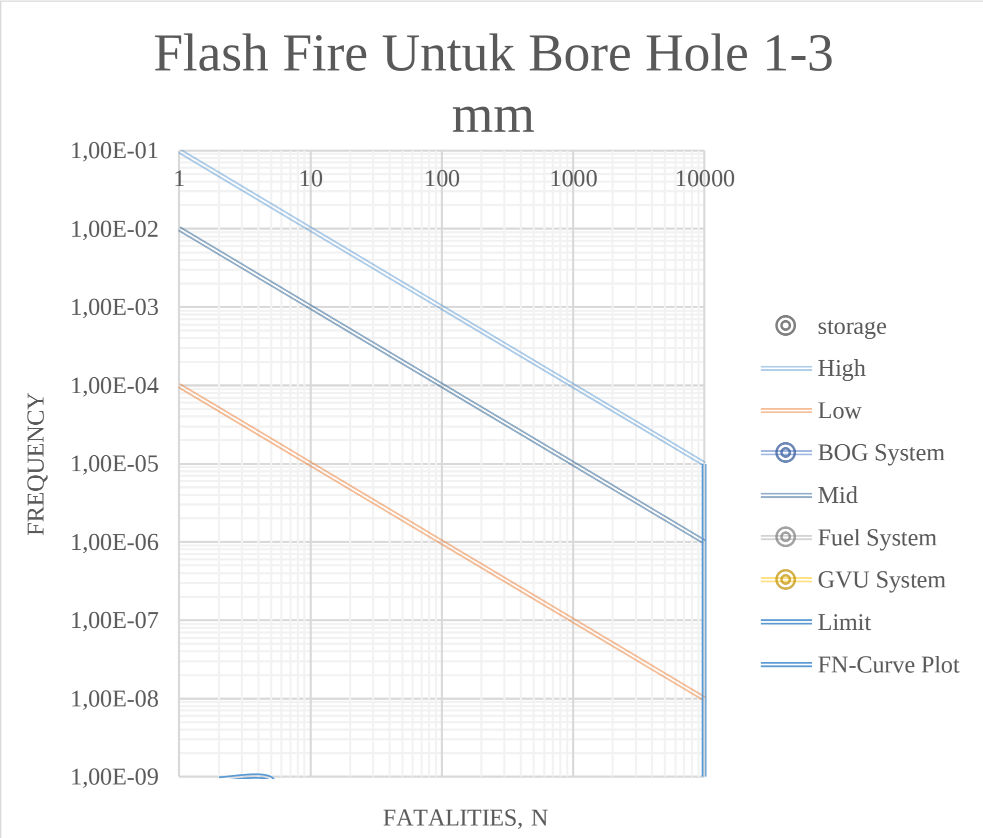


Figure 5.13 Flash Fire Bore 1-3 mm

Figure 5.13 show that risk of flash fire in fuel system locate in acceptable level. For BOG, Fuel system, GVU cannot show because risk frequency to small not exceds than 1,00-09. In level ALARP, risk is acceptable and allow to mitigate or not.

Table 5.25 Scenario Jet Fire Bore 1-3

Skenario Jet Fire For Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,34E-09	2,34E-09
2	Fuel Sytem	5	5,21E-09	7,55E-09
3	GVU System	5	3,97E-23	7,55E-09
4	storage	24	0	7,55E-09

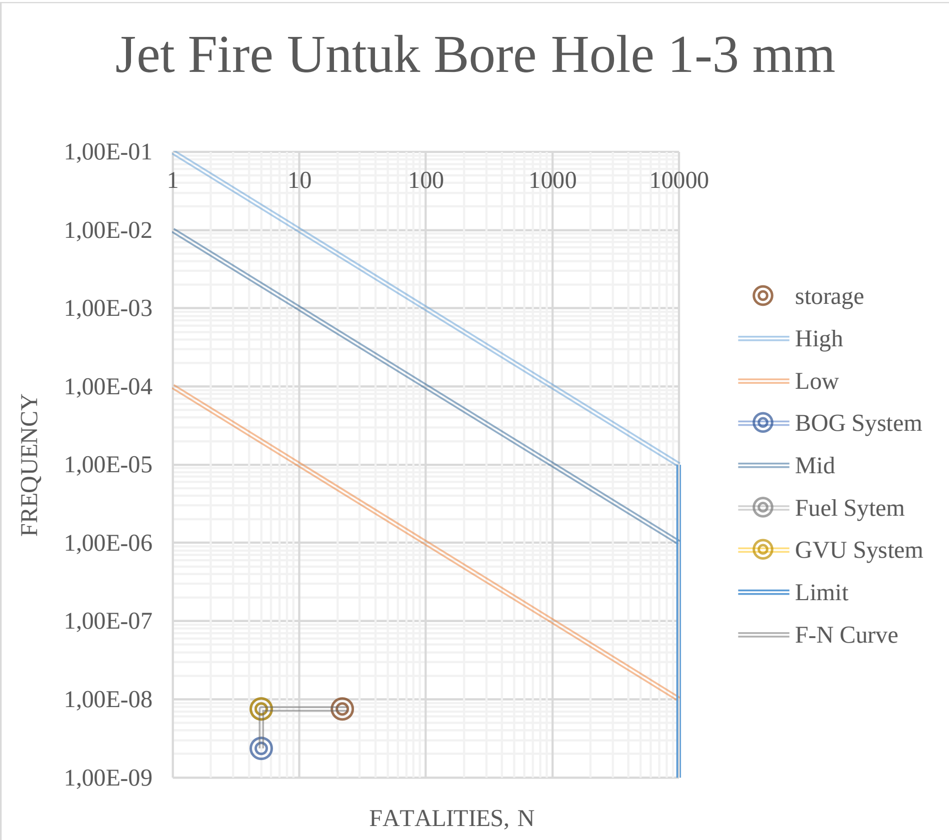


Figure 5.14 Jet Fire Bore 1-3 mm

Figure 5.14 show that risk of jet fire in fuel system locate in acceptable. In level ALARP, risk is acceptable and allow to mitigate or not.

Table 5.26 Scenario Gas Dispersion Bore 1-3

Skenario Gas Dispersion For Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,63E-06	2,63E-06
2	Fuel Sytem	5	5,84E-06	8,47E-06
3	GVU System	2	4,46E-20	8,47E-06
4	storage	2	7,03E-10	8,47E-06

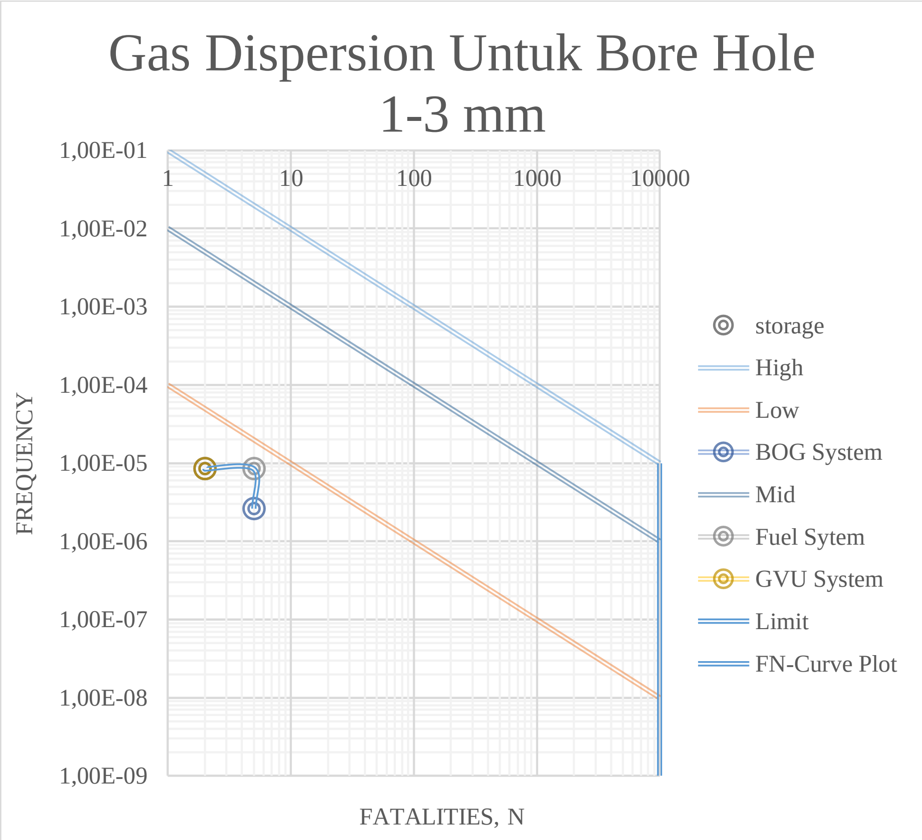


Figure 5.15 Gas Dispersion Bore 1-3 mm

Figure 5.15 show that risk of gas dispersion in fuel system locate in acceptable level. In level ALARP, risk is acceptable and allow to mitigate or not.

5.4.5 Mitigation

From risk assessment result all scenarios are located at ACCEPTABLE and ALARP levels. At ACCEPTABLE level there is no need for mitigation. For ALARP level in this research will be mitigation to enter into ACCEPTABLE category even though for the level of ALARP do not need mitigation.

This mitigation is done by adding components to system processes, safety components, and components that can be installed indepen without affecting the calculation of system processes that have been done before. The addition of independent components was selected to mitigate this study.

Results from mitigation using LOPA table method from Geun Woong Yun thesis entitled "Bayesian-LOPA methodology For Risk Assessment Of An LNG Importation Terminal". Below is storage system that need to mitigate although in ALARP level.

Table 5.27 LOPA Storage System Bore Hole 10-50 mm

Scenario Gas Dispersion	Scenario Title: Gas Dispersion on Storage System Bore Hole 10-50 mm	Sytem Number : 1	
Date	Description	Probability	Frequency (Per Year)
Consequence Description	LNG storage, pipe or equipment in Storage System leak because overpressure and lead to fire or explosion		
Risk Tolerance Criteria (Frequency)	Action Required		1,00E-02
	Tolerable		1,00E-04
Initiating Event (Frequency)	Gas Dispersion from Storage system		4,80E-04
Enabling Event or Condition	N/A		
Conditional Modifiers	N/A		
Frequency of Unmitigated Consequence			4,85E-04
	Gas Detector	5,64E-02	
	Temperature alarm	5,52E-02	
	Pressure alarm	4,22E-02	
Total PFD for all IPLs		1,31E-04	
Frequency of Mitigated Consequence			6,38E-08
Risk Status		ACCEPTABLE	

Actions Required to Meet Risk Tolerance Criteria	Install gas detector, pressure, and temperature alarm as IPL to reduce risk
Notes	
References	

Table above, shows that the frequency after mitigate lower than before.

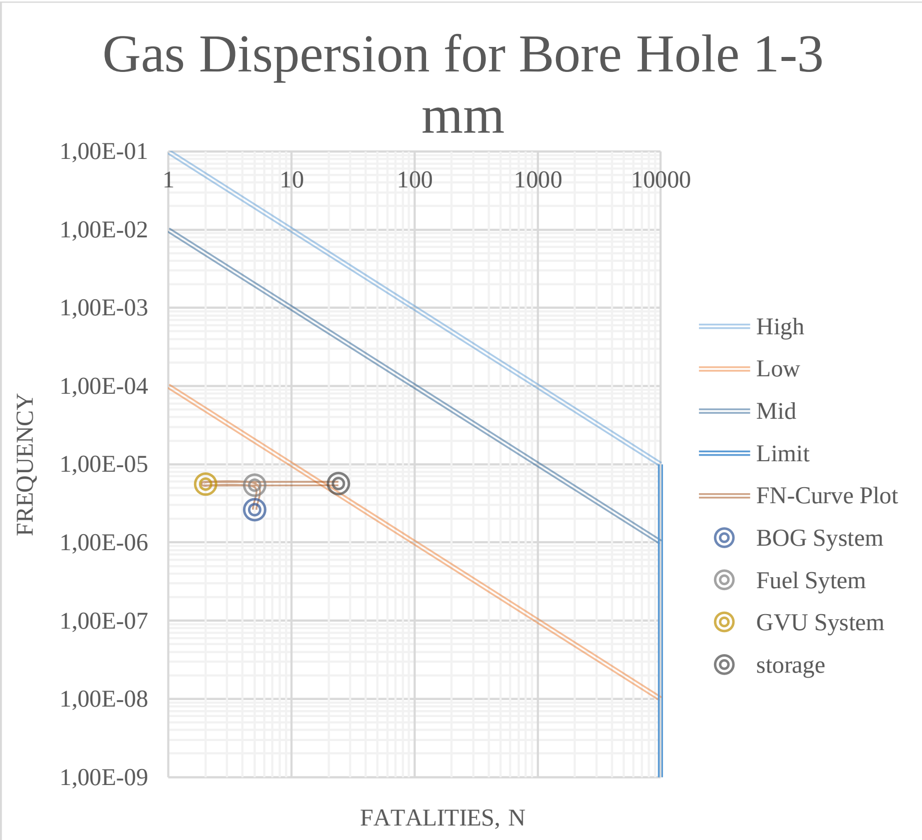


Figure 5.16 Gas Dispersion Bore 10-50 mm

Table 5.28 LOPA Storage System Bore Hole 10-50 mm after mitigated

Skenario Gas Dispersion For Bore Hole 10-50 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,62703E-06	2,62703E-06
2	Fuel Sytem	5	2,7679E-06	5,39493E-06
3	GVU System	2	2,10436E-07	5,60536E-06
4	storage	24	6,30E-08	5,67E-06

Grafik above show storage risk get lower frequency after mitigated

CHAPTER 6
ECONOMICAL ASSESSMENT

6.1 Economic analysis

Economic analysis in this study will view from conversion passenger ship KM. Gunung Dempo diesel engine to be dual fuel engine so can get result of NPV, IRR and payback period. Then, this study also analys which one is more profitable between design LNG tank inside compartement or LNG tank outside compartement. Variable that will use for which one decide most feasible investment are capital expenditure CAPEX and operational expenditure (OPEX). (Abdillah,2017)

6.1.1 Capex

Capital expenditure (CAPEX) is all of initial investment costs concerning the allocation of planned funds (budget) to make purchases / repairs / replacements of everything that is categorized as corporate assets in accounting. In this study, the amount of investment is self-financed.

Ship retrofit planning will be carried out in accordance with the ship's operational rule which is 4 years once the overhaul cost is equated with the history of 4 year overhaul costs such as previous cost history. On KM. Gunuung Dempo for engine overhaul costs Rp 1,174,154,894,00 for Conventional Diesel Engine usage. In the use of Dual Fuel engine because there is no use of Dual Fuel on passenger ships it will be assumed 20% larger than the conventional Diesel Engine on the basis that the system on dual fuel diesel engine is more complex and detailed and requires good handling. Calculations on overhaul can be explained as follows:

Overhaul Diesel Engine = Rp 1.174.154.894

Cost Overhaul Dual Fuel Diesel Engine = Cost Overhaul Diesel Engine + (Cost Overhaul Diesel Engine x 20%)

= Rp 1.174.154.894 + (Rp 1.174.154.894 x 20%)

= Rp 1.408.985.872 = 97,088.3 USD

KM. Gunung Dempo with engine upgrades that previously had a power of 6,000 Kilowatts (KW). So because the Dual Fuel Engine selection using 6 L MAN B & W 51 - 60 with the closest power is 6,300 Killowatt. Engine Dual Fuel price on data engine maker is € 655 Euro per kilowatt. Calculation of the cost requirements for the purchase of engines can be explained through the calculation as follows:

= Power x Engine Cost / power

= 6.300 KW x € 655 Euro/ Killowatt

= € 4.126.500 Euro

(assumtion 1 Euro = Rp 14.608),

Engine Cost = € 4.126.500 Euro x Rp 14.608/Euro

= Rp 58.051.602.000

With data from the LNG tank maker, for one LNG tank for $ 35,000 USD. Then can be done as follows:

= number of tank required x Cost per unit tank

= 10 Tanki LNG x $ 35.000 USD/ Tanki LNG

= $ 350.000 USD

Table 6.1 CAPEX KM. Gunung Dempo Conversion

CAPEX KM. Gunung Dempo Conversion			
Items	Scenario		
	Unit	Price ($)	Total Price ($)
LNG Tank	10	$ 35,000	$ 350,000
Engine MAN BW	1	$ 3,999,461	$ 3,999,461
Compressor	1	$ 150,000	$ 150,000
Temperature Indicator	13	$ 2,000	$ 26,000
Pressure Indicator	13	$ 2,000	$ 26,000
Shutdown Valve	17	$ 5,000	$ 85,000
Control Valve	14	$ 5,000	$ 70,000
Check Valve	5	$ 5,000	$ 25,000
Manual Valve	25	$ 3,000	$ 75,000
Pressure Safety Valve	4	$ 7,500	$ 30,000
Docking			$ 100,000
			$ 4,936,461

6.1.2 OPEX

Operational expenditure (Opex) is all costs incurred to perform operations for a certain period. In calculation of this final assignment period is determined for 19 years. On the side of ship provider required operational costs include salary of crew ship, vessel maintenance cost, main engine fuel costs, administration, lubricating oil, crew salary, crew insurance, crew accomodation. The List of crew salary will be attach in attachement.

KM. Gunung Dempo obtained distribution of speed usage on the vessel. The ship uses 85% power from the engine used. Therefore can be obtained the number of BHP is 6300 kW. In 85% power obtained SFGC at 85% is 7106 kJ / KWH and SFOC is 2.2 g / KWH. For endurance used based on data that is 350 days or 8400 hours. Fuel Oil Consumption can be obtained by calculation that is:

FCOil = BHP x SFOC x Endurance

= 6300 kW x 2,2 gr/Kwh x 8400 H

= 98.960.400 gram

= 98.960,4 Kg

Average cost PT. PELNI for HSD is Rp 5.000,00/Liter. Below is ecconomic calculation :

FCm3 = FCOil : Density HSD

= 98.960,4 Kg : 820 Kg/m^3

= 120,683 m^3

FCliter = 120,683m^3 x 1000 Liter/m^3

= 120.683 Liter

FCliter x Rp 5.000,00/Liter

= 120.683 Liter x Rp 5.000,00/Liter

= Rp 603.415.000,00

For gas fuel,

FCGas = BHP x SFGC x Endurance

= 6300 kW x 7.106 kJ/KWH x 8400 H

= 319.642.092 x 106 Joule

Change become mmbtu (1 mmbtu = 9,47086 x 10-10 Joule)

FCGas = 319.642.092 x 106 Joule x 9,47086 x 10-10 mmbtu/Joule

= 302.729 mmbtu

LNG price is USD 7 or Rp 91.000/mmbtu (kurs 1USD = Rp 13.000)

Total Gas Fuel = 302.729 mmbtu x Rp 91.000/mmbtu

= Rp 27.548.339.000,00

Total usage of fuel in this engine (MAN 6L 51/60 DF) is :

Total = Rp 603.415.000,00 (Oil) + Rp 27.548.339.000,00 (Gas)

= Rp 28.151.754.000,00

Table 6.2 OPEX KM. Gunnung Dempo

OPEX KM Gunung Dempo		
Items	Price ($)	Total Price ($)
Lubricating	$ 52,364	
Fuel Oil	$ 42,623	
Fuel Gas	$ 1,946,026	
Maintenance	$ 942,835	
Administration	$ 74,375	
Salary	$ 2,252,400	
Crew Insurance	$ 110,100	
Crew Acomodation	$ 68,900	
Total		$ 5,489,623

6.1.3 Revenue

Revenue is amount of money that a company actually receives during a specific period, including discounts and deductions for returned merchandise. It is the top line or gross income figure from which costs are subtracted to determine net income. Revenue in here is form of passenger ticket and container.

Table 6.3 Revenue KM. Gunung Dempo

Revenue KM. Gunung Dempo				
Year		Charge	Total * Trip	Revenue / Year
1	Dry Container	1829.2115	$ 1,920.0	$ 3,512,086
2	reefer Container	2958.5393	$ 864.0	$ 2,556,178
3	Passenger	20.89	$ 48,000.0	$ 1,002,720
				$ 7,070,984

note :
1. Total*Trip = (total container or passenger * Sailing period/year)*Trip
2. Dry Container = 40
3. Reefer Container = 18
4. Passenger =800
5. Sailing Period = 24 /year

6.1.4 Depreciation

Depreciation is a decline value of a property because of its time and usage (Pujawan, 2012). Depreciation does not fall into cash flow, but goes into tax deductible expenses. Depreciated assets are assets with the following conditions:

a) The asset generates income
b) Has economic value
c) Has economic value of more than one year
d) The usage value of the asset decreases due to natural causes

Table 6.4 Depresiation Table

Year	Capex	Percent (%)	Depreciation	Value
0	4,936,461.00	2.5%		4,936,461.00
1	0.00	2.5%	$ 123,412	4,813,049.48
2	0.00	2.5%	$ 123,412	4,689,637.95
3	0.00	2.5%	$ 123,412	4,566,226.43
4	0.00	2.5%	$ 123,412	4,442,814.90
5	0.00	2.5%	$ 123,412	4,319,403.38
6	0.00	2.5%	$ 123,412	4,195,991.85
7	0.00	2.5%	$ 123,412	4,072,580.33
8	0.00	2.5%	$ 123,412	3,949,168.80
9	0.00	2.5%	$ 123,412	3,825,757.28
10	0.00	2.5%	$ 123,412	3,702,345.75
11	0.00	2.5%	$ 123,412	3,578,934.23
12	0.00	2.5%	$ 123,412	3,455,522.70
13	0.00	2.5%	$ 123,412	3,332,111.18
14	0.00	2.5%	$ 123,412	3,208,699.65
15	0.00	2.5%	$ 123,412	3,085,288.13
16	0.00	2.5%	$ 123,412	2,961,876.60
17	0.00	2.5%	$ 123,412	2,838,465.08
18	0.00	2.5%	$ 123,412	2,715,053.55
19	0.00	2.5%	$ 123,412	2,591,642.03
Total Depresiation			$ 2,344,819	
Asset Value			$ 2,591,642	2,591,642.03

6.1.5 Tax Value

The tax regulation in this economic study is based on Government Regulation No.43 of 2013 concerning income tax on income business entities. The amount of tax imposed is differentiated by gross or gross income which is divided into three types as shown in the table 6.5

Table 6.5 Tax Businnes Entity

Groos Income	**Tax**
Less than Rp. 4.8 M	1% x Groos income
More than Rp. 4.8 M s/d Rp. 50 M	{0.25 - (0.6 M/Groos income)} x PKP
More than Rp. 50 M	25% x PKP

Included in gross income or PFM (Taxable Income) is value of income minus expense for operations and depreciation

6.1.6 Cashflow

Cash flow is sum of income and expenditure of a business. The cash flow is capex minus income after tax and principal debt

6.1.7 Payback Period

Payback period show number of periods (years) required to recover initial investment cost. Calculation is based on both annual cash flow and residual value (Pujawan, 2012). In calculation in this final project payback period value associated with value of cummulative cashflow where value shows cash flow in certain year.

$$Pp = (n - x) + (-b/c) \qquad (4.4)$$

Where :

Pp : payback periode

n : last year negative cash flow accumulation
x: Contruction Period

b: absolute value of the accumulated cash flow in the nth year

c: discounted cash flow value

6.1.8 NPV

NPV value is derived from discounted cash flow value and accumulated in last year of project life. NPV of this project will show in table 6.6

6.1.9 IRR

In this study the value of study seach by using function on microsoft excel is = IRR (cash flow value). So the IRR in this project is 20% and IRR value must be greater or equal to bank loan interest rate.

6.1.9 Economic Result

Calculation all of variable above will make a conclusion about feasibility of project conversion KM. Gunung Dempo. Table below will show the result of NPV, IRR and payback period.

Table 6.6 Economic Calculation

Economic Analysis NPV IRR Payback Period								
	Premis :							
	1. Fuel and lub oil		2.00%		4. Revenue	4.00%		
	2. Salary		3.7%		5. Administration	1.50%		
	3. Maintenance		2.50%					
Year	Description							
	CAPEX	Revenue	Lubricating	Fuel Oil	Fuel Gas	Maintenance	Administration	Salary
0	$ 4,936,461							
1		$ 7,070,984.0	$ 52,364.3	$ 74,374.9	$ 1,946,026.4	$ 942,834.9	$ 42,623.0	$ 2,431,400
2		$ 7,353,823.4	$ 53,411.6	$ 75,862.4	$ 1,984,946.9	$ 966,405.8	$ 43,262.3	$ 2,521,848
3		$ 7,647,976.3	$ 54,479.8	$ 77,379.6	$ 2,024,645.8	$ 990,565.9	$ 43,911.2	$ 2,615,661
4		$ 7,953,895.4	$ 55,569.4	$ 78,927.2	$ 2,065,138.8	$ 1,015,330.1	$ 44,569.9	$ 2,712,963
5		$ 8,272,051.2	$ 56,680.8	$ 80,505.8	$ 2,106,441.5	$ 1,040,713.3	$ 45,238.5	$ 2,813,886
6		$ 8,602,933.2	$ 57,814.4	$ 82,115.9	$ 2,148,570.4	$ 1,066,731.2	$ 45,917.0	$ 2,918,562
7		$ 8,947,050.6	$ 58,970.7	$ 83,758.2	$ 2,191,541.8	$ 1,093,399.5	$ 46,605.8	$ 3,027,133
8		$ 9,304,932.6	$ 60,150.1	$ 85,433.4	$ 2,235,372.6	$ 1,120,734.4	$ 47,304.9	$ 3,139,742
9		$ 9,677,129.9	$ 61,353.1	$ 87,142.0	$ 2,280,080.1	$ 1,148,752.8	$ 48,014.4	$ 3,256,540
10		$ 10,064,215.1	$ 62,580.1	$ 88,884.9	$ 2,325,681.7	$ 1,177,471.6	$ 48,734.7	$ 3,377,684
11		$ 10,466,783.7	$ 63,831.7	$ 90,662.6	$ 2,372,195.3	$ 1,206,908.4	$ 49,465.7	$ 3,503,334
12		$ 10,885,455.1	$ 65,108.4	$ 92,475.8	$ 2,419,639.2	$ 1,237,081.1	$ 50,207.7	$ 3,633,658
13		$ 11,320,873.3	$ 66,410.5	$ 94,325.4	$ 2,468,032.0	$ 1,268,008.1	$ 50,960.8	$ 3,768,830
14		$ 11,773,708.2	$ 67,738.8	$ 96,211.9	$ 2,517,392.6	$ 1,299,708.4	$ 51,725.2	$ 3,909,030
15		$ 12,244,656.5	$ 69,093.5	$ 98,136.1	$ 2,567,740.5	$ 1,332,201.1	$ 52,501.1	$ 4,054,446
16		$ 12,734,442.8	$ 70,475.4	$ 100,098.8	$ 2,619,095.3	$ 1,365,506.1	$ 53,288.6	$ 4,205,271
17		$ 13,243,820.5	$ 71,884.9	$ 102,100.8	$ 2,671,477.2	$ 1,399,643.7	$ 54,087.9	$ 4,361,708
18		$ 13,773,573.3	$ 73,322.6	$ 104,142.8	$ 2,724,906.7	$ 1,434,634.8	$ 54,899.2	$ 4,523,963
19		$ 14,324,516.2	$ 74,789.1	$ 106,225.7	$ 2,779,404.9	$ 1,470,500.7	$ 55,722.7	$ 4,692,254

Table 6.7 Cash Flow

Cash Flow							
Year	Description						
	CAPEX	Revenue	OPEX	Depresiation	EBT	Tax 25%	EAT
0	$ (4,936,461)						
1		$ 7,070,984.0	$ 5,489,623.4	$ 123,411.5	$ 1,581,360.6	$ 364,487.3	$ 1,216,873.3
2		$ 7,353,823.4	$ 5,645,737.0	$ 123,411.5	$ 1,708,086.4	$ 396,168.7	$ 1,311,917.7
3		$ 7,647,976.3	$ 5,806,643.3	$ 123,411.5	$ 1,841,333.1	$ 429,480.4	$ 1,411,852.7
4		$ 7,953,895.4	$ 5,972,498.8	$ 123,411.5	$ 1,981,396.6	$ 464,496.3	$ 1,516,900.3
5		$ 8,272,051.2	$ 6,143,465.5	$ 123,411.5	$ 2,128,585.7	$ 501,293.5	$ 1,627,292.1
6		$ 8,602,933.2	$ 6,319,711.0	$ 123,411.5	$ 2,283,222.2	$ 539,952.7	$ 1,743,269.5
7		$ 8,947,050.6	$ 6,501,408.6	$ 123,411.5	$ 2,445,642.0	$ 580,557.6	$ 1,865,084.4
8		$ 9,304,932.6	$ 6,688,737.4	$ 123,411.5	$ 2,616,195.2	$ 623,195.9	$ 1,992,999.3
9		$ 9,677,129.9	$ 6,881,882.9	$ 123,411.5	$ 2,795,247.0	$ 667,958.9	$ 2,127,288.2
10		$ 10,064,215.1	$ 7,081,036.7	$ 123,411.5	$ 2,983,178.4	$ 714,941.7	$ 2,268,236.7
11		$ 10,466,783.7	$ 7,286,397.3	$ 123,411.5	$ 3,180,386.4	$ 764,243.7	$ 2,416,142.7
12		$ 10,885,455.1	$ 7,498,169.8	$ 123,411.5	$ 3,387,285.3	$ 815,968.4	$ 2,571,316.8
13		$ 11,320,873.3	$ 7,716,566.5	$ 123,411.5	$ 3,604,306.8	$ 870,223.8	$ 2,734,083.0
14		$ 11,773,708.2	$ 7,941,806.9	$ 123,411.5	$ 3,831,901.3	$ 927,122.4	$ 2,904,778.8
15		$ 12,244,656.5	$ 8,174,118.3	$ 123,411.5	$ 4,070,538.2	$ 986,781.7	$ 3,083,756.6
16		$ 12,734,442.8	$ 8,413,735.6	$ 123,411.5	$ 4,320,707.2	$ 1,049,323.9	$ 3,271,383.2
17		$ 13,243,820.5	$ 8,660,902.1	$ 123,411.5	$ 4,582,918.4	$ 1,114,876.7	$ 3,468,041.7
18		$ 13,773,573.3	$ 8,915,869.3	$ 123,411.5	$ 4,857,704.0	$ 1,183,573.1	$ 3,674,130.9
19		$ 14,324,516.2	$ 9,178,897.5	$ 123,411.5	$ 5,145,618.7	$ 1,255,551.8	$ 3,890,066.9

Table 6.8 NPV Calculation

Year	*i* 10.25%	Cashflow Discounted	NPV
0	1	$ (4,936,461)	$ (4,936,461)
1	0.907029478	$ 1,340,285	$ 1,215,678
2	0.822702475	$ 1,435,329	$ 1,180,849
3	0.746215397	$ 1,535,264	$ 1,145,638
4	0.676839362	$ 1,640,312	$ 1,110,228
5	0.613913254	$ 1,750,704	$ 1,074,780
6	0.556837418	$ 1,866,681	$ 1,039,438
7	0.505067953	$ 1,988,496	$ 1,004,326
8	0.458111522	$ 2,116,411	$ 969,552
9	0.415520655	$ 2,250,700	$ 935,212
10	0.376889483	$ 2,391,648	$ 901,387
11	0.341849871	$ 2,539,554	$ 868,146
12	0.31006791	$ 2,694,728	$ 835,549
13	0.281240735	$ 2,857,494	$ 803,644
14	0.255093637	$ 3,028,190	$ 772,472
15	0.231377449	$ 3,207,168	$ 742,066
16	0.209866167	$ 3,394,795	$ 712,453
17	0.1903548	$ 3,591,453	$ 683,650
18	0.172657415	$ 3,797,542	$ 655,674
19	0.156605365	$ 4,013,478	$ 628,532
Total			$ 12,342,813

Table 6.9 Net Cash Flow

i	NPV	IRR	PP
10.25%	$ 12,342,813	33%	4.0

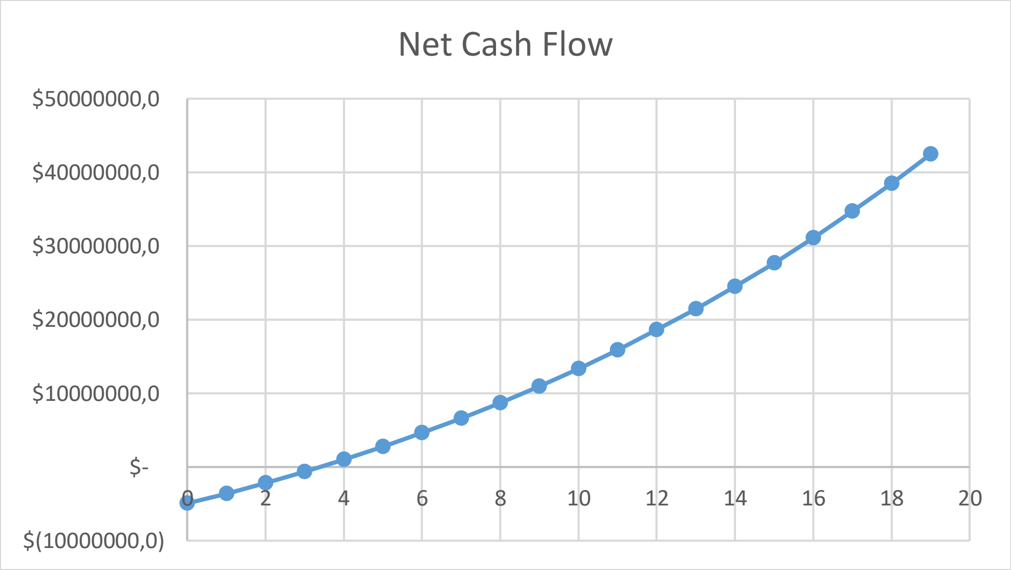


Figure 6.1 Economic Statistic

Analysis performed to know parameter of project or conversion value of project. This analysis use CAPEX and OPEX which variation 7% and find value of NPV, PP and IR

CHAPTER 7
CONCLUSION

7.1 Conclusion

From reasearch about risk and economical assessment for dual fuel conversion KM. Gunung Dempo can concluted that :

1. Hazard and failure mode include failure component dual fuel system that can generate failure and hazard have impact in system and fatalities. Frequency analysis using FTA and ETA method to calculate frequency from hazad gas release from each component. In the calculation of FTA using software simulation relec 2009. While ETA used for deciding last impact of gas release include risk of BLEEVE, explotion, flash fire jet fire and gas dispersion.
2. Concequence from risk of BLEEVE, explotion, flash fire, jet fire, and gas dispersion simulate using aloha software and will show in desain layout, so concequence value can decided
3. From result of risk assessment with representation frequency value and concequences in Figure risk criteria FN curve BLEEVE, explosionflash fire, jet fire locate in acceptable level, while for gas dispersion locate in ALARP level. Mitigation step may to do for gas dispersion for location of risk move in acceptable zone. Mitigation method using LOPA. Result of mitigation shows all of risk enter in acceptable level, while dual fuel system conversion with design of LNG tank inside compartement and LNG tank outside compartement are safe to use in MV. Gunung Dempo.
4. Economical assessment of LNG tank inside compartemen and outside compatement calculate every component that include in CAPEX (Capital Expenditure) and OPEX (Operational Expenditure). The parameter of chosing design is which one is the most profitable to do. NPV, IRR (interest rate of return), payback period analyzed with CAPEX and OPEX. From the calculation shows that design LNG tank inside compartement is more profitable because the area cargo hold upper LNG tank compartement can placed more container.

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ATTACHMENT FREQUENCY ANALYSIS USING FTA

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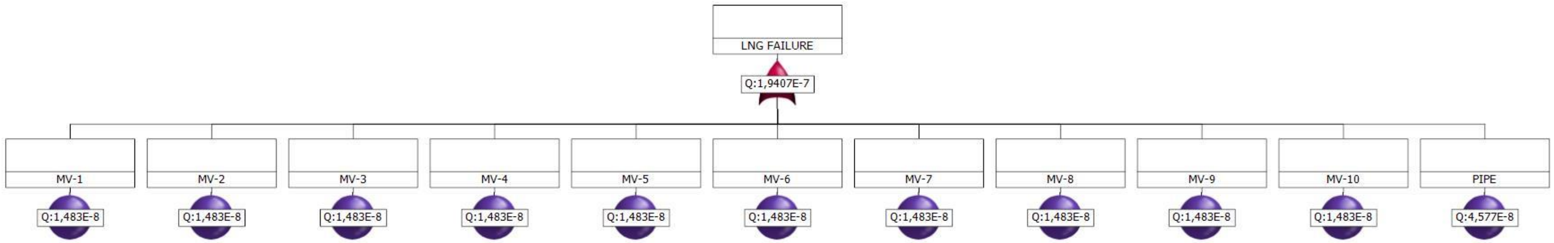
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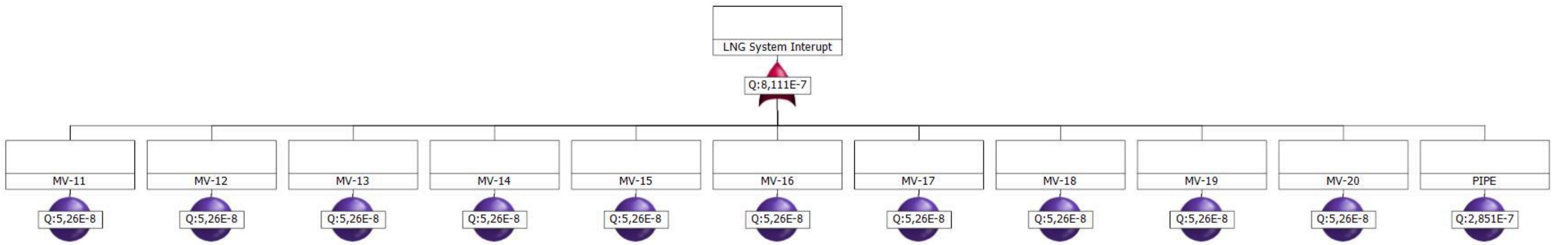
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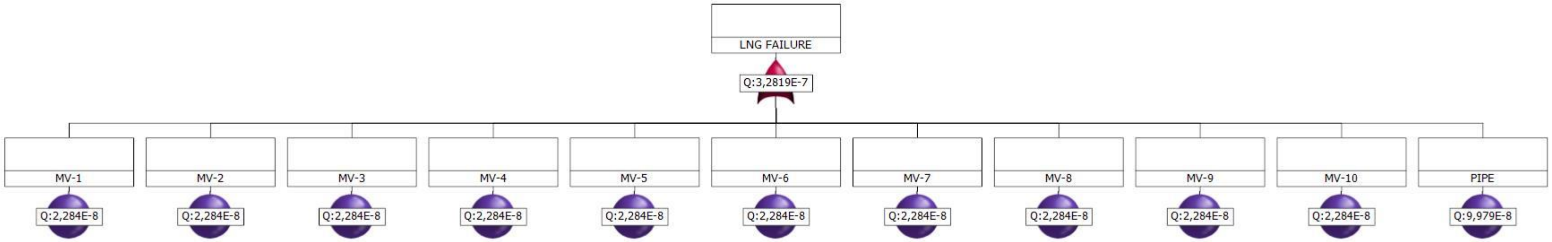
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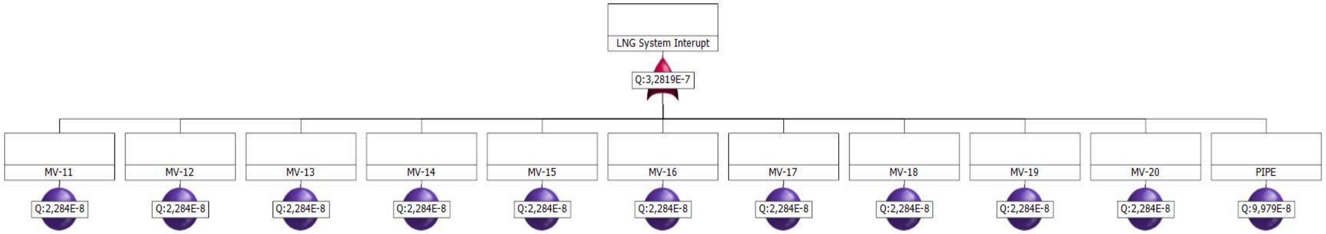
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MV-16
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MV-17
Q:2,284E-8
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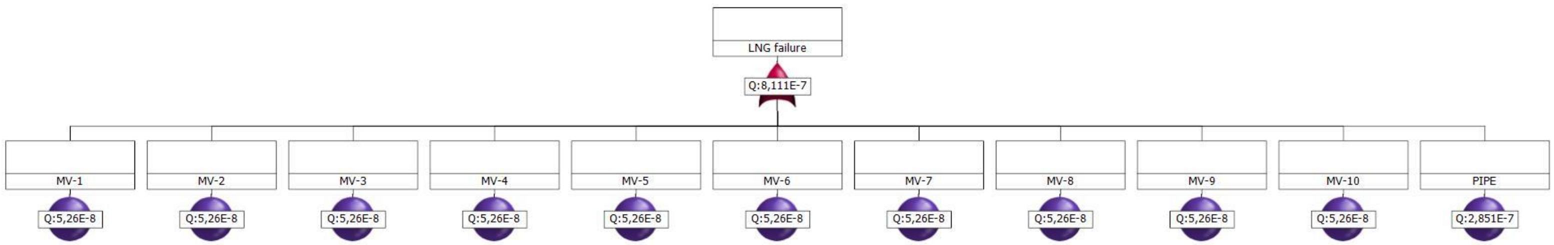
PIPE
Q:9,979E-8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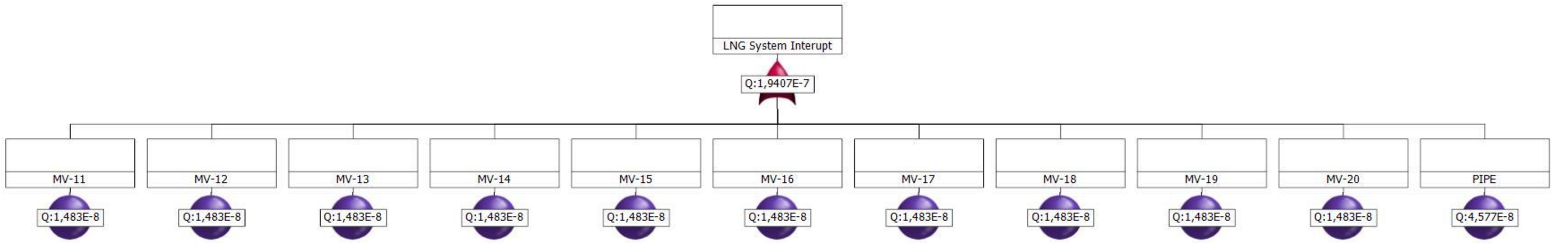
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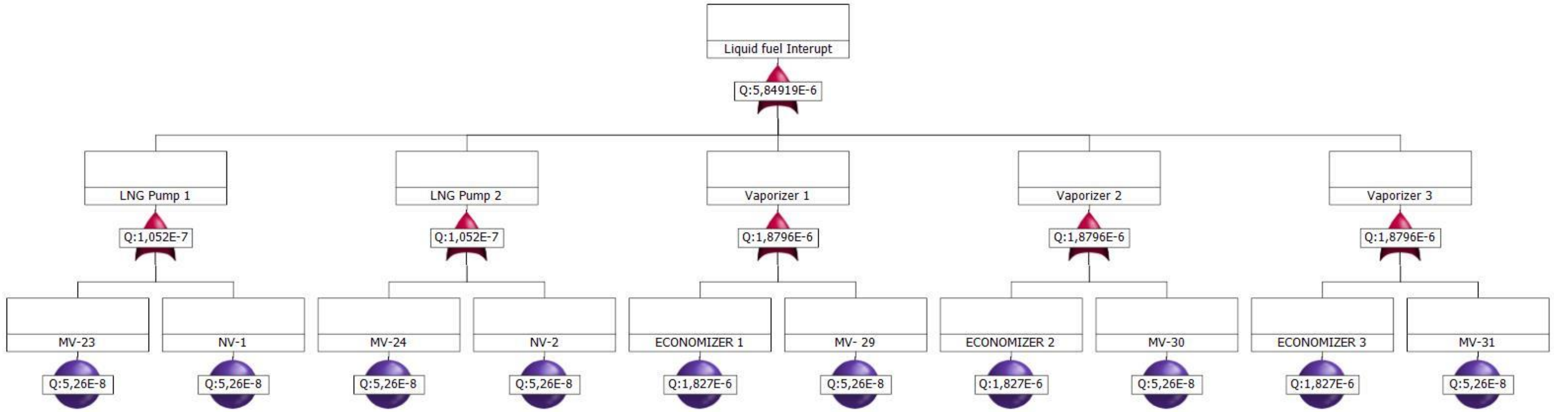
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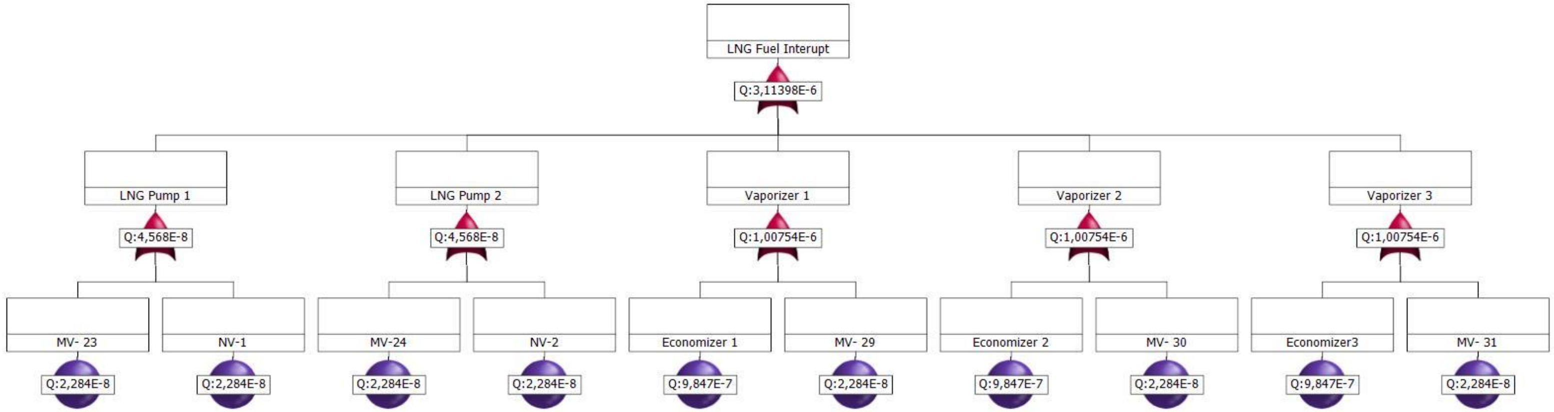
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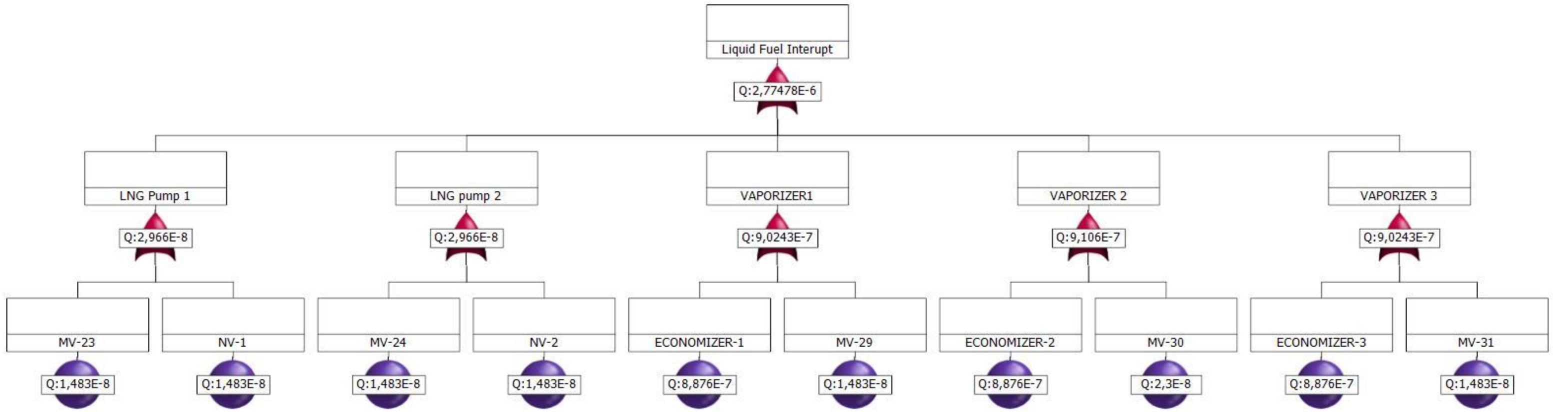
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VAPORIZER 3
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NV-1
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MV-24
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NV-2
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ECONOMIZER-1
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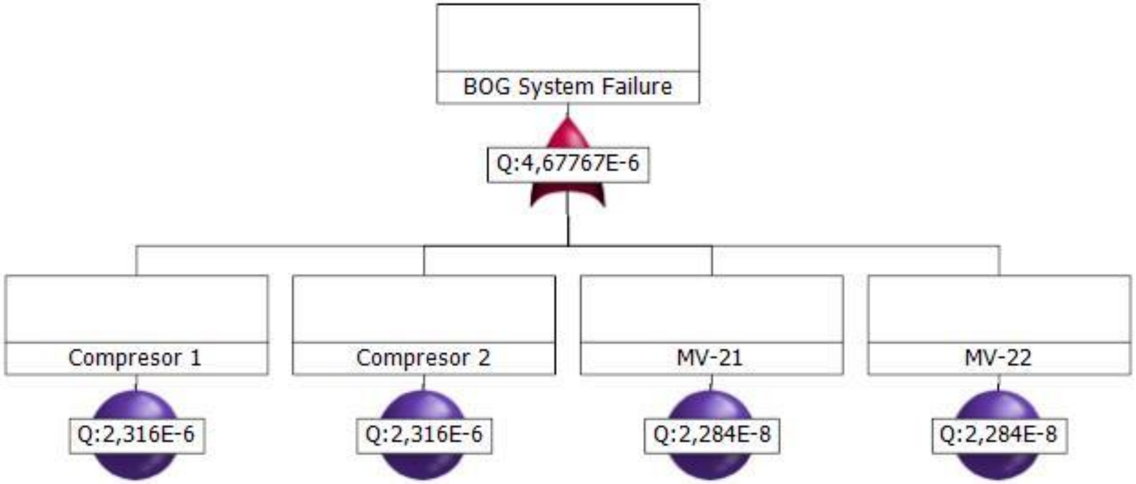
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Compresor 2
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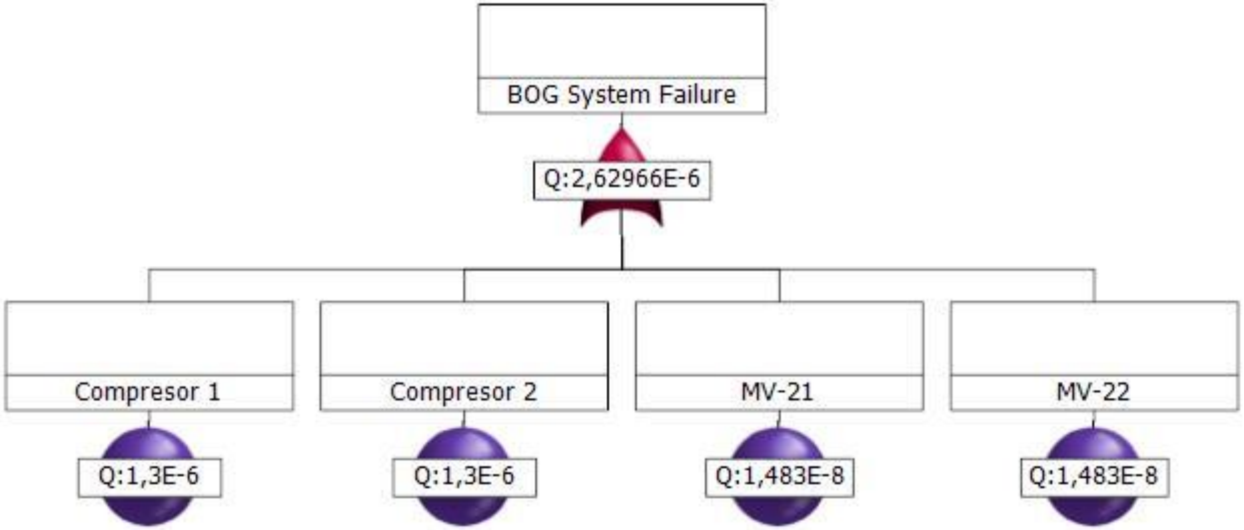
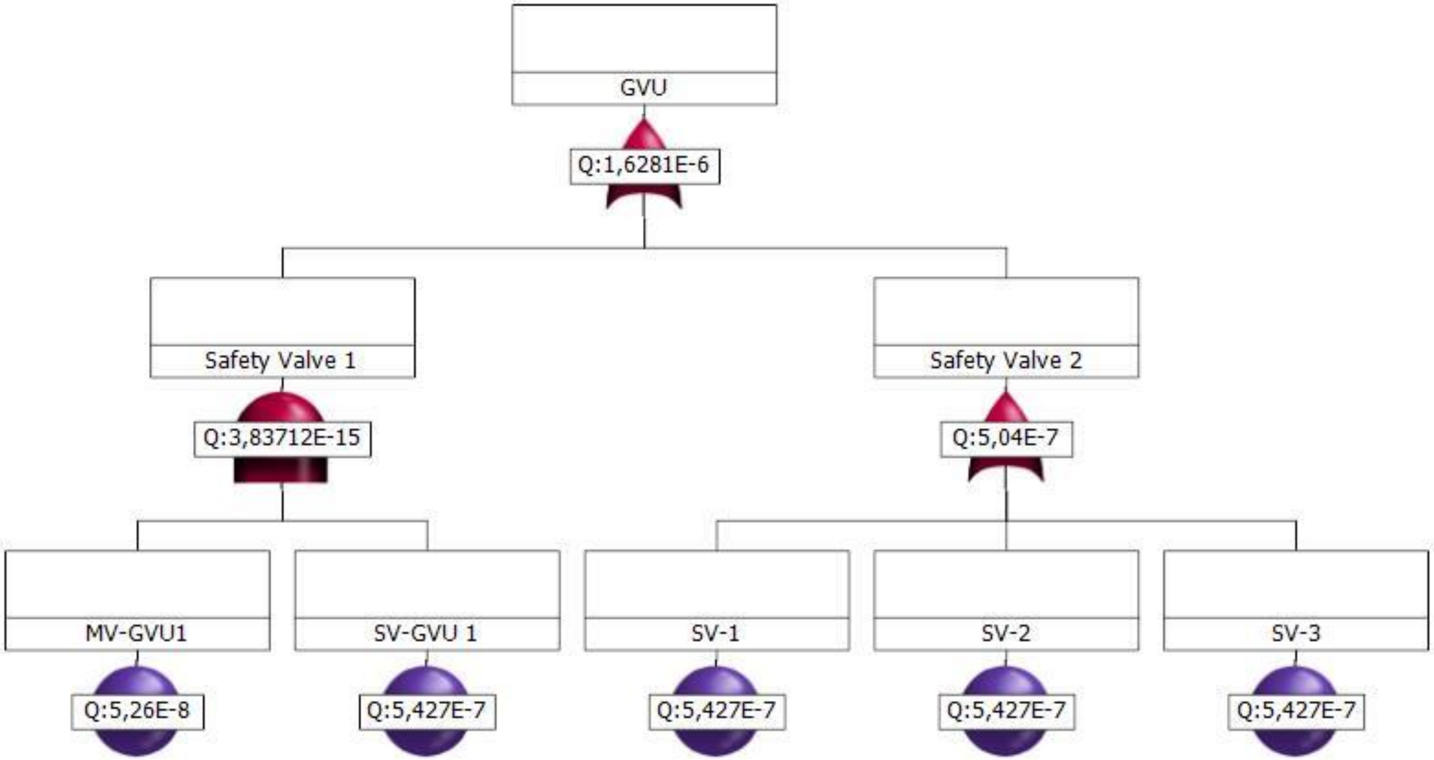
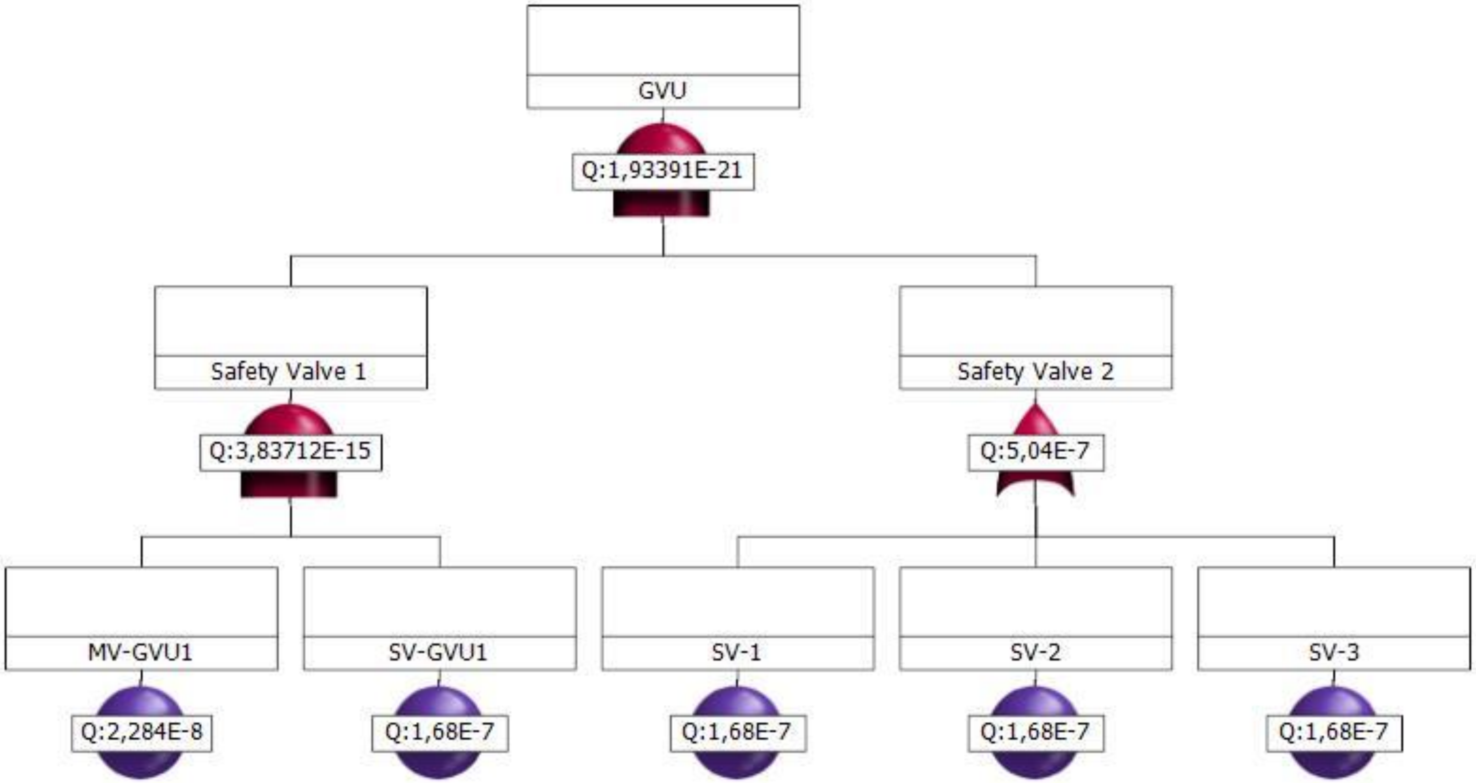
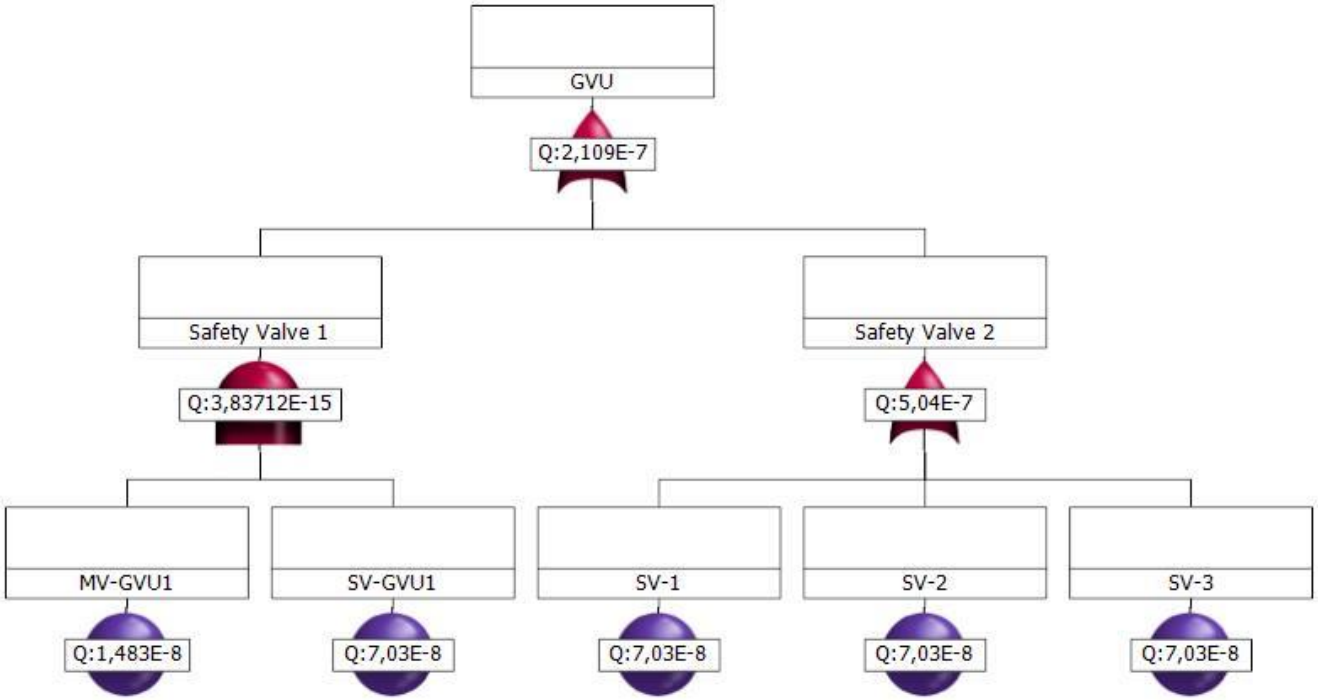
Q:2,284E-8
MV-22
Q:2,284E-8


BOG System Failure
Q:2,62966E-6
Compresor 1
Compresor 2
MV-21
MV-22
Q:1,3E-6
Q:1,3E-6
Q:1,483E-8
Q:1,483E-8


GVU
Q:1,6281E-6
Safety Valve 1
Q:3,83712E-15
Safety Valve 2
Q:5,04E-7
MV-GVU1
Q:5,26E-8
SV-GVU 1
Q:5,427E-7
SV-1
Q:5,427E-7
SV-2
Q:5,427E-7
SV-3
Q:5,427E-7


GVU
Q:1,93391E-21
Safety Valve 1
Q:3,83712E-15
Safety Valve 2
Q:5,04E-7
MV-GVU1
Q:2,284E-8
SV-GVU1
Q:1,68E-7
SV-1
Q:1,68E-7
SV-2
Q:1,68E-7
SV-3
Q:1,68E-7


GVU
Q:2,109E-7
Safety Valve 1
Q:3,83712E-15
Safety Valve 2
Q:5,04E-7
MV-GVU1
Q:1,483E-8
SV-GVU1
Q:7,03E-8
SV-1
Q:7,03E-8
SV-2
Q:7,03E-8
SV-3
Q:7,03E-8

ATTACHMENT EVENT TREE ANALYSIS (ETA)

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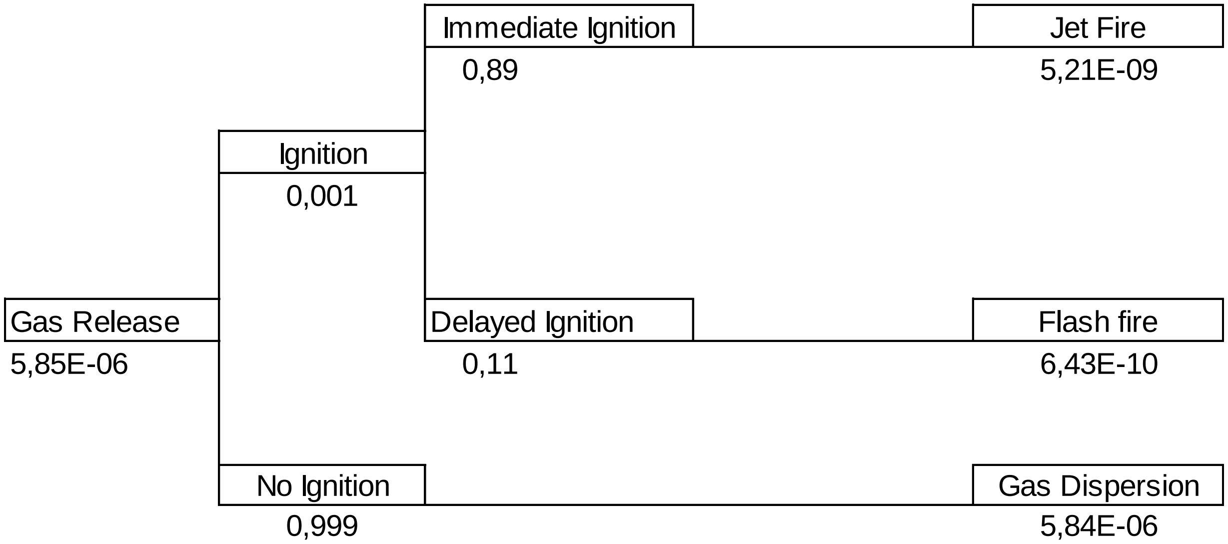
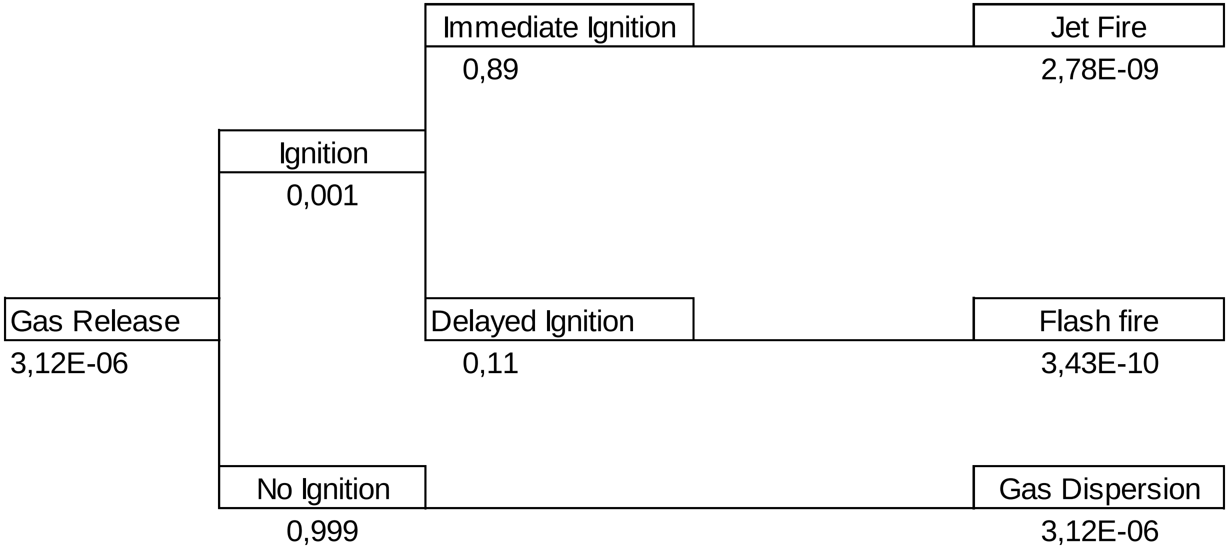
Node 1 (small) (1-3) Fuel System

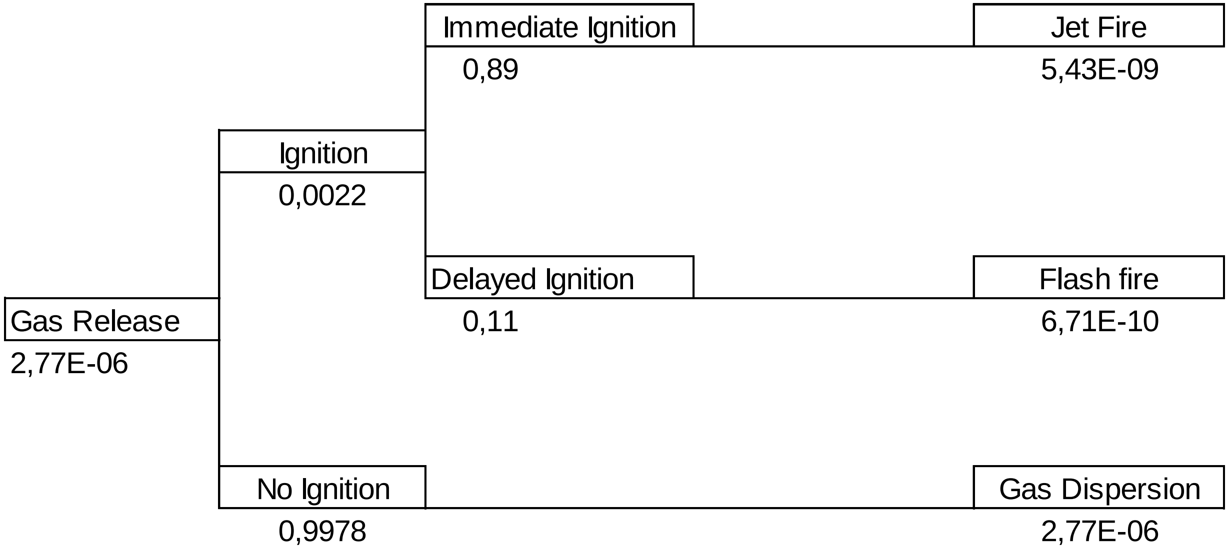
flow release	0,004 kg/s
Ignition prob.	0,001



Node 1 (small) (3-10) Fuel System
flow release 0,047 kg/s
Ignition prob. OGP



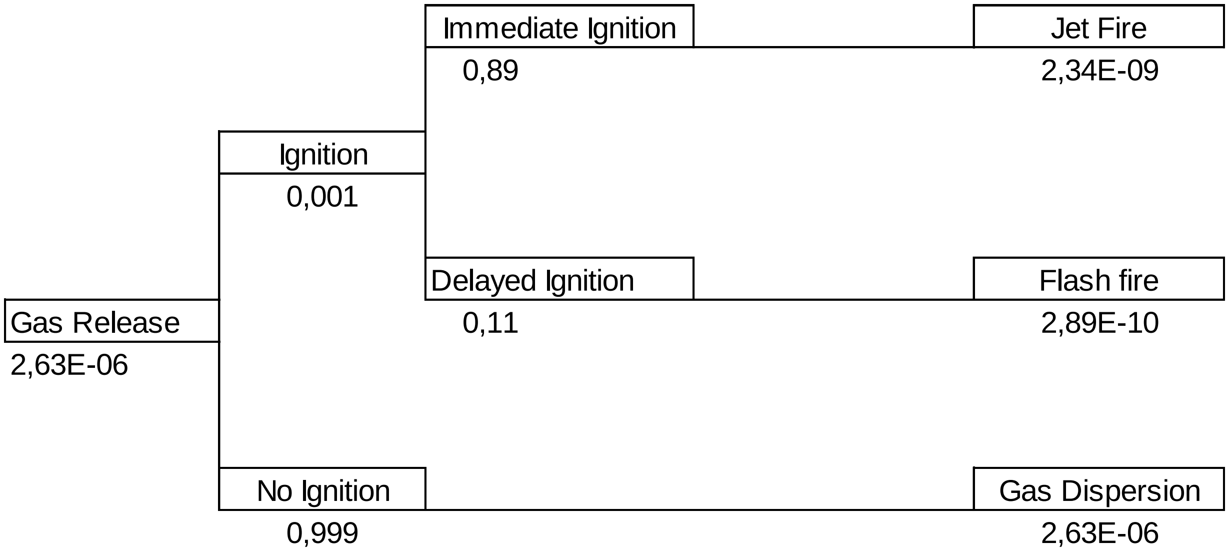
Node 1 (small) (10-50) Fuel System
flow release 1,175 kg/s
Ignition prob. OGP



Node 3 (Large) (1-3) BOG System

flow release 0,008 kg/s

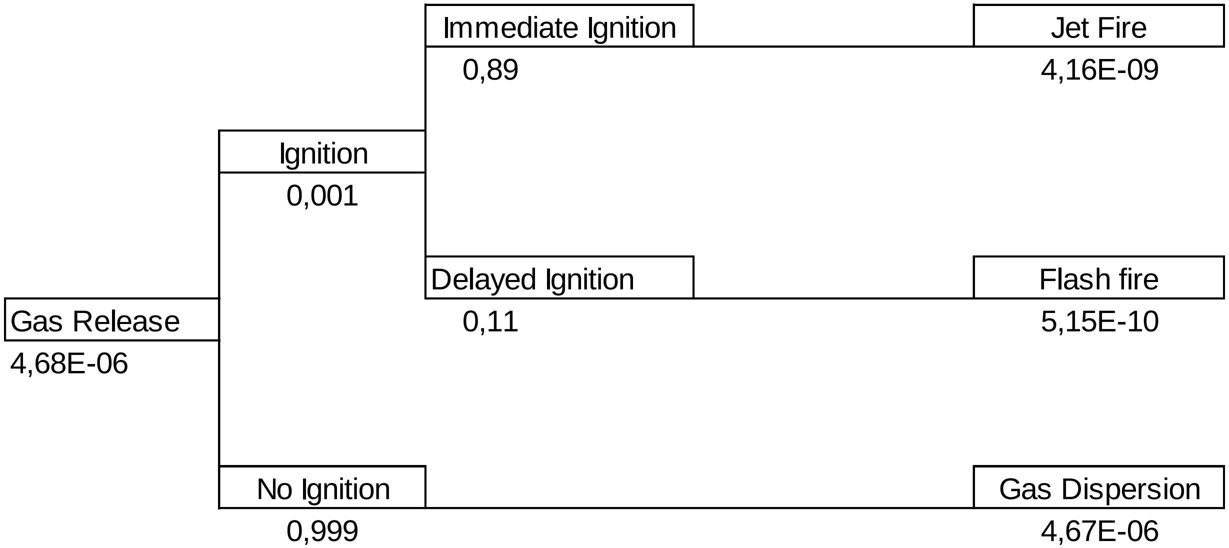
Ignition prob. 0,001



Node 3 (Large) (3-10) BOG System

flow release 0,091 kg/s

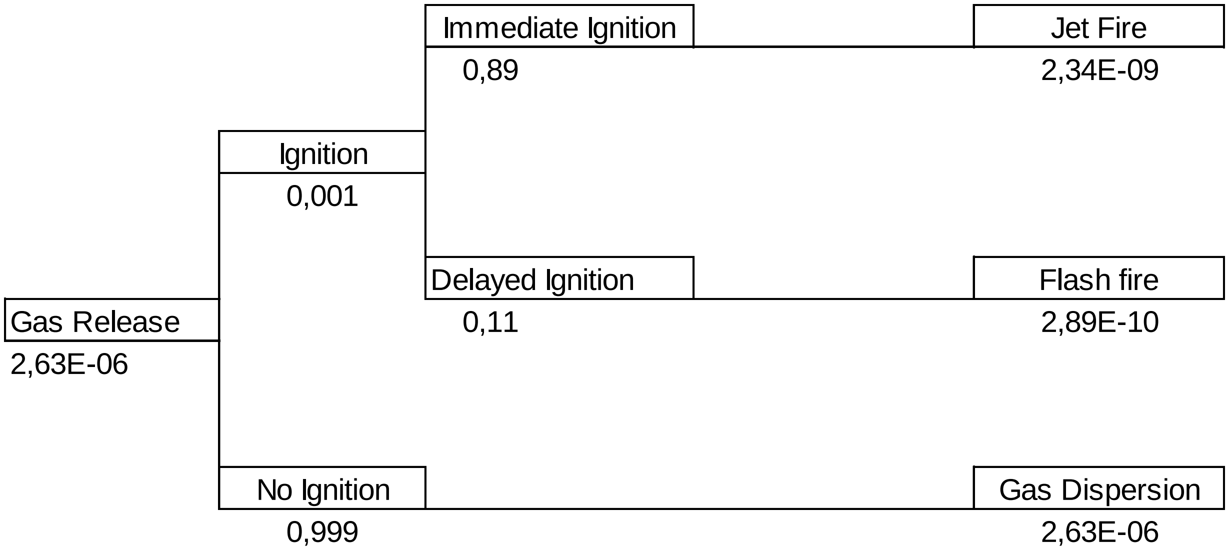
Ignition prob. 0,001



Node 3(Large) (10-50) BOG System

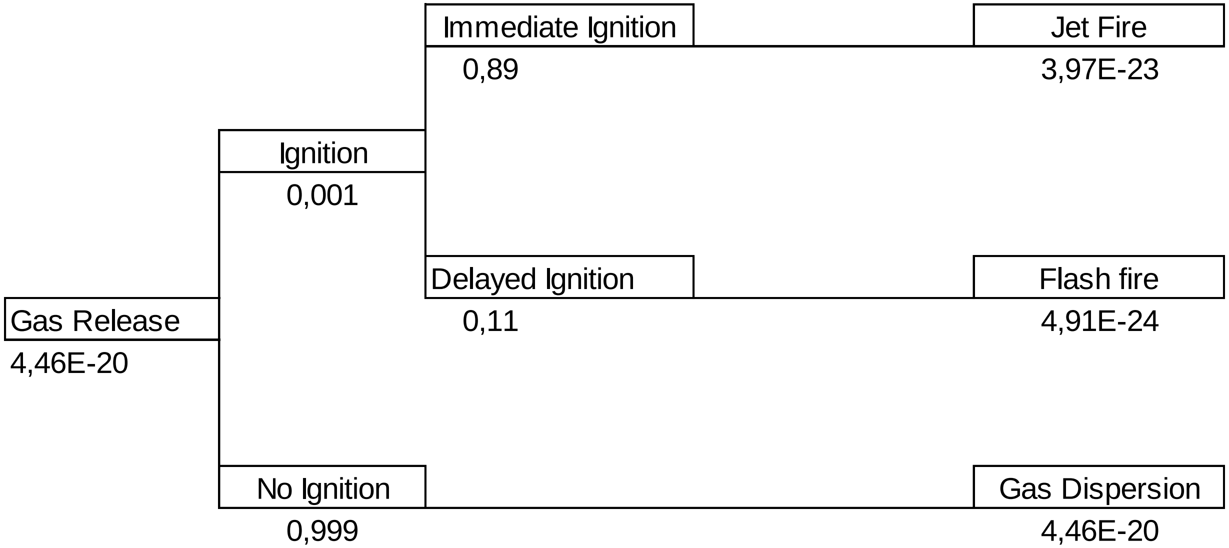
flow release 2,275 kg/s

Ignition prob. 0,0213



Node 4(small) (1-3) GVU System

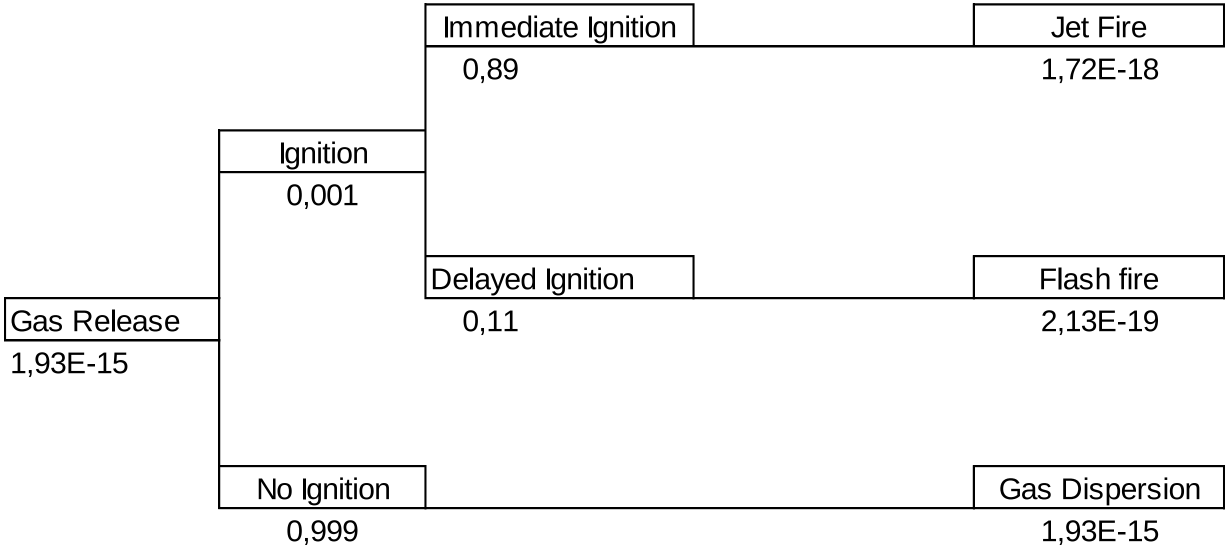
flow release	0,000028	kg/s
Ignition prob.	0,001	



Node 4(medium) (3-10) GVU System

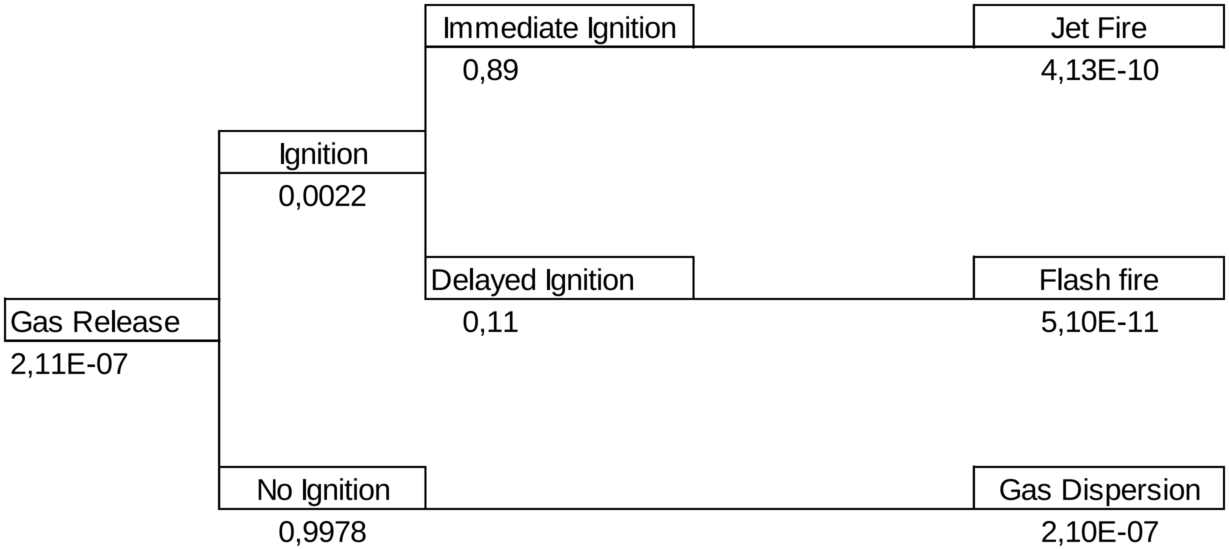
flow release 0,000 kg/s

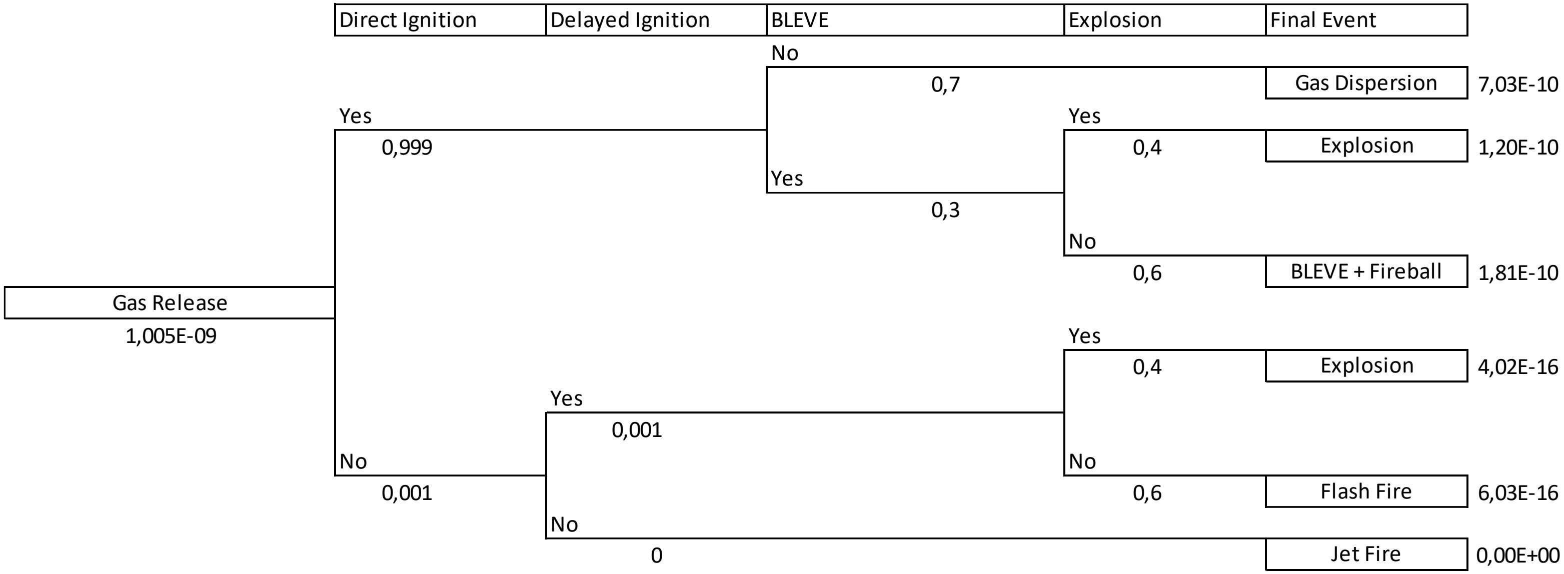
Ignition prob. 0,001



Node 4(Large) (10-50) GVU System

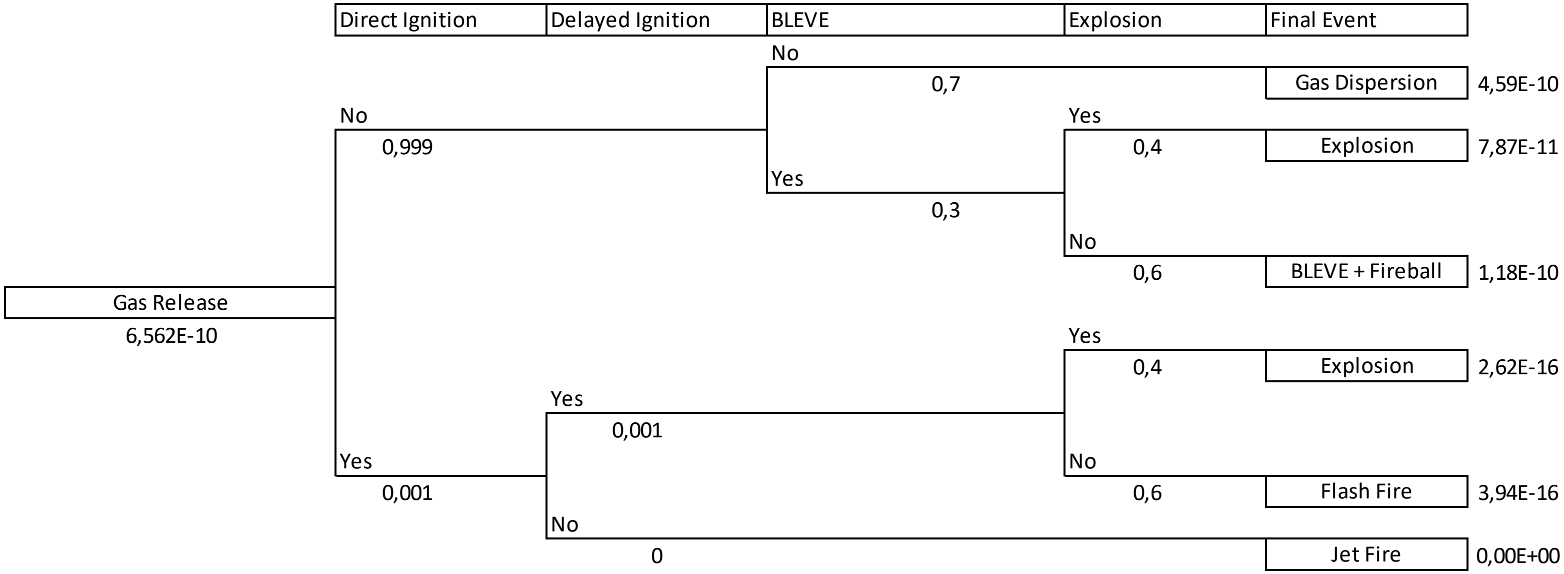
flow release	0,008	kg/s
Ignition prob.	0,0022	





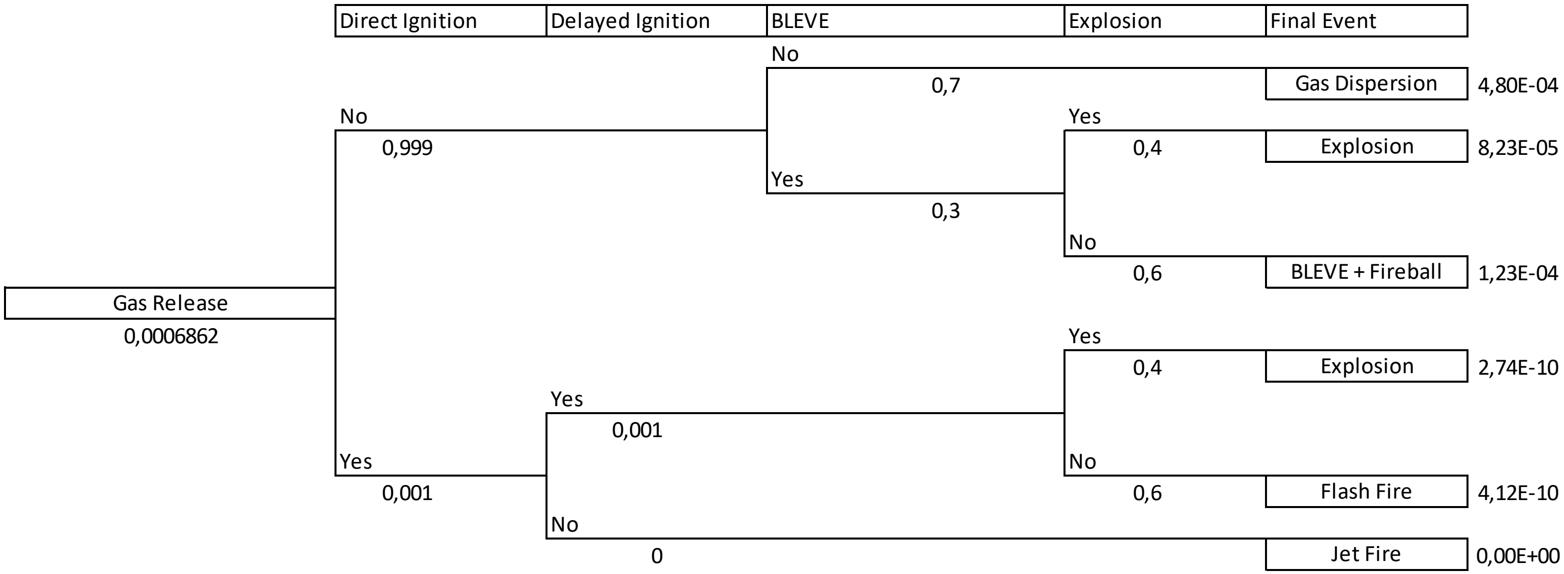
Storage System Gas Release (Leakage Hole 1-3 mm)

Flow release	0,004230	kg/s
Ignition probability OGP	0,001	



Storage System Gas Release (Leakage Hole 3-10 mm)

Flow release	0,046996	kg/s
Ignition probability OGP	0,001	



Storage System Gas Release (Leakage Hole 10-50 mm)

Flow release	1,762337	kg/s
Ignition probability OGP	0,0022	

CONCEQUENCES ANALYSIS

(USING ALOHA)

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Flash Fire Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wakt				Heat Flux	Fatality (N)
				First	Second	Third	Tolerable	(kW/m^2)	
1	BOG System	deck 1	#VALUE!	5/10 m/60 s	1	1	-	> 10	5
		deck 2	418	-	-	-	3/- / -	< 2	-
		deck 3	257	-	-	-	4/- / -	< 2	-
		deck 4	431	-	-	-	4/- / -	< 2	-
		deck 5	490	-	-	-	8/- / -	< 2	-
		deck 6	96	-	-	-	5/- / -	< 2	-
		deck 7	18	-	-	-	3/- / -	< 2	-
		deck 8	14	-	-	-	1/- / -	< 2	-
Total									5

Jet Fire Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wakt				Heat Flux	Fatality (N)
				Red	Orange	Yellow	Tolerable	(kW/m^2)	
1	BOG System	deck 1	7	5/10 m/60 s	1	1	-	>10	5
		deck 2	418	-	-	-	-	-	-
		deck 3	257	-	-	-	-	-	-
		deck 4	431	-	-	-	-	-	-
		deck 5	490	-	-	-	-	-	-
		deck 6	96	-	-	-	-	-	-
		deck 7	18	-	-	-	-	-	-
		deck 8	14	-	-	-	-	-	-
Total									5

Gas Dispersion Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	BOG System	deck 1	7	5/10 m/60 s	-	-	-	> 17000	5
		deck 2	418	-	-	-	3/- / -	< 2900	-
		deck 3	257	-	-	-	4/- / -	< 2900	-
		deck 4	431	-	-	-	4/- / -	< 2900	-
		deck 5	490	-	-	-	8/- / -	< 2900	-
		deck 6	96	-	-	-	5/- / -	< 2900	-
		deck 7	18	-	-	-	3/- / -	< 2900	-
		deck 8	14	-	-	-	1/- / -	< 2900	-
Total									5

Flash Fire Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				First	Second	Third	Tolerable		
1	BOG System	deck 1	7	5/10 m/60 s	-	-	-	> 10	5
		deck 2	418		-	-	3/- / -	< 2	-
		deck 3	257	-	-	-	4/- / -	< 2	-
		deck 4	431	-	-	-	4/- / -	< 2	-
		deck 5	490	-	-	-	8/- / -	< 2	-
		deck 6	96	-	-	-	5/- / -	< 2	-
		deck 7	18	-	-	-	3/- / -	< 2	-
		deck 8	14	-	-	-	1/- / -	< 2	-
Total									5

Jet Fire Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	BOG System	deck 1	7	5/10 m/60 s	1	1	-	>10	5
		deck 2	418	-	-	-	-	-	-
		deck 3	257	-	-	-	-	-	-
		deck 4	431	-	-	-	-	-	-
		deck 5	490	-	-	-	-	-	-
		deck 6	96	-	-	-	-	-	-
		deck 7	18	-	-	-	-	-	-
		deck 8	14	-	-	-	-	-	-
Total									5

Gas Dispersion Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	BOG System	deck 1	7	5/10 m/60 s	-	-	-	> 17000	5
		deck 2	418	-	-	-	3/- / -	< 2900	-
		deck 3	257	-	-	-	4/- / -	< 2900	-
		deck 4	431	-	-	-	4/- / -	< 2900	-
		deck 5	490	-	-	-	8/- / -	< 2900	-
		deck 6	96	-	-	-	5/- / -	< 2900	-
		deck 7	18	-	-	-	3/- / -	< 2900	-
		deck 8	14	-	-	-	1/- / -	< 2900	-
Total									5

Flash Fire Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				First	Second	Third	Tolerable		
1	BOG System	deck 1	7	5/10 m/60 s	-	-	-	> 10	5
		deck 2	418				3/- / -	< 2	-
		deck 3	257				4/- / -	< 2	-
		deck 4	431				4/- / -	< 2	-
		deck 5	490				8/- / -	< 2	-
		deck 6	96				5/- / -	< 2	-
		deck 7	18				3/- / -	< 2	-
		deck 8	14				1/- / -	< 2	-
Total									5

Jet Fire Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	BOG System	deck 1	7	5/10 m/60 s	-	-	-	>10	5
		deck 2	418	-	-	-	-	>5	-
		deck 3	257	-	-	-	-	>2	-
		deck 4	431	-	-	-	-	-	-
		deck 5	490	-	-	-	-	-	-
		deck 6	96	-	-	-	-	-	-
		deck 7	18	-	-	-	-	-	-
		deck 8	14	-	-	-	-	-	-
Total									5

Gas Dispersion Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	BOG System	deck 1	7	5/10 m/60 s	-		-	>17000	5
		deck 2	418	-	-	-	3/- / -	>17001	-
		deck 3	257	-	-	-	4/- / -	'	-
		deck 4	431	-	-	-	4/- / -	>17003	-
		deck 5	490	-	-	-	8/- / -	>17004	-
		deck 6	96	-	-	-	5/- / -	>17005	-
		deck 7	18	-	-	-	3/- / -	>17006	-
		deck 8	14	-	-	-	1/- / -	>17007	-
Total									5

Flash Fire Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	Fuel Sytem	deck 1	7	5/10 m/60 s	-	-	-	> 17000	5
		deck 2	418	-	-	-	3/- /-	< 2900	-
		deck 3	257		-	-	-	> 17000	
		deck 4	431	-	-	-	3/- /-	< 2900	-
		deck 5	490	-	-	-	3/- /-	< 2900	-
		deck 6	96	-	-	-	3/- /-	< 2900	-
		deck 7	18	-	-	-	3/- /-	< 2900	-
		deck 8	14	-	-	-	3/- /-	< 2900	-
Total									5

Jet Fire Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wakt				Heat Flux	Fatality (N)
				Red	Orange	Yellow	Tolerable	(kW/m^2)	
1	Fuel Sytem	deck 1	7	5/10 m/60 s	-	-	-	> 10	5
		deck 2	418	-	-	-	3/- /-	< 2	-
		deck 3	257		-	-	-	> 10	
		deck 4	431	-	-	-	4/- /-	< 2	-
		deck 5	490	-	-	-	8/- /-	< 2	-
		deck 6	96	-	-	-	5/- /-	< 2	-
		deck 7	18	-	-	-	3/- /-	< 2	-
		deck 8	14	-	-	-	1/- /-	< 2	-
Total									5

Gas Dispersion Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	Fuel Sytem	deck 1	7	5/10 m/60 s	-	-	-	> 17000	5
		deck 2	418	-	-	-	3/- /-	< 2900	-
		deck 3	257		-	-	-	> 17000	
		deck 4	431	-	-	-	4/- /-	< 2900	-
		deck 5	490	-	-	-	8/- /-	< 2900	-
		deck 6	96	-	-	-	5/- /-	< 2900	-
		deck 7	18	-	-	-	3/- /-	< 2900	-
		deck 8	14	-	-	-	1/- /-	< 2900	-
Total									5

Flash Fire Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	Fuel Sytem	deck 1	7	5/10 m/60 s	-	-	-	> 17000	5
		deck 2	418	-	-	-	3/- /-	< 2900	-
		deck 3	257		-	-	-	> 17000	
		deck 4	431	-	-	-	3/- /-	< 2900	-
		deck 5	490	-	-	-	3/- /-	< 2900	-
		deck 6	96	-	-	-	3/- /-	< 2900	-
		deck 7	18	-	-	-	3/- /-	< 2900	-
		deck 8	14	-	-	-	3/- /-	< 2900	-
Total									5

Jet Fire Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	Fuel Sytem	deck 1	7	5/10 m/60 s	-	-	-	> 10	5
		deck 2	418	-	-	-	3/- /-	< 2	-
		deck 3	257		-	-	-	> 10	
		deck 4	431	-	-	-	4/- /-	< 2	-
		deck 5	490	-	-	-	8/- /-	< 2	-
		deck 6	96	-	-	-	5/- /-	< 2	-
		deck 7	18	-	-	-	3/- /-	< 2	-
		deck 8	14	-	-	-	1/- /-	< 2	-
Total									5

Gas Dispersion Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	Fuel Sytem	deck 1	7	5/10 m/60 s	-	-	-	> 17000	5
		deck 2	418	-	-	-	3/- /-	< 2900	-
		deck 3	257		-	-	-	> 17000	
		deck 4	431	-	-	-	4/- /-	< 2900	-
		deck 5	490	-	-	-	8/- /-	< 2900	-
		deck 6	96	-	-	-	5/- /-	< 2900	-
		deck 7	18	-	-	-	3/- /-	< 2900	-
		deck 8	14	-	-	-	1/- /-	< 2900	-
Total									5

Flash Fire Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	Fuel Sytem	deck 1	7	5/10 m/60 s	-	-	2/- /-	< 5000	5
		deck 2	418	-	-	-	3/- /-	< 5000	-
		deck 3	257	-	-		-	5000-17000	
		deck 4	431	-	-	-	4/- /-	< 5000	-
		deck 5	490	-	-	-	8/- /-	< 5000	-
		deck 6	96	-	-	-	5/- /-	< 5000	-
		deck 7	18	-	-	-	3/- /-	< 5000	-
		deck 8	14	-	-	-	1/- /-	< 5000	-
Total									5

Jet Fire Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	Fuel Sytem	deck 1	7	5/10 m/60 s	-		-	2.0 - 5.0	5
		deck 2	418	-	-	-	3/- /-	< 2.0	-
		deck 3	257		-		-	> 10	
		deck 4	431	-	-	-	4/- /-	< 2.0	-
		deck 5	490	-	-	-	8/- /-	< 2.0	-
		deck 6	96	-	-	-	5/- /-	< 2.0	-
		deck 7	18	-	-	-	3/- /-	< 2.0	-
		deck 8	14	-	-	-	1/- /-	< 2.0	-
Total									5

Gas Dispersion Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	Fuel Sytem	deck 1	7	5/10 m/60 s	-	-	2/- /-	< 2900	5
		deck 2	418	-	-	-	3/- /-	< 2900	-
		deck 3	257	-		-	-	2900-17000	
		deck 4	431	-	-	-	4/- /-	< 2900	-
		deck 5	490	-	-	-	8/- /-	< 2900	-
		deck 6	96	-	-	-	5/- /-	< 2900	-
		deck 7	18	-	-	-	3/- /-	< 2900	-
		deck 8	14	-	-	-	1/- /-	< 2900	-
Total									5

Flash Fire Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wakt				Heat Flux (kW/m^2)	Fatality (N)
				First	Second	Third	Tolerable		
1	GVU System	deck 1	7	2/10 m/60 s	-	-	2/- /-	< 2900	2
		deck 2	418		-	-	-	> 17000	
		deck 3	257	-	-	-	3/- /-	< 2900	-
		deck 4	431	-	-	-	3/- /-	< 2900	-
		deck 5	490	-	-	-	3/- /-	< 2900	-
		deck 6	96	-	-	-	3/- /-	< 2900	-
		deck 7	18	-	-	-	3/- /-	< 2900	-
		deck 8	14	-	-	-	3/- /-	< 2900	-
Total									2

Jet Fire Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wakt				Heat Flux (kW/m^2)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	GVU System	deck 1	7	5/10 m/60 s	-	-	2/- /-	< 2.0	5
		deck 2	418		-	-	-	> 10	
		deck 3	257	-	-	-	4/- / -	< 2.0	-
		deck 4	431	-	-	-	4/- / -	< 2.0	-
		deck 5	490	-	-	-	8/- / -	< 2.0	-
		deck 6	96	-	-	-	5/- / -	< 2.0	-
		deck 7	18	-	-	-	3/- / -	< 2.0	-
		deck 8	14	-	-	-	1/- / -	< 2.0	-
Total									5

Gas Dispersion Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	GVU System	deck 1	7	2/10 m/60 s	-	-	2/- /-	< 2900	2
		deck 2	418		-	-	-	> 17000	
		deck 3	257	-	-	-	3/- /-	< 2900	-
		deck 4	431	-	-	-	3/- /-	< 2900	-
		deck 5	490	-	-	-	3/- /-	< 2900	-
		deck 6	96	-	-	-	3/- /-	< 2900	-
		deck 7	18	-	-	-	3/- /-	< 2900	-
		deck 8	14	-	-	-	3/- /-	< 2900	-
Total									2

Flash Fire Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				First	Second	Third	Tolerable		
1	GVU System	deck 1	7	2/10 m/60 s	-	-	2/- /-	< 2900	2
		deck 2	418		-	-	-	> 17000	
		deck 3	257	-	-	-	3/- /-	< 2900	-
		deck 4	431	-	-	-	3/- /-	< 2900	-
		deck 5	490	-	-	-	3/- /-	< 2900	-
		deck 6	96	-	-	-	3/- /-	< 2900	-
		deck 7	18	-	-	-	3/- /-	< 2900	-
		deck 8	14	-	-	-	3/- /-	< 2900	-
Total									2

Jet Fire Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	GVU System	deck 1	7	5/10 m/60 s	-	-	2/- /-	< 2.0	5
		deck 2	418		-	-	-	> 10	
		deck 3	257	-	-	-	4/- / -	< 2.0	-
		deck 4	431	-	-	-	4/- / -	< 2.0	-
		deck 5	490	-	-	-	8/- / -	< 2.0	-
		deck 6	96	-	-	-	5/- / -	< 2.0	-
		deck 7	18	-	-	-	3/- / -	< 2.0	-
		deck 8	14	-	-	-	1/- / -	< 2.0	-
Total									5

Gas Dispersion Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	GVU System	deck 1	7	5/10 m/60 s	-	-	2/- /-	< 2900	5
		deck 2	418		-	-	-	> 17000	
		deck 3	257	-	-	-	3/- /-	< 2900	-
		deck 4	431	-	-	-	3/- /-	< 2900	-
		deck 5	490	-	-	-	3/- /-	< 2900	-
		deck 6	96	-	-	-	3/- /-	< 2900	-
		deck 7	18	-	-	-	3/- /-	< 2900	-
		deck 8	14	-	-	-	3/- /-	< 2900	-
Total									5

Flash Fire Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				First	Second	Third	Tolerable		
1	GVU System	deck 1	7	2/10 m/60 s	-	-	2/- /-	< 2900	5
		deck 2	418		-	-	-	> 17000	
		deck 3	257	-	-	-	3/- /-	< 2900	-
		deck 4	431	-	-	-	3/- /-	< 2900	-
		deck 5	490	-	-	-	3/- /-	< 2900	-
		deck 6	96	-	-	-	3/- /-	< 2900	-
		deck 7	18	-	-	-	3/- /-	< 2900	-
		deck 8	14	-	-	-	3/- /-	< 2900	-
Total									5

Jet Fire Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	GVU System	deck 1	7	5/10 m/60 s	-	-	2/- /-	< 2.0	5
		deck 2	418		-	-	-	> 10	
		deck 3	257	-	-	-	4/- / -	< 2.0	-
		deck 4	431	-	-	-	4/- / -	< 2.0	-
		deck 5	490	-	-	-	8/- / -	< 2.0	-
		deck 6	96	-	-	-	5/- / -	< 2.0	-
		deck 7	18	-	-	-	3/- / -	< 2.0	-
		deck 8	14	-	-	-	1/- / -	< 2.0	-
Total									5

Gas Dispersion Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	GVU System	deck 1	7	2/10 m/60 s	-	-	2/- /-	< 2900	2
		deck 2	418		-	-	-	> 17000	
		deck 3	257	-	-	-	3/- /-	< 2900	-
		deck 4	431	-	-	-	3/- /-	< 2900	-
		deck 5	490	-	-	-	3/- /-	< 2900	-
		deck 6	96	-	-	-	3/- /-	< 2900	-
		deck 7	18	-	-	-	3/- /-	< 2900	-
		deck 8	14	-	-	-	3/- /-	< 2900	-
Total									2

BLEVE/ Fireball Skenario 1-3 mm										
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wakt				Heat Flux (kW/m^2)	Fatality (N)
				First	Second	Third	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	-	-
		deck 2	418	-	-	-	-	-	-
		deck 3	257	-	-	-	-	-	-
		deck 4	431	-	-	-	-	-	-
		deck 5	490	85/25/60s	-	-	-	-	85
		deck 6	96	-	-	-	-	-	-
		deck 7	18	-	-	-	-	-	-
		deck 8	14	-	-	-	-	-	-
Total									85

Explosion Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	ffect (Jumlah orang terdampak/Jangkauan/Waktu				Pressure (psi)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	-	-
		deck 2	418	-	-	-	-	-	-
		deck 3	257	-	-	-	-	-	-
		deck 4	431	-	-	-	-	-	-
		deck 5	490	85/25/60s	-	-	-	-	85
		deck 6	96	-	-	-	-	-	-
		deck 7	18	-	-	-	-	-	-
		deck 8	14	-	-	-	-	-	-
Total									85

Flash Fire Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wakt				Heat Flux (kW/m^2)	Fatality (N)
				First	Second	Third	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	< 2900	-
		deck 2	418	-	-	-	-	> 17000	-
		deck 3	257	-	-	-	-	< 2900	-
		deck 4	431	-	-	-	-	< 2900	-
		deck 5	490	15/10/60s	-	-	-	< 2900	15
		deck 6	96	-	-	-	-	< 2900	-
		deck 7	18	-	-	-	-	< 2900	-
		deck 8	14	-	-	-	-	< 2900	-
Total									15

Jet Fire Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wakt				Heat Flux (kW/m^2)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	Storage System	deck 1	7	5/10 m/60 s	-	-	-	< 2.0	5
		deck 2	418		-	-	-	> 10	
		deck 3	257	-	-	-	-	< 2.0	-
		deck 4	431	-	-	-	-	< 2.0	-
		deck 5	490	17/10/60s	-	-	-	> 10	17
		deck 6	96	-	-	-	-	< 2.0	-
		deck 7	18	-	-	-	-	< 2.0	-
		deck 8	14	-	-	-	-	< 2.0	-
Total									22

Gas Dispersion Skenario 1-3 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	< 2900	-
		deck 2	418	-	-	-	-	< 2900	
		deck 3	257	-	-	-	-	< 2900	-
		deck 4	431	-	-	-	-	< 2900	-
		deck 5	490	15/10/60s	-	-	-	> 17000	15
		deck 6	96	-	-	-	-	< 2900	-
		deck 7	18	-	-	-	-	< 2900	-
		deck 8	14	-	-	-	-	< 2900	-
Total									15

BLEVE/ Fireball Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				First	Second	Third	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	-	-
		deck 2	418	-	-	-	-	-	-
		deck 3	257	-	-	-	-	-	-
		deck 4	431	-	-	-	-	-	-
		deck 5	490	85/25/60s	-	-	-	-	85
		deck 6	96	-	-	-	-	-	-
		deck 7	18	-	-	-	-	-	-
		deck 8	14	-	-	-	-	-	-
Total									85

Explosion Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	ffect (Jumlah orang terdampak/Jangkauan/Waktu				Pressure (psi)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	-	-
		deck 2	418	-	-	-	-	-	-
		deck 3	257	-	-	-	-	-	-
		deck 4	431	-	-	-	-	-	-
		deck 5	490	85/25/60s	-	-	-	-	85
		deck 6	96	-	-	-	-	-	-
		deck 7	18	-	-	-	-	-	-
		deck 8	14	-	-	-	-	-	-
Total									85

Flash Fire Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				First	Second	Third	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	< 2900	-
		deck 2	418	-	-	-	-	> 17000	-
		deck 3	257	-	-	-	-	< 2900	-
		deck 4	431	-	-	-	-	< 2900	-
		deck 5	490	16/10 m/60 s	-	-	-	> 17000	16
		deck 6	96	-	-	-	-	< 2900	-
		deck 7	18	-	-	-	-	< 2900	-
		deck 8	14	-	-	-	-	< 2900	-
Total									16

Jet Fire Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	Storage System	deck 1	7	5/10 m/60 s	-	-	-	< 2.0	-
		deck 2	418		-	-	-	> 10	-
		deck 3	257	-	-	-	-	< 2.0	-
		deck 4	431	-	-	-	-	< 2.0	-
		deck 5	490	18/10 m/60 s	-	-	-	> 10	18
		deck 6	96	-	-	-	-	< 2.0	-
		deck 7	18	-	-	-	-	< 2.0	-
		deck 8	14	-	-	-	-	< 2.0	-
Total									18

Gas Dispersion Skenario 3-10 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	< 2900	-
		deck 2	418	-	-	-	-	> 17000	-
		deck 3	257	-	-	-	-	< 2900	-
		deck 4	431	-	-	-	-	< 2900	-
		deck 5	490	13/10 m/60 s	-	-	-	< 2900	13
		deck 6	96	-	-	-	-	< 2900	-
		deck 7	18	-	-	-	-	< 2900	-
		deck 8	14	-	-	-	-	< 2900	-
Total									13

BLEVE/ Fireball Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				First	Second	Third	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	-	-
		deck 2	418	-	-	-	-	-	-
		deck 3	257	-	-	-	-	-	-
		deck 4	431	-	-	-	-	-	-
		deck 5	490	85/25/60s	-	-	-	-	85
		deck 6	96	-	-	-	-	-	-
		deck 7	18	-	-	-	-	-	-
		deck 8	14	-	-	-	-	-	-
Total									85

Explosion Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	ffect (Jumlah orang terdampak/Jangkauan/Waktu				Pressure (psi)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	-	-
		deck 2	418	-	-	-	-	-	-
		deck 3	257	-	-	-	-	-	-
		deck 4	431	-	-	-	-	-	-
		deck 5	490	85/25/60s	-	-	-	-	85
		deck 6	96	-	-	-	-	-	-
		deck 7	18	-	-	-	-	-	-
		deck 8	14	-	-	-	-	-	-
Total									85

Flash Fire Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				First	Second	Third	Tolerable		
1	Storage System	deck 1	7	350/21 m/60 s	-	-	-	< 2900	-
		deck 2	418		-	-	-	> 17000	-
		deck 3	257	-	-	-	-	< 2900	-
		deck 4	431	-	-	-	-	< 2900	-
		deck 5	490	350/21 m/60 s	-	-	-	< 2900	350
		deck 6	96	-	-	-	-	< 2900	-
		deck 7	18	-	-	-	-	< 2900	-
		deck 8	14	-	-	-	-	< 2900	-
Total									350

Jet Fire Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	rn Degree (Jumlah orang terdampak/Radius/Wak				Heat Flux (kW/m^2)	Fatality (N)
				Red	Orange	Yellow	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	< 2.0	
		deck 2	418	-	-	-	-	> 10	
		deck 3	257	-	-	-	-	< 2.0	-
		deck 4	431	-	-	-	-	< 2.0	-
		deck 5	490	5/10 m/60 s	-	-	-	> 10	15
		deck 6	96	-	-	-	-	< 2.0	-
		deck 7	18	-	-	-	-	< 2.0	-
		deck 8	14	-	-	-	-	< 2.0	-
Total									15

Gas Dispersion Skenario 10-50 mm									
No.	System	Location	Jumlah Orang	Action Criteria (Jumlah orang terdampak/Jangkau				PPM	Fatality (N)
				PAC-3	PAC-2	PAC-1	Tolerable		
1	Storage System	deck 1	7	-	-	-	-	< 2900	
		deck 2	418	-	-	-	-	> 17000	
		deck 3	257	-	-	-	-	< 2900	-
		deck 4	431	-	-	-	-	< 2900	-
		deck 5	490	38/10 m/60 s	-	-	-	< 2900	38
		deck 6	96	-	-	-	-	< 2900	-
		deck 7	18	-	-	-	-	< 2900	-
		deck 8	14	-	-	-	-	< 2900	-
Total									38

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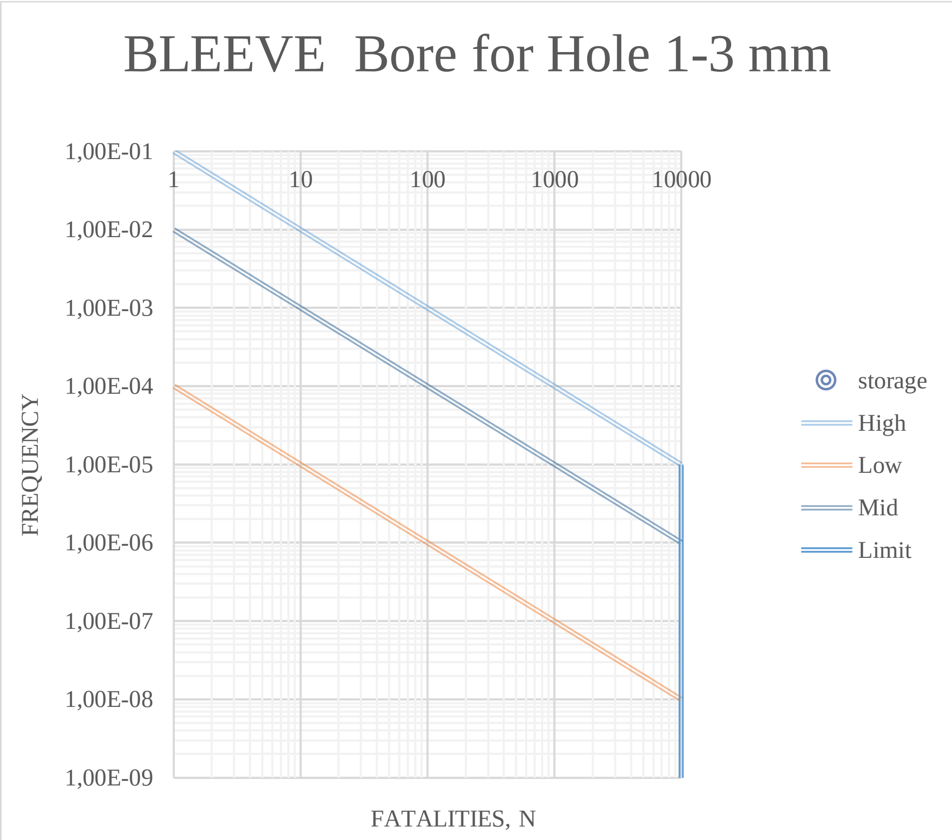
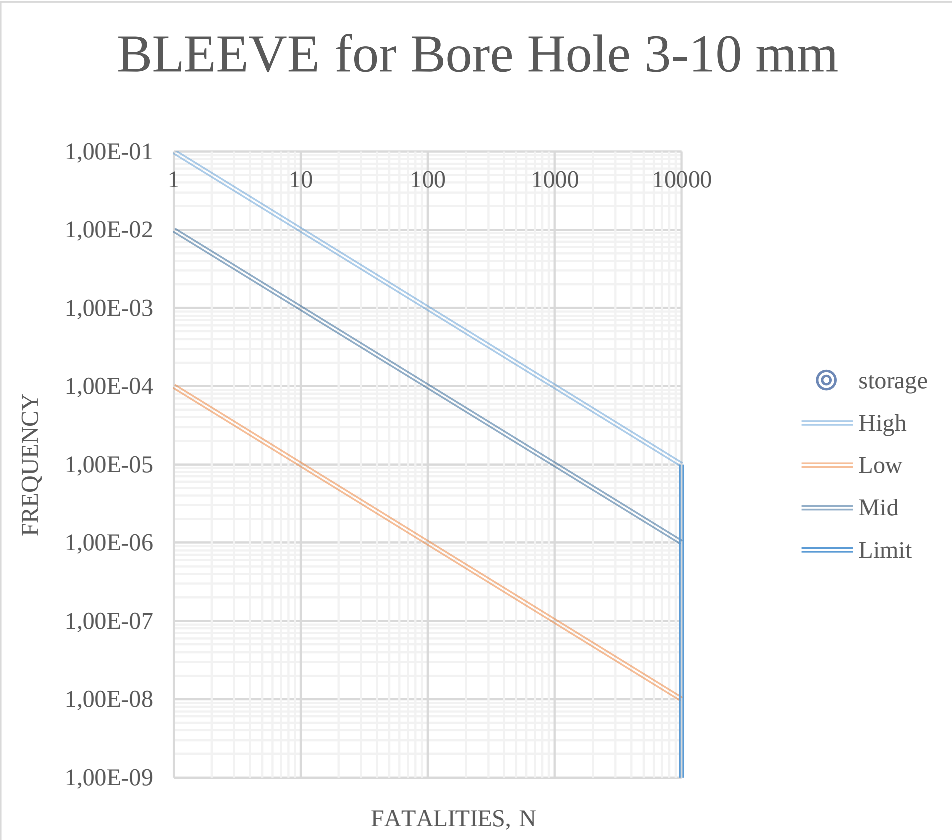
RISK REPRESENTATIVE ATTACHMENT

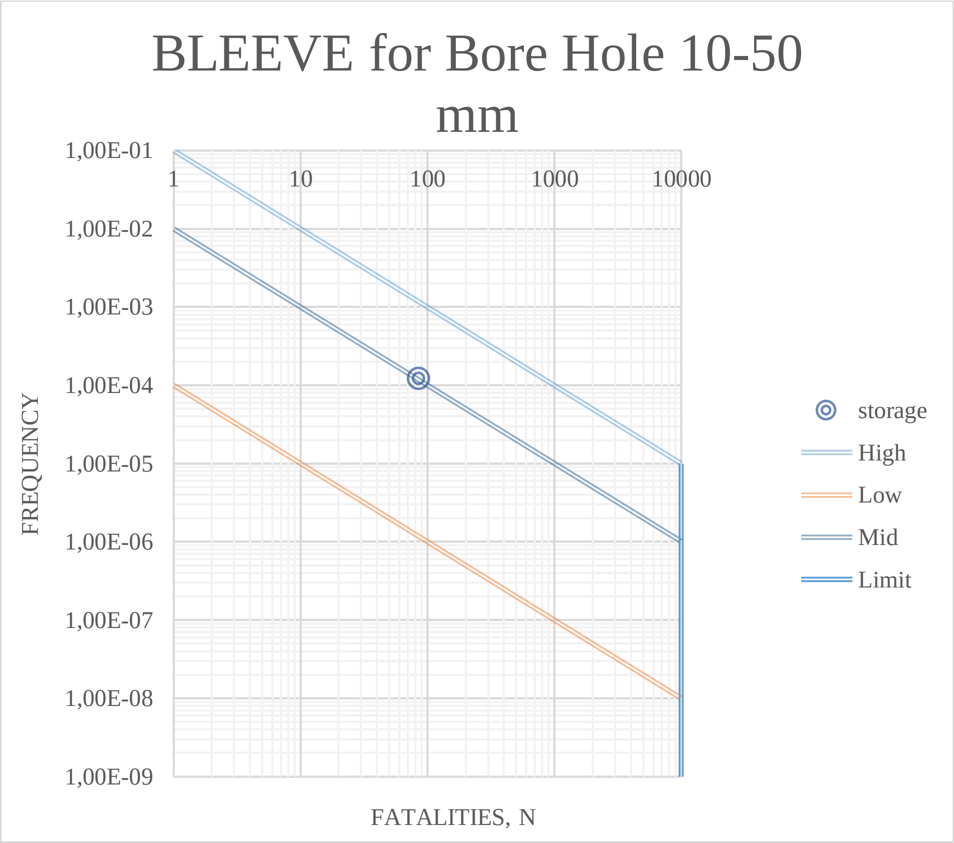
Skenario BLEEVE in Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	0	0,00E+00	0,00E+00
2	MGE System	0	0,00E+00	0,00E+00
3	GVU System	0	0,00E+00	0,00E+00
4	storage	85	1,80719E-10	



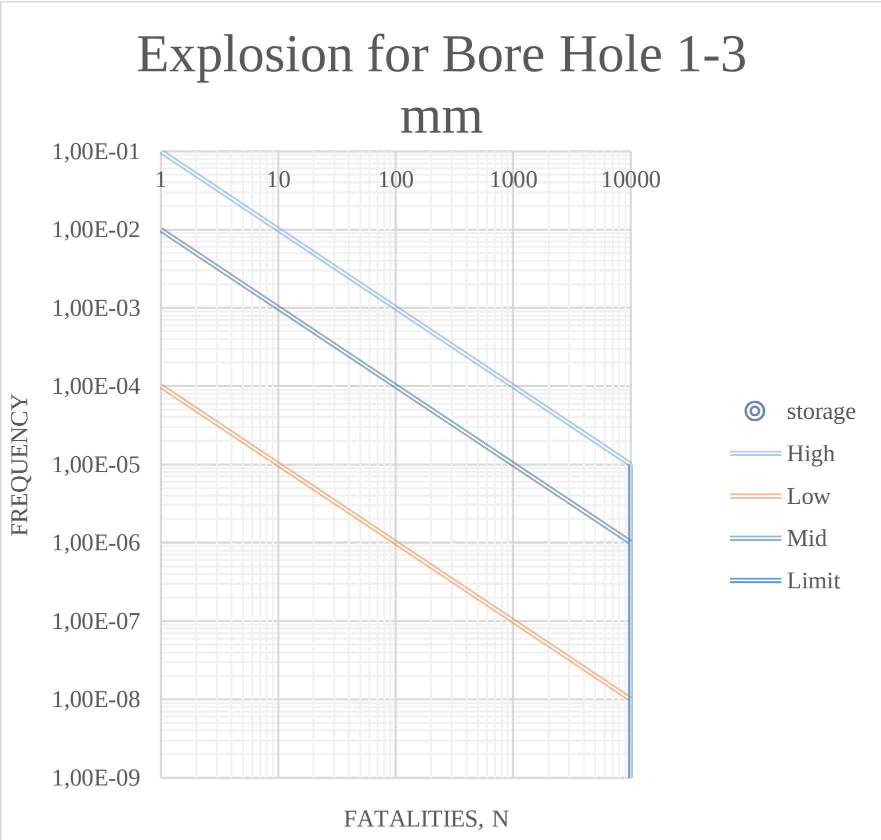
Skenario BLEEVE For Bore Hole 3-10 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	0	0,00E+00	0,00E+00
2	MGE System	0	0,00E+00	0,00E+00
3	GVU System	0	0,00E+00	0,00E+00
4	storage	85	1,17998E-10	



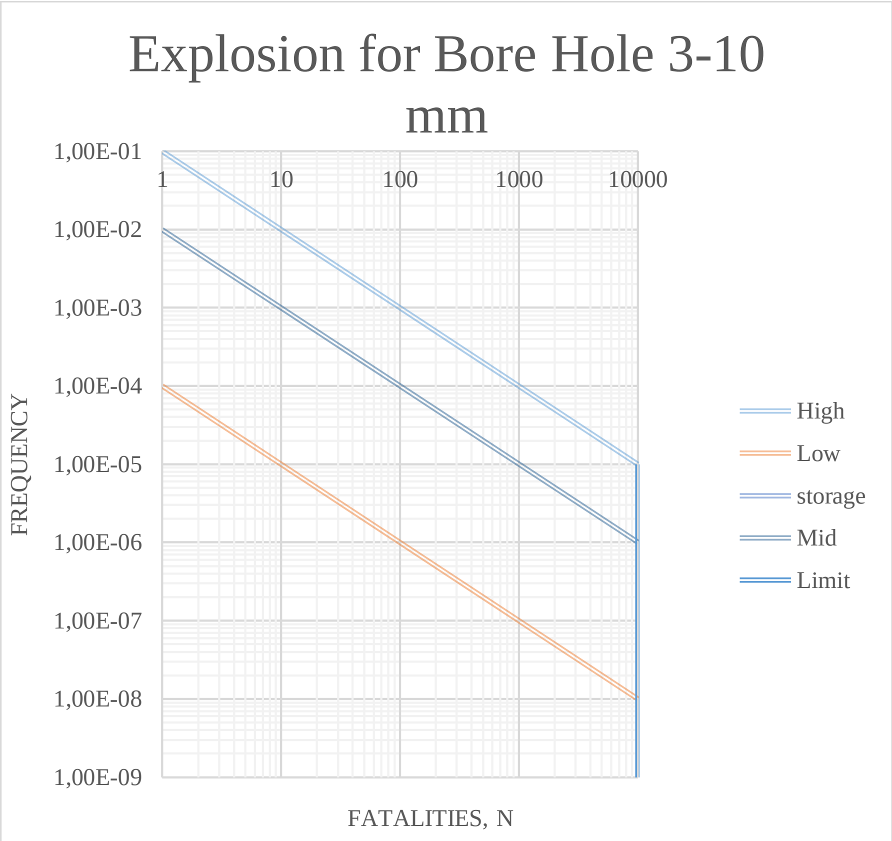
Skenario BLEEVE For Bore Hole 10-50 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	0	0,00E+00	0,00E+00
2	Fuel System	0	0,00E+00	0,00E+00
3	GVU System	0	0,00E+00	0,00E+00
4	storage	85	0,000123392	



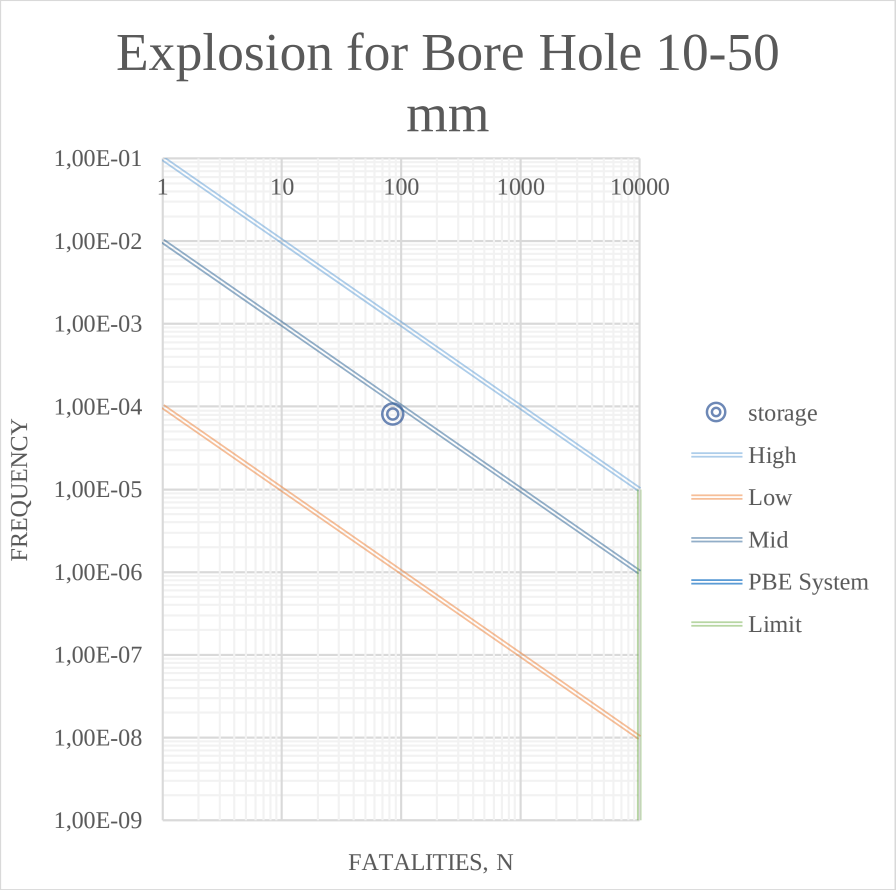
Skenario Explosion For Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	0	0,00E+00	0,00E+00
2	Fuel System	0	0,00E+00	0,00E+00
3	GVU System	0	0,00E+00	0,00E+00
4	storage	85	1,2048E-10	



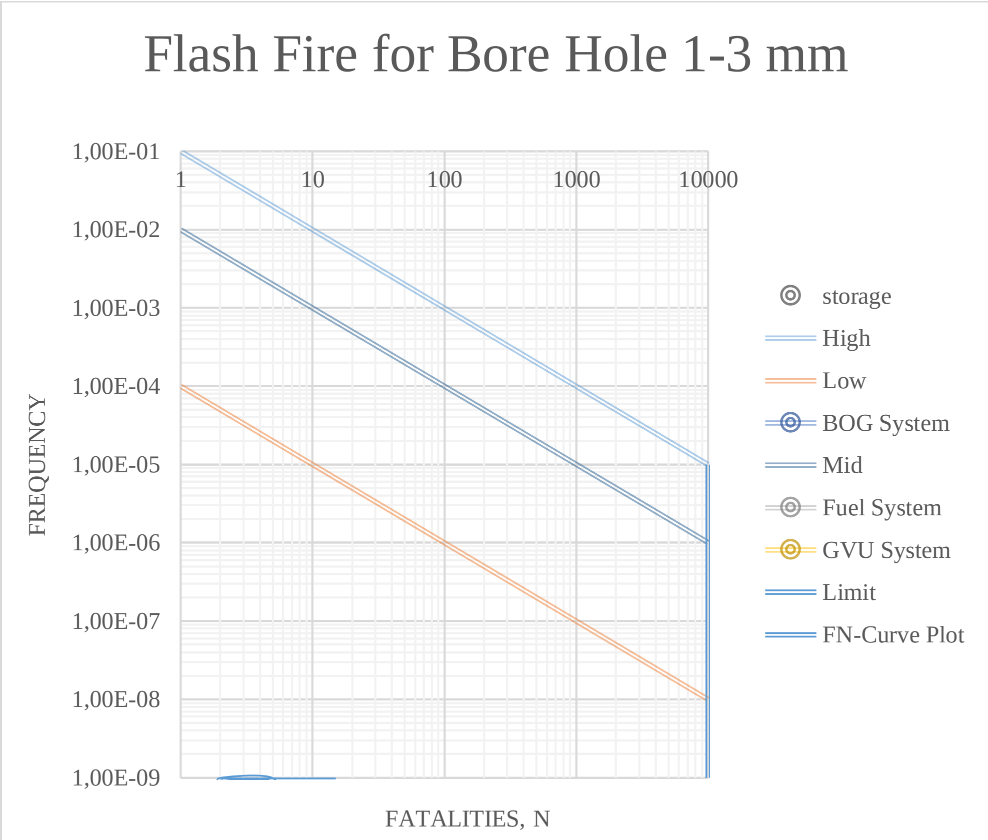
Skenario Explosion For Bore Hole 3-10 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	0	0,00E+00	0,00E+00
2	Fuel System	0	0,00E+00	0,00E+00
3	GVU System	0	0,00E+00	0,00E+00
4	storage	85	7,86655E-11	



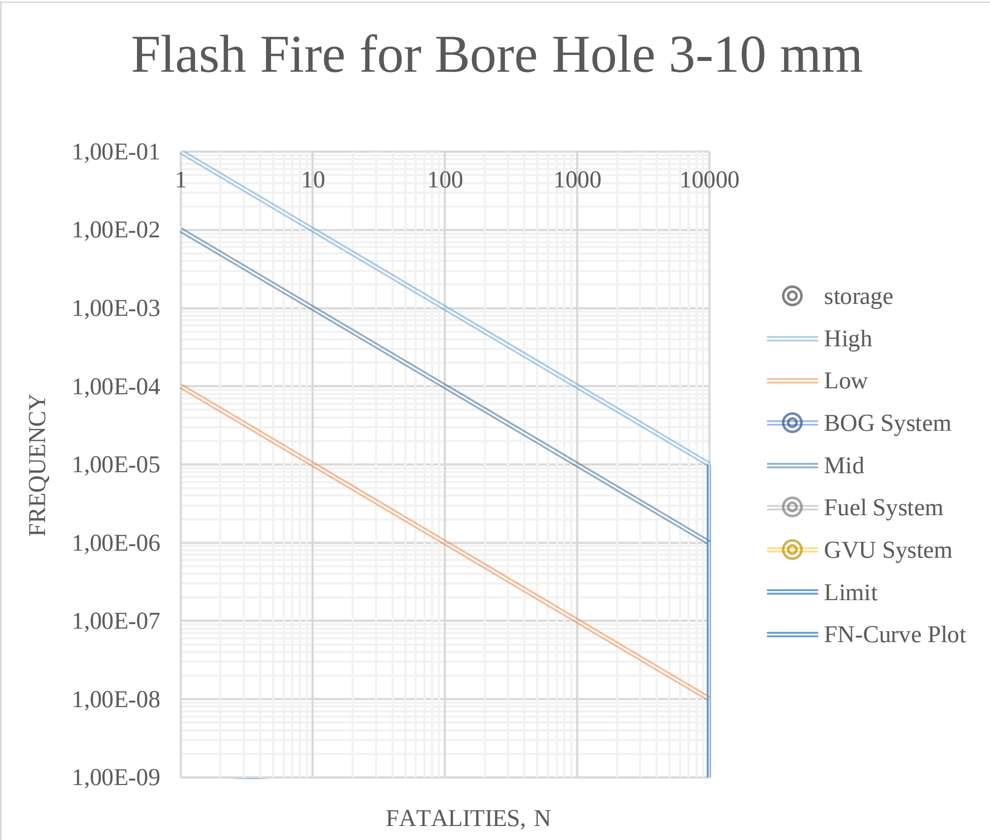
Skenario Explosion For Bore Hole 10-50 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	0	0,00E+00	0,00E+00
2	Fuel System	0	0,00E+00	0,00E+00
3	GVU System	0	0,00E+00	0,00E+00
4	storage	85	8,22619E-05	



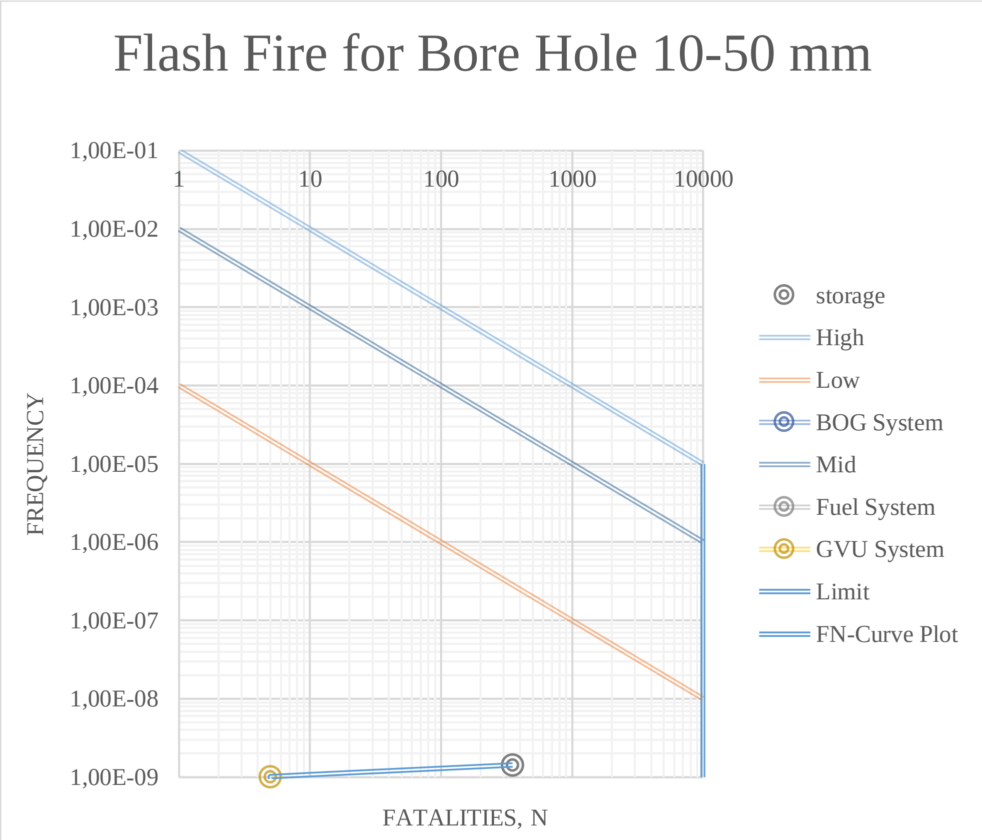
Skenario Flash Fire For Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,89E-10	2,89E-10
2	Fuel System	5	6,43E-10	9,33E-10
3	GVU System	2	4,91E-24	9,33E-10
4	storage	15	6,03E-16	9,33E-10



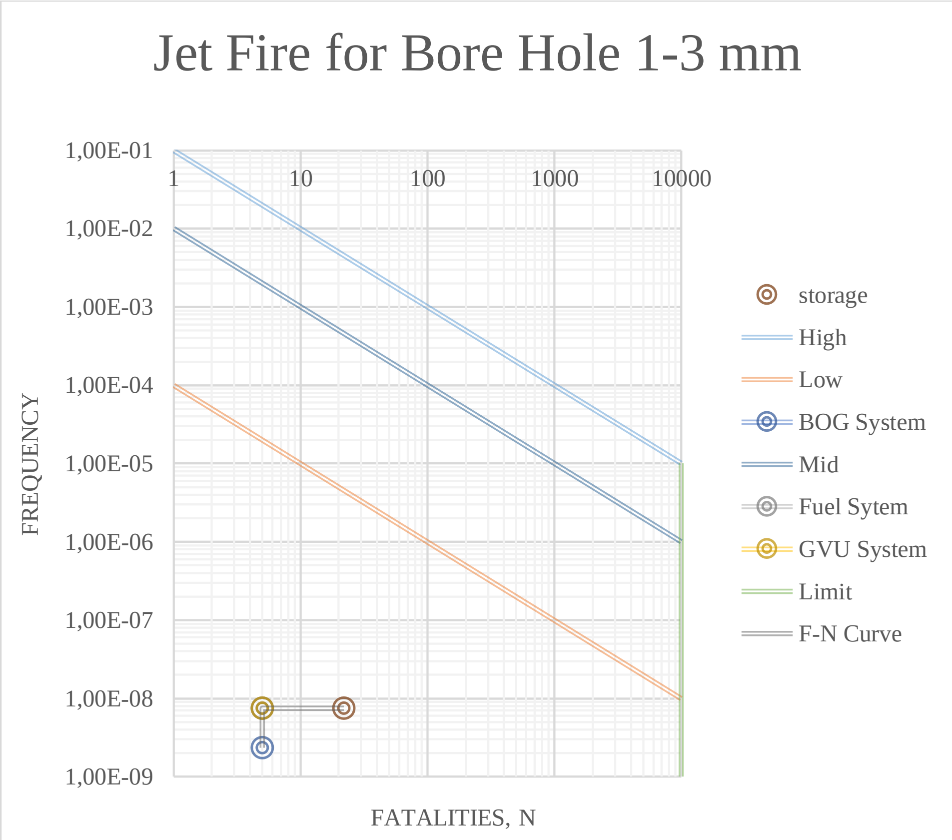
Skenario Flash Fire For Bore Hole 3-10 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	5,15E-10	5,15E-10
2	Fuel System	5	3,43E-10	8,58E-10
3	GVU System	2	2,13E-19	8,58E-10
4	storage	16	3,9372E-16	8,58E-10



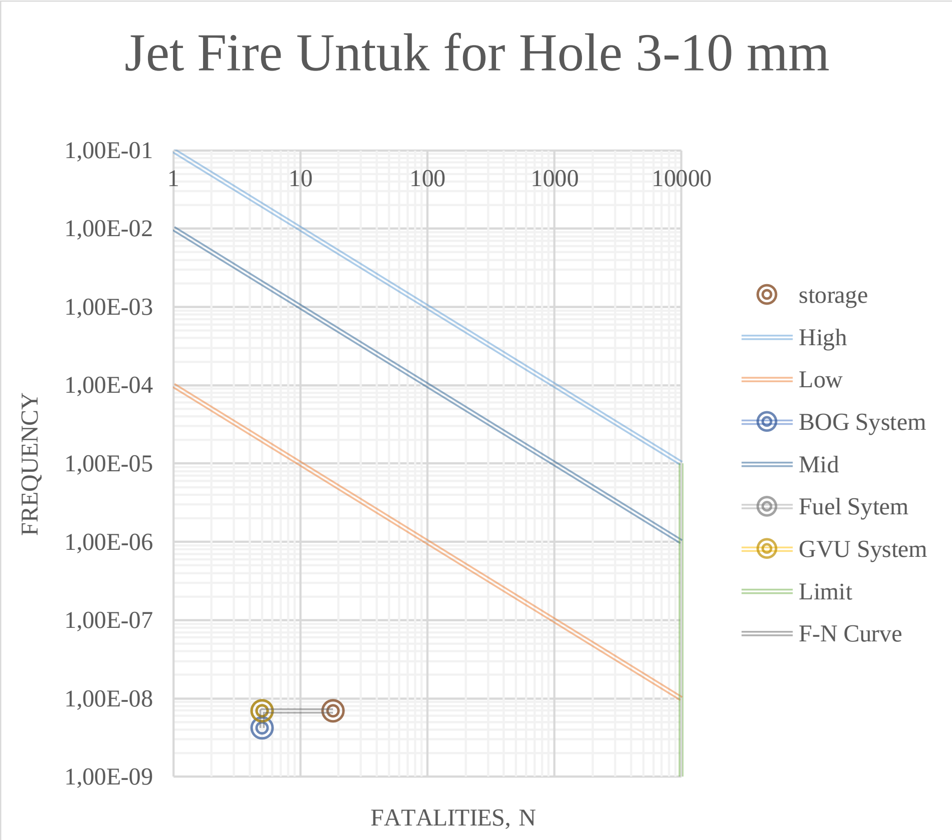
Skenario Flash Fire For Bore Hole 10-50 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,89E-10	2,89E-10
2	Fuel System	5	6,71E-10	9,61E-10
3	GVU System	5	5,10E-11	1,01E-09
4	storage	350	4,1172E-10	1,42E-09



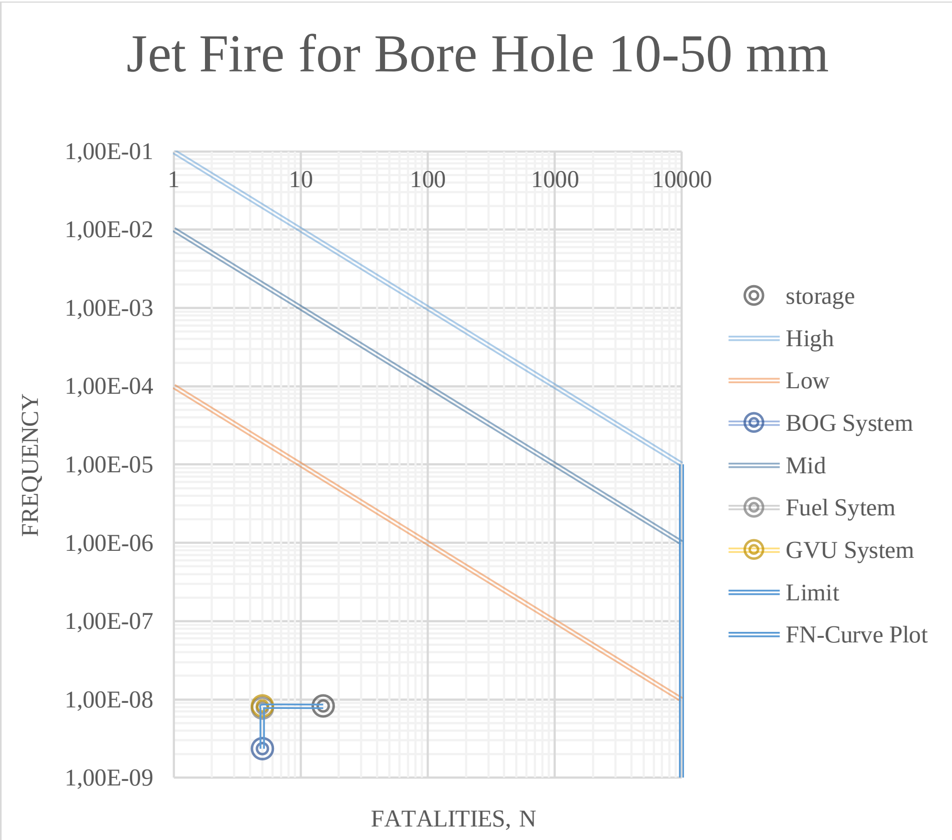
Skenario Jet Fire For Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,34E-09	2,34E-09
2	Fuel Sytem	5	5,21E-09	7,55E-09
3	GVU System	5	3,97E-23	7,55E-09
4	storage	22	0	7,55E-09



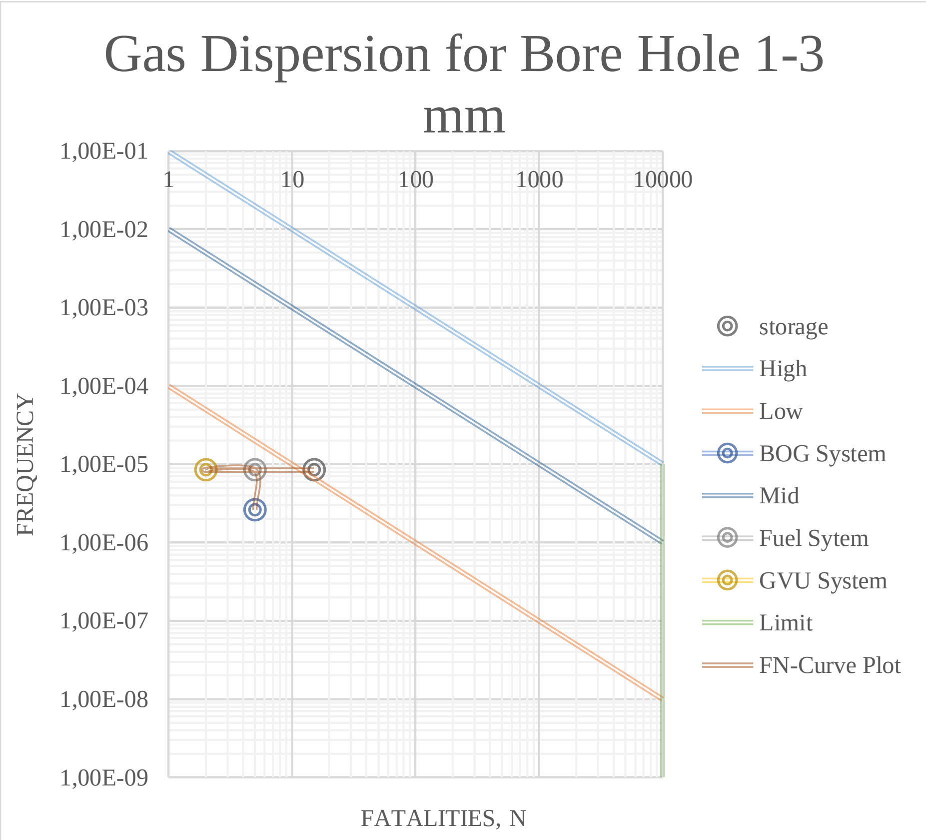
Skenario Jet Fire For Bore Hole 3-10 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	4,16E-09	4,16E-09
2	Fuel Sytem	5	2,78E-09	6,94E-09
3	GVU System	5	1,72E-18	6,94E-09
4	storage	18	0	6,94E-09



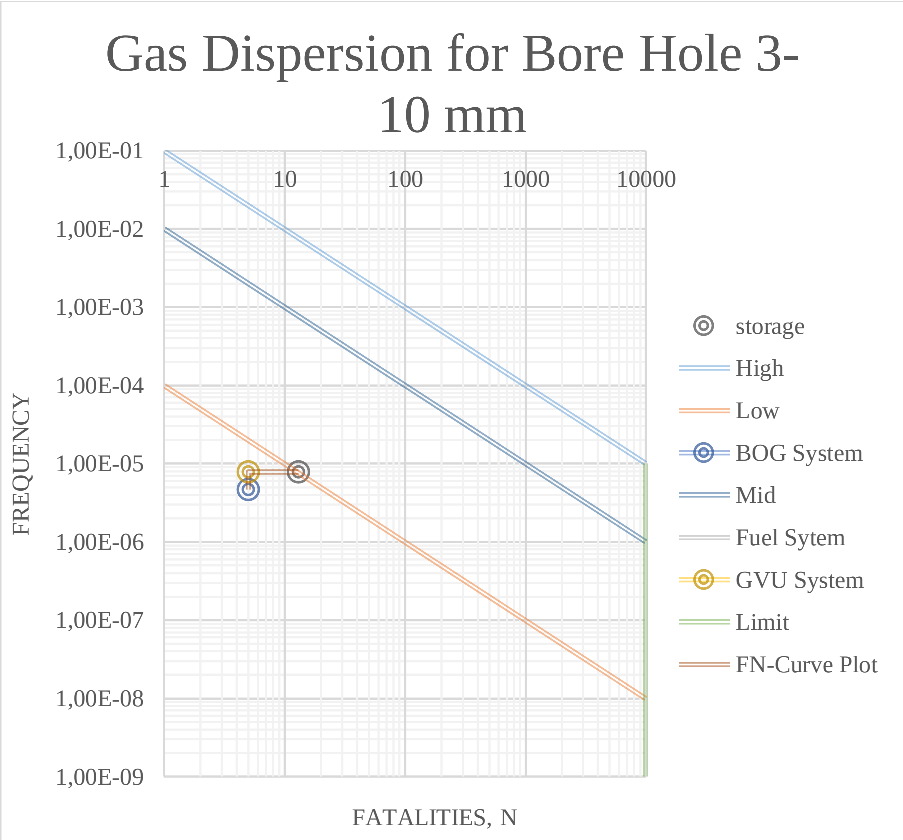
Skenario Jet Fire For Bore Hole 10-50 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,34E-09	2,34E-09
2	Fuel Sytem	5	5,43E-09	7,77E-09
3	GVU System	5	4,13E-10	8,18E-09
4	storage	15	0	8,18E-09



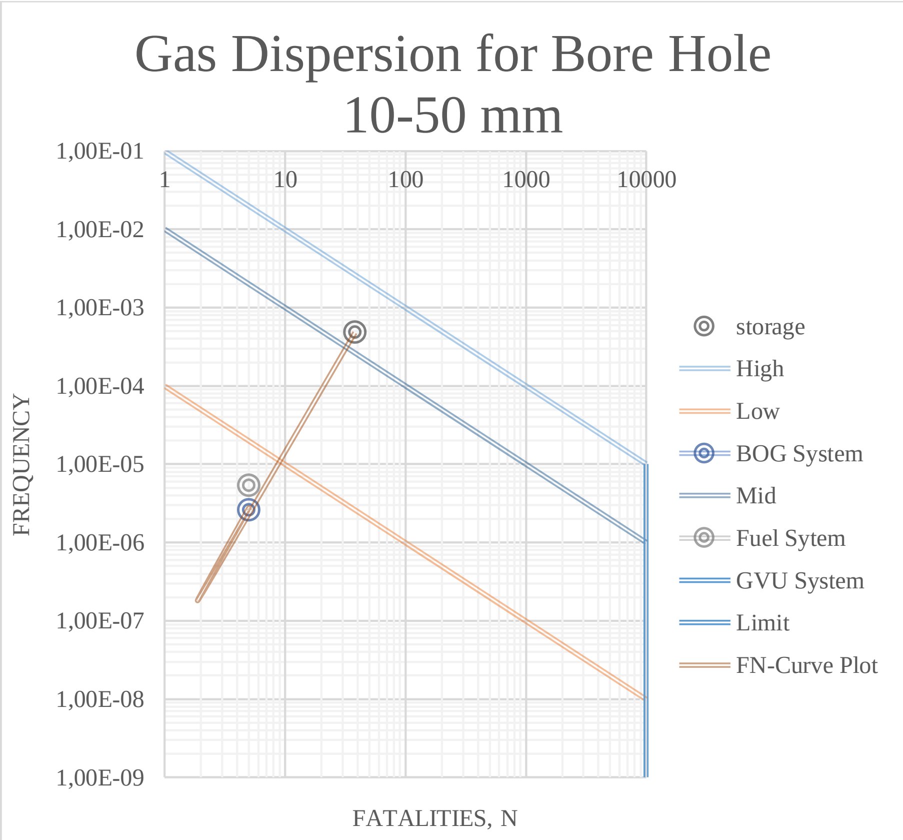
Skenario Gas Dispersion For Bore Hole 1-3 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,63E-06	2,63E-06
2	Fuel Sytem	5	5,84E-06	8,47E-06
3	GVU System	2	4,46E-20	8,47E-06
4	storage	15	7,02797E-10	8,47E-06



Skenario Gas Dispersion For Bore Hole 3-10 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	4,67E-06	4,67E-06
2	Fuel Sytem	5	3,12E-06	7,79E-06
3	GVU System	5	1,93E-15	7,79E-06
4	storage	13	4,58881E-10	7,79E-06



Skenario Gas Dispersion For Bore Hole 10-50 mm				
No.	System	Number of Fatalities	Frequency	Cumulative Frequency
1	BOG System	5	2,63E-06	2,63E-06
2	Fuel Sytem	5	2,77E-06	5,39E-06
3	GVU System	2	2,10E-07	5,61E-06
4	storage	38	0,00047986	4,85E-04



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 180ºF	
	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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A Cryogenic Industries subsidiary

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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)

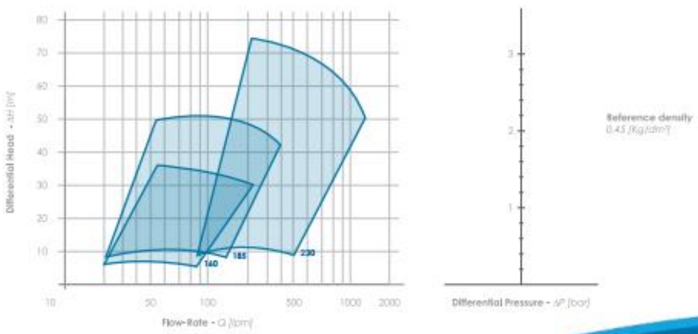
Applications

- 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
- Electrical 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:

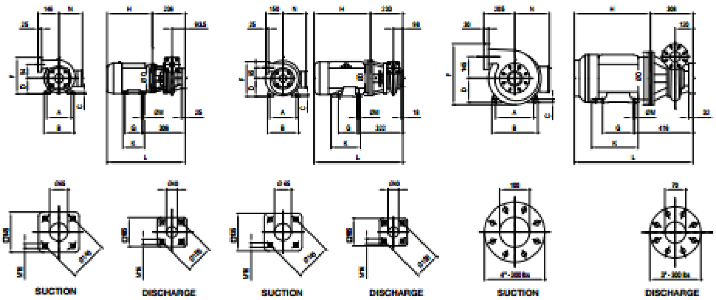
- European Directive 2006/42/CE Machinery
- European Directive PED 97/23/CE
- European Directive 94/9/CE ATEX*
- EIGA/IGC/CGA guidelines

*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

Vanzetti Engineering s.r.l.
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Tel. (+39) 0172 915811 - Fax (+39) 0172 915822
www.vanzettiengineering.com

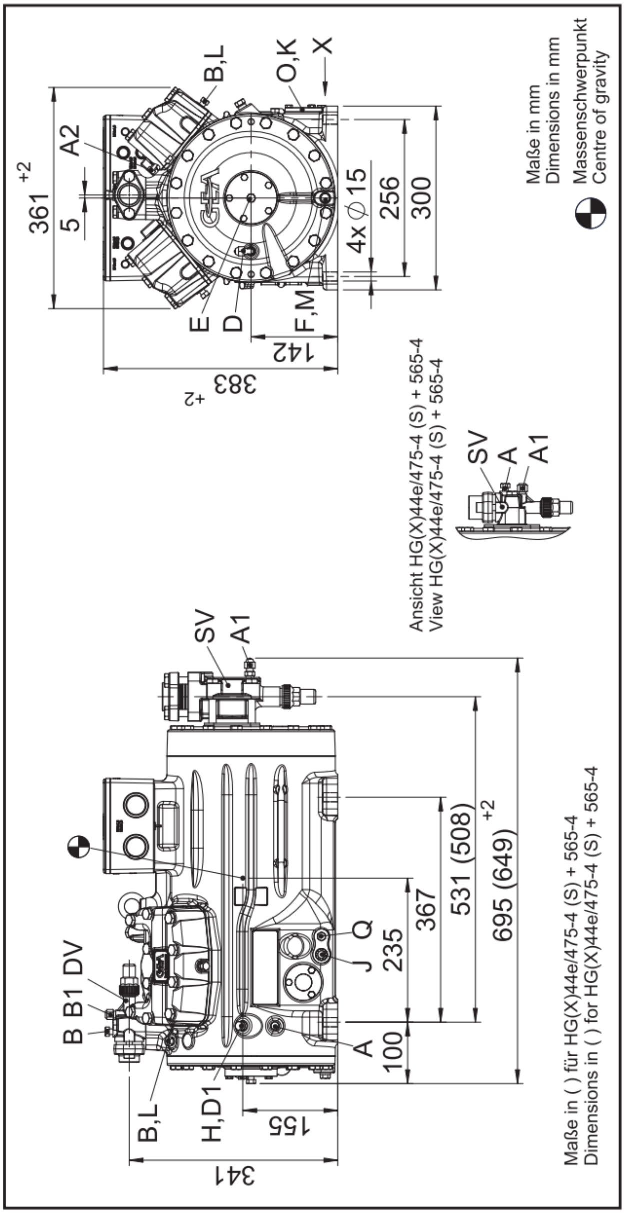
herborner.F-PM Dimensions • Weights

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

herborner.F-PM Dimensions • Weights

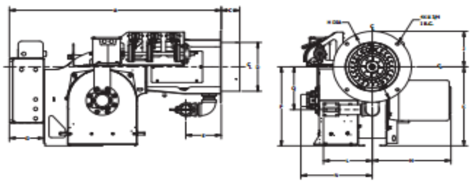
Dimensions with frequency converter for direct installation on request.

- BOG Compressor

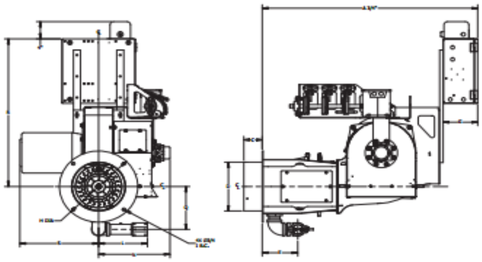


Standard Dimensions
V Series

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.

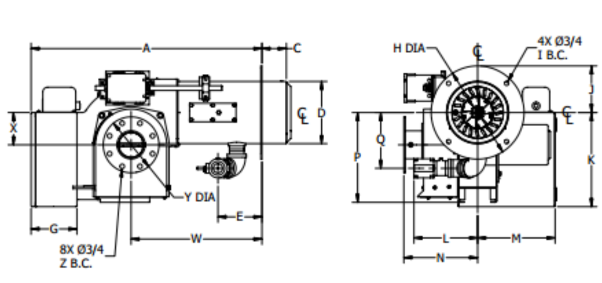
Standard Ratings

V Series

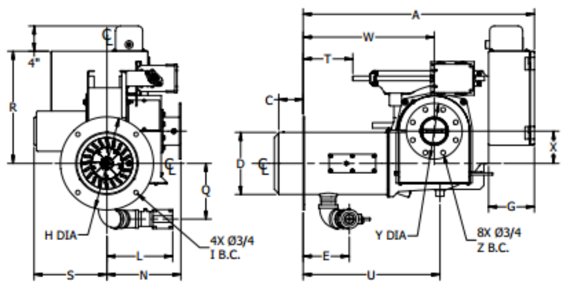
VG - VL - VLG: Gas, #2 Oil, Gas/Oil Configuration

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]	
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

AUTHORS’S BIOGRAPHY

The author’s was born in Grobogan, on 5th October 1996, the author is the first child in his and has taken formal education in SD N 4 Karangrayung, SMP N 1 Karangrayung. The Author was graduated from SMA N Sragen Bilingual Boarding School in 2014, having accomplished senior high school the writter continue his study to bachelor degree at Institut Teknology Sepuluh Nopember in Departement of Marine Engineering, Double Degree Program at faculty of Marine Technology – Institut Teknologi Sepuluh Nopember with Hochschule Wismar Germany. The writter took the Marine Reliability, Availability, Maintainability and Safety (RAMS) for (RAMS) for his concern. Author’s hoby are badminton, basket, futsal, voly and reading novel. When still in Senior high school author have many achievement in sport like 1st winner badminton man single in Sragen, become delegation man single badminton in province central java bring name of Sragen regency, 3rd winner Basket ball competition in SMAN 1 Ngawi. Then the Author’s achievement in college are 1st winner man single badminton in Semarang, 1 st winner ITS Badminton Competition, 1st Winner Intern Cup and become Head of Unit Badminton Activity in ITS (UKM Badminton ITS).