BACHELOR THESIS AND COLLOQUIUM – ME 141502

FIRE RISK ASSESSMENT OF TERMINAL LPG SEMARANG

Thariq Arafatul Akbar
NRP 4213 101 025

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DEPARTMENT OF MARINE ENGINEERING
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APPROVAL FORM

FIRE RISK ASSESSMENT OF TERMINAL LPG SEMARANG

BACHELOR THESIS

Submitted to Comply One of the Requirement to Obtain a Bachelor of Engineering Degree
On
Reliability, Availability, Management, and Safety (RAMS) Laboratory
S-1 Programe Department of Marine Engineering
Faculty of Marine Technology
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JULY, 2017

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DECLARATION OF HONOUR

I hereby who signed below declare that:

This thesis 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, literature, and other professional sources.

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Surabaya, July 2017

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FIRE RISK ASSESSMENT OF TERMINAL LPG SEMARANG

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ABSTRACT

Terminal LPG Semarang as one of vital facilities in handling hydrocarbon energy for cooking fuel covering Northern Central Java region is one of appealing subject to do safety assessment, espescially fire risk assessment. The importance of the assessment is inevitable since in similar facility such as Terminal LPG Cilacap there was already an fire occurence that lead in conclussion that it's fire fighting equipment cannot overcome incoming incident. The unavailability of fire risk assessment in Terminal LPG Semarang also has inevitable escalation since the specific action that need to be taken during certain fire incident have not planned well. This research are focusing to do the Quantitative Risk Assessment as an baseline for determining the Fire Risk and its hazard potency. The process are involving performing Hazard and Operability (HAZOP) based on Terminal System P&ID, Frequency analysis such as Fault Tree Analysis and Event Tree Analysis, and Consequences analysis using Process Hazard Analysis Software Tools, and risk representation using Company Risk Matrix. And the result will be baseline to arrange Pre Fire Planning Assessment based on the possible event that may occur and analyze Terminal Fire Fighting Facility wether it can overcome the possible occurence or not. The concern to model the outcome of the fire risk are to determine what the output based on various leak scenario such as: 3 mm, 10 mm, 50 mm, and 150 mm bore diameter. The result concluded that in the operational process of the LPG system there are several potential hazard such as: overpressure, high temperature, high flow rate, and blockage of the system that can lead into failure of the system caused gas leak and then gas released from the system. The frequency analysis conclude the node involved in Loading Line has the higher frequency, meanwhile the lowest frequency located on system which involved the storage tank. The consequences modelling show the effect of the scenario is differ based on the working parameter of the corresponding facility. The risk representation shows that affected zone based on leak scenarios shows that several locations are located in high risk area of fire hazard and need special attention regarding its Terminal's ability to overcome the possible scenarios. The high risk level in need of special attention will become baseline to dtermine the mitigation plan, or so called the Pre Fire Planning. To overcome the potential hazard mitigation plan found that Terminal LPG Semarang need improvement at their fire extinguishing equipment such as improvement of water supply capacity as fire extinguishing agent by atleast 4.000 m^3.

Keywords: LPG, QRA, HAZOP, ETA, FTA, Consequences Modelling

PENILAIAN RISIKO KEBAKARAN PADA TERMINAL LPG SEMARANG

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ABSTRACT

Terminal LPG Semarang sebagai salah satu fasilitas vital yang menunjang aktivitas bongkar muat dan distribusi LPG sebagai bahan bakar untuk kebutuhan rumah tangga yang mencakup area Jawa Tengah muncul sebagai salah satu objek yang cukup vital untuk dilakukan penilaian risiko risiko kebakaran. Hal ini didasarkan pada fakta bahwa pada fasilitas serupa pada Depot LPG Cilacap telah terjadi kasus kebakaran pada tangki timbun LPG yang dimilik Depot LPG Cilacap. Ekskalasi yang akan dihadapi yang akan dihadapi juga tidak terbantahkan terutama ketika ketidatersediaan penilaian risiko kebakaran mengakibatkan rencana mitigasi menjadi tidak terpetakan. Riset ini menekankan kepada penilaian risiko secara kuantitatif untuk menentukan level resiko. Proses penilaian dilakukan dengan menggunakan metode *Hazard and Operability (HAZOP) Study* untuk menilai potensi bahaya yang didasarkan pada bagaimana keseluruhan sistem di terminal bekerja, Analisa Frekuensi menggunakan metode *Fault Tree Analysis (FTA)* dan *Event Tree Analysis (ETA),* Analisa konsekuensi menggunakan perangkat lunak *Process Hazard Analysis Software Tools,* dan representasi risiko menggunakan *Company Risk Matrix*. Proses analisa dibatasi hanya dengan memodelkan kemungkinan-kemungkinan dari kebucoran instalasi menggunakan variasi kebocoran sebesar 3 mm, 10 mm, 50 mm, dan 150 mm. Hasil dari penilaian risko secara kuantitatif kemudian akan menjadi dasar analisa mitigasi kebakaran atau *Pre Fire Planning* untuk menganalisa kemampuan dari fasilitas pemadam pada Terminal LPG Semarang. Hasil dari keseluruhan penilaian risiko ditemukan bahwa dalam kegiatan operasi terminal ditemukan potensi bahaya dari kegagalan seperti *overpressure,* temperatur tinggi, *flow rate* tinggi dapat menyebabkan eskalasi yang menyebabkan kegagalan komponen yang mengakibatkan kebocoran gas. Analisa frekuensi menemukan bahwa frekuensi tertinggi terdapat dalam sistem bongkar LPG dari kapal pengangkut LPG, sedangkan frekuensi terendah ditemukan pada sistem yang melibatkan tangki timbun LPG. Dari analisa konsekuensi ditemukan bahwa kkonsekuensi tertinggi ditemukan pada sistem yang melibatkan tangki timbun dimana faktor yang menyebabkan hal tersebut adalah banyaknya jumlah LPG yang terdapat pada tangki timbun dibanding sistem lainnya. Dalam proses representasi resiko ditemukan bahwa konsekuensi dari beberapa skenario tidak dapat ditangani oleh fasilitas yang ada sehingga membutuhkan sebuah rencana mitigasi yang dituangkan dalam *Pre Fire Planning*. Dari perencanaan mitigasi ditemukan bahwa beberapa parameter fasilitas tidak memenuhi syarat untuk mengatasi skenario yang menjadi tinjauan. Salah satu fasilitas yang perlu dilakukan peningkatan kemampuannya adalah peningkatan kapasitas suplai air pemadam sebanyak setidaknya 4.000 m^3.

Keywords: LPG, QRA, HAZOP, ETA, FTA, Consequences Modelling

PREFACE

Alhamdulillahirobil alamin huge thanks to Allah SWT the Almighty for giving the author the chance, health, and prosperity so the author finally can make it finish this Bachelor Thesis.

This bachelor thesis aims to assess the potential fire risk assessment at Terminal LPG Semarang so that the coreesponding parties can take benefits regarding the content of this Bachelor Thesis.

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The author realizes that this Bachelor Thesis still far from perfect. Therfore, every constructive and supportive suggestion and idea to to improve this Bachelor Thesis are highly expected by the author so that the better version of this Bachelor Thesis can be reached in the future.

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Surabaya, July 2017
Author

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CHAPTER 1
INTRODUCTION

1.1. Background

Terminal LPG Semarang is one of strategic facility in the supply chain of LPG covering the Indonesia’s Central Java region. Terminal LPG Semarang which its main business activity are involving receiving, storage, and distribution activity involving 1600 MT – 2000 MT of LPG uses as household needs as cooking fuel each day is the one of the National Vital Object *(OBVITNAS)* that need higher practice of risk management to minimize the fatal risk or accident that may occur.

As one of the facilities that handling the hydrocarbons material that most likely risk occurrence that may occur is the fire and explosion even though the event of another occurrence such as release and dispersion, the consequences of two another occurrence when its ignite are inevitable. Based on that background Terminal LPG Semarang is one of subject that to be most likely appeal to do an research in safety assessment due to the absences of any specific analysis or assessment regarding emergency action to overcome certain accident such as fire or explosion of its facility. One of the chain reaction that occur due to its absences is the authorities are blindly does not know how big the effect of accident can affect the surrounding or how much the amount of action need to be taken for specific accident since the consequences have a lot of variations and type of accident that may occur. The location of Terminal LPG Semarang which located in the Tanjung Emas Port area as seen on Figure 1.1. which act as main gateway of sea transportation at Central Java region is also creates such a concern that the effect also affected Port activity and not only cause loses in operational or lives in Terminal LPG Semarang but also disturb Port of Tanjung Emas activity.

Figure 1.1. Location of Terminal LPG Semarang

Another reason why fire risk assessment and pre fire planning such an important thing is that in similar facility (LPG Terminal) in Cilacap, Central Java Province. On Thursday 22 March 2012 at 10.00 PM on Cilacap LPG Terminal storage tank F which contains mixed LPG is ongoing LPG supplying into that tank from RU IV T-105 tank. Suddenly the fire spark occurs on the roof side of the tank, and the tank also suffers a leakage on pressure release valve causing a fire on relief valve. The fire first saw by one of the employees and immediately reported into tank security officer.

The consequences modelling of this case is using software called ARCHIE to determine the effect of the event. The result of the modelling later become the baseline to evaluate the existing firefighting equipment in *Depot LPG Cilacap*. The result of the assessment concluding that certain firefighting facility is not comply with the minimum requirement based on NFPA (National Fire Protection Agency). The recommendation of this paper is to evaluate the facility to overcome the event in the future based on a recent accident that happened. The affected area of the leakage can be seen in Figure 1.2.

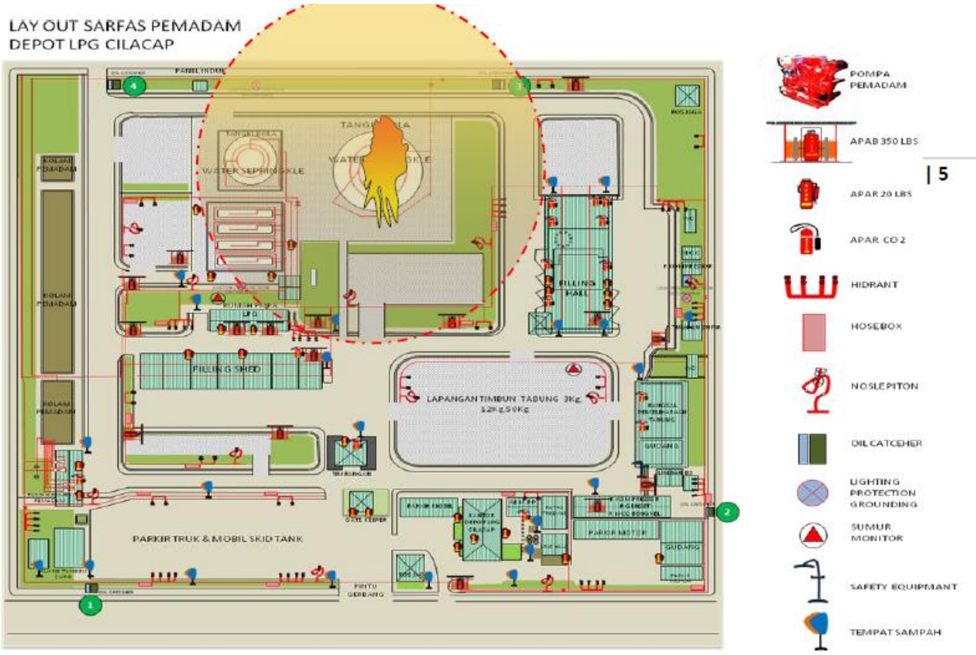


Figure 1.2 Terminal Layout Cilacap LPG Terminal (Pertmina HSSE Jawa Tengah, 2012)

The major concern why this thesis is focused on fire risk is that because Terminal LPG Semarang is concerning to create such as pre fire planning assessment that using the Process Hazard Analysis Software Tools as an consequences modelling tools to predict the incident outcome consequences, or so called quantitative risk assessment. But as the stage in risk assessment cannot suddenly to modelling the outcome without doing another assessment to support the consequences modelling that can become baseline for pre fire planning or fire risk assessment.

To do the complete fire risk assessment several methods also need to do as a complete schematic stage to perform a risk assessment. First is to determine the hazard that may occur using HAZOP (Hazard and Operability) method. This will reveal potential hazard in every component that involving in Terminal's operation.

The next stage performs the frequencies analysis and the system failure analysis. As each components potential hazard that may occur already examine in HAZOP assessment, the system failure, and its consequences also need to be determined. At this stage, the idea of using FTA (Fault Tree Analysis) and ETA (Event Tree Analysis) will be used. Event trees and fault trees are logic diagrams used to represent, respectively, the effects of an event and the contributory causes of an event (Mannan, 2005).

The next step is to modelling the possible outcome from FTA and ETA analysis using Consequences Modelling. Consequences modelling is a method to predict or calculate the physical damage and losses or how big the area is threatened due to a certain accident involving hazardous or toxic substances in oil & gas, processing, distribution, and transmission industry. The visual outcome can be seen in Figure 1.3. In one case the end point of the consequences can be predicted as well as the amount of heat radiation or flux during the event.

On this thesis, the software that chosen is Process Hazard Analysis Software Tools. Process Hazard Analysis Software Tools is one of most comprehensive hazard analysis software for all stages including process industry, design, and operation will 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 result from the modelling process. Process Hazard Analysis Software Tools is also in compliance with the safety regulations that are strictly monitored in oil and gas industry. Regarding the background above doing the consequences modelling using Process Hazard Analysis Software Tools can be used as a platform for Terminal LPG Semarang to create such as detailed and specific assessment (DNV, 2014).

The outcome of consequences modelling can be a platform for determining the firefighting evaluation based on NFPA standard. The evaluation is consist of calculation of the water requirement to prevent higher escalation causalities caused by the former incident. This firefighting evaluation asses whether the existing facility in Terminal LPG Semarang are capable to overcome fire incident that may occur.

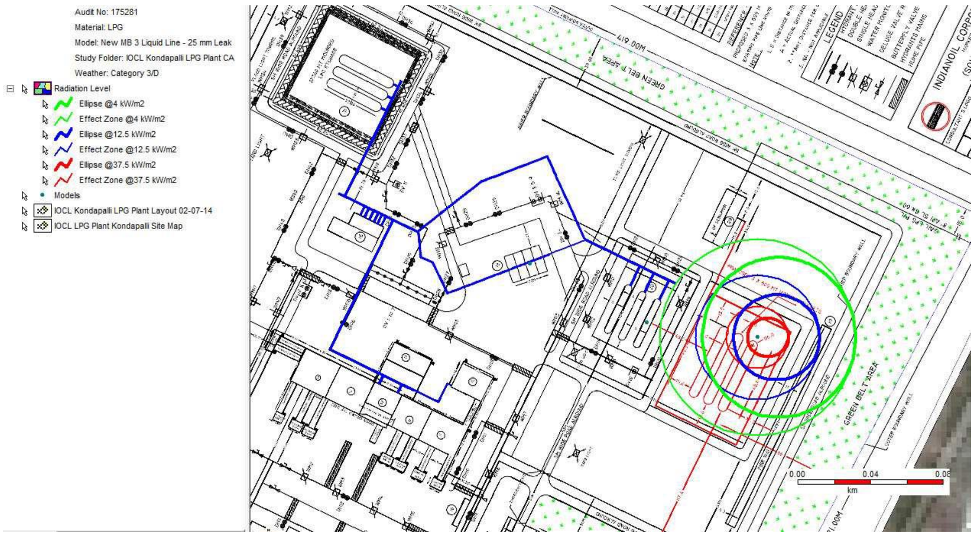


Figure 1.3 Consequences Modelling Result (UltraTech Environmental Consultancy and Laboratory, 2015)

All the methods that being implemented hopefully become a recommendation for Terminal LPG Semarang as an platform to perform further risk assessment and also evaluation for their facility so that in the future there will be major safety improvement in Terminal LPG Semarang.

1.2. Statement of the Problem

The process of thesis is to determine several problem that have to be answered during the research, in this thesis the problem are:

1. How to determine the Hazard and Operability Scenario on Terminal LPG Semarang using BS IEC 61882-2001 HAZOP standard?
2. How to analyze the system failure and event frequencies using FTA (Fault Tree Analysis) and ETA (Event Tree Analysis) methods?
3. How did the consequences modelling outcome using Process Hazard Analysis Software Tools?
4. How to formulate the risk outcome using Company Risk Matrix?
5. What needs to be evaluate in firefighting equipment based on consequences modelling outcome?
6. What are the mitigation if the facility are not comply to overcome certain event?

1.3. Problem Limitations

The problem limitation of this thesis are:

1. This thesis scope is at entire section of the Terminal's facility including receiving, storage, and distribution facility but not consider the potential loss outside Terminal surrounding.
2. Consequences analysis of this research only based on iginited hazard.
3. The quantity of LPG in storage are considered at its maximum amount (2500 MT).
4. The system work are considerd in its maximum capacity.
5. The representation of severity only assess the indiviual losses and not assess through operational losses point of view.

.

1.4. Research Objectives

1. Identify the potential hazard using Hazard and Operability Assesment.
2. After the potential hazard identified, the process is necessary to describe systems failure frequencies using Fault Tree Analysis and Event Tree Analysis.
3. The probable consequences based on event which has been determined have to be calculated using Process Hazard Analysis Software Tools.
4. To examine whether the possible risk are acceptable or not using company risk profile formulation.
5. To assess the pre fire planning as further mitigation
6. To conclude the Pre Fire Planning to overcome the possible action to take in certain occurence.

1.5. Research Benefits

As the process of assessment in this thesis are involving various and sequential Quantitative Risk Assessment methods each method is giving Terminal LPG Semarang greater improvement in their safety aspect. The hazard identification process in this thesis is giving Terminal LPG Semarang major depiction in their LPG handling system which aspects and components may lead into posible hazard in operational prpocess.

The Frequency Analysis in this thesis are giving Terminal LPG Semarang detailed calculation of the failure frequency and probability of their commponents in LPG handling systems. The quantitive result on this assessment stage are giving Terminal LPG Semarang the chance to determine its risk based ranking by the quantitative result.

Consequences evaluation on the consequences modelling stage are conduct better understanding for Terminal LPG Semarang the physical effect of certain event or occurence into Terminal LPG Semarang surrounding area and how much the consequences will impact the societal aspect and the effect of certain event that can lead into another or escalated effect that may occur.

The pre fire planning evaluation gives brief depiction of the possibility that Terminal LPG Semarang firefighting equipment cannot get over certain effect. The deviation occurs in this analysis further will be recomend Terminal LPG Semarang to evaluate its firefighting facility.

CHAPTER 2
LITERATURE STUDY

2.1. Recent Conditions

Terminal LPG Semarang as one of vital facility in LPG supply chain especially in Central Java region is one of gas facility that required to have absolute and strict regulation in safety standard including a planning of action to be taken when an accident occurred. Regarding of those requirement Terminal LPG Semarang is prosecuted to have a detailed procedure such as Fire Risk Assessment. The Fire Risk Assessment later will be a platform to examine pre fire planning. Pre fire planning is an method to plan such as action to overcome specific accident that may occur due to specific condition when the event of accident occur, in this case the pre fire planning is due to fire event.

The things that considered in pre fire planning are mostly the action that have to be taken when the fire event occur. Other things that consist in pre fire plan is the analysis of firefighting equipment such as sprinkle, fire hose, etc. to calculate the need of the firefighting equipment the calculation are based on the NFPA (National Fire Protection Agency) standard.

The effect of unavailability of the pre fire plan can be catastrophic. The escalation of the effect is can be increasing due to lack of action. The action has to be correct information and in details. Also the good action are has to be synchronize with good firefighting equipment planning.

The platform to plan and analysis whether the firefighting equipment or firefighting action is taken from the calculation and modelling how big the accident may occur based on specific condition that affect how catastrophic the event will. This can be done by certain method using consequences modelling with the correct and specific approach.

2.2. Previous Research

2.2.1. Hazard Potency Analysis Of LPG Loading Process In Terminal LPG Semarang

The previous research regarding hazard potency in unloading process of LPG in Terminal LPG Semarang has been done by Bawono Rizki Putra. The research are analyze variuos hazard that may occur during unoading process from Ship into shore storage facility. To reduce any hazard possibility, some methods could be used. Hazard and Operability (HAZOP) is a proper method to be used to analyze any hazard probability, Fault Tree Analysis (FTA) and Layer of Protection (LOPA) shall be used too to analyze the failure rate and the mitigation if the risk level is in medium or higher level. All LPG loading system should be analyzed to guarantee that the system would not cause small or big accident (Putra, 2016).

All LPG loading system should be analyzed to guarantee that the system would not cause small or big accident. An LPG loading system is a system that load propane and butane from the carrier vessel to the tank in the LPG plant. The system that have been analyzed then must be categorized based on it risk level, a low or moderate risk level shall not be mitigated while a medium or higher risk level shall be mitigated, the risk level itself was based on the risk matrix, this risk matrix had it definition to determine the probability and severity level, when the severity and probability number was combined, a risk level could be determined, which means risk level is a combination of severity and probability of a system or sub-system. The mitigation process shall reduce the risk xii level of the LPG loading process.

This research resulted in a decission that all the hazard are in allowed level so thet significant mitigatioin plant are not necessarily conducted.

2.2.2. Pre Fire Planning Assessment Of *Depot LPG Cilacap*.

On Thursday at 22 March 2012 at 10.00 PM on Cilacap LPG Terminal storage tank F which contains mixed LPG which ongoing LPG supply operations into corresponding tank from RU IV T-105 tank. Suddenly the fire spark is occur on the roof side of the tank, and the tank is also suffer a leakage on pressure release valve causing a fire on relief valve. The fire was first saw by one of the employee and immediately reported into tank security officer.

The consequences modelling of this case are using software called ARCHIE to determine the effect of the event. The result of the modelling later become the baseline to evaluate the existing firefighting equipment in *Depot LPG Cilacap*. The result of the assessment concluding that certain firefighting facility are not comply with the minimum requirement based on NFPA (National Fire Protection Agency). The recommendation of this paper are to evaluate the facility to overcome the event in the future based on recent accident that happened (Pertmina HSSE Jawa Tengah, 2012).

2.3. Theories

2.3.1. Liquefied Petroleum Gas (LPG)

Liquefied Petroleum Gas (LPG) or in Indonesia so called ELPIJI is a major fuel to support Indonesia’s household needs as cooking fuel. LPG contains 2 (two) main components of Hydrocarbons gases which are Propane (C_3H_8) and Butane (C_4H_{10}). In Indonesia LPG for cooking purpose is mixture LPG with 50:50 ratio between Butane and Propane. As the complete specification of mixed LPG has been determine by Indonesia's Ministry of Natural Resources *(ESDM)* can be seen in Table 2.1.

Table 2.1 Mixed LPG Specification (Kementrian ESDM, 2010)

NO.	CHARACTERISTIC	UNIT	LIMIT		TEST METHODS	
			MINIMUM	MAXIMUM	ASTM	OTHERS
1.	Relative Density at 60°F	-	To be reported		D-1657	-
2.	Vapor Pressure at 100°F	Psig	-	145	D-1267	-
3.	Weathering Test at 30°F	%vol	95	-	D-1837	-
4	Copper Bar Corrosion	1 Hour/100°F	-	ASTM No. 1	D-1838	-
5.	Total Sulphur Content	Grains/100 cuff	-	15	D-2764	-
6.	Water content	-	No. Free water		-	Visual
7.	Composition C_2 C_3 and C_4 C_5+ (and heavier)	 %vol %vol %vol	 - 97,5 -	 0,8 - 2,0	D-2153	-
8.	Ethyl Or Butyl Mercaptan	ml/100AG	50		-	-

LPG in Indonesia mainly supplied by importing from another country and carried into floating storage in *Teluk Semangka* for Western Indonesia region and *Kalbut* for Eastern Indonesia region, then transferred into main receiving terminal accross Indonesia using Gas Carrier Ship as seen in Figure 2.1. From inland main terminal then carried by skid tank or truck with gas tank into bottling station or known as *SPBE (Stasiun Pengisian Bahan Bakar Elpiji)* accross the country before its distributed in botlled gas in various capacity such as 3 kg, 12 kg, and 50 kg.

Since the type of LPG being used in Indonesia is mixture LPG, during carriage by the ship the Propane and Butane are carried separately. And during unloading process will be mixing process in shore storage tank, and also will be an mercaptan injection as odor agent for LPG.

Figure 2.1 Gas Carrier Ship Unloading Process

2.3.2. Hazard And Operability (HAZOP) Assessment

HAZOP (Hazard and Operability) is one of technique to analyze the potential hazard in specific system with the intention of knowing the cause from the guidewords that lead the analysis into what kind of consequences that may occur. This technique is a development from critical examination. It is a team exercise, which involves examining the design intent in the light of guidewords. The technique has itself been subject to numerous variations (Mannan, 2005).

The basic concept of the HAZOP study is to take a full description of the process and to question every part of it to discover what deviations from the intention of the design can occur and what the causes and consequences of these deviations might be. This is done systematically by applying suitable guidewords. Thus important features of the study are:

1. design intent
2. deviations
3. causes of deviations
4. consequences
5. hazards
6. Operating difficulties. (Mannan, 2005)

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 2.2 Example of HAZOP Assessment (British Standard, 2001)

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

2.3.3. Fault Tree Analysis (FTA) Assessment

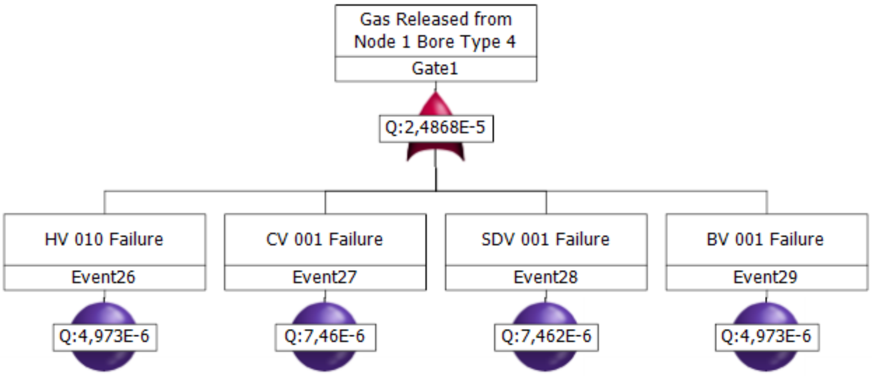


Figure 2.2 FTA Applications

Fault Tree Analysis (FTA) is a method to determining cause of specific top event incident that caused by several basics cause, using logical graphic depiction that called Bolean Logic Gate. The fault tree is a graphical 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. FTA is well suited for analyses of highly redundant systems (American Institute of Chemical Engineers, 1992). The example of FTA basic application as seen in Figure 2.2.

2.3.4. Event Tree Analysis (ETA) Assessment

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. These results describe the possible accident outcomes in terms of the sequence of events (successes or failures of safety functions) that follow an initiating event (American Institute of Chemical Engineers, 1992).

As seen in Figure 2.3 show the typical LPG handing Event Tree Analysis result. The results of an Event Tree Analysis are the event tree models and the safety system successes or failures that lead to each defined outcome. Accident sequences depicted in an event tree represent logical and combinations of events; thus, these sequences can be put into the form of a fault tree model for further qualitative analysis (American Institute of Chemical Engineers, 1992).

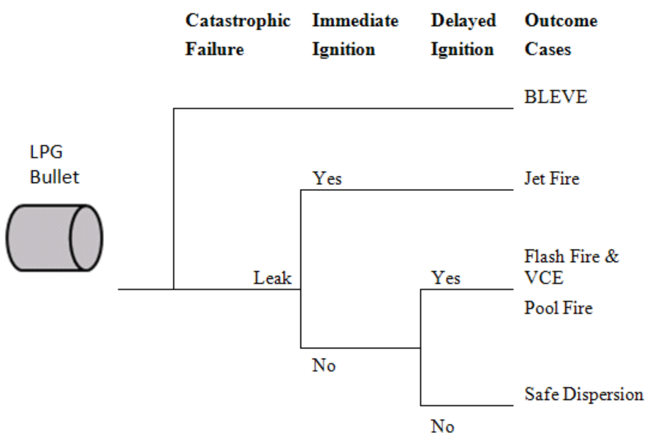


Figure 2.3 Typical ETA for LPG Handling (Selvan, 2015)

2.3.5. 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 the 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. The result is as shown in Figure 2.4 the modelling gives clear visual outcome that show the affected areas and the physical outcome such as heat flux.

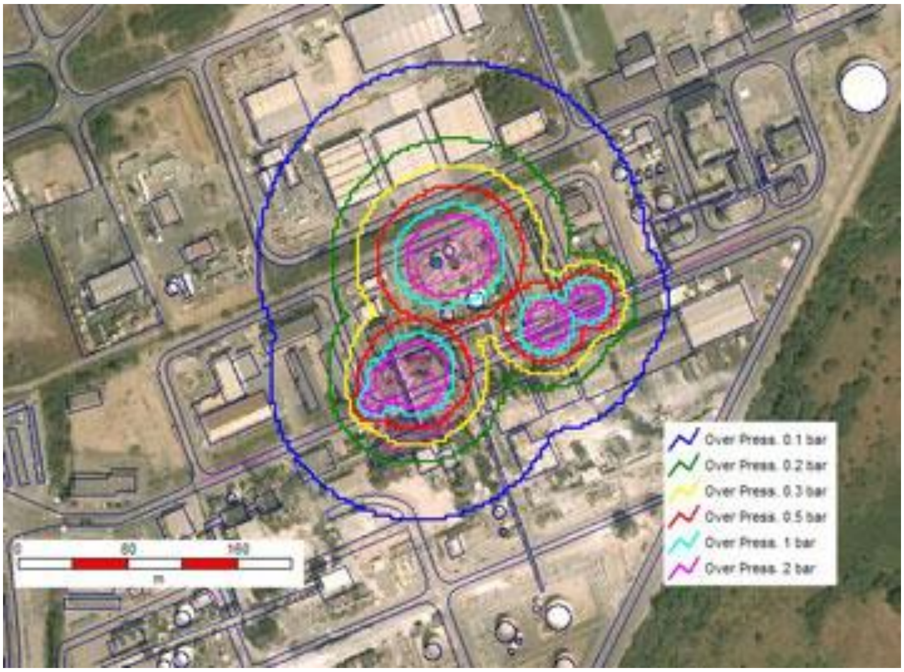


Figure 2.4 Process Hazard Analysis Software Tools Modelling Result (DNV GL, 2015)

2.3.6. Consequences Evaluation: Fire, Release, Explosion, and Dispersion

The main scenario of accident that may occur in a process industry are consist four scenarios, which are: Fire, Release, Explosion, and Dispersion. Every scenario has their own affect and effect and their severity are also different as seen in Table

2.3. The hazardous event that may appear also differ based on what kind of material and what kind of process involved.

Table 2.3 Event Scenario for Flammable Material (Mannan, 2005)

Material	State	Storage	Hazardous Event
Flamable	Liquids	Atmospheric	Liquid Release, then Tank or bund fire Tank Explosion, then Tank or bund fire
	Liquefied Gas	Pressure	Flashing liquid release –flamable vapour cloud, liquid pool, then Pool fire Running liquid fire Jet Fire Vapour cloud fire Vapour cloud explosion Fire engulfed fire, then Jet fire BLEVE
	Liquefied Gas	Refigerated	Flashing liquid release –flamable vapour cloud, liquid pool, then Tank or bund pool fire Running liquid fire Vapour cloud fire Vapour cloud explosion Fire engulfed tank, then Tank or bund pool fire Running fire

2.3.6.1. Jet Fire

Basically Jet Fire is an event when certain material or gases release followed by ignition of the material. This caused spray fire which is turbulent diffusion flame resulting from the combustion of a fuel continuously released with some significant momentum in a particular direction or directions as seen in Figure 2.5. Jet fires can arise from releases of gaseous, flashing liquid (two phase) and pure liquid inventories (Cowley, 1992).

There are a lot of aspect that that make jet fire is become harmful such as:

1. Flame extent and geometry.
2. Ignitability, stability, and lift off.
3. Radiation to surrounding.
4. Directional stability.
5. Properties of combustion products (eg. Smoke, gases, liquids)
6. Heat fluxes.
7. Turbulence level and aerodynaics forces into fire.
8. And temporal variations of aspect above. (Cowley, 1992)

Figure 2.5 Jet Fire (Kontrol, 2013)

2.3.6.2. Vapour Cloud Fire

Figure 2.6 Vapour Cloud Fire (Royal Society, 2012)

A vapor cloud fire, or flash fire, occurs when a vapor cloud forms from a leak and is ignited, but without creation of significant overpressure. If such overpressure occurs, the event is a vapor cloud explosion (VCE) rather than a vapor cloud fire (VCF) (Mannan, 2005).

Cloud Fires are transient event resulting from the ignition of a cloud of gas vapour and not subject to significant flame acceleration via the effect of confinment or turbulence (Cowley, 1992).

As can be seen in Figure 2.6 the example of cloud fire which an massive fire that create such as “cloud-like” form.

2.3.6.3. Boiling Liquid Expanding Vapor Explosion (BLEVE)

BLEVE is simply explosively expanding vapor or two-phase fluid. A BLEVE results from a “hot rupture” of a vessel typically containing hydrocarbons such as LPG3, stored and maintained as a liquid under pressure, due to an impinging or engulfing fire. A flammable material will be ignited immediately upon rupture by the impinging/engulfing fire and will burn as a fireball (International Associations of Oil and Gas Producers (OGP), 2010).

2.4. Standards

2.4.1. British Standard IEC 61882:2001 Hazard And Operabilities (HAZOP) Studies Applications Guide

As on methods on this assessment is to determine the potential hazard using Hazard and Operability (HAZOP) study one of the concern is determining the sguidance so tht during the process of hazard identification is going objective.

British Standard as one of major standarization organization has provide a guideline to do HAZOP assesment. This is providing the method to be standarize as one complete schematic stage that must be follow with the object of:

- Identifying potential hazards in the system. The hazards involved may include both those essentially relevant only to the immediate area of the system and those with a much wider sphere of influence, e.g. some environmental hazards;
- Identifying potential operability problems with the system and in particular identifying causes of operational disturbances and production deviations likely to lead to nonconforming products (British Standard, 2001).

Using British Standard the HAZOP studies follow several sequential step as shown in Figure 2.7.

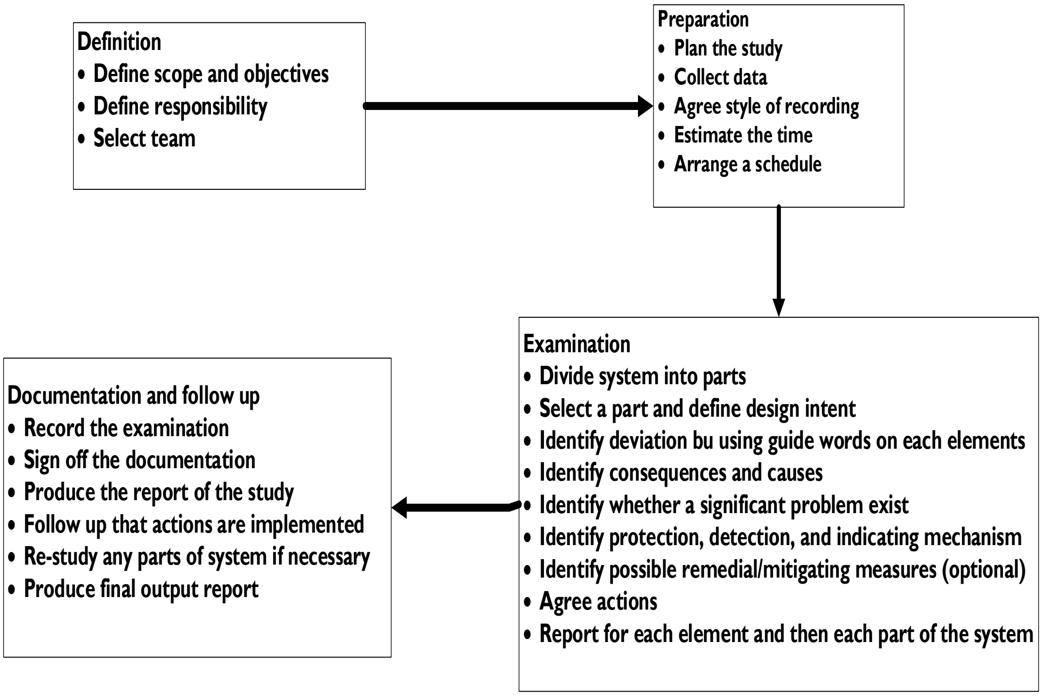


Figure 2.7 British Standard for HAZOP Studies (British Standard, 2001)

2.4.2. DNV Failure Frequency Guidance

DNV as one of safety Assessor is providing data of failure or leak event from various source of process industry; DNV's data is derived from the Hydrocarbon Release Database (HCRD) which has been compiled by the UK Health and Safety Executive (HSE) over a 20 year period The database contains details of over 4000 leak events at oil and gas installations in the UK Continental Shelf. It identifies 78 different types and size categories of process equipment, and records the quantity of the release and the release holes size (DNV, 2014). This data then proceed and analyze so that become an frequency analysis as shown in Table 2.4.and being used for various risk assessment in process industry.

The failure frequency usage is based on consideration on what kind of components that being used and its dimension. The spesifically identification of type of components and dimension makes for certain case it is not listed on the failure frequency datasheet. It makes the usage of different data source are needed for determine the failure frequency. The other source for external data usage on this research is using OGP Failure frequency datasheet.

Process Equipment Leak Frequencies		Rev.:	1
		Date:	26/9/2012
Equipment Type:	Process Pipe	Source:	HCRD 10/92 – 03/10

Definition:

Includes pipes located on topsides (between well and riser) and subsea (between well and pipeline). The scope includes welds but excludes all valves, flanges, and instruments.

Frequency Data:

Equipment Size	Category	Total	Full Pressure	Zero Pressure
0.5 in	1 - 3 mm	9.169E-04	9.409E-04	7.564E-06
	3 - 10 mm	3.435E-04	3.294E-04	5.300E-06
	10 - 50 mm	1.680E-04	1.442E-04	1.084E-05
	50 - 150 mm	0.000E+00	0.000E+00	0.000E+00
	> 150 mm	0.000E+00	0.000E+00	0.000E+00
	Total	1.428E-03	1.414E-03	2.371E-05
1 in	1 - 3 mm	2.725E-04	2.851E-04	4.768E-06
	3 - 10 mm	1.021E-04	9.979E-05	3.341E-06
	10 - 50 mm	5.310E-05	4.577E-05	7.575E-06
	50 - 150 mm	0.000E+00	0.000E+00	0.000E+00
	> 150 mm	0.000E+00	0.000E+00	0.000E+00
	Total	4.277E-04	4.307E-04	1.568E-05
2 in	1 - 3 mm	9.989E-05	1.032E-04	3.551E-06
	3 - 10 mm	3.742E-05	3.611E-05	2.488E-06
	10 - 50 mm	1.389E-05	1.238E-05	1.936E-06
	50 - 150 mm	8.424E-06	6.095E-06	4.216E-06
	> 150 mm	0.000E+00	0.000E+00	0.000E+00
	Total	1.596E-04	1.578E-04	1.219E-05
4 in	1 - 3 mm	5.363E-05	5.270E-05	3.022E-06
	3 - 10 mm	2.009E-05	1.845E-05	2.117E-06
	10 - 50 mm	7.457E-06	6.325E-06	1.647E-06
	50 - 150 mm	6.607E-06	4.581E-06	3.886E-06
	> 150 mm	0.000E+00	0.000E+00	0.000E+00
	Total	8.779E-05	8.205E-05	1.067E-05
6 in	1 - 3 mm	4.454E-05	4.248E-05	2.864E-06
	3 - 10 mm	1.669E-05	1.487E-05	2.007E-06
	10 - 50 mm	6.192E-06	5.098E-06	1.561E-06
	50 - 150 mm	1.127E-06	8.497E-07	6.230E-07
	> 150 mm	5.123E-06	3.425E-06	3.165E-06
	Total	7.366E-05	6.672E-05	1.022E-05

Table 2.4 DNV Failure Frequencies (DNV, 2014)

2.4.3. International Association of Oil & Gas Producers (OGP) Storage Incident Frequencies

From various hydrocarbon containtment system around the world which becomes OGP's research object, OGP conduct datasheet about the failure or incident frequencies per years that can be use as an baseline for determining our failure frequencies of hydrocarbons containtment systems. The datasheet presents frequencies of releases from the following types of storage:

1. Atmospheric storage
2. Refrigerated storage
3. Pressurized storage
4. Oil storage on FPSOs

5. Non-process Hydrocarbon Storage Offshore
6. Underground storage (International Association of Oil and Gas Producers (OGP) , 2010).

The complete table of pressurised storage cann be seen on Table 2.5.

Table 2.5 Pressurised Storage Failure Frequancies (International Association of Oil and Gas Producers (OGP) , 2010)

Hole Diameter		**Leak Frequency (per vessel year)**	
Range (mm)	Nominal (mm)	Storage Vessel	Small Containers
1-3	2	$2,3 \times 10^{-5}$	$4,4 \times 10^{-7}$
3-10	5	$1,2 \times 10^{-5}$	$4,6 \times 10^{-7}$
10-50	25	$7,1 \times 10^{-6}$	
50-150	100	$4,3 \times 10^{-6}$	
>150	Catastrophic	$4,7 \times 10^{-7}$	$1,0 \times 10^{-7}$
Total		$4,7 \times 10^{-5}$	$1,0 \times 10^{-6}$

2.4.4. International Association of Oil & Gas Producers (OGP) Ignition Probability

In the process of gas leakage or release there are probability the released gas to be ignited so that its no longer release or dispersion, its become fire. OGP has conduct a research that identified the connection between released gases and its probability to be ignited. Development of the research deliver datasheets that can be use to predict the probability of ignited gas release. The complete datasheet table for specific scenarios in this thesis can be seen on Table 2.6.

Table 2.6 OGP Ignition Probability (Oil and Gas Producers, 2013)

Large Plant Gas LPG	
Release of flamable gases, vapour or liquids significantly above their normal (NAP) boiling point from large onshore outdors plants.	
Release Rate (kg/s)	Ignition Probability
0,1	0,0010
0,2	0,0014
0,5	0,0019
1	0,0025
2	0,0050

Continued to next table

Continued from previous table

5	0,0125
10	0,0250
20	0,0500
50	0,1250
100	0,2500
200	0,5000
500	0,6500
1000	0,6500

2.4.5. NFPA 15 Standard for Water Spray Fixed Systems for Fire Protection

Table 2.7 Requirement for Flow Rate (NFPA, 2007)

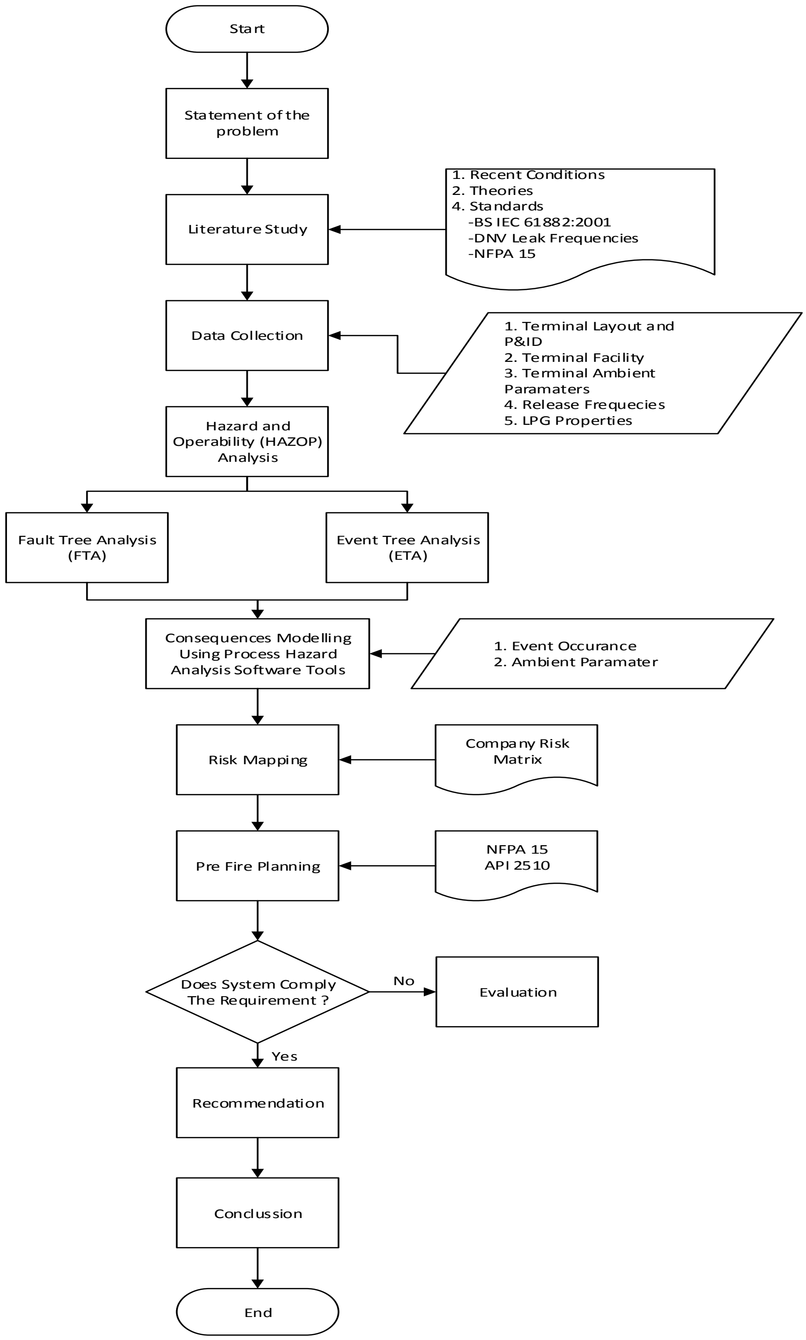
Pipe Size		**Flow**	
In.	mm	gpm	L/min
4	100	300	1.476
6	150	880	3.331
8	200	1.560	5.905
10	250	2.440	9.235
12	300	3.520	13.323

As the evaluation of fire protection system in Terminal LPG Semarang there should be an standar as an standard and guideline. This will determine whether the facility in Terminal LPG Semarang are comply with certain regulation and can overcome certain fire incident. For example as shown in Table 2.7. there are minimum flow rate for water spray supply.

This standard provides the minimum requirements for the design, installation, and system acceptance testing of water spray fixed systems for fire protection service and the minimum requirements for the periodic testing and maintenance of ultra-high-speed water spray fixed systems (NFPA, 2007).

CHAPTER 3
METHODOLOGY

3.1. Methodology Flowchart



3.2. Research Methodology

Research methododlogy is the proposed solution methods to solve the problem at one specific research. On this thesis the main framework for solving the problem are consist of 4 (four) stage, which are: hazard identification, frequency analysis using fault tree and event tree analysis, consequences modelling, and pre fire planning evaluation. The complete stage of this thesis methodology will be explained further below.

1. **Statement of the problem**

   First to identify the problem to determine what kind of formulation and methods to be taken. This is the initial stage to start the research. The amount of problem and the limitation are things to be considered during this stage, and in the middle of the research there are might be correction depend on the course of the research.

2. **Literature Study**

   There are a lot of reference to do a research. On this stage all the reference during this thesis work will be reviewed. This including the basic theories that come from various literature source, recent condition, and standard including: BS IEC 61882:2001, DNV Leak Frequencies, NFPA 15. And also various previous resaerach on risk assessment that may useful to this thesis.

3. **Collection of Data**

   One of the main stage of this research are to be modelling the consequences of accident that may occur and its effect. The modelling process is need various data to be considered an as close as actual condition in operation process. This data collection have very big influence further in analytical process so the validity of data are the things that need to be considered very carefully.

   Kind of data that need to be collected in this research are such as: Terminal Layout and P&ID, Terminal facility, Terminal operation data, Terminal ambient parameters, Release frequencies, LPG Properties.

4. **Hazard and Operability (HAZOP) Analysis**

   Potential cause of failure describes how a process failure could occur, in terms of something that can be controlled or corrected. The goal is to describe the direct relationship that exists between the cause and resulting process failure mode. The major steps to do HAZOP assessment are: 1. Preparing for the review, 2. Performing the review, and 3. Documenting the results. (American Institute of Chemical Engineers, 1992)

5. **Fault Tree Analysis Assessment**

Based on previous HAZOP assessment the FTA determine the probability of failure event that may occur. There are four steps an analyst must take to perform a Fault Tree Analysis: 1. defining the problem, 2. constructing the fault tree, 3. analyzing the fault tree model qualitatively, and 4. documenting the results (American Institute of Chemical Engineers, 1992).

6. **Event Tree Analysis**

Event Tree Analysis evaluates the potential for an accident that is the result of a general type of equipment failure or process upset (known as an initiating event. The general procedure for Event Tree Analysis contains six steps: 1. identifying the initiating events of interest that can result in the type of accident of concern, 2. identifying the safety functions designed to mitigate the initiating event, 3. constructing the event tree, 4. describing the resulting accident sequence outcomes, 5. determining the accident sequence minimal cut sets, and 6. documenting the results.

7. **Consequences Modelling**

From the event which already predicted using ETA the actual consequences will be modelling using Process Hazard Analysis Software Tools. This will give clear visual representation how the consequences will affect, and the effect of the occurence.

8. **Risk Representation**

From the analysis the posible risk outcome will be determined for each scenarios. Every possible occurence will be represented into company based risk evaluation whether the outcomes are acceptable (low risk) or not. The desired result are the majority scenarios will be not in high risk level area. But if theres any medium or high risk outcome there will be mitigation efforts. The risk mapping in this thesis will be using company risk matrix where the company already determine by themself which grouping certain risk by it’s severity and occurence likelihood.

9. **Pre Fire Planning Evaluation**

The modelling give result that can be a baseline to evaluate the terminal facility whether the consequences that may be occur can be overcome by terminal facility. This resulting as pre fire planning which this stage when pre fire planning will be made. The standard thet will be used is NFPA 15. If there’s found incompliance the process will prosecuted into evaluation of terminal facility.

10. **Result and Discussion**

This stage are summarize the analytical stage and evaluation stage, and also considering certain deviation that may occur.

11. **Conclusion**

At this stage all the research process and result will be conclude and as validation of this research is this answering the problem or not. And the end result is to be suggested and recommend the terminal LPG Semarang as its evaluation tools.

CHAPTER 4
DATA REQUIREMENT

4.1. General Description

This thesis analyze potential fire risk and pre fire planning to overcome the fire occurrence that may occur based on the risk evaluation using quantitative risk assessment, with Terminal LPG Semarang as an object to assess. The scope of the assessment are in entire system on the terminal which handling the LPG including receiving (from tanker ship), storage, and distribution process.

4.2. Data Requirement

In the assessment process there are required several data to support the assessment process, the required data on this thesis are:

4.2.1. Terminal Plant Layout

The terminal layout are required to give the depiction of the area to be assess and further the layout also needed to plot the consequences evaluation. The brief layout of Terminal LPG Semarang can be seen on Figure 4.1. The lyout of Terminal LPG Semarang shows the coverage area of entire Terminal. The Jetty which exceed 1.200 m consist of the Jetty area of Marine Loading arm, Trestle area, and the pipeline exceed into partial part of shoreline. The Terminal area consist of Tank Farm, office, filling shed, pumphouse and skid tank parking area. The more detailed layout can be seen on Appendix 1.

4.2.2. Systems Piping and Instrumental (P&ID) Diagrams

To find certain possible hazard on the systems the analysis is involving to analyze how the systems works and during operational what are the possible failure that can lead into hazard. To do that it required the complete schematic P&ID of the systems and its components so it can be analyze. Considering in this thesis will be assess entire terminal system from receiving (from tanker ship), storage, and distribution the complete the following P&ID are:

1. LPG Ship Loading and Unloading P&ID
2. LPG Loading Storage Tank P&ID (consist 2 sheets of documents)
3. LPG Loading Pumps and Filling Points P&ID (consist 3 sheets of documents)
4. Fire Water Distribution System P&ID.

The further and more detailed diagrams can be seen on Appendix 2.

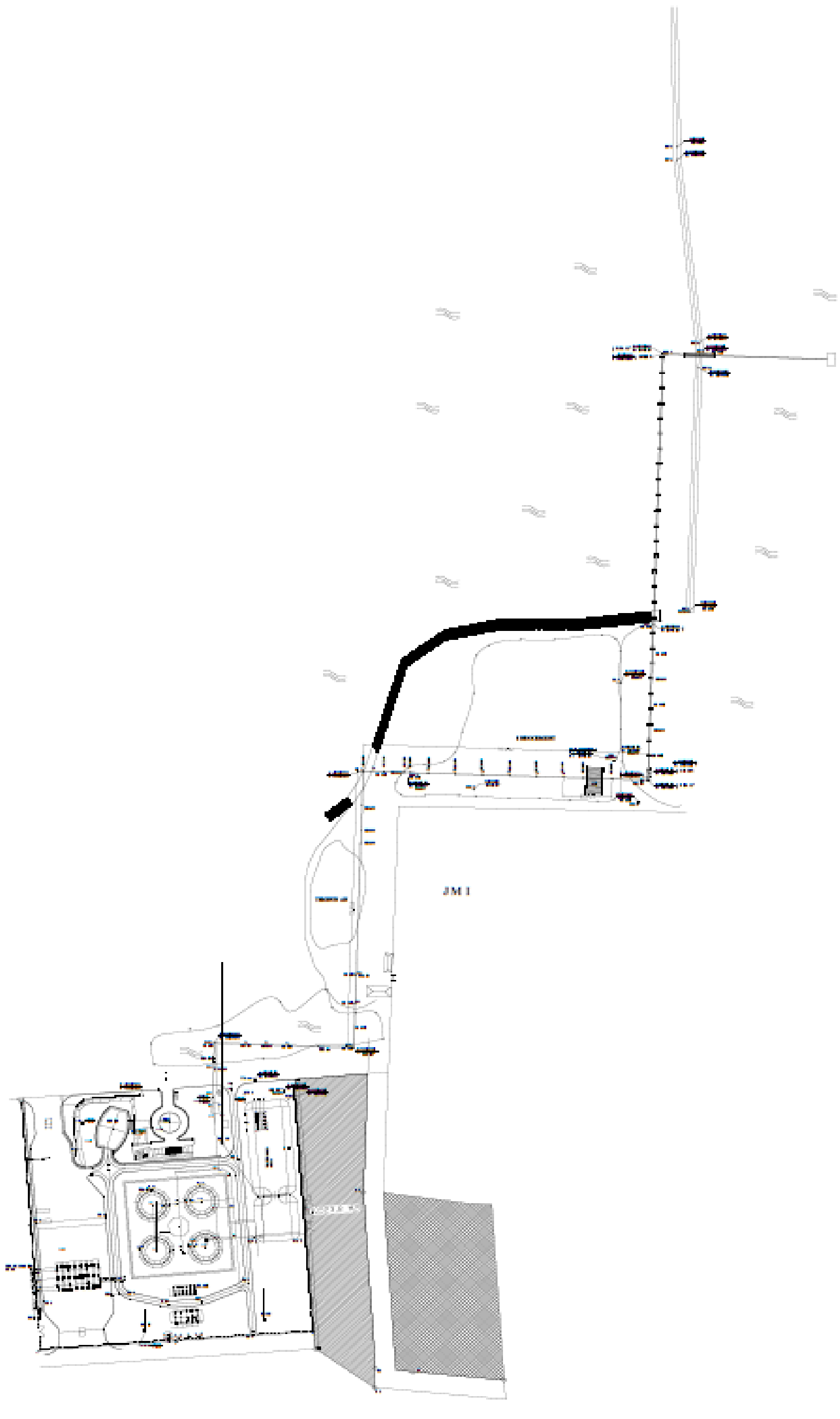


Figure 4.1 Layout of Terminal LPG Semarang

4.2.3. Company Risk Matrix

The risk mapping process require the standard to determine the level of risk. To fulfill the process this thesis will be using company risk matrix as standard (Terminal LPG Semarang, 2013). The risk matrix consist of two axis which determine the likelihood and the severity of certain risk. The ranking of each aspect then otted into matrix then the resul will be determine as the risk level. The description of likelihood and severity can be seen on Table 4.2. and 4.3. The risk matrix can be seen on Figure 4.4.

Table 4.2 Company Risk Likelihood Descriptions (Terminal LPG Semarang, 2013)

Likelihood			
Level	**Criteria**	**Description**	
		Qualitative	**Quantitative**
1	Rare	Considered but not only in extreme condition.	Less than 1 time in 10 years.
2	Unlikely	Not happen yet but can be occur sometimes	1 times in 10 years.
3	Possible	Supposed to be occur here / in other places.	1 time in 5 years until 1 time a year.
4	Likely	Easily occur, might occur in a more likely way.	More than 1 time a year until 1 time a month.
5	Almost certain	Often occur and appear in a often occurence.	More than 1 times a month.

Table 4.3 Company Risk Severity Descriptions (Terminal LPG Semarang, 2013)

Consequences / Severity			
Level	**Description**	**Severity**	**Workdays**
1	Not significant	Occurence does not caused loss or injury.	Not causing loss of workdays
2	Minimal	Causing minor injury and no direct effect into business activity.	Still can work on the same day / shift.
3	Moderate	Major injury and hospitalized but not causing permanent disability, and moderate financial loss.	Loss of workdays under 3 days.
4	Major	Major injury and permanent disability and major financial loss and seriously damage business activity.	Loss of workdays more than 3 days.
5	Catastrophic	Serious causality (die) and stopping business activity forever	Loss of workdays forever.

RISK LEVEL						
LIKELIHOOD	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
SCALE		1	2	3	4	5
		SEVERITY CONSEQUENCES				

Figure 4.3 Company Risk Matrix

Definitions

Low Risk
Medium Risk
High Risk
Extreme

4.2.4. Terminal Fire Fighting Arrangement and Components

The arrangement are required to assess whether the firefighting facility can overcome the possible outcome. The terminal Fire Fighting can be seen on Figure 4.3. The terminal Fire Fighting facility also can be seen on Table 4.1, and the complete equipment list can be seen on Appendix 3.

Table 4.1 Fire Fighting Equipment (Terminal LPG Semarang, 2013)

Fire Fighting Equipment	Quantity	Amount	Brand	Type	Engine	Mover
Fixed Fire Pump cap @3000 GPM	Unit(s)	4	Amarillo	Vertical	Clarke	Diesel
			Amarillo	Vertical	Clarke	Diesel
			Amarillo	Vertical	Clarke	Diesel
			Amarillo	Vertical	Clarke	Diesel
Jockey Pump Cap. 13.51 GPM	Unit(s)	2	Grunfos	Vertical	-	Electric
			Mufitec	Vertical	-	Electric
Fixed Fire Pump Jetty Area Cap 1000 GPM	Unit(s)	1	Amarillo	Vertical	Clarke	Diesel

As a primary system to overcome fire evnent in the Terminal are using fresh water as an estinguisher the firefighting system in Terminal LPG Semarang are mainly consist of fixed water spray or sprinkle and fire hose. All the main estinguisher are provided with water from water pond using main fire pump which use diesel as a prime mover. The water pond get its water from external resource so that the design intent of the fire fighting system are closed loop so that no external resources (such as sea water coming from the sea which surround the Terminal) are intentionally come in handy when in condition of the water pond is out of water.

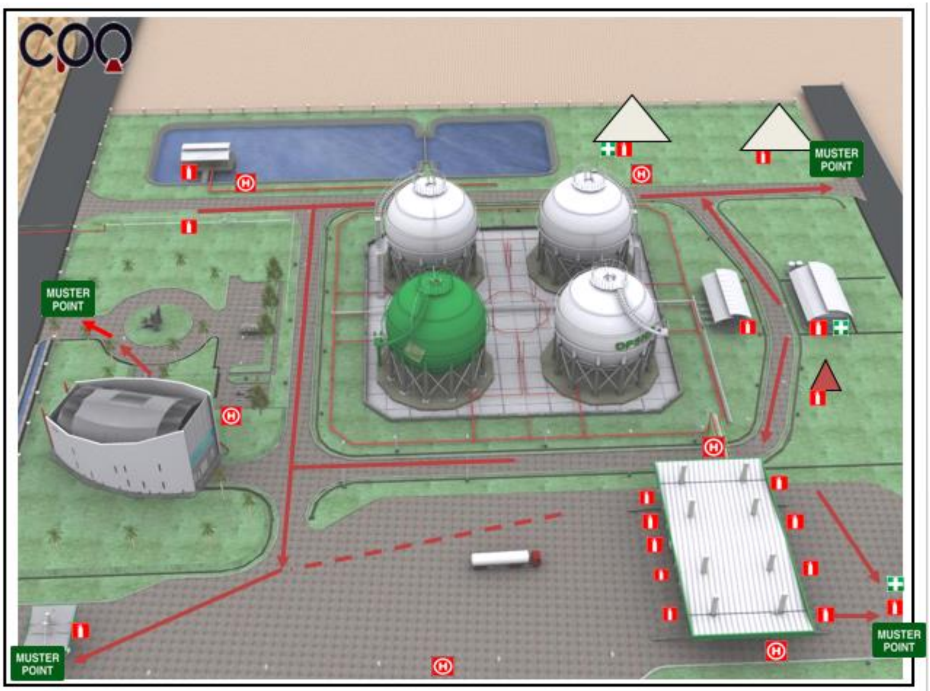


Figure 4.4 Terminal Fire Fighting Arrangement

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CHAPTER 5
TERMINAL SYSTEM DESCRIPTION

5.1. General Description

Terminal LPG Semarang consist 3 (three) main subsystem on its facility. The first are receiving subsystem that conduct receiving operation of bulk LPG from Gas Carrier Ship the second subsystem is storage of LPG in storage tank. The last subsystems are distribution system that responsible in transferring the LPG from storage tank into filling station related with the transfer process into Skid Tank (Truck equipped with tank) for transportation into the destination.

5.2. Receiving System

During receiving operations of bulk LPG from ship, the LPG are transfered using pump onboard ship. The preliminary step of the transfer process are including the connection of Terminal's Marine Loading Arm (MLA) into ship's manifold.

The major components to be considered in Receiving subsyetem are Marine Loading Arm (MLA) as seen on Figure 5.1 which connect the shore with ship's manifold. Materring station as shore measurement components to calculate the amount and flow rate of the LPG. And Mercaptan injection station as component with the purpose of odorizing the LPG. Another components to be considered are main pipeline, various valve such as Shutdown Valve (SDV). Control Valve (CV), erc. Also various measuring components such as: Temperature Indicator (TI), Pressure Indicator (PI), etc.

Figure 5.1 Marine Loading Arm

This system are using 10" pipeline as a main pipe, the complete components specification of this system are:

Marine Loading Arm

- Producer: Woodfield Systems Limited
- Equipment Type: Hydraulic Lever
- Model Number: A2/08/1200/600/008
- Manufacturing year: 2008
- Flow/Pressure: 4 LMP/13,6 BarG

Ship Unloading Meterring Package

- Max. Flow Rate : 300 MT/Hr
- Operational Press : 7-14 BarG
- Operational Temp. : 5-30°C

Vapour Return Meterring Package

- Max. Flow Rate : 8 MT/Hr
- Operational Press : 7-14 BarG
- Operational Temp. : 5-30°C

The process of loading LPG into shore storage tank beside the liquid LPG loading are also involve with unloading the LPG vapour back into Gas Carrier Ship. The process make the receiving process also invlove two different flow of fluids: the liquid LPG flow into storage tank, and Vapour LPG from storage tank into Gas Carrier Ship which using 4" pipelines. The complete system P7ID can be seen on Appendix 2.

Figure 5.2 Meterring Station

5.3. Storage Tank System

The next system is storage tank system, storage tank are the end point of transferring LPG from Gas Carrier after injected by Mercaptan. The Storage Tank type are Spherical type storage as seen on Figure 5.3. As main system of handling that involve a lot amont of LPG the storage tank are equipped with various safeguard and measurement and instrumentation of LPG Cpndition such as: Atomatic Tank Gauging (ATG), Pressure Safety Valve (PSV), Pressure Indicator (PI), Temperature Indicator (TI), etc.

Figure 5.3 Spherical Storage Tank

The operational activity on storage tank subsystem are consists of receiving activity, intertank activity, and distribution activity. The activity listed above are supported by various dimension of pipeline. The pipeline for receiving and intertank activity are using 10″ pipelines, the distribution activity are using 12″ pipelines. Meanwhile the vapour return line are using 4″ pipelines.

The techinical specification for Storage Tank are:

- Size : 21216 mm
- Capacity : 2500 MT
- Operation Press. : 7-14 BarG
- Operating Temp : 5-30^{o}C
- Manufacturer : Shi-Asia Company LTD
- Design Pressure : 17,2 BarG at 70^{0}C
- Test Pressure : 21,93 kg/cm^{2} (Top of vessel)
- Min. Metal Design Temp. : Minus 10^{0}C
- Year built : 2009

5.4. Distribution Subsystem

Distribution system are responsible for distribute the LPG into filling point as well as do intertank operation. The distribution system are consist of 4 (four) LPG Pumps, and that supply activity in filling point into Skid Tank using Quick Coupling Connection. The operation of 4 (Four) LPG pumps are redundant considering the operation cycle requested by distribution division so that the redundant system are designed the distribution are still can fulfill the need when something happend with one of the pump. Also in the system is consist of one unloading pump from skid tank in a case when overfilling is happend into Skid Tank. In normal distribution activity usually 2 (two) LPG pumps are used.

The distribution process from storage tanle into pumps suction head are using 12″ pipelines, and reduced into 6″ pipelines so do with the pipelines in filling point. Meanwhile the filling process into skid tank are using various size of pipelines depends on the intent of the operational.

The technical specification for distribution subsystem are:

LPG Pumps

- Type : Centrifugal Pump
- Flow rate : 30 MT/hr max 50 MT/hr
- Max. Press. : 17,24 BarG
- Rated Discharge Press. : 205,65 psi ~ 13, 99 BarG

Figure 5.4 LPG Pumps

CHAPTER 6
HAZARD AND OPERABILITY (HAZOP) STUDY

Hazard and Operability (HAZOP) study giving the detailed assessment of the potential hazard which may occur. The basis of HAZOP is a "guide word examination" which is a deliberate search for deviations from the design intent (British Standard, 2001). The basic concept of the HAZOP study is to take a full description of the process and to question every part of it to discover what deviations from the intention of the design can occur and what the causes and consequences of these deviations might be. Based on BS IEC 61882:2001 the process of HAZOP study are include in determining the nodes, deviations, safeguards, and another criteria to support the study.

6.1. Node Classification

The LPG handling facility consists of various system that divided into main division: Receiving (from Gas Carrier), Storage, and Distribution. The complete system of the Terminal as P&ID can be seen in Appendix 2. 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 complete node classifications can be seen on Table 5.1. above.

The technical description of the node classification above are:

1. Node 1

   This Node are concerned in liquid loading line from Gas Carrier into meterring station this system are divided based certain part in unloading system and Jetty Area. Considering the length of unloading line are 1.200 m that divides into in Trestle area and shore area, every line need to be separate since the system has its own hazard potency based on its location. The part considered in this node are MLA (Marine Loading Arm) Liquid loading line, and pipeline located on trestle and causeway. The specification of liquid loading line of MLA are mentioned below:

   - Max. Flow Rate : 300 MT/Hr
   - Operational Press : 7-14 BarG
   - Operational Temp. : 5-30^{o}C

2. Node 2

The concern of this node are the system of liquid loading LPG from Gas Carrier into meterring station and located in shore area. Since this node are exposed into labour and open space rather than enclosed area like node 1. The part considered in this node are meterring station that show how much amount of Liquid LPG that transferred from Gas Carrier.

3. Node 3
   The loading process of liquid LPG are followed by the unloading process of LPS vapour from storage tank into Gas Carrier. The reason why this line need to be separate into different node are because the flow direction and the type of fluids involved are different than loading line. The process of vapour return are only involving vapour phase of LPG rather than liquid phase. The consideration of this node to be determined are because this line are located in shore are of the Terminal. The part considered in this node is vapour return meterring station.

4. Node 4
   This node is considered as the vapour return line at trestle or causeway area the pipeline are located in same location as node 1 but with different fluuids and flow direction works eventhough with the same part consideration such as MLA (Marine Loading Arm).

5. Node 5
   This node classified storage tank subsystem that consist 4 (four) storage tank which are V110, V120, V130, and V140. This node are assess the possible hazard on storage in all operation intent into all storage tank. The operational specification of this node are:
   - Size : 21216 mm
   - Amount of Storage : 4(four)
   - Capacity : 2500 MT
   - Operation Press. : 7-14 BarG
   - Operating Temp : 5-30°C

6. Node 6: Receiving Operation
   Apart from storage tank itself, the storage tank system have the pipelines that have to assess separately since the system has different components and different safeguard implementation comparing with the storage tank itself. The operational specification of this node are:
   - Pipe Size : 10" Pipe, 4" Pipe (Vapour Return)
   - Flow Rate : Max 300 MT/Hr, 8 MT/Hr (Vapour Return)

- Operation Press. : 7-14 BarG
- Operating Temp : 5-30^{o}C

7. Node 6: Distribution Operation
   This process has the same design intent with Node 3: Receiving above but with differetnt operational intent, this node conduct assess in distribution operation. The operational specification of this node are:
   - Pipe Size : 12" Pipe
   - Flow Rate : 30 - 50 MT/Hr
   - Operation Press. : 7-14 BarG
   - Operating Temp : 5-30^{o}C

8. Node 6: Intertank Operation
   This process has the design intent with Node 3: Receiving with Intertank Operation. The operational specification of this node are:
   - Pipe Size : 12" Pipe
   - Flow Rate : 30 - 50 MT/Hr
   - Operation Press. : 7-14 BarG
   - Operating Temp : 5-30^{o}C

9. Node 7
   Node 4 is conduct assessment on LPG Pumps system. This pump provide the distribution into filling point. On this system consists of 4 (four) identical LPG Pumps with redundant operation. The technical specification of this node are:
   - Type : Centrifugal Pump
   - Flow rate : 30 MT/hr max 50 MT/hr
   - Max. Press. : 17,24 BarG
   - Rated Discharge Press. : 205,65 psi ~ 13, 99 BarG

10. Node 8
    Node 5 are assess the filling point of LPG into Skid Tank. There are 6 (six) filling point into skid tank which operate simoltaneusly all of them that serviced by LPG Pumps.

Table 6.1 Node Classification

No	P&ID Drawing Code and Description	Node Classification	Description
1	FTLS-30-DW-C006 LPG Ship Loading/Unloading P&ID	Node 1	Liquid loading MLA (Marine Loading Arm), Liquid loading line at trestle/jetty area
2	FTLS-30-DW-C006 LPG Ship Loading/Unloading P&ID	Node 2	Liquid loading line at shore area and meterring station
3	FTLS-30-DW-C006 LPG Ship Loading/Unloading P&ID	Node 3	Vapour return line located in shore area, and vapour return meterring station
4	FTLS-30-DW-C006 LPG Ship Loading/Unloading P&ID	Node 4	Vapour return line located in trestle and jetty, Vapur return MLA (Marine Loading Line)
5	FTLSMG-30-DW-C007 LPG Loading Storage Tank V110, V120, V130, V140 P&ID	Node 5	Storage Tank V110, V120, V130, V140
6	FTLSMG-30-DW-C007 LPG Storage System Pipelines	Node 6: Receiving Operation	Storage System Pipelines Receiving Operation
		Node 6: Distribution Operation	Storage System Pipelines Distribution Operation
		Node 6: Intertank Operation	Storage System Pipelines Intertank Operation
7	FTLSMG-30-DW-C008 LPG Loading Pumps	Node 7	LPG loading pumps in Distribution Operation
8	FTLSMG-30-DW-C008 Filling Point P&ID	Node 8	LPG Filling/Distribution into Skid Tank (LPG Tanker Truck)

6.2. Systems Deviation Determination

The Process of system deviation is to choose the guide word that comply with the desgn intent. Based on BS IEC 61882:2001 the list of the deviation are already provided as seen in Table 5.2. The guide word then combined with the type of deviation. The variables of the deviation can be determined based on the type of system that need to be asses. For the purpose of design and operational intent in this thesis are LPG handling 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 LPG.

Table 5.2 HAZOP Guide Word (British Standard, 2001)

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

6.3. 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.

6.4. 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.

6.5. 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 the absence of any safeguard can be covered and the overcome planning are determined.

6.6. 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 5.3 below.

Table 5.3 List of Abbreviations

No	Abbreviation	Definition
1	HV	Hand Valve
2	CV	Control Valve
3	SDV	Shutdown Valve
4	BV	Butterfly Valve
5	PSV	Pressure Safety Valve
6	SV	Safety Valve
7	PI	Pressure Indicator
8	TI	Temperature Indicator
9	ATG	Automatic Tank Gauging
10	ESD	Emergency Shutdown
11	LAH	Level Alarm High
12	LAL	Level Alarm Low
13	RED	Reducer
14	STR	Strainer
15	P	Pump
16	AV	Automatic Valve (Ball Valve)

Study Title: Node 1							Sheet: 1 of 2	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Compositio							Meeting Date:	
Part Considered:		Marine Loading Arm (MLA) Liquid Loading Line						
Design Intent:		Material: LPG Source: Gas Carrier		Destination: Metering Station Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
1	NO	NO FLOW	HV-0010 Blocked, CV-0001 Failure, SDV 0001 Failure, BV 001 Blocked	No LPG supply, No Flow into Meterring Station	PI 0004, PI 0003		Visual and condition check before operate unloading operation, routine maintenance and check on safeguard and supporting components	Receiving and Storage (R&S) Division
2	MORE	MORE PRESSURE	HV-0010 Blocked, CV-0001 Failure, SDV 0001 Failure, BV 001 Blocked	Over pressure in the system that can lead into rupture and leakage in one/more components in the system	PI 0001, 003; Pressure Safety Valve 1005, ESD SV 0001		Visual and condition check before operate unloading operation, routine maintenance and check on safeguard and supporting components	Receiving and Storage (R&S) Division
3	REVERSE	REVERSE FLOW	Pump 001 (bypass line) turned on, meanwhile Shutdown Valve 0001 blocked	Backpressure or reverse flow back into Gas Carrier, Failure in Loading Arm Connection that can lead into leak and gas release	None Shows		Visual and condition check before operate unloading operation, routine maintenance and check on safeguard and supporting components	Receiving and Storage (R&S) Division

Study Title: Node 1							Sheet: 2 of 2	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		Marine Loading Arm (MLA) Liquid Loading Line						
Design Intent:		Material: LPG Source: Gas Carrier		Destination: Metering Station Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
4	MORE	MORE FLOW	Too high discharge rate from Gas Carrier unloading pump	Higher flow rates on the systems	Pressure Indicator 0001, 003; Pressure Safety Valve 1005		Visual and condition check before operate unloading operation, routine maintenance and check on safeguard and supporting components	Receiving and Storage (R&S) Division

Study Title: Node 2							Sheet: 1 of 1	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		Meterring Package Liquid Line						
Design Intent:		Material: LPG Source: Gas Carrier		Destination: Metering Station Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
1	NO	NO FLOW	BV 002 Blocked, SDV 0003 Failure, HV 0001 Blocked, CV 002 Blocked, HV 0003 Blocked	No LPG supply, No Flow into Meterring Station	PI 0004, PI 0001		Visual and condition check before operate unloading operation, routine maintenance and check on safeguard and supporting components	Receiving and Storage (R&S) Division
2	MORE	MORE PRESSURE	BV 002 Blocked, SDV 0003 Failure, HV 0001 Blocked, CV 002 Blocked, HV 0003 Blocked	No LPG supply, No Flow into Meterring Station	PI 0004, PI 0002		Visual and condition check before operate unloading operation, routine maintenance and check on safeguard and supporting components	Receiving and Storage (R&S) Division
3	REVERSE	REVERSE FLOW	Overfilling into storage tank, Meterring station Blocked	Back pressure into Gas Carrier	PI 0004, PI 0003		Visual and condition check before operate unloading operation, routine maintenance and check on safeguard and supporting components	Receiving and Storage (R&S) Division
4	MORE	MORE FLOW	*This deviation considered equal as "MORE PRESSURE" deviation*					

Study Title: Node 3							Sheet: 1 of 1	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		Vapour Return Meterring Package						
Design Intent:		Material: LPG Source: Gas Carrier		Destination: Metering Station Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
1	NO	NO FLOW	CV 003 Blocked, HV 006 Blocked, SDV 007 Failure, BV 004 Blocked	No vapour return into Gas Carrier	PI 004, ESD SV 004		Visual and condition check before operate unloading operation, routine maintenance and check on safeguard and supporting components	Receiving and Storage (R&S) Division
2	MORE	MORE PRESSURE	CV 003 Blocked, HV 006 Blocked, SDV 007 Failure, BV 004 Blocked	Over pressure in the system that can lead into rupture and leakage in one/more components in the system	PI 004, ESD SV 005		Visual and condition check before operate unloading operation, routine maintenance and check on safeguard and supporting components	Receiving and Storage (R&S) Division
3	REVERSE	REVERSE FLOW	*No issue regarding this deviation*					
4	MORE	MORE FLOW	*No issue regarding this deviation*					

Study Title: Node 4							Sheet: 1 of 1	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		Marine Loading Arm (MLA) Vapour Return Line						
Design Intent:		Material: LPG Source: Gas Carrier		Destination: Metering Station Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
1	NO	NO FLOW	BV 003 Blocked, SDV 002 Failure, HV 012 Blocked	No vapour return into Gas Carrier	PI 004, ESD SV 004		Visual and condition check before operate unloading operation, routine maintenance and check on safeguard and supporting components	Receiving and Storage (R&S) Division
2	MORE	MORE PRESSURE	BV 003 Blocked, SDV 002 Failure, HV 012 Blocked	No vapour return into Gas Carrier	PI 004, ESD SV 005		Visual and condition check before operate unloading operation, routine maintenance and check on safeguard and supporting components	Receiving and Storage (R&S) Division
3	REVERSE	REVERSE FLOW	Blocked ship's vapour return manifold	Vapour not returned caused high pressure on storage tank	PI 004, PI 003, ESD SV 004		Visual and condition check before operate unloading operation, routine maintenance and check on safeguard and supporting components	Receiving and Storage (R&S) Division
4	MORE	MORE FLOW	*No issue regarding this deviation*					

Study Title: Node 5							Sheet: 1 of 2	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		Spherical Storage Tank V110, V120, V130, V140						
Design Intent:		Material: LPG Source: Gas Carrier		Destination: Metering Station Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
1	MORE	MORE PRESSURE	Too high inlet flow, Higher vapour - liquid ratio, Overfill of vapour LPG into tank	High pressure on storage tank	PSV 1101, PSV 1102, PSV 1201, PSV 1202, PSV 1301, PSV 1302, PSV 1401, PSV 1402, PI 1101, PI 1102, PI 1201, PI 1202, PI 1301, PI1302, PI1401, PI 1402 ATG 1101, ATG 1201, ATG 1301, ATG 1401, PT 1101, PT 1201, PT 1301, PT 1401		Constant monitoring of perimeters, PSV routine calibration	Receiving and Storage (R&S) Division
2	MORE	MORE TEMPERATU RE	High ambient temperature, Vapour pressure increasing	Expansion of vapour inside storage tank	TI 1101, TI 1102, TI 1201, TI 1202, TI 1301, TI 1302, TI 1401, TI 1402, Water spray system		Constatnt monitoring of perimeters	Receiving and Storage (R&S) Division

Study Title: Node 5							Sheet: 2 of 2	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		Spherical Storage Tank V110, V120, V130, V140						
Design Intent:		Material: LPG Source: Meterring station		Destination: Storage Tank Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
3	MORE	MORE LEVEL	Overfilling during receiving and inertank operation	Too much level of LPG	ATG 1201, ATG 1301, ATG 1401, LAH 1102, LAH 1201, LAH 1301, LAH 1401		Constatnt monitoring of perimeters	Receiving and Storage (R&S) Division
4	NO	NO FLOW	No issue regarding this deviation					
5	REVERSE	REVERSE FLOW	No issue regarding this deviation					

Study Title: Node 6: Receiving Operation							Sheet: 1 of 2	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		Storage receiving system						
Design Intent:		Material: LPG Source: Meterring station		Destination: Storage Tank Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
1	NO	NO FLOW	HV 1501 Blocked, STR 1104 Blocked, FJ 17 Blocked, RED 4"x 6" Blocked, HV 1601 Blocked, STR 1204 Blocked, FJ 19 Blocked, RED 4"x6" Blocked, HV 1701 Blocked, STR 1304 Blocked, FJ 21 Blocked, RED 4"x6" Blocked, HV 1801 Blocked, STR 1404 Blocked, FJ 23 Blocked, RED 4"x6" Blocked	No LPG supply into storage tank	SV 1101 ESD, SV 1201 ESD, SV 1301 ESD, SV 1401 ESD		Constant monitoring of perimeters, Visual and condition check of components	Receiving and Storage (R&S) Division
			HV 1114 Blocked, FJ 01 Blocked, SDV 1104 Failure, HV 1214 Blocked, FJ 05 Blocked, SDV 1204 Failure, HV 1314 Blocked FJ 09 Blocked, SDV 1304 Failure, HV 1414 Blocked, FJ 13 Blocked, SDV 1404 Failure	No Vapour return into Gas Carrier, High Pressure in storage tank	SV 1104 ESD, SV 1204 ESD, SV 1304 ESD, SV 1404 ESD		Constant monitoring of perimeters, Visual and condition check of components	Receiving and Storage (R&S) Division

Study Title: Node 6: Receiving Operation							Sheet: 2 of 2	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		Storage receiving system						
Design Intent:		Material: LPG Source: Meterring station		Destination: Storage Tank Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
2	REVERSE	REVERSE FLOW	Sudden shutdown of Gas Carrier pump, Too high pressure on storage tank lead into back pressure	Back pressure into Gas Carrier	SV 1104 ESD, SV 1204 ESD, SV 1304 ESD, SV 1404 ESD		Constant monitoring of perimeters	Receiving and Storage (R&S) Division
3	MORE	MORE PRESSURE	Too high discharge rate from Gas Carrier	High pressure in pipelines	None Shown		Lower discharge rate from Gas Carrier	Receiving and Storage (R&S) Division
4	MORE	FLOW	*This deviation considered equal to "MORE PRESSURE" deviation*					
5	MORE	MORE TEMPERATURE	*No issue regarding this deviation*					

Study Title: Node 6: Distribution Operation							Sheet: 1 of 1	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		Storage distribution system						
Design Intent:		Material: LPG Source: Meterring station		Destination: Storage Tank Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
1	NO	FLOW	HV 1104 Blocked, SDV 1103 Failure, HV 1204 Blocked, SDV 1203 Failure, HV 1304 Blocked, SDV 1404 Failure	No flow into LPG pumps suction head	SV 1103 ESD, SV 1203 ESD, SV 1303 ESD, SV 1403 ESD		Visudal and condition check before operation	Distribution Division
2	REVERSE	REVERSE FLOW	Back pressure from suction head, false valve opening that lead reverse flow into another tank	Back flow into storage tank, overfilling storage tank	None shown		Recheck the procedure before operation begin	Distribution Division
3	MORE	PRESSURE	Too high suction head rate from LPG pumps, high vapor - liquid ratio in the system	High pressure in system pipelines	None Shown		Recheck the procedure before operation begin	Distribution Division
4	MORE	FLOW	*This deviation considered equal to "MORE PRESSURE" deviation*					
5	MORE	MORE TEMPERATURE	*No issue regarding this deviation*					

Study Title: Node 6: Intertank Operation							Sheet: 1 of 2	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		Storage intertank system						
Design Intent:		Material: LPG Source: Meterring station		Destination: Storage Tank Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
1	NO	NO FLOW	HV 1051 Blocked, CV 1061 Blocked, RED 10"x8" Blocked, SDV 1101 Failure, FJ 02 Blocked, CV 110 Blocked, HV 1103 Blocked, SDV 1201 Failure, FJ 06 Blocked, CV120 Blocked, HV 1203 Blocked, SDV 1301 Failure, FJ 10 Blocked, CV 130 Blocked, HV 1303 Blocked, SDV 1401 Failure, FJ 14 Blocked, CV 140 Blocked, HV 1403 Blocked	No supply LPG into destination tank, No discharge from source tank	None shown		Recheck prosedure before begin operation	Receiving and Storage (R&S) Division
2	REVERSE	REVERSE FLOW	Too high pressure on destination tank, false operation of related components (eg. Valve, pumps, etc)	Back flow into source tank	None shown		Recheck prosedure before begin operation	Receiving and Storage (R&S) Division

Study Title: Node 6: Intertank Operation							Sheet: 1 of 2	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		Storage intertank system						
Design Intent:		Material: LPG Source: Meterring station		Destination: Storage Tank Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
1	NO	NO FLOW	HV 1051 Blocked, CV 1061 Blocked, RED 10"x8" Blocked, SDV 1101 Failure, FJ 02 Blocked, CV 110 Blocked, HV 1103 Blocked, SDV 1201 Failure, FJ 06 Blocked, CV120 Blocked, HV 1203 Blocked, SDV 1301 Failure, FJ 10 Blocked, CV 130 Blocked, HV 1303 Blocked, SDV 1401 Failure, FJ 14 Blocked, CV 140 Blocked, HV 1403 Blocked	No supply LPG into destination tank, No discharge from source tank	None shown		Recheck prosedure before begin operation	Receiving and Storage (R&S) Division
2	REVERSE	REVERSE FLOW	Too high pressure on destination tank, false operation of related components (eg. Valve, pumps, etc)	Back flow into source tank	None shown		Recheck prosedure before begin operation	Receiving and Storage (R&S) Division

<table>
<tr><td colspan="8">Study Title: Node 7</td><td colspan="2">Sheet: 1 of 2</td></tr>
<tr><td colspan="2">Drawing No.:</td><td colspan="6">FTLS-30-DW-C006</td><td colspan="2">Date:</td></tr>
<tr><td colspan="2">Team Composition:</td><td colspan="6"></td><td colspan="2">Meeting Date:</td></tr>
<tr><td colspan="2">Part Considered:</td><td colspan="8">LPG Pumps System</td></tr>
<tr><td colspan="2">Design Intent:</td><td colspan="8">Material: LPG Destination: Pump Suction Operating Temp.: 5-30˚C
Source: Storage Tank Operating Press.: 7- 14 BarG</td></tr>
<tr><td>No.</td><td>Guide Word</td><td>Deviation</td><td>Possible Causes</td><td>Consequences</td><td>Safeguard</td><td>Comments</td><td>Action Required</td><td>Action Allocated</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">NO</td><td rowspan="2">NO FLOW</td><td>HV 1501 Blocked, STR 1104 Blocked, FJ 17 Blocked, RED 4"x 6" Blocked, HV 1601 Blocked, STR 1204 Blocked, FJ 19 Blocked, RED 4"x6" Blocked, HV 1701 Blocked, STR 1304 Blocked, FJ 21 Blocked, RED 4"x6" Blocked, HV 1801 Blocked, STR 1404 Blocked, FJ 23 Blocked, RED 4"x6" Blocked</td><td>No supply into suction head</td><td rowspan="2">PI 1501 & 1502, PI 1601 & PI 1602, PI 1701 & 1702, PI 1801 &1802</td><td rowspan="2"></td><td rowspan="2">Visual and condition check of the components, recheck prosedure before operation begin</td><td rowspan="2">Distribution Division</td></tr>
<tr><td>RED 4"x3" Blocked, FJ 18 Blocked, CV 1501 Blocked, HV 1502 Blocked, RED 4"x3" Blocked, FJ 20 Blocked, CV 1601 Blocked, HV 1602 Blocked, RED 4"x3" Blocked</td><td>No supply LPG into filling point</td></tr>
</table>

Study Title: Node 7							Sheet: 2 of 2	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		LPG Pumps System						
Design Intent:		Material: LPG Source: Storage Tank		Destination: Pump Suction Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
			FJ 22 Blocked, CV 1701 Blocked, HV 1702 Blocked, RED 4"x3" Blocked, FJ 24 Blocked, CV 1801 Blocked, HV 1802 Blocked					
			P-110 Trouble, P-120 Trouble, P-130 Trouble, P-140 Trouble					
2	REVERSE	REVERSE FLOW	False procedure in valve operation	Back flow into storage tank	None shown		procedure check	Distribution Division
3	MORE	MORE PRESSURE	Too high discharge rate of LPG Pumps	High Pressure on the system	PI 1501 & 1502, PI 1601 & PI 1602, PI 1701 & 1702, PI 1801 &1802		Constant monitoring of perimeters	Distribution Division
4	MORE	FLOW	*This deviation considered equal to "MORE PRESSURE" deviation*					
5	MORE	MORE TEMPERATURE	*No issue regarding this deviation*					

Study Title: Node 8							Sheet: 1 of 2	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		LPG Pumps System						
Design Intent:		Material: LPG Source: Discharge LPG Pumps		Destination: Filling Point Operating Press.: 7- 14 BarG		Operating Temp.: 5-30˚C		
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
1	NO	NO FLOW	HV 1011 Blocked, RED 4"x3" Blocked, HV 2604 Blocked, AV 2602 Failure, HV 2609 Blocked, HV 2606 Blocked, HV 2609 Blocked, HV 2509 Blocked, SDV 2502 Failure, HV 2506 Blocked, HV 2509 Blocked, SDV 2401 Blocked, DCV 2401 Failure, HV 2402 Blocked, SDV 2402 Failure, HV 2403 Failure, HV 2301 Blocked, SDV 2301 Failure, HV 2302 Blocked, HV 2303 Blocked, SDV 2201 Failure, SDV 2202 Failure, HV 2203 Blocked, HV 2101 Blocked, SDV 2101 Failure,	No flow into filling point	PI 2102, PI 2401		Constant check of perimeters	Distribution Division

Study Title: Node 8							Sheet: 1 of 2	
Drawing No.:		FTLS-30-DW-C006					Date:	
Team Composition:							Meeting Date:	
Part Considered:		LPG Pumps System						
Design Intent:		Material: LPG Source: Discharge LPG Pumps		Destination: Filling Point Operating Press.: 7- 14 BarG			Operating Temp.: 5-30˚C	
No.	Guide Word	Deviation	Possible Causes	Consequences	Safeguard	Comments	Action Required	Action Allocated
1	NO	NO FLOW	HV 1011 Blocked, RED 4"x3" Blocked, HV 2604 Blocked, AV 2602 Failure, HV 2609 Blocked, HV 2606 Blocked, HV 2609 Blocked, HV 2509 Blocked, SDV 2502 Failure, HV 2506 Blocked, HV 2509 Blocked, SDV 2401 Blocked, DCV 2401 Failure, HV 2402 Blocked, SDV 2402 Failure, HV 2403 Failure, HV 2301 Blocked, SDV 2301 Failure, HV 2302 Blocked, HV 2303 Blocked, SDV 2201 Failure, SDV 2202 Failure, HV 2203 Blocked, HV 2101 Blocked, SDV 2101 Failure,	No flow into filling point	PI 2102, PI 2401		Constant check of perimeters	Distribution Division

CHAPTER 7
FREQUENCY ANALYSIS

7.1. General Description

Frequency analysis are used to identified the probability of the system's components to fail so that the escalation of components failure can lead into hazardous event. The process of frequency analysis are involving two cind of probabilistic factor methods which are Fault Tree Analysis and Event Tree Analysis. Fault tree analysis will identified each component's individual failure frequency that can contribute into system failure. The event tree analysis are induced the assessment from components failure into the event of hazard and it's consequencies such as Jet Fire, Flash Fire, etc. The typical event tree in hydrocarbon handling process especially in LPG facility are shown in Figure 7.1.

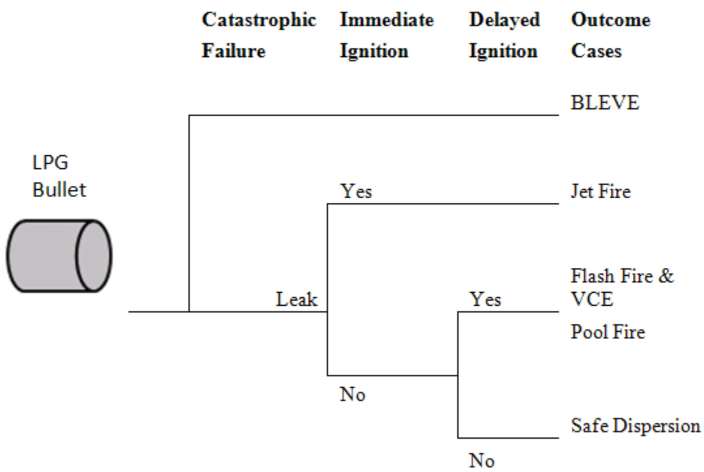

Figure 7.1 Event Tree for LPG Handling (Selvan, 2015)

The components failure frequencies can be derrived from specific source of data. The data can be conduct from previous occurence onsite facility, or similar facility's failure frequency from other places. On this thesis the failure frequencies of the components are conducted from DNV Failure Frequencies Guidelines and OGP (Oil and GAS Producers) Process Release Frequencies. The data source mentioned are for components on the system but not including the storage facility. Since in this thesis the object are including the assesmnet of the storage facility, the storage failure frequencies are conducted from OGP (Oil and Gas Producers) Storage Incident Frequencies.

7.2. Table of Components Failure Frequencies

Table 7.1 Node 1 Failure Frequency

Node 1				Frequencies/Hole Diameters				
No	Equipment	Identification	Size	1-3 mm	3-10 mm	10-50 mm	50-150 mm	>150 mm
1	Hand Valve (Manual)	HV 0010	10"	1,18E-05	5,22E-05	2,26E-05	4,97E-06	4,46E-06
2	Butterfly Valve (Manual)	BV 001	10"	1,18E-05	5,22E-05	2,26E-05	4,97E-06	4,46E-06
3	Shutdown Valve (Actuated)	SDV 001	10"	5,669E-04	1,748E-04	5,238-05	7,46E-06	1,314E-05
4	Control Valve (Actuated)	CV 0001	10"	5,669E-05	1,748E-05	5,238-06	1,00E+00	1,314E-06

Table 7.2 Node 2 Failure Frequency

Node 2				Frequencies/Hole Diameters				
No	Equipment	Identification	Size	1-3 mm	3-10 mm	10-50 mm	50-150 mm	>150 mm
1	Hand Valve (Manual)	HV 0001 HV 003	10"	1,18E-05	5,22E-05	2,26E-05	4,97E-06	4,46E-06
2	Butterfly Valve (Manual)	BV 002	10"	1,18E-05	5,22E-05	2,26E-05	4,97E-06	4,46E-06
3	Shutdown Valve (Actuated)	SDV 003	10"	5,669E-04	1,748E-04	5,238-05	7,46E-06	1,314E-05
4	Control Valve (Actuated)	CV 0002	10"	5,669E-05	1,748E-05	5,238-06	1,00E+00	1,314E-06

Table 7.3 Node 3 Failure Frequency

Node 3				**Frequencies/Hole Diameters**				
No	Equipment	Identification	Size	1-3 mm	3-10 mm	10-50 mm	50-150 mm	>150 mm
1	Hand Valve (Manual)	HV 0008 HV 0006	4"	5,85E-06	2,54E-03	1,12E-06	5,18E-06	0
2	Butterfly Valve (Manual)	BV 004	4"	5,85E-06	2,54E-03	1,12E-06	5,18E-06	0
3	Shutdown Valve (Actuated)	SDV 004	4"	5,487E-04	1,702E-04	5,070E-05	2,026E-05	0
4	Control Valve (Actuated)	CV 0003	4"	5,487E-05	1,702E-05	5,070E-06	2,026E-06	1

Table 7.4 Node 4 Failure Frequency

Node 4				Frequencies/Hole Diameters				
No	Equipment	Identification	Size	1-3 mm	3-10 mm	10-50 mm	50-150 mm	>150 mm
1	Hand Valve (Manual)	HV 0012	4"	5,85E-06	2,54E-03	1,12E-06	5,18E-06	0
2	Butterfly Valve (Manual)	BV 003	4"	5,85E-06	2,54E-03	1,12E-06	5,18E-06	0
3	Shutdown Valve (Actuated)	SDV 0002	4"	5,487E-04	1,702E-04	5,070E-05	2,026E-05	0

Table 7.5 Node 5 Failure Frequency

Node 5				Frequencies/Hole Diameters				
No	Equipment	Identification	Size	1-3 mm	3-10 mm	10-50 mm	50-150 mm	>150 mm
1	Pressure Safety Valve (Actuated)	PSV 1102	6"	5,540E-04	1,70E-04	5,07E-05	2,026E-05	0
		PSV 1102						
		PSV 1201						
		PSV 1202						
		PSV 1301						
		PSV 1302						
		PSV 1401						
		PSV 1402						
2	Storage Tank			2,3E-06	1,2E-06	7,1E-08	4,30E-08	4,70E-07

Table 7.6 Node 6: Receiving Operation Failure Frequency

Node 6: Receiving Operation				**Frequencies/Hole Diameters**				
No	Equipment	Identification	Size	1-3 mm	3-10 mm	10-50 mm	50-150 mm	>150 mm
1	Hand Valve (Manual)	HV 1103	10"	1,163E-04	5,405E-05	2,261E-05	4,968E-06	4,462E-06
		HV 1203						
		HV 1303						
		HV 1403						
		HV 1114	4"	5,85E-06	2,54E-03	1,12E-06	5,18E-06	0
		HV 1214						
		HV 1314						
		HV 1414						
2	Shutdown Valve (Actuated)	SDV 1101	10"	5,669E-04	1,702E-04	5,238-05	7,462E-06	1,314E-05
		SDV 1201						
		SDV 1301						
		SDV 1401						
		SDV 1104	4"	5,487E-04	1,702E-04	5,070E-05	2,026E-05	0
		SDV 1204						
		SDV 1304						
		SDV 1404						
3	Control Valve (Actuated)	CV 110	10"	5,669E-04	1,702E-04	5,238-05	7,462E-06	1,314E-05
		CV 120						
		CV 130						
		CV 140						

Table 7.6 Node 6: Distribution Operation Failure Frequency

Node 6: Distribution Operation				Frequencies/Hole Diameters				
No	Equipment	Identification	Size	1-3 mm	3-10 mm	10-50 mm	50-150 mm	>150 mm
1	Hand Valve(Manual)	HV 1104	12"	8,4E-05	4,3E-05	2,3E-05	6,3E-06	7,8E-06
		HV 1204						
		HV 1304						
2	Shutdown Valve (Actuated)	SDV 1103		3,3E-04	1,4E-04	6,0E-05	1,3E-05	1,8E-05
		SDV 1203						
		SDV 1304						

Table 7.6 Node 6: Intertank Operation Failure Frequency

Node 6: Intertank Operation				**Frequencies/Hole Diameters**				
No	Equipment	Identification	Size	1-3 mm	3-10 mm	10-50 mm	50-150 mm	>150 mm
1	Hand Valve(Manual)	HV 1051	10"	1,163E-04	5,405E-05	2,261E-05	4,968E-06	4,462E-06
		HV 1103						
		HV 1203						
		HV 1303						
		HV 1403						
2	Control Valve(Actuated)	CV 1061		5,669E-04	1,702E-04	5,238-05	7,462E-06	1,314E-05
		CV 110						
		CV 120						
		CV 130						
		CV 140						
3	Shutdown Valve (Actuated)	SDV 1101		5,669E-04	1,702E-04	5,238-05	7,462E-06	1,314E-05
		SDV 1201						
		SDV 1301						
		SDV 1401						

Table 7.6 Node 7 Failure Frequency

Node 7				**Frequencies/Hole Diameters**				
No	Equipment	Identification	Size	1-3 mm	3-10 mm	10-50 mm	50-150 mm	>150 mm
1	Hand Valve(Manual)	HV 1501	6"	6,984E-05	3,032E-05	1,337E-05	2,983E-06	3,047E-06
		HV 1601						
		HV 1701						
		HV 1801						
		HV 1502	4"	5,85E-06	2,54E-03	1,12E-06	5,18E-06	0
		HV 1602						
		HV 1702						
		HV 1802						
2	Control Valve(Actuated)	CV 1501	4"	5,487E-04	1,702E-04	5,070E-05	2,026E-05	0
		CV 1601						
		CV 1701						
		CV 1801						
3	Centrifugal Pump	P 110	6"	4,044e-03	1,432E-03	4,973E-04	8,411E-05	4,276E-05
		P 120						
		P 130						
		P 140						

Table 7.6 Node 8 Failure Frequency

Node 8				Frequencies/Hole Diameters				
No	Equipment	Identification	Size	1-3 mm	3-10 mm	10-50 mm	50-150 mm	>150 mm
1	Hand Valve(Manual)	HV 1011	4"	5,85E-06	2,54E-03	1,12E-06	5,18E-06	0
		HV 2604						
		HV 2609						
		HV 2606						
		HV 2509						
		HV 2506						
		HV 2509						
		HV 2402						
		HV 2403						
		HV 2301						
		HV 2302						
		HV 2303						
		HV 2203						
		HV 2101						
		HV 2103						
2	Shutdown Valve(Actuated)	SDV 2502	4"	5,487E-04	1,702E-04	5,070E-05	2,026E-05	0
		SDV 2401						
		SDV 2402						
		SDV 2301						
		SDV 2201						
		SDV 2101						
3	Control Valve(Actuated)	DCV 2401	4"	5,487E-04	1,702E-04	5,070E-05	2,026E-05	0
		DCV 2401						
		DCV 2101						

7.3. Fault Tree Analysis (FTA)

Fault Tree Analysis is a schematic process that using a diagram to represent the possible outcome start from the most basic event and using logical gateway (eg. AND OR) to lead the analysis into the top event. On this thesis the concern of the components failures are the release frequency since the release lead into gas dispersion, and the escalation of gas dispersion when its ignited will become a fire incident event. So, on this thesis the failure of FTA will be determine as the release of gas from the system.

Since the components failure frequency are already determined in previous subsection the Fault Tree Analysis are giving us the linkage between components failure into system failure, the entire system already divided into subsystem into several nodes, the Fault Tree Analysis give the probability of failure each node, and contribution of each node failure probability into entire system failure probability.

The basic logical gate of FTA can be determined using the AND OR logic the explanation of the logic are explained below:

- Top event
  Top event is a uppermost gate that explain what kind of failure analyzed
- OR gate
  The output event associated with this gate exists if at least one of the input events exists. The mathematical equation for this logic can be represent using:
  $$P(A \cap B) = P(A) \times P(B)$$
- AND gate the output event associated with this gate exists only if all of the input events exist simultaneously. The mathematical equation for this logic can be represent using:
  $$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$
- Basic event
  Basic events are the lowermost event that in the system can occur.

Since the frequency of release frequency are consist of various bore diameter the process of FTA also have to acomodate the various of bore size diameter for every node calculation.

On this thesis the process of Fault Tree Analysis are using Relex Evaluation Software. The software are helping to develop the calculation of the FTA value and also the graphical representation of FTA.

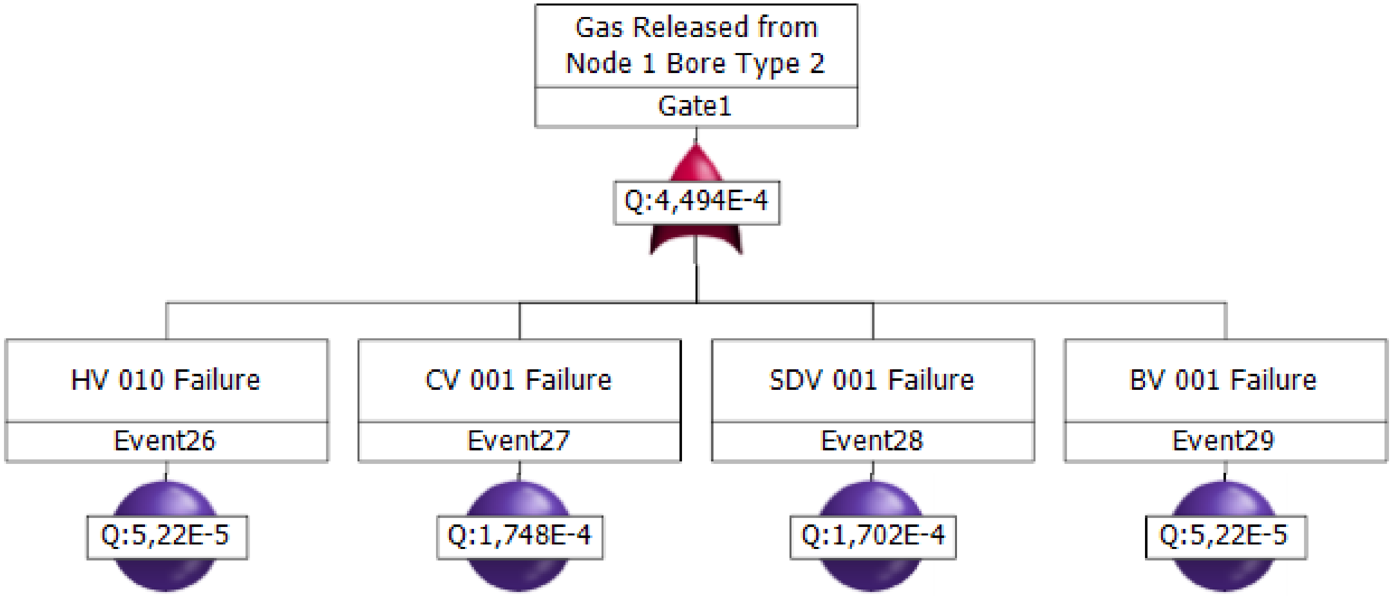

Figure 7,2 FTA Result of Node 5 Bore Size Diameter 50-150 mm

7.3.1. Fault Tree Result Recapitulation

The result of each Node Fault Tree Analysis and its variable of every leak bore size diameter can be seen on Table 7.8.

Table 7.8 Fault Tree Recapitulation

Node	Top Event (Scenario)	Failure Frequency				
		1-3 mm	3-10 mm	10-50 mm	50-150 mm	>150 mm
1	Gas Release	1,157E-4	4,494E-4	1,4996E-4	2,4868E-5	3,52E-5
2	Gas Release	1,169E-4	5,016E-4	1,7256E-4	2,9843E-5	3,966E-5
3	Gas Release	6,177E-4	5,799E-4	1,0364E-4	5,088E-5	0
4	Gas Release	5,557E-4	5,25E-4	5,294E-5	3,062E-5	0
5	Gas Release	3,58762E-15	1,3553E-14	1,36553E-16	2,8656E-21	4,87968E-26
6 Receiving	Gas Release	4,951E-4	1,1738E-3	5,0904E-4	1,5148E-4	6,5946E-5
6 Distribution	Gas Release	2,9376e-14	1,12151e-15	4,74583e-17	1,3874e-19	4,43077e-19
7	Gas Release	4,72596e-10	9,37514e-11	6,86068e-14	7,69633e-10	4,40278e-18
8	Gas Release	3,321e-3	1,6261e-3	3,098e-4	1,5264e-4	0

7.4. Event Tree Analysis

The Event Tree Analysis is a method to predict the probability of certain event. Event tree analyze the intial event and based certain probability will conduct the escalation of the intial event. Since on ths thesis are concerning on fire risk assessment the intial event are gas dispersion which the frequency of gas dispersion derrived from the Fault Tree Analysis. The escalation of gas dispersion will become fire if there is a ignition of fire, the probability of ignition are using the database conducted in Oil and Gas Producers (OGP) Ignition Probability. To calculate the ignition probability the process will need the amount of gas released from the system. Since the frequencies data from Fault Tree Analysis are ranged value, the diameter to be taken to calculate the gas release are using the higher value of range in hole diameter (eg. For range 1-3 mm hole, the gas release amount will be taken from 3 mm hole). The equation to calculate gas release amount are derrived from DNV Failure Frequency guide, the equation are:

$$Qg = Cd\,.A.Po\sqrt{\frac{M\gamma}{RTo}}\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}}$$ (7.1) (DNV, 2014)

Where:

Qg : initial gas release rate (kg/s)
Cd : discharge coefficient
A : hole area (m^2)
Po : initial pressure of gas absolute (N/m^2)
M : molecular weight of gas
γ : ratio specific heats
R : universal gas constant (8314 J/kg mol K)
To : initial temperature of gas (K)

By approximating the gauge pressure to absolute pressure subtituting γ = 1,31, C_D = 0,85 and converting the units of pressure to bar and noting that the units of the diameter are in mm the equation will become:

$$Qg = 1{,}4\;x\;10^{-2}\,.\,d^2.\sqrt{\rho g P g}$$ (7.2) (DNV, 2014)

Where:

Qg : initial gas release rate (kg/s)
ρ_g : initial density of gas (kg/m^2)
P_g : initial pressure of gas (bar gauge)
d : diameter of the hole

To find the gas release, considering the density of LPG Gases are 0,63 and the operational pressure of the Terminal are 13 BarG. The tabulation of gas relase mass at variation of leak hole diameter can be seen on Table 7.9.

Table 7.9 Mass of Gas Release (Oil and Gas Producers, 2013)

No	Hole Diameter (mm)	Mass of Gas Release at higher range of Hole(kg/s)
1	3	3,5190E-3
2	10	3,9100E-2
3	50	9,7750E-1
4	150	8,7975E+0
5	>150	2,5226E+1

The result above then plotted into the ignition probability chart in Figure 7.21 or the process can be done by interpolate the value in between release rate from Table so this process get exact amount of the ignition probability in various leak hole diameter.

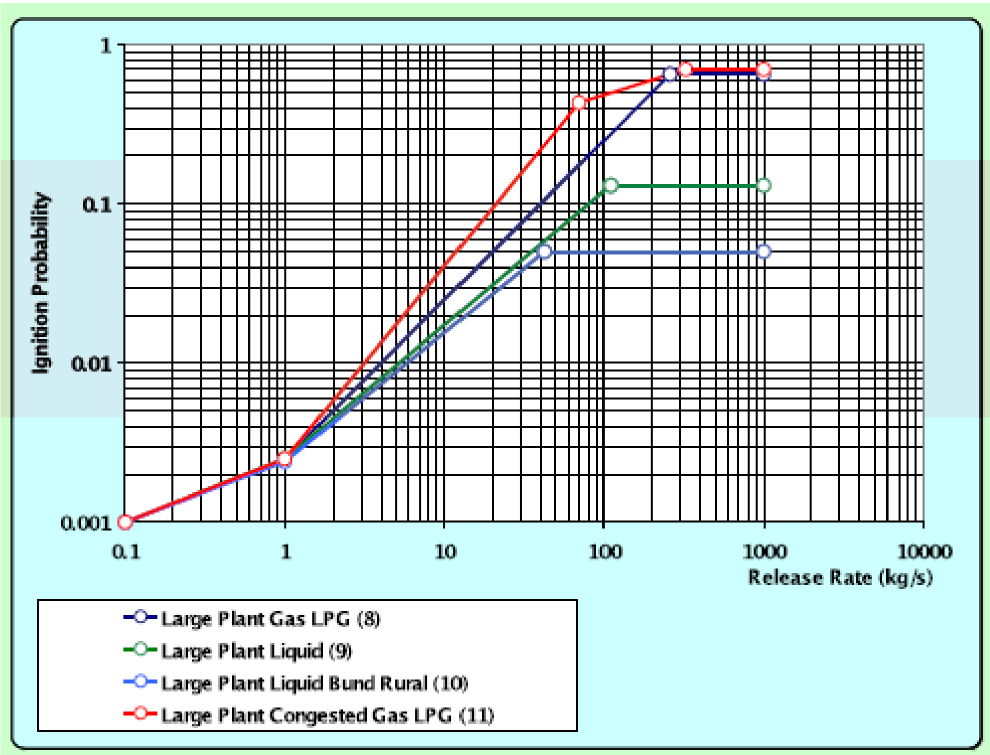

Figure 7.3 Chart of Ignition Probability (Oil and Gas Producers, 2013)

Table 7.10 Ignition Probability For Large LPG Plant (Oil and Gas Producers, 2013)

Release Rate (kg/s)	Ignition Probability
0,1	0,0010
0,2	0,0013
0,5	0,0019
1	0,0025
2	0,0050
5	0,0125
10	0,0250
20	0,0500
50	0,1250
100	0,2500
200	0,5000
500	0,6500
1000	0,6500

(Source: OGP Ignition Probability)

In the Event Tree Analysis the escalation of probability divided into 2 (two) events. The first event are immidiate ignition that will become Jet Fire, or delayed ignition which will become Flash Fire. The probability of every ignition which on will become ignited and which one are not are further explained in Oil and Gas Producers Ignition Probability as seen in Table 7.11.

Table 7.11 Immidiate and Delayed Ignition Probability (Oil and Gas Producers, 2013)

Release Type	Immidiate Igition	Delayed Ignition
Shallow Gas Blowout	0,07	0,11
Deep Blowout	0,09	-
Deep Well Release	0,03	-

From the data listed above now the process can coclude the Event Tree Analysis so the probability of escalated event form each scenario and each variations of leak hole diameters can be determined.

7.4.1. Event Description

The possible event on hydrocarbon material when its released are majorly become fire if there is an ignition. The variable fire event are depends on the environment of the subject and and how the gas released ignite. On this sub section will explained what the possible event that may occur based on the Terminal LPG Semarang condition.

1. Jet Fire
   Jet Fire is occur when there are leak on the pressurized system, so the gas released. The released then immidiately ignite so that the fire form become what so called “jet” so this type of fire called Jet Fire.
2. Flash Fire
   This type of event is occur when the gas released from leaked but not ignite immiediately. The process is delayed until certain time and the gas are reach its saturated point and then ignited. The result are quick fire event and immediately disperse.
3. Explosion
   The event of explosion on Terminal LPG Semarang is not considered because no pipe or storgage are burried in the soil, so that no external pressure that caused the system to be pressed from outside and caused such an explosion.
4. Gas Dispersion
   Dispersion is an event when the gas eak are not ignited at all and just disperse into atmosphere. From the perspective of fire risk the gas dispersion are not dangerous, since the gas dispersion are not contributed into fire event.

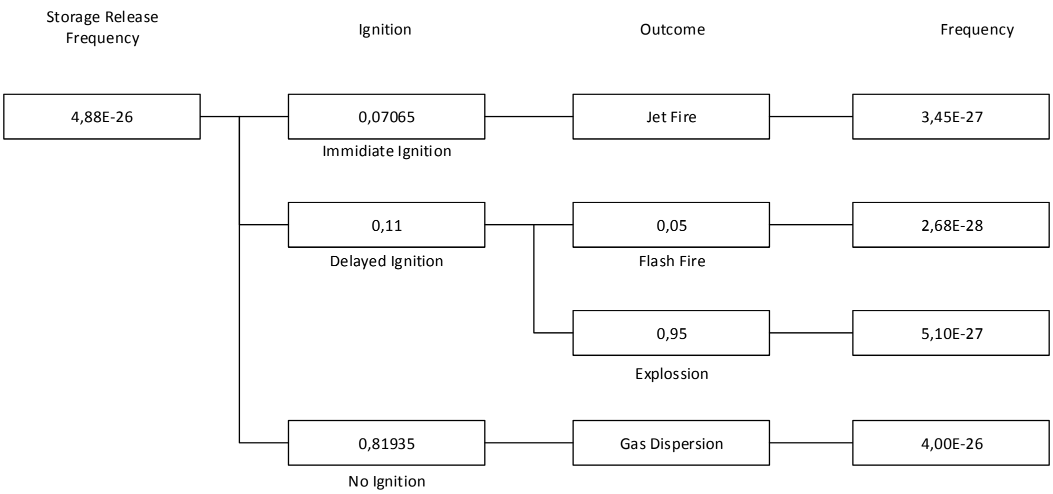

Figure 7.4 Event Tree of Node 5 Bore Size >150 mm

Table 7.12 Recapitulation for Event Frequencies

Node	**Hole Diameter (mm)**	**Scenario Frequencies**			
		Jet Fire	Flash Fire	Explosion	Gas Dispersion
1	3	1,16E-07	1,27E-05	-	1,03E-04
	10	4,49E-07	4,94E-05	-	4,00E-04
	50	3,71E-07	1,65E-05	-	1,33E-04
	150	4,60E-07	2,74E-06	-	2,17E-05
	>150	2,49E-06	3,87E-06	-	2,88E-05
2	3	1,17E-07	1,29E-05	-	1,04E-04
	10	5,02E-07	5,52E-05	-	4,46E-04
	50	4,27E-07	1,90E-05	-	1,53E-04
	150	5,52E-07	3,28E-06	-	2,60E-05
	>150	2,80E-06	4,36E-06	-	3,25E-05
3	3	6,18E-07	6,79E-05	-	5,49E-04
	10	5,80E-07	6,38E-05	-	5,16E-04
	50	2,56E-07	1,14E-05	-	9,20E-05
	150	9,42E-07	5,60E-06	-	4,43E-05
	>150	0	0	-	0
4	3	5,56E-07	6,11E-05	-	4,94E-04
	10	5,25E-07	5,78E-05	-	4,67E-04
	50	1,31E-07	5,82E-06	-	4,70E-05
	150	5,67E-07	3,37E-06	-	2,67E-05
	>150	0	0	-	0
5	3	3,59E-18	1,97E-17	3,75E-16	3,19E-15
	10	1,36E-17	7,45E-17	1,42E-15	1,20E-14
	50	3,38E-19	7,51E-19	1,43E-17	1,21E-16
	150	5,30E-23	1,58E-23	2,99E-22	2,50E-21
	>150	3,45E-27	2,68E-28	5,10E-27	4,00E-26

Continued from previous Table

Node	**Hole Diameter (mm)**	**Scenario Frequencies**			
		Jet Fire	Flash Fire	Explosion	Gas Dispersion
6 Receiving	3	4,95E-07	5,45E-05	-	4,40E-04
	10	1,17E-06	1,29E-04	-	1,04E-03
	50	1,26E-06	5,60E-05	-	4,52E-04
	150	2,80E-06	1,67E-05	-	1,32E-04
	>150	4,66E-06	7,25E-06	-	5,40E-05
6 Distributio n	3	2,94E-17	3,23E-15	-	2,61E-14
	10	1,12E-18	1,23E-16	-	9,97E-16
	50	1,17E-19	5,22E-18	-	4,21E-17
	150	2,57E-21	1,53E-20	-	1,21E-19
	>150	3,13E-20	4,87E-20	-	3,63E-19
7	3	4,73E-13	5,20E-11	-	4,20E-10
	10	9,38E-14	1,03E-11	-	8,33E-11
	50	1,70E-16	7,55E-15	-	6,09E-14
	150	1,42E-11	8,47E-11	-	6,71E-10
	>150	3,11E-19	4,84E-19	-	3,61E-18
8	3	3,32E-06	3,65E-04	-	2,95E-03
	10	1,63E-06	1,79E-04	-	1,45E-03
	50	7,66E-07	3,41E-05	-	2,75E-04
	150	2,83E-06	1,68E-05	-	1,33E-04
	>150	0	0	-	0

CHAPTER 8
CONSEQUENCES ANALYSIS

8.1. General Description

The process of Quantitative Risk Assessment is including the consequnces analysis to determine the effect of the described scenario in frequencies analysis into the people in the surrounding area or so called the societal risk. On this assessment case the major concern is how the fire will behave based on certain site/facility parameters and its location into the people or the workers around the site. The process of consequences analysis on this thesis is using Process Hazard Analysis Software Tools that will provide visual modelling of how big the affected area and the probable severity effect into the workers of Terminal LPG Semarang based on certain parameters. The process on consequences analysis also need to determine the receiver area of the possible incident and the amount of people covered on those area.

8.2. Receiver Determination

Receiver is a point to determine a place to conduct the consequences modelling. Since the previous system and area dtermination in nodes mode have too big coverage area the receiver determination will emphasize on the higher concentration of worker in every node or area. The amount of worker in the receiver later will become the platform to determine the fatality number of the hazard. The complete table of the receiver and amount of worker contained in those receiver can be seen on the Table 8.1.

Table 8.1. Receiver Determination

Receiver	Location	Corresponding Node	Amount of worker(s)
1	Marine Loading Arm area and control station	1	6
2	Meterring Station	2	2
3	Storage Area (V110, V120, V130, V140	5	5
4	Storage Area System	6	5
5	Office and Control Room	5	25
6	Warehouse	5	4
7	Pump House	7	1
8	Powerhouse	6	2
9	Filling Shed	8	15
10	Skid Tank Parking Area	8	20

8.3. Consequences Modelling of Jet Fire using Process Hazard Analysis Software Tool

Jet Fire hazard occur when the leak from pipeline or containtment immediately ignited and create an fire in such a “jet” form. The consequences modelling later will be analyzed into the number of people affected in the receiver area and will be platform to determine the level of the risk based on the Hazard’s Level of Concern (LOC) on this thesis using Process Hazard Analysis Software Tools the program can determine the Level of Concern (LOC) as our need. The Level of Concern (LOC) for jet fire are determined by jet fire intensity radiation which are: 25 kW/m^2, 35 kW/m^2, and 45 kW/m^2, This Level of Concern are determined based on communication with Head of HSE departement at Terminal LPG Semarang refer to their policy and ease the process to determination in risk representation using comapany risk matrix. The visual representation of Jet Fire heat intensity radiation can be seen on Figure 8.1. The complete result for consequences modelling can be found on Appendix 6.

Heat Intensity Radiation Area for Jet Fire

25 kW/m^2

35 kW/m^2

45 kW/m^2

Figure 8.1. Jet Fire Consequences on Jetty and MLA for Leak Scenario 150 mm

The complete data recapitulation of jet fire at every receiver and leak scenario can be seen at Table 8.2.

Table 8.2. Consequences Datasheet for Jet Fire

Consequences Data For Jet Fire			Consequences Datasheet				
No.	Receiver	Leak Bore Diameter (mm)	Corresponding Node	No. Of People	Heat Intensity Radius (m)		
					25 kw/m2	35 kw/m2	45 kw/m2
1	Jetty & MLA	3	1	6	-	-	-
		10			10,03	7,48	-
		50			36,83	27,16	17,82
		150			82,59	57,13	35,82
2	Metering Station	3	2	2	-	-	-
		10			10,03	7,48	-
		50			36,83	27,16	17,82
		150			82,59	57,13	35,82
3	Storage Area V110	3	5	5	-	-	-
		10			10,03	7,48	-
		50			36,83	27,16	17,82
		150			82,59	57,13	35,82
4	Storage Area V120	3	5	5	-	-	-
		10			10,03	7,48	-
		50			36,83	27,16	17,82
		150			82,59	57,13	35,82
5	Storage Area V130	3	5	5	-	-	-
		10			10,03	7,48	-
		50			36,83	27,16	17,82
		150			82,59	57,13	35,82
6	Storage Area V140	3	5	5	-	-	-
		10			10,03	7,48	-
		50			36,83	27,16	17,82
		150			82,59	57,13	35,82
7	Storage Area System	3	6	5	-	-	-
		10			10,03	7,48	-
		50			36,83	27,16	17,82
		150			82,59	57,13	35,82
8	Office and Control Room	3	5	25	-	-	-
		10			-	-	-
		50			-	-	-
		150			-	-	-
9	Warehouse	3	5	4	-	-	-
		10			-	-	-
		50			-	-	-
		150			-	-	-
10	Pump house	3	7	1	-	-	-
		10			10,98	7,48	-
		50			34,25	24,85	13,54
		150			80,72	51,11	29,76
11	Powerhouse	3	6	2	-	-	-
		10			-	-	-
		50			-	-	-
		150			51,75	48,06	-
12	Filling Shed	3	8	15	-	-	-
		10			10,98	7,48	-
		50			34,25	24,85	13,54
		150			80,72	51,11	29,76
13	Skid Tank Parking Area	3	8	20	-	-	-
		10			-	-	-
		50			-	-	-
		150			21,34	-	-

8.4. Consequences Modelling of Flash Fire using Process Hazard Analysis Software Tools

Flash Fire hazard is occur when leak from containtment or pipe and not immediately ignited (delayed). The saturated concentration of LPG that been released than later burnt create quick or flash ignition of flames. On the Process Hazard Analysis Software Tools the coverage of Flash Fire area are deternined using the envlope of gas released that contained in the air that ignited. In this case the Level of Concern of content of the gas released are 8.000 ppm and 17.000 ppm. During the events of flash fire the area coverage of flash fire area not affceted much by wind direction since the flash fire occurence typically occur at one point at time and not continously happend so the envelope of coverage area will only shown the circle pattern without The depiction of Flash Fire envelope can be seen on Figure 8.2.

To predict the radiation effects from burning vapour cloud it is necessary to know the size and shape of the fire, position, the radioactive properties of the flame and how these factors vary with time. There are no fundamental theoritical models available to evaluate this. A model that accurately represent all the features that have been observed experimentally would be very complex. Fortunately for determination of hazard zone beyond the cloud boundary caused by thermal radiation from a cloud fire may not be primary significance. This is because the size of flammable hazard zone is essential determined by the size of the cloud, which can be calculated fwom vapour dispersion model. Thats why on the risk representation of flash fire on this research are shown in ppm unit, which measure the content of gas vapour content on the air that potentially become flash fire, or in the modelling would be mentioned as flash fire envelope.

The complete result for consequences modelling can be found on Appendix 6.

Flash Fire Envlope

8.000 ppm

17.000 ppm

Figure 8.2. Flash Fire Envelope for Storage Tank for leak scenario 50 mm

The complete recapitulation Table for Flash Fire Envelope can be seen on Table 8.3.

8.4.1. Conversion of Flash Fire Envelope Into Heat Intensity

The outcome from consequence modelling only shows the envelope of potential flammable gas conten being released. The consequences in other hand it eed the severity level to be determined in a depiction that can be converted ito severity of individual loss.

Eventhough the theoritical fundamental to calculate the heat release has not developed yet to determine the level of heat released intensity, the simple approach to calculate the heat released can be addopted. The approach is to convert the content of LPG in the air into mass and then calculate the heat release from the heating value. The calculation of the conversion can be seen below:

Where:

Density of air	= *1,644 kg/m*^{3}
1 ppm	= *1 mg/kg*
1,644 kg of air contains	= *1,644 x 10*$^{-6}$ *kg of LPG*
Heating Value of LPG	= *46.011,448 kJ/kg*
Level of LPG Content	= *8.000 ppm = 0,013312 kg*
	17.000 ppm = 0,027948 kg
Heat Release	= *NHV of LPG x mass content of LPG*

So,

Heat Release of 8.000 ppm LPG

Q = 0,013312 x 46.011,448 = 4,286058 kW/m^3

Heat Release of 17.000 ppm LPG

Q = 0,027948 x 46.001,448 = 9,107874 kW/m^3

After the conversion of the Flash Fire Envelope modelling the risk representation will be the heat release amount that will be plotted into severity index. The further explanation of severity index of Flash Fire can be seen on Table 9.2. After the conversion the modelling result will further considered as heat radiation.

Table 8.3. Consequences Datasheet for Flash Fire

Consequences Data For Flash Fire **Consequences Datasheet**

No.	Receiver	Leak Bore Diameter (mm)	Corresponding Node	No. Of People	Gas Content Radius (m)	
					8000 ppm	17000 ppm
1	Jetty & MLA	3	1	6	1,2	0,5
		10			4,03	1,83
		50			14,38	8,42
		150			15,94	9,5
2	Metering Station	3	2	2	1,2	0,5
		10			3,71	1,81
		50			14,38	8,42
		150			15,94	9,5
3	Storage Area V110	3	5	5	1,2	0,5
		10			3,71	1,81
		50			20,51	9,19
		150			59,19	32,68
4	Storage Area V120	3	5	5	1,2	0,5
		10			3,71	1,81
		50			20,51	9,19
		150			59,19	32,68
5	Storage Area V130	3	5	5	1,2	0,5
		10			3,71	1,81
		50			20,51	9,19
		150			59,19	32,68
6	Storage Area V140	3	5	5	1,2	0,5
		10			3,71	1,81
		50			20,51	9,19
		150			59,19	32,68
7	Storage Area System	3	6	5	1,2	0,5
		10			4,03	1,83
		50			14,38	8,42
		150			15,94	9,5
8	Office and Control Room	3	5	25	-	-
		10			-	-
		50			-	-
		150			-	-
9	Warehouse	3	5	4	-	-
		10			-	-
		50			-	-
		150			-	-
10	Pump house	3	7	1	1,17	0,53
		10			3,91	1,87
		50			8,85	5,38
		150			9,21	5,65
11	Powerhouse	3	6	2	-	-
		10			-	-
		50			-	-
		150			-	-
12	Filling Shed	3	8	15	1,17	0,53
		10			3,91	1,87
		50			8,85	5,38
		150			9,21	5,65
13	Skid Tank Parking Area	3	8	20	-	-
		10			-	-
		50			-	-
		150			-	-

8.5. Consequences Modelling of Explosion using Process Hazard Analysis Tools Sofware

The explosion considered is Vapour Cloud Explossio which may occur only in storage tank which involve pressure vessels that contained the most LPG on the terminal make the storage tank the only facility with possible explosion hazard. The Level of Concern of the explosion using Process Hazard Analysis Software Tools are determined using the amount of pressure at corresponding radius from the center of the explosion. The value of corresponding explosion based on the modelling are 0,2 bar, 1,3 bar, and 2,0 bar. Same as flash fire the explosion envelope on the modelling will not shows any affection by the winds, since the explosion typically only occur once at a time and not affected by time function variable. The visual depiction of the explosion radiation zone can be seen on Figure 8.3. The complete result for consequences modelling can be found on Appendix 6.

Explosion Pressure

0,2 bar

1,3 bar

2,0 bar

Figure 8.3. Explosion Zone of Storage Tank for Leak Scenario 50 mm

The complete recapitulation for explosion hazard can be seen on Table 8.4.

Table 8.4. Consequences Datasheet for Explosion

Consequences Data For Explosion **Consequences Datasheet**

No.	Receiver	Leak Bore Diameter (mm)	Corresponding Node	No. Of People	Explosion Radius (m)		
					0,2 bar	1,3 bar	2,0 bar
1	Jetty & MLA	3	1	6	-	-	-
		10			-	-	-
		50			-	-	-
		150			-	-	-
2	Metering Station	3	2	2	-	-	-
		10			-	-	-
		50			-	-	-
		150			-	-	-
3	Storage Area V110	3	5	5	7,84	2,77	2,37
		10			21,937	6,42	5,19
		50			61,02	16,58	13,06
		150			99,25	26,44	20,68
4	Storage Area V120	3	5	5	7,84	2,77	2,37
		10			21,937	6,42	5,19
		50			61,02	16,58	13,06
		150			99,25	26,44	20,68
5	Storage Area V130	3	5	5	7,84	2,77	2,37
		10			21,937	6,42	5,19
		50			61,02	16,58	13,06
		150			99,25	26,44	20,68
6	Storage Area V140	3	5	5	7,84	2,77	2,37
		10			21,937	6,42	5,19
		50			61,02	16,58	13,06
		150			99,25	26,44	20,68
7	Storage Area System	3	6	5	-	-	-
		10			-	-	-
		50			-	-	-
		150			-	-	-
8	Office and Control Room	3	5	25	-	-	-
		10			-	-	-
		50			-	-	-
		150			-	-	-
9	Warehouse	3	5	4	-	-	-
		10			-	-	-
		50			-	-	-
		150			-	-	-
10	Pump house	3	7	1	-	-	-
		10			-	-	-
		50			-	-	-
		150			-	-	-
11	Powerhouse	3	6	2	-	-	-
		10			-	-	-
		50			-	-	-
		150			-	-	-
12	Filling Shed	3	8	15	-	-	-
		10			-	-	-
		50			-	-	-
		150			-	-	-
13	Skid Tank Parking Area	3	8	20	-	-	-
		10			-	-	-
		50			-	-	-
		150			-	-	-

CHAPTER 9
RISK REPRESENTATION

9.1. General

The risk assessment usually will represent its level of risk by using the risk mapping method the commony used are F/N Curve which shows the number of fatality and its frequency, and another one is risk matrix which depend on which aspect that shall be plotted based on the axis of the matrix. On this thesis the application of risk representatio is using company (Terminal LPG Semarang) risk matrix since Terminal LPG Semarang has develop their own risk criteria in the purpose to determine the level of risk of activity on the terminal. The company risk matrix can be seen on the Figure 9.1.

RISK LEVEL						
LIKELIHOOD	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
SCALE		1	2	3	4	5
		SEVERITY CONSEQUENCES				

Figure 9.1. Company Risk Matrix

The risk matrix of Terminal LPG Semarang shows the level of severity and likelihood. The level of lkelihood can be determined using the frequency of possible hazard that have been calculated on ETA on the previous chapter. The level of severity are determined based on variation of the impact based on hazard radius in the consequences modelling and then transferred into lost of workdays of the workers affected by the hazard. Because every hazard for example Jet Fire has different intensity radiation, every hazard have its variatio in the severity level. To validate the risk level the radiatio then plotted into the possible people suffered per receiver location. For example the jet fire hazard at 45 kW/m^2 have the severity level of 4 (four) in the risk matrix so it shall be classified as high risk level, but since the radiation zone of 45 kW/m^2 is rather a small radius its possily that that level of intensity may not affected any people or workers. So, as the purpose to validate the risk level the number of people affected in the receiver need to be consider. As the consideration the risk representation has limitation such as the hazard of Jet Fire at 3 mm leak size diameter can not be represented because the 3 mm leak can not modelled using Process Hazard Analysis Software Tools because the limit to model the consequences since the effect may be very small to depicted. So note that in risk representationi there will be no risk representation for Jet Fire leak 3 mm scenario. Another things to consider is that since the level of severity may be not accurately describe the outcome the process of determining the severity level has been conducted by communicating with the Terminal LPG Semarang. The complete risk representation for each scenario can be seen at Table below. Another think to consider that in company risk matrix the likelihood axis have the most likely event is at once at 10 years or so that considered 1 x 10^{-1} frequency. It makes the scenarion on the assesment determined as

For consideration the various level of severity based on the scenario can be seen on Table 9.1, 9.2. and 9.3 meanwhile the complete descriptive explanation of the risk matrix can be found on chapter 4.3.2.

Table 9.1. Jet Fire Severity Index

Jet Fire Severity Index	
Level of Concern	**Severity Level**
25 kW/m^2	1
35 kW/m^2	3
45 kW/m^2	4

Table 9.2. Flash Fire Severity Index

Flash Fire Severity Index	
Level of Concern	**Severity Level**
4,286058 kW/m^3	1
9,107874 kW/m^3	3

Table 9.3. Explosion Severity Index

Explosion Severity Index	
Level of Concern	**Severity Level**
0,2 bar	1
1,3 bar	3
2,0 bar	4

9.2. Risk Representation of Jet Fire

The risk representation of Jet fire usig company risk matrix can be seen on Table 9.1. Table 9.1. shows the risk representation for 150 mm leak Jet Fire scenario. The Acceptable status means the scenario is in low risk area, ALARP status means the scenario located in medium risk area, and Tolerable status indicates that risk may located in hugh risk area but have no possible people affected. Further the Jet fire hazard will be concern of the mitigation since the Jet Fire has the most excalation effect due to its occurence, not like other hazard (Flash Fire and Explosion) which its occurences only take few seconds when its happened so there is no possible excalation, meanwhile Jet Fire can occur up to several minutes even hours, that possibly creates further impact. The risk representation for 150 mm leak Jet Fire Scenario can be seen on Table 9.4. and the complete risk representation of Jet Fire can be found on Appendix 7.

9.3. Risk Representation of Flash Fire

The risk representation of flash fire only consist of two severity level based on the LPG content in the air that will ignited as flash fire envelope. The Level of concern of content are 8.000 ppm and 17.000 ppm. The Level of concern 8.000 ppm would considered as medium risk in the severity index and 17.000 ppm considered as high risk. The risk representation for 150 mm leak Flash Fire scenario can be seen on Table 9.5. and the complete result for Flash Fire risk representation can be seen on Appendix 7.

9.4. Risk Representation of Explosion

Explosion one of the concerned hazard since it is the most lethal of the hazard. The severity of the explosion hazard are based on the pressure caused by the explosion the Level of Concern caused by explosion hazard are 2 bar, 13 bar and 20 bar. The sevirty index caused by the explosion are already dtermined in Table 9.3. The risk representation of 150 mm lek explosion scenarion can be seen on Table 9.6. And the complete recapitulation of all scenarios of explosion ca be seen on Appendix 7.

Table 9.4. Risk Representation for Jet Fire 150 mm Leak Scenario

Category: Jet Fire Bore Diameter 150 mm

No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty MLA	1	4,60E-07	25 kw/m2	82,59	1	1	1	6	NO
				35 kw/m2	57,13	3	1	3	6	NO
				45 kw/m2	35,82	4	1	4	6	YES
2	Metering Station	2	5,52E-07	25 kw/m2	82,59	1	1	1	2	NO
				35 kw/m2	57,13	3	1	3	2	NO
				45 kw/m2	35,82	4	1	4	2	YES
3	Storage Area V110	5	5,30E-23	25 kw/m2	82,59	1	1	1	5	NO
				35 kw/m2	57,13	3	1	3	5	NO
				45 kw/m2	35,82	4	1	4	5	YES
4	Storage Area V120	5	5,30E-23	25 kw/m2	82,59	1	1	1	5	NO
				35 kw/m2	57,13	3	1	3	5	NO
				45 kw/m2	35,82	4	1	4	5	YES
5	Storage Area V130	5	5,30E-23	25 kw/m2	82,59	1	1	1	5	NO
				35 kw/m2	57,13	3	1	3	5	NO
				45 kw/m2	35,82	4	1	4	5	YES
6	Storage Area V140	5	5,30E-23	25 kw/m2	82,59	1	1	1	5	NO
				35 kw/m2	57,13	3	1	3	5	NO
				45 kw/m2	35,82	4	1	4	5	YES
7	Storage Area System	6	2,80E-06	25 kw/m2	82,59	1	1	1	5	NO
				35 kw/m2	57,13	3	1	3	5	NO
				45 kw/m2	35,82	4	1	4	5	YES
8	Office and Control Room	5	5,30E-23	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
9	Warehouse	5	5,30E-23	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
10	Pump house	7	1,42E-11	25 kw/m2	80,72	1	1	1	1	NO
				35 kw/m2	51,11	3	1	3	1	NO
				45 kw/m2	29,76	4	1	4	1	YES
11	Powerhouse	6	2,80E-06	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
12	Filling Shed	8	2,83E-06	25 kw/m2	80,72	1	1	1	15	NO
				35 kw/m2	51,11	3	1	3	15	NO
				45 kw/m2	29,76	4	1	4	15	yes
13	Skid Tank Parking Area	8	2,83E-06	25 kw/m2	21,34	1	1	1	20	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO

Table 9.5. Risk Representation for Flash Fire 150 mm Leak Scenario

Category: Flash Fire Bore Diameter 150 mm										
No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty & MLA	1	2,74E-06	4,286 kW/m3	15,94	3	1	3	6	NO
				9,107 kW/m3	9,5	4	1	4	6	YES
2	Metering Station	2	3,28E-06	4,286 kW/m3	15,94	3	1	3	2	NO
				9,107 kW/m3	9,5	4	1	4	2	YES
3	Storage Area V110	5	1,58E-23	4,286 kW/m3	59,19	3	1	3	5	NO
				9,107 kW/m3	32,68	4	1	4	5	YES
4	Storage Area V120	5	1,58E-23	4,286 kW/m3	59,19	3	1	3	5	NO
				9,107 kW/m3	32,68	4	1	4	5	YES
5	Storage Area V130	5	1,58E-23	4,286 kW/m3	59,19	3	1	3	5	NO
				9,107 kW/m3	32,68	4	1	4	5	YES
6	Storage Area V140	5	1,58E-23	4,286 kW/m3	59,19	3	1	3	5	NO
				9,107 kW/m3	32,68	4	1	4	5	YES
7	Storage Area System	6	1,67E-05	4,286 kW/m3	59,19	3	1	3	5	NO
				9,107 kW/m3	32,68	4	1	4	5	YES
8	Office and Control Room	5	1,58E-23	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
9	Warehouse	5	1,58E-23	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
10	Pump house	7	8,47E-11	4,286 kW/m3	9,21	3	1	3	1	NO
				9,107 kW/m3	5,65	4	1	4	1	YES
11	Powerhouse	6	1,67E-05	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
12	Filling Shed	8	1,68E-05	4,286 kW/m3	9,21	3	1	3	15	NO
				9,107 kW/m3	5,65	4	1	4	15	YES
13	Skid Tank Parking Area	8	1,68E-05	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO

Table 9.6. Risk Representation for Explosion 150 mm Leak Scenario

Category: Explosion Bore Diameter 150 mm

No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty MLA	1	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
2	Metering Station	2	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
3	Storage Area V110	5	2,99E-22	0,2 bar	99,25	1	1	1	5	NO
				1,3 bar	26,44	3	1	3	5	NO
				2,0 bar	20,68	4	1	4	0	NO
4	Storage Area V120	5	2,99E-22	0,2 bar	99,25	1	1	1	5	NO
				1,3 bar	26,44	3	1	3	5	NO
				2,0 bar	20,68	4	1	4	0	NO
5	Storage Area V130	5	2,99E-22	0,2 bar	99,25	1	1	1	5	NO
				1,3 bar	26,44	3	1	3	5	NO
				2,0 bar	20,68	4	1	4	0	NO
6	Storage Area V140	5	2,99E-22	0,2 bar	99,25	1	1	1	5	NO
				1,3 bar	26,44	3	1	3	5	NO
				2,0 bar	20,68	4	1	4	0	NO
7	Storage Area System	6	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
8	Office and Control Room	5	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
9	Warehouse	5	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
10	Pump house	7	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
11	Powerhouse	6	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
12	Filling Shed	8	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
13	Skid Tank Parking Area	8	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-

CHAPTER 10
MITIGATION AND PRE FIRE PLANNING

10.1. General

The mitigation and pre fire planning is one effort to minimize the risk. On this thesis which fire hazard become concern one way to minimize the effect is by analyze the parametrics requirement to extinguish the fire that may occur. One fire hazard that become major concern is a Jet Fire since Jet Fire is one hazard that last longer than other fire hazard which only last few second. Another reason why Jet Fire is one of the major concern is that Jet Fire is the most appealing fire risk hazard that occur in most facility handling in hydrocarbon gases such as LPG.

The process to analyze the requirement to extinguish the fire are to calculate the possible outcome caused by Jet Fire such as: the heat flux, radiation zone, fire temperature, etc. The next step is to calculate extinguisher requirement based on the fire outcome. The detailed process of determining the pre fire planning are further will explained on this chapter.

10.2. Fire Fighting Specification of Terminal LPG Semarang

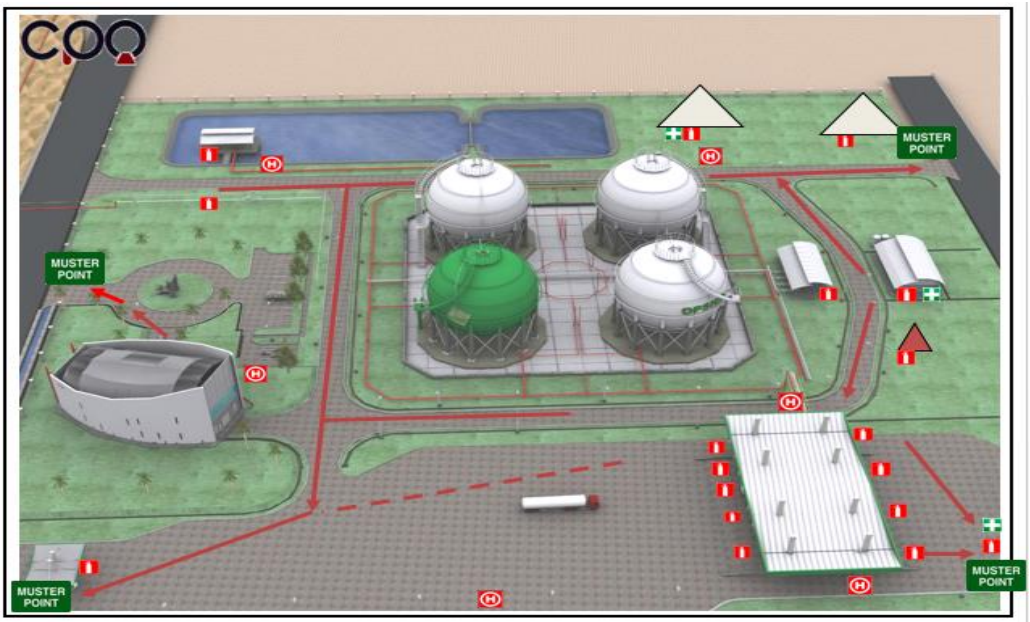

Figure 10.1. Location of the Fire Extinguisher at Terminal LPG Semarang

Terminal LPG Semarang is equiped with various apparatus to extinguish such as fire incident. In this subchapter will provide detailed information about Terminal LPG Semarang's fire fighting facility. The brief data of the main extinguisher can be seen on Table 10.1., meanwhile the detailed information of the fire extinguisher facility can be found on Appendix 3. Besides analyze the requiement for fire extinguisher, Pre Fire Planning also analyze the reachability of the possible receiver with higher risk into a fire hose which can be seen on Figure 10.1.

10.3. Calculation of Auxilliary Cooling for Storage Tank

The regulation regarding the requirement for fire extinguising apparatus mainly comes from NFPA (National Fire Protection Agency) regulation. The auxilliary cooling has function as cooleing agent for storage tank in case one or more tanks is burnt, it will prevent the fire to affect another tank, and to prevent the escalation of the effect. For auxilliary cooling of storage tank the regulation is stated on NFPA 15: Standard for Water Spray Fixed System for Fire Protection. The NFPA 15 regulate the specific water spray system density over the area covered. The Table that regulate the specification of the spray stated on the Table 7.4.3.4.3. NFPA 15 as can be seen on Table 10.1.

Table 10.1. Density requirement for Fire Protection (NFPA, 2007)

Number of Rack Levels	**Plan View Density at Lowest Level**		**Plan View Density at Upper Level(s)***		**Levels Requiring Nozzels**
	gpm/ft^2	**$(L/min)/m^2$**	**gpm/ft^2**	**$(L/min)/m^2$**	
1	0,25	10,2	N/A	N/A	All
2	0,20	8,2	0,15	6,1	All
3, 4, or 5	0,20	8,2	0,15	6,1	Alternate
6 or more	0,20	8,2	0,10	4,1	Alternate

*The table values contemplate exposure from spill fire.

From the Table above, since Terminal LPG Semarang has 6 rack of water spray it stated that the density requirement for storage tank of Terminal LPG Semarang are 0,20 gpm/ft^2 or 8,2 $(L/min)/m^2$.

To calculate the total amount of the required capacity it need to be calculate the surface area of the storage tank. Since the storage tank at Terminal LPG Semarang with the diameter of 21,9 m, it can be determined using formula of spherical surface area which:

$$A = 4\,\pi r^2 \qquad (10.1)$$

Where:

A = Surface area of Sphere

r = radius of the sphere = 10,95 m

So, it obtaiined that the surface area of the tank are:

$$A = 4 \,.\, 3{,}14 \,.\, 10{,}95^2$$
$$= 1505{,}975\ m^2$$
$$= 16201{,}89\ ft^2$$

From the surface area of the spherical tank surface area and the water density requirement now the capacity of the fire pump can be conducted. The capacity of the fire pump is considered to accomodate 4 (four) storage tanks.

The total pump capacity to serve the storage tanks can be calculated by accumulate the total of surface area times with the water density requirement.

$$\text{Total Pump Capacity} = \text{Density Requirement} \,.\, \text{Surface area of the tank}$$
$$= 0{,}25\ gpm/ft^2 \,.\, 16201\ ft^2$$
$$= 3240{,}377\ gpm/tank$$

From the requirement for each tank from the result it can obtain the requirement for each scenaio on which tank may burn and calculate the total requirement of the auxilliary cooling for each scenario. The typical occurence regarding the fire in the storage tank is that one tank burnt and makes another tank need auxilliary cooling as a prevention of the unburnt tank tonot occur a higher pressure caused by increasing of the temperature.

Another think to consider during auxilliary cooling process is the compliance of the water supply. As in the Terminal LPG Semarang the water supply for fire extinguisher are internally supplied by water pond inside the terminal. In the NFPA 15 Chapter A.4.4.8. that it is the requirement for auxilliary cooling is atleast cover the operation for 4 (four) hours as the regulation stated:

"It is desirable to contain runoff for the anticipated duration of any fire. However, in large chemical or petrochemical facilities, a major fire can last for 8 hours or more, resulting in extremely large holding basins or retention ponds. Where the anticipated incident duration results in retention basins that are of impractical size, methods to limit the duration of runoff might be required.

When an extended duration is anticipated, a duration of 4 hours is usually considered the practical maximum. During that time, it is often possible to isolate equipment and reduce the flow rate of water and other materials so that the continuous discharge flow rate is less than the initial flow rate. If a significant amount of flammable materials can be removed from the protected area, it could be possible to shut down water spray systems and manually fight the fire, greatly reducing the amount of material that needs to be contained (NFPA, 2007)."

Based on the requirement and calculation mentioned above the complete recapitulation for auxilliary cooling can be seen on table 10.2.

Table 10.2. Recapitulationi for Auxilliary Cooling Scenario

No.	Tank Identification	Burnt Tank Scenario	Diameter (m)		Surface Area (m2)		Auxiliary Cooling Requirement	
			m	ft.	m2	ft2	gpm	L/min
1	V110	✓	21,9	71,832	1505,975	16201,89	3240,377149	12264,82751
2	V120		21,9	71,832	1505,975	16201,89	3240,377149	12264,82751
3	V130		21,9	71,832	1505,975	16201,89	3240,377149	12264,82751
4	V140		21,9	71,832	1505,975	16201,89	3240,377149	12264,82751
					Total		12961,50859	49059,31003

Based on calculation above the compliance of the Terminal facility to overcome the requirement can be seen on Table 10.3. below.

Table 10.3. Compliance the Parametric Requirement against Existing Facility

No	Description	Requirement	Existing Facility	Unit	Status
1	Minimum Pump Req.	12961,50859	4 x 3000	gpm	Comply
2	Water supply for 4 hours	11774,23441	7825	m3	Not Comply

10.4. Calculation of Fixed Fire Extinguisher at High Risk Receiver

Based on the risk representation there are appeal to be several receiver has higher level of fire risk. On this subchapter will conduct the calculation of the required parameter to extinugish the corresponding effect caused by the fire. It stated on the beginning of this chapter the major concern of fire hazard is that Jet Fire, since Jet Fire appears to have higher escalation effect and occur in most longer period of occurence. To calculate the required amount of water as fire extinguisher the step will be explained in the following subchapter.

10.4.1. Calculation of Gas Release Rate

The gas released from the orifice are calculated based on the DNV Failure Frequency method as already explained in the Equation 7.1. The orifice to be considered is only the higher values which is 150 mm diameter. This consideration is assumed because if the facility can overcome the worst scenario it should be able to overcome less fatal scenarios. The formula to calculate 150 mm leak can be seen below:

$$Qg = 1{,}4\,x\,10^{-2}\,.\,d^2.\sqrt{\rho g P g} \qquad \text{(7.2) (DNV, 2014)}$$

Where:
Qg : initial gas release rate (kg/s)
ρ_g : initial density of gas (kg/m^2)
P_g : initial pressure of gas (bar gauge)
d : diameter of the hole

So, the gas release rate are:

$$Qg = 1{,}4\,x\,10^{-2}\,.\,d^2.\sqrt{\rho g P g}$$
$$Qg = 1{,}4\,x\,10^{-2}\,.\,150^2.\sqrt{0{,}62\,.\,13{,}4}$$
$$Qg = 25{,}22 \text{ kg/s}$$

10.4.2. Calculation of Jet Fire Heat Release

To calculate the heat amount of Jet Fire, assumed that the mass of gas relased is burnt completely, consider the Net Calorific Value of LPG is 10.997 kcal/kg and converted into kJ the heat released by Jet Fire is shown on calculation below:

$$Q = NCV_{LPG}\ .\ 4{,}18 / 1000$$
$$= 10.997\ .\ 4{,}18\ / 1000$$
$$= 1159{,}3 \text{ kW} = 1097{,}86 \text{ btu/s}$$

10.4.3. Calculation of Fire Temperature

To determine the fire temperature the formula is derrived from SPFE Handbook of Fire Protection Engineering. The formula to calculate the temperature is shown below:

$$T_0 = 9.1\left(\frac{T_\infty}{g c_\rho^2 \rho_\infty^2}\right)^{1/3} \dot{Q}_c^{2/3}(z - z_0)^{-5/3} \qquad (10.2)\ (SPFE, 2016)$$

Where,
T_o= plume centerline temperature (°C)
Qc = convective portion of the heat release rate (kW)
Ta = ambient air temperature (K)
g = acceleration of gravity (m/sec2)
cp = specific heat of air (kJ/kg-K)
ra = ambient air density (kg/m3)
z = distance from the top of the fuel package to the ceiling (m)
z_0 = hypothetical virtual origin of the fire (m)

Based on the formula above figured out the temperature of the fire is 578,513 °C

10.4.4. Calculation of Water Absorpent Requirement

The required water absorpent to extinguish the fire are calculated using the following formula:

$$Q = Mass\ of\ Water\ (g)\ .\ \Delta T\ .\ Cwater \qquad (10.3)$$

So to calculate the mass of water:

$$Mass\ of\ Water = \frac{Q}{\Delta T\ .\ Cwater}$$

Where:
ΔT = The initial Fire Temperature – Auto ignite temperature of LPG (405 °C, to be taken at 400 °C)
Q = Heat Released from Jet Fire (400 kW (taken from consequences modelling))
C_{Water} = Specific heat absorpent of water (4,184 J/kg°C)

From the equation above it can be concluded the various water requirment on various receiver based on each receiver specification. The recapitulation of water requirement for extinguish the fire at Storage Tank can be seen on Table 10.4. below.

Table 10.4. Fire Extinguishing Requirement for Storage Tank

Fire Extinguisher requirement for Storage Tank with 150 mm leak Jet Fire Scenario

No.	Tank Identification	Diameter (m)		Surface Area (m2)		Tank Volume (MT)	Jet Fire Diameter (m) (From Consequences Modelling)	Jet Fire Release Rate*		Jet Fire Emissivity Power kW/m2**	Flame Temperature (degC)***	Water Heat Absorption Requirement ****		Water Supply Requirement 4 Hours (m3)
		m	ft	m2	ft2			kW	btu/s			lpm	gpm	
1	V110	21,9	71,832	1505,975	16201,89	2500	96	1159,299	1097,856	400	578,5134275	1552,147624	403,5583823	372,5154299
2	V120	21,9	71,832	1505,975	16201,89	2500	96	1159,299	1097,856	400	578,5134275	1552,147624	403,5583823	372,5154299
3	V130	21,9	71,832	1505,975	16201,89	2500	96	1159,299	1097,856	400	578,5134275	1552,147624	403,5583823	372,5154299
4	V140	21,9	71,832	1505,975	16201,89	2500	96	1159,299	1097,856	400	578,5134275	1552,147624	403,5583823	372,5154299

Table 10.5. Fire Extinguishing Requiremnt for Jetty Area and MLA

Fire Extinguisher of Jetty Area and MLA for Leak 150 mm Jet Fire Scenario

No	Pipe Diameter (inch)	Release Rate (kg/s)	Jet Fire Diameter (m) (From Consequences Modelling)	Jet Fire Release Rate*		Jet Fire Emissivity Power kW/m2**	Flame Temperature (degC)***	Water Heat Absorption Requirement ****		Water Supply Requirement 4 Hours (m3)
				kW	btu/s			lpm	gpm	
1	10	25,22	94	1159,299	1097,856	400	578,524965	1552,047314	403,5323016	372,4913553

Table 10.6. Fire Extinguishing Requirement for Meterring Station

Fire Extinguisher of Metering Station for Leak 150 mm Jet Fire Scenario

No	Pipe Diameter (inch)	Release Rate (kg/s)	Jet Fire Diameter (m) (From Consequences Modelling)	Jet Fire Release Rate*		Jet Fire Emissivity Power kW/m2**	Flame Temperature (degC)***	Water Heat Absorption Requirement ****		Water Supply Requirement 4 Hours (m3)
				kW	btu/s			lpm	gpm	
1	10	25,22	94	1159,299	1097,856	400	578,524965	1552,047314	403,5323016	372,4913553

Table 10.7 Fire Extinguishing Requirement for Pumphouse

Fire Extinguisher of Pump house for Leak 150 mm Jet Fire Scenario										
No	**Pipe Diameter (inch)**	**Release Rate (kg/s)**	**Jet Fire Diameter (m) (From Consequences Modelling)**	**Jet Fire Release Rate***		**Jet Fire Emissivity Power kW/m2****	**Flame Temperature (degC)*****	**Water Heat Absorption Requirement ********		**Water Supply Requirement 4 Hours (m3)**
				kW	**btu/s**			**lpm**	**gpm**	
1	6	25,22	105,81	1159,299	1097,856	400	578,4623392	1552,591957	403,6739087	372,6220696

Table 10.8. Fire Extinguishing Requirement for Filling Shed

Fire Extinguisher of Filling Shed for Leak 150 mm Jet Fire Scenario										
No	**Pipe Diameter (inch)**	**Release Rate (kg/s)**	**Jet Fire Diameter (m) (From Consequences Modelling)**	**Jet Fire Release Rate***		**Jet Fire Emissivity Power kW/m2****	**Flame Temperature (degC)*****	**Water Heat Absorption Requirement ********		**Water Supply Requirement 4 Hours (m3)**
				kW	**btu/s**			**lpm**	**gpm**	
1	3	25,22	104,7	1159,299	1097,856	400	578,4676992	1552,545327	403,661785	372,6108785

10.4.5. Determination of Compliance and Reachability of Fire Extinguisher

From the calculation of fire extinguisher requiremnt on the previous subchapter it need to be analyze wether the existing facility can overcome or not. The compliance is not only the required capacity and water supply but also the reachability aspect of the fire extinguishing facility. The complete analysis of the compliance and the reachability aspect can be seen on the Table below. The scope of aspect that become consideration at determine wheter the aspect comply or not are as follows:

1. Pump Capacity Requirement
2. Water supply avaibility for atleats 4 (four) hours of fire extinguishing
3. Water Nozzle Specification
4. Reachability from nearest water hose

Various aspect will be determine which aspect at Terminal LPG Semarang that probably not comply to overcome certain scenarios. One thing to consider the calculations are based on the worst case scenario which. It is privilege to Terminal LPG Semarang to determine wheteher the worst case scenario is as their point of view or not since the occurence of the worst case scenario may less likely to occur.

10.1. Fire Risk Card

Based on the analysisi on the previous chapter the result can be determined as baseline to conduct the fire risk card to suggest Terminal LPG Semarang as their platform to determine actions durig fire incident. The Fire risk card contains summarize of the required amount of the fire extinguisher requirement. The example of the Fire Risk Card can be seen on the Table 10.9. The complete recapitulation of Fire Risk Card can be found on Appendix 8.

Table 10.7. Compliance and Reachability of Jetty Area and MLA

Compliance and Reachability of Fire Extinguisher at Jetty and MLA area

No	Location	Pump Capacity (gpm)		Water Nozzle		Water Supply for 4 (four) hours		Reachability From Nearest Hose		Status
		Requirement	Existing	Requirement	Existing	Requirement	Existing	Location	Reachability	
1	Jetty and MLA	403,5583823	1000	403,5583823	800 275	372,5154299	Unlimited (sea water)	Independent on Jetty Area	Reachable	OK

Table 10.8. Compliance and Reachability at Various High Risk Area

Compliance and Reachability of Fire Extinguisher at High Risk Area

No	Location	Pump Capacity (gpm)		Water Nozzle		Water Supply for 4 (four) hours (m3)		Reachability From Nearest Hose		Status
		Requirement	Existing	Requirement	Existing	Requirement	Existing	Location	Reachability	
1	Storage Tank		4 x 3000	4 x 379,1610002	8 x 800 & 2 x 275		7825	Dedicated for Storage Tank 1 each storage Tank	Reachable	OK
	V110	403,5583823				372,5154299				
	V120	403,5583823				372,5154299				
	V130	403,5583823				372,5154299				
	V140	403,5583823				372,5154299				
	Total	1614,233529				1490,061719				
2	Metering Station	403,5323016	4 x 3000	1 x 379,1610002	8 x 800 & 2 x 275	372,4913553	7825	Dedicated for metering station and fire pump area	Reachable	OK

Continued from previous Table

3	Pump house	403,6739087	4 x 3000	1 x 379,1610002	8 x 800 & 2 x 275	403,6739087	7825	No dedicated hose for pump house area, only portable fire extinguisher	Not reachable	Considerable
4	Filling Shed Area	403,661785	4 x 3000	1 x 379,1610002	8 x 800 & 2 x 275	372,6108785	7825	Dedicated for filling shed area 2 @each side	Reachable	OK

Table 10.9. Fire Risk Card of Terminal LPG Semarang

Fire Risk Card Terminal LPG Semarang

Incident Scenario:
Storage tank V110 encounter 150 mm leak and the gas released become jet fire, and Storage Tank V120, V130, V140 in need of auxiliary cooling

Hazard				***Location Description***
Flame Emissivity	: 400	kw/m2		Storage V110
Heat Flux Radiation Zone (m)				
25 kw/m2	:		82,59	
35 kw/m2	:		57,13	
45 kw/m2	:		35,82	

Facility Information

Type of Facility	:	Storage Tank	
Size	:	-	
Capacity	:	2500	MT
Surface Area (for Storage Tank)	:	1505,975	m2

Auxiliary Cooling Requirement

Burnt Tank	:	V110	
Tank to be cooled down	:	V120, V130, V140	
Pump flow rate Requirement	:	9721,131	gpm
Water supply for for auxiliary cooling	:	8830,676	m3

Minimum Fire Extinguisher Requirement

Fire Pump flow rate	:	403,5584	gpm
Fire Hose flow rate	:	403,5584	gpm
Water Supply for 4 (four) hours	:	372,5154	m3

Note

CHAPTER 11
CONCLUSSION AND SUGGESTION

11.1. Conclussion

Based on the Fire Risk Assessment of Termina; LPG Semarang it concluded that:

1. Based on Hazard Identification the fire hazard such as Jet Fire, Flash Fire and Explosion occur when the components suffer failures that lead into leaks or gas released then ignited, therefore the major cause that lead into release are: high pressure in the system, blockage in the system, high temperature, and too much flow rate.
2. On the frequency analysis the approach is to analysze the system failure frequecncy, it makes the result are dependent based on the how system work, the result is vary, the lowest frequency comes in system that involving storage.
3. During the Consequences Analysis the highest source of the consequences are caused by the Storage tank since the storage tank containts the most amount of LPG and has the highest working pressure.
4. The result of risk representation often lead to conclusion that even the lowest frequency can caused the most effect in consequences. The risk representation also reveal that the most likely occurence in this researh still located on the rare area of the likelihood classification on Company Risk Matrix. The process of risk representation also reveal because in the severity only describe the individual severity and not operational activity the potential loss is only represent the loss of individual and not seeing it through operational or assets loss.
5. The Pre Fire Planing mitigation process conclude that several facility in Terminal LPG Semarang still not comply the minimum requirement to overcome the worst case scenario of fire incident.
6. The analysis of Pre Fire Planning reveal that improvemet on the facility is required eventhough not major evaluations needed.

11.2. Sugestion

1. As the Pre Fire Planning sugest Terminal LPG Semarang to increase water Pond capacity by at least 4.000 m^3
2. The risk matrix used by company not quantitively well describe the likelihood that creates most of likelihood/frequency appear to be rare. In the future it may become object to be revised.

3. The assessment regarding fire incident in the Terminal LPG Semarang should be followed up by drilling practice so that every incident can be overcome.
4. During operational activity Terminal LPG Semarang is suggested that the clear standard operational procedure is strcitly applied so that any operational failure leading into potential hazard can be reduced.
5. As this research not assess from the design point of view of fire extinguishing of Terminal LPG Semarang the further research can be initiated to assess wheter all the Fire Extinguishing facility of Terminal LPG Semarang are fully comply with considered Regulation or not regarding the corresponding standard.

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APPENDIX

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Appendix 1: Terminal Layout

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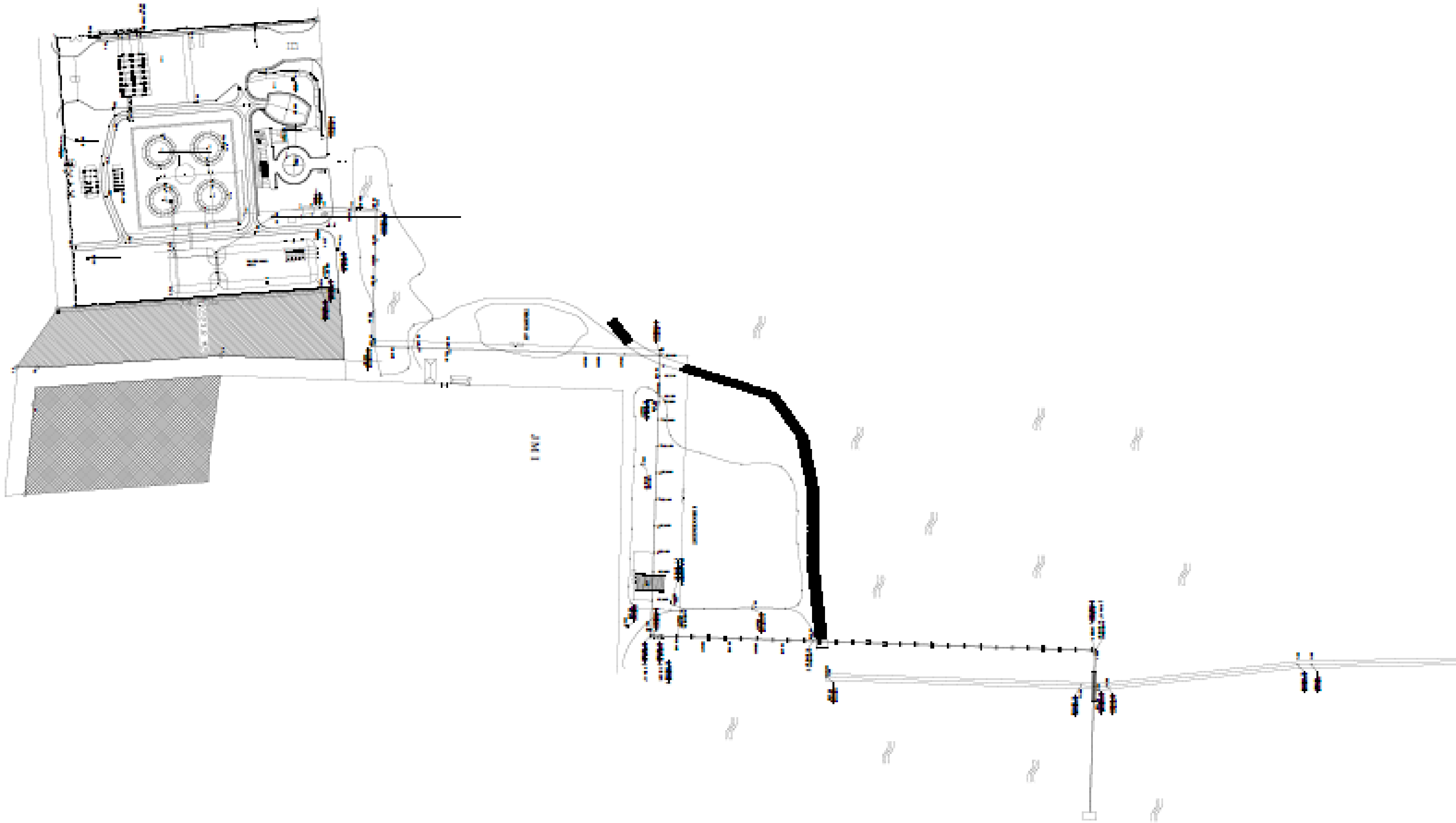

Appendix 2: Terminal System P&ID

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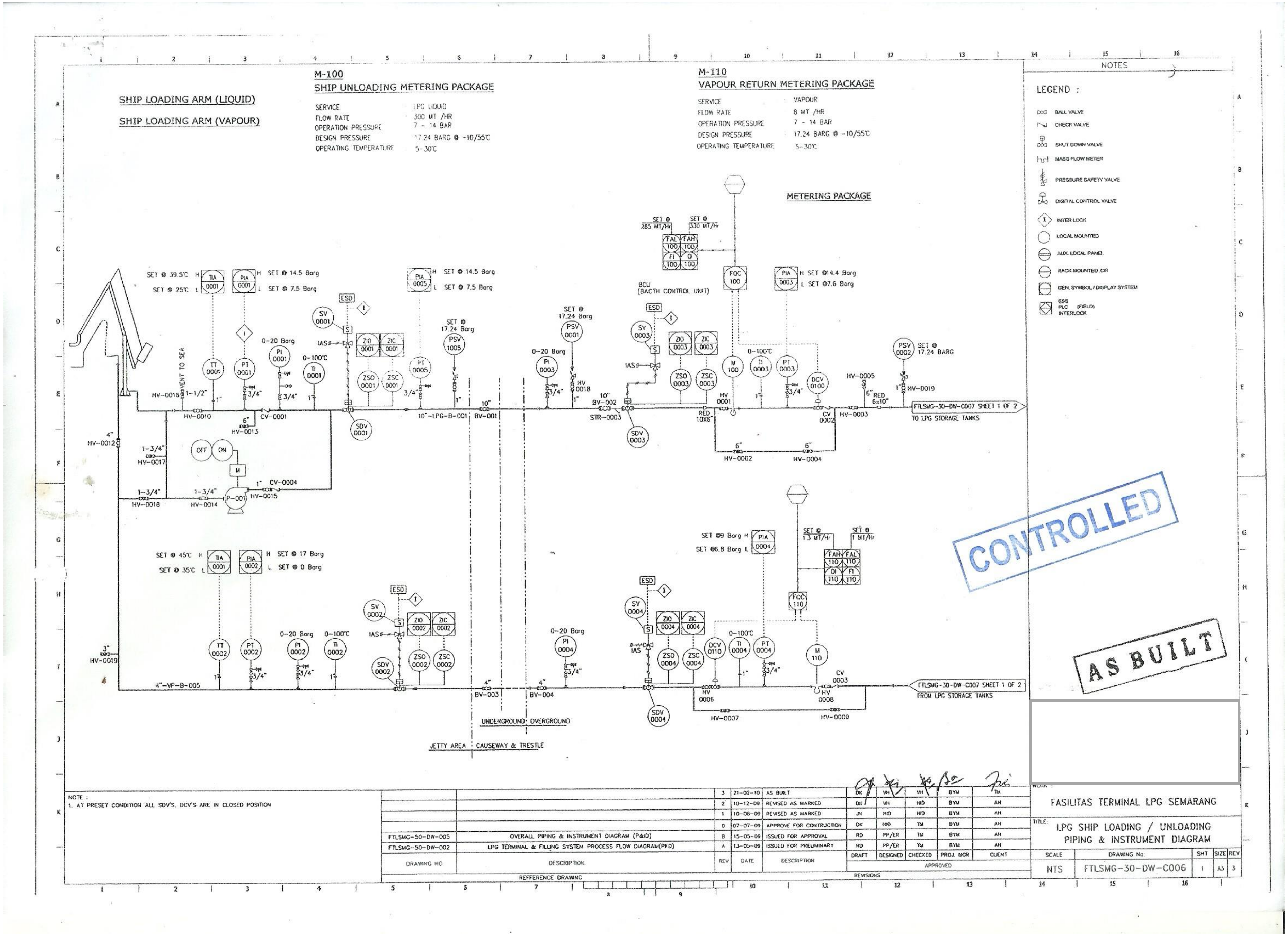
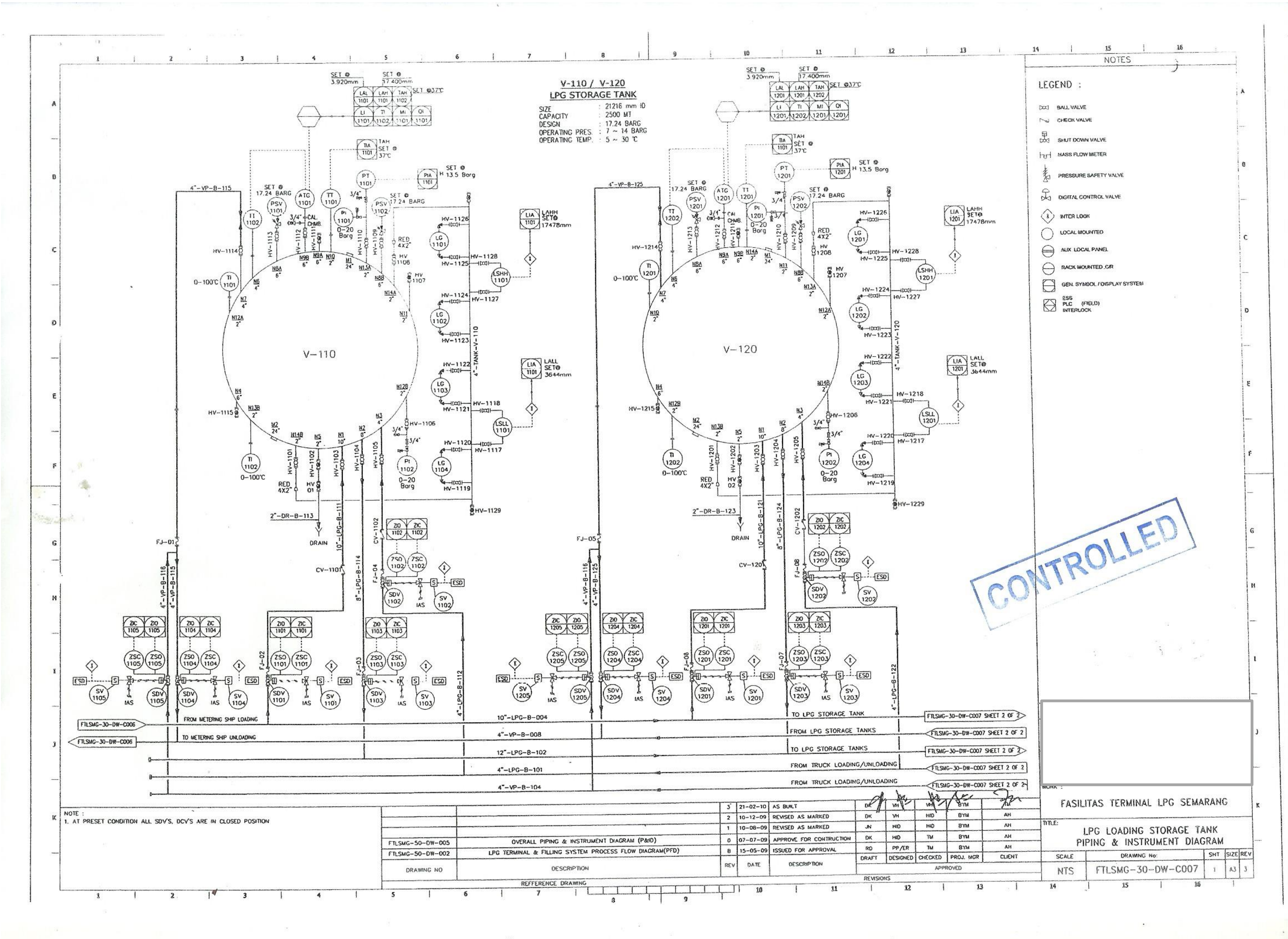
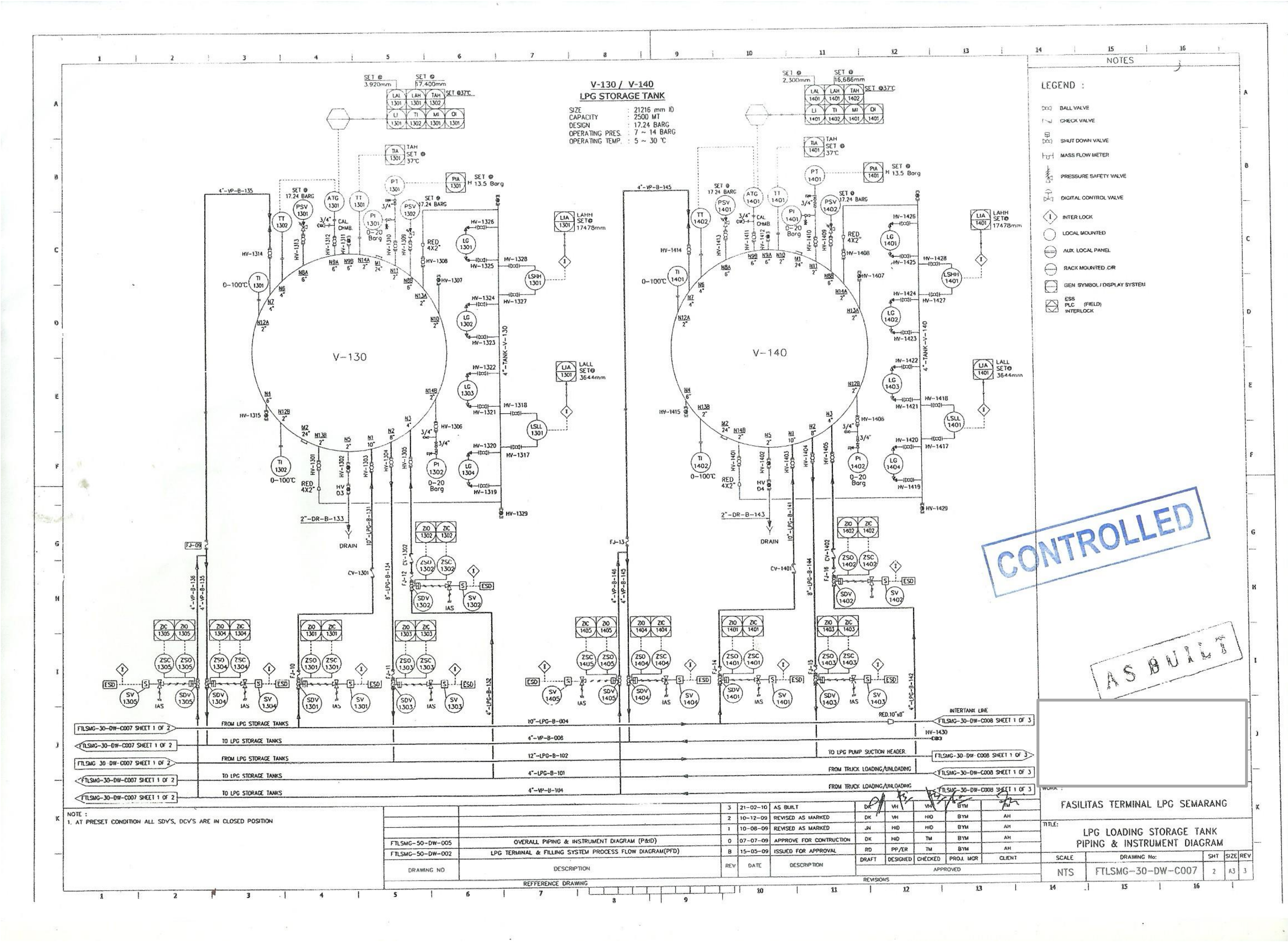
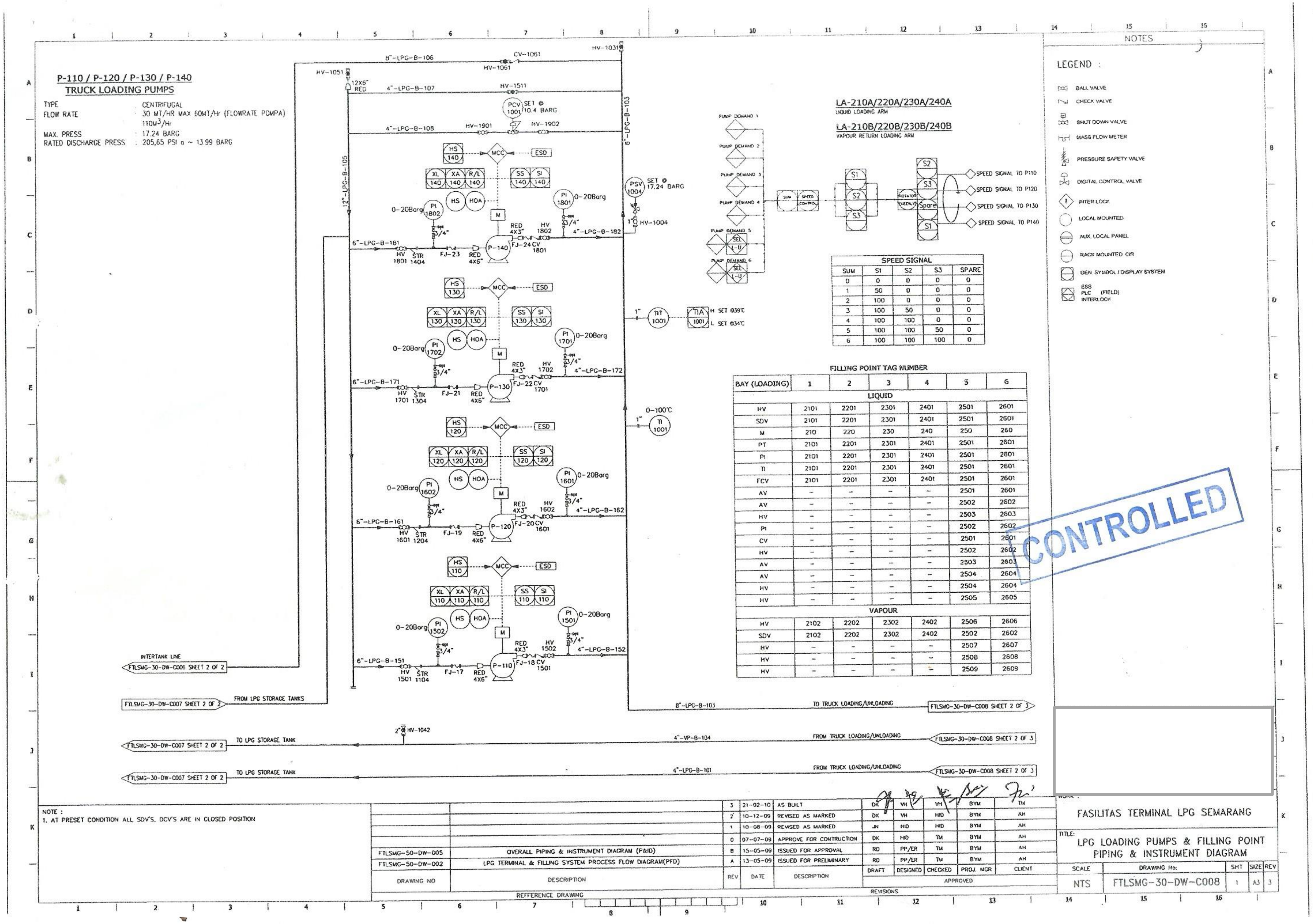

SHIP LOADING ARM (LIQUID)
SHIP LOADING ARM (VAPOUR)
M-100
SHIP UNLOADING METERING PACKAGE
SERVICE LPG LIQUID
FLOW RATE 300 MT /HR
OPERATION PRESSURE 7 - 14 BAR
DESIGN PRESSURE 17.24 BARG @ -10/55℃
OPERATING TEMPERATURE 5-30℃
M-110
VAPOUR RETURN METERING PACKAGE
SERVICE VAPOUR
FLOW RATE 8 MT /HR
OPERATION PRESSURE 7 - 14 BAR
DESIGN PRESSURE 17.24 BARG @ -10/55℃
OPERATING TEMPERATURE 5-30℃
METERING PACKAGE
NOTES
LEGEND :
BALL VALVE
CHECK VALVE
SHUT DOWN VALVE
MASS FLOW METER
PRESSURE SAFETY VALVE
DIGITAL CONTROL VALVE
INTER LOCK
LOCAL MOUNTED
AUX. LOCAL PANEL
RACK MOUNTED CR
GEN. SYMBOL / DISPLAY SYSTEM
ESS PLC (FIELD) INTERLOCK
BCU (BACTH CONTROL UNIT)
10"-LPG-B-001
4"-VP-B-005
UNDERGROUND OVERGROUND
JETTY AREA CAUSEWAY & TRESTLE
FTLSMG-30-DW-C007 SHEET 1 OF 2 TO LPG STORAGE TANKS
FTLSMG-30-DW-C007 SHEET 1 OF 2 FROM LPG STORAGE TANKS
CONTROLLED
AS BUILT
NOTE :
1. AT PRESET CONDITION ALL SDV'S, DCV'S ARE IN CLOSED POSITION
FTLSMG-50-DW-005 OVERALL PIPING & INSTRUMENT DIAGRAM (P&ID)
FTLSMG-50-DW-002 LPG TERMINAL & FILLING SYSTEM PROCESS FLOW DIAGRAM (PFD)
DRAWING NO DESCRIPTION
REFFERENCE DRAWING
3 21-02-10 AS BUILT
2 10-12-09 REVISED AS MARKED
1 10-08-09 REVISED AS MARKED
0 07-07-09 APPROVE FOR CONTRUCTION
B 15-05-09 ISSUED FOR APPROVAL
A 13-05-09 ISSUED FOR PRELIMINARY
REV DATE DESCRIPTION
DRAFT DESIGNED CHECKED PROJ. MGR CLIENT
APPROVED
REVISIONS
FASILITAS TERMINAL LPG SEMARANG
TITLE: LPG SHIP LOADING / UNLOADING PIPING & INSTRUMENT DIAGRAM
SCALE NTS
DRAWING No: FTLSMG-30-DW-C006
SHT 1 SIZE A3 REV 3


V-110 / V-120
LPG STORAGE TANK
SIZE : 21216 mm ID
CAPACITY : 2500 MT
DESIGN : 17.24 BARG
OPERATING PRES. : 7 ~ 14 BARG
OPERATING TEMP. : 5 ~ 30 °C
V-110
V-120
NOTES
LEGEND :
BALL VALVE
CHECK VALVE
SHUT DOWN VALVE
MASS FLOW METER
PRESSURE SAFETY VALVE
DIGITAL CONTROL VALVE
INTER LOCK
LOCAL MOUNTED
AUX LOCAL PANEL
RACK MOUNTED CR
GEN. SYMBOL / DISPLAY SYSTEM
ESS PLC (FIELD) INTERLOCK
CONTROLLED
FROM METERING SHIP LOADING
TO METERING SHIP UNLOADING
TO LPG STORAGE TANK
FROM LPG STORAGE TANKS
TO LPG STORAGE TANKS
FROM TRUCK LOADING/UNLOADING
FROM TRUCK LOADING/UNLOADING
NOTE :
1. AT PRESET CONDITION ALL SDV'S, DCV'S ARE IN CLOSED POSITION
FTLSMG-50-DW-005 OVERALL PIPING & INSTRUMENT DIAGRAM (P&ID)
FTLSMG-50-DW-002 LPG TERMINAL & FILLING SYSTEM PROCESS FLOW DIAGRAM(PFD)
DRAWING NO
DESCRIPTION
REFFERENCE DRAWING
3 21-02-10 AS BUILT
2 10-12-09 REVISED AS MARKED
1 10-08-09 REVISED AS MARKED
0 07-07-09 APPROVE FOR CONTRUCTION
B 15-05-09 ISSUED FOR APPROVAL
REV DATE DESCRIPTION
DRAFT DESIGNED CHECKED PROJ. MGR CLIENT
APPROVED
REVISIONS
FASILITAS TERMINAL LPG SEMARANG
TITLE:
LPG LOADING STORAGE TANK
PIPING & INSTRUMENT DIAGRAM
SCALE NTS
DRAWING No: FTLSMG-30-DW-C007
SHT 1
SIZE A3
REV 3


V-130 / V-140
LPG STORAGE TANK
SIZE : 21216 mm ID
CAPACITY : 2500 MT
DESIGN : 17.24 BARG
OPERATING PRES. : 7 ~ 14 BARG
OPERATING TEMP. : 5 ~ 30 °C
V-130
V-140
NOTES
LEGEND :
BALL VALVE
CHECK VALVE
SHUT DOWN VALVE
MASS FLOW METER
PRESSURE SAFETY VALVE
DIGITAL CONTROL VALVE
INTER LOCK
LOCAL MOUNTED
AUX. LOCAL PANEL
RACK MOUNTED OR
GEN SYMBOL / DISPLAY SYSTEM
CONTROLLED
AS BUILT
FROM LPG STORAGE TANKS
TO LPG STORAGE TANKS
TO LPG PUMP SUCTION HEADER
FROM TRUCK LOADING/UNLOADING
INTERTANK LINE
DRAIN
NOTE :
1. AT PRESET CONDITION ALL SDV'S, DCV'S ARE IN CLOSED POSITION
FTLSMG-50-DW-005 OVERALL PIPING & INSTRUMENT DIAGRAM (P&ID)
FTLSMG-50-DW-002 LPG TERMINAL & FILLING SYSTEM PROCESS FLOW DIAGRAM(PFD)
DRAWING NO
DESCRIPTION
REFFERENCE DRAWING
3 21-02-10 AS BUILT
2 10-12-09 REVISED AS MARKED
1 10-08-09 REVISED AS MARKED
0 07-07-09 APPROVE FOR CONTRUCTION
B 15-05-09 ISSUED FOR APPROVAL
REV DATE DESCRIPTION
DRAFT DESIGNED CHECKED PROJ. MGR CLIENT
APPROVED
REVISIONS
FASILITAS TERMINAL LPG SEMARANG
TITLE:
LPG LOADING STORAGE TANK
PIPING & INSTRUMENT DIAGRAM
SCALE NTS
DRAWING No: FTLSMG-30-DW-C007
SHT 2 SIZE A3 REV 3

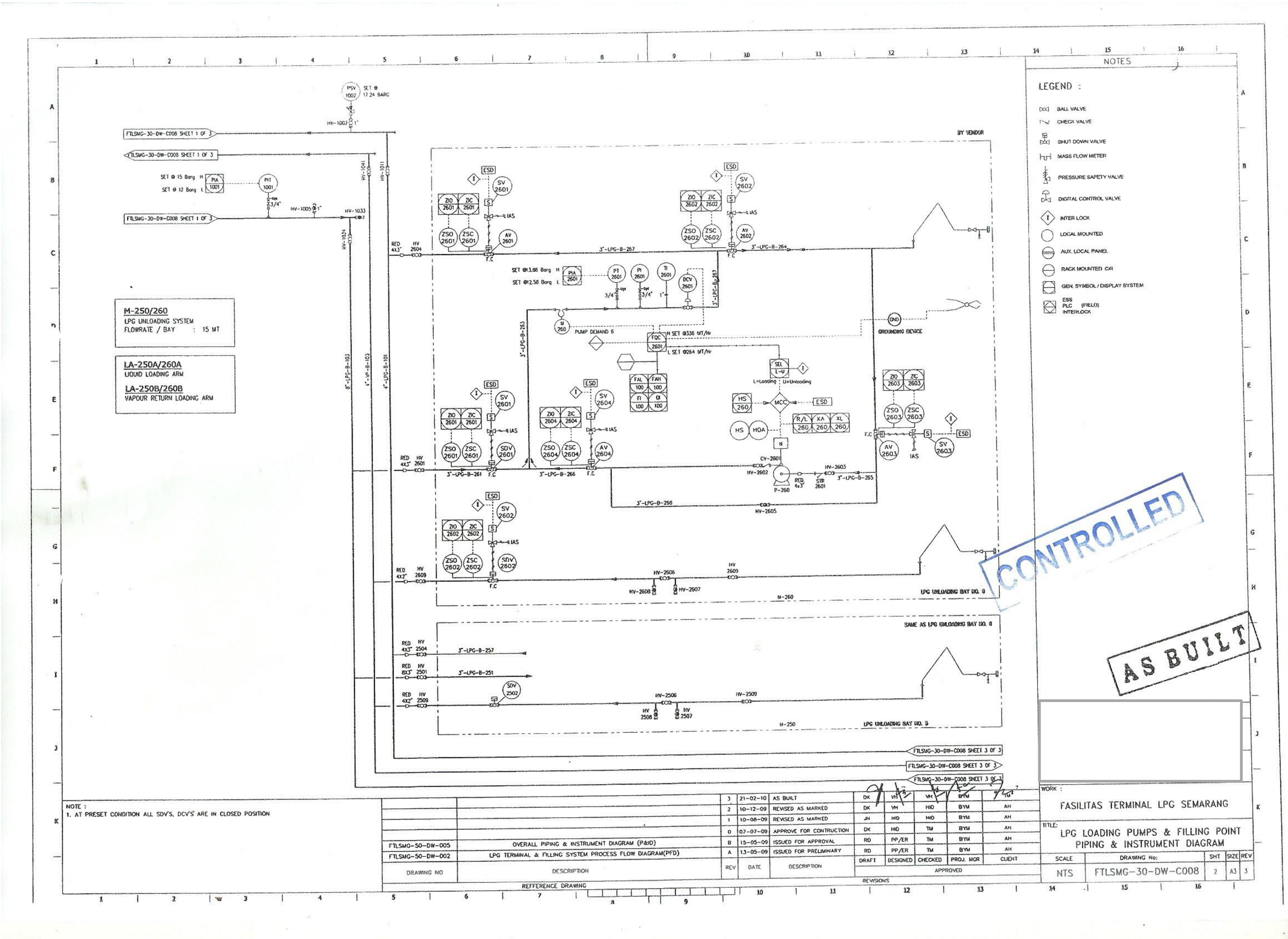


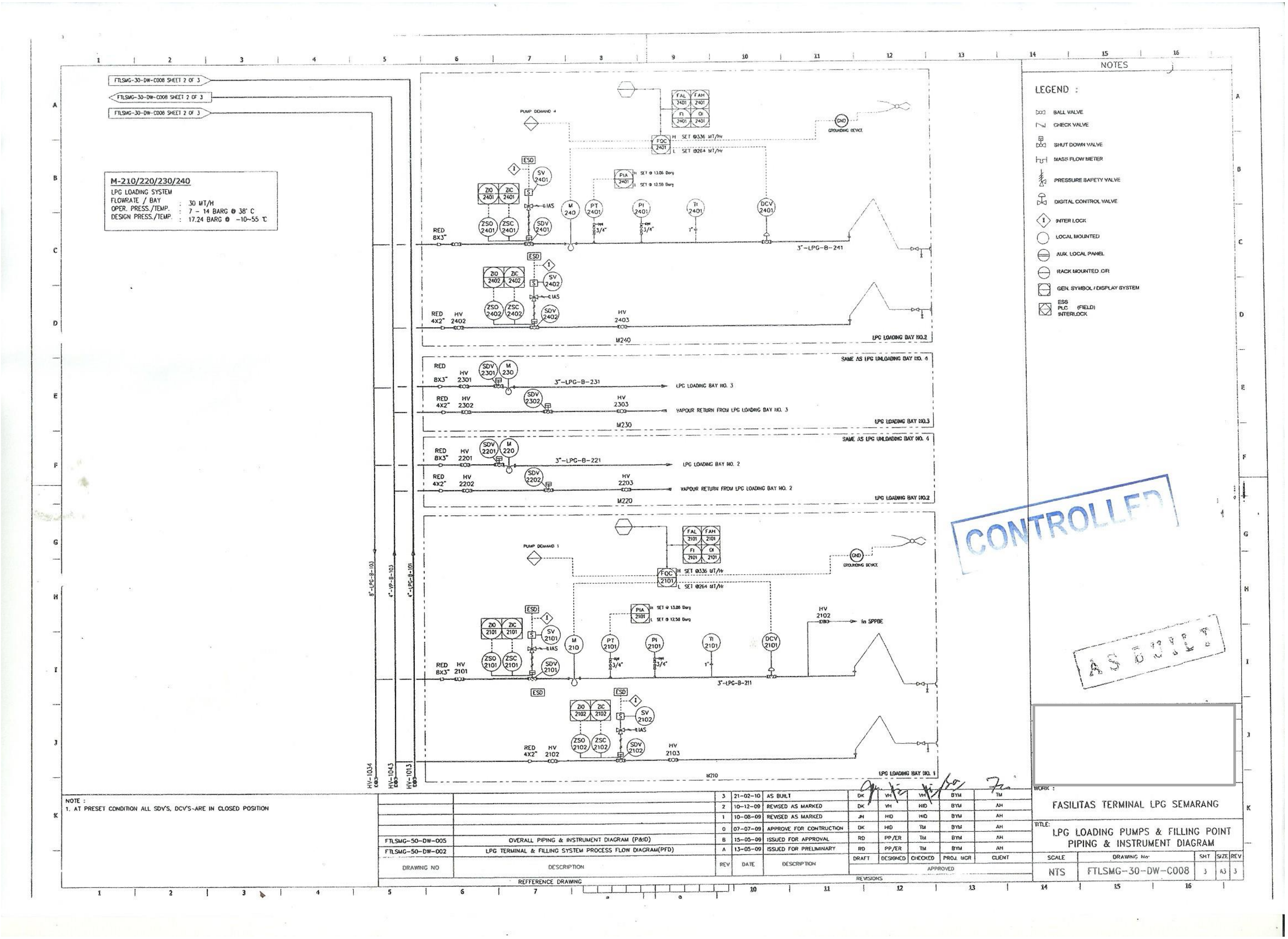
SPEED SIGNAL

SUM	S1	S2	S3	SPARE
0	0	0	0	0
1	50	0	0	0
2	100	0	0	0
3	100	50	0	0
4	100	100	0	0
5	100	100	50	0
6	100	100	100	0

FILLING POINT TAG NUMBER

BAY (LOADING)	1	2	3	4	5	6
LIQUID						
HV	2101	2201	2301	2401	2501	2601
SDV	2101	2201	2301	2401	2501	2601
M	210	220	230	240	250	260
PT	2101	2201	2301	2401	2501	2601
PI	2101	2201	2301	2401	2501	2601
TI	2101	2201	2301	2401	2501	2601
FCV	2101	2201	2301	2401	2501	2601
AV	–	–	–	–	2501	2601
AV	–	–	–	–	2502	2602
HV	–	–	–	–	2503	2603
PI	–	–	–	–	2502	2602
CV	–	–	–	–	2501	2601
HV	–	–	–	–	2502	2602
AV	–	–	–	–	2503	2803
AV	–	–	–	–	2504	2604
HV	–	–	–	–	2504	2604
HV	–	–	–	–	2505	2605
VAPOUR						
HV	2102	2202	2302	2402	2506	2606
SDV	2102	2202	2302	2402	2502	2602
HV	–	–	–	–	2507	2607
HV	–	–	–	–	2508	2608
HV	–	–	–	–	2509	2609


NOTES
LEGEND :
BALL VALVE
CHECK VALVE
SHUT DOWN VALVE
MASS FLOW METER
PRESSURE SAFETY VALVE
DIGITAL CONTROL VALVE
INTER LOCK
LOCAL MOUNTED
AUX. LOCAL PANEL
RACK MOUNTED CR
GEN. SYMBOL / DISPLAY SYSTEM
ESS PLC (FIELD) INTERLOCK
M-250/260
LPG UNLOADING SYSTEM
FLOWRATE / BAY : 15 MT
LA-250A/260A
LIQUID LOADING ARM
LA-250B/260B
VAPOUR RETURN LOADING ARM
BY VENDOR
PUMP DEMAND 6
GROUNDING DEVICE
LPG UNLOADING BAY NO. 6
SAME AS LPG UNLOADING BAY NO. 6
LPG UNLOADING BAY NO. 5
FTLSMG-30-DW-C008 SHEET 1 OF 3
FTLSMG-30-DW-C008 SHEET 3 OF 3
CONTROLLED
AS BUILT
NOTE :
1. AT PRESET CONDITION ALL SDV'S, DCV'S ARE IN CLOSED POSITION
FTLSMG-50-DW-005 OVERALL PIPING & INSTRUMENT DIAGRAM (P&ID)
FTLSMG-50-DW-002 LPG TERMINAL & FILLING SYSTEM PROCESS FLOW DIAGRAM(PFD)
DRAWING NO
DESCRIPTION
REFFERENCE DRAWING
3 21-02-10 AS BUILT
2 10-12-09 REVISED AS MARKED
1 10-08-09 REVISED AS MARKED
0 07-07-09 APPROVE FOR CONTRUCTION
B 15-05-09 ISSUED FOR APPROVAL
A 13-05-09 ISSUED FOR PRELIMINARY
REV DATE DESCRIPTION
DRAFT DESIGNED CHECKED PROJ. MGR CLIENT
APPROVED
REVISIONS
WORK :
FASILITAS TERMINAL LPG SEMARANG
TITLE:
LPG LOADING PUMPS & FILLING POINT
PIPING & INSTRUMENT DIAGRAM
SCALE NTS
DRAWING No: FTLSMG-30-DW-C008
SHT 2 SIZE A3 REV 3



FTLSMG-30-DW-C008 SHEET 2 OF 3
M-210/220/230/240
LPG LOADING SYSTEM
FLOWRATE / BAY : 30 MT/H
OPER. PRESS./TEMP. : 7 - 14 BARG @ 38° C
DESIGN PRESS./TEMP. : 17.24 BARG @ -10~55 °C
PUMP DEMAND 4
SET @336 MT/H
SET @264 MT/H
GROUNDING DEVICE
3"-LPG-B-241
LPG LOADING BAY NO.2
M240
SAME AS LPG UNLOADING BAY NO. 4
3"-LPG-B-231
LPG LOADING BAY NO. 3
VAPOUR RETURN FROM LPG LOADING BAY NO. 3
LPG LOADING BAY NO.3
M230
3"-LPG-B-221
LPG LOADING BAY NO. 2
VAPOUR RETURN FROM LPG LOADING BAY NO. 2
LPG LOADING BAY NO.2
M220
PUMP DEMAND 1
to SPPBE
3"-LPG-B-211
LPG LOADING BAY NO. 1
M210
NOTES
LEGEND :
BALL VALVE
CHECK VALVE
SHUT DOWN VALVE
MASS FLOW METER
PRESSURE SAFETY VALVE
DIGITAL CONTROL VALVE
INTER LOCK
LOCAL MOUNTED
AUX. LOCAL PANEL
RACK MOUNTED OR
GEN. SYMBOL / DISPLAY SYSTEM
ESS PLC (FIELD) INTERLOCK
CONTROLLED
AS BUILT
NOTE :
1. AT PRESET CONDITION ALL SDV'S, DCV'S ARE IN CLOSED POSITION
FTLSMG-50-DW-005 OVERALL PIPING & INSTRUMENT DIAGRAM (P&ID)
FTLSMG-50-DW-002 LPG TERMINAL & FILLING SYSTEM PROCESS FLOW DIAGRAM (PFD)
DRAWING NO
DESCRIPTION
REFFERENCE DRAWING
3 21-02-10 AS BUILT
2 10-12-09 REVISED AS MARKED
1 10-08-09 REVISED AS MARKED
0 07-07-09 APPROVE FOR CONTRUCTION
B 15-05-09 ISSUED FOR APPROVAL
A 13-05-09 ISSUED FOR PRELIMINARY
REV DATE DESCRIPTION
DRAFT DESIGNED CHECKED PROJ. MGR CLIENT
APPROVED
REVISIONS
WORK :
FASILITAS TERMINAL LPG SEMARANG
TITLE:
LPG LOADING PUMPS & FILLING POINT
PIPING & INSTRUMENT DIAGRAM
SCALE NTS
DRAWING No FTLSMG-30-DW-C008
SHT 3 SIZE A3 REV 3

Appendix 3: Terminal Fire Fighting Arrangement

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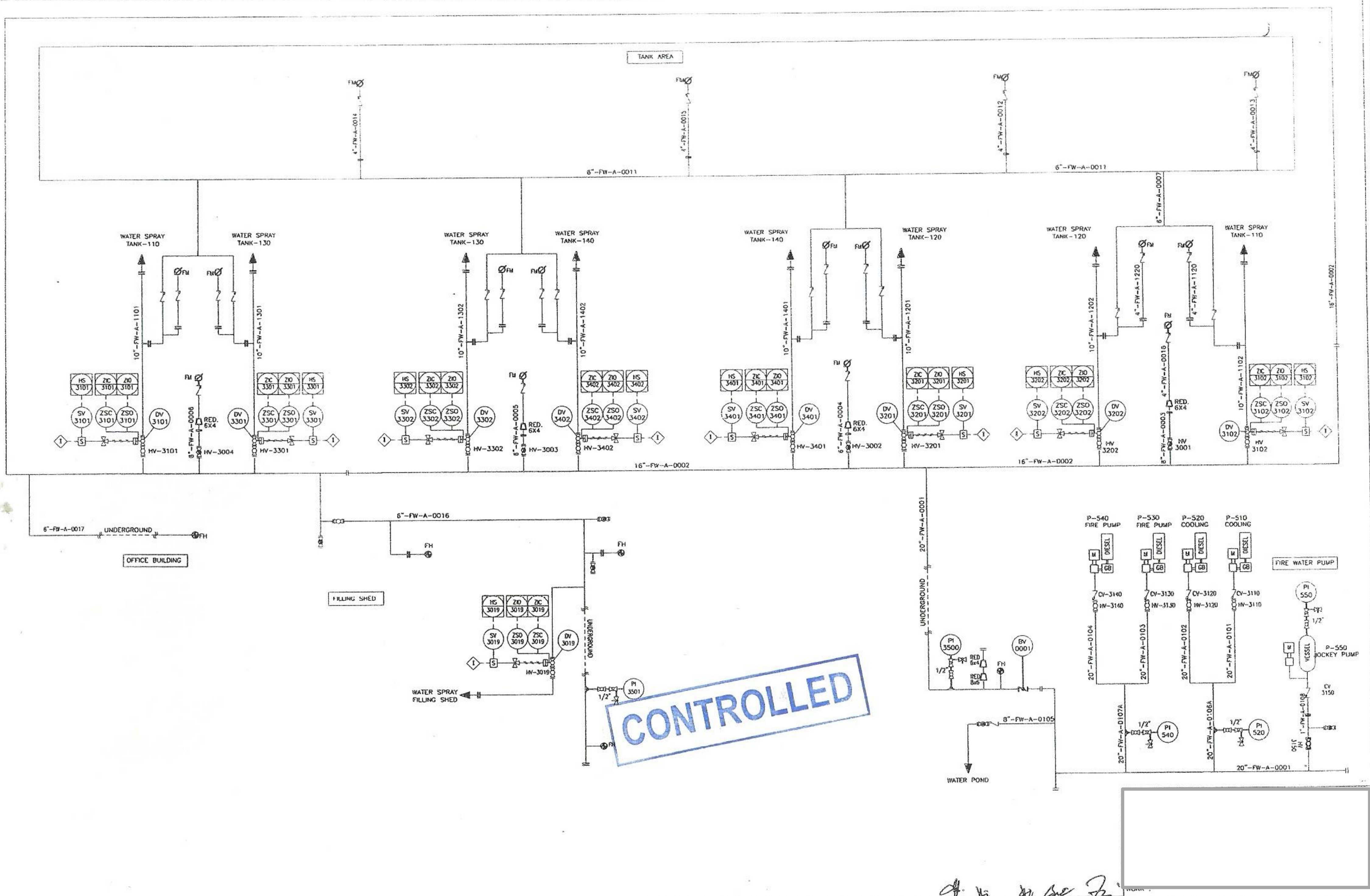


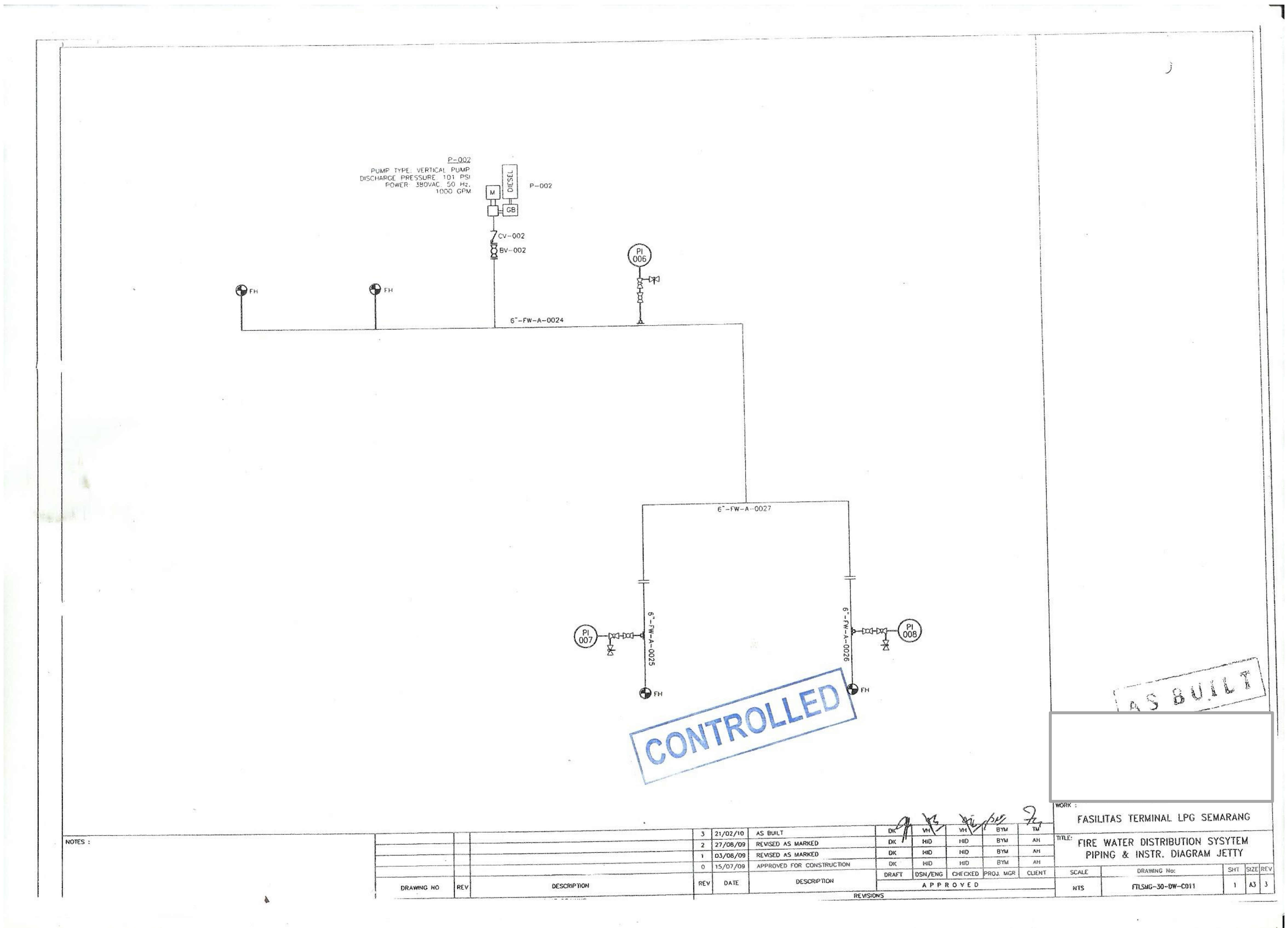
NOTES :

2	21/02/10	AS BUILT	DK	VH	VH	BYM	TM	
1	11/08/09	REVISED AS MARKED	DK	HID	HID	BYM	AH	
0	15/07/09	APPROVED FOR CONSTRUCTION	DK	HID	HID	BYM	AH	
B	13/07/09	ISSUED FOR APPROVAL	DK	HID	HID	BYM	AH	
A	09/07/09	ISSUED FOR PRELIMINARY	DK	HID	HID	BYM	AH	
DRAWING NO	DESCRIPTION	REV	DATE	DESCRIPTION	DRAFT	DSN/ENG	CHECKED	PROJ. MGR	CLIENT
					APPROVED				

WORK : FASILITAS TERMINAL LPG SEMARANG

TITLE: FIRE WATER DISTRIBUTION SYSYTEM PIPING & INSTRUMENT DIAGRAM

SCALE	DRAWING No:	SHT	SIZE	REV
NTS	FTLSMG-30-DW-C010	1	A3	2


P-002
PUMP TYPE: VERTICAL PUMP
DISCHARGE PRESSURE: 101 PSI
POWER: 380VAC, 50 Hz,
1000 GPM
DIESEL
M
GB
P-002
CV-002
BV-002
PI 006
FH
FH
6"-FW-A-0024
6"-FW-A-0027
6"-FW-A-0025
6"-FW-A-0026
PI 007
PI 008
FH
FH
CONTROLLED
AS BUILT
NOTES :
DRAWING NO
REV
DESCRIPTION
3 | 21/02/10 | AS BUILT | DK | VH | VH | BYM | TM
2 | 27/08/09 | REVISED AS MARKED | DK | HID | HID | BYM | AH
1 | 03/08/09 | REVISED AS MARKED | DK | HID | HID | BYM | AH
0 | 15/07/09 | APPROVED FOR CONSTRUCTION | DK | HID | HID | BYM | AH
REV | DATE | DESCRIPTION | DRAFT | DSN/ENG | CHECKED | PROJ. MGR | CLIENT
APPROVED
REVISIONS
WORK :
FASILITAS TERMINAL LPG SEMARANG
TITLE:
FIRE WATER DISTRIBUTION SYSYTEM
PIPING & INSTR. DIAGRAM JETTY
SCALE | DRAWING No: | SHT | SIZE | REV
NTS | FTLSMG-30-DW-C011 | 1 | A3 | 3

HSE FACILITY AND INFRASTRUCTURE DATA
TERMINAL LPG SEMARANG

Checked: 31 January 2017 — **No. : TLS-80-SF-012-XIV**

No.	Type of Facility	Description						
I. Protection and Fire Extinguisher								
1,1	**Fire Extinguisher Pumps**	**Unit**	**Qty**	**Brand**	**Pump Type**	**Engine Brand**	**Mover**	**Notes**
	a. Fixed Fire Pump							
	Cap @3000 GPM	Unit	4	Amarillo	Vertikal	Clarke	Diesel	Proper Condition
				Amarillo	Verticals	Clarke	Diesel	Proper Condition
				Amarillo	Verticals	Clarke	Diesel	Proper Condition
				Amarillo	Verticals	Clarke	Diesel	Proper Condition
	b. Jockey Pump							
	Cap. 13.51 GPM	Unit	2	Grunfos	Verticals	-	Electric	Proper Condition
				Mufitec	Verticals	-	Electric	Proper Condition
	c. Fixe Fire Pump Jetty							
	Cap 1000 GPM	Unit	1	Amarillo	Verticals	Clarke	Diesel	Proper Condition
1,2	**Water Supply**	**Unit**	**Qty**	**Capacity**	**Dimension**	**Notes**		
	a. Water Pond	Unit	1	7825 M^3	111x30x2.35	Proper Condition		
		Unit						
	b. Shallow well		3	**Flow rate**		Infiltration Well		
				Flow rate				
1,3	**Fire extinguisher Distribution Apparatus**	**Unit**	**Length**	**∑ Block Valve**	**Valve Type**	**Notes**		
	a. Fire Extinguisher Pipe							
	> Ø 1 1/2 Inchi	Meter	14			Proper Condition		
	> Ø 2 Inchi	Meter	42			Proper Condition		
	> Ø 4 Inchi	Meter	128			Proper Condition		
	> Ø 6 Inchi	Meter	471	6	gate valve	Proper Condition		
	> Ø 8 Inchi	Meter	5			Proper Condition		
	> Ø 10 Inchi	Meter	48	8	gate valve	Proper Condition		
	> Ø 12 Inchi	Meter	48			Proper Condition		
	> Ø 16 Inchi	Meter	304			Proper Condition		
	> Ø 20 Inchi	Meter	84	1	BV	Proper Condition		
	b. Fire Hydrant	**Unit**	**Qty**	**Brand**	**Coupling Type**	**Notes**		
	> Fire Hydrant Double (Ø2½" x 2)	Unit	8	Gunebo	Machino	Proper Condition		
		Unit						
	> Fire Hydrant Single (Ø2½" x 1)	Unit						
	c. Hose Box	Unit	8	Gunebo	Machino	Proper Condition		
	d. Water Sprinkler	**Satuan**	**Jumlah**	**Type**	**Ø Pipe & ∑Nozzle**	**Cap. Nozzle**	**Notes**	
	Tank V-110	Unit	2	Deluge Valve	Ø 2		Cap 2500 MT	
	Tank V-120	Unit	2	Deluge Valve	Ø 2		Cap 2500 MT	
	Tank V-130	Unit	2	Deluge Valve	Ø 2		Cap 2500 MT	
	Tank V-140	Unit	2	Deluge Valve	Ø 2		Cap 2500 MT	
	e. Fire hose	**Total**		**Brand**	**Coupling Type**	**Notes**		

	Item	Unit	Field	Warehouse			Notes	
	> Canvas Hose	**Unit**	**Field**	**Warehouse**				
	- Ø 2 ½ Inchi	Length		8	Germany	Machino	Proper Condition	
	- Ø 1 ½ Inchi	Length	-	-				
	> Rubber Hose	Length	8	10	Germany	Machino	Proper Condition	
	- Ø 2 ½ Inchi	Length	30 m	18	Germany	Machino	Proper Condition	10 kondisi baru
	- Ø 1 ½ Inch	Length	30 m	9	Germany	Machino	Proper Condition	
f.	Portable Suction Hose	**Unit**	**Field**	**Warehouse**	**Brand**	**Coupling Type**	**Notes**	
	- Ø 6 Inchi	Length	-	1		Chicago	New	
	- Ø 4 Inchi	Length	-	3		Threeded	New	
	- Ø 3 Inchi	Length						
g.	Water Nozzle	**Unit**	**Field**	**Warehouse**	**Brand**	**Capacity**	**Notes**	
	Jet - Spay Nozzle 2,5 Inchi	Pcs	8	6	Elkhart-Akron	800 LPM		Proper Condition
	Jet - Spay Nozzle 1,5 Inchi	Pcs	6		Akron	275 LPM	Proper Condition	
	Incalating Fix Monitor	Pcs		1	Ozzie	800 LPM		New Condition
	Jet Nozzle 2.5 Inchi	Pcs	1		Elkhart			Proper Condition
h.	Fix Ground Monitor	Unit	16		Gunebo			Proper Conition
i.	Portable Fire Pump	Unit	3		Tohatsu	172 GPM	V20D2S	New Condition
j	Portable Fire Pump	Unit	1		Lambordini	500 GPM		New Condition
k.	Wat " R " wall	Pcs	4		Gunebo			Proper Condition
l.	Hose Accessories	**Unit**	**Field**	**Warehouse**	**Brand**	**Coupling Type**	**Notes**	
	> Y - Piece 2 x Ø1½" x Ø2½"	Pcs	8			Machino	2 New Condition 2 Broke	
	> Collecting 2 x Ø2½" x Ø4"	Pcs						
	> Reducer Ø2½" to Ø1½"	Pcs						
	> Female to Male Ø2½" to Ø2½"	Pcs	8	7	Unidur	Machino	Proper Condition	
	> Female to Male Ø1½" to Ø1½"	Pcs	6	3	Unidur	Machino	Kondisi layak	
	> Female to Famele Ø2½" to Ø2½"	Pcs		3	Kanvas	Machino	Kondisi Layak	
	> Female to Famele Ø1½" to Ø1½"	Pcs						
	> Male to Male Ø2½" to Ø2½"	Pcs						
	> Male to Male Ø1½" to Ø1½"	Pcs						
	> Spaner	Pcs						
	> Valve fastener	Pcs	8			Gunebo		Proper Conditioni

Appendix 4: Node Classsification

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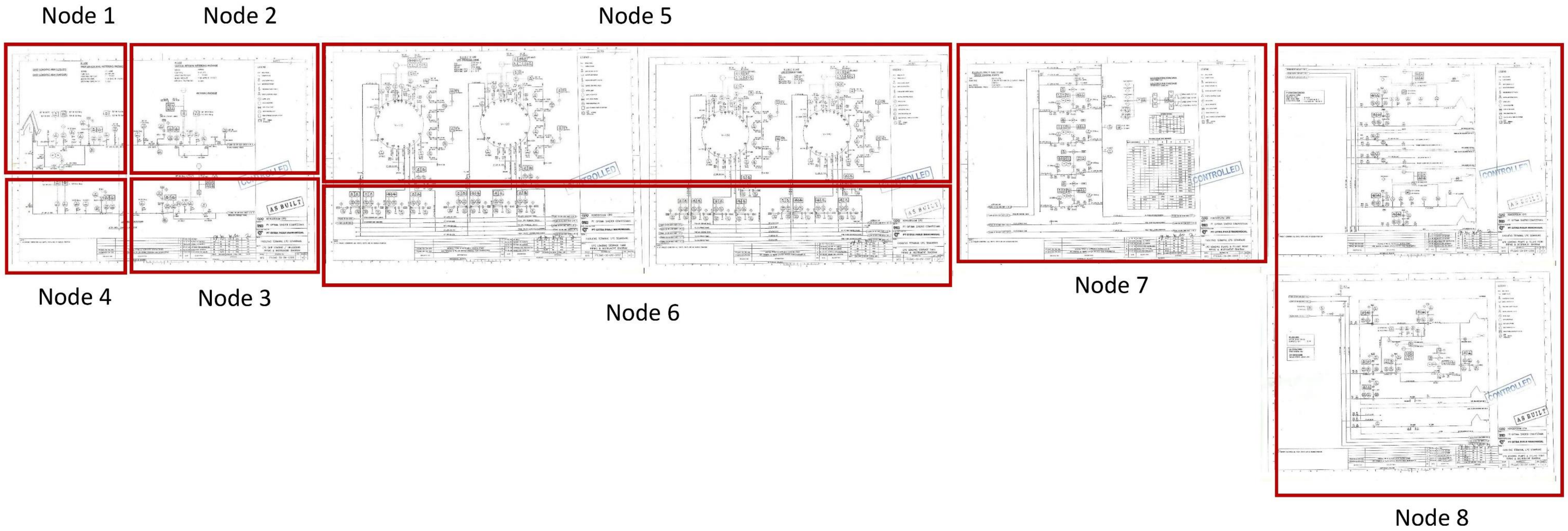
Node 1
Node 2
Node 5
Node 4
Node 3
Node 6
Node 7
Node 8

Appendix 5: Fault Tree Result

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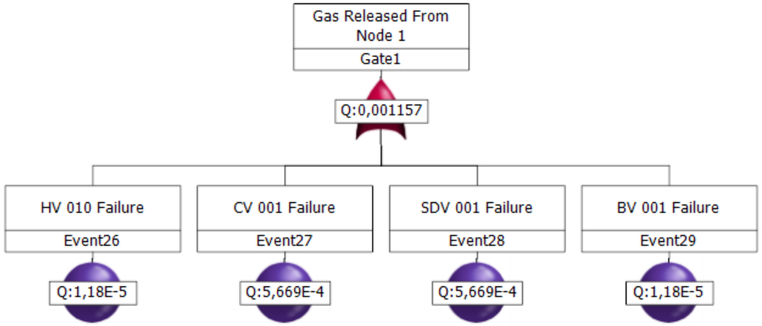
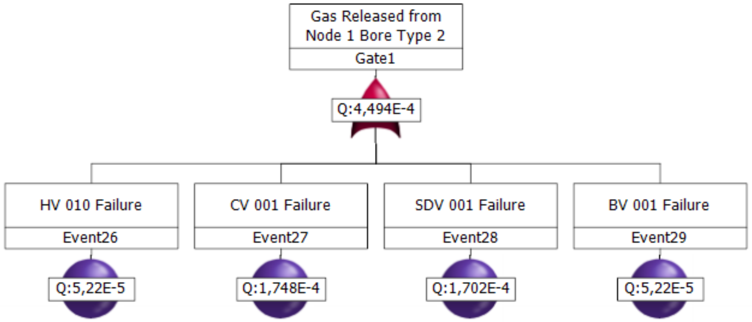
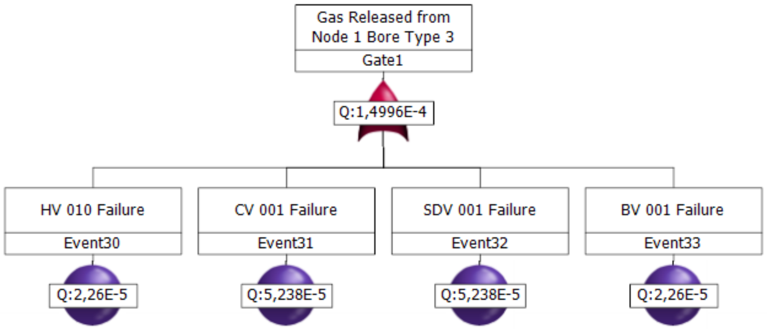


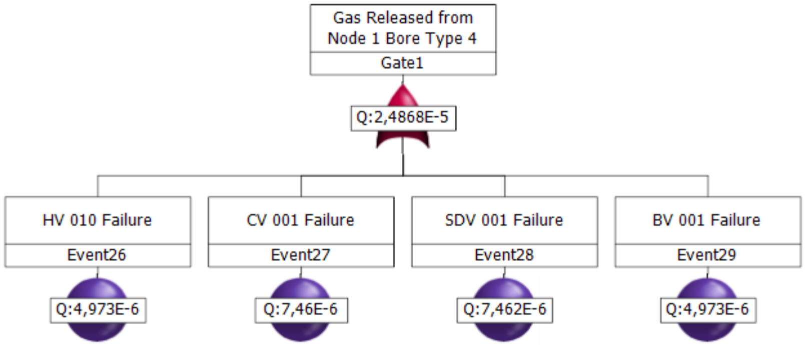
FTA Result of Node 1 Bore Size Diameter 1-3 mm



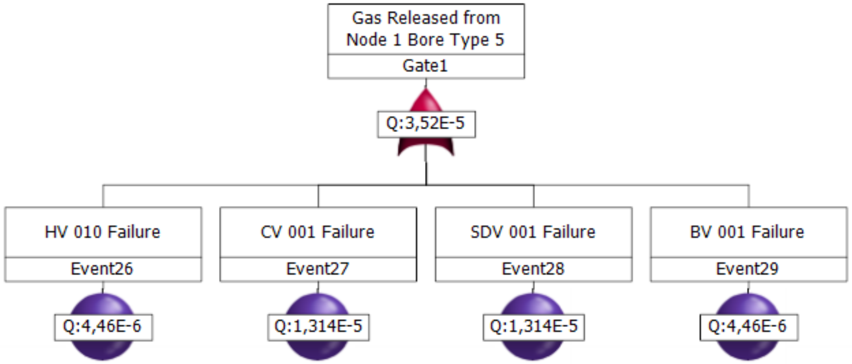
FTA Result of Node 1 Bore Size Diameter 3-10 mm



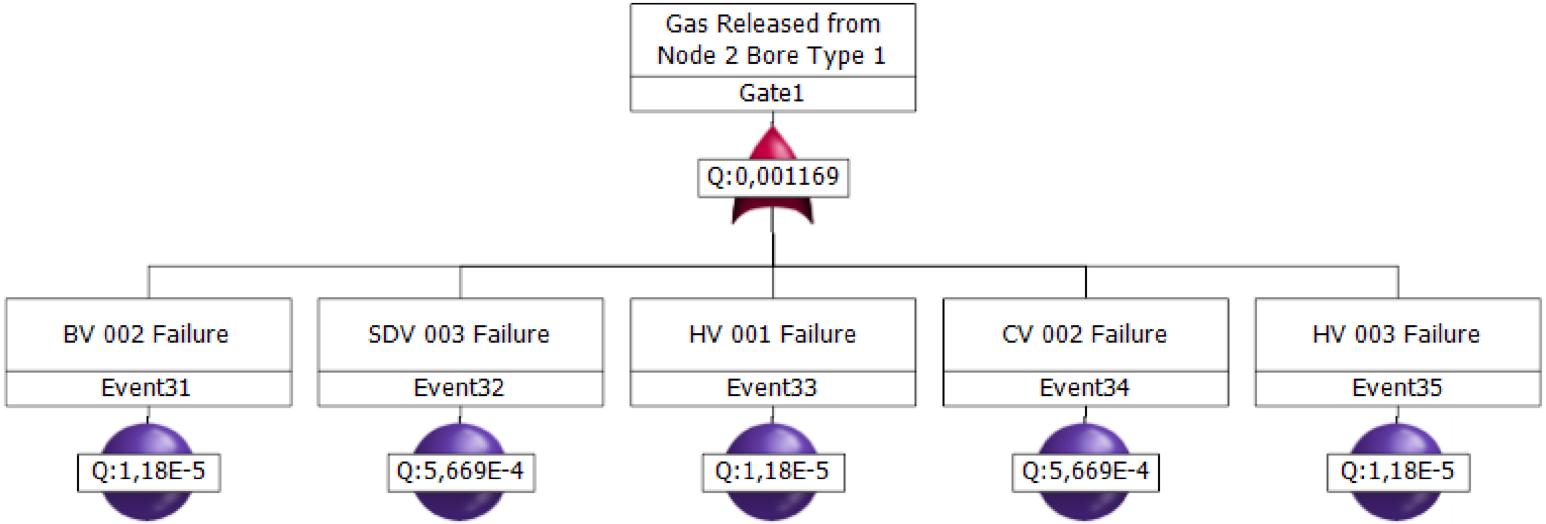
FTA Result of Node 1 Bore Size Diameter 10-50 mm



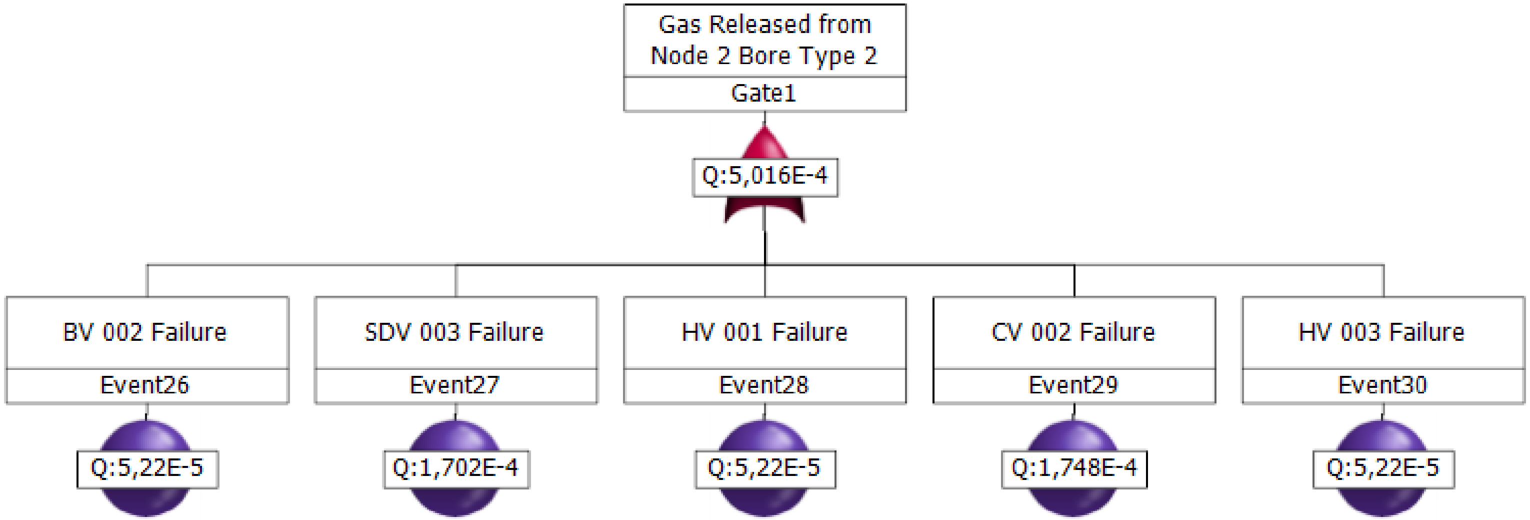
FTA Result of Node 1 Bore Size Diameter 50-150 mm



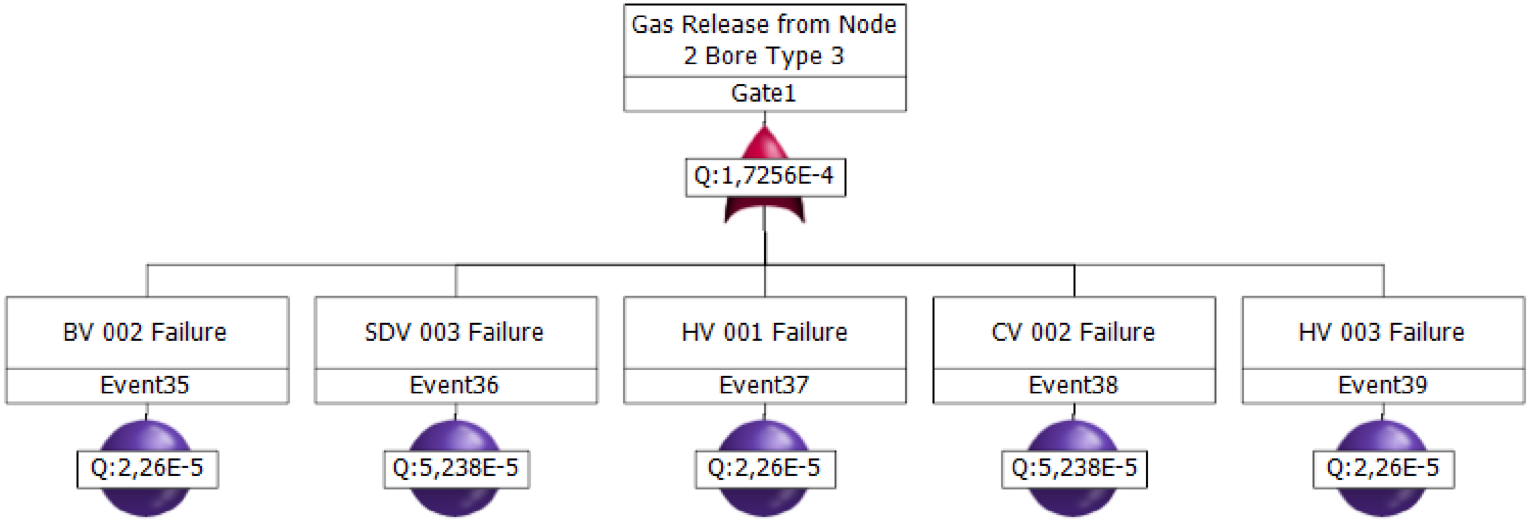
FTA Result of Node 1 Bore Size Diameter >150 mm



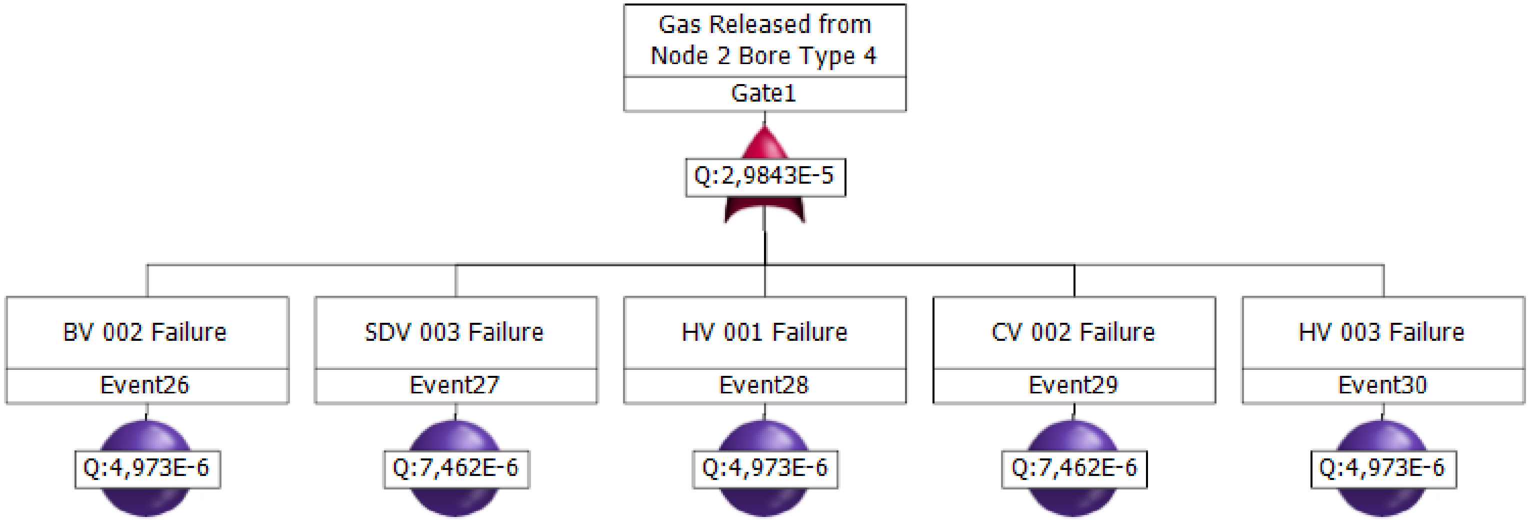
FTA Result of Node 2 Bore Size Diameter 1-3 mm



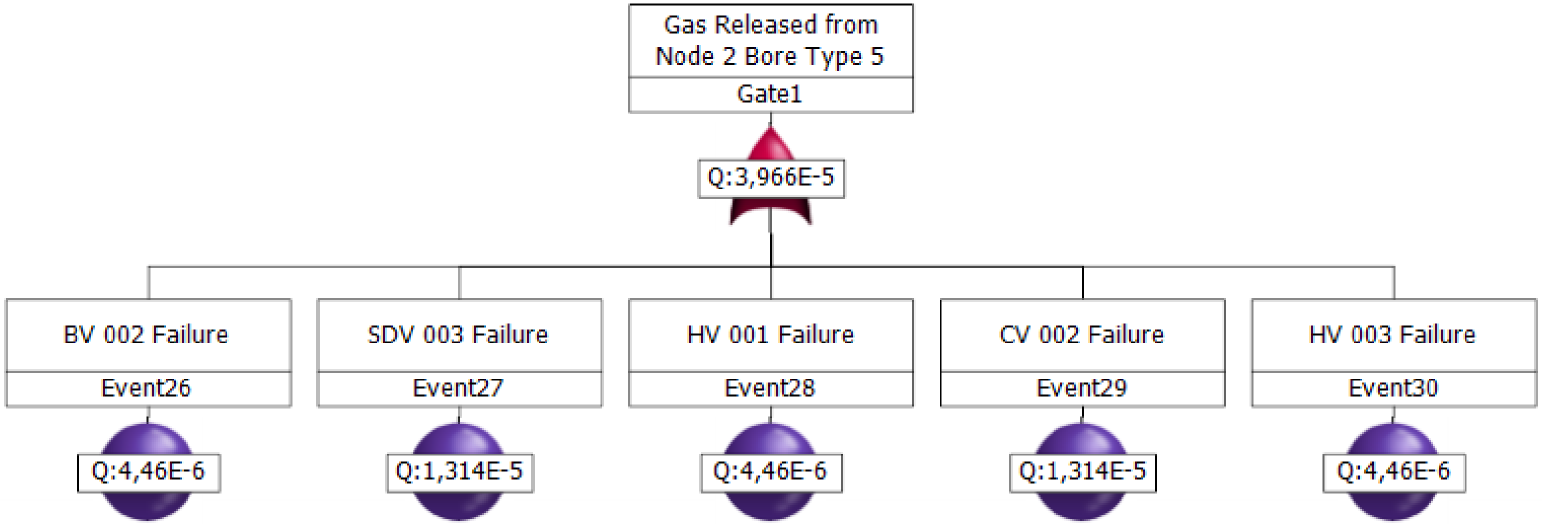
FTA Result of Node 2 Bore Size Diameter 3-10 mm



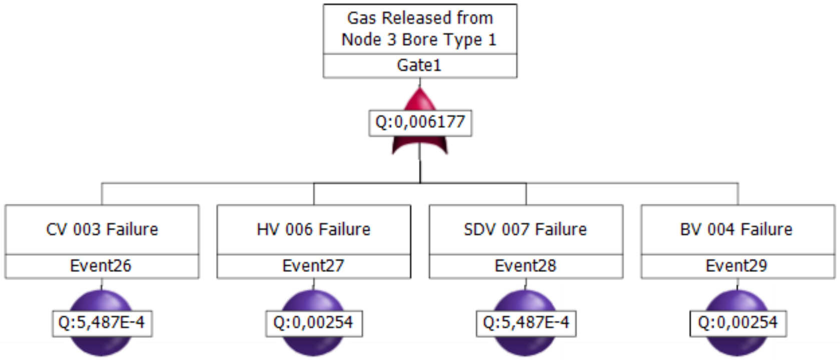
FTA Result of Node 2 Bore Size Diameter 10-50 mm



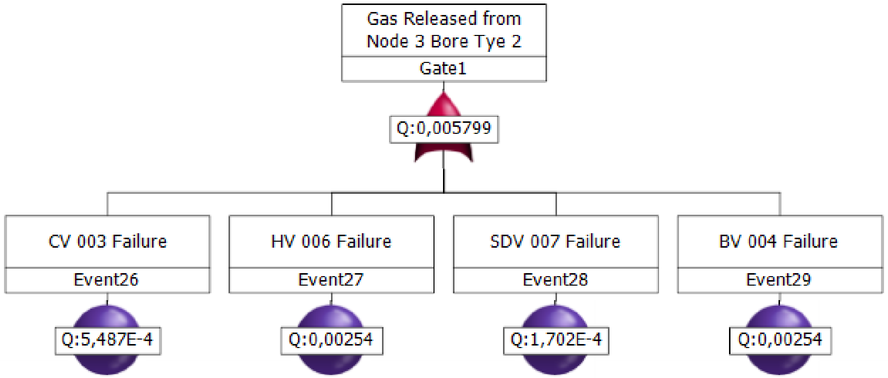
FTA Result of Node 2 Bore Size Diameter 50-150 mm



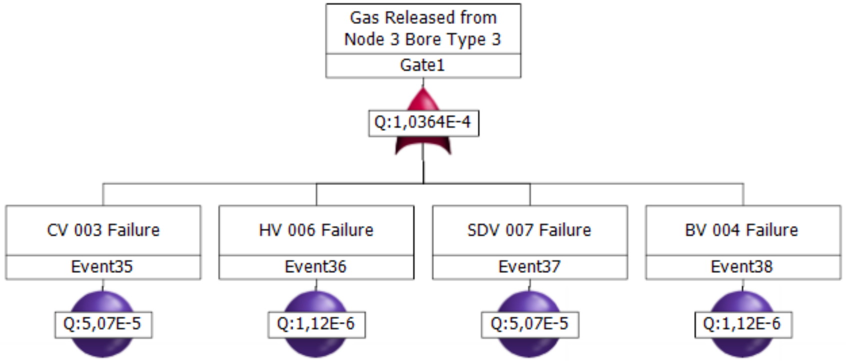
FTA Result of Node 2 Bore Size Diameter >150 mm



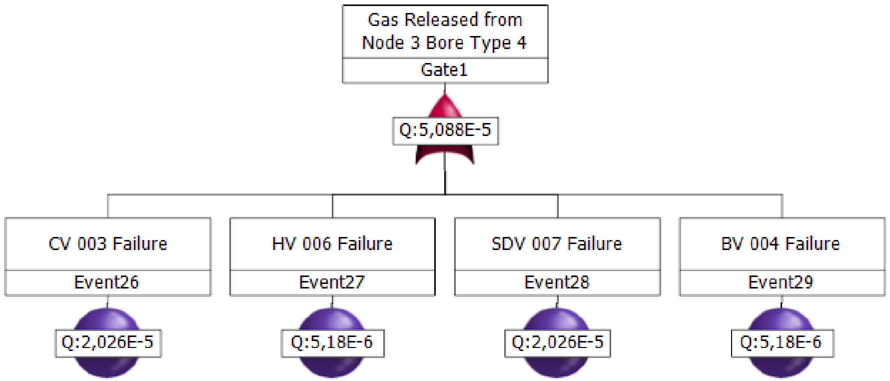
FTA Result of Node 3 Diameter 1-3 mm



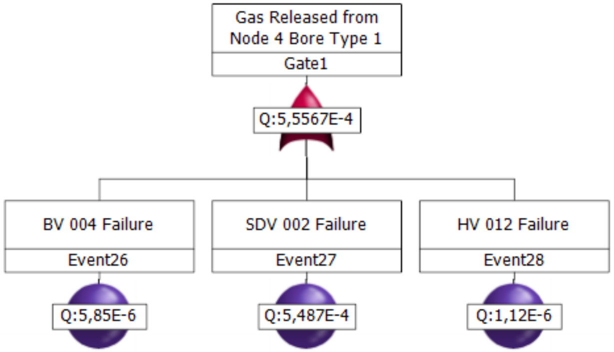
FTA Result of Node 3 Diameter 3-10 mm



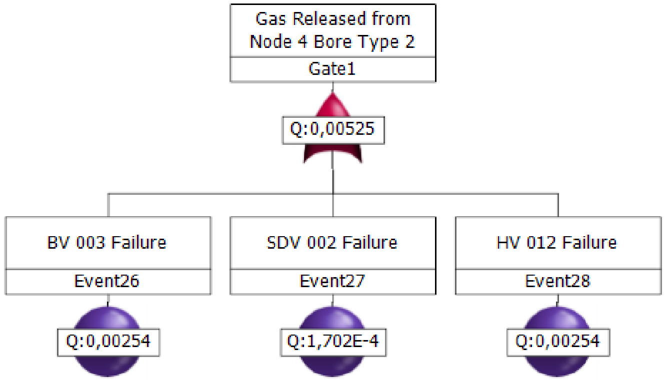
FTA Result of Node 3 Bore Size Diameter 10-50 mm



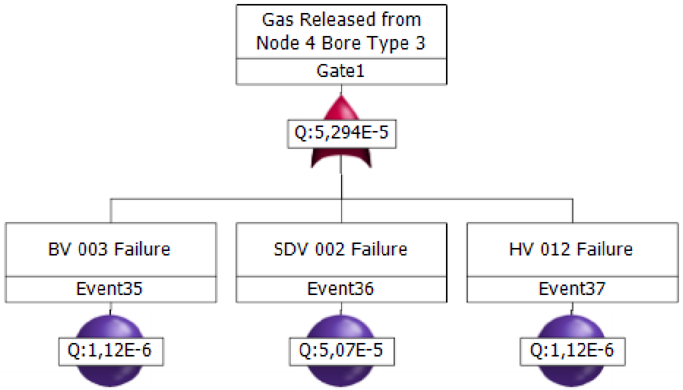
Result of Node 3 Bore Size Diameter 50-150 mm



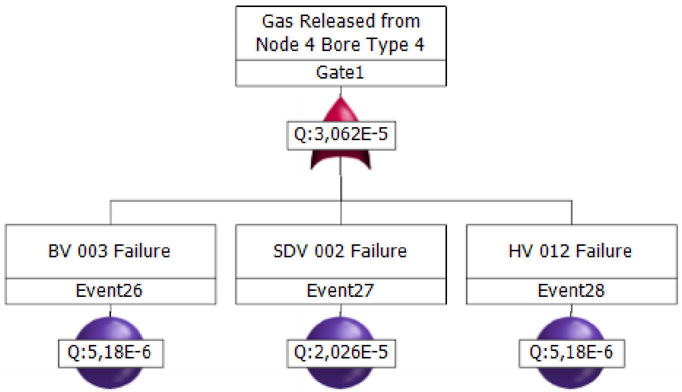
FTA Result of Node 4 Bore Size Diameter 1-3 mm



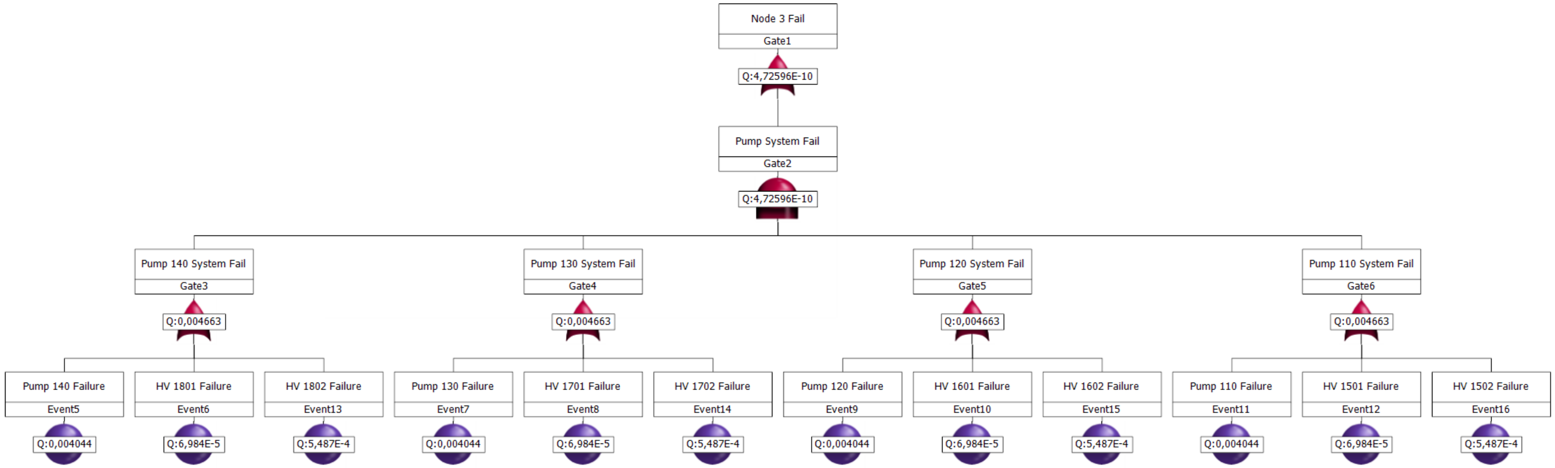
FTA Result of Node 4 Bore Size Diameter 3-10 mm



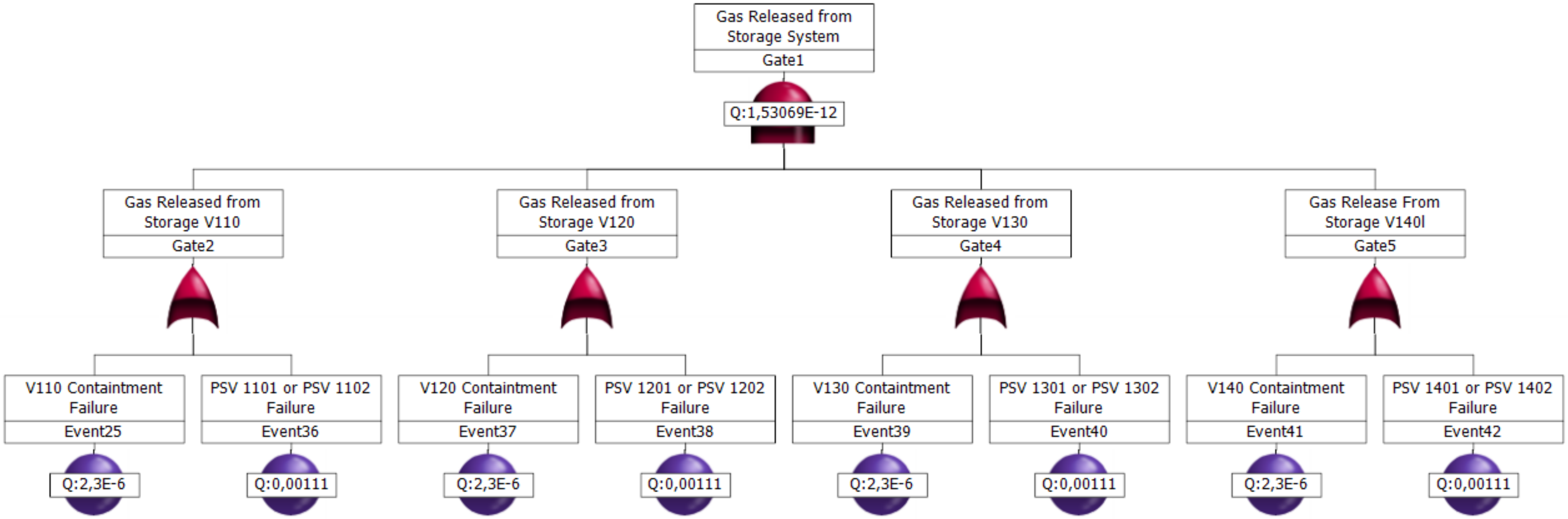
FTA Result of Node 4 Bore Size Diameter 10-50 mm



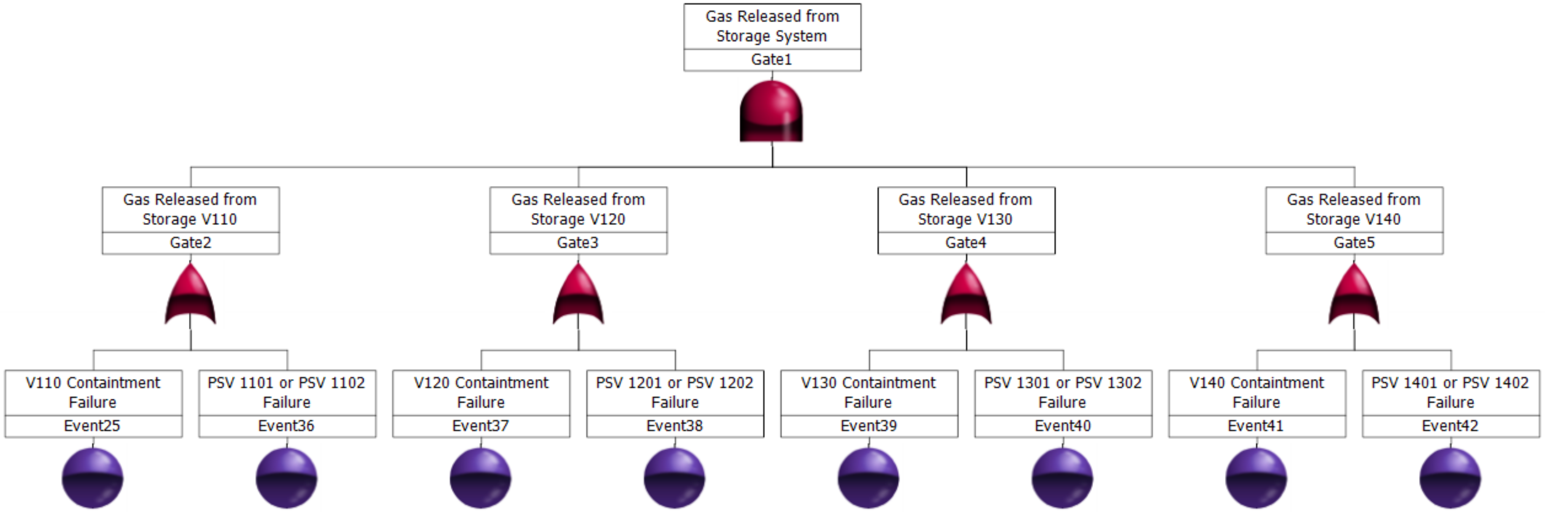
FTA Result of Node 4 Bore Size Diameter 50-150 mm



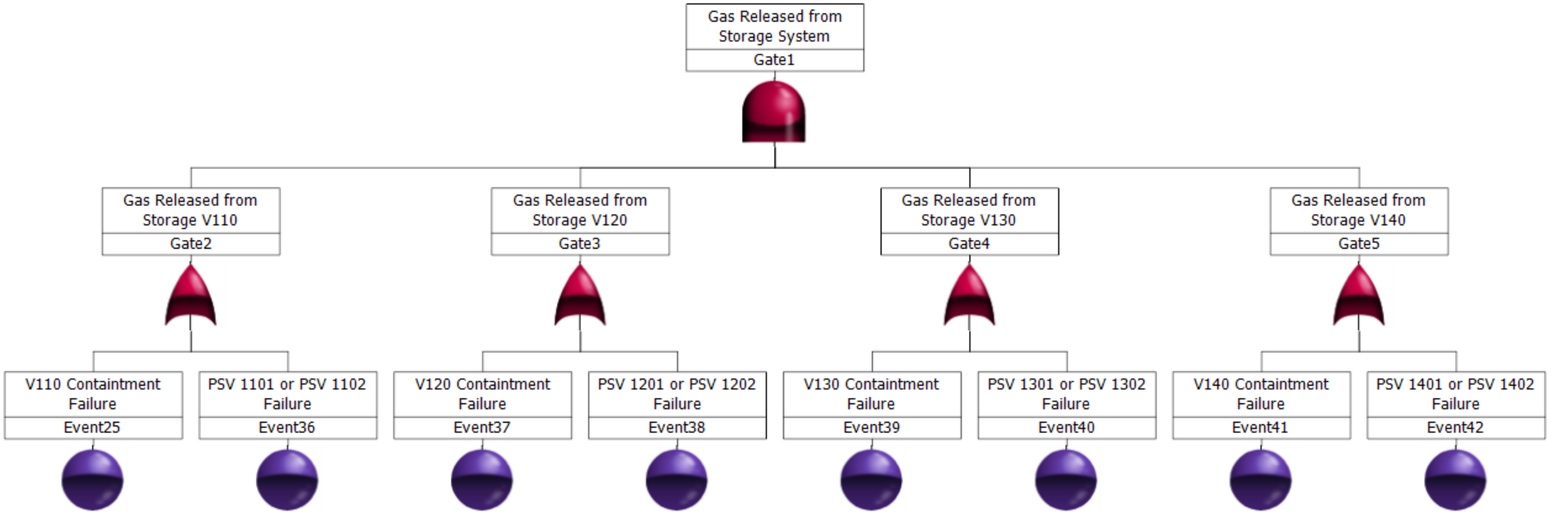
FTA Result of Node 5 Bore Size Diameter 1-3 mm



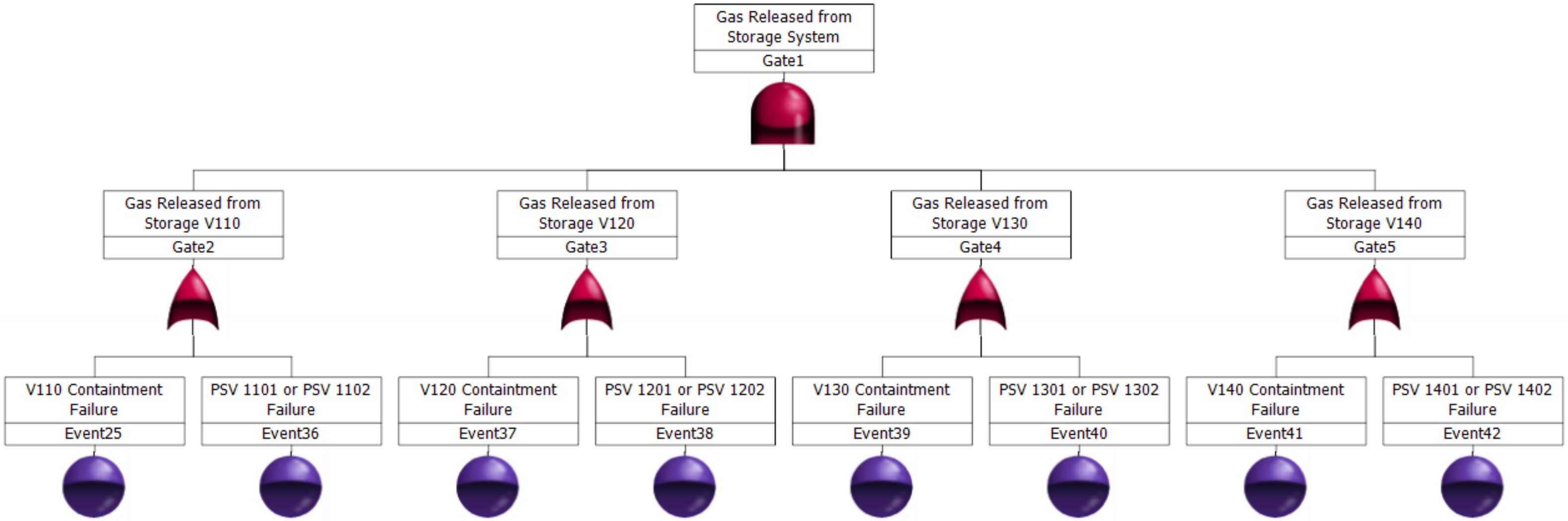
FTA Result of Node 5 Bore Size Diameter 3-10 mm



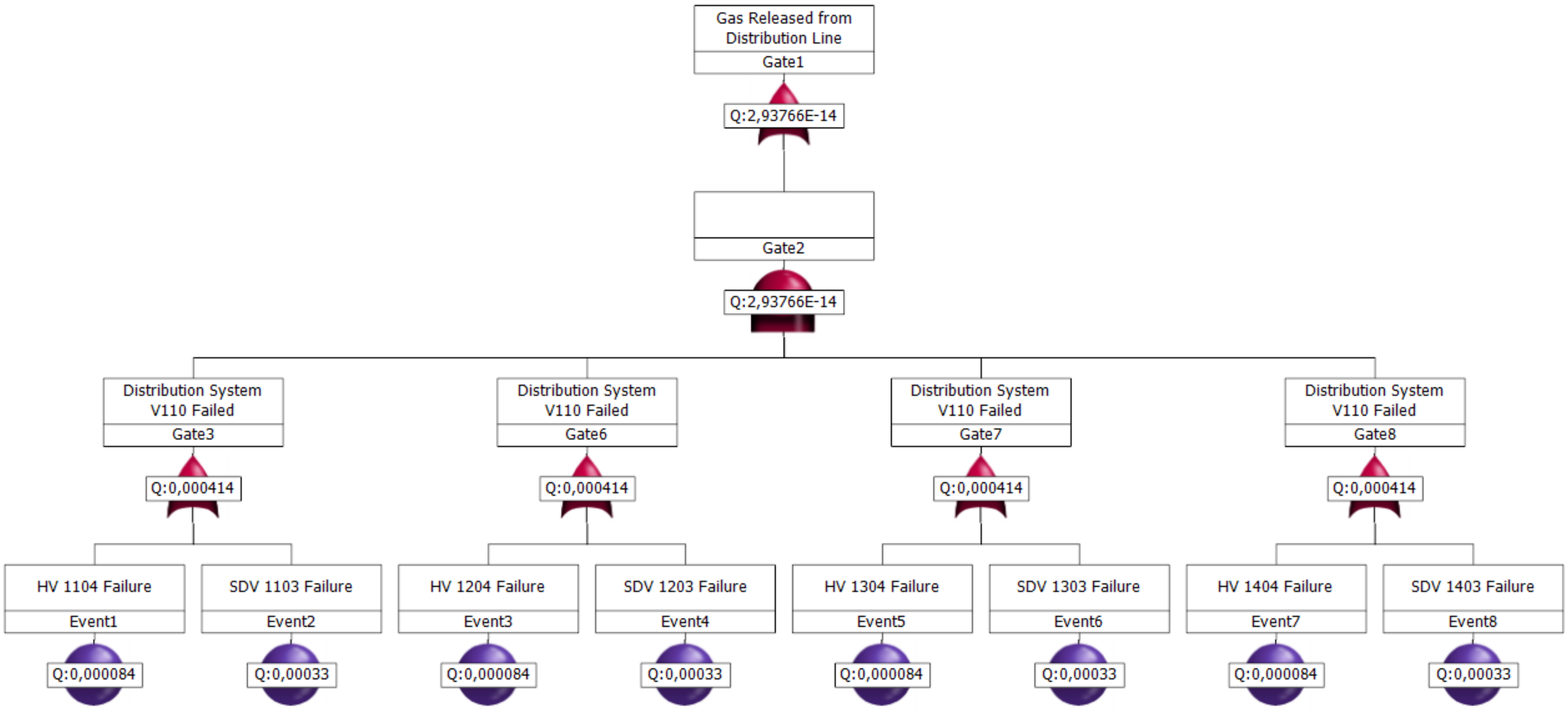
FTA Result of Node 5 Bore Size Diameter 10-50 mm



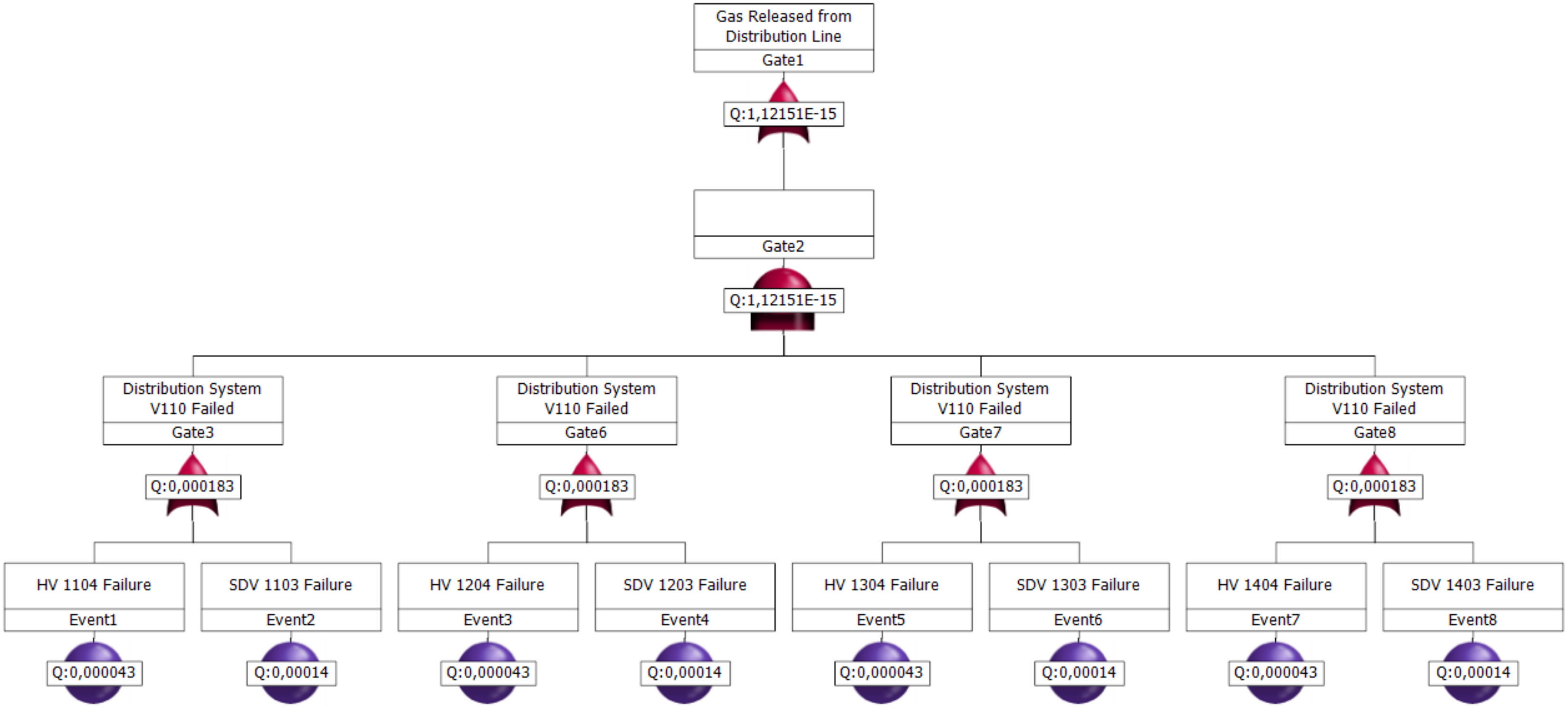
FTA Result of Node 5 Bore Size Diameter 50-150 mm



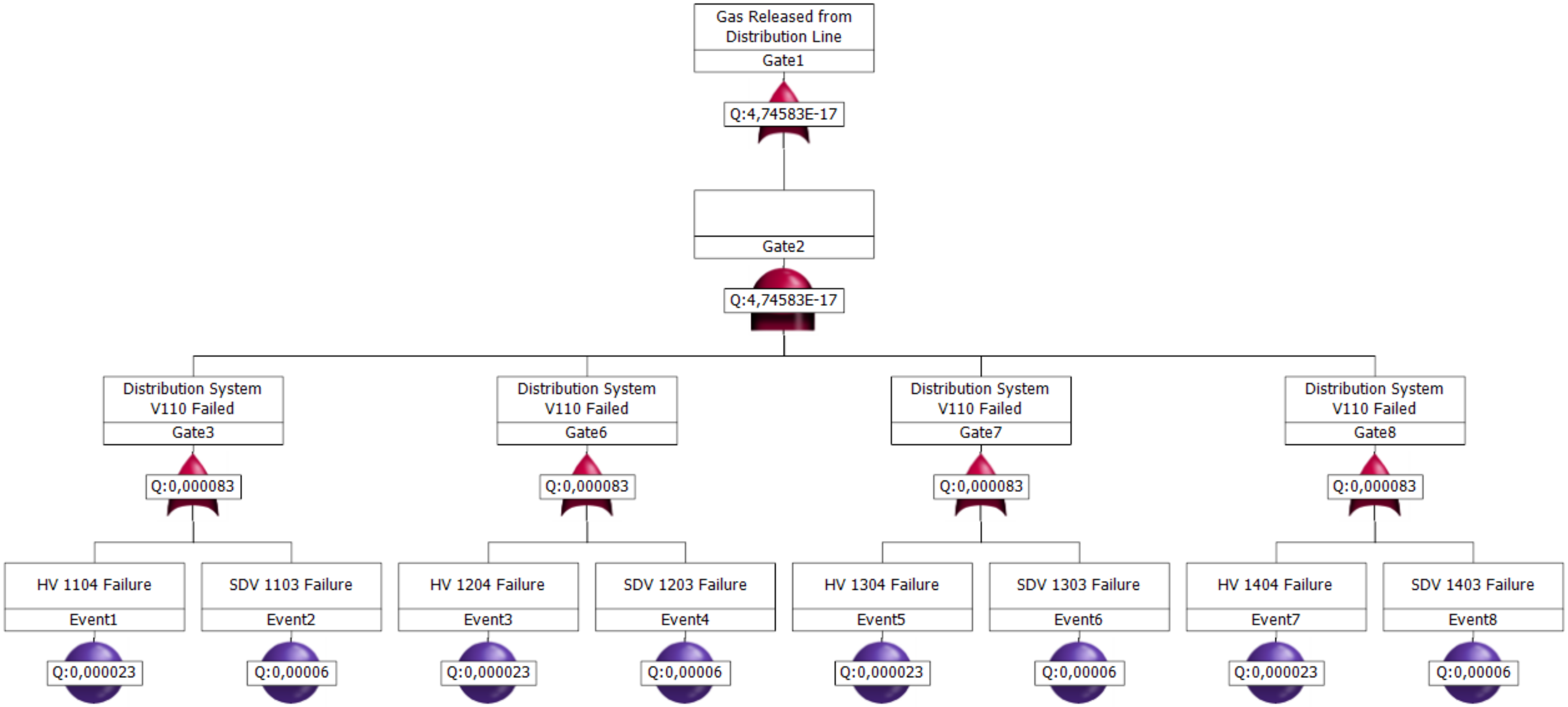
FTA Result of Node 5 Bore Size Diameter >150 mm



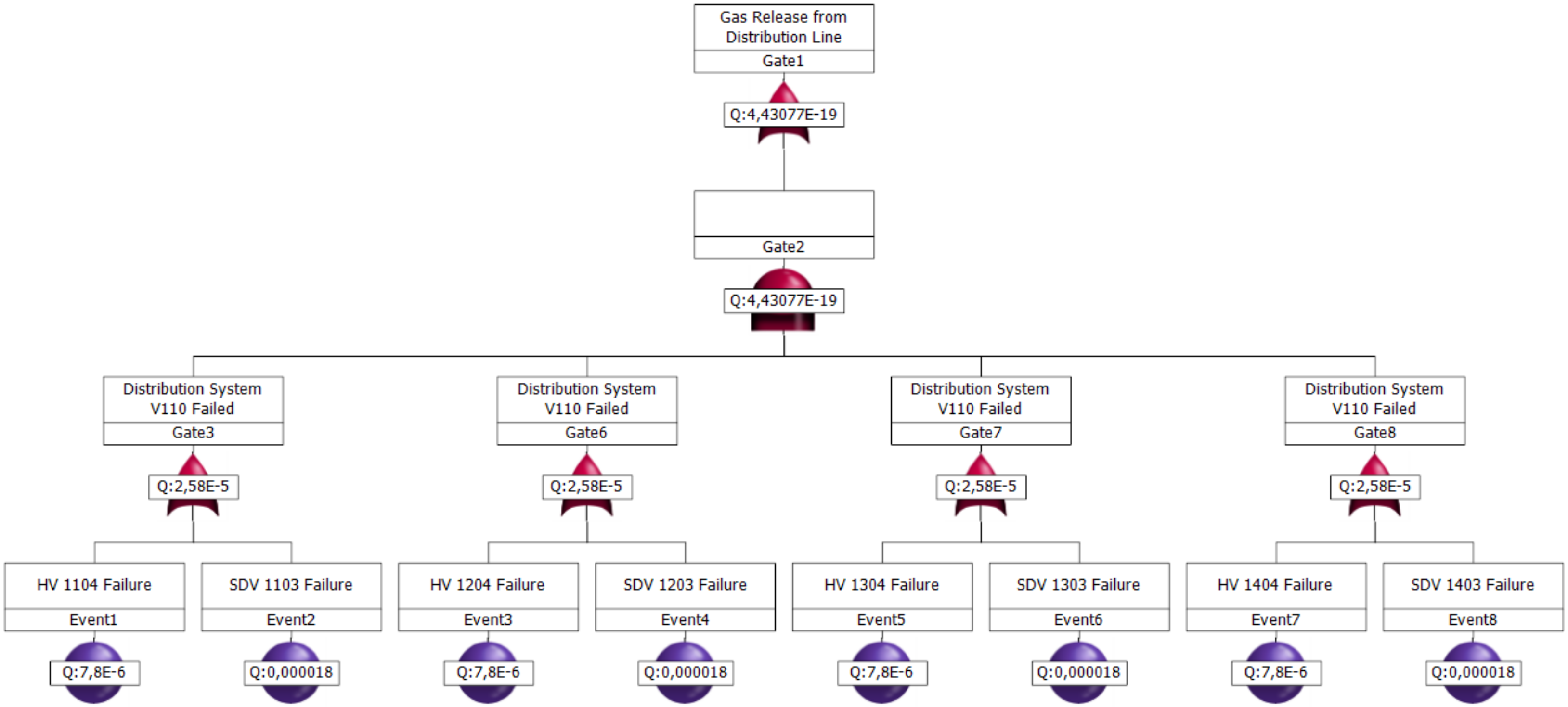
FTA Result of Node 6: Distribution Bore Size Diameter 1-3 mm



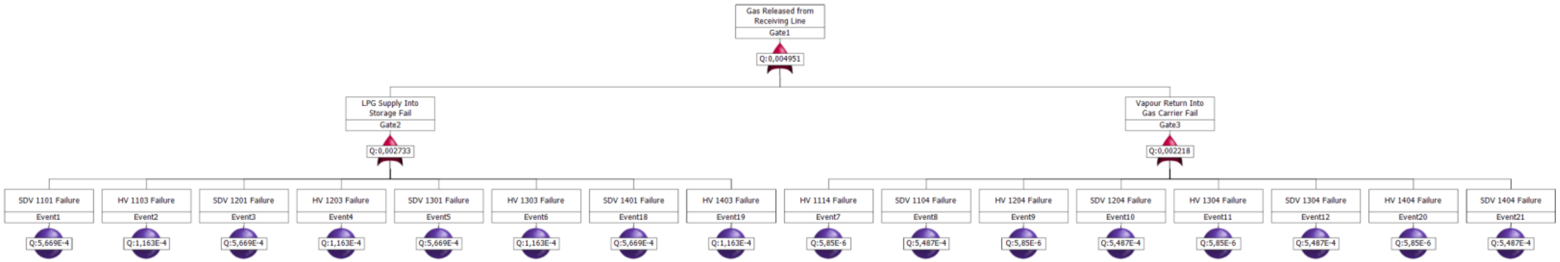
FTA Result of Node 6: Distribution Bore Size Diameter 3-10 mm



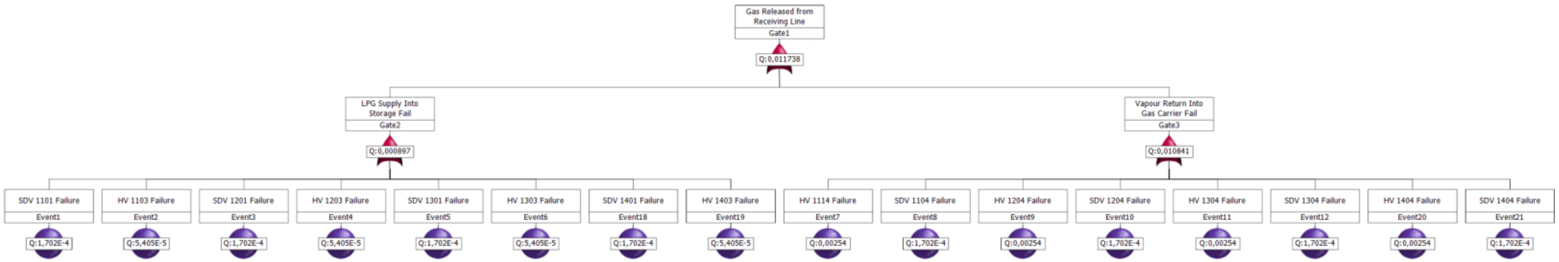
FTA Result of Node 6: Distribution Bore Size Diameter 10-50 mm



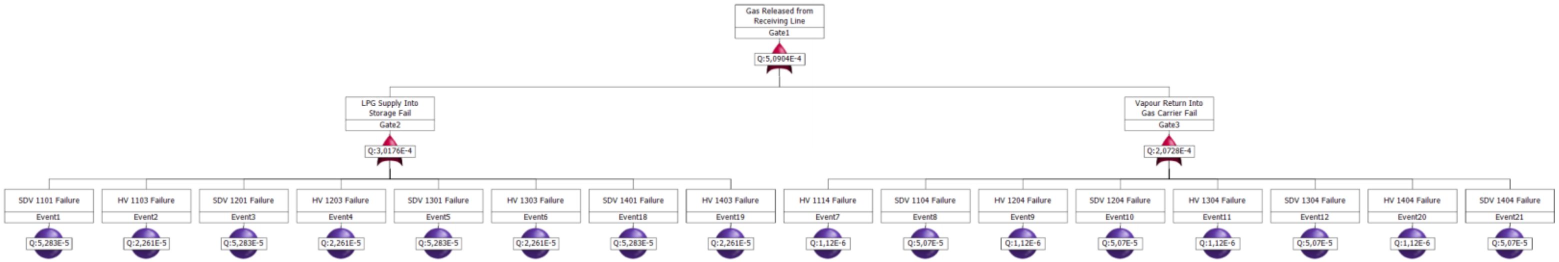
FTA Result of Node 6: Distribution Bore Size Diameter 50-150 mm



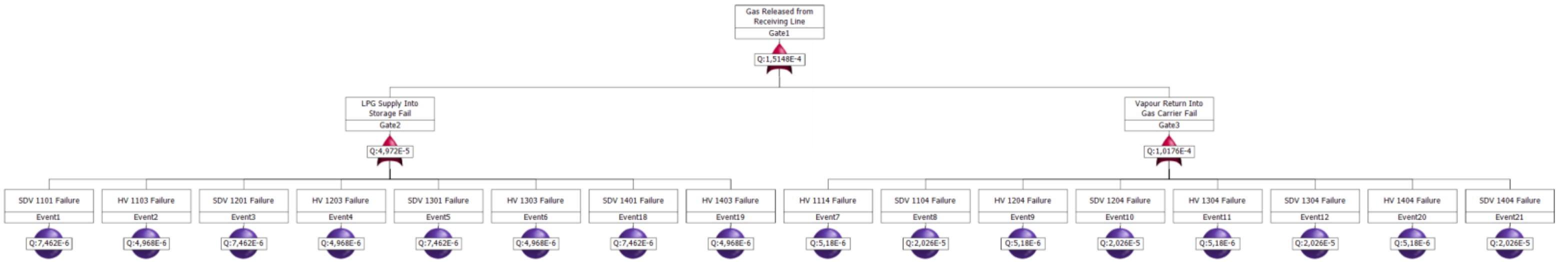
FTA Result of Node 6: Reciving Bore Size Diameter 1-3 mm



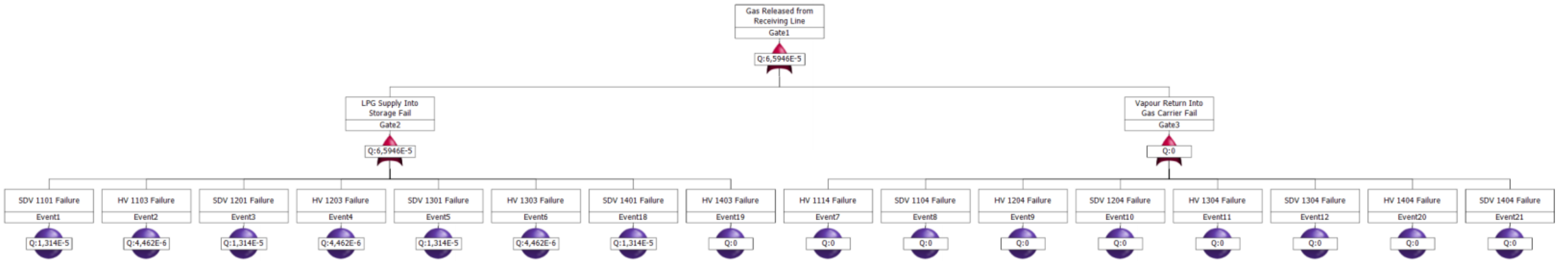
FTA Result of Node 6: Reciving Bore Size Diameter 3-10 mm



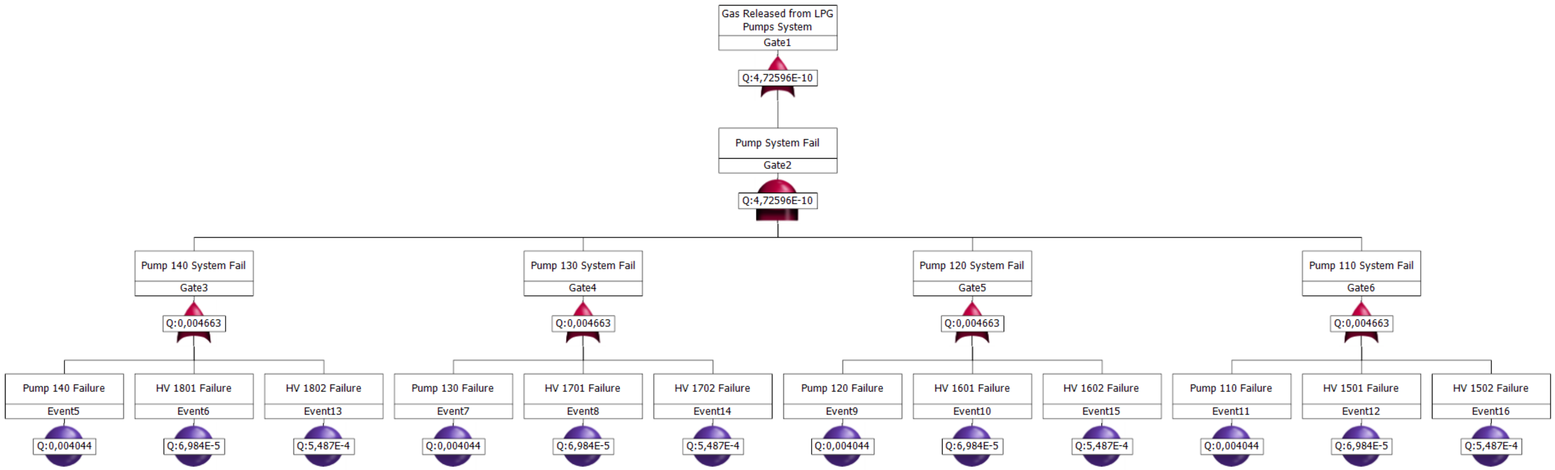
FTA Result of Node 6: Reciving Bore Size Diameter 10-50 mm



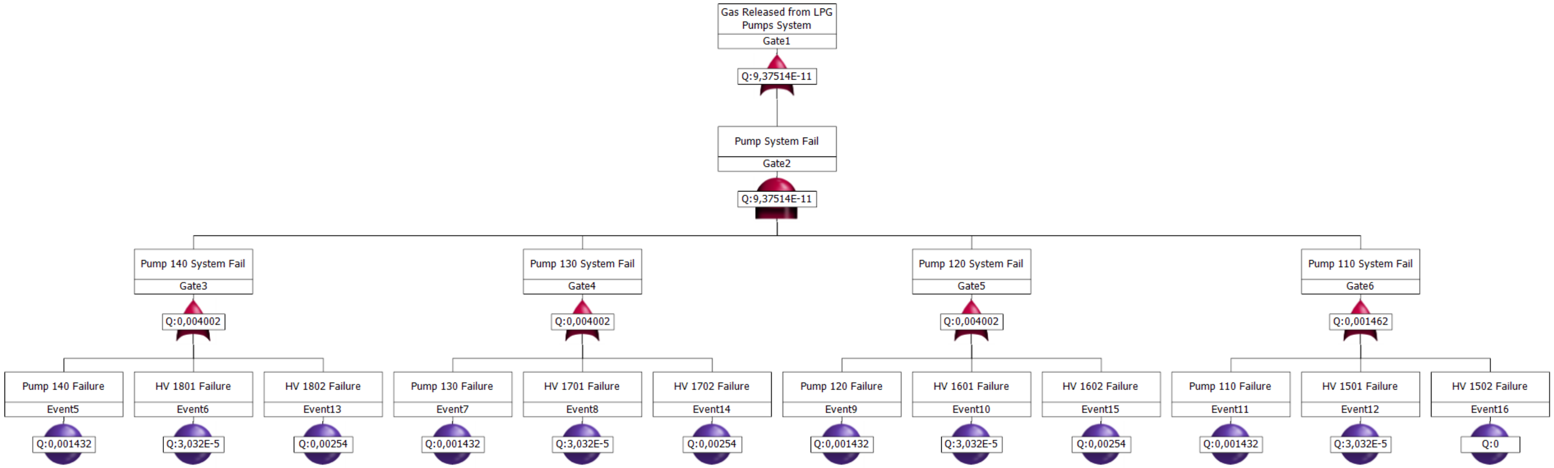
FTA Result of Node 6: Reciving Bore Size Diameter 50-150 mm



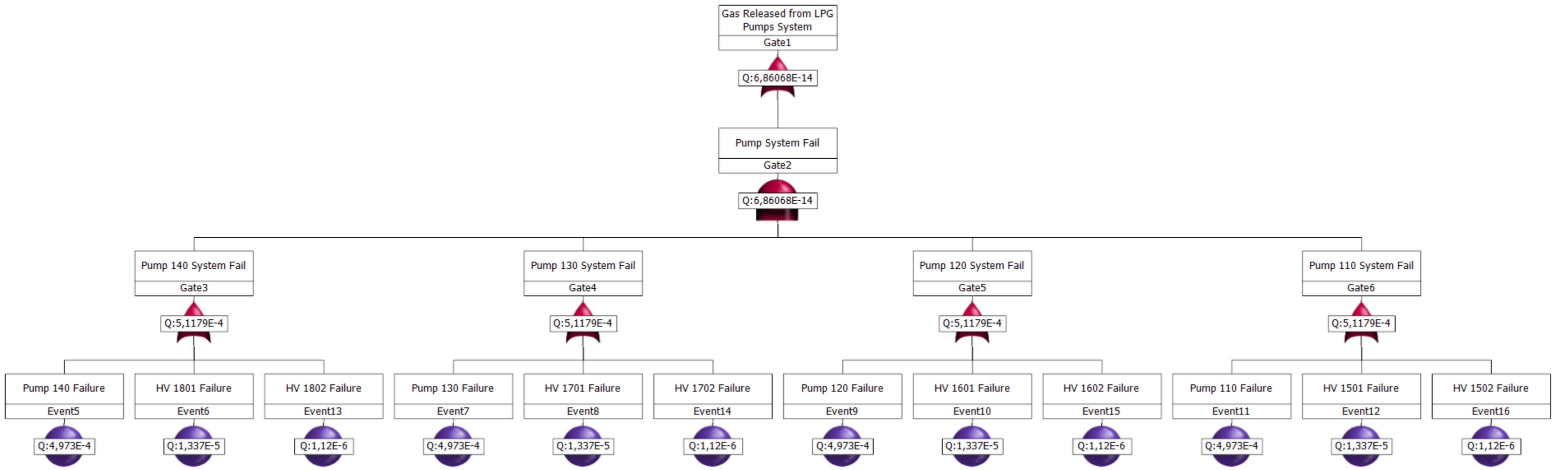
FTA Result of Node 6: Reciving Bore Size Diameter >150 mm



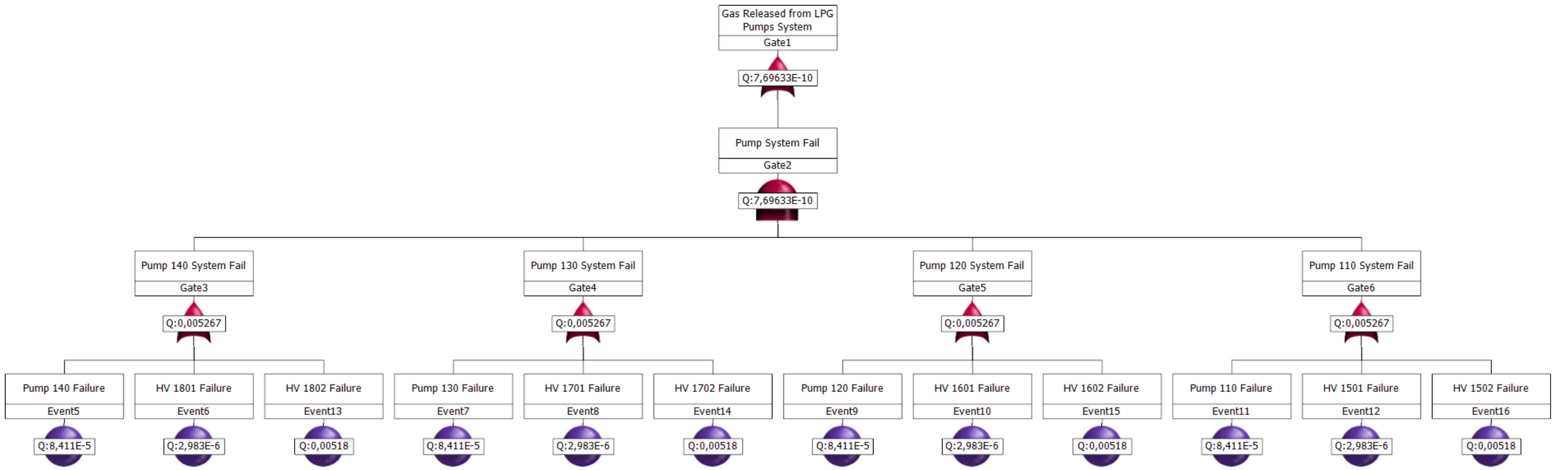
FTA Result of Node 7 Bore Size Diameter 1-3 mm



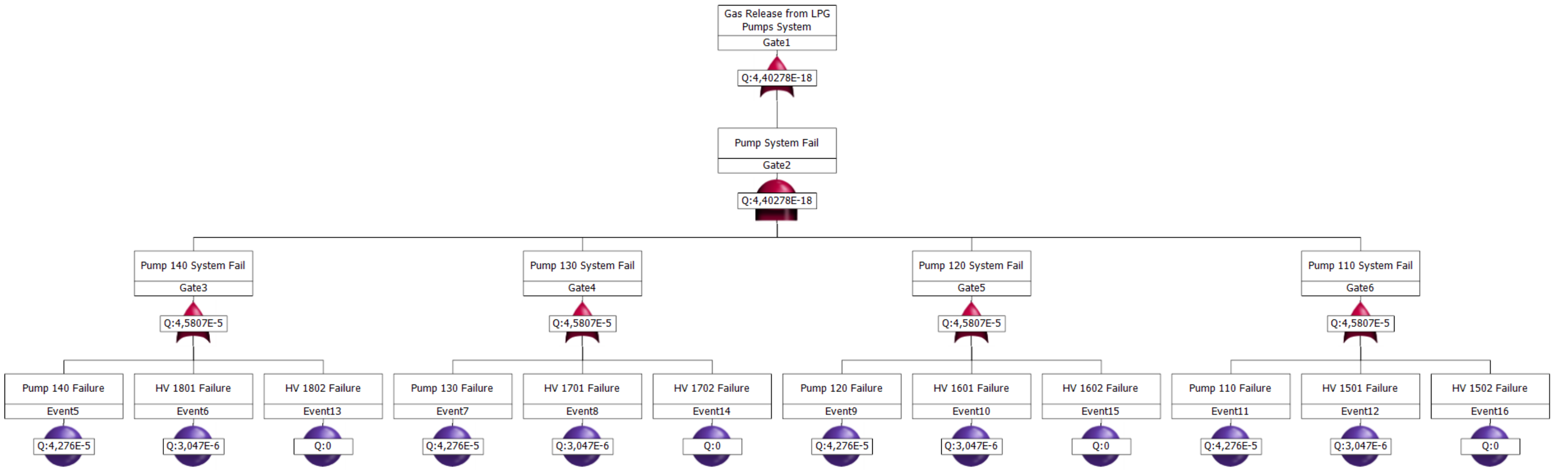
FTA Result of Node 7 Bore Size Diameter 3-10 mm



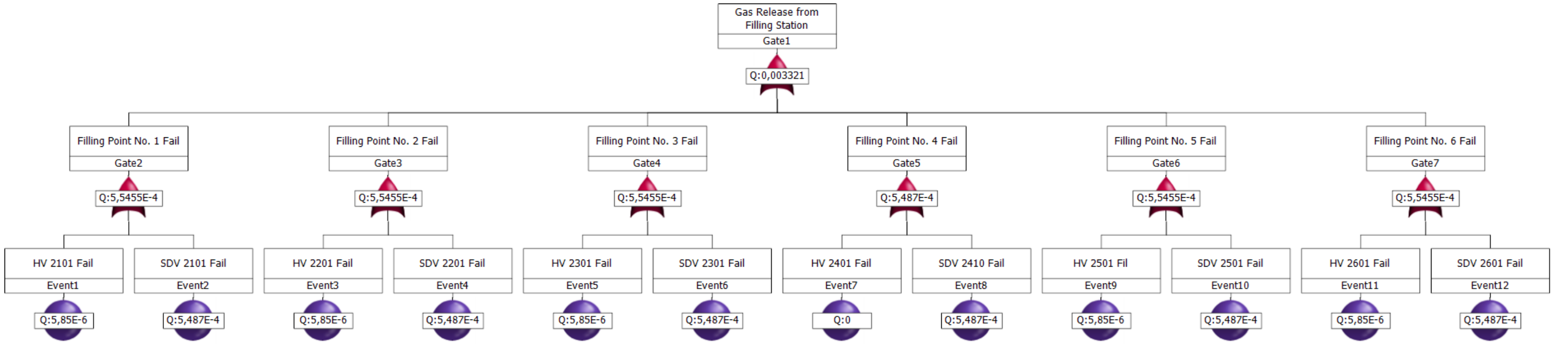
FTA Result of Node 7 Bore Size Diameter 10-50 mm



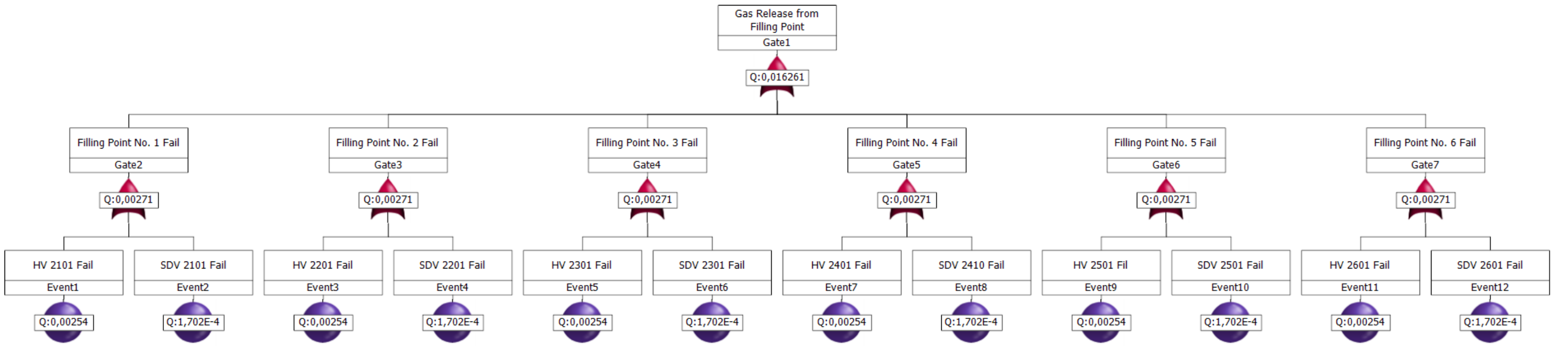
FTA Result of Node 7 Bore Size Diameter 50-150 mm



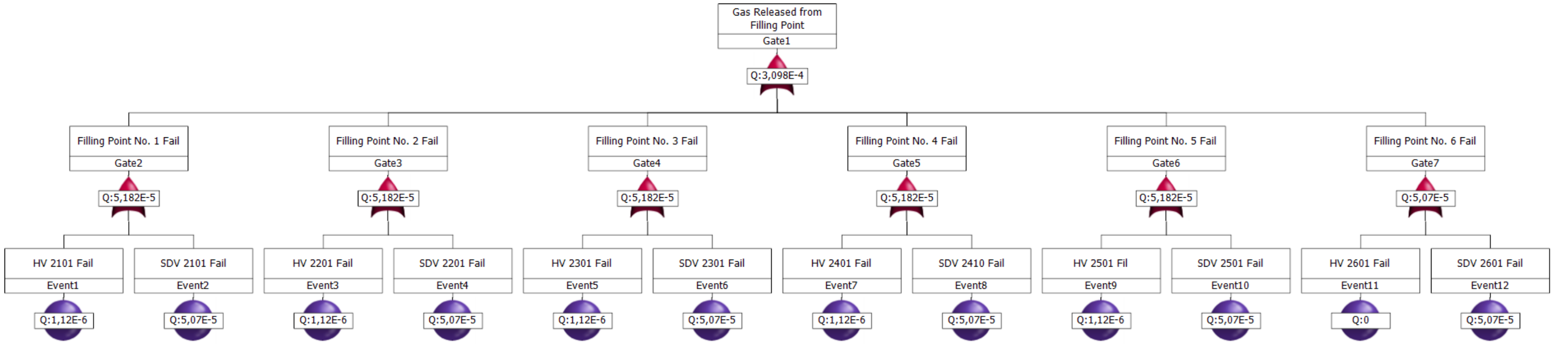
FTA Result of Node 7 Bore Size Diameter >150 mm



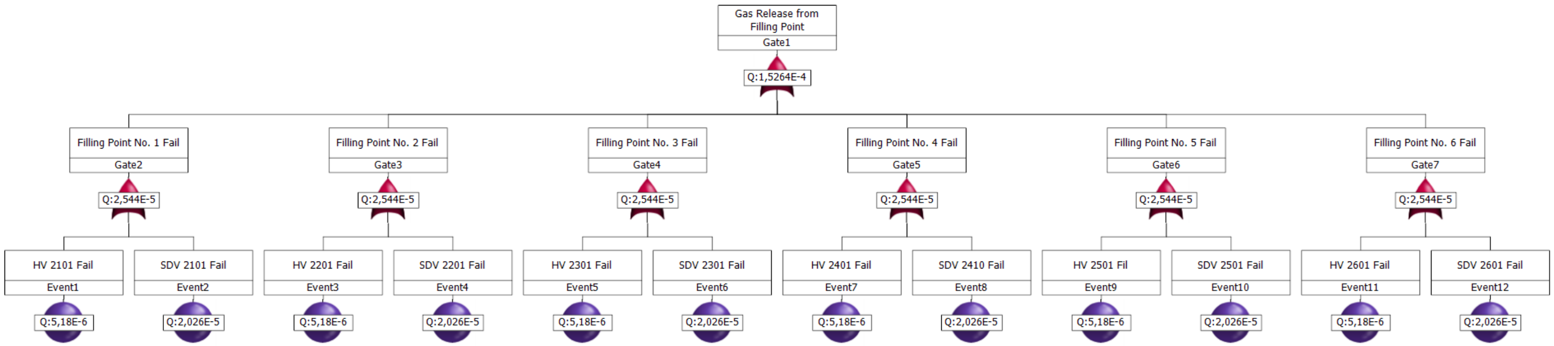
FTA Result of Node 8 Bore Size Diameter 1-3 mm



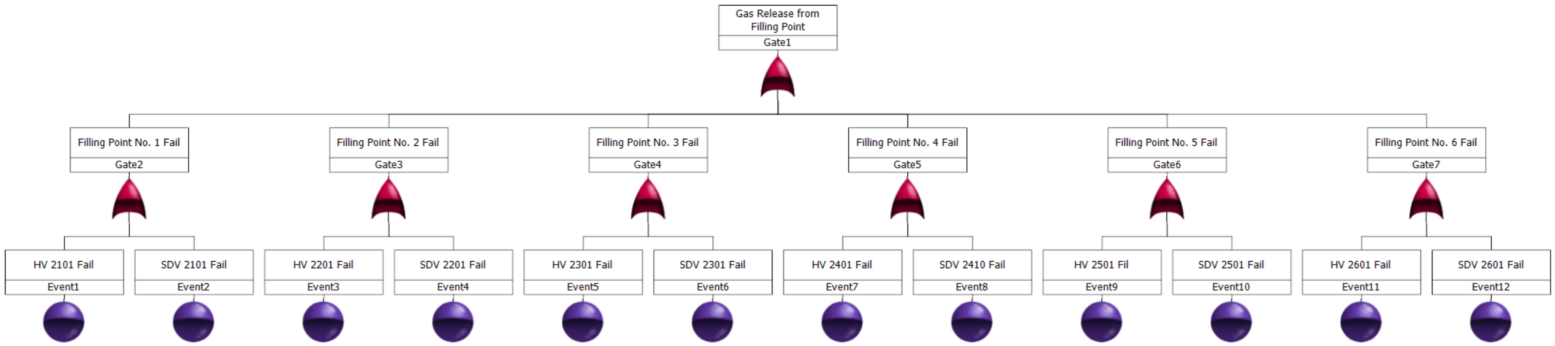
FTA Result of Node 8 Bore Size Diameter 3-10 mm



FTA Result of Node 8 Bore Size Diameter 10-50 mm



FTA Result of Node 8 Bore Size Diameter 50-150 mm



FTA Result of Node 8 Bore Size Diameter >150 mm

Appendix 5: Event Tree Result

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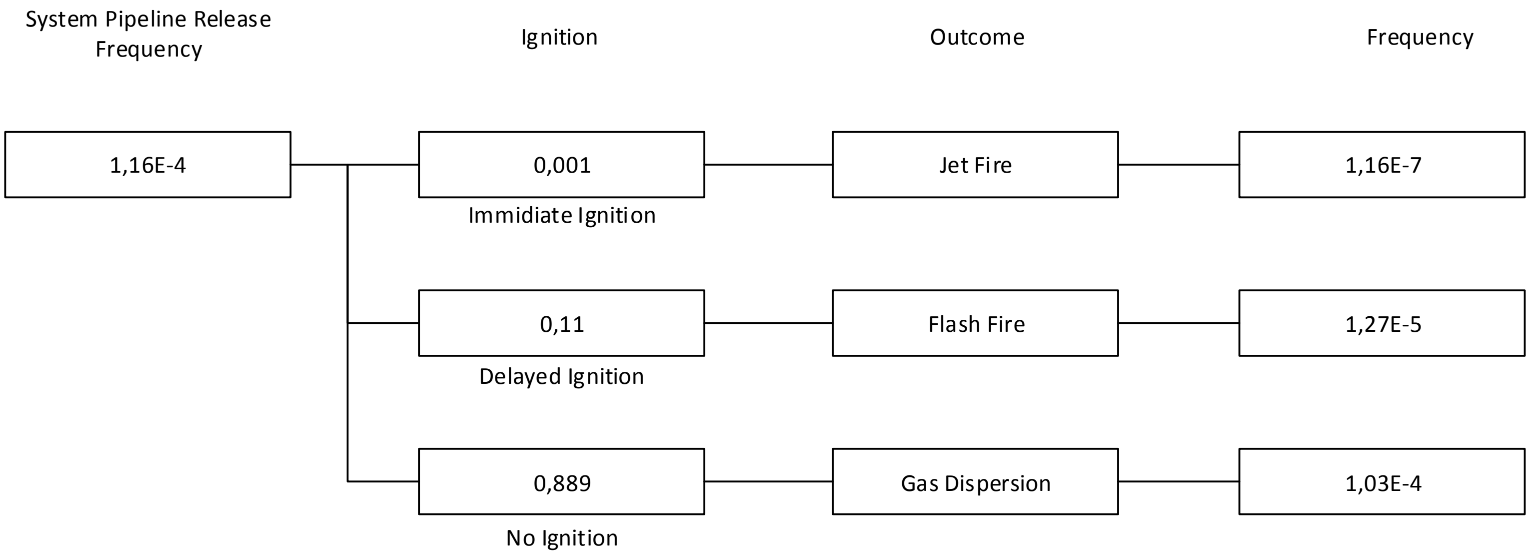
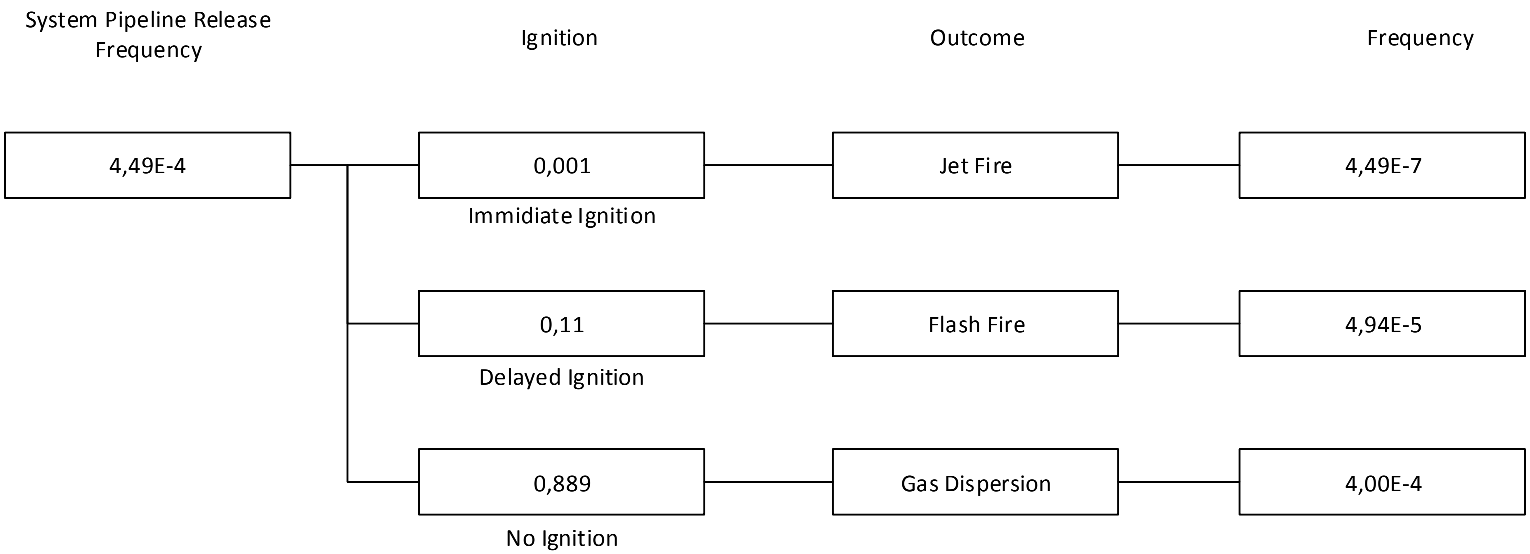
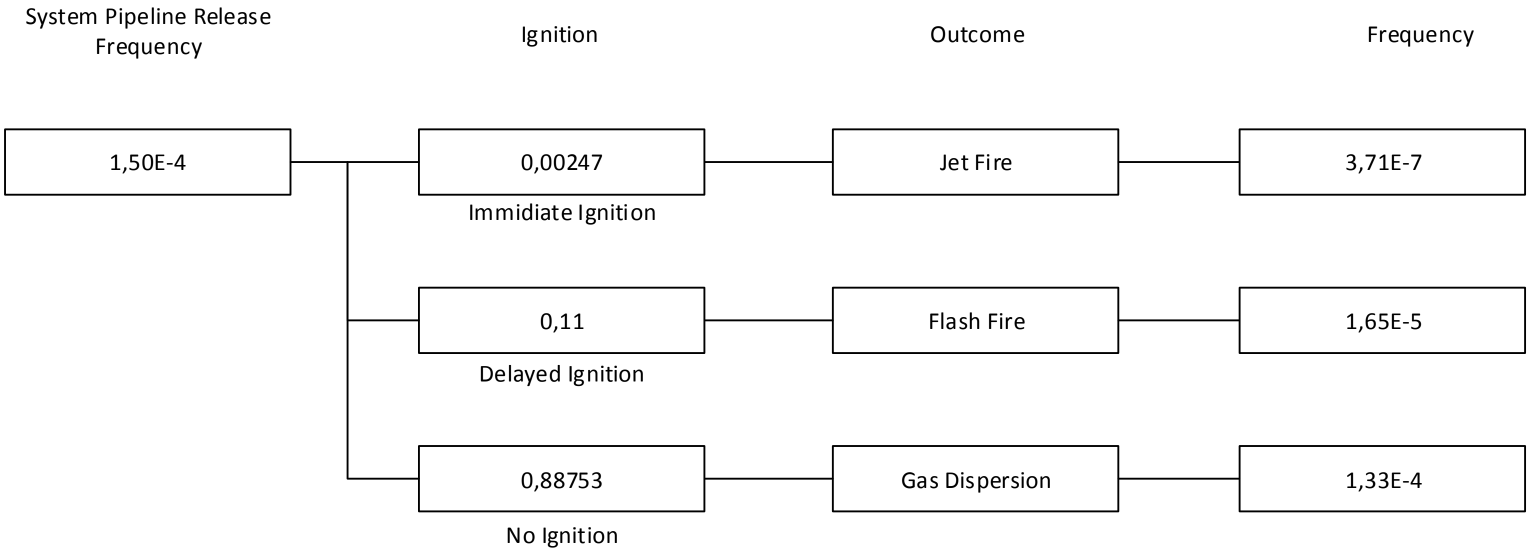


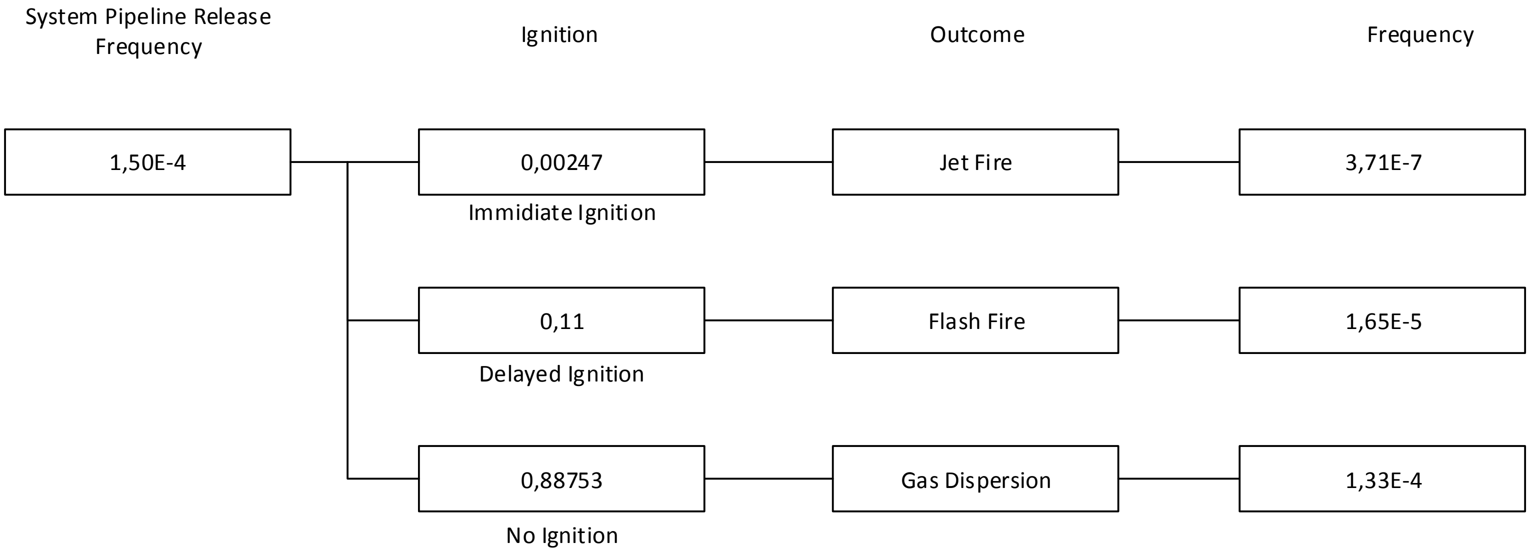
Event Tree of Node 1 Bore Size 1-3 mm



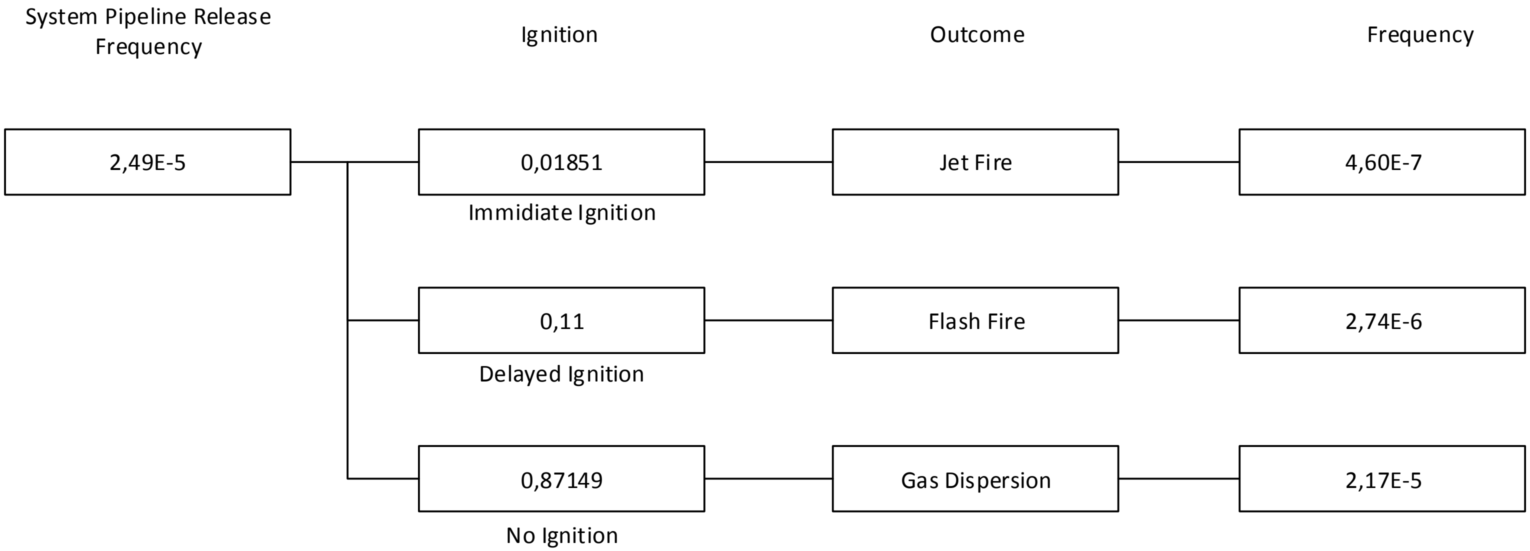
Event Tree of Node 1 Bore Size 3-10 mm



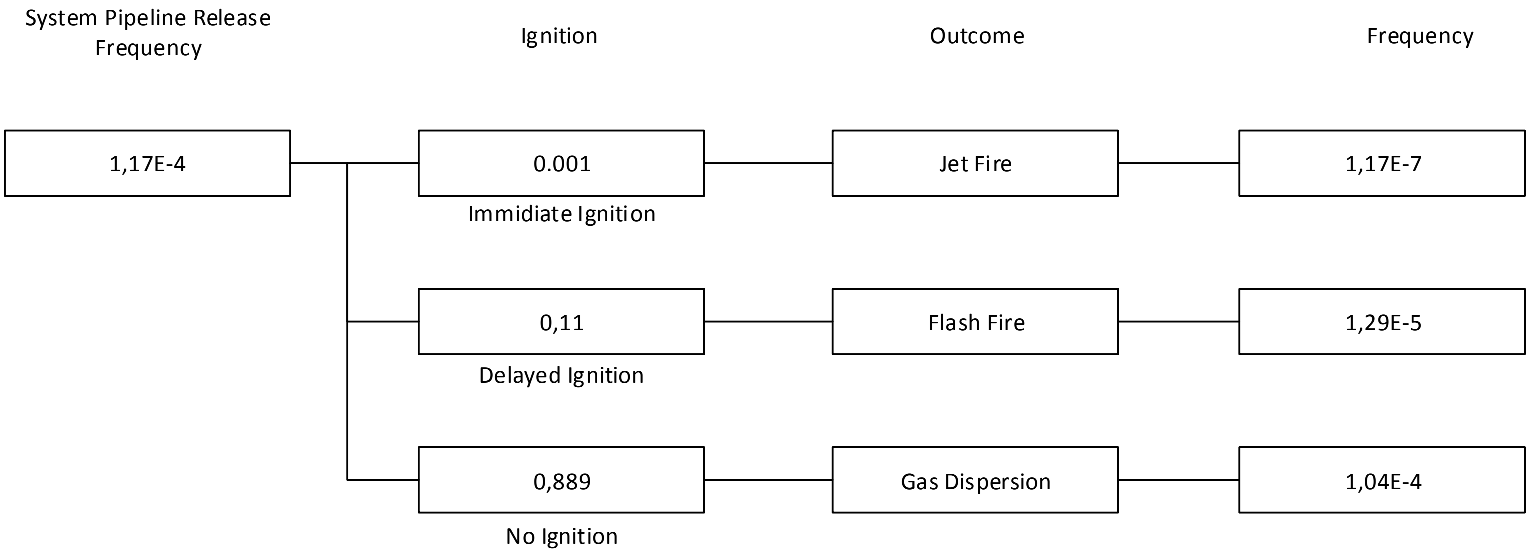
Event Tree of Node 1 Bore Size 10-50 mm



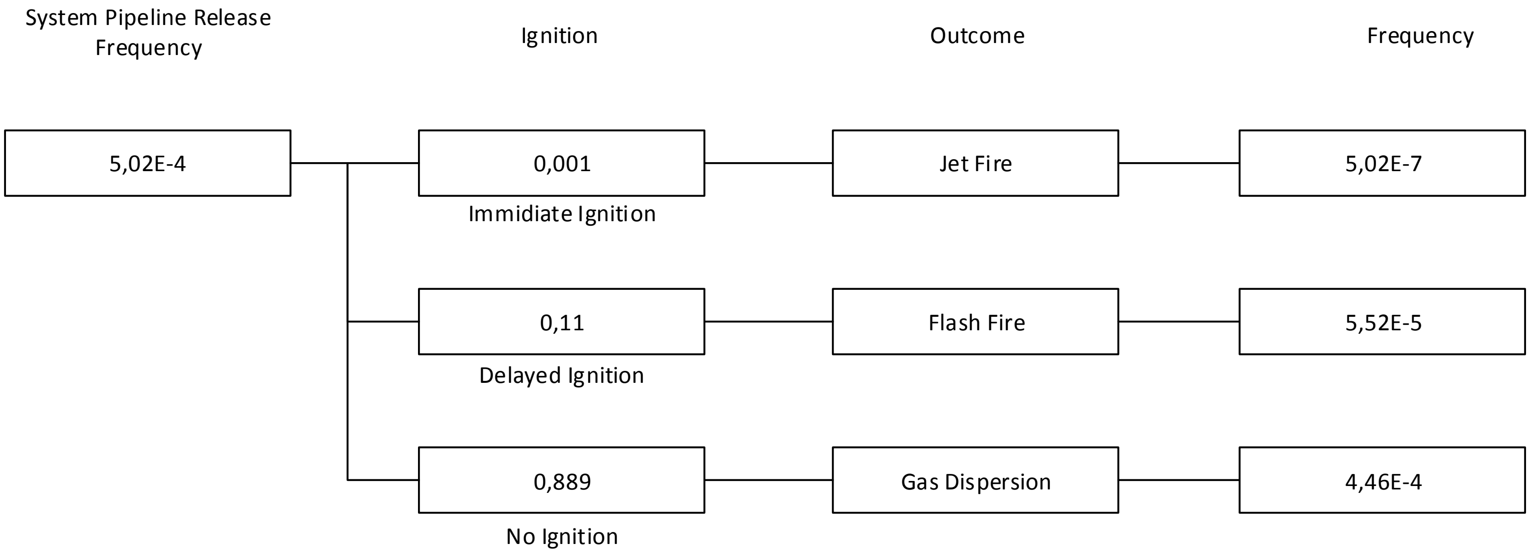
Event Tree of Node 1 Bore Size 50-150 mm



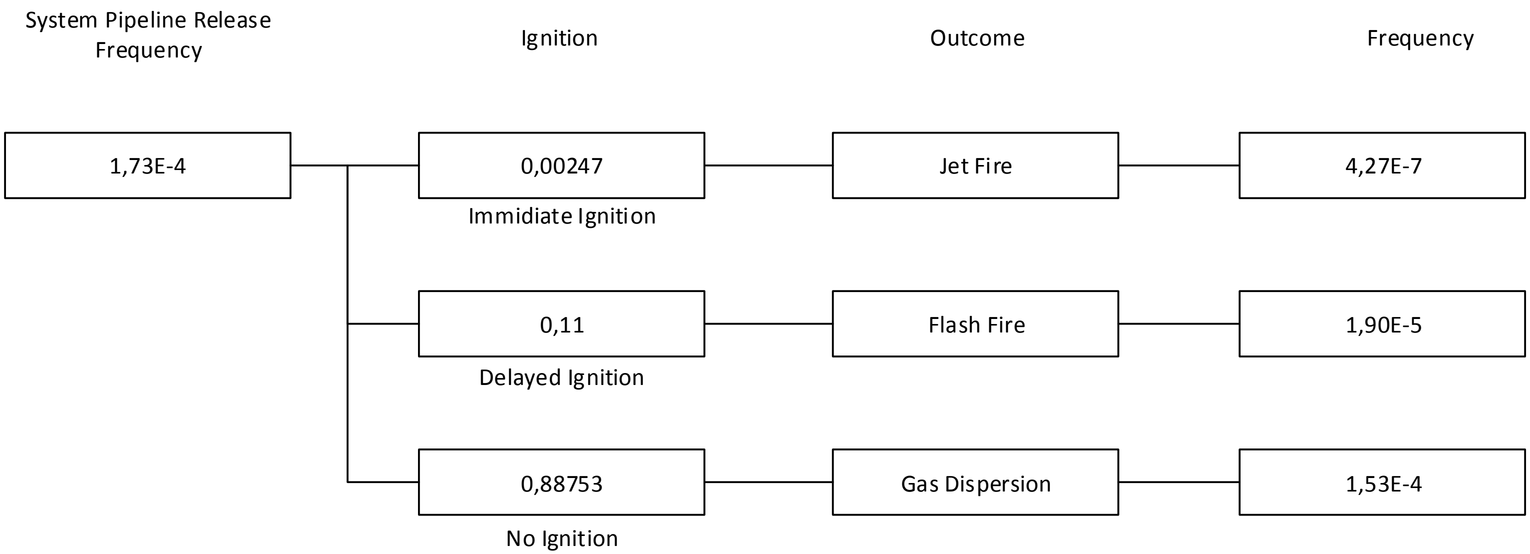
Event Tree of Node 1 Bore Size >150 mm



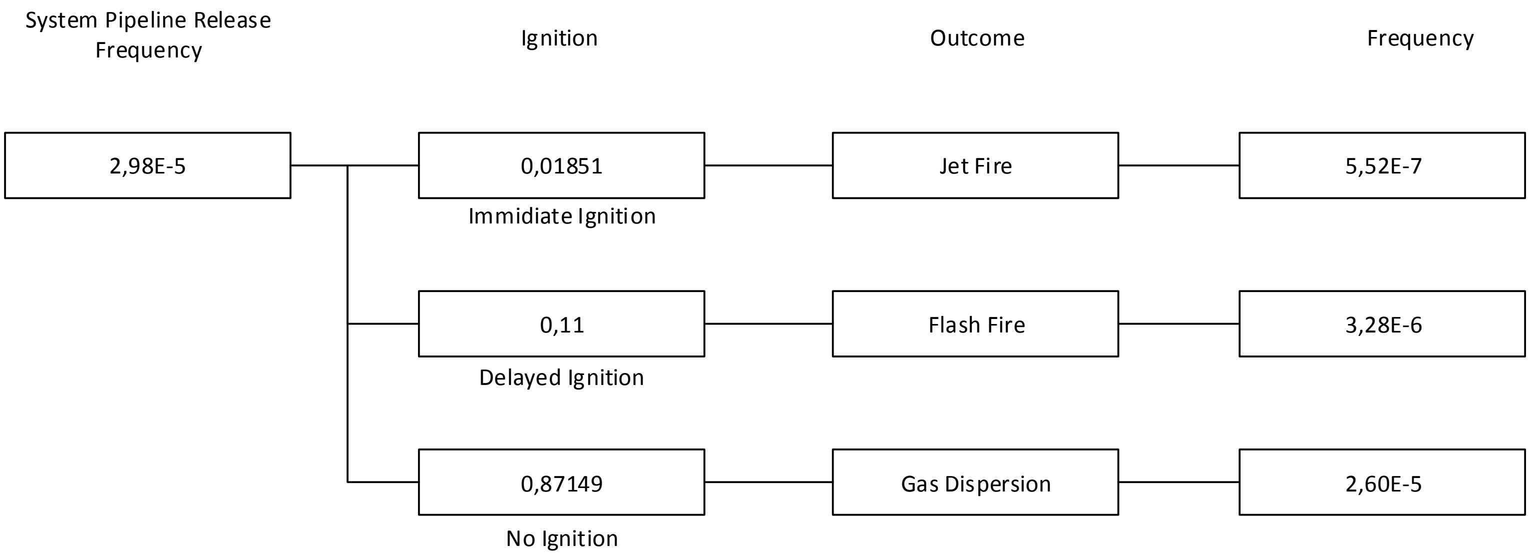
Event Tree of Node 2 Bore Size 1-3 mm



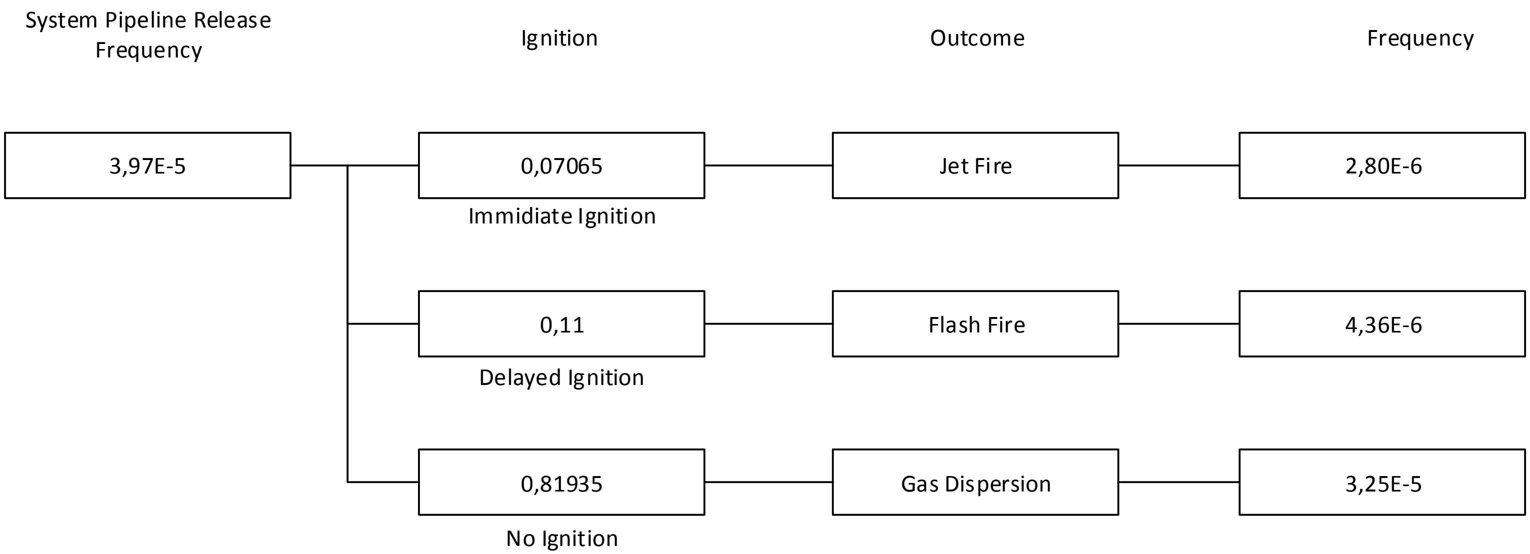
Event Tree of Node 2 Bore Size 3-10 mm



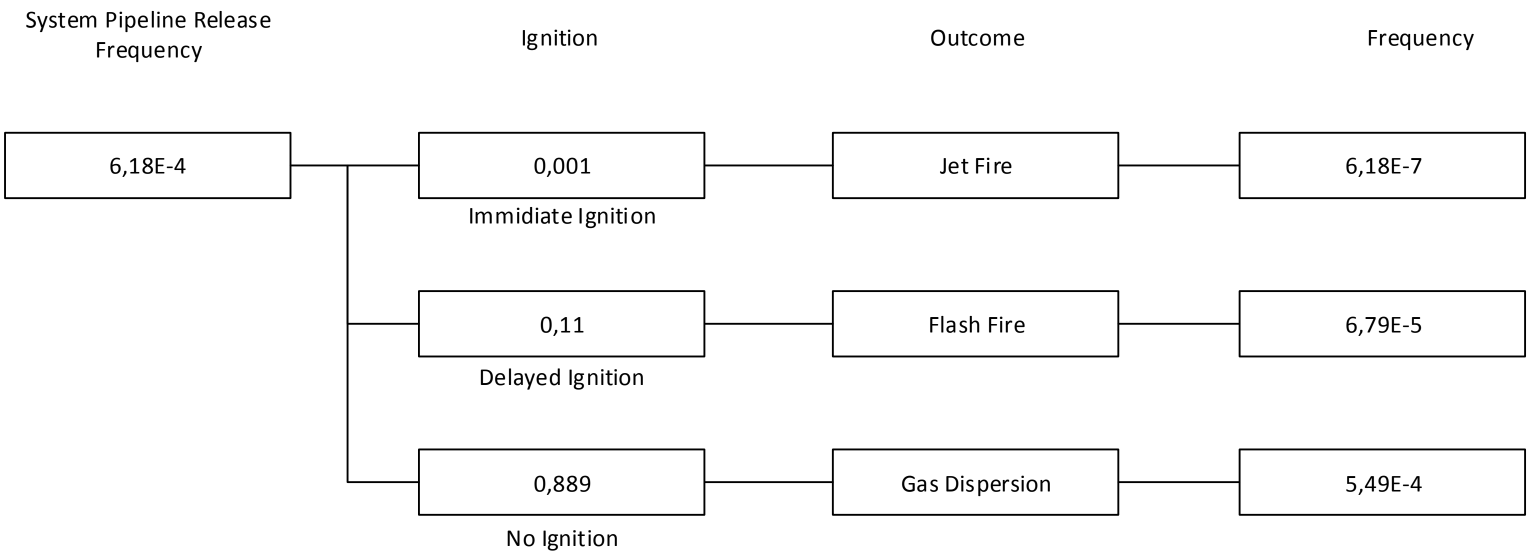
Event Tree of Node 2 Bore Size 10-50 mm



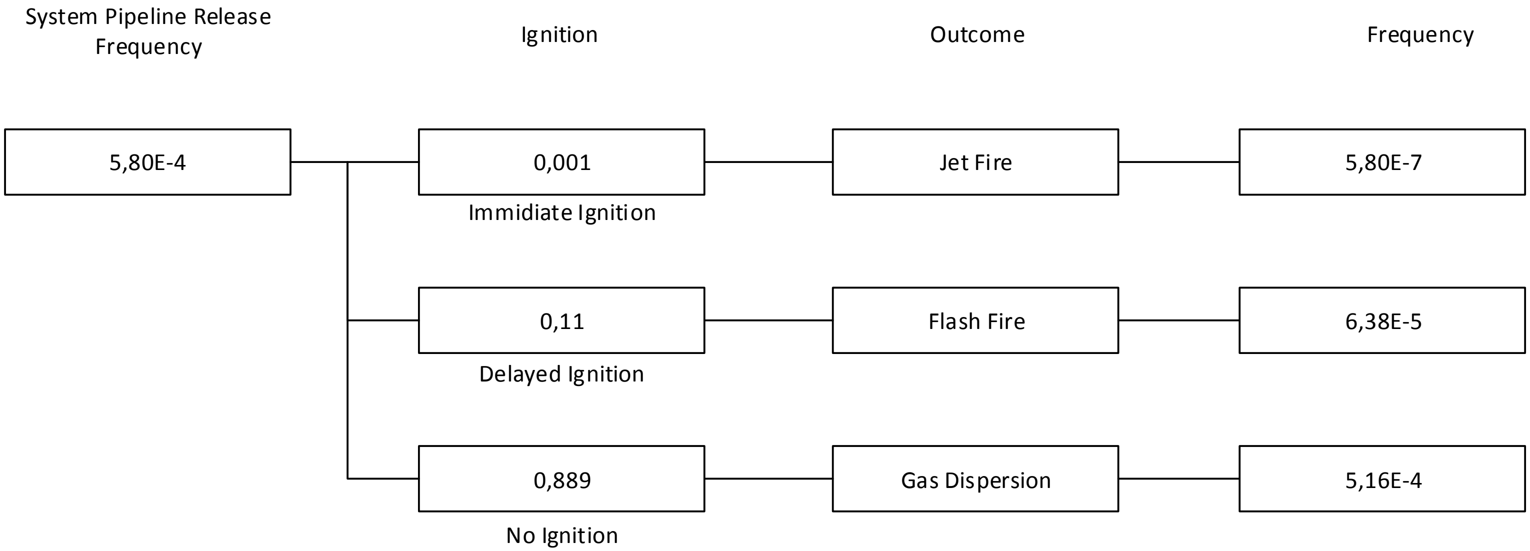
Event Tree of Node 2 Bore Size 50-150 mm



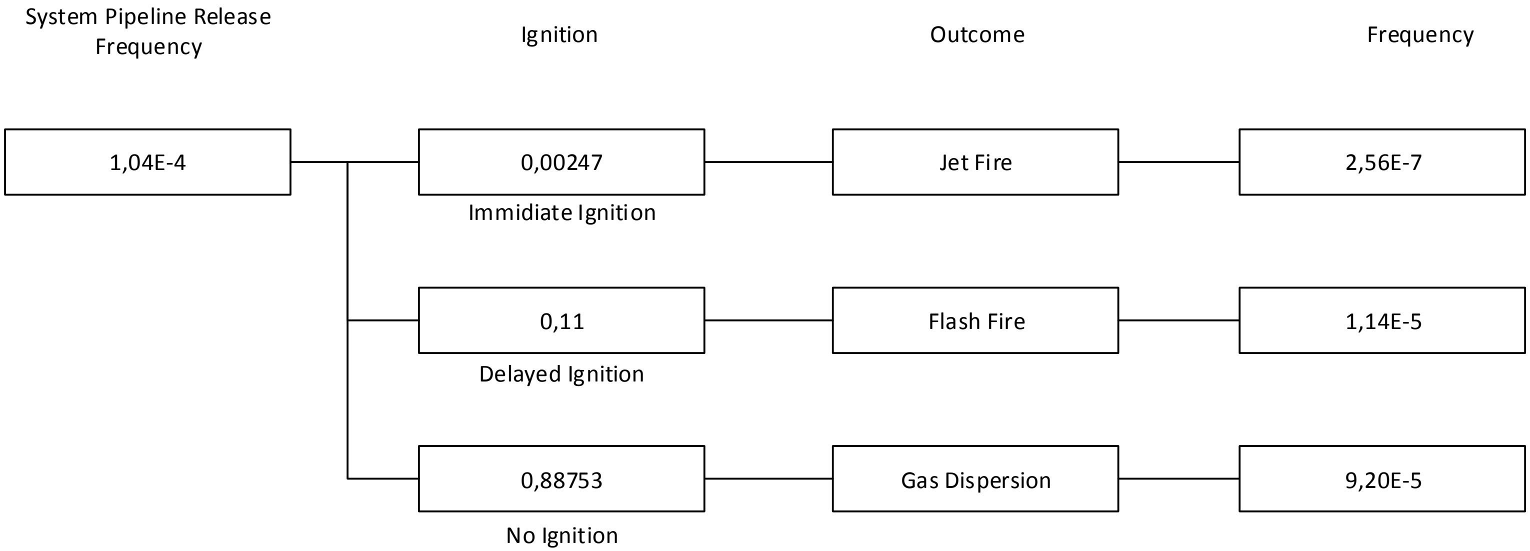
Event Tree of Node 2 Bore Size >150 mm



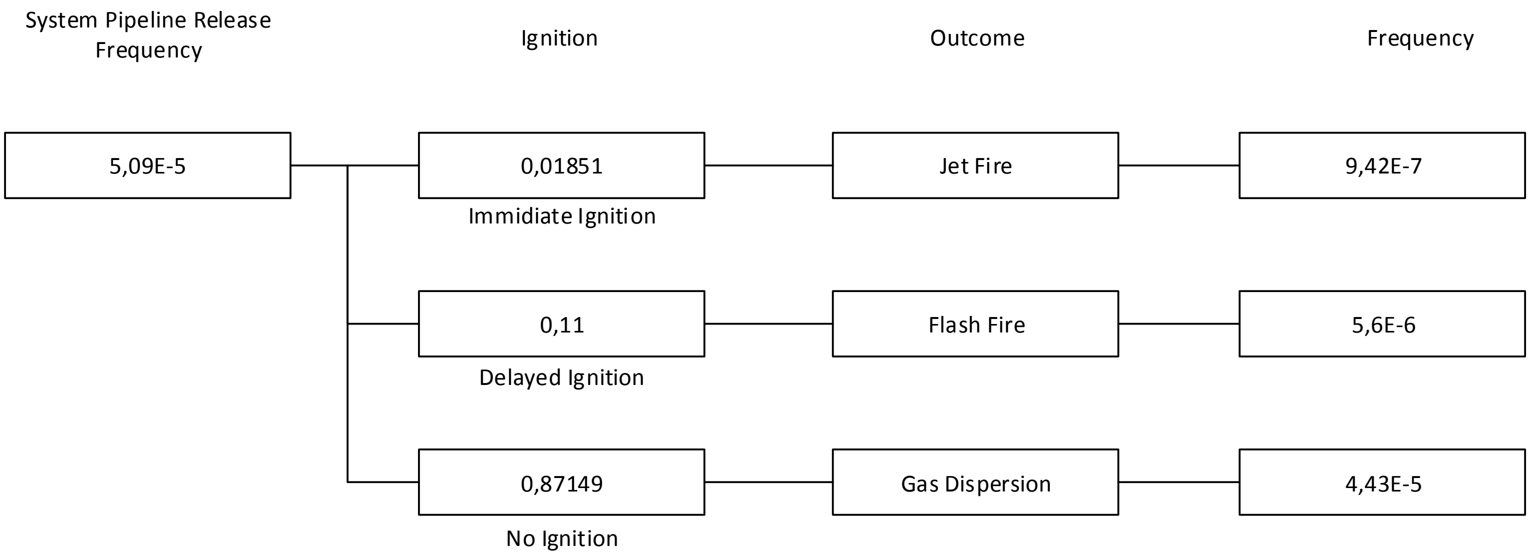
Event Tree of Node 3 Bore Size 1-3 mm



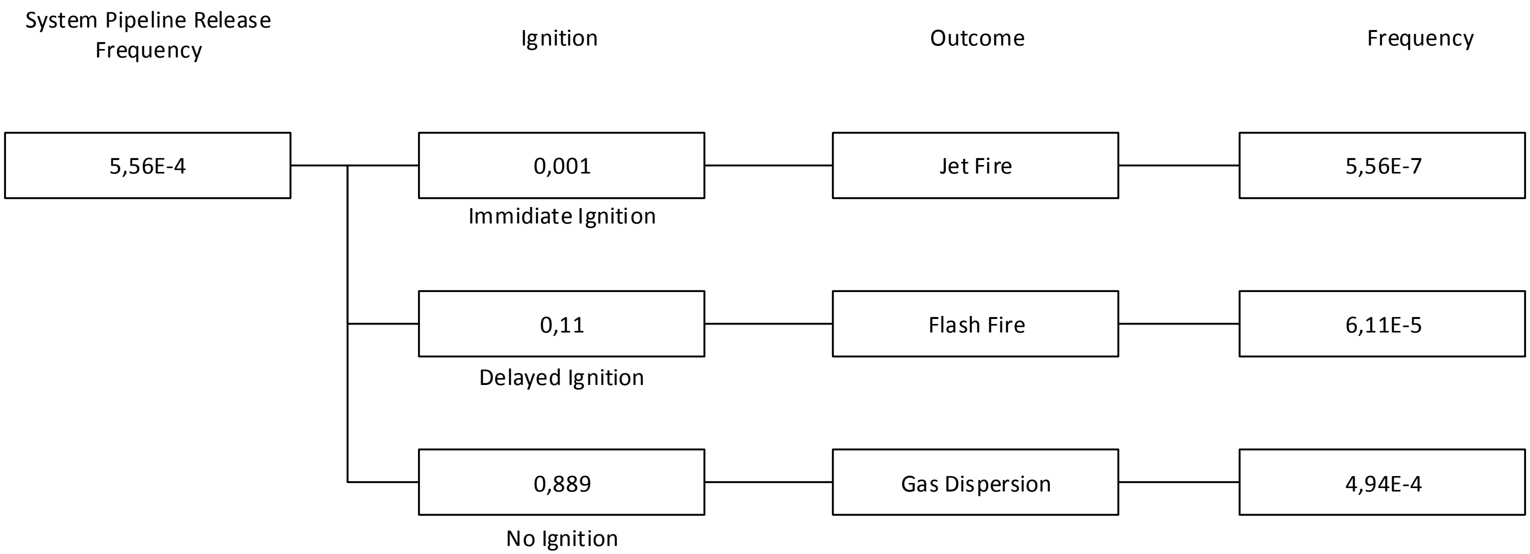
Event Tree of Node 3 Bore Size 3-10 mm



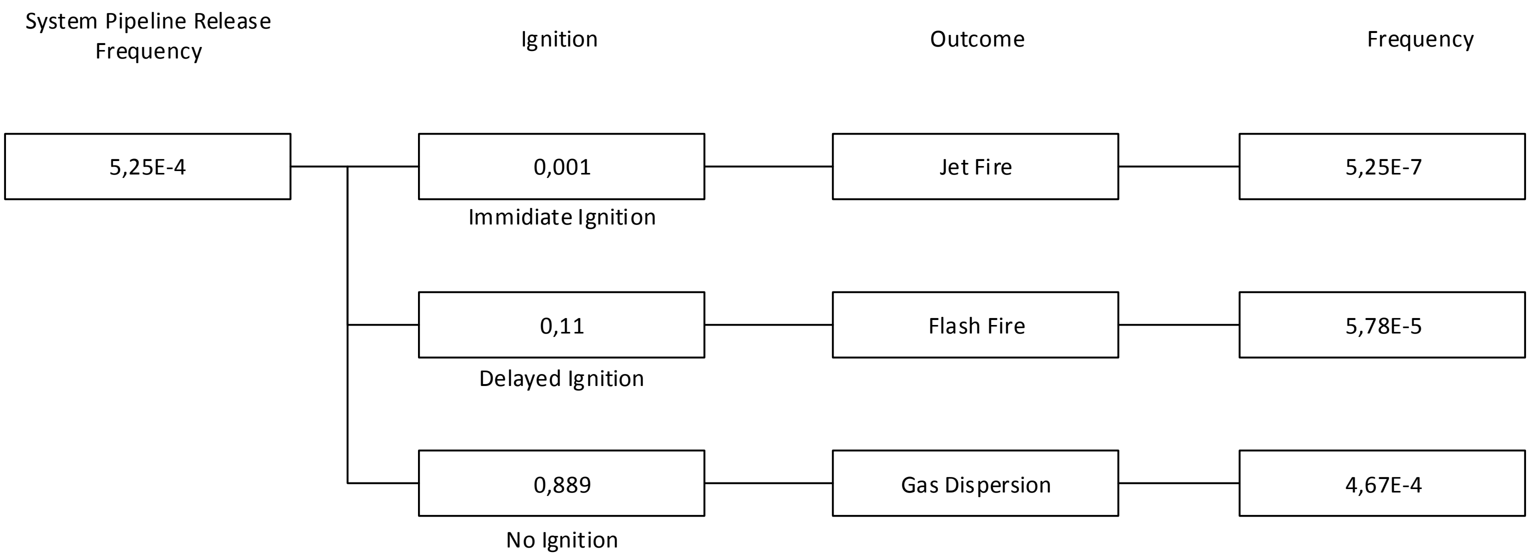
Tree of Node 3 Bore Size 10-50 mm



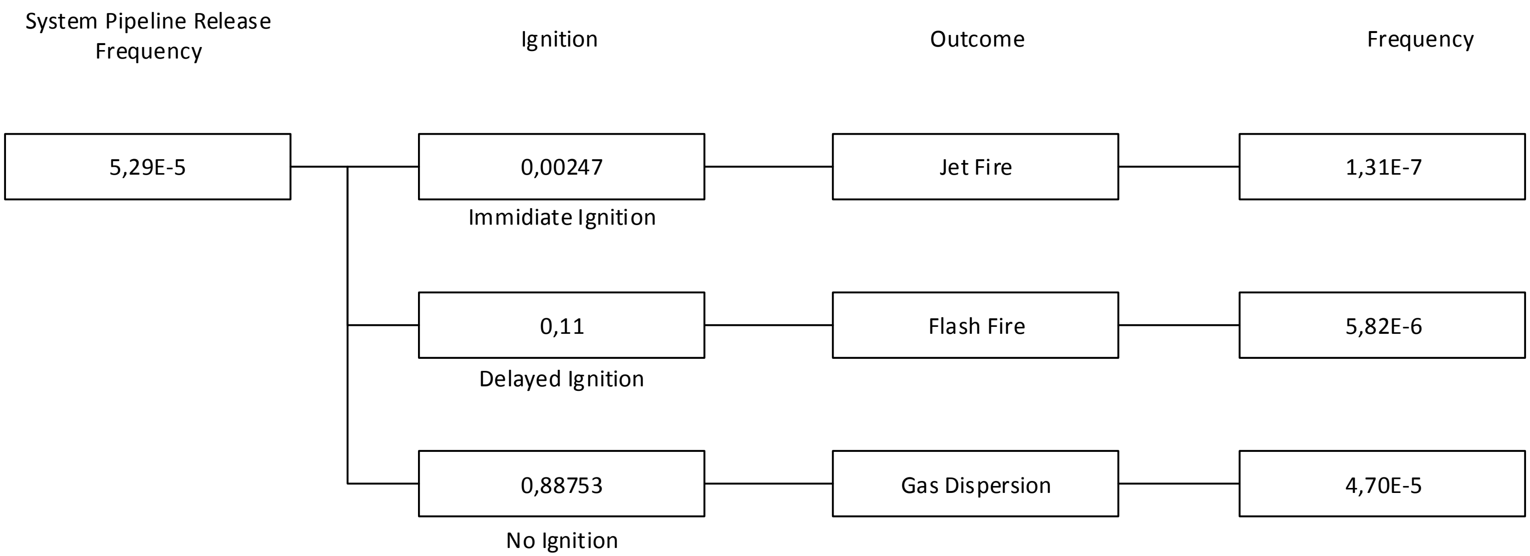
Event Tree of Node 3 Bore Size 50-150 mm



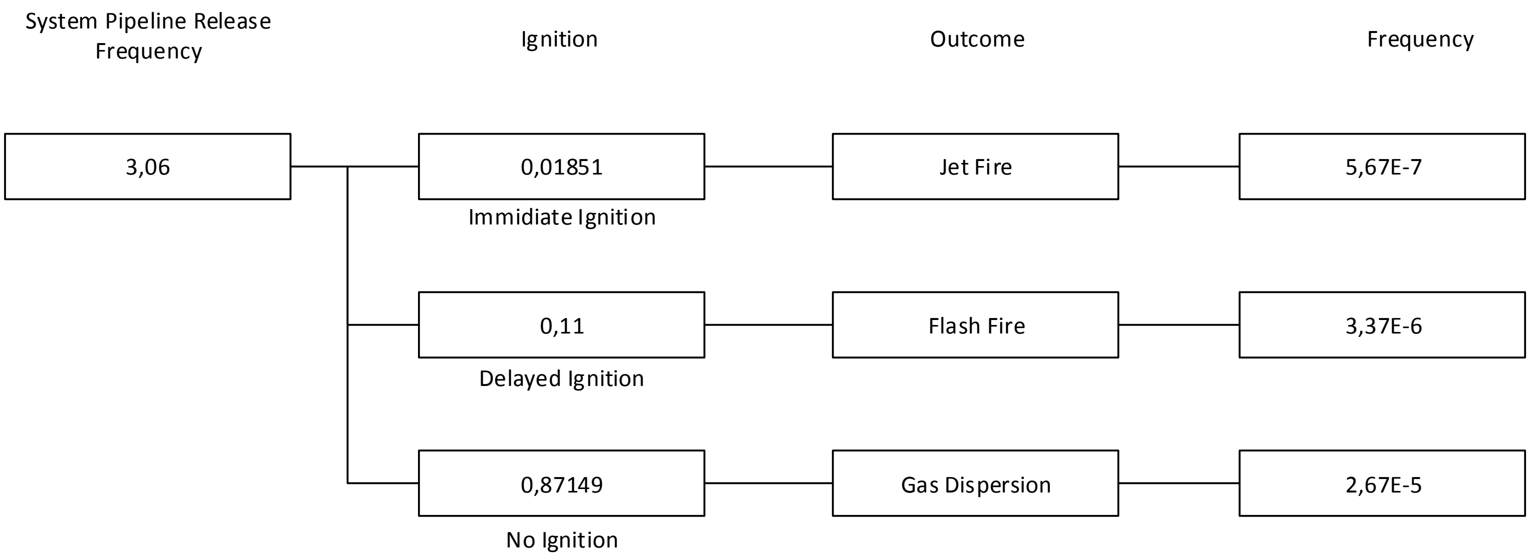
Event Tree of Node 4 Bore Size 1-3 mm



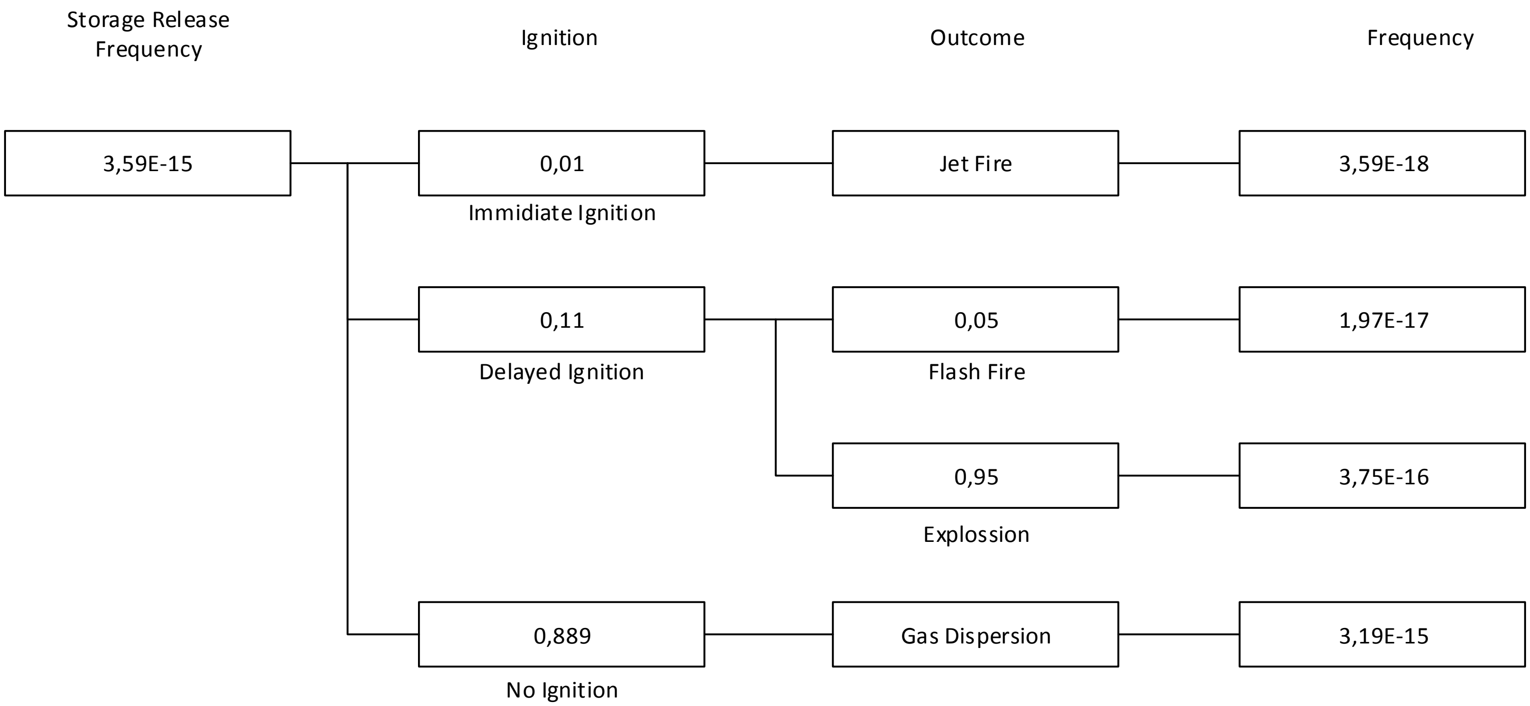
Event Tree of Node 4 Bore Size 3-10 mm



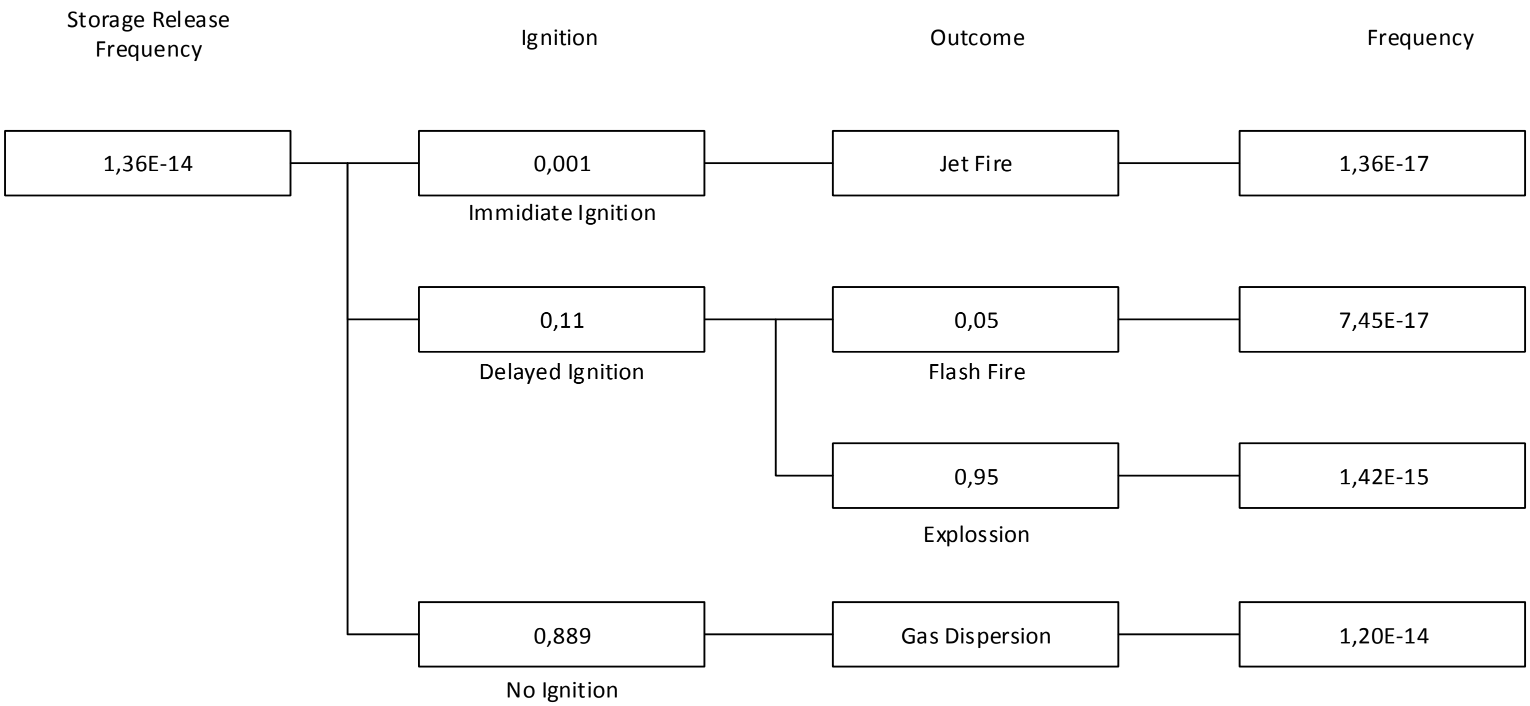
Event Tree of Node 4 Bore Size 10-50 mm



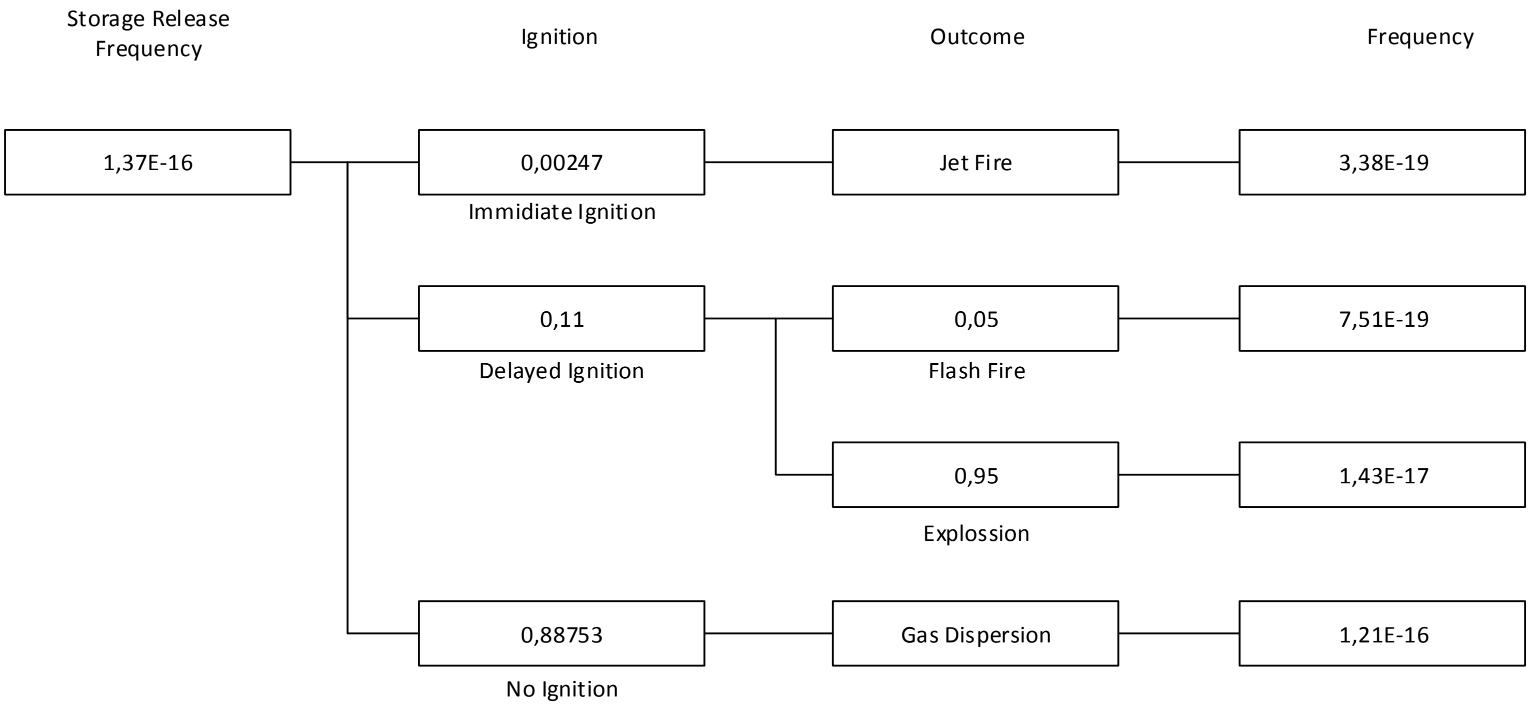
Event Tree of Node 4 Bore Size 50-150 mm



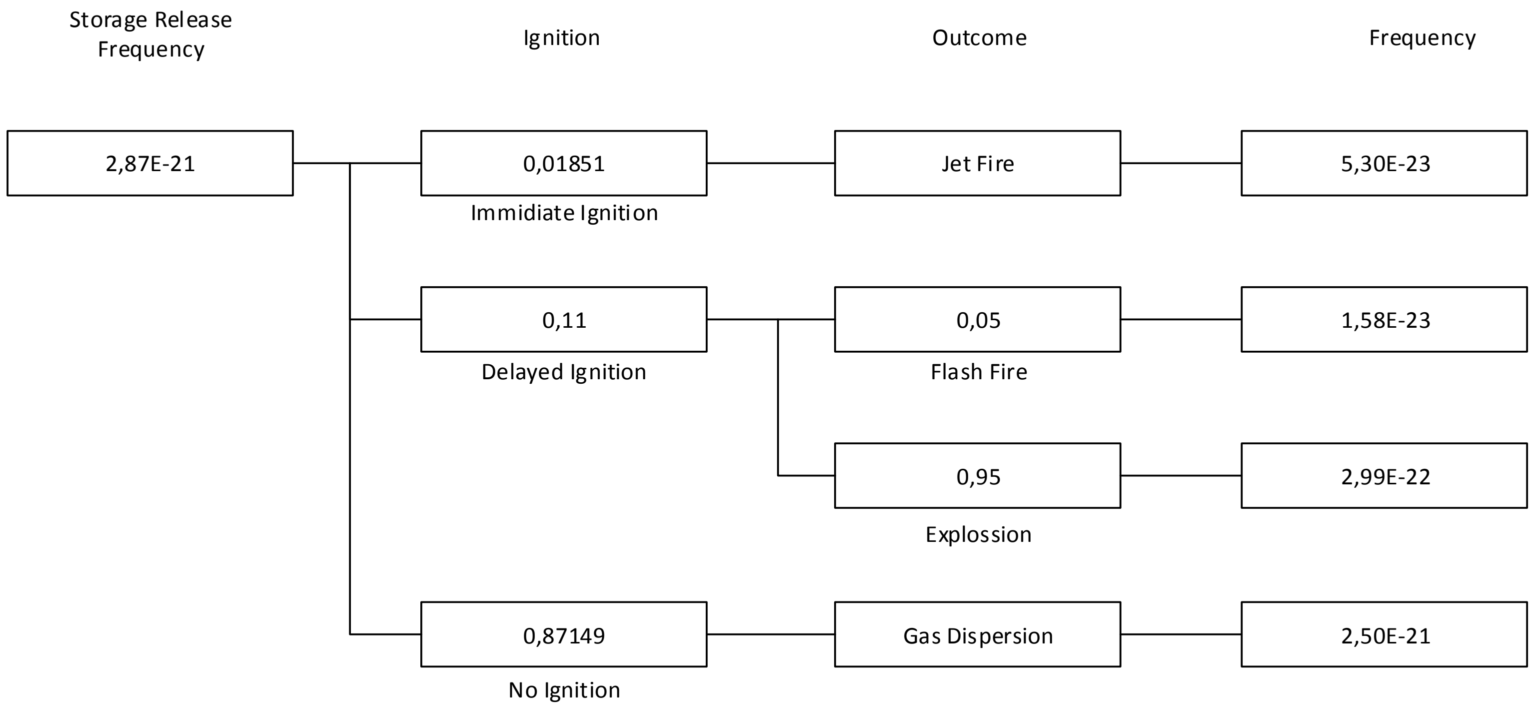
Event Tree of Node 5 Bore Size 1-3 mm



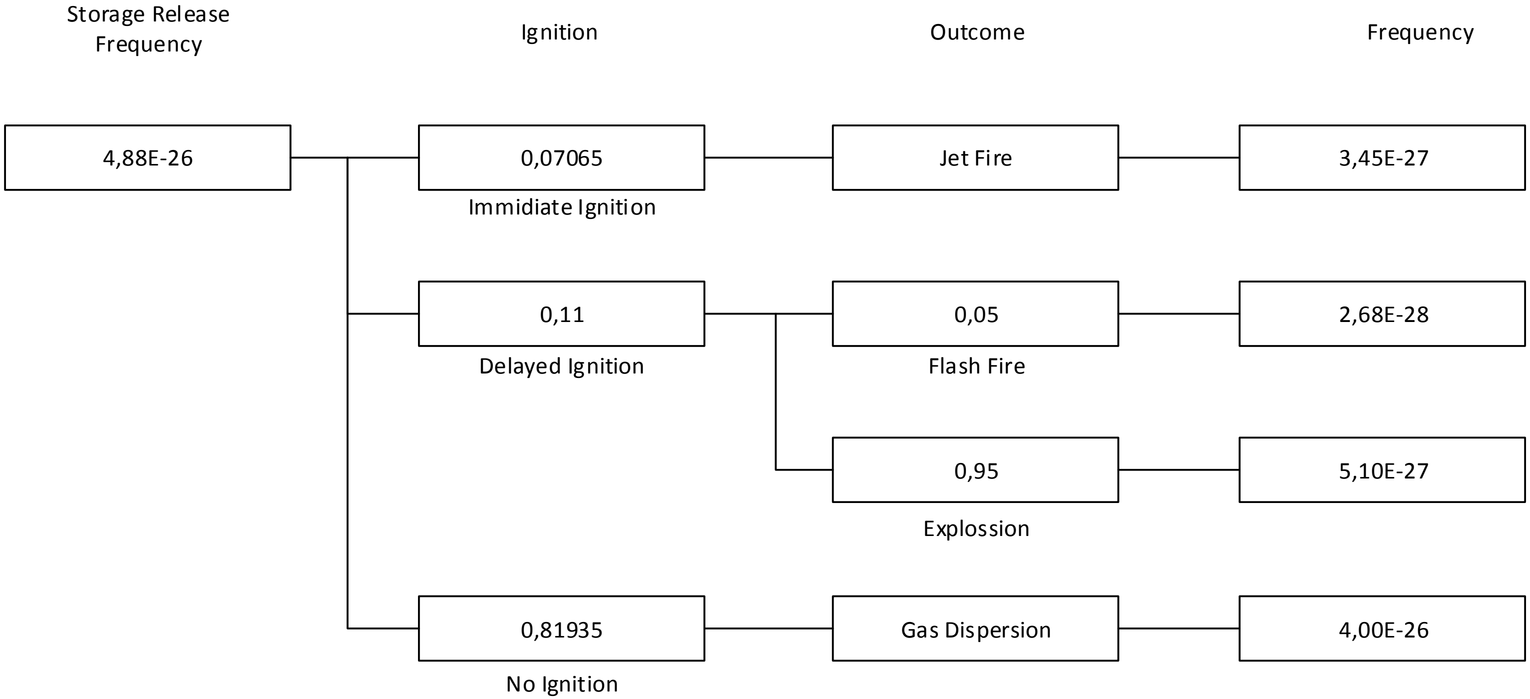
Event Tree of Node 5 Bore Size 3-10 mm



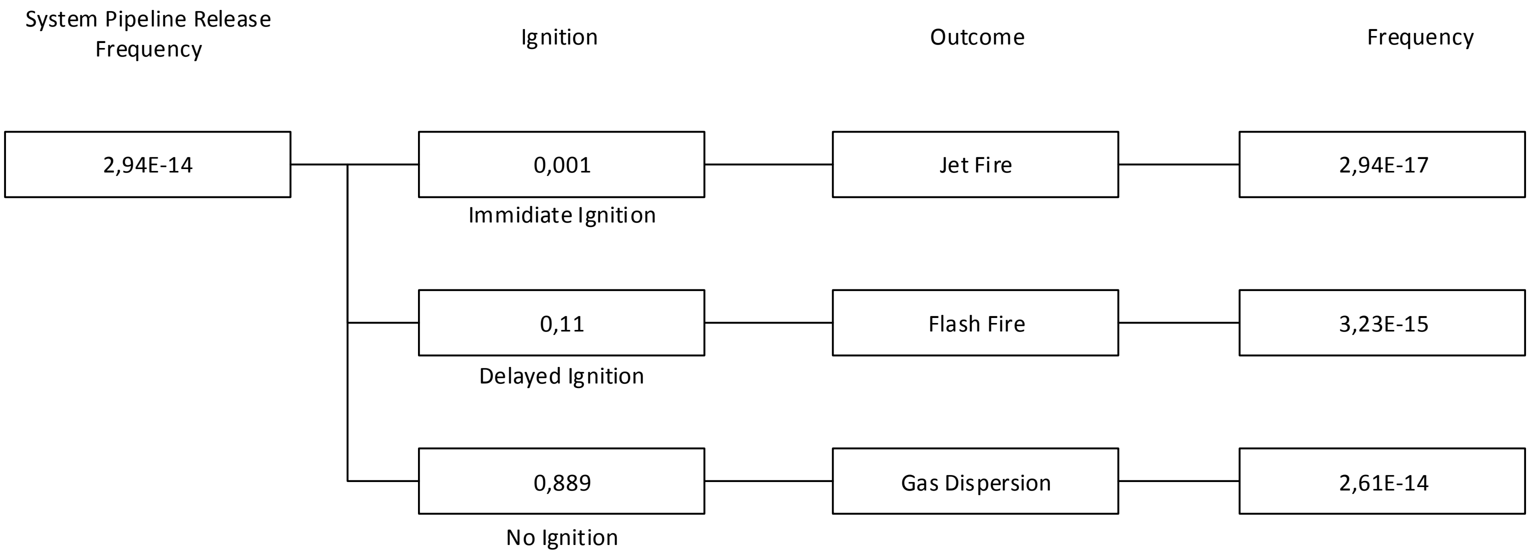
Event Tree of Node 5 Bore Size 10-50 mm



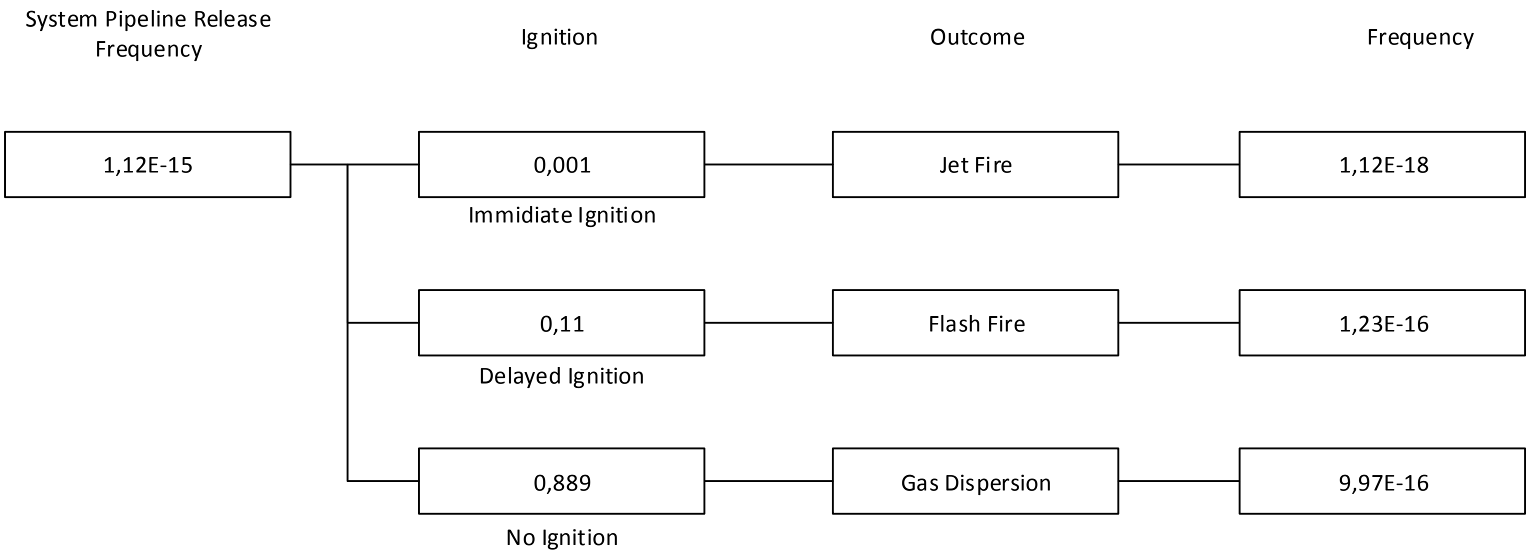
Event Tree of Node 5 Bore Size 50-150 mm



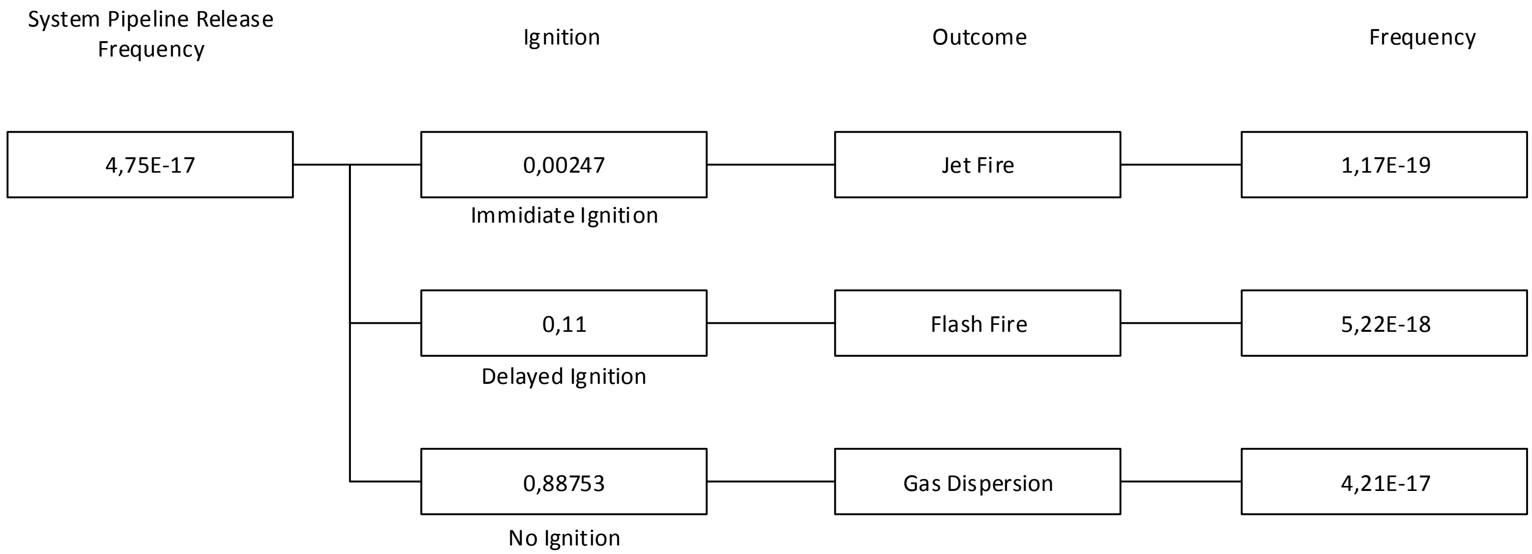
Event Tree of Node 5 Bore Size >150 mm



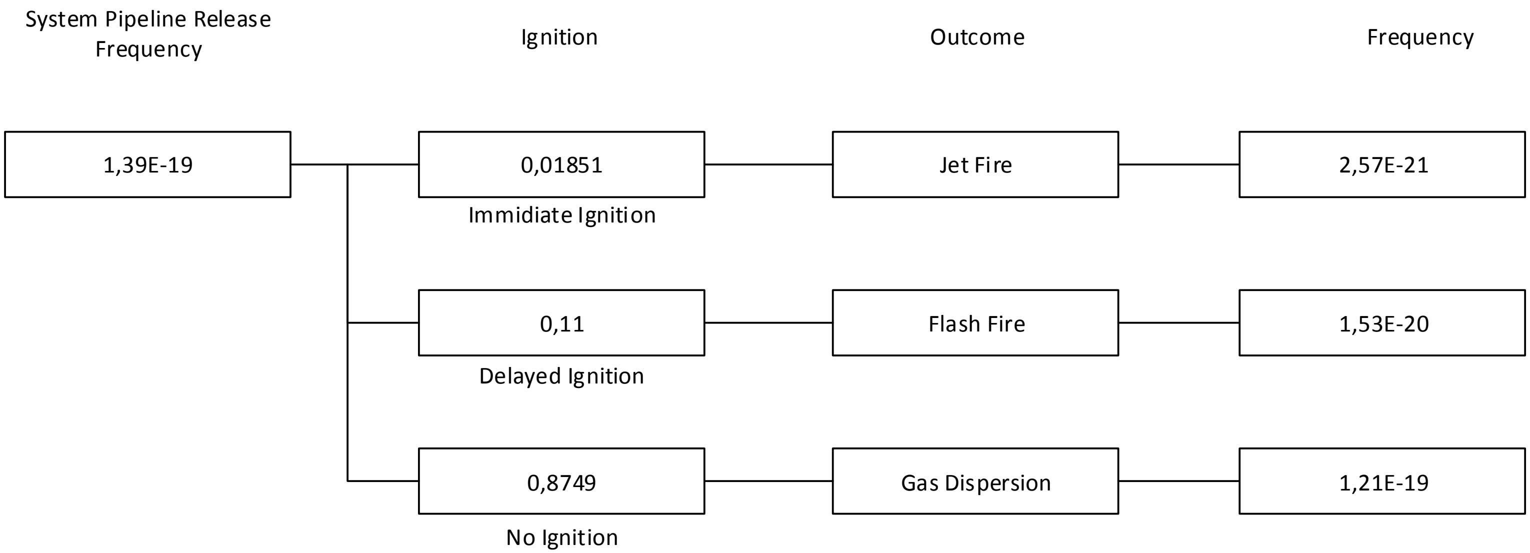
Event Tree of Node 6: Distrbution Bore Size 1-3 mm



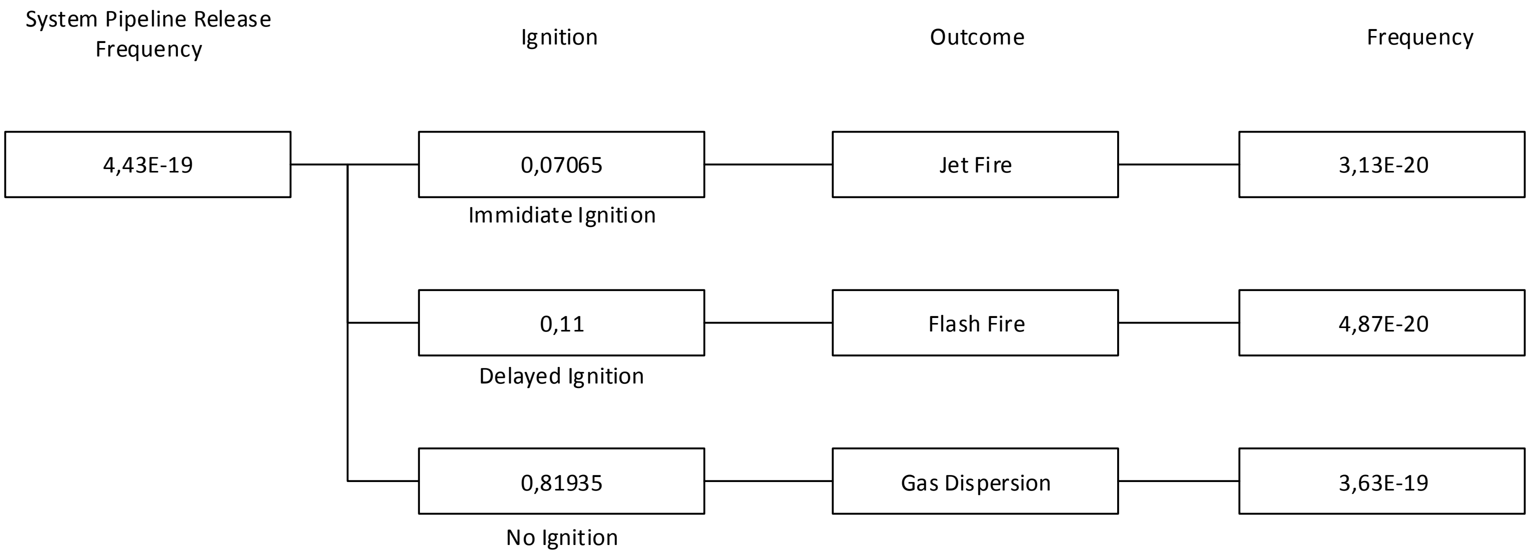
Event Tree of Node 6: Distrbution Bore Size 3-10 mm



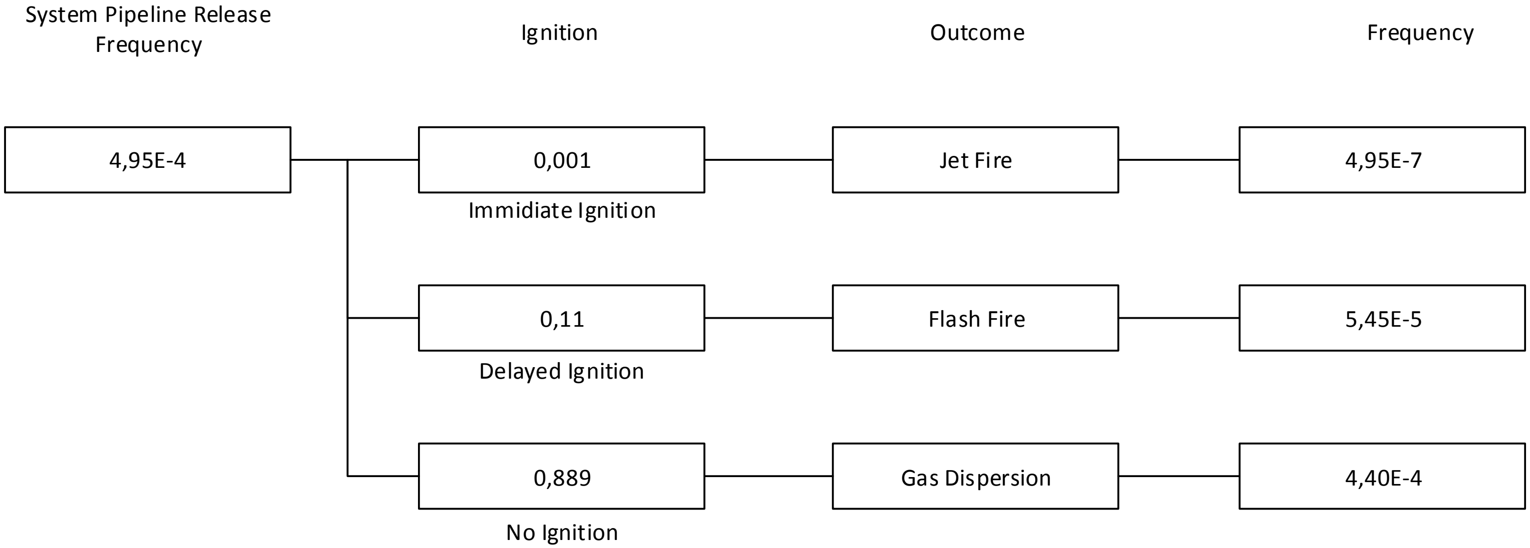
Event Tree of Node 6: Distrbution Bore Size 10-50 mm



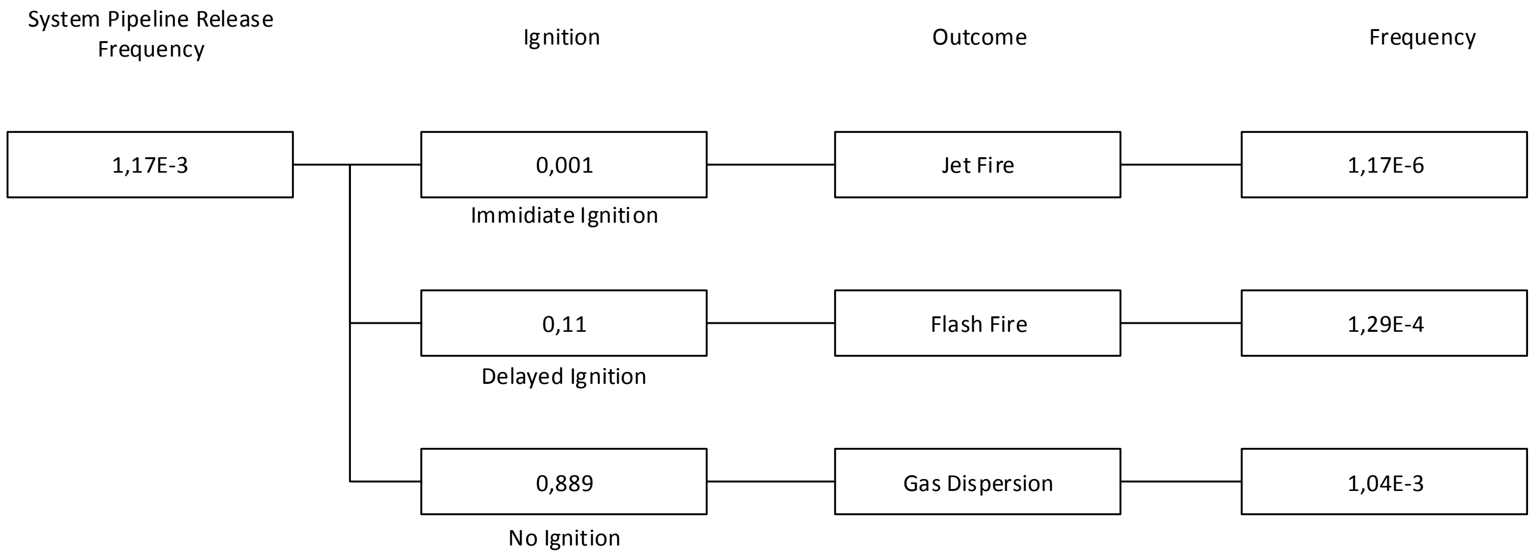
Event Tree of Node 6: Distrbution Bore Size 50-150 mm



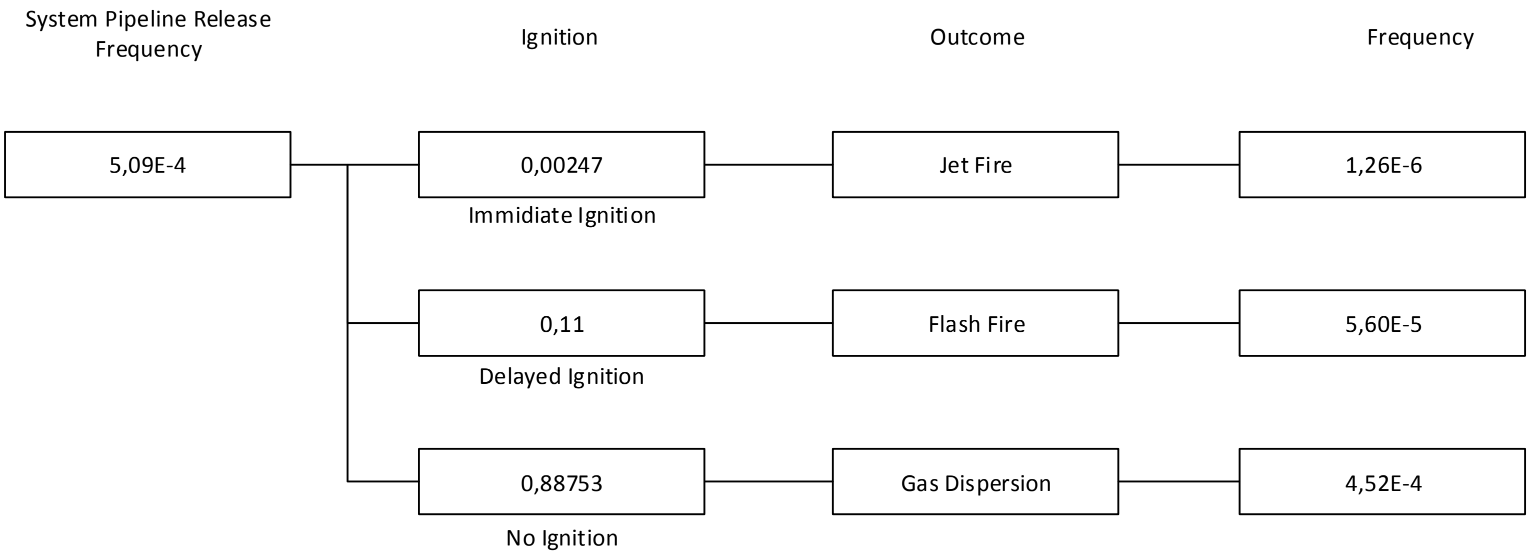
Event Tree of Node 6: Distrbution Bore Size >150 mm



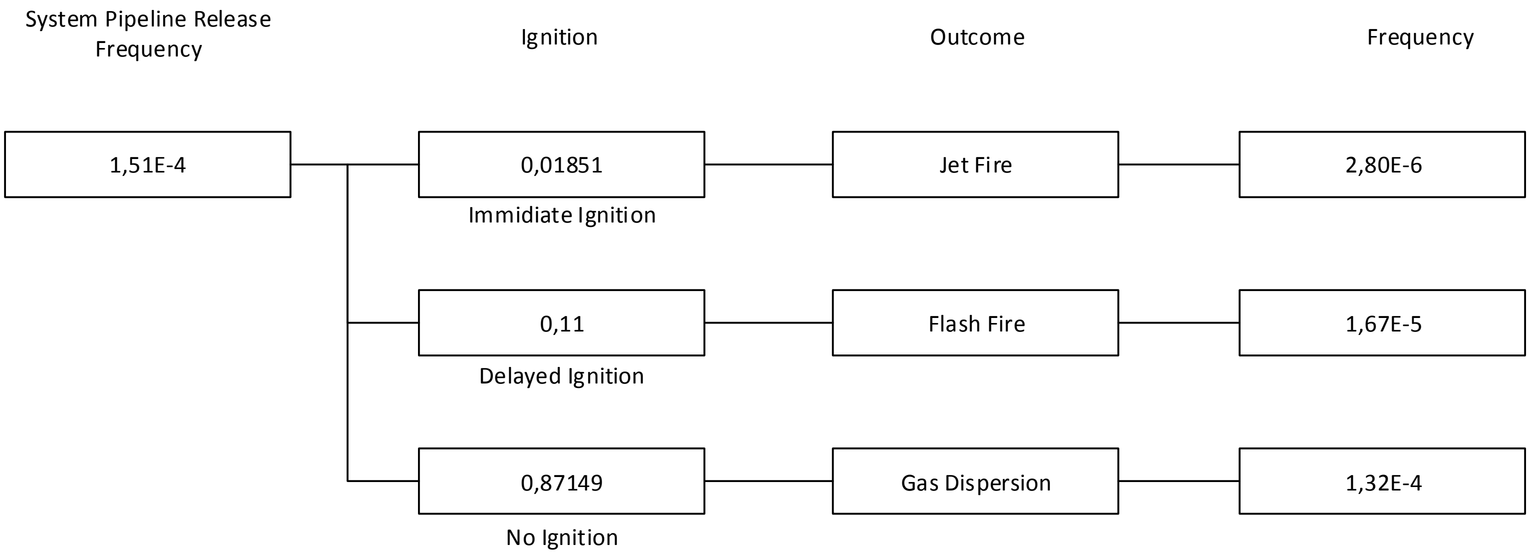
Event Tree of Node 6: Receiving Bore Size 1-3 mm



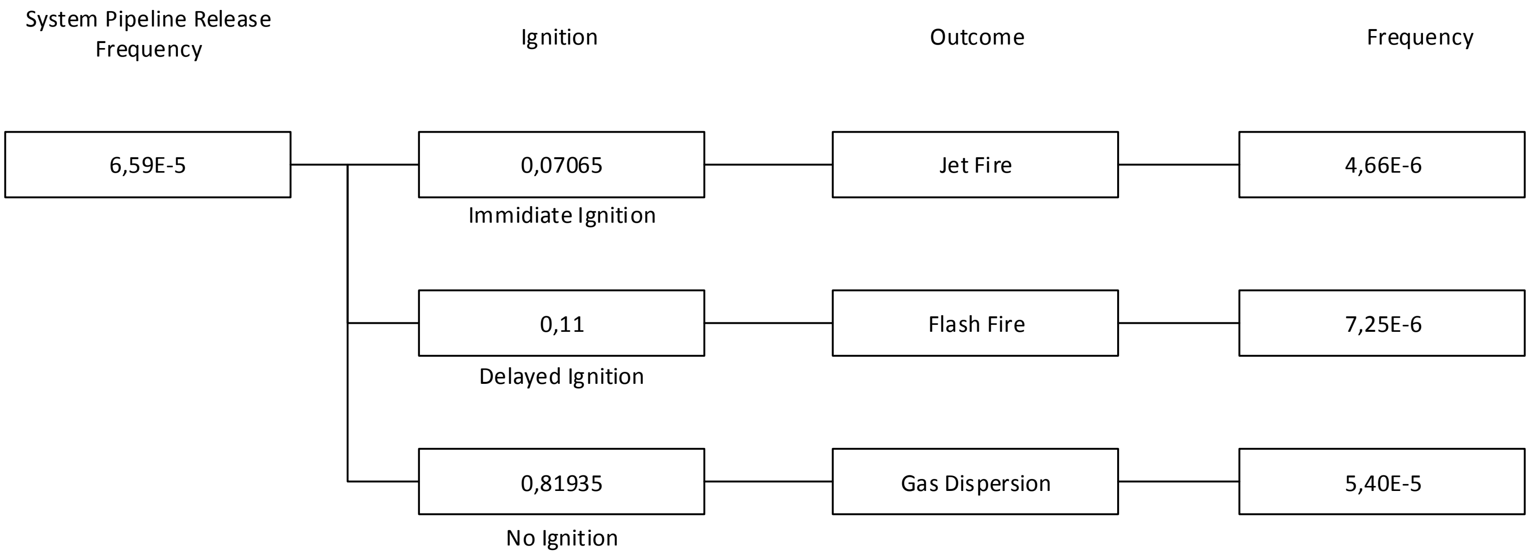
Event Tree of Node 6: Receiving Bore Size 3-10 mm



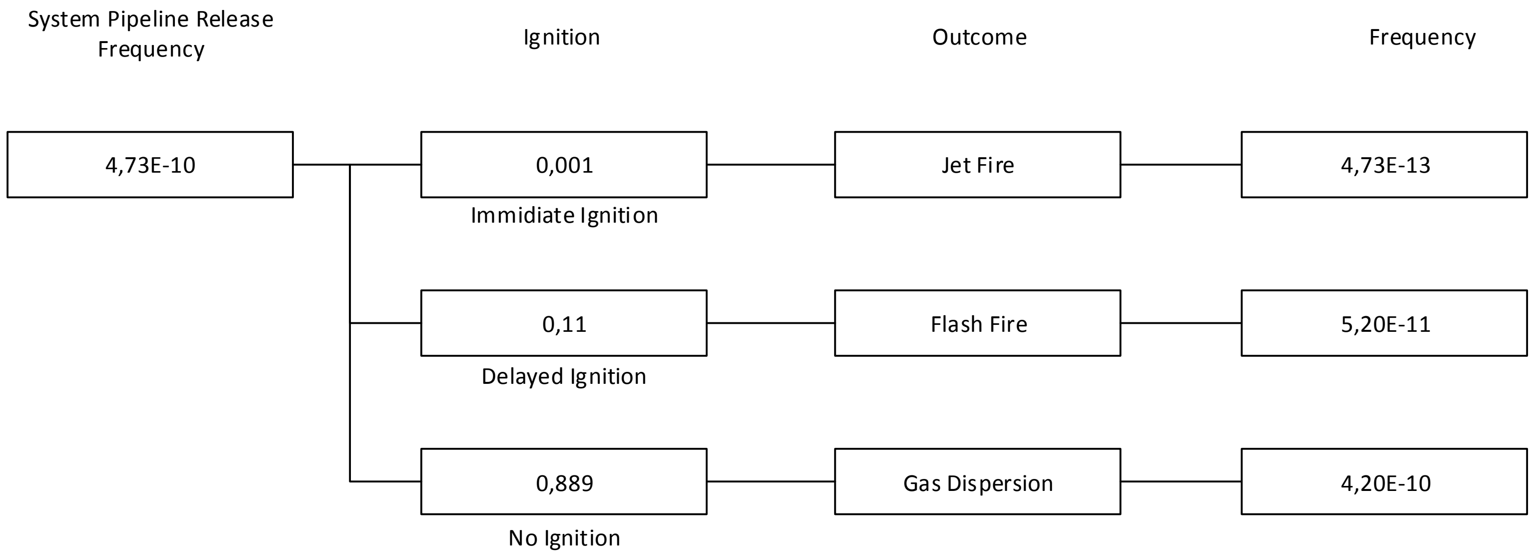
Event Tree of Node 6: Receiving Bore Size 10-50 mm



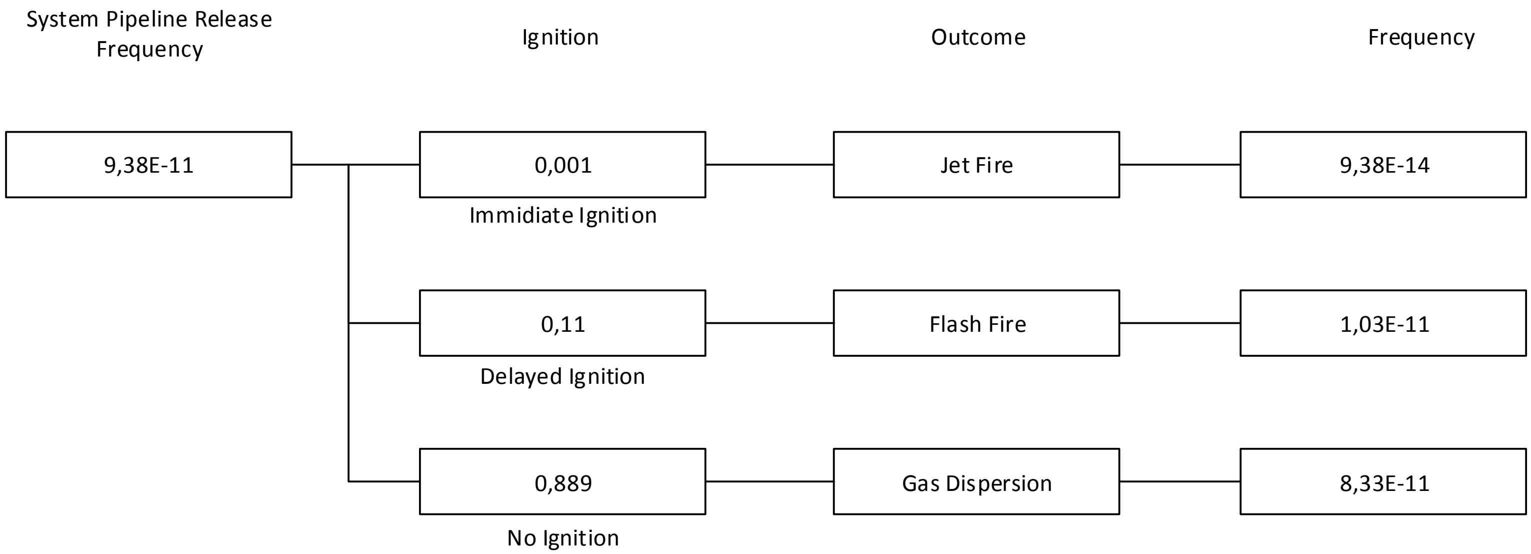
Event Tree of Node 6: Receiving Bore Size 50-150 mm



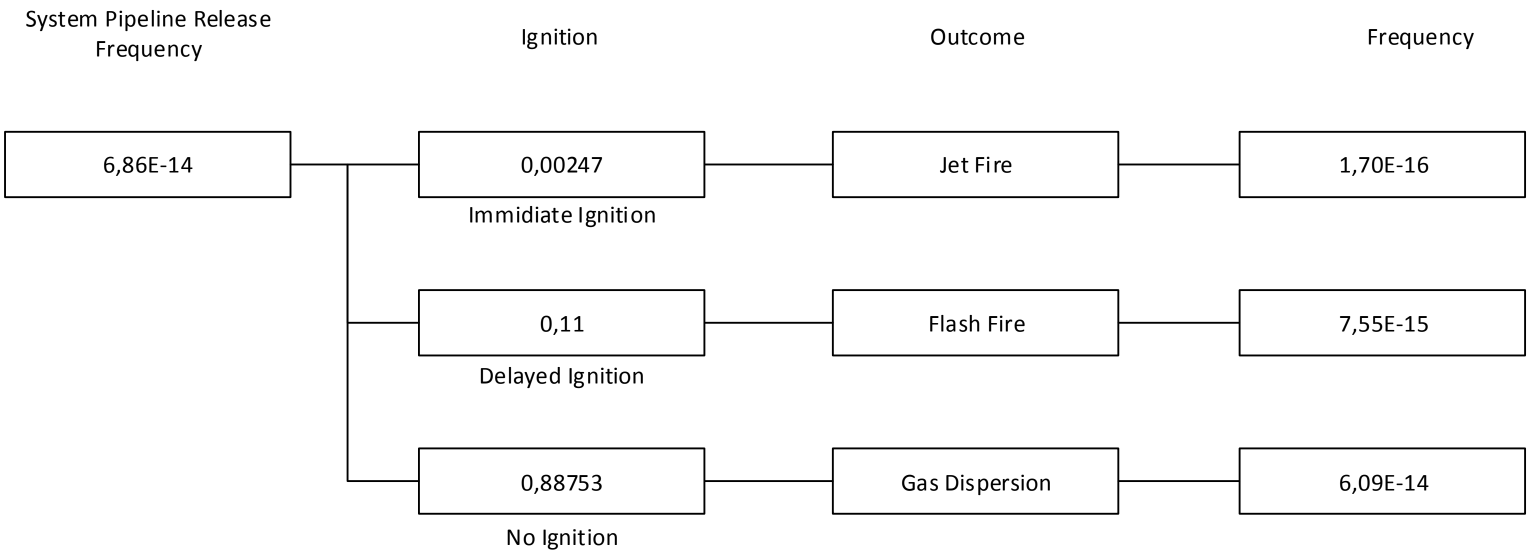
Event Tree of Node 6: Receiving Bore Size >150 mm



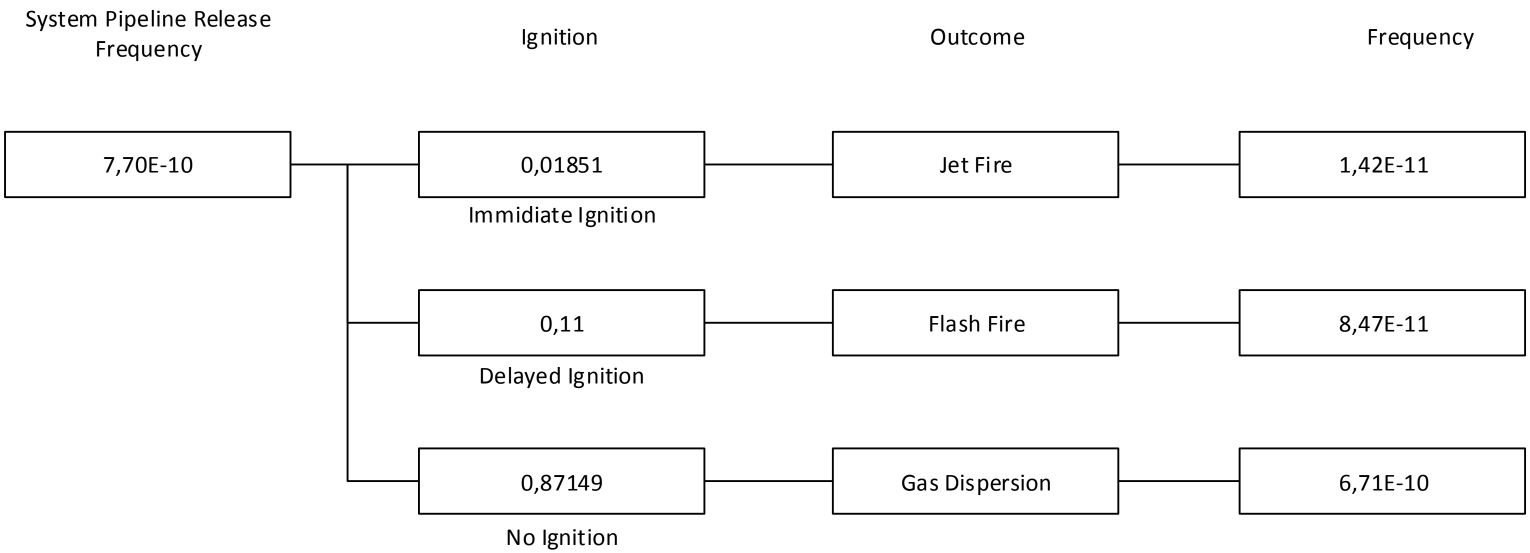
Event Tree of Node 7 Bore Size 1-3 mm



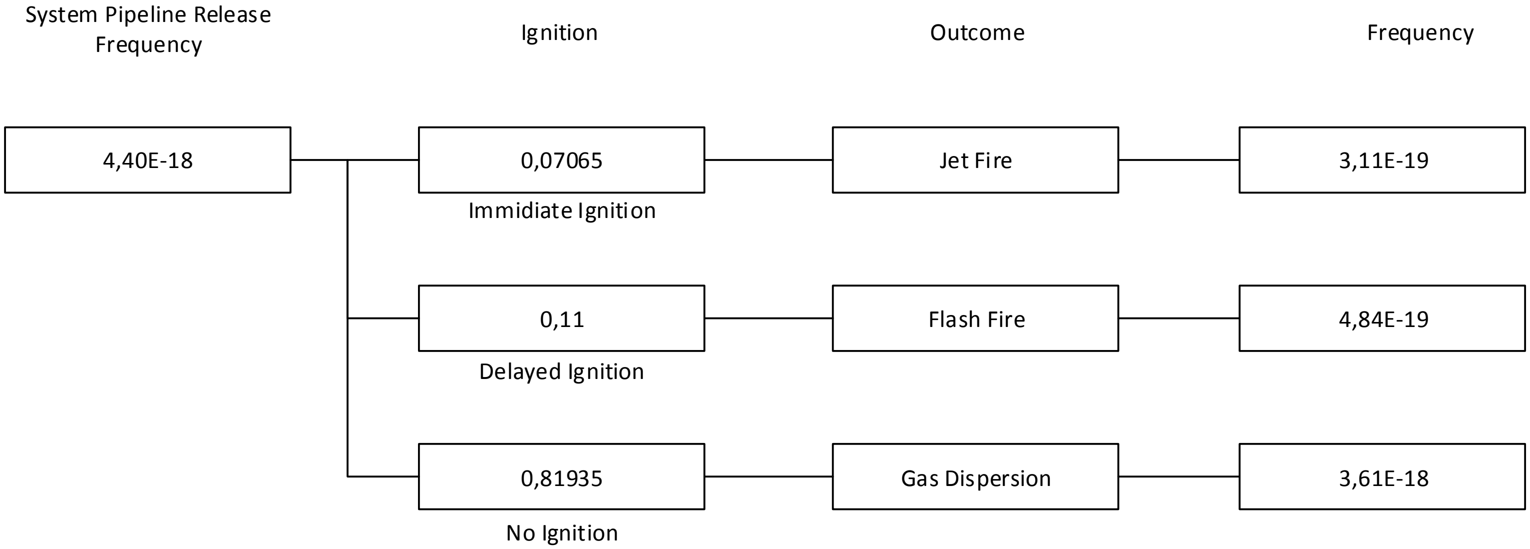
Event Tree of Node 7 Bore Size 3-10 mm



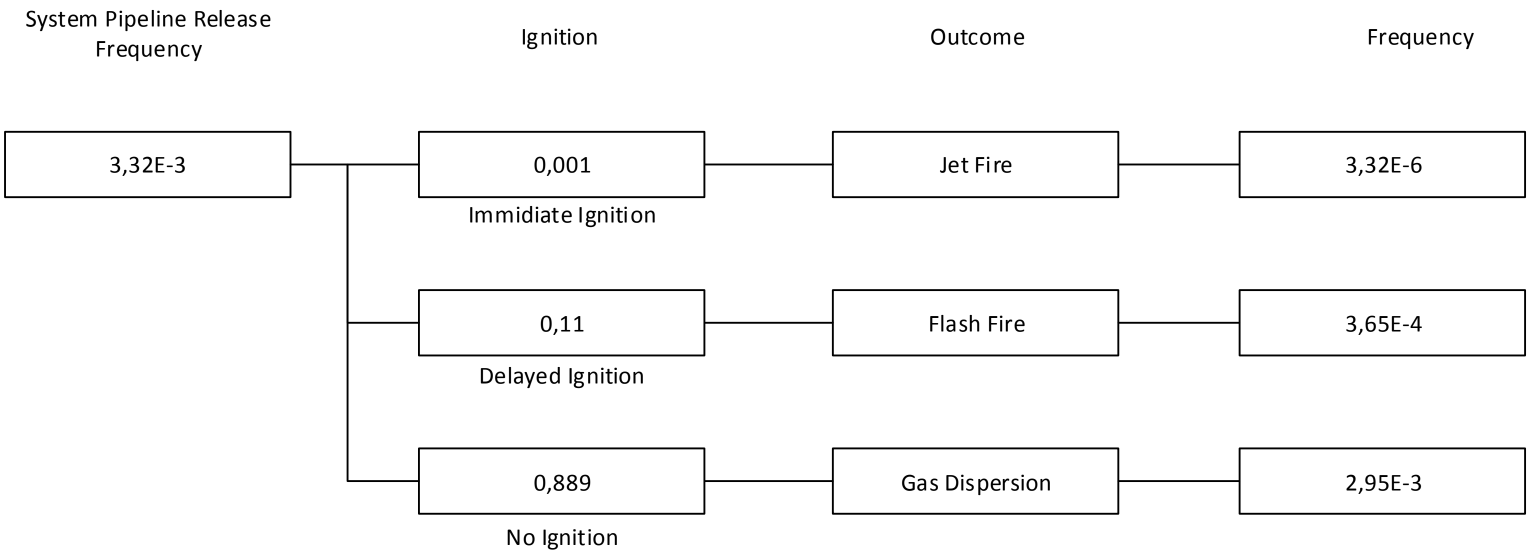
Event Tree of Node 7 Bore Size 10-50 mm



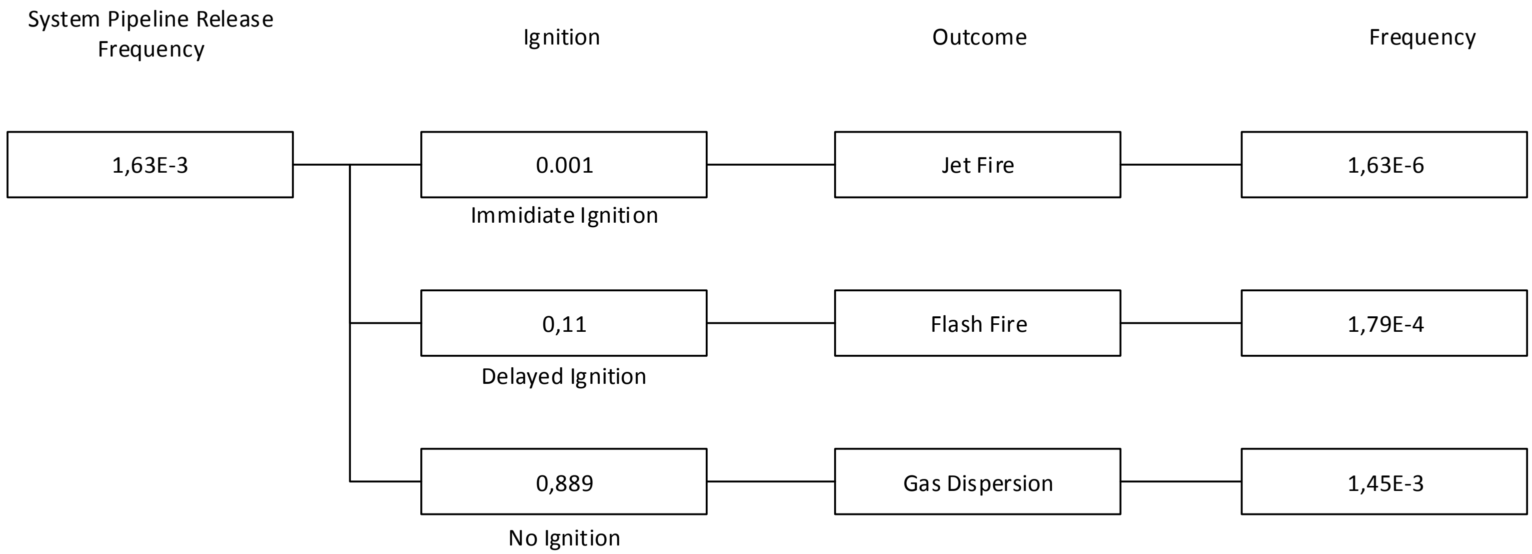
Event Tree of Node 7 Bore Size 50-150 mm



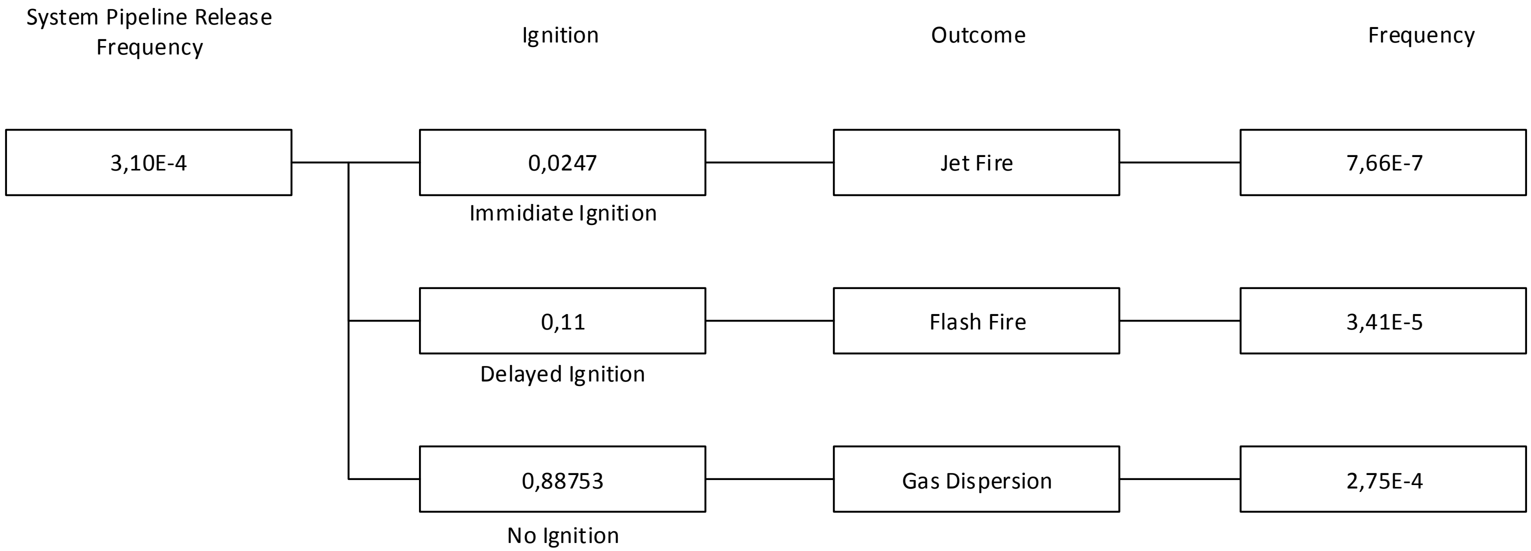
Event Tree of Node 7 Bore Size >150 mm



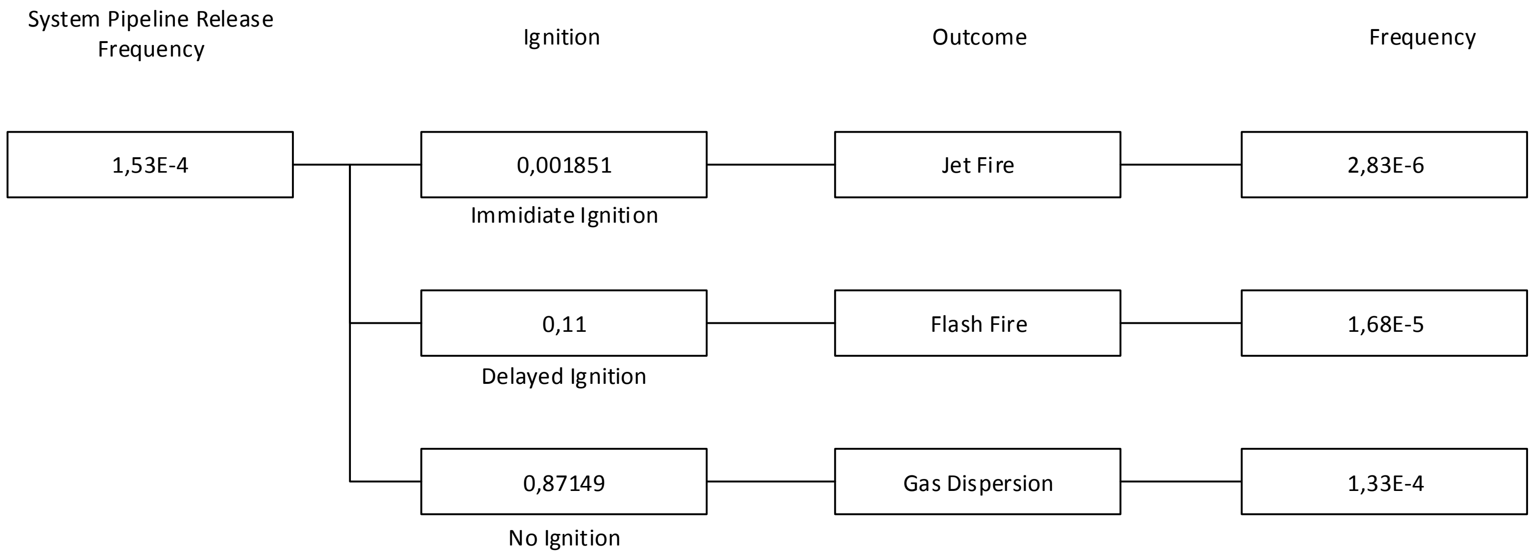
Event Tree of Node 8 Bore Size 1-3 mm



Event Tree of Node 8 Bore Size 3-10 mm



Event Tree of Node 8 Bore Size 10-50 mm



Event Tree of Node 8 Bore Size 50-150 mm

Appendix 6: Consequences Modelling Result

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ATTACHMENT
Consequences Modelling Result

Legend

1. **Heat Intensity Radiation Area for Jet Fire**

(blue line) 25 kW/m^2

(green line) 35 kW/m^2

(red line) 45 kW/m^2

2. **Flash Fire Envlope**

(blue line) 4,286058 kW/m^3

(green line) 9,107874 kW/m^3

3. **Explosion Pressure**

(blue line) 0,2 bar

(green line) 1,3 bar

(red line) 2,0 bar

- **Leak 3 mm (MLA & Jetty)**

Jet Fire

-

Flash Fire

- **Leak 10 mm (MLA & Jetty)**

Jet Fire

Flash Fire

- **Leak 50 mm (MLA & Jetty)**

Jet Fire

Flash Fire

- **Leak 150 mm (MLA & Jetty)**

Jet Fire

Flash Fire

- **Leak 3 mm (Meterring Station)**

Jet Fire

-

Flah Fire

- **Leak 10 mm (Meterring Station)**

Jet Fire

Flash Fire

- **Leak 50 mm (Meterring Station)**

Jet Fire

Flash Fire

- **Leak 150 mm (Meterring Station)**

Jet Fire

Flash Fire

- **Leak 3 mm (Storage V110)**

Jet Fire

-

Flash Fire

Explosion

- **Leak 10 mm (Storage V110)**

Jet Fire

Flash Fire

Explosion

- **Leak 50 mm (Storage V110)**

Jet Fire

Flash Fire

Explosion

- **Leak 150 mm (Storage V110)**

Jet Fire

Flash Fire

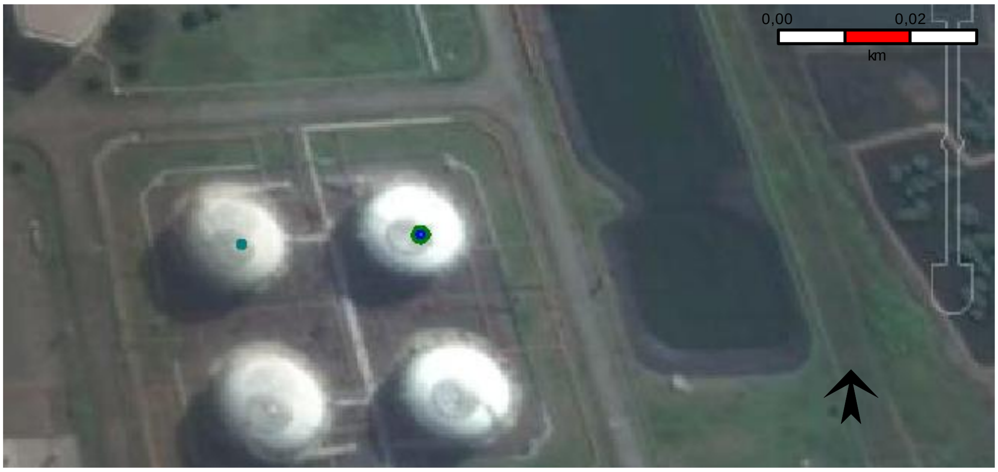
Explosion

- **3 mm Leak (Storage V120)**

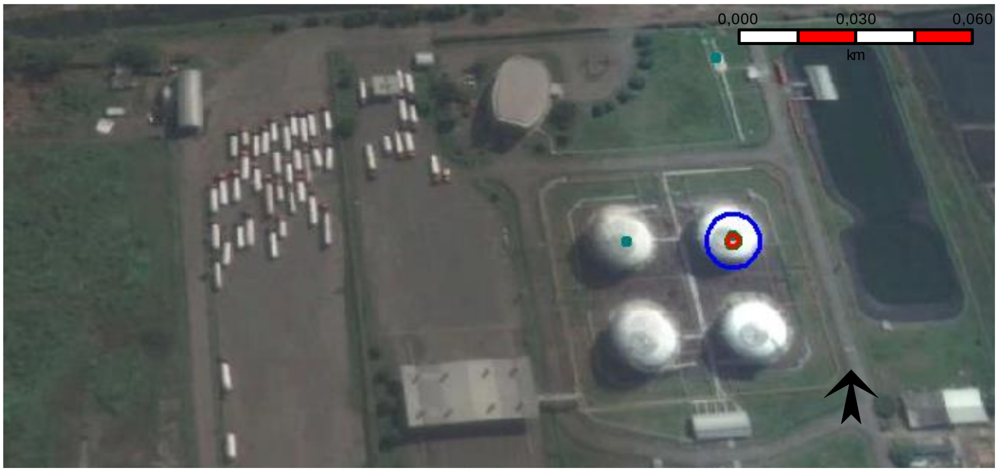
Jet Fire

-

Flash Fire



Explosion

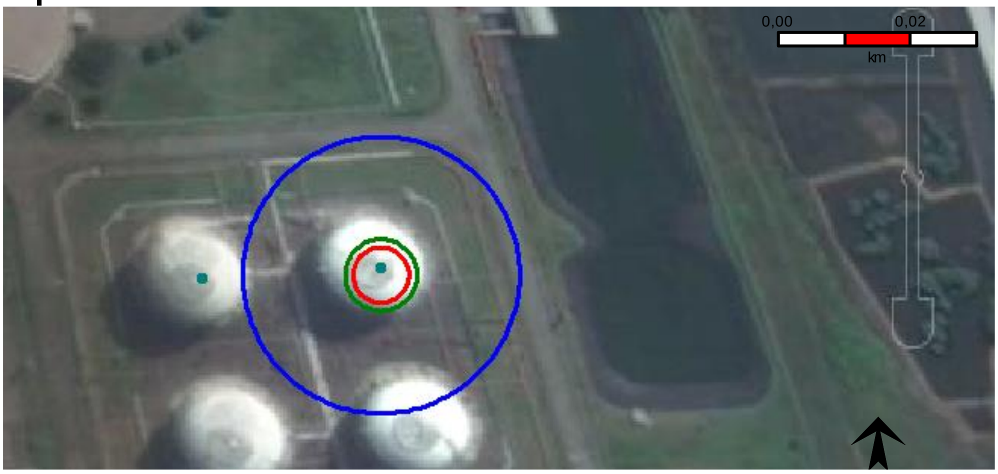


- **Leak 10 mm (Storage V120)**

Jet Fire

Flash Fire

Explosion



- **Leak 50 mm (Storage V120)**

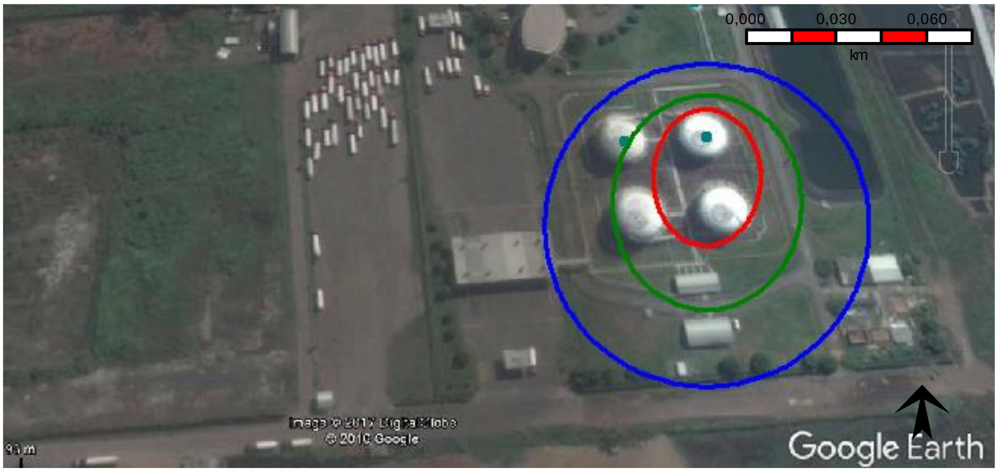
Jet Fire

Flash Fire

Explosion

- **Leak 150 mm (Storage V120)**

Jet Fire



Flash Fire

Explosion

- **Leak 3 mm (Storage V130)**

Jet Fire

-

Flash Fire

Explosion

- **Leak 10 mm (Storage V130)**

Jet Fire

Flash Fire

Explosion

- **Leak 50 mm (Storage V130)**

Jet Fire

Flash Fire

Explosion

- **Leak 150 mm**

Jet Fire

Flash Fire

Explosion

- **Leak 3 mm (Storage V140)**

Jet Fire

-

Flash Fire

Explosion

- **Leak 10 mm (Storage V140)**

Jet Fire

Flash Fire

Explosion

- **Leak 50 mm (Storage V140)**

Jet Fire

Flash Fire

Explosion

- **Leak 150 mm (Storage V140)**

Jet Fire

Flash Fire

Explosion

- **Leak 3 mm (Pump House)**

Jet Fire

-

Flash Fire

Explosion

-

- **Leak 10 mm (Pump House)**

Jet Fire

Flash Fire

- **Leak 50 mm (Pump House)**

Jet Fire

Flash Fire

- **Leak 150 mm (Pump House)**

Jet Fire

Flash Fire

- **Leak 3 mm (Filling Shed)**

Jet Fire

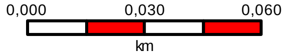
-

Flash Fire

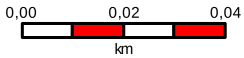
Gas Dispersion

- **Leak 10 mm (Filling Shed)**

Jet Fire



Flash Fire



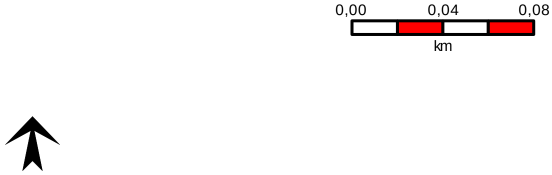
- **Leak 50 mm (Filling Shed)**

Jet Fire

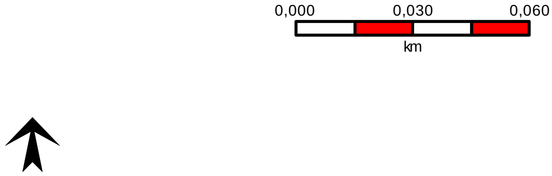
Flash Fire

- **Leak 150 mm**

Jet Fire



Flash Fire



- **Leak 3 mm (Storage System Pipelines)**

Jet Fire

-

Flash Fire

- **Leak 10 mm (Storage System Pipeline)**

Jet Fire

Flash Fire

- **Leak 50 mm (Storage System Pipeline)**

Jet Fire

Flash Fire

- **Leak 150 mm (Storage System Pipeline)**

Jet Fire

Flash Fire

Appendix 7: Risk Representation Recapitulation

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Category: Jet Fire Bore Diameter 10 mm										
No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jettty MLA	1	4,49E-07	25 kw/m2	10,03	1	1	1	6	NO
				35 kw/m2	7,48	3	1	3	6	NO
				45 kw/m2	-	4	1	4	0	NO
2	Metering Station	2	5,02E-07	25 kw/m2	10,03	1	1	1	2	NO
				35 kw/m2	7,48	3	1	3	2	NO
				45 kw/m2	-	4	1	4	0	NO
3	Storage Area V110	5	1,36E-17	25 kw/m2	10,03	1	1	1	0	NO
				35 kw/m2	7,48	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
4	Storage Area V120	5	1,36E-17	25 kw/m2	10,03	1	1	1	0	NO
				35 kw/m2	7,48	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
5	Storage Area V130	5	1,36E-17	25 kw/m2	10,03	1	1	1	0	NO
				35 kw/m2	7,48	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
6	Storage Area V140	5	1,36E-17	25 kw/m2	10,03	1	1	1	0	NO
				35 kw/m2	7,48	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
7	Storage Area System	6	1,17E-06	25 kw/m2	10,03	1	1	1	5	NO
				35 kw/m2	7,48	3	1	3	5	NO
				45 kw/m2	-	4	1	4	0	NO
8	Office and Control Room	5	1,36E-17	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
9	Warehouse	5	9,38E-14	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
10	Pump house	7	9,38E-14	25 kw/m2	10,98	1	1	1	1	NO
				35 kw/m2	7,48	3	1	3	1	NO
				45 kw/m2	-	4	1	4	0	NO
11	Powerhouse	6	1,17E-06	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
12	Filling Shed	8	1,63E-06	25 kw/m2	10,98	1	1	1	15	NO
				35 kw/m2	7,48	3	1	3	15	NO
				45 kw/m2	-	4	1	4	0	NO
13	Skid Tank Parking Area	8	1,63E-06	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO

Category: Jet Fire Bore Diameter 50 mm										
No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty MLA	1	3,71E-07	25 kw/m2	36,83	1	1	1	6	NO
				35 kw/m2	27,16	3	1	3	6	NO
				45 kw/m2	17,82	4	1	4	6	YES
2	Metering Station	2	4,27E-07	25 kw/m2	36,83	1	1	1	2	NO
				35 kw/m2	27,16	3	1	3	2	NO
				45 kw/m2	17,82	4	1	4	2	YES
3	Storage Area V110	5	3,38E-19	25 kw/m2	36,83	1	1	1	5	NO
				35 kw/m2	27,16	3	1	3	5	NO
				45 kw/m2	17,82	4	1	4	0	NO
4	Storage Area V120	5	3,38E-19	25 kw/m2	36,83	1	1	1	5	NO
				35 kw/m2	27,16	3	1	3	5	NO
				45 kw/m2	17,82	4	1	4	0	NO
5	Storage Area V130	5	3,38E-19	25 kw/m2	36,83	1	1	1	5	NO
				35 kw/m2	27,16	3	1	3	5	NO
				45 kw/m2	17,82	4	1	4	0	NO
6	Storage Area V140	5	-3,38E-19	25 kw/m2	36,83	1	1	1	5	NO
				35 kw/m2	27,16	3	1	3	5	NO
				45 kw/m2	17,82	4	1	4	0	NO
7	Storage Area System	6	1,26E-06	25 kw/m2	36,83	1	1	1	5	NO
				35 kw/m2	27,16	3	1	3	5	NO
				45 kw/m2	17,82	4	1	4	0	NO
8	Office and Control Room	5	3,38E-19	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
9	Warehouse	5	3,38E-19	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
10	Pump house	7	1,70E-16	25 kw/m2	34,25	1	1	1	1	NO
				35 kw/m2	24,85	3	1	3	1	NO
				45 kw/m2	13,54	4	1	4	1	NO
11	Powerhouse	6	1,26E-06	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
12	Filling Shed	8	7,66E-07	25 kw/m2	34,25	1	1	1	15	NO
				35 kw/m2	24,85	3	1	3	15	NO
				45 kw/m2	13,54	4	1	4	15	NO
13	Skid Tank Parking Area	8	7,66E-07	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO

Category: Jet Fire Bore Diameter 150 mm										
No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty MLA	1	4,60E-07	25 kw/m2	82,59	1	1	1	6	NO
				35 kw/m2	57,13	3	1	3	6	NO
				45 kw/m2	35,82	4	1	4	6	YES
2	Metering Station	2	5,52E-07	25 kw/m2	82,59	1	1	1	2	NO
				35 kw/m2	57,13	3	1	3	2	NO
				45 kw/m2	35,82	4	1	4	2	YES
3	Storage Area V110	5	5,30E-23	25 kw/m2	82,59	1	1	1	5	NO
				35 kw/m2	57,13	3	1	3	5	NO
				45 kw/m2	35,82	4	1	4	5	YES
4	Storage Area V120	5	5,30E-23	25 kw/m2	82,59	1	1	1	5	NO
				35 kw/m2	57,13	3	1	3	5	NO
				45 kw/m2	35,82	4	1	4	5	YES
5	Storage Area V130	5	5,30E-23	25 kw/m2	82,59	1	1	1	5	NO
				35 kw/m2	57,13	3	1	3	5	NO
				45 kw/m2	35,82	4	1	4	5	YES
6	Storage Area V140	5	5,30E-23	25 kw/m2	82,59	1	1	1	5	NO
				35 kw/m2	57,13	3	1	3	5	NO
				45 kw/m2	35,82	4	1	4	5	YES
7	Storage Area System	6	2,80E-06	25 kw/m2	82,59	1	1	1	5	NO
				35 kw/m2	57,13	3	1	3	5	NO
				45 kw/m2	35,82	4	1	4	5	YES
8	Office and Control Room	5	5,30E-23	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
9	Warehouse	5	5,30E-23	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
10	Pump house	7	1,42E-11	25 kw/m2	80,72	1	1	1	1	NO
				35 kw/m2	51,11	3	1	3	1	NO
				45 kw/m2	29,76	4	1	4	1	YES
11	Powerhouse	6	2,80E-06	25 kw/m2	-	1	1	1	0	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO
12	Filling Shed	8	2,83E-06	25 kw/m2	80,72	1	1	1	15	NO
				35 kw/m2	51,11	3	1	3	15	NO
				45 kw/m2	29,76	4	1	4	15	yes
13	Skid Tank Parking Area	8	2,83E-06	25 kw/m2	21,34	1	1	1	20	NO
				35 kw/m2	-	3	1	3	0	NO
				45 kw/m2	-	4	1	4	0	NO

Category: Flash Fire Bore Diameter 3 mm										
No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty & MLA	1	1,27E-05	4,286 kW/m3	1,2	3	1	3	0	NO
				9,107 kW/m3	0,5	4	1	4	0	NO
2	Meterring Station	2	1,29E-05	4,286 kW/m3	1,2	3	1	3	0	NO
				9,107 kW/m3	0,5	4	1	4	0	NO
3	Storage Area V110	5	1,97E-17	4,286 kW/m3	1,2	3	1	3	0	NO
				9,107 kW/m3	0,5	4	1	4	0	NO
4	Storage Area V120	5	1,97E-17	4,286 kW/m3	1,2	3	1	3	0	NO
				9,107 kW/m3	0,5	4	1	4	0	NO
5	Storage Area V130	5	1,97E-17	4,286 kW/m3	1,2	3	1	3	0	NO
				9,107 kW/m3	0,5	4	1	4	0	NO
6	Storage Area V140	5	1,97E-17	4,286 kW/m3	1,2	3	1	3	0	NO
				9,107 kW/m3	0,5	4	1	4	0	NO
7	Storage Area System	6	5,45E-05	4,286 kW/m3	1,2	3	1	3	0	NO
				9,107 kW/m3	0,5	4	1	4	0	NO
8	Office and Control Room	5	1,97E-17	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
9	Warehouse	5	1,97E-17	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
10	Pumphouse	7	5,20E-11	4,286 kW/m3	1,17	3	1	3	0	NO
				9,107 kW/m3	0,53	4	1	4	0	NO
11	Powerhouse	6	5,45E-05	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
12	Filling Shed	8	3,65E-04	4,286 kW/m3	1,17	3	1	3	0	NO
				9,107 kW/m3	0,53	4	1	4	0	NO
13	Skid Tank Parking Area	8	3,65E-04	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO

Category: Flash Fire Bore Diameter 10 mm										
No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty & MLA	1	4,94E-05	4,286 kW/m3	4,03	3	1	3	6	NO
				9,107 kW/m3	1,83	4	1	4	0	NO
2	Meterring Station	2	5,52E-05	4,286 kW/m3	3,71	3	1	3	2	NO
				9,107 kW/m3	1,81	4	1	4	0	NO
3	Storage Area V110	5	7,45E-17	4,286 kW/m3	3,71	3	1	3	0	NO
				9,107 kW/m3	1,81	4	1	4	0	NO
4	Storage Area V120	5	7,45E-17	4,286 kW/m3	3,71	3	1	3	0	NO
				9,107 kW/m3	1,81	4	1	4	0	NO
5	Storage Area V130	5	7,45E-17	4,286 kW/m3	3,71	3	1	3	0	NO
				9,107 kW/m3	1,81	4	1	4	0	NO
6	Storage Area V140	5	7,45E-17	4,286 kW/m3	3,71	3	1	3	0	NO
				9,107 kW/m3	1,81	4	1	4	0	NO
7	Storage Area System	6	1,29E-04	4,286 kW/m3	4,03	3	1	3	0	NO
				9,107 kW/m3	1,83	4	1	4	0	NO
8	Office and Control Room	5	7,45E-17	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
9	Warehouse	5	7,45E-17	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
10	Pumphouse	7	1,03E-11	4,286 kW/m3	3,91	3	1	3	1	NO
				9,107 kW/m3	1,87	4	1	4	0	NO
11	Powerhouse	6	1,29E-04	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
12	Filling Shed	8	1,79E-04	4,286 kW/m3	3,91	3	1	3	5	NO
				9,107 kW/m3	1,87	4	1	4	0	NO
13	Skid Tank Parking Area	8	1,79E-04	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO

Category: Flash Fire Bore Diameter 50 mm										
No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty & MLA	1	1,65E-05	4,286 kW/m3	14,38	3	1	3	6	NO
				9,107 kW/m3	8,42	4	1	4	6	YES
2	Meterring Station	2	1,90E-05	4,286 kW/m3	14,38	3	1	3	2	NO
				9,107 kW/m3	8,42	4	1	4	2	YES
3	Storage Area V110	5	7,51E-19	4,286 kW/m3	20,51	3	1	3	5	NO
				9,107 kW/m3	9,19	4	1	4	5	YES
4	Storage Area V120	5	7,51E-19	4,286 kW/m3	20,51	3	1	3	5	NO
				9,107 kW/m3	9,19	4	1	4	5	YES
5	Storage Area V130	5	7,51E-19	4,286 kW/m3	20,51	3	1	3	5	NO
				9,107 kW/m3	9,19	4	1	4	5	YES
6	Storage Area V140	5	7,51E-19	4,286 kW/m3	20,51	3	1	3	5	NO
				9,107 kW/m3	9,19	4	1	4	5	YES
7	Storage Area System	6	5,60E-05	4,286 kW/m3	20,51	3	1	3	5	NO
				9,107 kW/m3	9,19	4	1	4	5	YES
8	Office and Control Room	5	7,51E-19	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
9	Warehouse	5	7,51E-19	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
10	Pumphouse	7	7,55E-15	4,286 kW/m3	8,85	3	1	3	1	NO
				9,107 kW/m3	5,38	4	1	4	1	YES
11	Powerhouse	6	5,60E-05	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
12	Filling Shed	8	3,41E-05	4,286 kW/m3	8,85	3	1	3	15	NO
				9,107 kW/m3	5,38	4	1	4	15	YES
13	Skid Tank Parking Area	8	3,41E-05	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO

Category: Flash Fire Bore Diameter 150 mm										
No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty & MLA	1	2,74E-06	4,286 kW/m3	15,94	3	1	3	6	NO
				9,107 kW/m3	9,5	4	1	4	6	YES
2	Meterring Station	2	3,28E-06	4,286 kW/m3	15,94	3	1	3	2	NO
				9,107 kW/m3	9,5	4	1	4	2	YES
3	Storage Area V110	5	1,58E-23	4,286 kW/m3	59,19	3	1	3	5	NO
				9,107 kW/m3	32,68	4	1	4	5	YES
4	Storage Area V120	5	1,58E-23	4,286 kW/m3	59,19	3	1	3	5	NO
				9,107 kW/m3	32,68	4	1	4	5	YES
5	Storage Area V130	5	1,58E-23	4,286 kW/m3	59,19	3	1	3	5	NO
				9,107 kW/m3	32,68	4	1	4	5	YES
6	Storage Area V140	5	1,58E-23	4,286 kW/m3	59,19	3	1	3	5	NO
				9,107 kW/m3	32,68	4	1	4	5	YES
7	Storage Area System	6	1,67E-05	4,286 kW/m3	59,19	3	1	3	5	NO
				9,107 kW/m3	32,68	4	1	4	5	YES
8	Office and Control Room	5	1,58E-23	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
9	Warehouse	5	1,58E-23	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
10	Pumphouse	7	8,47E-11	4,286 kW/m3	9,21	3	1	3	1	NO
				9,107 kW/m3	5,65	4	1	4	1	YES
11	Powerhouse	6	1,67E-05	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO
12	Filling Shed	8	1,68E-05	4,286 kW/m3	9,21	3	1	3	15	NO
				9,107 kW/m3	5,65	4	1	4	15	YES
13	Skid Tank Parking Area	8	1,68E-05	4,286 kW/m3	-	3	1	3	0	NO
				9,107 kW/m3	-	4	1	4	0	NO

Category: Explosion Bore Diameter 3 mm										
No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty MLA	1	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
2	Metering Station	2	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
3	Storage Area V110	5	3,75E-16	0,2 bar	7,84	1	1	1	0	NO
				1,3 bar	2,77	3	1	3	0	NO
				2,0 bar	2,37	4	1	4	0	NO
4	Storage Area V120	5	3,75E-16	0,2 bar	7,84	1	1	1	0	NO
				1,3 bar	2,77	3	1	3	0	NO
				2,0 bar	2,37	4	1	4	0	NO
5	Storage Area V130	5	3,75E-16	0,2 bar	7,84	1	1	1	0	NO
				1,3 bar	2,77	3	1	3	0	NO
				2,0 bar	2,37	4	1	4	0	NO
6	Storage Area V140	5	3,75E-16	0,2 bar	7,84	1	1	1	0	NO
				1,3 bar	2,77	3	1	3	0	NO
				2,0 bar	2,37	4	1	4	0	NO
7	Storage Area System	6	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
8	Office and Control Room	5	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
9	Warehouse	5	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
10	Pump house	7	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
11	Powerhouse	6	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
12	Filling Shed	8	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
13	Skid Tank Parking Area	8	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-

Category: Explosion Bore Diameter 10 mm

No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty MLA	1	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
2	Metering Station	2	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
3	Storage Area V110	5	1,42E-15	0,2 bar	21,937	1	1	1	5	NO
				1,3 bar	6,42	3	1	3	0	NO
				2,0 bar	5,19	4	1	4	0	NO
4	Storage Area V120	5	1,42E-15	0,2 bar	21,937	1	1	1	5	NO
				1,3 bar	6,42	3	1	3	0	NO
				2,0 bar	5,19	4	1	4	0	NO
5	Storage Area V130	5	1,42E-15	0,2 bar	21,937	1	1	1	5	NO
				1,3 bar	6,42	3	1	3	0	NO
				2,0 bar	5,19	4	1	4	0	NO
6	Storage Area V140	5	1,42E-15	0,2 bar	21,937	1	1	1	5	NO
				1,3 bar	6,42	3	1	3	0	NO
				2,0 bar	5,19	4	1	4	0	NO
7	Storage Area System	6	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
8	Office and Control Room	5	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
9	Warehouse	5	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
10	Pump house	7	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
11	Powerhouse	6	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
12	Filling Shed	8	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
13	Skid Tank Parking Area	8	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-

Category: Explosion Bore Diameter 50 mm

No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty MLA	1	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
2	Metering Station	2	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
3	Storage Area V110	5	1,43E-17	0,2 bar	61,02	1	1	1	5	NO
				1,3 bar	16,58	3	1	3	0	NO
				2,0 bar	13,06	4	1	4	0	NO
4	Storage Area V120	5	1,43E-17	0,2 bar	61,02	1	1	1	5	NO
				1,3 bar	16,58	3	1	3	0	NO
				2,0 bar	13,06	4	1	4	0	NO
5	Storage Area V130	5	1,43E-17	0,2 bar	61,02	1	1	1	5	NO
				1,3 bar	16,58	3	1	3	0	NO
				2,0 bar	13,06	4	1	4	0	NO
6	Storage Area V140	5	1,43E-17	0,2 bar	61,02	1	1	1	5	NO
				1,3 bar	16,58	3	1	3	0	NO
				2,0 bar	13,06	4	1	4	0	NO
7	Storage Area System	6	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
8	Office and Control Room	5	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
9	Warehouse	5	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
10	Pump house	7	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
11	Powerhouse	6	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
12	Filling Shed	8	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
13	Skid Tank Parking Area	8	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-

Category: Explosion Bore Diameter 150 mm										
No.	Receiver	Corresponding Node	Frequencies	Type of Consequences	Radius (m)	Severity Level	Likelihood Level	Risk Level	No. Of People Affected	Mitigation
1	Jetty MLA	1	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
2	Metering Station	2	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
3	Storage Area V110	5	2,99E-22	0,2 bar	99,25	1	1	1	5	NO
				1,3 bar	26,44	3	1	3	5	NO
				2,0 bar	20,68	4	1	4	0	NO
4	Storage Area V120	5	2,99E-22	0,2 bar	99,25	1	1	1	5	NO
				1,3 bar	26,44	3	1	3	5	NO
				2,0 bar	20,68	4	1	4	0	NO
5	Storage Area V130	5	2,99E-22	0,2 bar	99,25	1	1	1	5	NO
				1,3 bar	26,44	3	1	3	5	NO
				2,0 bar	20,68	4	1	4	0	NO
6	Storage Area V140	5	2,99E-22	0,2 bar	99,25	1	1	1	5	NO
				1,3 bar	26,44	3	1	3	5	NO
				2,0 bar	20,68	4	1	4	0	NO
7	Storage Area System	6	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
8	Office and Control Room	5	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
9	Warehouse	5	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
10	Pump house	7	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
11	Powerhouse	6	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
12	Filling Shed	8	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-
13	Skid Tank Parking Area	8	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-
				-	-	-	-	-	-	-

Appendix 8: Fire Risk Card

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Fire Risk Card Terminal LPG Semarang

Incident Scenario:
Storage tank V110 encounter 150 mm leak and the gas released become jet fire, and Storage Tank V120, V130, V140 in need of auxiliary cooling

Hazard			***Location Description***
Flame Emissivity	: 400	kw/m2	Storage V110
Heat Flux Radiation Zone (m)			
25 kw/m2	:	82,59	
35 kw/m2	:	57,13	
45 kw/m2	:	35,82	

Facility Information

Type of Facility	:	Storage Tank	
Size	:	-	
Capacity	:	2500	MT
Surface Area (for Storage Tank)	:	1505,975	m2

Auxiliary Cooling Requirement

Burnt Tank	:	V110	
Tank to be cooled down	:	V120, V130, V140	
Pump flow rate Requirement	:	9721,131	gpm
Water supply for for auxiliary cooling	:	8830,676	m3

Minimum Fire Extinguisher Requirement

Fire Pump flow rate	:	403,5584	gpm
Fire Hose flow rate	:	403,5584	gpm
Water Supply for 4 (four) hours	:	372,5154	m3

Note

Fire Risk Card Terminal LPG Semarang

Incident Scenario:
Storage tank V120 encounter 150 mm leak and the gas released become jet fire, and Storage Tank V110, V130, V140 in need of auxiliary cooling

Hazard			***Location Description***
Flame Emissivity	: 400	kw/m2	Storage V120
Heat Flux Radiation Zone (m)			
25 kw/m2	:	82,59	
35 kw/m2	:	57,13	
45 kw/m2	:	35,82	

Facility Information

Type of Facility	:	Storage Tank	
Size	:	-	
Capacity	:	2500	MT
Surface Area (for Storage Tank)	:	1505,975	m2

Auxiliary Cooling Requirement

Burnt Tank	:	V120	
Tank to be cooled down	:	V110, V130, V140	
Pump flow rate Requirement	:	9721,131	gpm
Water supply for for auxiliary cooling	:	8830,676	m3

Minimum Fire Extinguisher Requirement

Fire Pump flow rate	:	403,5584	gpm
Fire Hose flow rate	:	403,5584	gpm
Water Supply for 4 (four) hours	:	372,5154	m3

Note

Fire Risk Card Terminal LPG Semarang

Incident Scenario:
Storage tank V130 encounter 150 mm leak and the gas released become jet fire, and Storage Tank V110, V120, V140 in need of auxiliary cooling

Hazard

Flame Emissivity	: 400	kw/m2	
Heat Flux Radiation Zone (m)			
25 kw/m2	:	82,59	
35 kw/m2	:	57,13	
45 kw/m2	:	35,82	

Location Description
Storage V130

Facility Information

Type of Facility	:	Storage Tank	
Size	:	-	
Capacity	:	2500	MT
Surface Area (for Storage Tank)	:	1505,975	m2

Auxiliary Cooling Requirement

Burnt Tank	:	V130	
Tank to be cooled down	:	V110, V120, V140	
Pump flow rate Requirement	:	9721,131	gpm
Water supply for for auxiliary cooling	:	8830,676	m3

Minimum Fire Extinguisher Requirement

Fire Pump flow rate	:	403,5584	gpm
Fire Hose flow rate	:	403,5584	gpm
Water Supply for 4 (four) hours	:	372,5154	m3

Note

Fire Risk Card Terminal LPG Semarang

Incident Scenario:
Storage tank V140 encounter 150 mm leak and the gas released become jet fire, and Storage Tank V110, V120, V140 in need of auxiliary cooling

Hazard			***Location Description***
Flame Emissivity	: 400	kw/m2	Storage V140
Heat Flux Radiation Zone (m)			
25 kw/m2	:	82,59	
35 kw/m2	:	57,13	
45 kw/m2	:	35,82	

Facility Information

Type of Facility	:	Storage Tank	
Size	:	-	
Capacity	:	2500	MT
Surface Area (for Storage Tank)	:	1505,975	m2

Auxiliary Cooling Requirement

Burnt Tank	:	V140	
Tank to be cooled down	:	V110, V120, V130	
Pump flow rate Requirement	:	9721,131	gpm
Water supply for for auxiliary cooling	:	8830,676	m3

Minimum Fire Extinguisher Requirement

Fire Pump flow rate	:	403,5584	gpm
Fire Hose flow rate	:	403,5584	gpm
Water Supply for 4 (four) hours	:	372,5154	m3

Note

Fire Risk Card Terminal LPG Semarang

Incident Scenario: Metering Station encounter 150 mm Jet Fire and need fire extinguisher				
Hazard				***Location Description***
Flame Emissivity	: 400	kw/m2		Metering Station
Heat Flux Radiation Zone (m)				
25 kw/m2	:		82,59	
35 kw/m2	:		57,13	
45 kw/m2	:		35,82	
Facility Information				
Type of Facility	:	Pipe with flow rate indicator		
Size	:	10		inch
Capacity	:	300		ton/hr
Surface Area (for Storage Tank)	:	-		m2
Auxiliary Cooling Requirement				
Burnt Tank	:	-		
Tank to be cooled down	:	-		
Pump flow rate Requirement	:	-		
Water supply for for auxiliary cooling	:	-		
Minimum Fire Extinguisher Requirement				
Fire Pump flow rate	:	403,5323		gpm
Fire Hose flow rate	:	403,5323		gpm
Water Supply for 4 (four) hours	:	372,4914		m3
Note				

Fire Risk Card Terminal LPG Semarang

Incident Scenario:
MLA and Jetty Area encounter 150 mm Jet Fire and need fire extinguisher

Hazard			***Location Description***
Flame Emissivity	: 400	kw/m2	Jetty and MLA
Heat Flux Radiation Zone (m)			
25 kw/m2	:	82,59	
35 kw/m2	:	57,13	
45 kw/m2	:	35,82	

Facility Information

Type of Facility	:	Marine Loading Arm and pipe connection	
Size	:	10	inch
Capacity	:	300	ton/hr
Surface Area (for Storage Tank)	:	-	m2

Auxiliary Cooling Requirement

Burnt Tank	:	-
Tank to be cooled down	:	-
Pump flow rate Requirement	:	-
Water supply for for auxiliary cooling	:	-

Minimum Fire Extinguisher Requirement

Fire Pump flow rate	:	403,5323	gpm
Fire Hose flow rate	:	403,5323	gpm
Water Supply for 4 (four) hours	:	372,4914	m3

Note

Fire Risk Card Terminal LPG Semarang

Incident Scenario:

Pump house encounter 150 mm Jet Fire and need fire extinguisher

Hazard

Flame Emissivity	:	400	kw/m2
Heat Flux Radiation Zone (m)			
25 kw/m2	:		80,72
35 kw/m2	:		51,11
45 kw/m2	:		29,76

Location Description

Pump house

Facility Information

Type of Facility	:	Pipe with flow rate indicator	
Size	:	6	inch
Capacity	:	30-60	ton/hr
Surface Area (for Storage Tank)	:	-	m2

Auxiliary Cooling Requirement

Burnt Tank	:	-
Tank to be cooled down	:	-
Pump flow rate Requirement	:	-
Water supply for for auxiliary cooling	:	-

Minimum Fire Extinguisher Requirement

Fire Pump flow rate	:	403,6739	gpm
Fire Hose flow rate	:	403,6739	gpm
Water Supply for 4 (four) hours	:	372,6221	m3

Note

Fire Risk Card Terminal LPG Semarang

Incident Scenario:
Filling Shed encounter 150 mm Jet Fire and need fire extinguisher

Hazard			***Location Description***
Flame Emissivity	: 400	kw/m2	Filling Shed
Heat Flux Radiation Zone (m)			
25 kw/m2	:	80,72	
35 kw/m2	:	51,11	
45 kw/m2	:	29,76	

Facility Information

Type of Facility	:	Pipe with flow rate indicator	
Size	:	3	inch
Capacity	:	15	ton/hr.
Surface Area (for Storage Tank)	:	-	m2

Auxiliary Cooling Requirement

Burnt Tank	:	-
Tank to be cooled down	:	-
Pump flow rate Requirement	:	-
Water supply for for auxiliary cooling	:	-

Minimum Fire Extinguisher Requirement

Fire Pump flow rate	:	403,6618	gpm
Fire Hose flow rate	:	403,6618	gpm
Water Supply for 4 (four) hours	:	372,6109	m3

Note

AUTHOR BIOGRAPHY

The author was born on 24 June 1995 in Tegal, as the last child of 3 siblings. His father is Mr. Bambang Murdadi, SE. MM. and his mother is Mrs. Endang Sri Harmini. The author has completed the formal education in SDN Wonotingal 04 Semarang, SMPN 5 Semarang, and SMAN 1 Semarang. The author continued his study for bachelor degree in Marine Engineering Double Degree (DDME) program of Institut Teknologi Sepuluh Nopember (ITS) and Hochschule Wismar, and took area of expertise in Reliability, Availibility, Maintenance, and Safety (RAMS). During the college, the author was active in academic and non-academic activities such as: METIC (Marine Engineering Technology and Inovation Club), including various training in engineering related course such as: Project Management, 3D Modelling. Computational Fluids Dynamic, etc, The author have done on the job training in Samudera Shipyard Semarang and Terminal LPG Semarang.

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