BACHELOR THESIS – ME 141502

HAZARD POTENCY ANALYSIS OF LPG LOADING PROCESS IN LPG TERMINAL SEMARANG

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DOUBLE DEGREE PROGRAM OF
MARINE ENGINEERING DEPARTMENT
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember
Surabaya
2016

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ANALISA POTENSI BAHAYA PADA PROSES BONGKAR LPG DI TERMINAL LPG SEMARANG

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APPROVAL FORM

HAZARD POTENCY ANALYSIS OF LPG LOADING PROCESS IN LPG TERMINAL SEMARANG

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This Bachelor Thesis is submitted as a partial fulfilment of the requirements for the Bachelor Engineering Degree on
Field study of Marine Reliability, Availability,
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ABSTRACT

LPG Plant is a very important plant in the LPG supply chain, it reliability must be good to avoid any loss, even a small accident could create huge effect in a supply chain. 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. 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 level of the LPG loading process. It shall make the plant become even more safe than the plant before the mitigation, but even the assessment result was there is no medium or higher level risk, the remaining risk shall be considered too to decrease the risk level to the lowest level, especially for a system which did not have any safeguard. The result of the assessment is all of the LPG plant is only on moderate or lower risk level, which means it did not need any mitigation.

Keywords: lpg plant, mitigation, risk, risk assessment, risk level.

ANALISA POTENSI BAHAYA PADA PROSES BONGKAR LPG DI TERMINAL LPG SEMARANG

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ABSTRAK

Fasilitas LPG merupakan sebuah fasilitas yang sangat penting dalam rantai distribusi LPG, keandalannya haruslah bagus untuk menghindari kerugian, bahkan sebuah insiden kecil dapat menimbulkan dampak yang besar pada rantai distribusi LPG. Untuk mengurangi kemungkinan bahaya, beberapa metode dapat digunakan. Hazard and Operabulity (HAZOP) merupakan metode yang sesuai untuk menganalisis kemungkinan terjadinya bahaya, selain itu *Fault Tree Analysis (FTA),* dan *Layer of Protection (LOPA)* juga dapat digunakan untuk menganalisa rasio kegagalan sebuah system dan langkah mitigasinya.apabila tingkat risikonya berada pada tingkat menegah ataupun lebih tinggi. Seluruh proses bongkar LPG harus dianalisis untuk memastikan bahwa sistem tersebut tidak akan menimbulkan insiden. Sebuah sistem bongkar LPG adalah sistem yang membawa muatan berupa Propana dan Butana dari kapal pengangkut ke tangki penyimpanan di fasilitas. Sistem yang sudah dianalisis kemudian akan dikategorikan dalam beberapa tingkat risiko, yang mana risiko level rendah tidak harus ditindak lanjuti, sedangkan risiko dengan level menengah atau lebih tinggi harus dimitigasi, tingkatan risiko itu sendiri berdasarkan pada matriks risiko, sebuah matriks risiko memiliki definisinya sendiri untuk menentukan tingkat kemungkinan maupun keparahannya, ketika angka kemungkinan dan keparahan digabungkan, maka tingkat risiko dapat ditentukan, yang mana hal tersebut berarti bahwa tingkatan risiko merupakan hasil gabungan dari angka keparahan dan kemungkinan gagal dari sebuah system atau sub-sistem. Proses mitigasi akan mengurangi tingkat risiko pada proses bongkar LPG. Hal ini akan membuat proses bongkar LPG lebih baik daripada sebelum mitigasi dilakukan, walaupun hasil dari analisa menunjukkan bahwa tidak ada risiko tingkat menengah atau level tinggi, risiko tingkat di bawahnya harus tetap diperhatikan juga, bila perlu diturunkan lagi risikonya hingga ke tingkatan paling rendah., terutama untuk system yang belum memiliki alat keselamatan. Hasilnya adalah seluruh sistem pada fasilitas LPG hanya berada pada tingkat bahaya kecil, yang berarti tidak butuh tindak lanjut.

Kata kunci: analisa risiko, fasilitas lpg, mitigasi, risiko, tingkat risiko.

PREFACE

Alhamdulillahirobbil'alamin. Thanks to Allah S.W.T. for the grace and bless, so that this bachelor thesis: "Hazard Potency Analysis on LPG Loading Process in LPG Terminal Semarang" could be finished. This Bachelor Thesis is submitted as a partial fulfilment of the requirements for the Bachelor Engineering Degree on Double Degree Program Marine Engineering Department, Faculty of Marine Technology, Sepuluh Nopember Institute of Technology

The author could finish this thesis with all helps from many people. So that the author would say thanks to:

1. Papa (Alm. Ir. Gandrie Simbardjo, M.M.), Mama (drg. Anies Bektiarsi), older sister (Alifianti Puspa Ramadhani, S.Psi.), and little sister (Tarisha Tristania Putri) who gave many support to help the authors finished this thesis.
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The author understood that this bachelor thesis is still far from perfectness. So that any critic and suggestion is welcomed. Finally, the author hopes that this thesis could be used as reference and not ended in unused bookshelf.

Surabaya, July 2016

Bawono Rizki Putra

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CHAPTER 1
INTRODUCTION

1.1 Background

Manpower is one of the most important aspect in production process in a company. So manpower must be protected from any risk which can be caused by environment or the work itself. Labor Minister Regulation number: PER.05/ MEN/ 1996, Chapter III, Article 3 state that: “Every company which have manpower equal or more than a hundred and have risk potency which can be caused by process characteristic or production material which can causing accident, such as explosion, fire, contamination, and illness, must implementing HSE Management System.”

To ensure the HSE (Health, Safety, Environment) management system works well, every company have their own HSE Department. The HSE Department of some companies are responsible for environmental protection, occupational health and safety at work. HSE management has two general objectives: prevention of incidents or accidents that might result from abnormal operating conditions on the one hand and reduction of adverse effects that result from normal operating conditions on the other hand.

For example, fire, explosion and release of harmful substances into the environment or the work area must be prevented. Also action must be taken to reduce a company’s environmental impact under normal operating conditions (like reducing the company’s carbon footprint) and to prevent workers from developing work related diseases. Regulatory requirements play an important role in both approaches and consequently, HSE managers must identify and understand relevant HSE regulations, the implications of which must be communicated to top management (the board of directors) so the company can implement suitable measures.

HSE management is already been implemented in many company in Indonesia. And the needs of good HSE management always increasing because of high accident number in Indonesia. BPJS Ketenagakerjaan, the insurance company of Indonesia's Government, claims that every year more than 10 thousand accidents occurred in Indonesia, that number always increasing every year.

Table 1. Accident Number in Indonesia

Tabel Kasus Klaim Program JKK

NO.	JENIS KLAIM	2009	2010	2011	2012	2013
1	Cacat Fungsi	4.380	4.061	4.130	3.915	3.985
2	Cacat Sebagian	2.713	2.550	2.722	2.685	2.693
3	Cacat Total Tetap	42	36	34	37	44
4	Meninggal Dunia	2.144	2.191	2.218	2.419	2.438
5	Kasus Sembuh	87.035	89.873	90.387	94.018	94.125
	Total	**96.314**	**98.711**	**99.491**	**103.074**	**103.285**

Accident number in workplace increasing about 1,76% every year. There are 103.285 accident occurred in 2013, or 283 accidents every day, with average 7 persons dead, 18 persons got physical disability, and the rest can completely recover.

Generally, the success rate of HSE program implementation is determined by the number of occurred incident. The more accident occurred, the worst HSE implementation is. The table above show that HSE implementation in Indonesia is still bad and need to be improved. To have good HSE implementation, a sustainable HSE implementation program is needed, and must be integrated in all of company area, support from every worker in the company is also needed. Therefore, to measure the success rate of the HSE implementation, the process which have been done must be considered, because evaluating the implementation process is a very important to ensure that the program has been implemented by every worker. Thus, accident in workplace can be prevented from the beginning, not only be decreased or eliminated.

A workplace risk assessment is one of the key tools for improving occupational safety and health conditions at work. Thus it plays an important role in protecting workers and businesses, as well as complying with the laws in many countries. It helps everyone focus on the risks that really matter in the workplace – the ones with the potential to cause real harm. In many instances, straightforward measures can readily control risks, for example providing drinking water to prevent dehydration, window blinds to reduce temperature gain in buildings, ensuring spillages are cleaned up promptly so people do not slip, or cupboard drawers are kept closed to ensure people do not trip. For most, that means simple, cheap and effective measures to ensure workers, businesses most valuable asset, are protected.

A well conducted workplace risk assessment will contribute to the protection of workers by eliminating or minimizing work related hazards and risks. It should also benefit businesses through better organization of working practices potentially increasing productivity. A risk assessment is simply a careful examination of what, in the workplace, could cause harm to people. It enables a weighing up of whether enough precautions are in place or whether more should be done to prevent harm to those at risk, including workers and members of the public.

Accidents and ill health can ruin lives as well as affecting businesses, for example if output is lost, machinery is damaged, insurance costs increase or other financial penalties. In many countries employers are legally required to assess the risks in their workplace so that they can put in place a plan to control these risks.

The concept of a workplace risk assessment is that it is a continual, ongoing process – like a film on a loop. Not a snapshot of a workplace, which can be likened to a workplace inspection. Whilst it may be beneficial to use information from workplace inspections when undertaking risk assessments, we must be clear on the difference between risk assessments and inspections. A risk assessment should identify the hazard and the required control measure, an inspection should verify if the required control measures are in fact being used.

Safety is also a very important aspect in loading-unloading process of LPG. Loading-unloading of LPG in the special wharf have a very important role in fuel and LPG distribution in Central Java or nearby area. Any failure, accident, or mistake in this process will give bad effect in LPG distribution.

Loading and unloading process is closely related to risk and accident. Failure and accident is a loss which must be controlled and avoided if all factors which related to the accident can be predicted as early as possible. Safety assessment study aims to find any weakness of a system which could causing an accident.

An accident could be caused by some factors, such as failure in loading-unloading equipment, loading-unloading procedure, safety procedure, human error probability, or even environment factor. And must also be considered that loading-unloading of LPG have big risk on safety, because of fire and explosion possibility, and it can even cause pollution to the environment.

On 4 January 1966, an accident occurred in LPG Tank in France, about 81 peoples dead and 130 people injured. On 19 November 1984 a major fire and a series of catastrophic explosions occurred at the government owned and operated PEMEX LPG Terminal at San Juan Ixhuatepec, Mexico City. As a consequence of these events some 500 individuals were killed and the terminal destroyed.

Some other minor accident also occurred in LPG terminal, even though the accident did not give big impact to the environment or to the worker, the accident still delayed the loading – unloading process of LPG, these are some accidents that occurred in Terminal LPG Surabaya along 21st century (Maryono, 2002):

- Fallen worker at MLA control ladder
- Leakage on cargo hose
- Fallen outboard arm and injuring the ship crew
- And some other system failures

Even tough accident in LPG Terminal is a rare case, but the severity will cause a very dangerous impact to the worker, or to the environment. To prevent any bad impact, a hazard potency analysis should be done to reveal all potency hazard that may occurred, and prevent the hazard to happen.

Beside, LPG consumption always increase every year, the LPG consumption will be shown below.

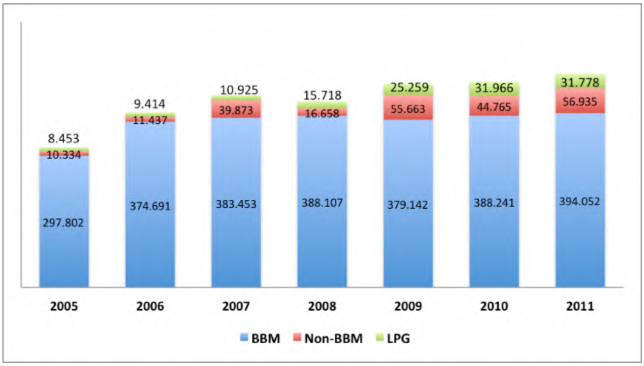

Figure 1. LPG Consumption Every Year

The increase of LPG consumption will give effect on the increases of LPG import or production, which will increase the needs of LPG terminal, it could be the increase of LPG terminal number or the increase of the existing LPG terminal capacity. The hazard potency analysis in Tanjung Mas LPG Terminal can give input to another LPG terminal or new LPG terminal to control the hazard in the terminal, because the system of every LPG terminal is similar.

1.2 Statement Of Problems

To ensure the research can work well, some problem that can appear while the research is on progress must be known, those are:

1. What are the hazard that may happen in the LNG loading-unloading system?
2. What kind of required mitigation to decrease the risk in the system?

1.3 Research Limitation

Some limitations of problem which must be used are:

1. The thesis object is limited inside the area of CPO Tanjung Mas Semarang
2. The thesis is focused on safety aspect on equipment in LPG loading process.

1.4 Research Benefit

The benefit of this research is:

4. Any risk probability can be revealed even before an accident happen
4. Mitigation plan can be made to avoid the risk.

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CHAPTER 2
LITERATURE STUDY

2.1 Theory

4.1.1. Indonesia Act

Indonesia government has made some act to ensure the workers safety, one of the act is UU No. 1 year 1970 about Safety in Work, which made by the Ministry of Employment, Directorate of HSE Norm Development, that legitimated on 12 January 1970. There are 15 article in the act, those are:

- Article 1 about the terms
- Article 2 about the scope
- Article 3 about the requirement of safety at work
- Article 5, 6, 7 about the supervision
- Article 9 about the development
- Article 10 about the development committee of health and safety at work
- Article 11 about accident
- Article 12 about the obligation and right of the workers
- Article 13 about the obligation when entering the work place
- Article 14 about the obligation of the management
- Article 15, 17, 18 about the closing.

4.1.2. OSHA

The Occupational Safety and Health Act (OSH Act), a federal law that became effective on April 28, 1971, is intended to pull together all federal and state occupational safety and health enforcement efforts under a federal program designed to establish uniform codes, standards, and regulations. The expressed purpose of the act is: “To assure, as far as possible, every working woman and man in the Nation safe and healthful working conditions, and to preserve our human resources.” To accomplish this purpose, the promulgation and enforcement of safety and health standards is provided for, as well as research, information, education, and training in occupational safety and health.

One of the greatest sources of criticism of OSHA in the past has been its more than 5000 consensus standard. These include many so-called Mickey Mouse rules that burden employers without really protecting worker standards that bear no relationship to employee safety.

Another complaint concerns OSHA’s inspection program. More than 100.000 inspections are conducted each year (DeReamer, 1980), but far too many of them have been performed in light hazard establishments and in organizations with good to outstanding safety records, rather than in establishments with significant safety and health problem and poor records.

Late in 1977 the Secretary of Labor and the Assistant Secretary of Labor for Occupational Safety and Health announced a redirection of OSHA priorities that would concentrate agency resources on serous health and safety problems. The agency goals included the following:

- Direct 95% of OSHA inspections to those industries with the most serious health problems, such as construction, manufacturing, transportation, and the petrochemical industries, as the part of an all-out combat occupational illness and disease. Some small businesses, such as auto repair, building materials, and dry cleaning, would also receive more frequent inspections

- Provide more cooperation and assistance to small business. Small business engaged in low-risk activities would be inspected less often. Educational and consultative services would be expanded to help the small businessman voluntarily comply with the law. Additionally, OSHA exempted the nation's 3,4 million small businesses with 10 or fewer employees from all record keeping requirement
- Eliminated unnecessary safety regulations and revise and simplify necessary regulations that are complicated or unclear

When the OSH Act became operative in April 1971, employees, labor organizations, business, and industry for the first time encountered large scale federal participation in occupational safety and health activity. Thousands of safety and health standards were promulgated, compliance officers were selected and trained, OSHA inspection priorities were established, a new reporting system for occupational injuries and illnesses, which differs widely from the Old American National Standard method, was instituted, and labor and management got underway an intensive educational efforts concerning employee rights and management responsibility under the act.

No one yet knows the effect of the OSH Act has had on the nation's work injury experience (because the reporting system was changed there is no adequate comparable data to compare the situations before and after the act). There is no doubt, however, that the act has given ever widening visibility to the whole realm of occupational safety and health. It has given new status and responsibility to the safety and health practitioners. The OSH Act has encouraged greater training of the practitioners in occupational safety and health. New curricula and university programs leading to degrees in safety and health have been inaugurated, and more are yet to come. The existence of the OSH Act has aroused many employers and labor unions to a heightened concern for safety and health problems and for compliance with OSH Act regulations.

The OSH Act and OSHA are not without limitations, although that is all for the good. The administration has been slow in adopting health standards, although this area is recognized as being the most critical by all sides. In a six-year period (1971 – 1977) just 17 health standards were adopted. Even if it were able to achieve a breakthrough in health standards development by a magnitude of 10 times the current level, it would take some 50 years to cover the 1500 suspect carcinogens identified by NIOSH. And the standards that have been issued are lengthy. As an example, the standard on coke-oven emissions ran some 50 pages in the Federal Register. If this trend in continued, the OSHA is headed toward a 100.000-page Federal Register for health standards alone.

For the most part, OSHA safety and health standards cover only those regulations that are enforceable-namely, control over physical conditions and environment. Important elements of a balanced safety program, such as supervisory safety training, system safety analysis, and human factors engineering, safety program elements have not generally been included in the OSHA standard. But in addition to those shortcomings, several OSHA standards are irrelevant, defective, and bear no relation to employee safety.

The Occupational Health and Safety Administration has revoked 928 of these irrelevant standards, but his should and must be only the beginning. Federal safety and health standards must be based on known causes of injuries and illness so that compliance therewith will produce significant reductions in injuries, illnesses, or associated risks.

This must be kept in sharp focus mere compliance with the requirements of the OSH Act will not achieve optimum safety and health in terms of accident and illness prevention and the well-being of employees. For the most part, the occupational safety and health standards constitute minimal criteria and represent a floor rather than a goal to achieve. Effective accident prevention and control of occupational health must go beyond the OSH Act. Achieving the purpose of the act,"to assure, as far as possible, every working woman and man in the nation safe and healthful working conditions." Will depend on the willingness and cooperation of all concerned employees, employers, labor organizations, institutions, and government.

4.1.3. Hazard Definition

There are some definitions about hazard. One of those is hazard involve risk and probability, which related to the unknown elements. (Asfahl, 1999)

Hazard as the potential condition to cause injury to the personnel, damage to the tools or another company asset. When a hazard is occurred, then the probability of those bad effects will show up. (DeReamer, 1980)

Primary hazard is a hazard which can directly causing dead; damage on the tools, structure, facility; degradation of functional capability; material losses. These are some hazard category:

- Physical hazard

  Noise, radiation, lighting, heat
- Chemical hazard

Dangerous material, chemical steam

• Biology hazard

Virus, fungi

• Mechanical hazard

Tools, machinery

• Ergonomics hazard

Confined space, material lifting

• Psychosocial hazard

Work-shift pattern, long work time

• Behavior hazard

Less on skill, not follow the standard

• Environment hazard

Bad lighting, weather, fire.

4.1.4. LPG Loading Process

Based on (Maryono, 2002) LPG loading – unloading process is divided into 3 steps, those are:

a) Mooring:

- The ship is pushed slowly by tug boat
- Mooring process is aided by mooring boat
- After the ship is completely moored, check all the mooring connection, ensure the ship is tightly moored.

b) Loading/ unloading:

LPG loading/ unloading process usually use Marine Loading Arm (MLA) to load/ unload the gas from/ to the port. The loading/ unloading process is divided into 3 part: connecting, loading/ unloading, and discharging.

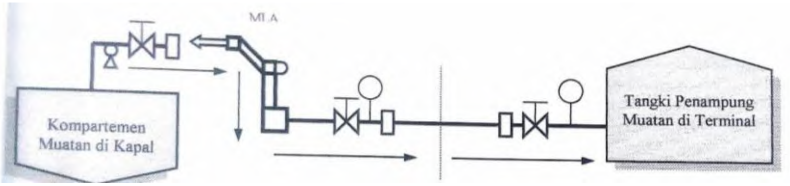

Figure 2. Loading Process

- Connecting:
  - Install the bounding cable
  - Ensure all clear
  - Push the electricity panel on
  - Turn the MLA on
  - Turn the hydraulic pump on
  - Open the selector valve on MLA.
- Loading/ unloading:
  - Ensure all valve are open
  - Start the pump
  - Check the discharging pipe pressure during the pumping process
  - Close the gate valve in MLA, port, tank, and the ship.
- Releasing:
  - Ensure the arm is clear
  - Release the bounding cable with the ship manifold
  - Release the outboard arm from the tanker manifold
  - Put MLA on non-operating state
  - Lock the inboard arm
  - Close the selector valve
  - Shut the pump and electricity panel off.

c) Ship release:

- Release the mooring from the port and buoy
- Tug boat will help the ship leaving the port

4.1.5. Hazard and Operability (HAZOP)

A hazard operability study (HAZOP) is a systematic, critical examination by a team of engineering and operating intentions of a process to assess the hazard potential of mal-operation or mal-function of individual items of equipment and the consequential effects on the facility as a whole. (IEC, 2001)

It is quite normal to carry out safety reviews. These may take different forms. Experts may be consulted in isolation, without reference to each other. They may instead be gathered in lengthy meetings to discuss the particular topic. HAZOP are meetings with a distinct structure, the structure imposing a certain organization, to enhance effectiveness. They are a generalized study technique, equally applicable to microchip manufacture, pharmaceutical synthesis, effluent plant operation or any process.

They should not be seen, however, as a solution to all ills, the ultimate review. The procedure is only anther tool in the safety locker and should be seen as complementary to other techniques. Indeed, it is best applied as one stage of a multi-stage procedure, applying different techniques as relevant to each stage. It does not replace, but rather supplements, existing Codes of Practice. Neither can it totally substitute for experience. But, both Codes of Practice and experience are evolved from existing situations. Innovative developments require a review which investigates the unknown. HAZOPs are a systematic, logical approach to determining problems.

The basis of HAZOP is a “guide word examination” which is a deliberate search for deviations from the design intent. To facilitate the examination, a system is divided into parts in such a way that the design intent for each part can be adequately defined. The size of the part chosen is likely to depend on the complexity of the system and the severity of the hazard. In complex systems or those which present a high hazard the parts are likely to be small. In simple systems or those which present low hazards, the use of larger parts will expedite the study. The design intent for a given part of a system is expressed in terms of elements which convey the essential features of the part and which represent natural divisions of the part. The selection of elements to be examined is to some extent a subjective decision in that there may be several combinations which will achieve the required purpose and the choice may also depend upon the particular application. Elements may be discrete steps or stages in a procedure, individual signals and equipment items in a control system, equipment or components in a process or electronic system, etc.

In some case it may be helpful to express the function of a part in terms of:

- the input material taken from a source;
- an activity which is performed on that material;
- a product which is taken to a destination.

Thus the design intent will contain the following elements: materials, activities, sources and destinations which can be viewed as elements of the part.

Elements can often be usefully defined further in terms of characteristics which can be either quantitative or qualitative. For example, in a chemical system, the element "material" may be defined further in terms of characteristics such as temperature, pressure and composition. For the activity "transport", characteristics such as the rate of movement or the number of passengers may be relevant. For computer-based systems, information rather than material is likely to be the subject of each part.

The HAZOP team examines each element (and characteristic, where relevant) for deviation from the design intent which can lead to undesirable consequences. The identification of deviations from the design intent is achieved by a questioning process using predetermined “guide words”. The role of the guide word is to stimulate imaginative thinking, to focus the study and elicit ideas and discussion, thereby maximizing the chances of study completeness. The guide word which used in HAZOP process will be shown in the table below (based on BS IEC 61882 2001).

Table 2. HAZOP Guide Word

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

Additional guide words relating to clock time and order or sequence are given in the next table.

Table 3. Additional Guideword

Guide Word	Meaning
EARLY	Relative to the clock time

LATE	Relative to the clock time
BEFORE	Relating to order or sequence
AFTER	Relating to order or sequence

There are a number of interpretations of the above guide words. Additional guide words may be used to facilitate identification of deviation. Such guide words may be used provided they are identified before the examination commences. Having selected a part for examination, the design intent of that part is broken into separate elements. Each relevant guide word is then applied to each element, thus a thorough search for deviations is carried out in a systematic manner. Having applied a guide word, possible causes and consequences of a given deviation is examined and mechanisms for detection or indication of failures may also be investigated. The results of the examination are recorded to an agreed format.

Guide word/element associations may be regarded as a matrix, with the guide words defining the rows and the elements defining the columns. Within each cell of the matrix thus formed will be a specific guide word/element combination. To achieve a comprehensive hazard identification, it is necessary that the elements and their associated characteristics cover all relevant aspects of the design intent and guide words cover all deviations. Not all combinations will give credible deviations, so the matrix may have several empty spaces when all guide word/element combinations are considered. There are two possible sequences in which the cells of the matrix can be examined, namely column by column, i.e. element first, or row by row, i.e. guide word first.

To make a HAZOP analysis, the process that must be done are:

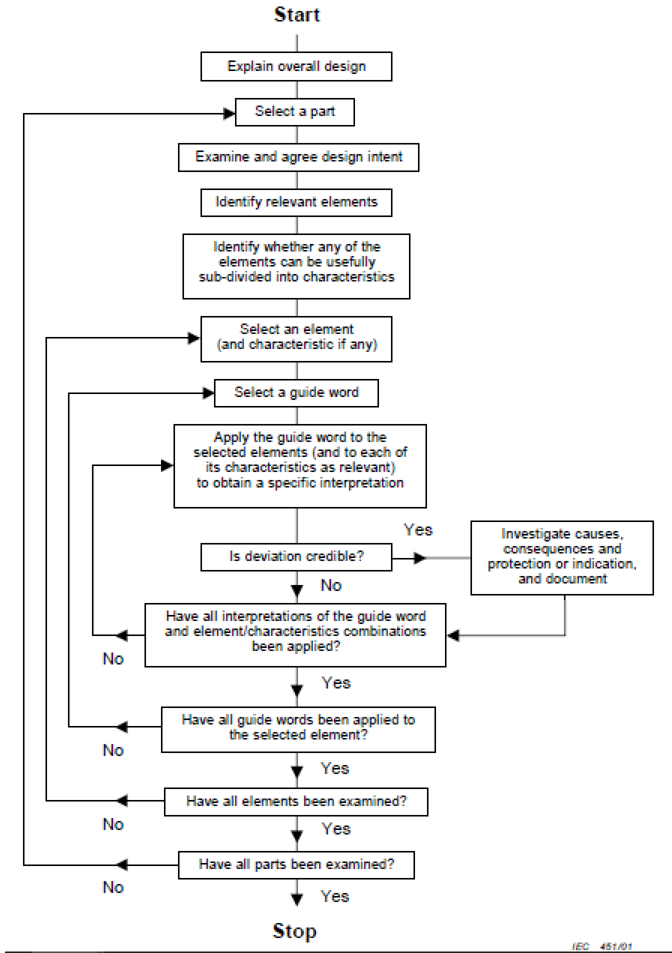

Figure 3. HAZOP Process

Based on BS IEC 61882 2001, the HAZOP table standard is shown in figure below.

Table 4. HAZOP Sheet

STUDY TITLE								
Drawing No.:							SHEET:	
TEAM COMPOSITION:							DATE:	
PART CONSIDERED:			LPG transfer line from the bulk vessel to the storage tank				MEETING DATE:	
DESIGN INTENT:			Material:			Activity:		
			Source:			Destination:		
No.	Guide Word	Element	Deviation	Possible Causes	Consequences	Safeguards	Comments	Actions Required

- Design Intent

The design intent is a description of how the process is expected to behave at the node; this is qualitatively described as an activity (e.g., feed, reaction, sedimentation) and/or quantitatively in the process parameters, like temperature, flow rate, pressure, composition, etc.

- Deviation

A deviation is a way in which the process conditions may depart from their design/process intent.

- Parameter

The relevant parameter for the condition(s) of the process (e.g. pressure, temperature, composition).

- Guideword

A short word to create the imagination of a deviation of the design/process intent. The most commonly used set of guide-words is: no, more, less, as well as, part of, other than, and reverse. In addition, guidewords like too early, too late, instead of, are used; the latter mainly for batch-like processes. The guidewords are applied, in turn, to all the parameters, in order to identify unexpected and yet credible deviations from the design/process intent.

- Cause

The reason(s) why the deviation could occur. Several causes may be identified for one deviation. It is often recommended to start with the causes that may result in the worst possible consequence. 38

- Consequence

The results of the deviation, in case it occurs. Consequences may both comprise process hazards and operability problems, like plant shut-down or reduced quality of the product. Several consequences may follow from one cause and, in turn, one consequence can have several causes

- Safeguard

Facilities that help to reduce the occurrence frequency of the deviation or to mitigate its consequences. There are, in principle, five types of safeguards that:

1. Identify the deviation (e.g., detectors and alarms, and human operator detection)

2. Compensate for the deviation (e.g., an automatic control system that reduces the feed to a vessel in case of overfilling it. These are usually an integrated part of the process control)

3. Prevent the deviation from occurring (e.g., an inert gas blanket in storages of flammable substances)

4. Prevent further escalation of the deviation (e.g., by (total) trip of the activity. These facilities are often interlocked with several units in the process, often controlled by computers)

5. Relieve the process from the hazardous deviation (e.g., pressure safety valves (PSV) and vent systems)

4.1.6. Fault Tree Analysis (FTA)

Fault tree analysis (FTA) is a top down, deductive failure analysis in which an undesired state of a system is analyzed using Boolean logic to combine a series of lower-level events. This analysis method is mainly used in the fields of safety engineering and reliability engineering to understand how systems can fail, to identify the best ways to reduce risk or to determine (or get a feeling for) event rates of a safety accident or a particular system level (functional) failure. FTA is used in the aerospace, nuclear power, chemical and process, pharmaceutical, petrochemical and other high-hazard industries; but is also used in fields as diverse as risk factor identification relating to social service system failure. FTA is also used in software engineering for debugging purposes and is closely related to cause-elimination technique used to detect bugs.

FTA needs to be carried out because of:

- To exhaustively identify the causes of a failure
- To identify weaknesses in a system
- To assess a proposed design for its reliability or safety
- To identify effects of human errors
- To prioritize contributors to failure
- To identify effective upgrades to a system
- To quantify the failure probability and contributors
- To optimize tests and maintenances (Vesely, 2006)

The tree structure is deemed sufficient to demonstrate the ways in which events arise. A list of recommendations is also developed for managing risks. The main elements most commonly used to construct a fault tree are (Mullai, 2006):

- The top event is the one that is analyzed, which is represented by a rectangle;
- Intermediate events are system states or occurrences that contribute to the accident, which are represented by rectangles;

- Basic events are the lowest levels of resolution in the fault tree, which are represented by circles;
- Undeveloped events are those that are not further developed in the fault tree, which are represented by diamonds;
- "AND" gates - the output event associated with this gate exists only if all of the input events exist simultaneously;
- "OR" gates - the output event associated with this gate exists if at least one of the input events exists.

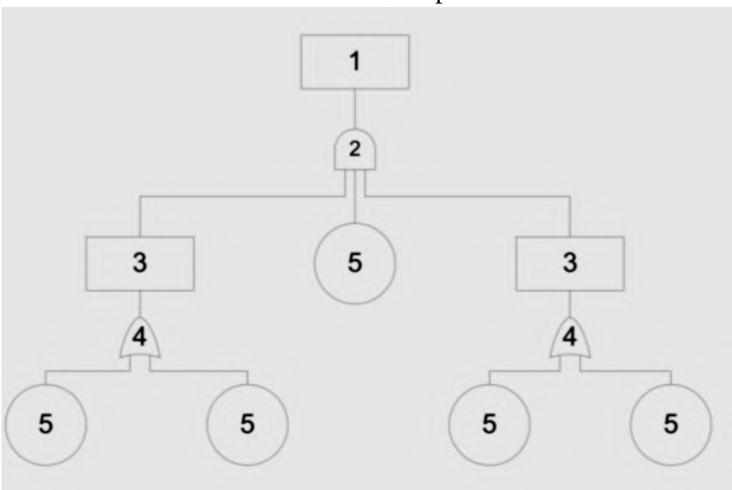

Figure 4. FTA Tree

OR Gate, either of two independent element failures produces system failure.

$R_T = R_A R_B$

$P_F = 1 – R_T$

$P_F = 1 – (R_A R_B)$

$P_F = 1- [(1-P_A) (1-P_B)]$

$P_F = P_A + P_B - P_AP_B$

$P + R = 1$
$R = e^{-\lambda T}$
$P = 1- e^{-\lambda T}$

Notes:
R: Reliability
P: Failure Probability
λ: Failure Rate
T: Exposure Interval

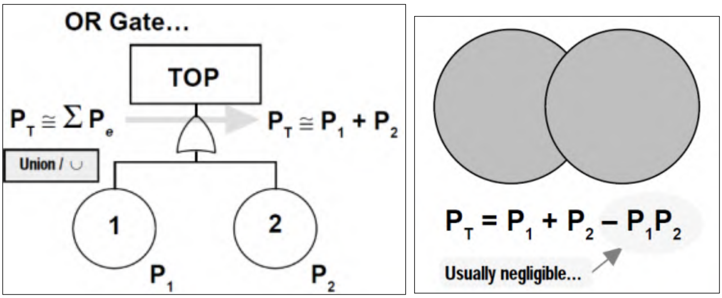

Figure 5. Propagation Through OR Gate

AND Gate, both of two independent elements must fail to produce system failure.

$R_T = R_A + R_B - R_AR_B$
$P_F = 1 - R_T$
$P_F = 1 - (R_A + R_B - R_AR_B)$
$P_F = 1- [(1-P_A) + (1-P_B) - (1-P_A)(1-P_B)]$
$P_F = P_AP_B$

$P + R = 1$
$R = e^{-\lambda T}$
$P = 1- e^{-\lambda T}$

Notes:
R: Reliability
P: Failure Probability
λ: Failure Rate
T: Exposure Interval

4.1.7. Risk Evaluation

The risk evaluation is represented by the achievement of a synthetic level of risk, which is the "magnitude of a risk or combination of risks, expressed in terms of the combination of consequences and their likelihood". This level of risk should be compared with risk criteria for determining if the risk is acceptable or tolerable. Evaluating risks is important for determining priorities for the implementation of risk control measures. The risk rating is a combination of the frequency (F) and the likelihood of the incident occurring and the severity of the possible consequences (C). (ISO (International Organization for Standardization), 2009)

On evaluate risk, there is a point which must know to determine criteria for the risk. This is will be a reference to know the criteria of the risk, tolerable, intolerable or ALARP (As Low as Reasonably Practicable). There for it will be need a standard as a reference to determine their criteria, some standard well most known are DNV-GL, NASA, US Coast Guard, US Department of Defense, UK HSE, IMO, etc. There are also several standards which made by company for their risk evaluation.

MICOPERI Risk Matrix			PROBABILITY				
			1	2	3	4	5
			Very Unlikely	Unlikely	Possible	Likely	Frequent
SEVERITY	1	Minor	1	2	3	4	5
	2	Moderate	2	4	6	8	10
	3	Significant	3	6	9	12	15
	4	Serious	4	8	12	16	20
	5	Catastrophic	5	10	15	20	25

Table 5. 5x5 Risk Measurement Matrix

Peter Bernstein, in his book Against the Gods: The Remarkable Story of Risk, wrote about the importance of the development of risk. He said: 'The revolutionary idea that defines the boundary between modern times and the past is the mastery of risk: the notion that the future is more than a whim of the gods and that men and women are not passive before nature. Until human beings discovered a way across that boundary, the future was a mirror of the past or the murky domain of oracles and soothsayers.' (IRCA, n.d.)

The description from the 5x5 risk matrix is:

Table 6. Severity Description

Rank	Severity	Description
1	Trivial	Minor injury/ no internal disruption
2	Minor	Injury which requires medical attention/ minor internal disruption.
3	Lost Time	Potentially life threatening injury causing temporary disability and/or requiring medevac/ disruption possibly requiring corrective action.
4	Major	Major life threatening injury or causing permanent disability/ incomplete

		recovery/ pollution with significant impact/ very serious disruption which may cause performance degraded.
5	Fatal	Fatality or multiple fatalities or multiple life threatening injuries causing permanent disabilities/ total loss.

Table 7. Probability Description

Rank	Description	Probability
1	Very Unlikely: Could only occur under a freak combination of factors	$< 10^{-5}$
2	Unlikely: May occur only in exceptional circumstances.	$10^{-5} - 10^{-4}$
3	Possible: Could occur at some time.	$10^{-4} - 10^{-2}$
4	Likely: Would not require extraordinary factors to occur at some time.	$10^{-2} - 10^{-1}$
5	Frequent: Almost certain to happen if conditions remain unchanged.	$10^{-2} - 1$

Where:

1-2: Low risk area, the potential hazards are under control.

3-8: Moderate risk area, there is the need to verify that the potential hazards are under control and improve the measures already adopted.

9-15: Medium risk area, there is the need to identify and schedule protection and prevention measures to be adopted in order to reduce or the probability P or the potential damage S.

16-25: High risk area, there is the need to identify and schedule protection and prevention measures to be adopted in order to reduce the probability of the potential hazard (they shall be considered as urgent).

4.1.8. Mitigation

If the analyzed risk has medium or high risk probability, then the risk must be mitigated to decrease the number. Mitigation process which be used in this thesis is using LOPA (Layer of Protection Analysis).

LOPA was introduced in the 1990s, and has recently gained international popularity. LOPA is referred to in literature as both a simplified risk assessment technique and a risk analysis tool. Capital improvement planning, incident investigation, and management of change can be found as additional applications. LOPA is a flexible tool which can be used in different contexts and applications making it confusing to understand what it really is. The application under consideration is LOPA as a SIL determination tool.

According to Marszal and Scharpf (2002) LOPA can be viewed as a special type of event tree analysis (ETA), which has the purpose of determining the frequency of an unwanted consequence, that can be prevented by a set of protection layers. The approach evaluates a worst-case scenario, where all the protection layers must fail in order for the consequence to occur. The frequency of the unwanted consequence is calculated by multiplying the PFDs of the protection layers with the demand on the protection system (represented as a frequency). Comparing the resulting frequency of the unwanted consequence with a tolerable risk frequency, identifies the necessary risk reduction and an appropriate SIL can be selected (Marszal and Scharpf, 2002; CCPS, 2001).

The LOPA worksheet can be seen in the figure below.

Table 8. LOPA Worksheet

Scenario No. 1	High back pressure on upstream line of LPG		Node No. 2
Date:	Description	Probability	Frequency/ year
Consequence Description	High back pressure to the tank		
Risk Tolerance Criteria	Action Required		
	Tolerable		
Initiating Event	SDV-1104/ 1204/ 1304/ 1404 on Tank Outlet is inadvertently closed		
Frequency of Unmitigated Consequence			2,08,E-03
Independent Protection Layers	Relief valve	1,0,E-02	
Total PFD		1,0,E-02	
Frequency of Mitigated Consequence			2,08,E-05
Risk Tolerance Criteria Met?		Yes, low (6)	
Actions Required to meet the Criteria	1. Put relief valve near the tank outlet		

2.2 Previous Research

Similar research has been done by a student of Marine Engineering, FTK-ITS. The research is done by Bayu Maryono in around 2001. While the title is “Studi Evaluasi Teknik Keselamatan pada Proses Pembongkaran Muatan di Dermaga Khusus Gospier Pertamina UPMS V Surabaya.”

This research and the research which done by Bayu Maryono have similarity, both research focused on safety aspect in loading-unloading process of LPG. The difference is the research which done by Bayu Maryono is held in Terminal LPG Surabaya, while this research will be held in Terminal LPG Semarang, which may have several difference in the system and work procedure. The other difference is the method, the Bayu Maryono's research used FMEA, FTA, and Task Analysis to assess the safety in loading-unloading process. While this research will use FMEA to assess the system, and JSA to assess the work procedure

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CHAPTER 3
METHODOLOGY

To solve the mentioned problem in the first page, some process will be used.

4. Background
   Before conducting the research, first will be explained the background of this study.

4. Literature Study
   The study of literature is an early stage is the stage of learning about the basic theories to be discussed or used in the thesis. Source taken at this stage comes from books, papers, websites, journals, and so forth.

4. Data collection.
   This phase is to obtain information about the ships that use gas fuel and learn the workings of their systems.

4. Identify Function, Requirements and Specification
   Identify and understand the process steps and their functions, requirements, and specifications that are within the scope of the analysis. The goal in this phase is to clarify the design intent or purpose of the process. This step leads quite naturally to the identification of potential failure modes.

4. Risk Identification (HAZOP)
   Potential cause of failure describes how a process failure could occur, in terms of something that can be

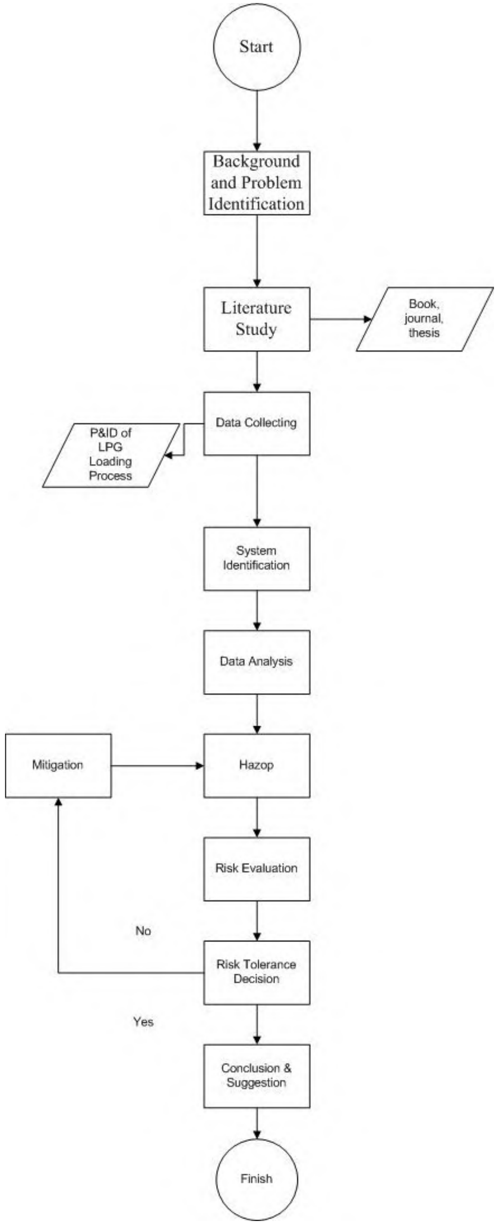
controlled or corrected. The goal is to describe the direct relationship that exists between the cause and resulting process failure mode.

4. Frequency Analysis
   Analysis of the data in order to determine the levels of risk. By using FTA for frequency analysis.

4. Risk Evaluation
   This stage will be determined whether the risks are acceptable or not, the decisions are made based on Risk Matrix.

4. Mitigation
   If there are any intolerable risk after the risk evaluation, then will be do a mitigation act to minimize those risk by using LOPA method.

4. Conclusions and Recommendations
   Make conclusions based on the results obtained and suggestions for further research development.


Start
Background and Problem Identification
Literature Study
Book, journal, thesis
Data Collecting
P&ID of LPG Loading Process
System Identification
Data Analysis
Mitigation
Hazop
Risk Evaluation
No
Risk Tolerance Decision
Yes
Conclusion & Suggestion
Finish

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CHAPTER 4
DATA ANALYSIS

4.1 Data Analysis

LPG Liquid loading process is a process to flow the LPG liquid from the vessel to the facility tanker, this process is using a system named Liquid Loading System. The system is also can flow back the vapour from the tank to the ship, this process is used for refrigerated type vessel.

1. Liquid Loading

Liquid loading is piping system which been used to transfer the LPG from the ship to the storage tank

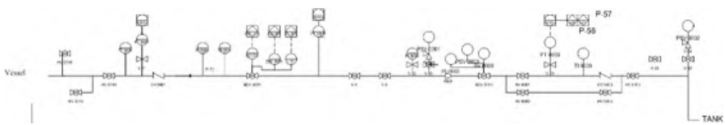


Figure 6. Liquid Loading System

Notes

HV : Hand Valve

CV : Check Valve

TI : Temperature Indicator

PI : Pressure Indicator

TT : Temperature Transducer

PT : Pressure Transducer

SDV : Shut Down Valve

2. Vapor Return

Vapor return is used when the ship type is refrigerated type.

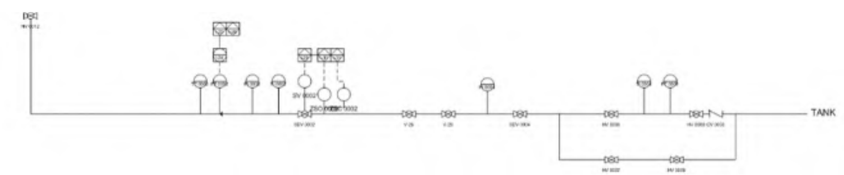


Figure 7. Vapor Return System

Notes:

HV : Hand Valve

CV : Check Valve

TI : Temperature Indicator

PI : Pressure Indicator

TT : Temperature Transducer

PT : Pressure Transducer

SDV : Shut Down Valve

Each part in the system have different function, but the main function of the parts is to ensure the safety of the system.

1. Hand valve

This is a manual valve that mostly are positioned as normally open. To open or close this valve, operator must open it manually and could not be opened from the control room.

Figure 8. Hand Valve

2. Check Valve

The function is to ensure the fluids flows to only one direction, this valve is located when there is an upstream pipeline.

Figure 9. Check Valve

3. Temperature Indicator

This part will show the temperature of the fluids inside the pipeline, temperature indicator must be monitored manually from the field.

Figure 10. Temperature Indicator

4. Temperature Transducer

This part is similar with the temperature indicator and have same function, but this transducer can be monitored from the control room.

Figure 11. Temperature Transducer

5. Pressure Indicator

This part will show the pressure of the liquid inside the pipe.

Figure 12. Pressure Indicator

6. Pressure Transducer

This part is similar with the previous part, but it can be monitored from the control room, same as Temperature Transducer.

Figure 13. Pressure Transducer

7. Shut Down Valve

This valve will shut down when an emergency situation occurred, so that the liquid will not pass through to the next pipeline and broke more parts.

Figure 14. Shut Down Valve

4.2 Risk Assessment

A risk assessment can be done by doing three main steps, those are:

- Risk identification, which will identify any risk that may occur in a system
- Risk analysis, which will analyze the risk that have been identify in the previous process
- Risk evaluation, which will evaluate the whole analysis and decide the risk is acceptable or not.

In this sub chapter, the process that will be used as example is Ship LPG Liquid Unloading based on the P&ID of the LPG Loading System. The complete assessment is attached in the Attachment.

4.2.1. Risk Identification

The risk identification can be done by doing HAZOP process, the identification must follow the HAZOP standard, including the Guide Word, Element, and the Deviation.

The first thing is to determine the guide word that will be used, e.g.: No, More, Less, etc. The next step is to determine the Element which will be used, this element can be chosen from many things, for example Flow to identify the liquid pressure, or temperature to identify the liquid temperature. The combination of Guide Word and Element will be a Deviation. These are the deviation which used in the Ship LPG Liquid Loading:

Table 9. The Deviation and It Meaning

Guide Word	Element	Deviation	Meaning
No	Flow	No Flow	The liquid could not pass through a certain section of the pipeline
More	Flow	More Flow	The liquid that pass through a certain part of the pipeline have higher pressure than the normal pressure
Less	Flow	Less Flow	The liquid that pass through a certain part of the pipeline have lower pressure than the normal pressure
Reverse	Flow	Reverse Flow	The liquid that pass through a

			certain part of the pipeline will not only flow in a direction
Less	Temperature	Less Temperature	The liquid that pass through a certain part of the pipeline have lower temperature than the normal temperature
More	Temperature	More Temperature	The liquid that pass through a certain part of the pipeline have higher temperature than the normal temperature

Each deviation has some possible causes or only one possible causes. The possible cause must be identified carefully to ensure that anything that may happen are completely identified. The possible causes may be a small cause that not too important or have very little possibility to happen or may be a big cause with very high possibility to happen, even a small cause must be identified.

Mostly, a No Flow deviation is caused by a closed valve that actually must be opened during the process. This deviation can also be caused by a leakage that occurred in the pipeline.

A Less Flow deviation usually caused by inproper opened valve or small leakage.

The opposite deviation, More Flow can be caused by too high pressure from the vessel pump.

While Reverse Flow deviation can happen in a branching pipe which become one line, because when the liquid from the branch pipe pass through the one-line pipe, there is a chance that the liquid will go through opposite direction of the flow, passing through the main pipe.

A Less Temperature and More Temperature deviation mostly be caused by heat exchanger faulty from the vessel.

After the possible causes is identified, then the consequences must be identified too. The consequences is any event that may happen when a failure occurred. A consequence which identified must be carefully wrote, even a small consequence until a big consequence can become a huge incident.

Each possible cause can create one or more consequences, for example a heat exchanger control failure can create two consequences, such as icing on the pipeline and too low liquid temperature.

The next step is to identify the available safeguard in the system, if there are no safeguard available, then the proper safeguard must be written in the recommendation.

Every possible cause may have some safeguard according it place, for example to identify the temperature and prevent icing on the pipeline, some Temperature Indicator are placed in the system, there are also some Temperature Transducer that have same function as Temperature Indicator but have more advantage, a Temperature Transducer can be monitored from the control room, while a Temperature Indicator could not, but a Temperature Indicator can be a good comparison data to the Temperature Transducer, in case there are some automatic measurement mistake (not well calibrated).

STUDY TITLE: Ship Loading/ Unloading Piping & Instrumentation Diagram										
Drawing No.:			FTLSMG-30-DW-C006 & FTLSMG-30-DW-C007						Node: 1	
TEAM COMPOSITION:									DATE:	
PART CONSIDERED:			LPG transfer line from the bulk vessel to the storage tank						MEETING DATE:	
DESIGN INTENT:			Material:	LPG liquid				Activity:	LPG transfer	
			Source:	Bulk vessel				Destination:	LPG storage tank	
No.	Guide Word	Element	Deviation	Possible Causes	Probability	Consequences	Severity Level	Safeguards	Risk Level	Actions Required
1	No	Flow	No Flow	One or more manual valve are inadvertently closed	7,003,E-05	High back pressure at pump discharge on bulk carrier vessel and upstream side of the pipeline		PSV-1005/ 0001/ 0002		
				SDV 0001/ 0003 inadvertently closed	2,081,E-03	High back pressure at pump discharge on bulk carrier		PI-001/ 003		
				SDV-1301/ 1201/ 1301/ 1401 on Tank Inlet is inadvertently closed	2,081,E-03	High back pressure at upstream side of pipeline system		PT-003, PSV-0002		
				LPG Liquid loading line leakage	9,512,E-07	LPG release to atmosphere		SDV-001/ 003		

2	Less	Flow	Less Flow	Small leaks on the pipeline, pipeline blocked, deffective pump from the vessel, filter blocked	9,512,E-07	Unstable flow, vibration in pipeline		PI-0001/ 0003, PT-0001/ 0005, 0003		
				Manual Valves are not fully opened	4,774,E-05	Unstable flow, vibration in pipeline		PI-0001/ 0003, PT-0001/ 0005, 0003		
3	More	Flow	More Flow	Too high pressure from the bulk carrier vessel	6,701,E-06	Too high pressure in piping system		PSV-0001/ 0002/ 1005		
4	Reverse	Flow	Reverse Flow	Upstream section indadvertently open	0,000,E+00	Back pressure to the bulk vessel or previous pipeline		CV-0002		
5	Less	Temperature	Less Temperature	Heater control failure	1,535,E-05	Icing on the pipe, too low pressure		TI-0001/ 0003, SDV 0001/ 0003		
				Fault measurement	9,343,E-06	Icing on the pipeline, too low pressure		TI-0001/ 0003, SDV 0001/ 0003/ 1305		

6	High	Temperature	High Temperature	Heater control failure	1,124,E-05	Higher fluid temperature, cavitation in the pipeline, LPG evaporated in the pipeline		TI-0001/ 0003, SDV 0001/ 0003/ 1305		
						Popping occured outside the PSV		No available safeguard		
				Fault measurement	9,343,E-06	Higher fluid temperature, cavitation in the pipeline, LPG evaporated in the pipeline		TI-0001/ 0003, SDV 0001/ 0003/ 1305		
						Popping occured outside the PSV		No available safeguard		

4.2.2. Risk Analysis

After finished on risk identification step for all system, the next step is risk analysis to determine level of frequency and consequence which will be used as an input for the risk evaluation. For the example will be shown the risk analysis result from HAZOP of LPG Transfer Process from the vessel to the tank.

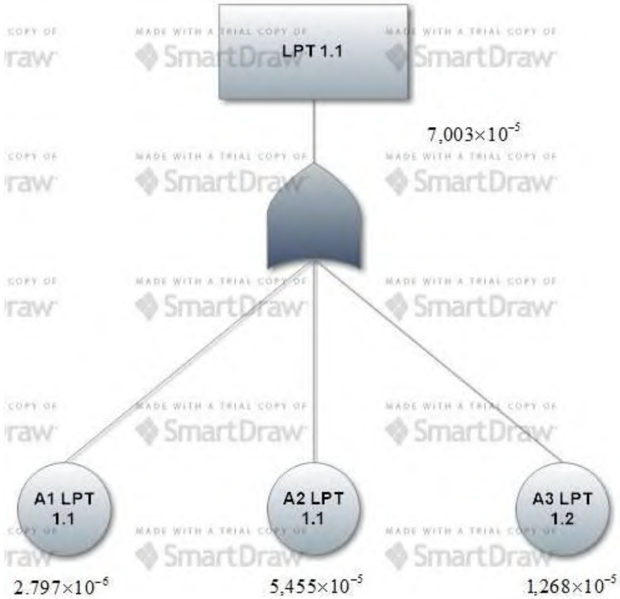
Frequency value for each causes are decided from FTA method which had explained before. The value of Basic Event is obtained from OREDA 2002. After obtained the value of Failure Rates and Probability of Failure, the value will be matched to Risk Matrix Table.

The FTA method will start from top event which refer to Possible Causes from HAZOP worksheet. For each causes will be given a code to simplify the process.

A1 LPT 1.1

The mentioned code above means:

A	: First level contributor
1	: First contributor
LPT	: Stands for LPG Transfer
1	: Failure mode's number, based on HAZOP worksheet
1	: Potential cause order



The used codes above are:

A1 = Delayed operation

A2 = Failed to open on demand

A3 = Spurious operation

The value of each event are decided based on the gate type. Failure Probability for Basic Event will be acquired from Failure Rates Value.

- **A1 LPT 1.1**

$$P = 1 - e^{-\lambda T}$$

$\lambda = 0{,}3 \times 10^{-6}$
$T = 9{,}325$

$$P_{A1} = 1 - e^{-(0{,}3 \times 10^{-6}) \times 9{,}325}$$
$$P_{A1} = 2{,}797 \times 10^{-6}$$

- **A2 LPT 1.1**

$$P = 1 - e^{-\lambda T}$$

$\lambda = 5{,}850 \times 10^{-6}$
$T = 9{,}325$

$$P_{A2} = 1 - e^{-(5.850 \times 10^{-6}) \times 9{,}325}$$

$$P_{A2} = 5{,}455 \times 10^{-6}$$

- **A3 LPT 1.1**

$$P = 1 - e^{-\lambda T}$$

$\lambda = 1{,}360 \times 10^{-6}$
$T = 9{,}325$

$$P_{A3} = 1 - e^{-(1{,}360 \times 10^{-6}) \times 9{,}325}$$

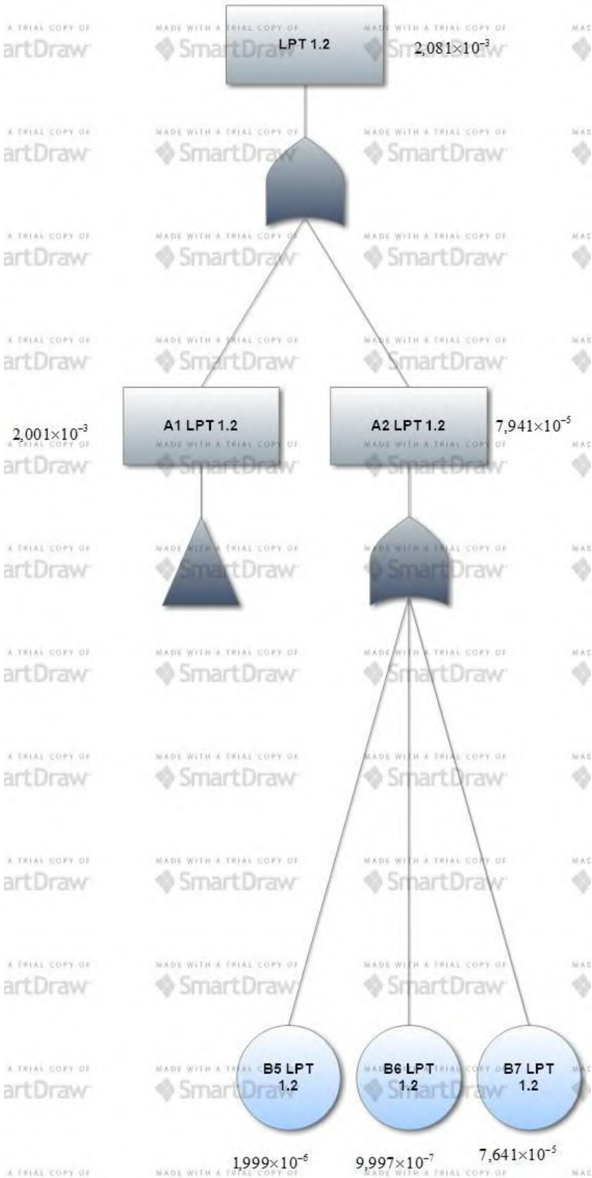
$$P_{A3} = 1{,}268 \times 10^{-6}$$

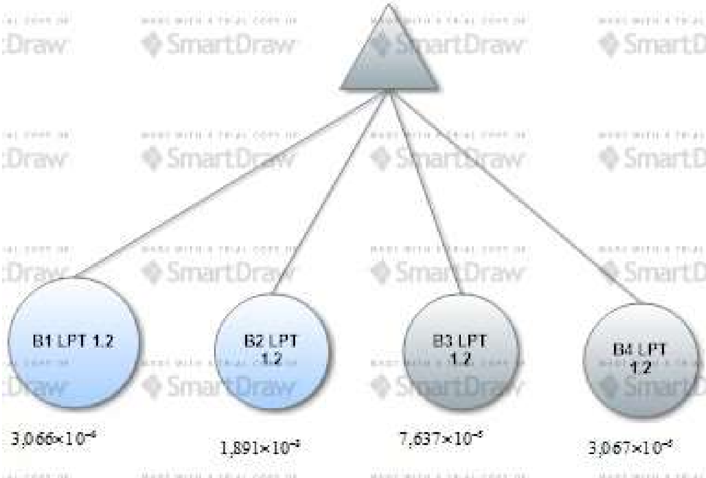
- $P_{LPT1.1} = P_{A1} + P_{A2} + P_{A3} - P_{A1A2} - P_{A1A3} - P_{A2A3} + P_{A1A2A3}$

  $$P_{LPT1.1} = (2{,}797 \times 10^{-6}) + (5{,}455 \times 10^{-6}) + (1{,}268 \times 10^{-6}) - (2{,}797 \times 10^{-6})(5{,}455 \times 10^{-6}) - (2{,}797 \times 10^{-6})(1{,}268 \times 10^{-6}) - (5{,}455 \times 10^{-6})(1{,}268 \times 10^{-6}) + (2{,}797 \times 10^{-6})(5{,}455 \times 10^{-6})(1{,}268 \times 10^{-6})$$

  $$\boldsymbol{P_{LPT1.1} = 7{,}003 \times 10^{-5}}$$

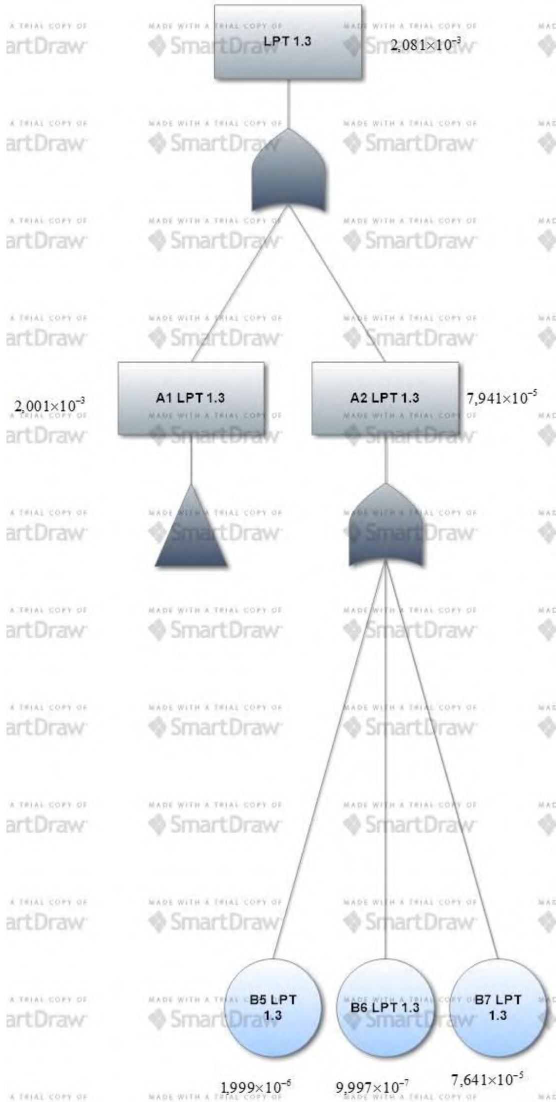
The other FTA result for the first node (LPT 1.1) will be shown below.


LPT 1.2
2,081×10⁻³
A1 LPT 1.2
2,001×10⁻³
A2 LPT 1.2
7,941×10⁻⁵
B5 LPT 1.2
B6 LPT 1.2
B7 LPT 1.2
1,999×10⁻⁶
9,997×10⁻⁷
7,641×10⁻⁵



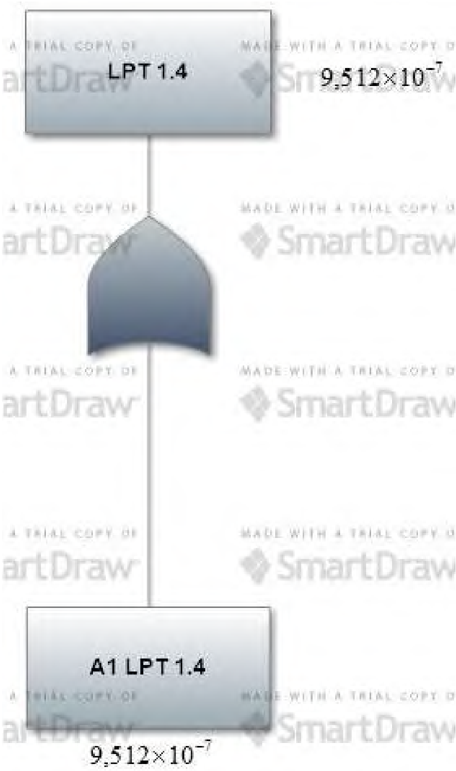
Notes:

B1	=	Breakdown
B2	=	Fail to start on demand
B3	=	Faulty output voltage
B4	=	Low output
A1	=	Loss power
B5	=	Delayed operation
B6	=	Failed to open on demand
B7	=	Spurious operation
A2	=	Fail to control valve


LPT 1.3
2,081×10⁻³
A1 LPT 1.3
2,001×10⁻³
A2 LPT 1.3
7,941×10⁻⁵
B5 LPT 1.3
B6 LPT 1.3
B7 LPT 1.3
1,999×10⁻⁶
9,997×10⁻⁷
7,641×10⁻⁵

Notes:

B1	=	Breakdown
B2	=	Fail to start on demand
B3	=	Faulty output voltage
B4	=	Low output
A1	=	Power loss
B5	=	Delayed operation
B6	=	Failed to open on demand
B7	=	Spurious operation
A2	=	Fail to control valve



Note:
A1 = External leakage

4.2.3. Risk Evaluation

As the example before, the risk evaluation will use A1 LPT 1.1 as the example, the other calculation will be shown in the table and the rest calculation will be attached.

A1 LPT 1 is the number 1 Deviation, that is No Flow. While 1.1 means the number 1 deviation with it first possible cause, that is One or more manual valves are inadvertently closed. The calculation before showed that the probability of the cause is $7x10^{-5}$.

Table 10. Probability Level of A1 LPT 1.1

Rank	Description	Probability
1	Very Unlikely: Could only occur under a freak combination of factors	$< 10^{-5}$
2	Unlikely: May occur only in exceptional circumstances.	$10^{-5} - 10^{-4}$
3	Possible: Could occur at some time.	$10^{-4} - 10^{-2}$
4	Likely: Would not require extraordinary factors to occur at some time.	$10^{-2} - 10^{-1}$
5	Frequent: Almost certain to happen if conditions remain unchanged.	$10^{-2} - 1$

From the table, can be know that the probability of the cause can be grouped in the second group, that is Unlikely to be happen.

Table 11. A1 LPT 1.1 Severity Level

Rank	Severity	Description
1	Trivial	Minor injury/ no internal disruption
2	Minor	Injury which requires medical attention/ minor internal disruption.
3	Lost Time	Potentially life threatening injury causing temporary disability and/or requiring medevac/ disruption possibly requiring corrective action.
4	Major	Major life threatening injury or causing permanent disability/ incomplete recovery/ pollution with significant

		impact/ very serious disruption which may cause performance degraded.
5	Fatal	Fatality or multiple fatalities or multiple life threatening injuries causing permanent disabilities/ total loss.

While the severity can be defined from the possible cause and grouped based on the table above. Then can be found that the cause can be grouped in the second group, that is Minor injury.

Table 12. A1 LPT 1.1 Risk Matrix

MICOPERI Risk Matrix			PROBABILITY				
			1	2	3	4	5
			Very Unlikely	Unlikely	Possible	Likely	Frequent
SEVERITY	1	Minor	1	2	3	4	5
	2	Moderate	2	4	6	8	10
	3	Significant	3	6	9	12	15
	4	Serious	4	8	12	16	20
	5	Catastrophic	5	10	15	20	25

From the table above, can be known that the risk level is 4.

Table 13. Risk Category

Where:
1-2: Low risk area, the potential hazards are under control.
3-8: Moderate risk area, there is the need to verify that the potential hazards are under control and improve the measures already adopted.

9-15: Medium risk area, there is the need to identify and schedule protection and prevention measures to be adopted in order to reduce or the probability P or the potential damage S.
16-25: High risk area, there is the need to identify and schedule protection and prevention measures to be adopted in order to reduce the probability of the potential hazard (they shall be considered as urgent).

The risk matrix result shown that A1 LPT 1.1 have 4 in number for the risk level. The number 4 is categorized as Moderate Risk Area, which is no correction is required for the cause.

STUDY TITLE: Ship Loading/ Unloading Piping & Instrumentation Diagram										
Drawing No.:			FTLSMG-30-DW-C006 & FTLSMG-30-DW-C007						Node: 1	
TEAM COMPOSITION:									DATE:	
PART CONSIDERED:			LPG transfer line from the bulk vessel to the storage tank						MEETING DATE:	
DESIGN INTENT:			Material:	LPG liquid				Activity:	LPG transfer	
			Source:	Bulk vessel				Destination:	LPG storage tank	
No.	Guide Word	Element	Deviation	Possible Causes	Probability	Consequences	Severity Level	Safeguards	Risk Level	Actions Required
1	No	Flow	No Flow	One or more manual valve are inadvertently closed	7,003,E-05	High back pressure at pump discharge on bulk carrier vessel and upstream side of the pipeline	2	PSV-1005/ 0001/ 0002	Moderate (4)	No
				SDV 0001/ 0003 inadvertently closed	2,081,E-03	High back pressure at pump discharge on bulk carrier	2	PI-001/ 003	Moderate (6)	No
				SDV-1301/ 1201/ 1301/ 1401 on Tank Inlet is inadvertently closed	2,081,E-03	High back pressure at upstream side of pipeline system	2	PT-003, PSV-0002	Moderate (6)	No
				LPG Liquid loading line leakage	9,512,E-07	LPG release to atmosphere	4	SDV-001/ 003	Moderate (4)	No

2	Less	Flow	Less Flow	Small leaks on the pipeline, pipeline blocked, deffective pump from the vessel, filter blocked	9,512,E-07	Unstable flow, vibration in pipeline	2	PI-0001/ 0003, PT-0001/ 0005, 0003	Low (2)	No
				Manual Valves are not fully opened	4,774,E-05	Unstable flow, vibration in pipeline	2	PI-0001/ 0003, PT-0001/ 0005, 0003	Moderate (4)	No
3	More	Flow	More Flow	Too high pressure from the bulk carrier vessel	6,701,E-06	Too high pressure in piping system	2	PSV-0001/ 0002/ 1005	Low (2)	No
4	Reverse	Flow	Reverse Flow	Upstream section indadvertently open	0,000,E+00	Back pressure to the bulk vessel or previous pipeline	2	CV-0002	Low (2)	No
5	Less	Temperature	Less Temperature	Heater control failure	1,535,E-05	Icing on the pipe, too low pressure	4	TI-0001/ 0003, SDV 0001/ 0003	Moderate (8)	No
				Fault measurement	9,343,E-06	Icing on the pipeline, too low pressure	4	TI-0001/ 0003, SDV 0001/ 0003/ 1305	Moderate (4)	No

6	High	Temperature	High Temperature	Heater control failure	1,124,E-05	Higher fluid temperature, cavitation in the pipeline, LPG evaporated in the pipeline	3	TI-0001/ 0003, SDV 0001/ 0003/ 1305	Moderate (6)	No
						Popping occured outside the PSV	4	No available safeguard	Moderate (8)	No
				Fault measurement	9,343,E-06	Higher fluid temperature, cavitation in the pipeline, LPG evaporated in the pipeline	3	TI-0001/ 0003, SDV 0001/ 0003/ 1305	Moderate (3)	No
						Popping occured outside the PSV	4	No available safeguard	Moderate (4)	No

4.3 Mitigation

The risk that need to be analyzed in the Mitigation process is the risk which have Medium Risk or above. In this bachelor thesis, there is no part that have Medium risk and there is no risk that can be categorized above Medium.

HAZOP TABLE: NODE 1

STUDY TITLE: Ship Loading/ Unloading Piping & Instrumentation Diagram										
Drawing No.:			FTLSMG-30-DW-C006 & FTLSMG-30-DW-C007						Node: 1	
TEAM COMPOSITION:									DATE:	
PART CONSIDERED:			LPG transfer line from the bulk vessel to the storage tank						MEETING DATE:	
DESIGN INTENT:			Material: Source:	LPG liquid Bulk vessel				Activity: Destination:	LPG transfer LPG storage tank	
No.	Guide Word	Element	Deviation	Possible Causes	Probability	Consequences	Severity Level	Safeguards	Risk Level	Actions Required
1	No	Flow	No Flow	One or more manual valve are inadvertently closed		High back pressure at pump discharge on bulk carrier vessel and upstream side of the pipeline		PSV-1005/ 0001/ 0002		
				SDV 0001/ 0003 inadvertently closed		High back pressure at pump discharge on bulk carrier		PI-001/ 003		
				SDV-1301/ 1201/ 1301/ 1401 on Tank Inlet is inadvertently closed		High back pressure at upstream side of pipeline system		PT-003, PSV-0002		
				LPG Liquid loading line leakage		LPG release to atmosphere		SDV-001/ 003		

2	Less	Flow	Less Flow	Small leaks on the pipeline, pipeline blocked, deffective pump from the vessel, filter blocked		Unstable flow, vibration in pipeline		PI-0001/ 0003, PT-0001/ 0005, 0003		
				Manual Valves are not fully opened		Unstable flow, vibration in pipeline		PI-0001/ 0003, PT-0001/ 0005, 0003		
3	More	Flow	More Flow	Too high pressure from the bulk carrier vessel		Too high pressure in piping system		PSV-0001/ 0002/ 1005		
4	Reverse	Flow	Reverse Flow	Upstream section indadvertently open		Back pressure to the bulk vessel or previous pipeline		CV-0002		
5	Less	Temperature	Less Temperature	Heater control failure		Icing on the pipe, too low pressure		TI-0001/ 0003, SDV 0001/ 0003		
				Fault measurement		Icing on the pipeline, too low pressure		TI-0001/ 0003, SDV 0001/ 0003/ 1305		

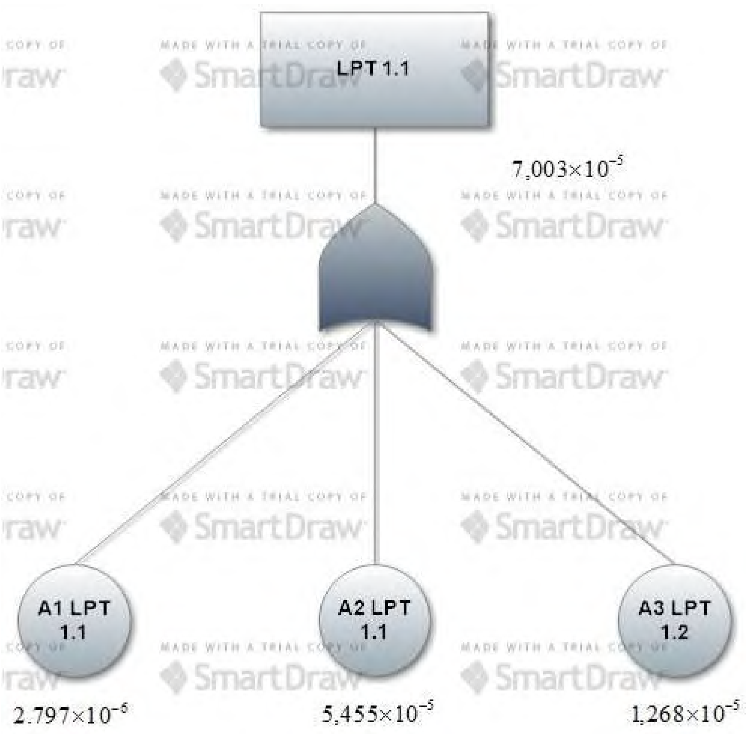
6	High	Temperature	High Temperature	Heater control failure		Higher fluid temperature, cavitation in the pipeline, LPG evaporated in the pipeline		TI-0001/ 0003, SDV 0001/ 0003/ 1305		
						Popping occured outside the PSV		No available safeguard		
				Fault measurement		Higher fluid temperature, cavitation in the pipeline, LPG evaporated in the pipeline		TI-0001/ 0003, SDV 0001/ 0003/ 1305		
						Popping occured outside the PSV		No available safeguard		

HAZOP TABLE: NODE 2

STUDY TITLE: Ship Loading/ Unloading Piping & Instrumentation Diagram										
Drawing No.:			FTLSMG-30-DW-C006 & FTLSMG-30-DW-C007						Node: 2	
TEAM COMPOSITION:									DATE:	
PART CONSIDERED:			LPG Vapour Return						MEETING DATE:	
DESIGN INTENT:			Material:	LPG liquid				Activity:	LPG transfer	
			Source:	Bulk vessel				Destination:	LPG storage tank	
No.	Guide Word	Element	Deviation	Possible Causes	Probability	Consequences	Severity Level	Safeguards	Risk Level	Actions Required
1	No	Flow	No Flow	One or more manual valve are inadvertently closed	3,174,E-05	High back pressure to the tank	2	PI-0004, PT-0004	Low (4)	No.
				SDV 0004/ 0003 inadvertently closed	2,081,E-03	High back pressure to the tank or previous pipeline	2	PI-0004, PT-0004	Moderate (6)	No.
				SDV-1104/ 1204/ 1304/ 1404 on Tank Outlet is inadvertently closed	2,081,E-03	High back pressure to the tank	2	PSV	Moderate (6)	No.
				LPG Liquid loading line leak	1,879,E-05	LPG release to atmosphere, potentially develop LPG vapour cloud	4	SDV-0002/ 0004/ 1104/ 1204/ 1304/ 1404	Moderate (5)	No.
2	Less	Flow	Less Flow	Small leaks on the pipeline, pipeline blocked, deffective pump from the vessel, filter blocked	1,879,E-05	Unstable flow, vibration in pipeline	2	PI-0004/ 0002, PT-0004/ 0002	Moderate (4)	No.
				Manual Valves are not fully opened	3,174,E-05	Unstable flow, vibration in pipeline	2	PI-0004/ 0002, PT-0004/ 0002	Moderate (4)	No.
3	More	Flow	More Flow	No credible events	0,000,E+00					No.
4	Reverse	Flow	Reverse Flow	Upstream section inadvertently open	0,000,E+00	Back pressure to the tank	2	CV-0003	Low (2)	No.
5	Less	Temperature	Less Temperature	Too low temperature from the tank	1,535,E-05	Icing on the pipe, too low pressure	4	TI-0003/ 0001, SDV 0004/ 0002	Moderate (5)	No.
				Fault measurement	9,343,E-06	Icing on the pipeline, too low pressure	4	TI-0003/ 0001, SDV 0004/ 0002	Moderate (4)	No.
6	High	Temperature	High Temperature	Too high temperature from the tank	1,124,E-05	Higher fluid temperature, cavitation in the pipeline, LPG evaporated in the pipeline	4	TI-0003/ 0001, SDV 0004/ 0002	Moderate (4)	No.

				Fault measurement	9,343,E-06	Higher fluid temperature, cavitation in the pipeline, LPG evaporated in the pipeline	4	TI-0003/ 0001, SDV 0004/ 0002	Moderate (4)	No.

FTA CHART: NODE 1



Notes:

A1	=	Delayed operation
A2	=	Failed to open on demand
A3	=	Spurious operation

A1 LPT 1.1

P	=	2,797,E-06	l	=	3,000,E-07
			T	=	9,325,E+0

A2 LPT 1.1

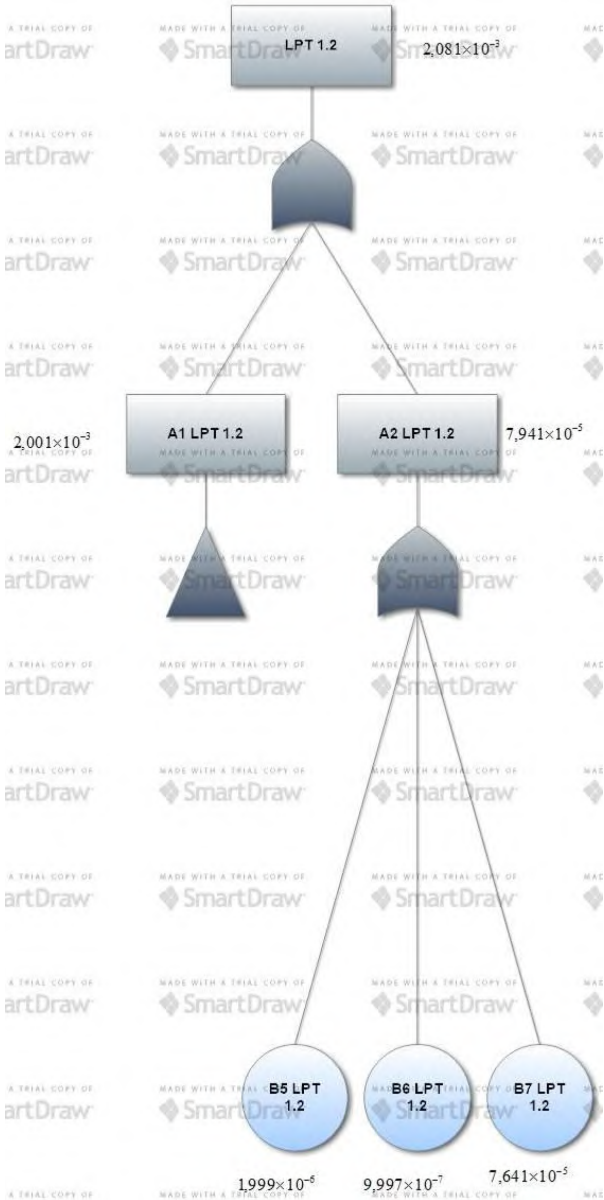
P	=	5,455,E-05	l	=	5,850,E-06
			T	=	9,325,E+0

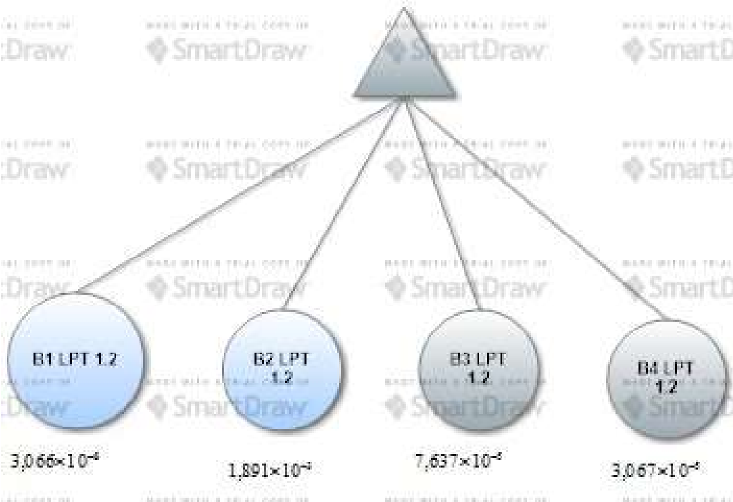
A3 LPT 1.1

P	=	1,268,E-05	l	=	1,360,E-06
			T	=	9,325,E+0

LPT
1.1

P = **7,003,E-05**


LPT 1.2
2,081×10⁻³
A1 LPT 1.2
2,001×10⁻³
A2 LPT 1.2
7,941×10⁻⁵
B5 LPT 1.2
B6 LPT 1.2
B7 LPT 1.2
1,999×10⁻⁶
9,997×10⁻⁷
7,641×10⁻⁵



Notes:

B1	=	Breakdown
B2	=	Fail to start on demand
B3	=	Faulty output voltage
B4	=	Low output
A1	=	Loss power
B5	=	Delayed operation
B6	=	Failed to open on demand
B7	=	Spurious operation
A2	=	Fail to control valve

B1 LPT 1.2

P	=	3,066,E-06	l	=	1,320,E-05
			T	=	2,323,E-01

B2 LPT 1.2

P	=	1,891,E-03	l	=	8,141,E-03
			T	=	2,323,E-01

B3 LPT 1.2

P	=	7,637,E-05	l	=	3,288,E-04
			T	=	2,323,E-01

B4 LPT 1.2

P	=	3,067,E-05	l	=	1,320,E-04
			T	=	2,323,E-01

A1 LPT 1.2

P = 2,001,E-03

B5 LPT 1.2

P	=	1,999,E-06	l	=	3,600,E-06
			T	=	5,554,E-01

B6 LPT 1.2

P	=	9,997,E-07	l	=	1,800,E-06
			T	=	5,554,E-01

B7 LPT 1.2

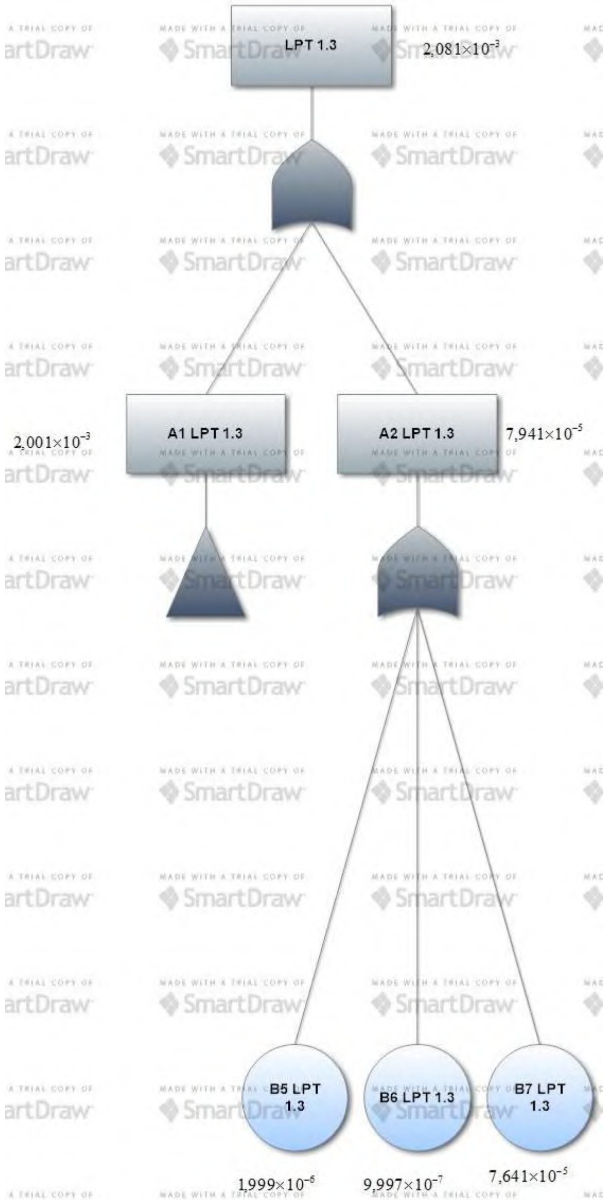
P	=	7,641,E-05	l	=	1,981,E-05
			T	=	3,857,E+0 0

A2 LPT 1.2

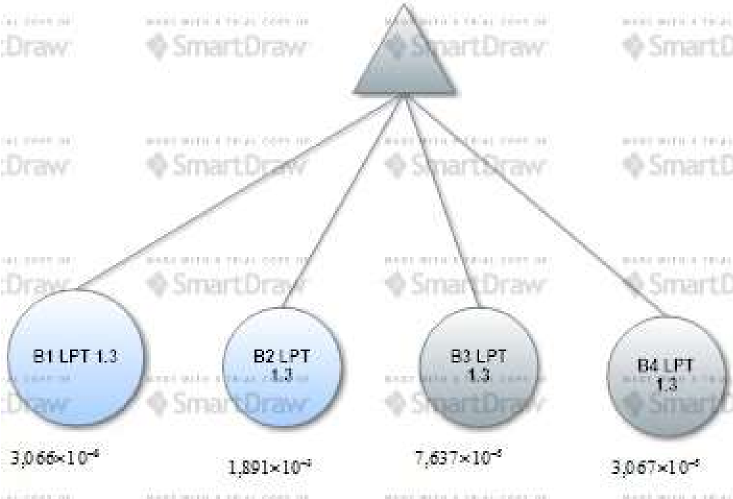
P = 7,941,E-05

LPT
1.2

P = 2,081,E-03



LPT 1.3
2,081×10⁻³
A1 LPT 1.3
2,001×10⁻³
A2 LPT 1.3
7,941×10⁻⁵
B5 LPT 1.3
B6 LPT 1.3
B7 LPT 1.3
1,999×10⁻⁶
9,997×10⁻⁷
7,641×10⁻⁵



Notes:

B1	=	Breakdown
B2	=	Fail to start on demand
B3	=	Faulty output voltage
B4	=	Low output
A1	=	Power loss
B5	=	Delayed operation
B6	=	Failed to open on demand
B7	=	Spurious operation
A2	=	Fail to control valve

B1 LPT 1.3

P	=	3,066,E-06	l	=	1,320,E-05
			T	=	2,323,E-01

B2 LPT 1.3

P	=	1,891,E-03	l	=	8,141,E-03
			T	=	2,323,E-01

B3 LPT 1.3

P	=	7,637,E-05	l	=	3,288,E-04
			T	=	2,323,E-01

B4 LPT 1.3

P	=	3,067,E-05	l	=	1,320,E-04
			T	=	2,323,E-01

A1 LPT 1.3

P = 2,001,E-03

B5 LPT 1.3

P	=	1,999,E-06	l	=	3,600,E-06
			T	=	5,554,E-01

B6 LPT 1.3

P	=	9,997,E-07	l	=	1,800,E-06
			T	=	5,554,E-01

B7 LPT 1.3

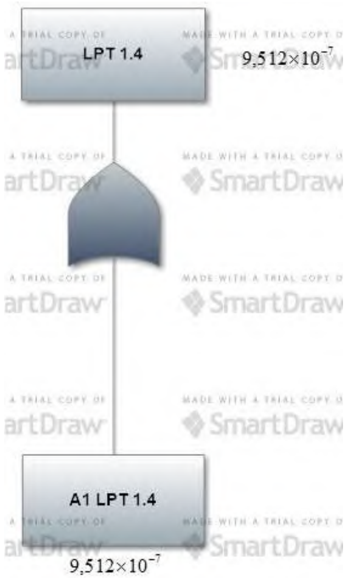
P	=	7,641,E-05	l	=	1,981,E-05
			T	=	3,857,E+0 0

A2 LPT 1.3

P = 7,941,E-05

LPT
1.3

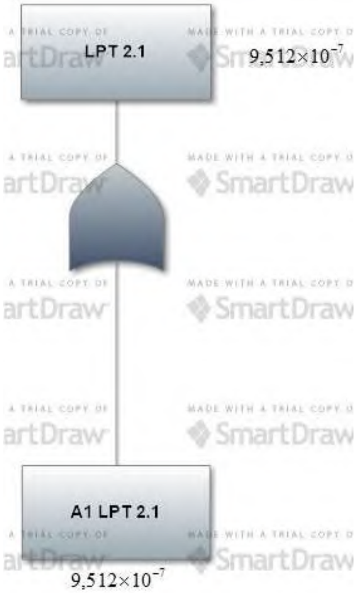
P = 2,081,E-03



Notes:

A1 = External leakage

A1 LPT 1.4					
P	=	9,512,E-07	l	=	6,100,E-07
					1,559,E+0
			T	=	0
LPT 1.4					
P	**=**	**9,512,E-07**			



Notes :

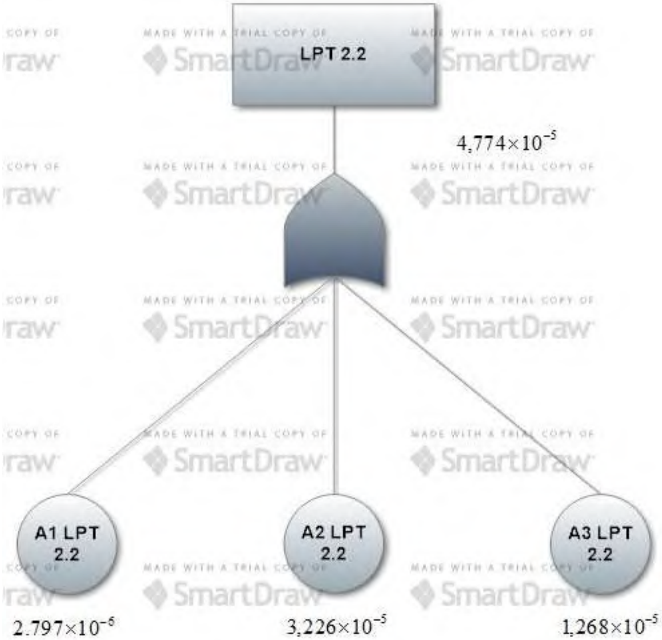
A1 = External leakage

A1 LPT 2.1

P	=	9,512,E-07	l	=	6,100,E-07
					1,559,E+0
			T	=	0

LPT
2.1

P = 9,512,E-07


LPT 2.2
4,774×10−5
A1 LPT 2.2
A2 LPT 2.2
A3 LPT 2.2
2.797×10−6
3,226×10−5
1,268×10−5

Notes:

A1	=	Delayed operation
A2	=	Failed to open on demand
A3	=	Spurious operation

A1 LPT 2.2

P	=	2,797,E-06	l	=	3,000,E-07
					9,325,E+0
			T	=	0

A2 LPT 2.2

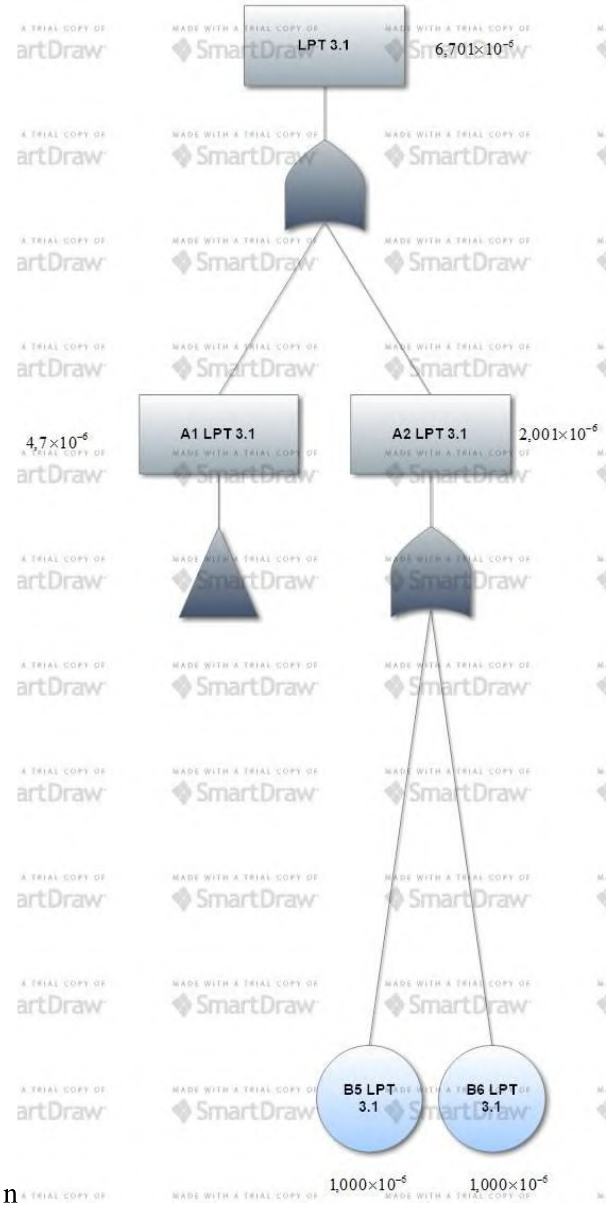
P	=	3,226,E-05	l	=	3,460,E-06
					9,325,E+0
			T	=	0

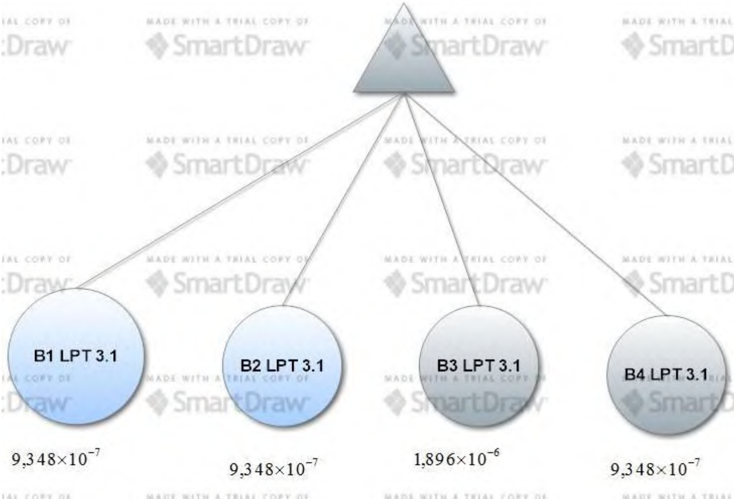
A3 LPT 2.2

P	=	1,268,E-05	l	=	1,360,E-06
					9,325,E+0
			T	=	0

LPT
2.2

P = 4,774,E-05


LPT 3.1
6,701×10⁻⁶
A1 LPT 3.1
4,7×10⁻⁶
A2 LPT 3.1
2,001×10⁻⁶
B5 LPT 3.1
B6 LPT 3.1
1,000×10⁻⁶
1,000×10⁻⁶



Notes:

B1	=	Breakdown
B2	=	Fail to start on demand
B3	=	Spurious stop
B4	=	Vibration
A1	=	Pump failure
B5	=	External leakage
B6	=	Delayed operation

B1 LPT 3.1

P	=	9,348,E-07	l	=	7,180,E-06
			T	=	1,302,E-01

B2 LPT 3.1

P	=	9,348,E-07	l	=	7,180,E-06
			T	=	1,302,E-01

B3 LPT 3.1

P	=	1,896,E-06	l	=	1,456,E-05
			T	=	1,302,E-01

B4 LPT 3.1

P	=	9,348,E-07	l	=	7,180,E-06
			T	=	1,302,E-01

A1 LPT 3.1

P = 4,700,E-06

B5 LPT 3.1

P	=	1,000,E-06	l	=	1,124,E-05
			T	=	8,900,E-02

B6 LPT 3.1

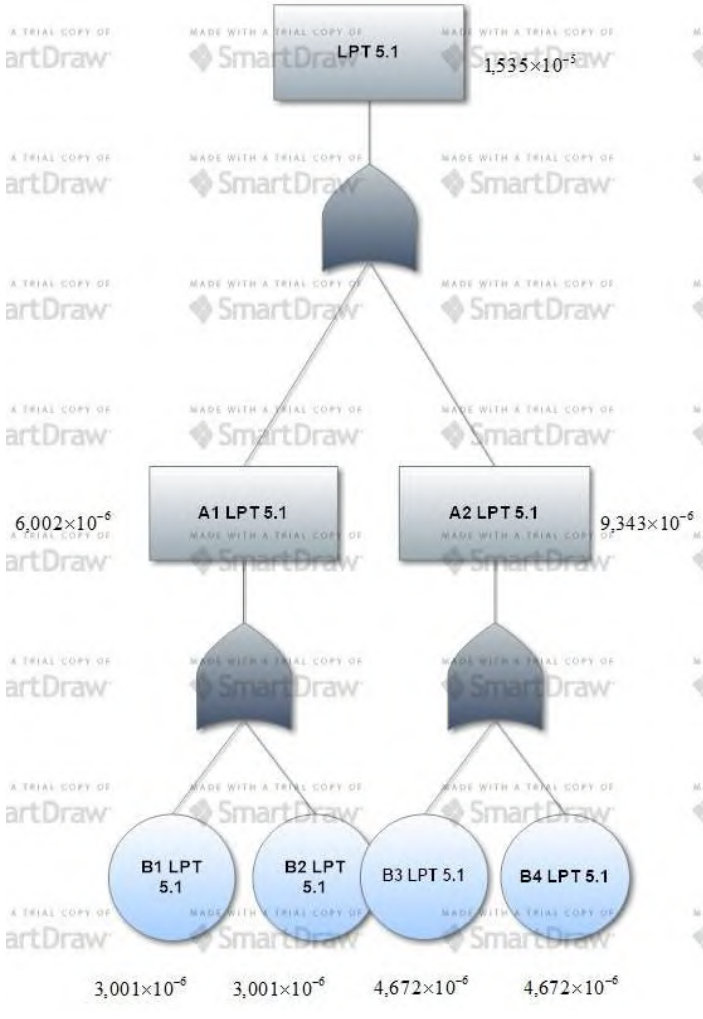
P	=	1,000,E-06	l	=	1,124,E-05
			T	=	8,900,E-02

A2 LPT 3.1

P = 2,001,E-06

LPT
3.1

P = 6,701,E-06


LPT 5.1
1,535×10⁻⁵
A1 LPT 5.1
6,002×10⁻⁶
A2 LPT 5.1
9,343×10⁻⁶
B1 LPT 5.1
B2 LPT 5.1
B3 LPT 5.1
B4 LPT 5.1
3,001×10⁻⁶
3,001×10⁻⁶
4,672×10⁻⁶
4,672×10⁻⁶

Notes:

B1	=	Insufficient heat transfer
B2	=	Abnormal in instrument reading
A1	=	Heater failure
B3	=	Fail to function on demand
B4	=	Spurious operation
A2	=	Incompatible temperature

B1 LPT 5.1

P	=	3,001,E-06	l	=	6,654,E-05
			T	=	4,510,E-02

B2 LPT 5.1

P	=	3,001,E-06	l	=	6,654,E-05
			T	=	4,510,E-02

A1 LPT 5.1

P = 6,002,E-06

B3 LPT 5.1

P	=	4,672,E-06	l	=	3,100,E-06
					1,507,E+0
			T	=	0

B4 LPT 5.1

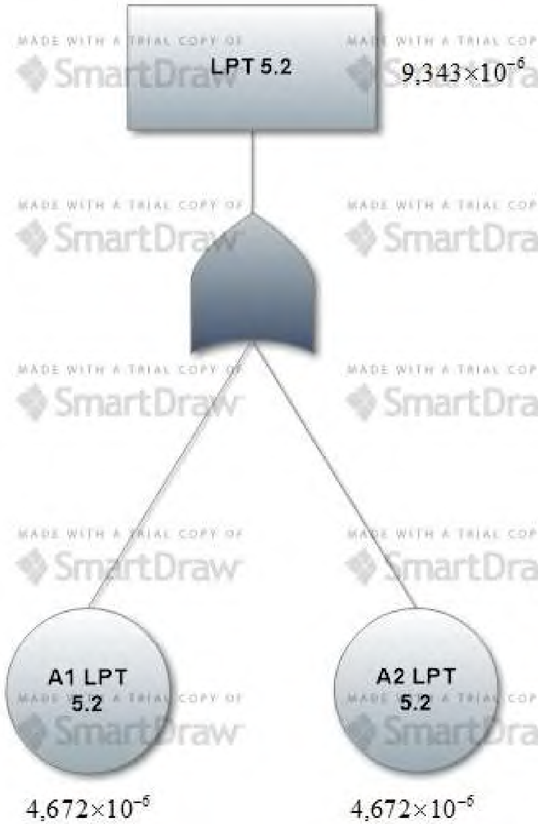
P	=	4,672,E-06	l	=	3,100,E-06
					1,507,E+0
			T	=	0

A2 LPT 5.1

P = 9,343,E-06

LPT
5.1

P = 1,535,E-05



LPT 5.2
$9{,}343\times10^{-6}$
A1 LPT 5.2
A2 LPT 5.2
$4{,}672\times10^{-6}$
$4{,}672\times10^{-6}$

Notes:

B1	=	Fail to function on demand
B2	=	Spurious operation
A1	=	Measurement failure

B1 LPT 5.2

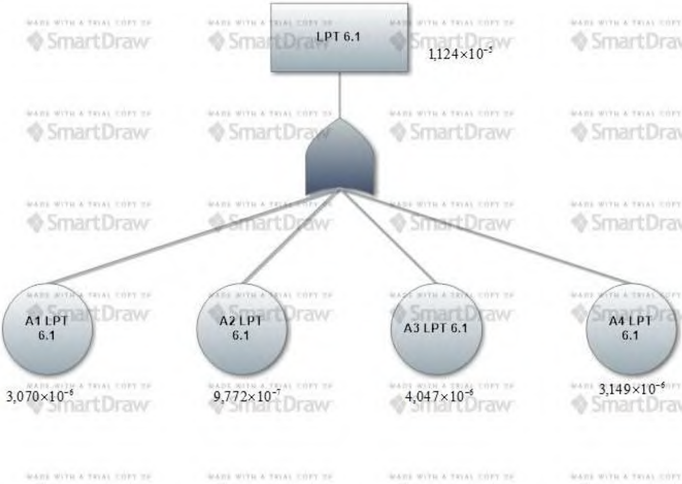
P	=	4,672,E-06	l	=	3,100,E-06
					1,507,E+0
			T	=	0

B2 LPT 5.2

P	=	4,672,E-06	l	=	3,100,E-06
					1,507,E+0
			T	=	0

LPT
5.2

P = 9,343,E-06



LPT 6.1
1,124×10⁻⁵
A1 LPT 6.1
A2 LPT 6.1
A3 LPT 6.1
A4 LPT 6.1
3,070×10⁻⁶
9,772×10⁻⁷
4,047×10⁻⁶
3,149×10⁻⁶

Notes:

B1 = Abnormal in instrument reading

B2 = Overheating

B3 = Parameter deviation

B4 = Structural deficiency

B1 LPT 6.1

P	=	3,070,E-06	l	=	1,357,E-05
			T	=	2,262,E-01

B2 LPT 6.1

P	=	9,772,E-07	l	=	4,320,E-06
			T	=	2,262,E-01

B3 LPT 6.1

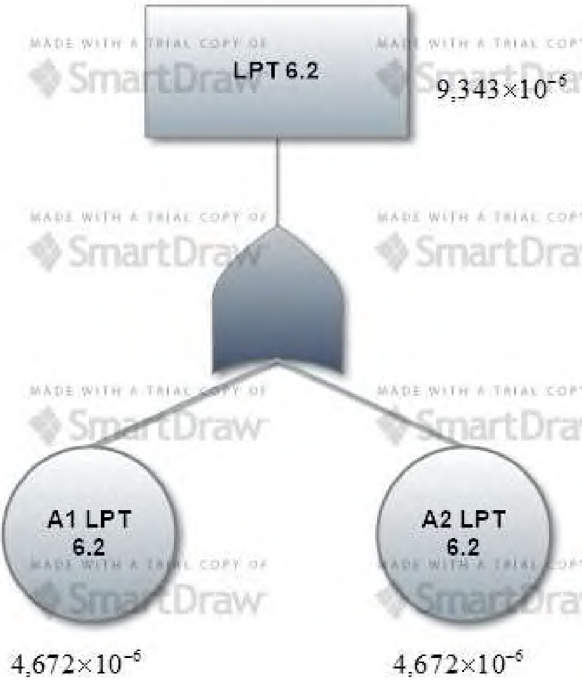
P	=	4,047,E-06	l	=	7,140,E-06
			T	=	2,262,E-01

B4 LPT 6.1

P	=	3,149,E-06	l	=	1,392,E-05
			T	=	2,262,E-01

LPT 6.1

P = 1,124,E-05



LPT 6.2
9,343×10⁻⁶
A1 LPT 6.2
A2 LPT 6.2
4,672×10⁻⁶
4,672×10⁻⁶

Notes:

B1	=	Fail to function on demand
B2	=	Spuriouos operation
A1	=	Measurement failure

B1 LPT 6.2

P	=	4,672,E-06	l	=	3,100,E-06
					1,507,E+0
			T	=	0

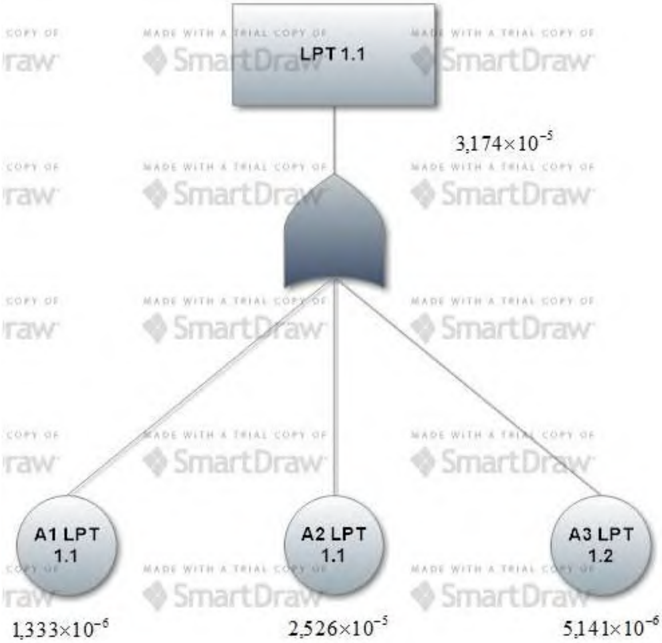
B2 LPT 6.2

P	=	4,672,E-06	l	=	3,100,E-06
					1,507,E+0
			T	=	0

A1 LPT 6.2

P = 9,343,E-06

FTA CHART: NODE 2



Notes:

A1	=	Delayed operation
A2	=	Failed to open on demand
A3	=	Spurious operation

A1 VPT 1.1

P	=	1,333,E-06	l	=	2,100,E-07
					6,347,E+0
			T	=	0

A2 VPT 1.1

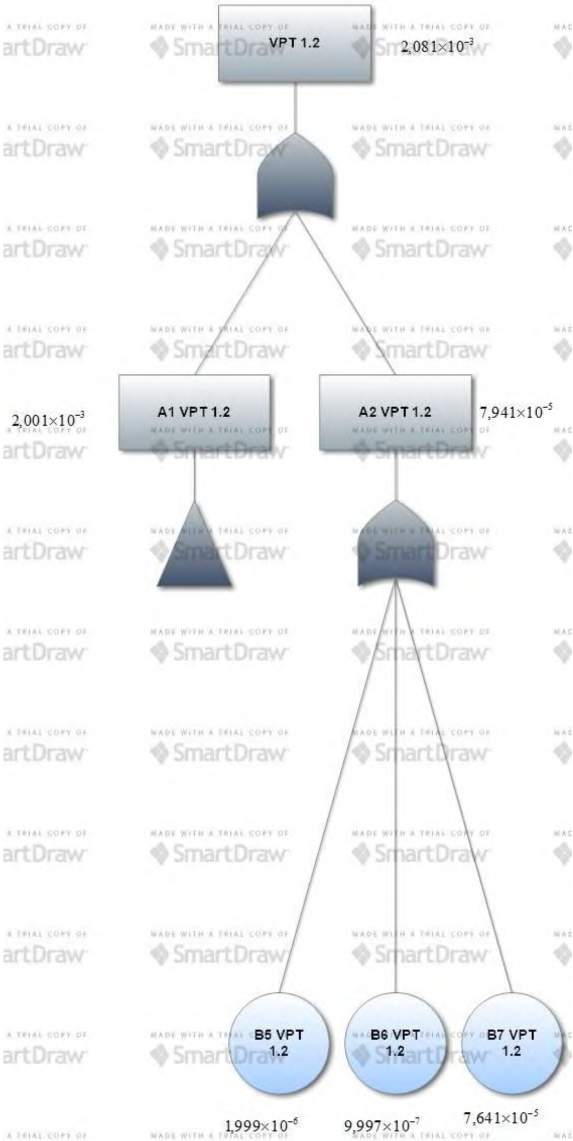
P	=	2,526,E-05	l	=	3,980,E-06
					6,347,E+0
			T	=	0

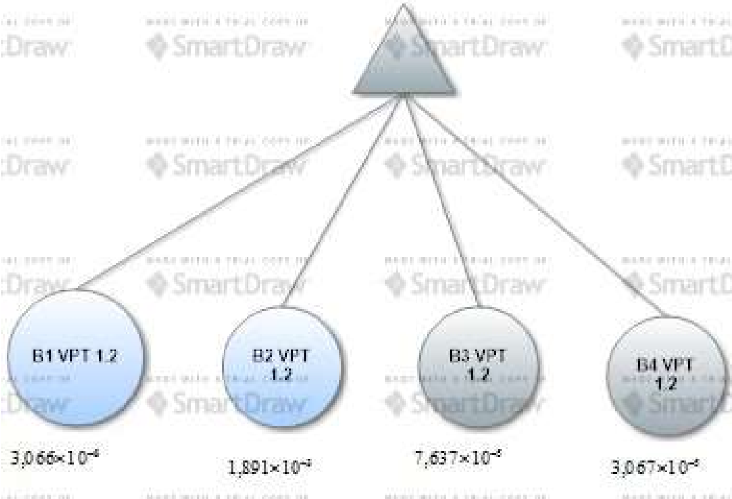
A3 VPT 1.1

P	=	5,141,E-06	l	=	8,100,E-07
					6,347,E+0
			T	=	0

VPT 1.1

P = 3,174,E-05


VPT 1.2
2,081×10⁻³
A1 VPT 1.2
2,001×10⁻³
A2 VPT 1.2
7,941×10⁻⁵
B5 VPT 1.2
1,999×10⁻⁶
B6 VPT 1.2
9,997×10⁻⁷
B7 VPT 1.2
7,641×10⁻⁵



Notes:

B1	=	Breakdown
B2	=	Fail to start on demand
B3	=	Faulty output voltage
B4	=	Low output
A1	=	Loss power
B5	=	Delayed operation
B6	=	Failed to open on demand
B7	=	Spurious operation
A2	=	Failure on valve

B1 VPT 1.2

P	=	3,066,E-06	1	=	1,320,E-05
			T	=	2,323,E-01

B2 VPT 1.2

P	=	1,891,E-03	1	=	8,141,E-03
			T	=	2,323,E-01

B3 VPT 1.2

P	=	7,637,E-05	1	=	3,288,E-04
			T	=	2,323,E-01

B4 VPT 1.2

P	=	3,067,E-05	1	=	1,320,E-04
			T	=	2,323,E-01

A1 VPT 1.2

P = 2,001,E-03

B5 VPT 1.2

P	=	1,999,E-06	l	=	3,600,E-06
			T	=	5,554,E-01

B6 VPT 1.2

P	=	9,997,E-07	l	=	1,800,E-06
			T	=	5,554,E-01

B7 VPT 1.2

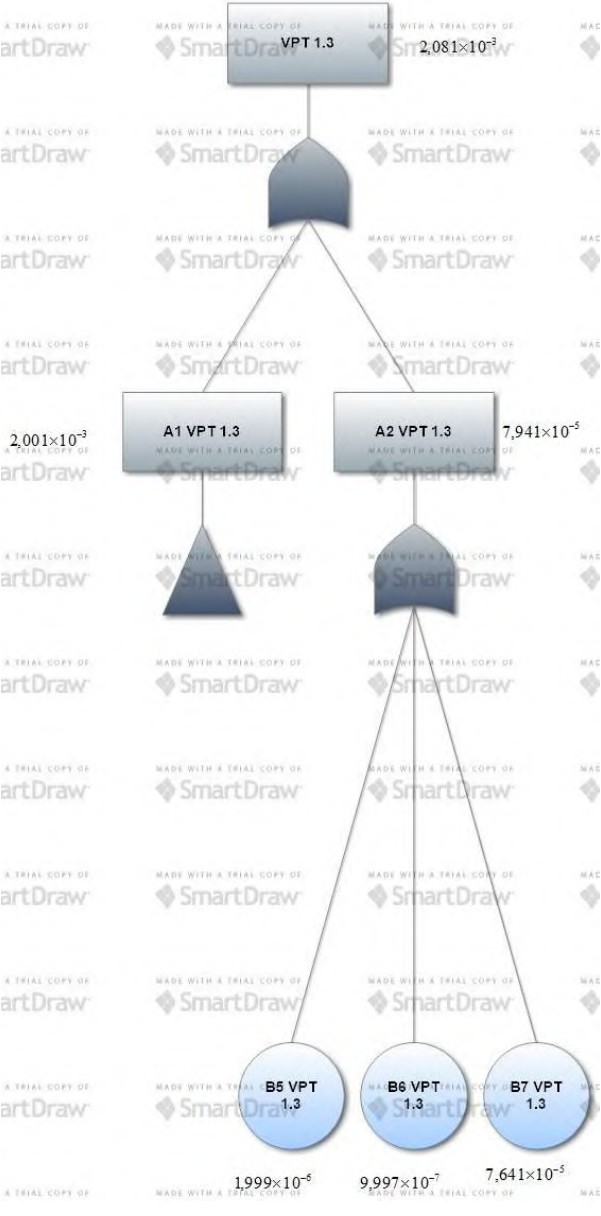
P	=	7,641,E-05	l	=	1,981,E-05
			T	=	3,857,E+0 0

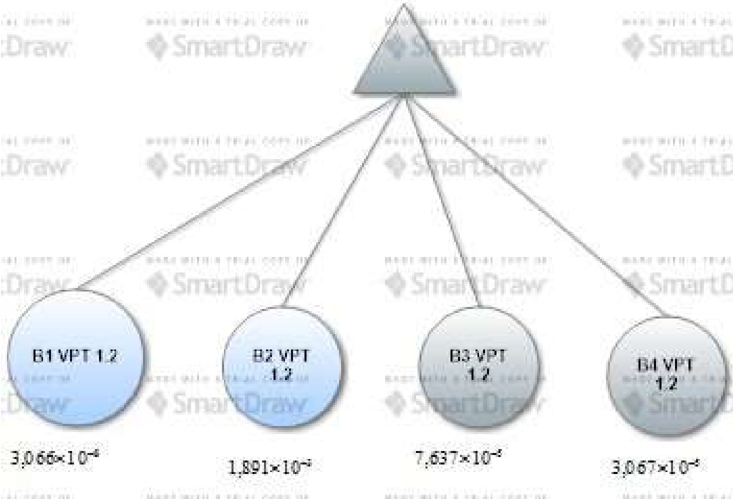
A2 VPT 1.2

P = 7,941,E-05

VPT 1.2

P = 2,081,E-03


VPT 1.3
2,081×10⁻³
A1 VPT 1.3
2,001×10⁻³
A2 VPT 1.3
7,941×10⁻⁵
B5 VPT 1.3
B6 VPT 1.3
B7 VPT 1.3
1,999×10⁻⁶
9,997×10⁻⁷
7,641×10⁻⁵



Notes:

B1	=	Breakdown
B2	=	Fail to start on demand
B3	=	Faulty output voltage
B4	=	Low output
A1	=	Loss power
B5	=	Delayed operation
B6	=	Failed to open on demand
B7	=	Spurious operation
A2	=	Failure on valve

B1 VPT 1.3

P	=	3,066,E-06	1	=	1,320,E-05
			T	=	2,323,E-01

B2 VPT 1.3

P	=	1,891,E-03	1	=	8,141,E-03
			T	=	2,323,E-01

B3 VPT 1.3

P	=	7,637,E-05	1	=	3,288,E-04
			T	=	2,323,E-01

B4 VPT 1.3

P	=	3,067,E-05	1	=	1,320,E-04
			T	=	2,323,E-01

A1 VPT 1.3

P = 2,001,E-03

B5 VPT 1.3

P	=	1,999,E-06	l	=	3,600,E-06
			T	=	5,554,E-01

B6 VPT 1.3

P	=	9,997,E-07	l	=	1,800,E-06
			T	=	5,554,E-01

B7 VPT 1.3

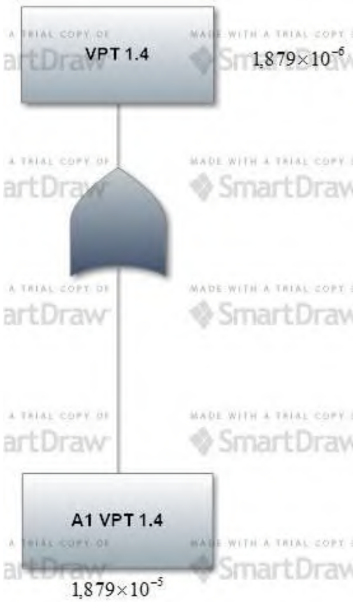
P	=	7,641,E-05	l	=	1,981,E-05
			T	=	3,857,E+0 0

A2 VPT 1.3

P = 7,941,E-05

VPT 1.3

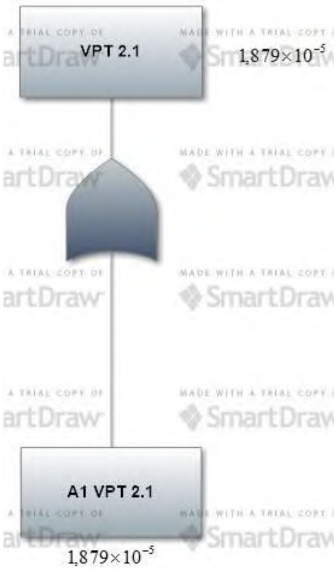
P = 2,081,E-03



Notes:

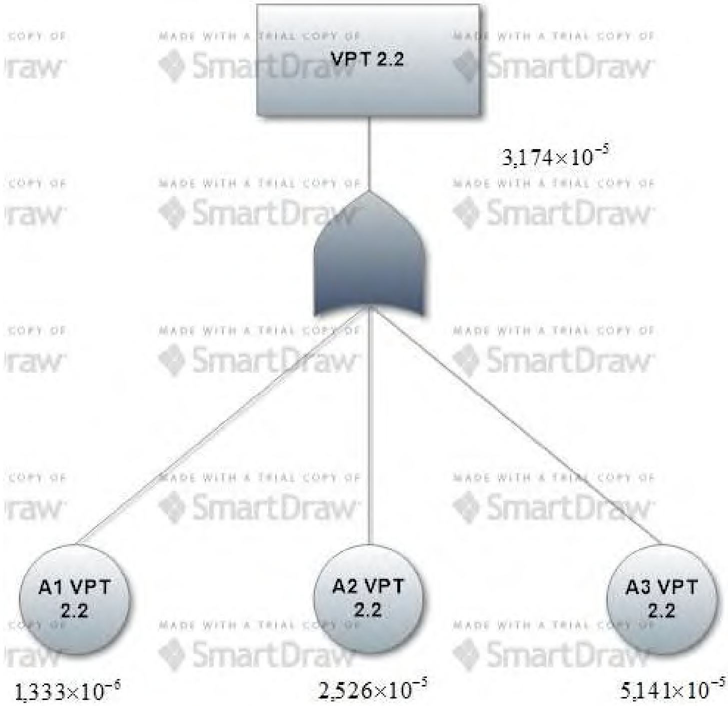
A1 = External leakage

A1 VPT 1.4					
P	=	1,879,E-05	l	=	2,960,E-06
			T	=	6,347,E+00
VPT 1.4					
P	**=**	**1,879,E-05**			



Notes :
A1 = External leakage

A1 VPT 2.1					
P	=	1,879,E-05	l	=	2,960,E-06
					6,347,E+0
			T	=	0
VPT 2.1					
P	**=**	**1,879,E-05**			



VPT 2.2
3,174×10⁻⁵
A1 VPT 2.2
A2 VPT 2.2
A3 VPT 2.2
1,333×10⁻⁶
2,526×10⁻⁵
5,141×10⁻⁵

Notes:

A1	=	Delayed operation
A2	=	Failed to open on demand
A3	=	Spurious operation

A1 VPT 2.2

P	=	1,333,E-06	l	=	2,100,E-07
					6,347,E+0
			T	=	0

A2 VPT 2.2

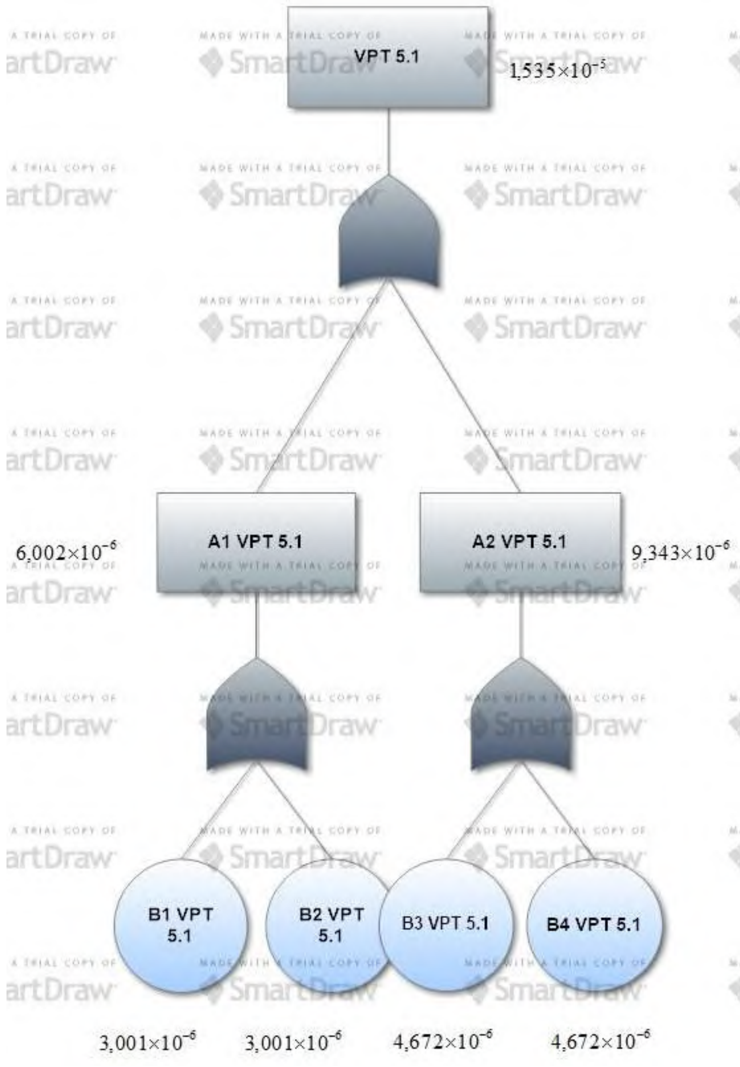
P	=	2,526,E-05	l	=	3,980,E-06
					6,347,E+0
			T	=	0

A3 VPT 2.2

P	=	5,141,E-06	l	=	8,100,E-07
					6,347,E+0
			T	=	0

VPT 2.2

P = 3,174,E-05


VPT 5.1
1,535×10⁻⁵
6,002×10⁻⁶
A1 VPT 5.1
A2 VPT 5.1
9,343×10⁻⁶
B1 VPT 5.1
B2 VPT 5.1
B3 VPT 5.1
B4 VPT 5.1
3,001×10⁻⁶
3,001×10⁻⁶
4,672×10⁻⁶
4,672×10⁻⁶

Notes:

B1	=	Insufficient heat transfer
B2	=	Abnormal in instrument reading
A1	=	Heater failure
B3	=	Fail to function on demand
B4	=	Spurious operation
A2	=	Incompatible temperature

B1 VPT 5.1

P = 3,001,E-06

l = 6,654,E-05

T = 4,510,E-02

B2 VPT 5.1

P = 3,001,E-06

l = 6,654,E-05

T = 4,510,E-02

A1 VPT 5.1

P = 6,002,E-06

B3 VPT 5.1

P	=	4,672,E-06	l	=	3,100,E-06
					1,507,E+0
			T	=	0

B4 VPT 5.1

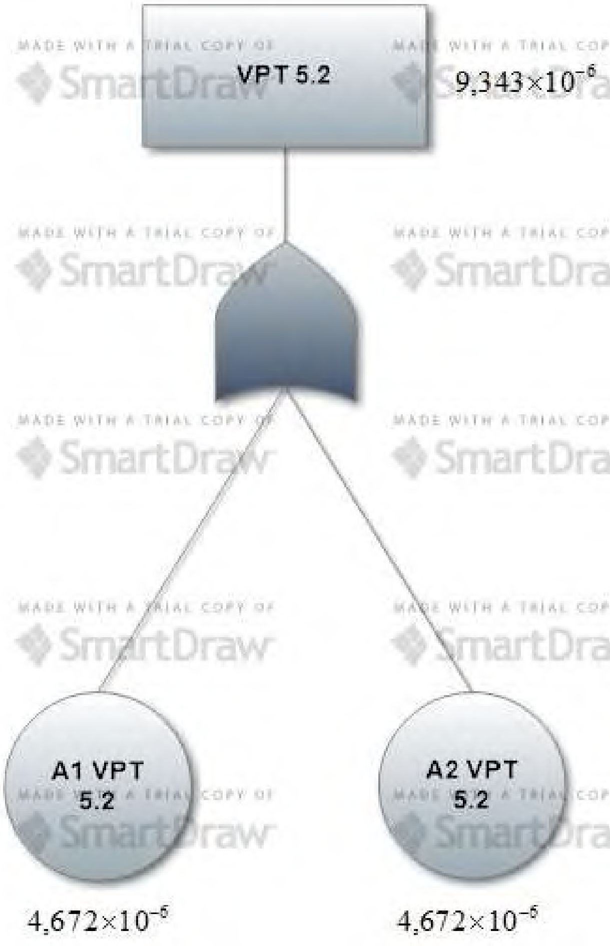
P	=	4,672,E-06	l	=	3,100,E-06
					1,507,E+0
			T	=	0

A2 VPT 5.1

P = 9,343,E-06

VPT 5.1

P = 1,535,E-05


VPT 5.2
$9,343\times10^{-6}$
A1 VPT 5.2
A2 VPT 5.2
$4,672\times10^{-6}$
$4,672\times10^{-6}$

Notes:

A1	=	Fail to function on demand
A2	=	Spuriouos operation

A1 VPT 5.2

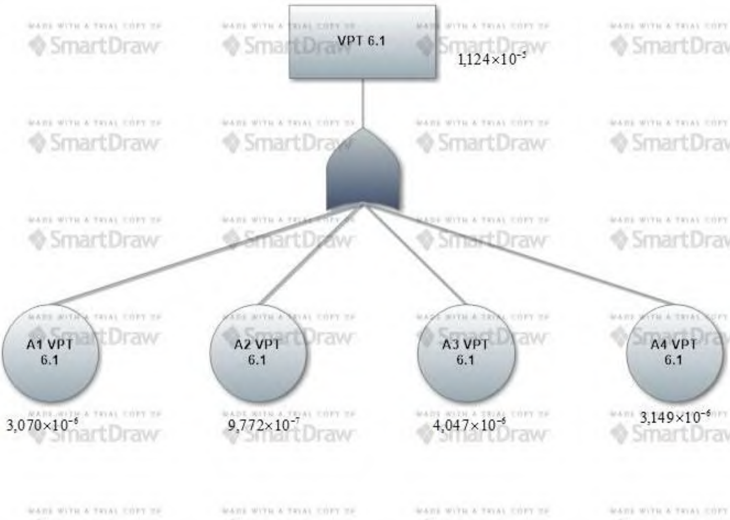
P	=	4,672,E-06	l	=	3,100,E-06
					1,507,E+0
			T	=	0

A2 VPT 5.2

P	=	4,672,E-06	l	=	3,100,E-06
					1,507,E+0
			T	=	0

VPT 5.2

P = 9,343,E-06


VPT 6.1
1,124×10⁻⁵
A1 VPT 6.1
A2 VPT 6.1
A3 VPT 6.1
A4 VPT 6.1
3,070×10⁻⁶
9,772×10⁻⁷
4,047×10⁻⁶
3,149×10⁻⁶

Notes:

B1	=	Abnormal in instrument reading
B2	=	Overheating
B3	=	Parameter deviation
B4	=	Structural deficiency

B1 VPT 6.1

P = 3,070,E-06 λ = 1,357,E-05

T = 2,262,E-01

B2 VPT 6.1

P = 9,772,E-07 λ = 4,320,E-06

T = 2,262,E-01

B3 VPT 6.1

P = 4,047,E-06 λ = 7,140,E-06

T = 2,262,E-01

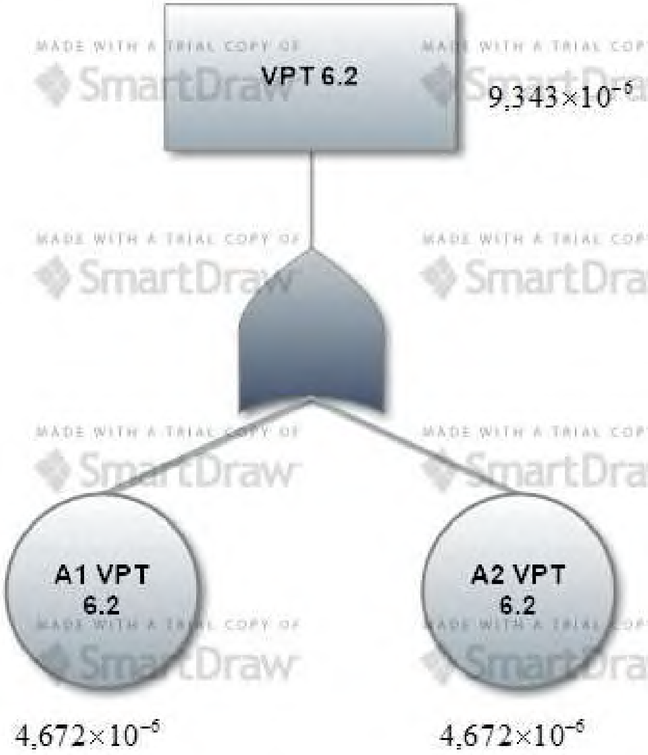
B4 VPT 6.1

P = 3,149,E-06 λ = 1,392,E-05

T = 2,262,E-01

VPT 6.1

P = 1,124,E-05


VPT 6.2
9,343×10⁻⁶
A1 VPT 6.2
A2 VPT 6.2
4,672×10⁻⁶
4,672×10⁻⁶

Notes:

B1	=	Fail to function on demand
B2	=	Spuriouos operation
A1	=	Measurement failure

B1 VPT 6.2

P	=	4,672,E-06	l	=	3,100,E-06
					1,507,E+0
			T	=	0

B2 VPT 6.2

P	=	4,672,E-06	l	=	3,100,E-06
					1,507,E+0
			T	=	0

A1 VPT 6.2

P = 9,343,E-06

RISK LEVEL TABLE: NODE 1

STUDY TITLE: Ship Loading/ Unloading Piping & Instrumentation Diagram										
Drawing No.:			FTLSMG-30-DW-C006 & FTLSMG-30-DW-C007						Node: 1	
TEAM COMPOSITION:									DATE:	
PART CONSIDERED:			LPG transfer line from the bulk vessel to the storage tank						MEETING DATE:	
DESIGN INTENT:			Material:	LPG liquid				Activity:	LPG transfer	
			Source:	Bulk vessel				Destination:	LPG storage tank	
No.	Guide Word	Element	Deviation	Possible Causes	Probability	Consequences	Severity Level	Safeguards	Risk Level	Actions Required
1	No	Flow	No Flow	One or more manual valve are inadvertently closed	7,003,E-05	High back pressure at pump discharge on bulk carrier vessel and upstream side of the pipeline	2	PSV-1005/ 0001/ 0002	Moderate (4)	No
				SDV 0001/ 0003 inadvertently closed	2,081,E-03	High back pressure at pump discharge on bulk carrier	2	PI-001/ 003	Moderate (6)	No
				SDV-1301/ 1201/ 1301/ 1401 on Tank Inlet is inadvertently closed	2,081,E-03	High back pressure at upstream side of pipeline system	2	PT-003, PSV-0002	Moderate (6)	No
				LPG Liquid loading line leakage	9,512,E-07	LPG release to atmosphere	4	SDV-001/ 003	Moderate (4)	No

2	Less	Flow	Less Flow	Small leaks on the pipeline, pipeline blocked, deffective pump from the vessel, filter blocked	9,512,E-07	Unstable flow, vibration in pipeline	2	PI-0001/ 0003, PT-0001/ 0005, 0003	Low (2)	No
				Manual Valves are not fully opened	4,774,E-05	Unstable flow, vibration in pipeline	2	PI-0001/ 0003, PT-0001/ 0005, 0003	Moderate (4)	No
3	More	Flow	More Flow	Too high pressure from the bulk carrier vessel	6,701,E-06	Too high pressure in piping system	2	PSV-0001/ 0002/ 1005	Low (2)	No
4	Reverse	Flow	Reverse Flow	Upstream section indadvertently open	0,000,E+00	Back pressure to the bulk vessel or previous pipeline	2	CV-0002	Low (2)	No
5	Less	Temperature	Less Temperature	Heater control failure	1,535,E-05	Icing on the pipe, too low pressure	4	TI-0001/ 0003, SDV 0001/ 0003	Moderate (8)	No
				Fault measurement	9,343,E-06	Icing on the pipeline, too low pressure	4	TI-0001/ 0003, SDV 0001/ 0003/ 1305	Moderate (4)	No

6	High	Temperature	High Temperature	Heater control failure	1,124,E-05	Higher fluid temperature, cavitation in the pipeline, LPG evaporated in the pipeline	3	TI-0001/ 0003, SDV 0001/ 0003/ 1305	Moderate (6)	No
						Popping occured outside the PSV	4	No available safeguard	Moderate (8)	No
				Fault measurement	9,343,E-06	Higher fluid temperature, cavitation in the pipeline, LPG evaporated in the pipeline	3	TI-0001/ 0003, SDV 0001/ 0003/ 1305	Moderate (3)	No
						Popping occured outside the PSV	4	No available safeguard	Moderate (4)	No

RISK LEVEL TABLE: NODE 2

STUDY TITLE: Ship Loading/ Unloading Piping & Instrumentation Diagram										
Drawing No.:			FTLSMG-30-DW-C006 & FTLSMG-30-DW-C007						Node: 2	
TEAM COMPOSITION:									DATE:	
PART CONSIDERED:			LPG Vapour Return						MEETING DATE:	
DESIGN INTENT:			Material:	LPG liquid				Activity:	LPG transfer	
			Source:	Bulk vessel				Destination:	LPG storage tank	
No.	Guide Word	Element	Deviation	Possible Causes	Probability	Consequences	Severity Level	Safeguards	Risk Level	Actions Required
1	No	Flow	No Flow	One or more manual valve are inadvertently closed	3,174,E-05	High back pressure to the tank	2	PI-0004, PT-0004	Low (4)	No.
				SDV 0004/ 0003 inadvertently closed	2,081,E-03	High back pressure to the tank or previous pipeline	2	PI-0004, PT-0004	Moderate (6)	No.
				SDV-1104/ 1204/ 1304/ 1404 on Tank Outlet is inadvertently closed	2,081,E-03	High back pressure to the tank	2	PSV	Moderate (6)	No.
				LPG Liquid loading line leak	1,879,E-05	LPG release to atmosphere, potentially develop LPG vapour cloud	4	SDV-0002/ 0004/ 1104/ 1204/ 1304/ 1404	Moderate (5)	No.
2	Less	Flow	Less Flow	Small leaks on the pipeline, pipeline blocked, deffective pump from the vessel, filter blocked	1,879,E-05	Unstable flow, vibration in pipeline	2	PI-0004/ 0002, PT-0004/ 0002	Moderate (4)	No.
				Manual Valves are not fully opened	3,174,E-05	Unstable flow, vibration in pipeline	2	PI-0004/ 0002, PT-0004/ 0002	Moderate (4)	No.
3	More	Flow	More Flow	No credible events	0,000,E+00					No.
4	Reverse	Flow	Reverse Flow	Upstream section inadvertently open	0,000,E+00	Back pressure to the tank	2	CV-0003	Low (2)	No.
5	Less	Temperature	Less Temperature	Too low temperature from the tank	1,535,E-05	Icing on the pipe, too low pressure	4	TI-0003/ 0001, SDV 0004/ 0002	Moderate (5)	No.
				Fault measurement	9,343,E-06	Icing on the pipeline, too low pressure	4	TI-0003/ 0001, SDV 0004/ 0002	Moderate (4)	No.
6	High	Temperature	High Temperature	Too high temperature from the tank	1,124,E-05	Higher fluid temperature, cavitation in the pipeline, LPG evaporated in the pipeline	4	TI-0003/ 0001, SDV 0004/ 0002	Moderate (4)	No.

				Fault measurement	9,343E-06	Higher fluid temperature, cavitation in the pipeline, LPG evaporated in the pipeline	4	1T-0003/1000, SDV 4000/2000		Moderate (4)	No.

CHAPTER 5
CONCLUSION

A LPG facility must have very low risk to avoid any damage, because a hazard can give big impact to the environment, human, or even from the LPG supply chain. Based on the risk assessment, could be concluded that:

1. All of the LPG loading process and Vapor Return process have low or moderate risk level
2. The lowest risk level is One or more manual valve inadvertently closed, which only have Low (2) risk level
3. The highest risk level is only on Moderate risk level
4. No high risk level means that the LPG Plant is a well-planned plant, which have been proven by until now the plant is still in Zero Accident status
5. Zero accident does not mean that it is impossible any accident will happen in the plant, so the mitigated process must be implemented to reduce the risk level.

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