TUGAS AKHIR – ME141502

PENILAIAN RESIKO KEBAKARAN PADA *FLOATING PRODUCTION UNIT*

EGI BAYU PERDANA

4212 101 014

DOSEN PEMBIMBING:

Dr. Eng. M. Badrus Zaman, S.T., M.T.

Dr. Eng. Trika Pitana, S.T., M.Sc.

PROGRAM DOUBLE DEGREE
JURUSAN TEKNIK SISTEM PERKAPALAN
FAKULTAS TEKNOLOGI KELAUTAN
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2016

BACHELOR THESIS – ME 141502

FIRE RISK ASSESSMENT ON FLOATING PRODUCTION UNIT

EGI BAYU PERDANA
NRP 4212 101 014

SUPERVISOR:
Eng. M. Badrus Zaman, S.T., M.T.
Dr. Eng. Trika Pitana, S.T., M.Sc.

DOUBLE DEGREE PROGRAM
DEPARTMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2016

APROVAL PAGE

FIRE RISK ASSESSMENT ON FLOATING PRODUCTION UNIT

BACHELOR THESIS

This Bachelor Thesis is submitted as a partial fulfilment of the requirements for the Bachelor Engineering Degree on Field study of Marine Reliability, Availability, Maintainability and Safety (RAMS)
Double Degree Program Marine Engineering Department
Faculty of Marine Technology
Sepuluh Nopember Institute of Technology

EGI BAYU PERDANA
NRP 4212 101 014

Approved by supervisor of Bachelor Thesis:

1. Dr. Eng. M. Badrus Zaman, S.T., M.T. (____________)

2. Dr. Eng. Trika Pitana, S.T., M.Sc. (____________)

SURABAYA

AUGUST, 2016

APROVAL PAGE

FIRE RISK ASSESSMENT ON FLOATING PRODUCTION UNIT

BACHELOR THESIS

This Bachelor Thesis is submitted as a partial fulfilment of the requirements for the Bachelor Engineering Degree on
Field study of Marine Reliability, Availability, Maintainability and Safety (RAMS)
Double Degree Program Marine Engineering Department
Faculty of Marine Technology
Sepuluh Nopember Institute of Technology

EGI BAYU PERDANA
NRP 4212 101 014

Approved by Head of Marine Engineering Department:

Dr. Eng. M. Badrus Zaman, S.T., M.T.

NIP. 197708022008011007

APPROVAL FORM

FIRE RISK ASSESMENT ON FLOATING PRODUCTION UNIT

BACHELOR THESIS

Proposed to One of Requirements Obtaining a Bachelor Engineering Degree
On
Marine Reliability and Safety (RAMS) Laboratory
Study Program Bachelor Double Degree Marine Engineering Department
Institut Teknologi Sepuluh Nopember Surabaya

Proposed by :
EGI BAYU PERDANA
NRP. 4212 101 014

Approved by
Representative Hoschschule Wismar in Indonesia

Dr.-Ing Wolfgang Busse

HOCHSCHULE WISMAR UNIVERSITY OF APPLIED SCIENCES TECHNOLOGY, BUSINESS AND DESIGN

PENILAIAN RESIKO KEBAKARAN PADA *FLOATING PRODUCTION UNIT*

Nama : Egi Bayu Perdana
NRP : 4212 101 014
Jurusan : Teknik Sistem Perkapalan FTK-ITS
Pembimbing : 1. Dr. Eng. M. Badrus Zaman, S.T., M.T.
2. Dr. Eng. Trika Pitana, S.T., M.Sc.

ABSTRAK

Pada FPU (*Floating Production Unit*) terdapat sumber berbahaya yaitu kondensat. Kondensate dapat menjadi berbahaya kepada awak kapal yang tinggal di kapal. Kondensat diletakan dan di proses di lepas pantai dapat memicu terjadinya kebakaran pada kapal FPU. Pada dasarnya terdapat kesempatan dari kondensat maupun kemungkinan yang lain yang dapat memicu terjadinya kebakaran pada kapal FPU. Pada kapal terdapat awak kapaldari FPU untuk mengatur kerja proses hidrokarbon dan pemindahan kondensat dan gas dari FPU ke ORF (*Onshore Receiving Facilities*). Hidrokarbon di dalam FPU diterima dari sumur minyak bawah laut yang disalurkan ke FPU, yang nantinya di terima dan di proses di FPU yang nantinya digunakan untuk bahan bakar. Kemungkinan terjadinya kecelakaan pada kapal FPU adalah besar, dan salah satu kemungkinannya adalah kebakaran. Api sendiri bisa terjadi dikarenakan banyak macam – macam penyebab. Api bisa terjadi dikarenakan listrik, oli, panas, dan penyebab lainnya. Pada kapal FPU seperti kondensat, bisa menjadi penyebab utama dari kebakaran. Pada dasarnya selain penyabab utama, oli juga dapat menjaadi penyebab tambahan bertambah besarnya kebakaran. Pada waktu itu terdapat kejadian kebakaran kapal FSO yang dimiliki oleh PT. CNOOC.

Analisa resiko pada tugas akhir ini menggunakan metode HAZOP.pada evaluasi resiko menggunakan metode FTA untuk menghitung frekuensi, menggunnakan ALOHA untuk penempatan konsekuensi, dan menggunakan *risk matix* perusahaan ENI Indonesia. Terdapat banyak mode kesalahan pada proses kondensat system. Terdapat satu resiko yang tidak dapat diterima, yaitu resiko pada pipa bocor dari condensate exchanger ke MP separator bisa menyebabkan dampak kerusakan yang besarpada FPU, tetapi tidak terdapat korban jiwa. Tetapi pada risk matrix menunjukan pada level kuning. Setelah dimitigasi menggunakan LOPA dengan menambahkan indicator tekanan dan indicator suhu pada system. Semua mode resiko lainnya bisa menyebabkan bahaya dan menyebabkan kerugian di FPU, tetapi semua resiko lainnya dapat diterima.

Kata kunci: FTA, HAZOP, LOPA, Penilaian Resiko

FIRE RISK ASSESSMENT ON FLOATING PRODUCTION UNIT

Name : Egi Bayu Perdana
NRP : 4212 101 014
Department : Marine Engineering FTK-ITS
Supervisor : 1. Dr. Eng. M. Badrus Zaman, S.T., M.T.
2. Dr. Eng. Trika Pitana, S.T., M.Sc.

ABSTRACT

On the FPU (Floating Production Unit) there is a dangerous congenital namely Condensate. The condensate could be a danger to the crew who stayed on the ship. The condensate is stored and process in offshore can be a trigger of fire at this FPU vessel. In addition there is a possibility of condensate or another possibility that can make a fire that occurred in this FPU vessel. On the ship there are crew of the FPU to handle the hydrocarbon process and transfer of condensate and gas from the FPU to the ORF. The hydrocarbon inside the FPU vessel derived from wells to FPU which will be retrieved and processed to be used as fuel in the process further. The possibility of accidents on FPU vessel is big, and one of big reason is fire. Fire itself can be caused by many variety of cause, it could happen because of electricity, oil, heat and other caused. At the FPU vessel like the condensate, can be a major cause of fires. In addition to being the main cause, the oil can also be a cause of the fire becomes larger. There is one fire accident that happen on FSO ship that belong to PT. CNOOC. Risk Assessment on this thesis using HAZOP method. For risk evaluation using FTA for the frequency, using ALOHA for the consequence plotting, and using ENI Risk Matrix for the consequence level. There are many failure mode on every system process of condensate process. There is one risk that unacceptable, the risk is when the pipe from the condensate exchanger to the MP separator leakage it can cause the major destruction of the FPU but there is no casualties, but on the risk matrix it shows that the failure mode on risk reduction measure level (yellow level). After The mitigation using LOPA the system add a pressure indicator and a temperature indicator to the system. All of the other risk that can cause hazard and make a local loss but all of it is acceptable.

Keyword: FTA, HAZOP, LOPA, Risk Assessment

LIST OF CONTENT

LIST OF TABLE

LIST OF FIGURE

CHAPTER I
INTRODUCTION

1.1. Background

On the FPU (Floating Production Unit) there is a dangerous congenital namely Condensate. The condensate could be a danger to the crew who stayed on the ship. The condensate is stored and process in offshore can be a trigger of fire at this FPU vessel. In addition there is a possibility of condensate or another possibility that can make a fire that occurred in this FPU vessel. On the ship there are crew of the FPU to handle the hydrocarbon process and transfer of condensate and gas from the FPU to the ORF. The hydrocarbon inside the FPU vessel derived from wells to FPU which will be retrieved and processed to be used as fuel in the process further. The possibility of accidents on FPU vessel is big, and one of big reason is fire. Fire itself can be caused by many variety of cause, it could happen because of electricity, oil, heat and other caused. At the FPU vessel like the condensate, can be a major cause of fires. In addition to being the main cause, the oil can also be a cause of the fire becomes larger. There is one fire accident that happen on FSO ship that belong to PT. CNOOC.

There are two process at the FPU based on location, Hull Process and Topside Process. At the Topside Process there are many system happen such as, Production wells and fluid separation system, low temperature separation and gas compression system, flash gas compression system, condensate stabilization, storage, and export system, and etc. One of the system is Condensate storage system. Condensate storage system is a system for the condensate separation between the on spec condensate and off spec condensate.

The risk of fire on the condensate on spec and of spec tank is high. Every dangers and risks that posed can cause a fire because the condensate. The damage will happen on their equipment, economic losses and may harm to the people around it. From the existing problems, there are should be a study for the risks that can be posed, it aims to reduce or eliminate them since fire accident can cause a tremendous loss.

1.2. Problem Formulation and Scope

Condensate storage system is a system that consist of on-spec condensate storage system and off-spec condensate storage system. The flow of the condensate through the on-spec tank and the off-spec tank has a risk. One of the risk is fire risk. If the condensate flow or the temperature is going to be error it can be a fire. Therefore fire risk assessment on the storage condensate system at FPU are required to avoid fire accident that can harm to people around it.

Based on the description above, presented several problems:

1. How to analyze the risk that can possible inside the FPU vessel
2. How to identify fire hazard that maybe occur in the FPU vessel
3. How to minimalize the risk that occurred in FPU

Scope of Problems:

1. The ship as the object of this study is vessel that is FPU Jangkrik
2. Evaluation of the risk is only at condensate storage system
3. Analysis the off-spec condensate tank and on-spec condensate tank

4. The method used to identifiaction the risk is HAZOP method.

1.3. Objective

The objectives of this Thesis are:

1. Identify the source of the fire in the ship and analyzing the risk
2. Know the level of the risk that can be occurred
3. Minimize the risk if cannot be tolerate

1.4. Benefit

The final results of this Thesis is the recommendations for the FPU Jangkrik to minimize the Fire Risk that can be occurred.

"This Page Intentionally Left Blank"

CHAPTER II
LITERATURE REVIEW

2.1. FPU

Floating Production Unit is a platform that works the same as FPU, split between crude oil with gas and water. FPU also does not have a permanent storages so that the results in the form of crude oil in the pump directly to the FSO or directly through a pipeline to an onshore. Inside the FPU there are two main process, topside process and hull process.

2.2. Topside FPU Process

The Floating Production Unit facilities are designed to continuously treat a maximum incoming production plateau of 450 MMscfd, seen as a total result of both Jangkrik Main (plateau rate: 300MMscfd) and Jangkrik NE (plateau rate: 150 MMscfd) production plus the maximum associated condensate (4100 SBPD) and produce water. Jangkrik Main is alson capable to produce 450MMscfd during Ramp-Up case. These 450MMscfd are considered as the FPU nameplate capacity.

The wells fluid arrives at FPU through 5 subsea Trunklines, with a provision for a connection of two additional trunklines in future phase. The mixed phase stream is distributed through two production manifolds and routed to two delicated slug catchers. From these receiving facilities the gas stream is sent to the gas section and liquid stream to a condensate collection header.

Two different operating phases are identified. During phase 1 the pressure at FPU battery limit for all Trunklines 945.7 barg as per hydraulic calculation) is high enough to directly routed to the 3X50% Low temperature separation

The Floating Production Unit facilities are designed to continuously treat a maximum incoming production plateau of 450MMscfd, seen as a total result of both Jangkrik Main (plateau rate: 300MMscfd) and Jangkrik NE (plateau rate: 150MMscfd) production plus the maximum associated condensate (4100 SBPD) and produced water. Jangkrik Main is also capable to produce 450MMscfd during Ramp-Up case. These 450MMscfd are considered as the FPU nameplate capacity.

The wells fluid arrives at FPU through 5 subsea Trunklines, with a provision for a connection of two additional Trunklines in future phase. The mixed phase stream is distributed through two productions manifolds and routed to two dedicated slug catchers. From these receiving facilities the gas stream is sent to the Gas Section and liquid stream to a condensate collection header.

The associated condensate collected in the slug catchers is, for its part, routed to the condensate stabilization train where it is mixed with condensates recovered from different locations in the process system (Booster Compressor KO drum, Low temperature separator, Flash Gas system, Fuel Gas System, Closed drain drum). During normal operation, the condensate is further let down in pressure and heated so as to pull out the flash gas and reach the export specification. The on-spec condensate stream is exported through a 4” pipeline under level control installed at the last step of the separation: LP separator.

2.1. Risk

Risk is the combination of the likelihood and consequence of such accidents. More scientifically, it is defined as the probability of a specific adverse event occurring in a specific period or in specified circumstances. The likelihood may be expressed either as a frequency (i.e. the rate of events per unit time) or a probability (i.e. the chance of the event occurring in specified circumstances). The consequence is the degree of harm caused by the event.

2.1.1. Risk Assessment

Risk assessment is the whole process of risk analysis against technological and economic, social and political criteria. Hazard evaluation can be encouraged through a few formal strategies. These diverse strategies may contain comparative ways to deal with answer the fundamental danger evaluation questions; be that as it may, a few systems might be more fitting than others for danger examination relying upon the circumstance.

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

Fire Risk assessment in this bachelor Thesis has aim to determine the level of risk that can be generated in the FPU, by using Hazard Operability (HAZOP) method can be obtained the levels of risk, and using FTA to obtain the frequency.

2.2.1. HAZOP Method

Hazard and Operability (HAZOP) use some keywords to identify the hazard from a system or process. Inside a process there are keyword such as (how, low no, etc.) used to know the deviation of system or process based on few parameters that has been set like pressure, temperature, flow, composition, etc.

HAZOP methodology widely used to evaluate or identify hazard on system level with qualitative approach. Even though, quantitative approach often found and used for hazard identification and operation capability from a continue system or process (fluid or thermal process). For an example is system for distribution of oil using few pumps, tank, and few pipeline. This method is usually used for review a procedure and stages of operation of existing system. Table below show us Hazop method in ship.

TABLE

Step from Hazop method can be translate into this activity:

1. Node selection
2. The application of deviation that want to used
3. Identify hazard cause associated with the guide word
4. Identify all of the consequence that comes from a cause that did not depend on safeguards.
5. Determination on the action that will eliminate or problem mitigation that has been identified if necessary.
6. Repetition on all nodes.

Inside identified hazard stages on HAZOP method on process engineering, then some terminology is often used. Here some terminology shown on table below:

Table 1 Basic Guide Words and Meaning

Guide word	Meaning
NO OR NOT	complete negation of the design intent
MORE	quantitative increase
LESS	quantitative decrease
AS WELL AS	qualitative modification/increase
PART OF	qualitative modification/decrease
REVERSE	logical opposite of the design intent
OTHER THAN	complete substitution

Table 2 Guide Words Relating to Clock Time and Order and Sequence

Guide word	Meaning
EARLY	Relative to the clock time
LATE	Relative to the clock time
BEFORE	Relating to the order or sequence
AFTER	Relating to the order or sequence

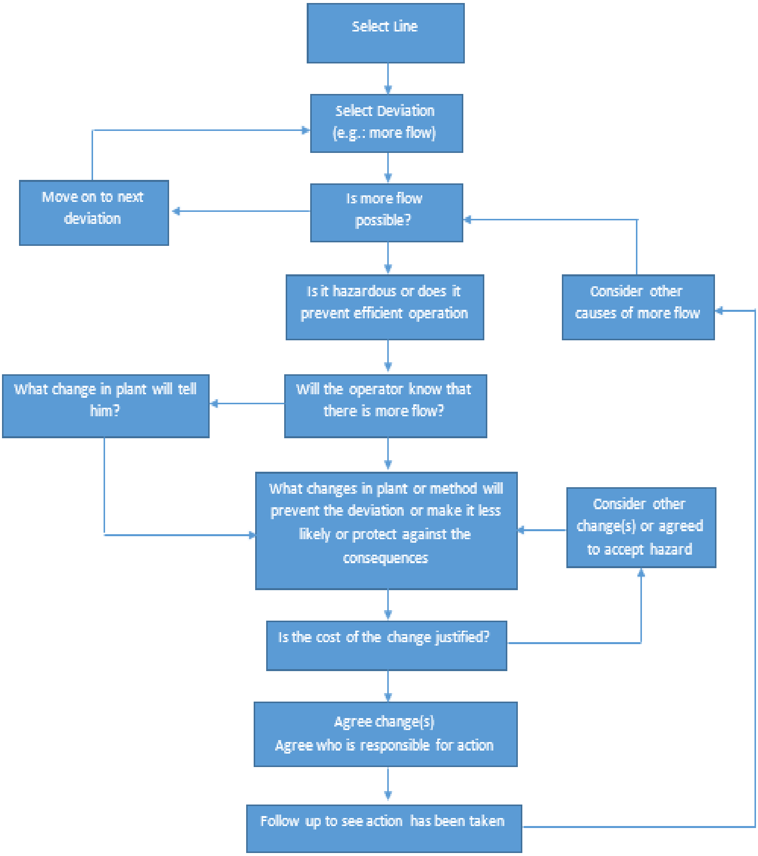


Figure 1 Diagram of HAZOP method

The step to get fulfil is shown at figure above the HAZOP worksheet, here are the steps:

1. Identify the safety that related to potential hazard and operation problem.

2. Identify the safeguard that has been installed and the operational procedure that could be reduce the consequence that related to hazard potential.
3. Determined the serious effect than the consequence for the problem that has to be identified.
4. Evaluate the safeguard availability and the procedure.
5. Safeguard recommendation if needed.

STUDY TITLE:							SHEET:	of
Drawing No.:			REV. No.:				DATE:	
PART CONSIDERED:								
DESIGN INTENT:			Material:			Activity:		
			Source:			Destination		
No.	Guide Word	Element	Deviation	Possible Causes	Consequences	Safeguards	Comments	Action Required
1								

Figure 2 HAZOP Worksheet BS IEC 61882

2.2.2. Risk Evaluation

The risk evaluation is judgment, on the basis of risk analysis, of whether a risk is tolerable (ISO 17776:2000). 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 (Intenational 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. For risk evaluation on this Bachelor Thesis will be use Risk Matrix from Event Risk Screening Matrix Table by ENI HSE risk management Standard.

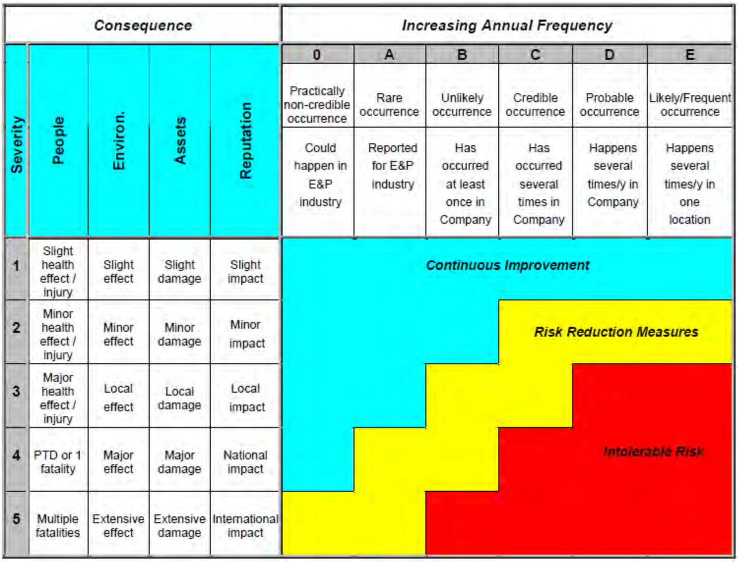


Figure 3 ENI HSE Risk Matrix

Every color has a meaning, where:

- Continuous improvement (blue color): The level of risk is broadly acceptable and generic control measures are required aimed at avoiding deterioration.
- Risk reduction measure (yellow color): The level of risk can be tolerable only once a structured review of risk reduction measures has been carried out (where necessary, the relevant guidance from the local Authorities should be adopted for application of ALARP). ALARP is a concept that applies well only to personnel risk. For environmental risk the concept of BPEO is more frequently applied. Asset risk is often most easily judged on a basis of costs and benefits alone.

- Intolerable risk (red color): The level of risk is not acceptable and risk control measures are required to move the risk figure to the previous regions.

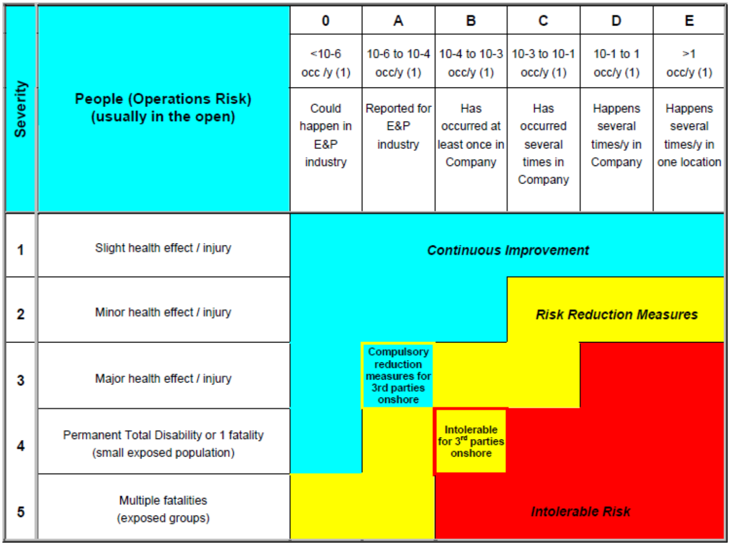


Figure 4 Risk to People Assessment Matrix

From the figure above we know if the risk is on which level. Each level of people effected by the hazard shows in severity level which level are:

1. Slight health effect / injury
2. Minor health effect / injury
3. Major health effect or injury
4. Permanent total disability of or 1 fatality (small exposed population)
5. Multiple fatalities (exposed groups)

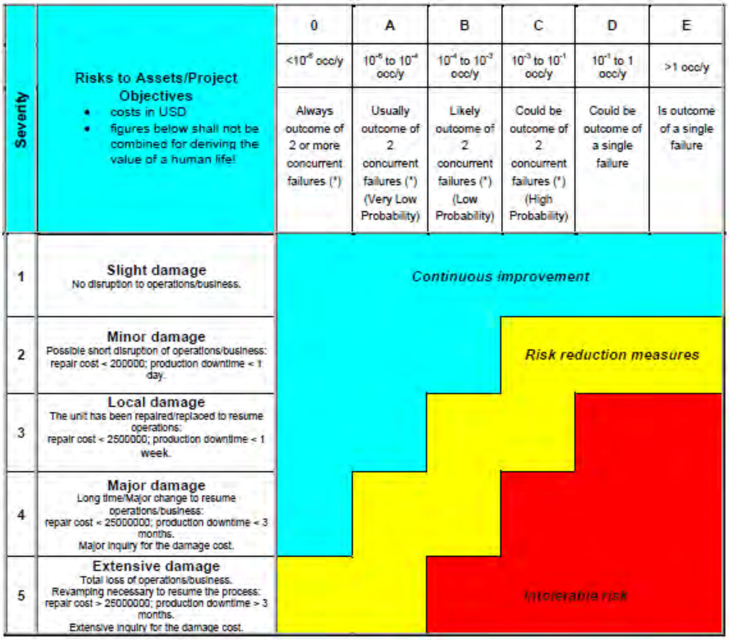


Figure 5 Asset Risk Matrix

From the figure above we know if the risk is on which level. Each level of assets loss effected by the hazard shows in severity level which level are:

1. Slight damage (no disruption to operation and business)
2. Minor damage (possible short disruption of operation business; repair cost = 200000 US$; production downtime = 1 day)
3. Local damage (the unit has been repaired replaced to resume operation; repair cost < 2500000 US$; production downtime < 1 week)

4. Major damage (long time/major change to resume operations/business; repair cost < 25000000 US$; production downtime < 3 months. Major inquiry for the damage cost)
5. Extensive damage (total loss of operations business; revamping necessary to resume the process; repair cost > 25000000 US$; production downtime > 3 months. Major inquiry for the damage cost)

2.2.3. Frequency and Consequence Analysis

Frequency analysis involves estimating the likelihood of occurrence of each failure case. There are several main approaches to estimating frequencies:

- Historical accident frequency data. This uses previous experience of accidents. It is a simple approach, relatively easy to understand, but is only applicable to existing technology with significant experience of accidents and where appropriate records have been kept.

- Fault tree analysis. This involves breaking down an accident into its component causes, including human error, and estimating the frequency of each component from a combination of generic historical data and informed judgment.

- Event tree analysis. This is a means of showing the way an accident may develop from an initiating event through several branches to one of several possible outcomes. The technique is usually used to extend the initiating event frequency estimated by one of the above means into a failure case frequency suitable for combining with the consequence models.

Frequencies are simply calculated by combining accident experience and population exposure, typically measured in terms of installation-years:

Event frequency per installation per year

$$= \frac{\text{Number of Instalation x Years of Exposure}}{\text{Number of Events}}$$

A prime source of data for frequency analysis on this Bachelor Thesis is the Offshore and Onshore Reliability Data (OREDA).

Taxonomy no		Item			
4.3.2.3		Control and Safety Equipment Valves Butterfly Oil systems			
Population	Installations	Aggregated time in service (10^6 hours)		No of demands	
		Calendar time *	Operational time †		
2	1	0.0985	0.0716		

Failure mode	No of failures	Failure rate (per 10^6 hours). Lower	Mean	Upper	SD	n/τ	Active rep.hrs	Repair (manhours) Min	Mean	Max
Critical	**1***	**0.51**	**10.15**	**48.15**	**10.15**	**10.15**	**2.0**	**2.0**	**2.0**	**2.0**
	1†	**0.70**	**13.96**	**66.26**	**13.96**	**13.96**				
Fail to regulate	1*	0.51	10.15	48.15	10.15	10.15	2.0	2.0	2.0	2.0
	1†	0.70	13.96	66.26	13.96	13.96				
Degraded	**1***	**0.51**	**10.15**	**48.15**	**10.15**	**10.15**	**4.0**	**4.0**	**4.0**	**4.0**
	1†	**0.70**	**13.96**	**66.26**	**13.96**	**13.96**				
External leakage - Utility medium	1*	0.51	10.15	48.15	10.15	10.15	4.0	4.0	4.0	4.0
	1†	0.70	13.96	66.26	13.96	13.96				

Figure 6 Example Data Record from OREDA 2002

Estimation of the consequences of each failure case is necessary to complete the analysis of the risks. The approach usually differs for each type of hazard. For this Bachelor Thesis, consequence analysis will be use ALOHA software to determine consequence which could be arise from all hazard.

2.2.4. Mitigation

On the off chance that there are any unsuitable danger on the situation, than those danger will be investigation for moderation act to lessen the danger. Relief investigation technique for this Bachelor Thesis is Layers of Protection Analysis.

Layers of assurance investigation (LOPA) is a semi-quantitative procedure that can be utilized to recognize shields that meet the free security layer (IPL). The IPL is equipped for identifying and averting or alleviating the outcomes of determined, conceivably dangerous event(s, for example, a runaway response, loss of regulation, or a blast. An IPL is free of the various security layers connected with the distinguished possibly perilous occasion. Autonomy requires that the execution is not influenced by the disappointment of another insurance layer or by the conditions that created another assurance layer to fall flat. In particular, the insurance layer is free of the starting cause. The assurance gave by the IPL lessens the recognized danger by a known and indicated sum (Summers, 2002).

2.3. Previous Research

The Previous Research about safety assessment of fuel system on dual fuel engine of ship had been done by:

1. Arfi, A. A., Pitana, T., Prastowo, H., “Analisa Fire Risk Assessment Pada Kapal Penumpang (Studi Kasis Rancangan Kapal 5000 GT Milik Dinas Perhubungan Darat)”, Jurnal ITS

Department of Marine Engineering, Institut Teknologi Sepuluh Nopember, pp. 1-9, Surabaya

Ship accident caused by fire in 2011 happened 25 times. 9 accidents contributed by passenger ship. Based on KNKT database the fire location where mostly at vehicle deck and engine room. Based on information above, this paper discusses about analysis of fire risk assessment at design of ferry 5000GT that owned by Dinas Perhubungan Darat that will be build at 2012. This ship has 6 deck assembly, 3 vehicle decks and 2 passenger decks with maximum capacity until 820 passengers. The analysis process were done by 5 steps. Designing of fire and safety plan arrangement early, hazard identification, evacuation identification, risk evaluation and analysis of evaluation and solution. Hazard identification use preliminary hazard analysis method. Evacuation route evaluation were done by pathfinder program and effectivity of automatic firefighting equipment were done by FDS program. The result of the simulation show that evacuation route from fire and safety plan arrangement could be accepted with person density 1,8 per /m2 and response time 50 s . Simulation of automatic fire extinguishers show that heat release rate from vehicle deck01's fire decrease from 25

MW to 0,5 MW, from vehicle deck02’s fire from 1,6 MW to 4 MW and from 1,5 MW to 0 MW at engine room.

"This Page Intentionally Left Blank"

CHAPTER III
RESEARCH METHODOLOGY

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

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

2. **Study of literature.**
   Study literature is step about learning an object, the method, and material that used in this thesis. Study literature are obtain from books, journals, website, etc.

3. **Data collection.**
   This phase is to obtain information about firefighting system inside FPU ship.

4. **Fire Hazard identification.**
   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.

5. **Identify Fire Hazard Scenario.**
   Identify the potential failure mode of the process, the potential effect of a failure, and the potential cause of the potential failure mode.

6. **Frequency Analysis, Consequence Analysis and Detection Analysis.**
   Analysis of the data in order to determine the levels of frequency, consequence, and detection and calculate the results of risk priority number (RPN).

7. **Risk Evaluation.**
   Evaluate the risk, knowing the risk acceptable or not acceptable based on risk ranking table.

8. **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.

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

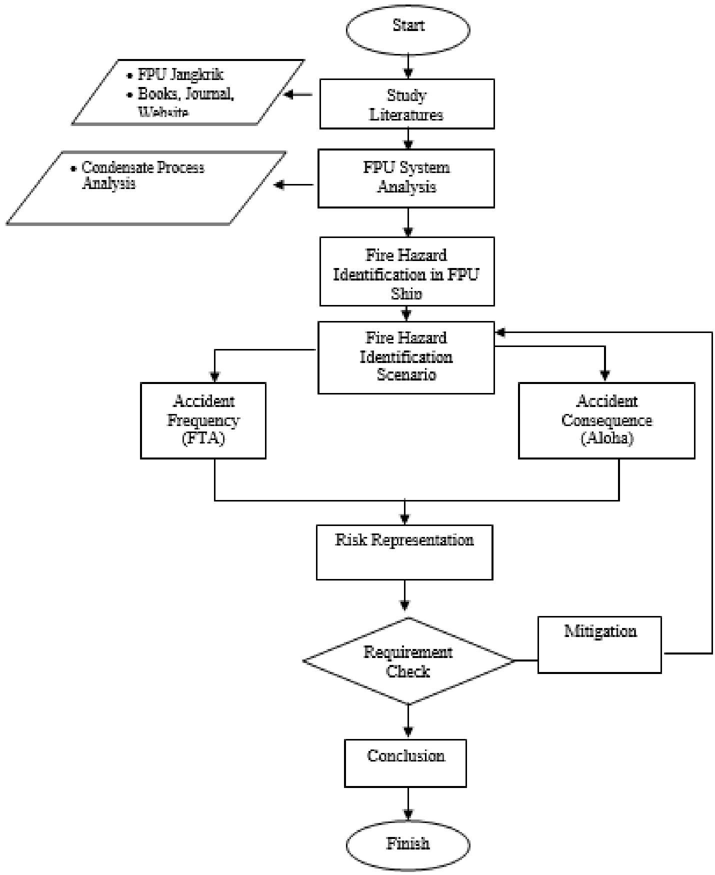


Figure 7 Methodology Flowchart

"This Page Intentionally Left Blank"

CHAPTER IV
DATA ANALYSIS AND FINDINGS

4.1. Data Analysis

In this data analyze we analyze the data of the ship, and data to process the scope of problems.

4.1.1. Floating Production Unit Data

Name	: Jangkrik Floating Production Unit
Type	: FPU
Length Overall	: 200 m
Breadth	: 46 m
Depth (side)	: 15 m
Depth (center)	: 15.3 m
Max Operating Draught	: 9 m
Min Operating Draught	: 6 m

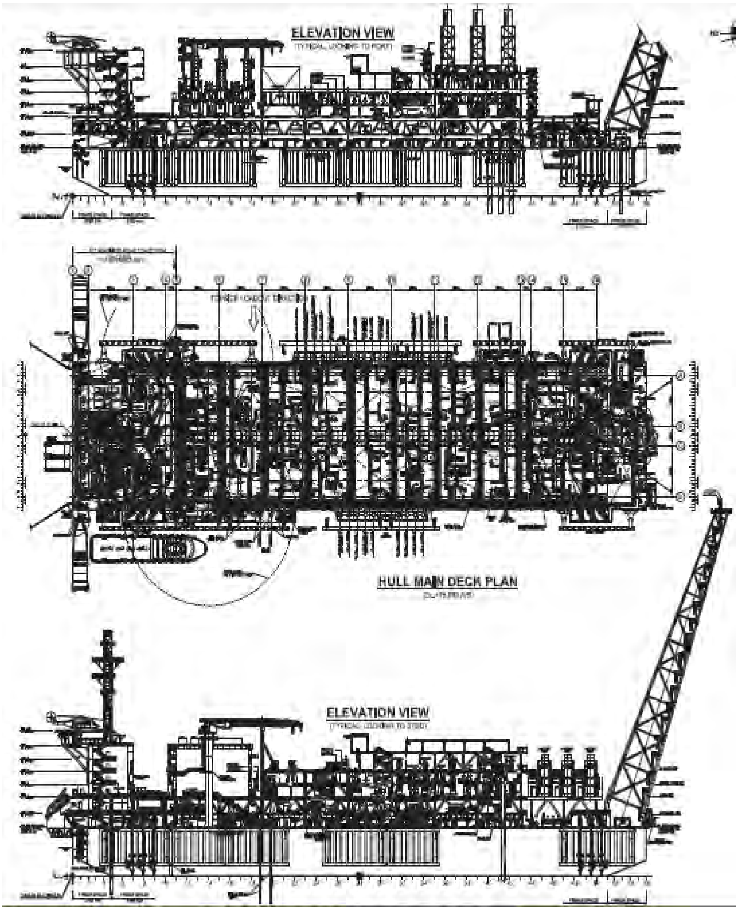


Figure 8 General Arrangement of Jankrik FPU

On the FPU there are divide into two, Topside process and Hull process. On the FPU there are condensate liquid process and gas process. On the condensate liquid process there are many process to purify the condensate liquid into the conditions that acceptable. The hydrocarbon from the well going to the FPU, then separate into the condensate liquid and gas.

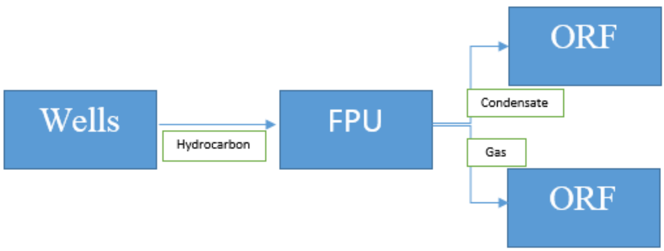


Figure 9 Flow Chart of Flow Process on Jangkrik Site

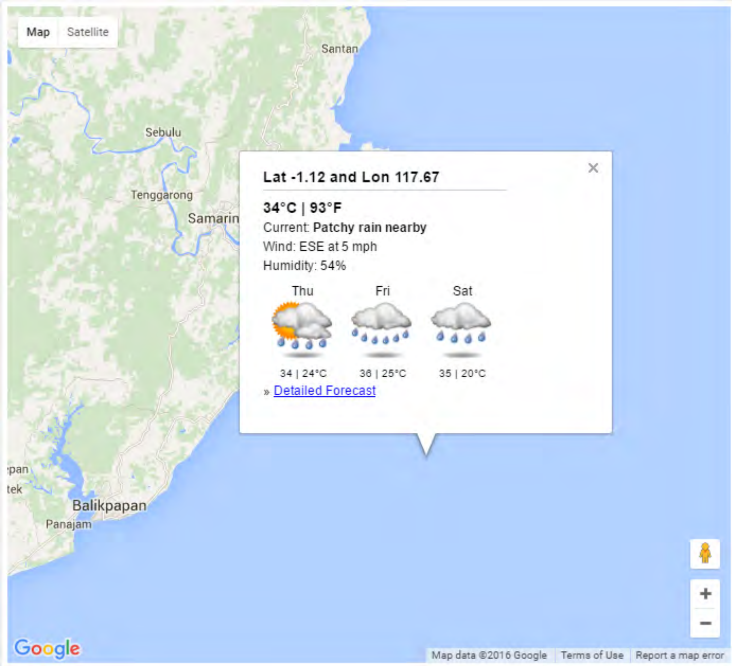
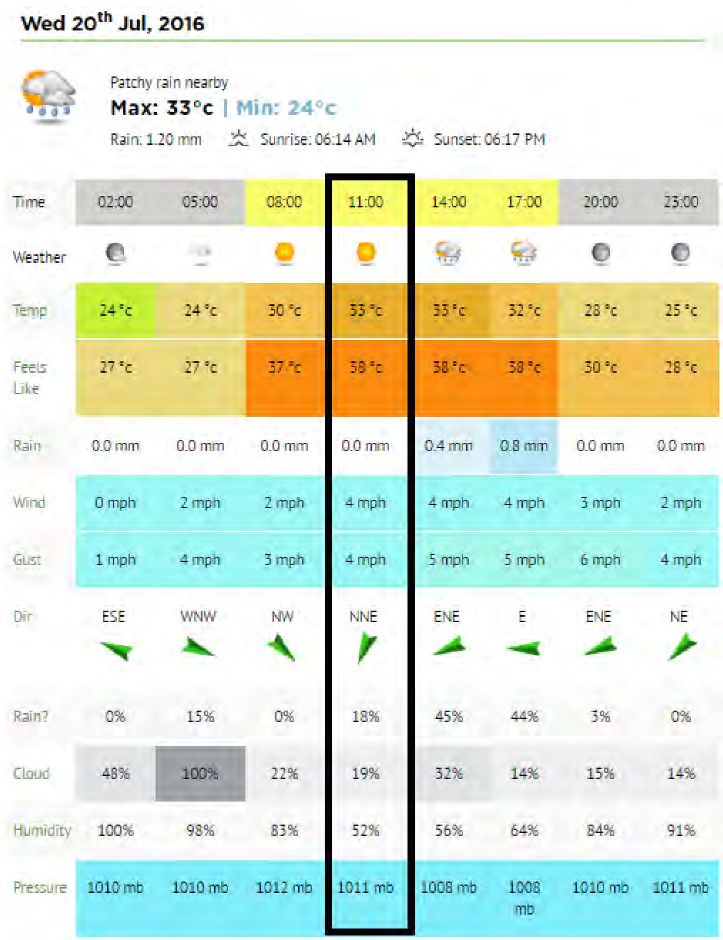


Figure 10 Location of Jangkrik FPU on Maps

The FPU located in Muara Bakau working area, in Makassar Straits offshore Kalimantan, Indonesia, approximately 70 kilometers from Balikpapan.



Wed 20th Jul, 2016

Patchy rain nearby

Max: 33°c | Min: 24°c

Rain: 1.20 mm Sunrise: 06:14 AM Sunset: 06:17 PM

Time	02:00	05:00	08:00	11:00	14:00	17:00	20:00	23:00
Weather								
Temp	24 °c	24 °c	30 °c	33 °c	33 °c	32 °c	28 °c	25 °c
Feels Like	27 °c	27 °c	37 °c	38 °c	38 °c	38 °c	30 °c	28 °c
Rain	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.4 mm	0.8 mm	0.0 mm	0.0 mm
Wind	0 mph	2 mph	2 mph	4 mph	4 mph	4 mph	3 mph	2 mph
Gust	1 mph	4 mph	3 mph	4 mph	5 mph	5 mph	6 mph	4 mph
Dir	ESE	WNW	NW	NNE	ENE	E	ENE	NE
Rain?	0%	15%	0%	18%	45%	44%	3%	0%
Cloud	48%	100%	22%	19%	32%	14%	15%	14%
Humidity	100%	98%	83%	52%	56%	64%	84%	91%
Pressure	1010 mb	1010 mb	1012 mb	1011 mb	1008 mb	1008 mb	1010 mb	1011 mb

Figure 11 Weather Condition at Latitude -1.12 and Longitude 117.67 (Jangkrik FPU Site)

The weather for this is risk assessment is take on summer season (20th July 2016) located at Lat -1.12 and Lon 117.67.

4.1.2. Process of Condensate

There are many process for condensate to meet the specific requirement then go to the Onshore Receiving Facilities (ORF).

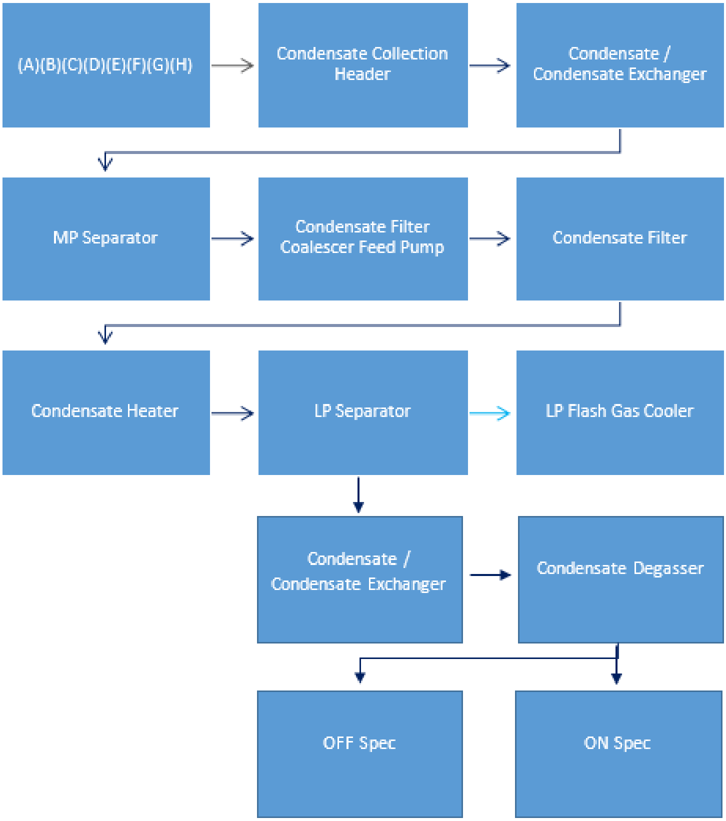


Figure 12 Diagram of Condensate Process

(A) : Booster Compression Suction Scrubber Train 1/2/3
(B) : Low Temperature Separation Train 1/2/3
(C) : JKK Main Slug Catcher
(D) : JKK North East Slug Catcher
(E) : HP Fuel Gas KO Drum
(F) : Flash Gas Condensate Recycle Pumps
(G) : OFF Spec Condensate Re-Run Pumps
(H) : Closed Drain Pumps

From the Table of process above the hydrocarbon trough ten process to meet the specification of the condensate then go to on spec condensate before go to the ORF.

- Condensate collection Header P&ID

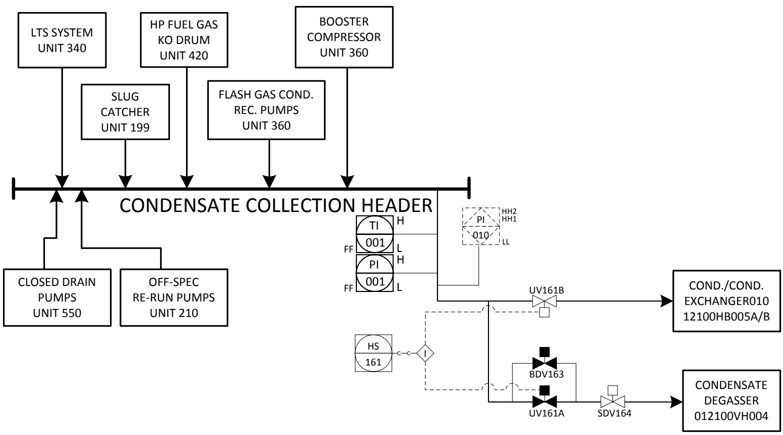


Figure 13 P&ID of Condensate Collection Heaser

Components:

UV161B : Gate Valve Normally Open

SDV164 : Shut Down Valve

Sensors and Indicators:

TI : Temperature Indicator
PI : Pressure Indicator
HS : Level Indicator

- Condensate / Condensate Exchanger

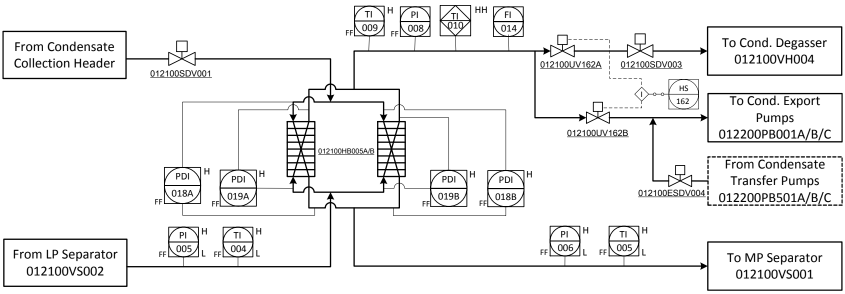


Figure 14 P&ID of Condensate / Condensate exchanger

Components:

SDV001 : Shut Down Valve

Sensors and Indicators:

TI : Temperature Indicator
PI : Pressure Indicator
PDI : Pressure Differential Indicator

- MP Separator

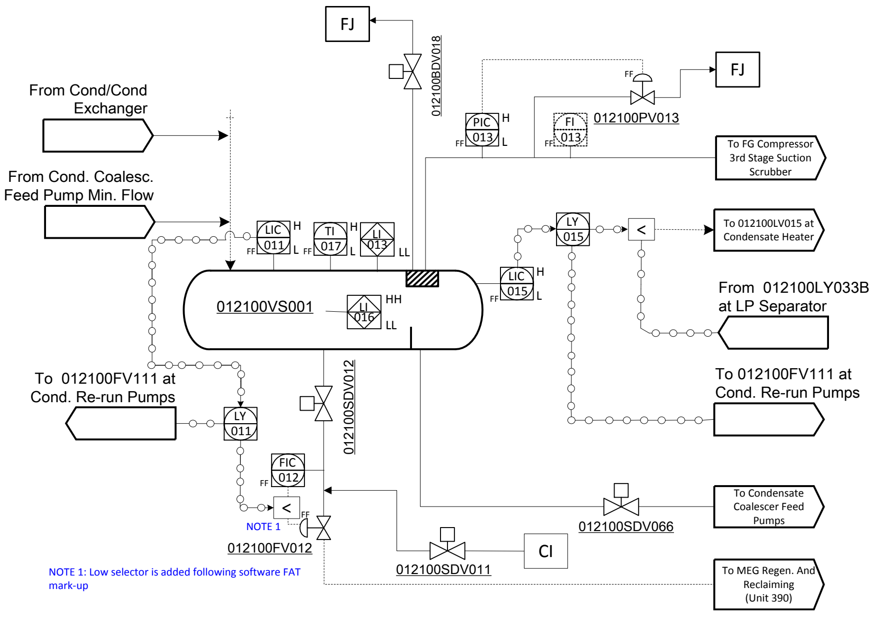


Figure 15 P&ID of MP Separator

Components:

VS001 : MP Separator
SDV : Shut Down Valve

Sensors and Indicators:

TI : Temperature Indicator

- Condensate Filter Coalescer Feed Pumps

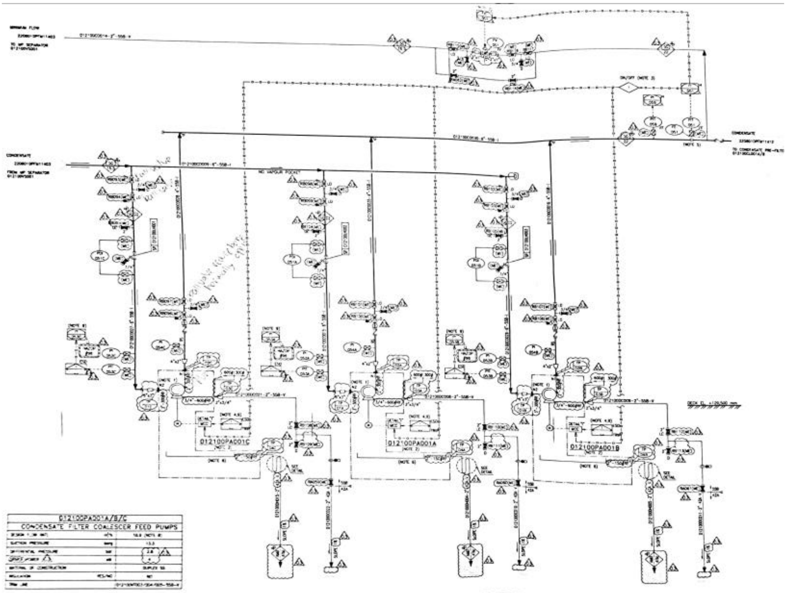


Figure 16 P&ID Condensate Filter Coalescer Feed Pumps

Components:

RB : Ball Valve
PA001 : Condensate Filter Coalescer Feed Pump

Sensors and Indicators:

PI : Pressure Indicator

- Condensate Filter

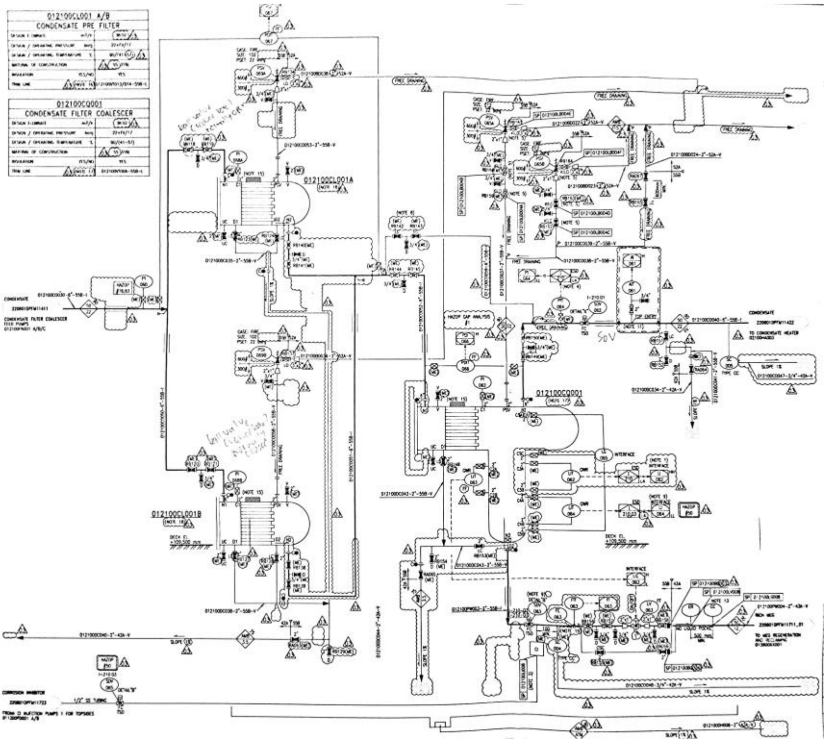


Figure 17 P&ID Condensate Fillter

Components:

CL001 : Condensate Filter
RB : Ball Valve (reduce bore)

Sensors and Indicators:

PI : Pressure Indicator

- Condensate Heater

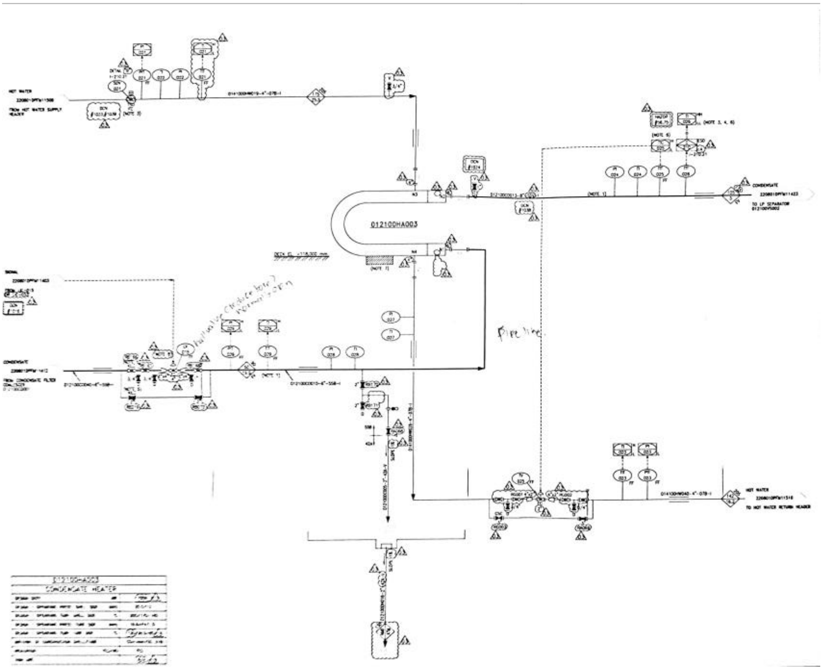


Figure 18 P&ID Condensate Heater

Components:

HA003 : Condensate Exchanger

LV : Ball Valve (reduce bore)
RB : Ball Valve

Sensors and Indicator:

PI : Pressure Indicator
TI : Temperature Indicator

- LP Separator

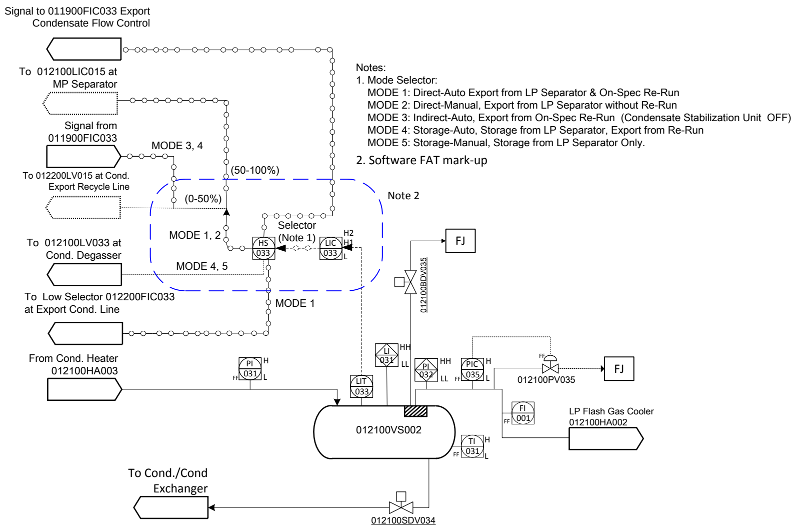


Figure 19 P&ID LP Separator

Components:

VS002 : LP Separator
SDV : Shut Down Valve

Sensors and Indicator

PI : Pressure Indicator
TI : Temperature Indicator

- Condensate Degasser

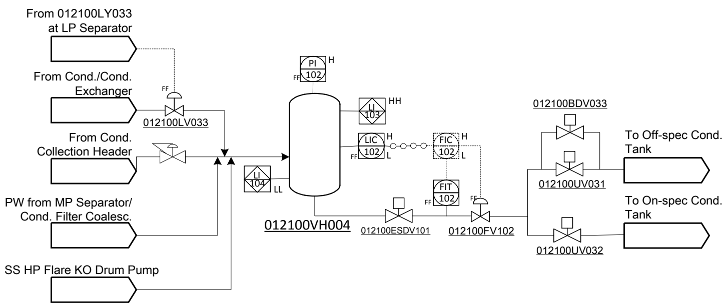


Figure 20 P&ID Condensate Degasser

Components:

VH004 : Condensate Degasser
SDV : Shut Down Valve
FV : Butterfly Valve
UV : Ball Valve

Sensors and Indicators:

PI : Pressure Indicator
LI : Level Indicator

- Off Spec Tanks

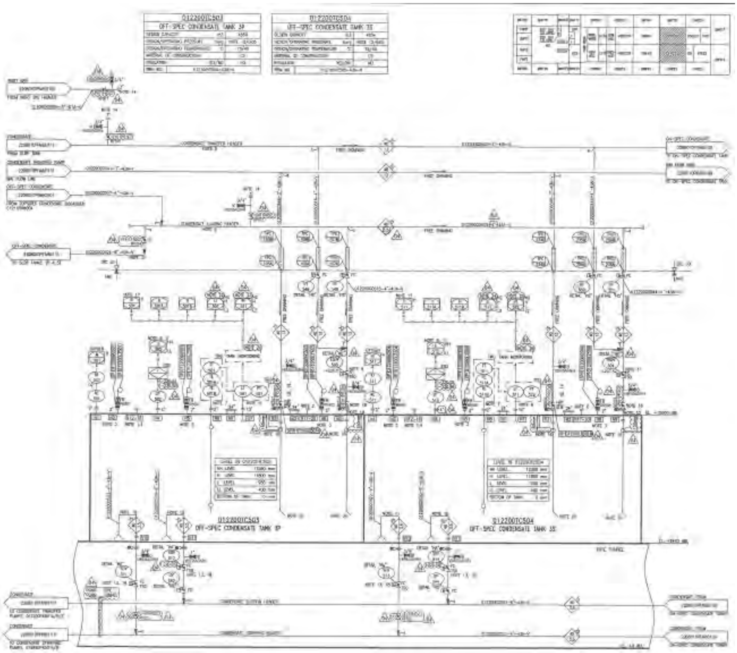


Figure 21 P&ID Off Spec Tanks

Components:

TC50 : Off Spec Condensate Tanks
SDV : Shut Down Valve

Sensors and Indicators:

PI : Pressure Indicator
TI : Temperature Indicator

- On Spec Condensate Tanks

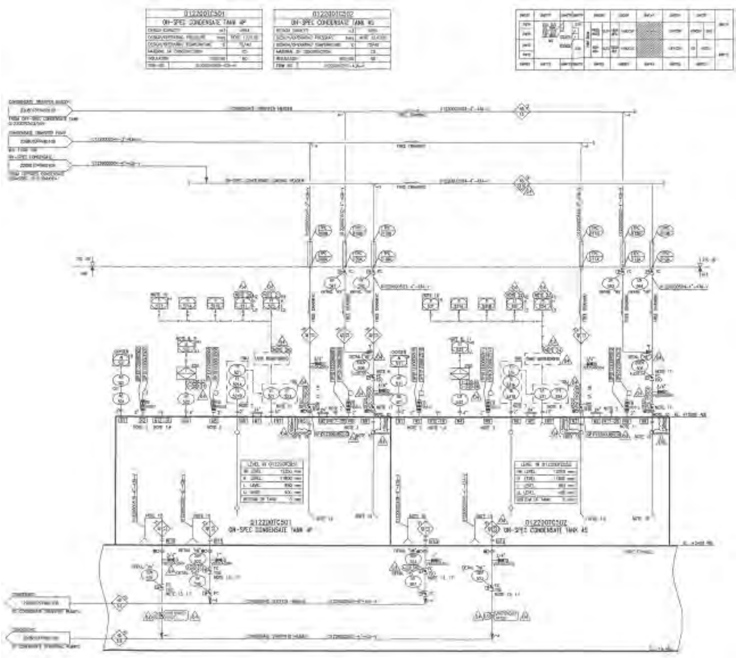


Figure 22 P&ID On Spec Tanks

Components:

TC50 : On Spec Condensate Tanks
SDV : Shut Down Valve

Sensors and Indicators:

PI : Pressure Indicator
TI : Temperature Indicator

4.2. Risk Assessment

There are three step of risk assessment has to be done, there are:

- Risk identification is the process of determining risk that could potentially prevent the program to achieving the objectives;
- Risk analysis is the process of analyzing the level of dangers to environment posed by potential risk events;
- Risk evaluation is the process used to compare the estimated risk against the given risk criteria so as to determine the significance of the risk whether the risk is acceptable or tolerable.

4.2.1. Risk Identification

The first step of risk assessment is risk identification. Risk identification in this bachelor thesis is identify and understand all the object of the process for the assessment. The result of risk identification is the scenario of failure mode. All of the scenario of the failure mode is on HAZOP worksheet as seen as figure below or on the attachment.

For the example is the risk identification of condensate process from condensate collection header to condensate exchanger. The part of the system selected for examination is the line from the condensate collection header with material is condensate to the condensate exchanger, this process has function to increase the temperature of the condensate to meet the requirement.

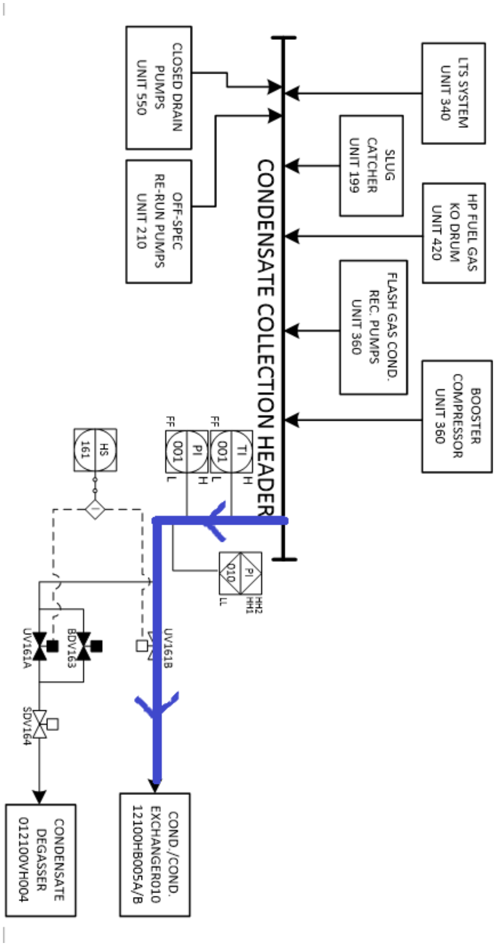


Figure 23 Condensate Flow from Condensate Collection Header to Condensate Exchanger

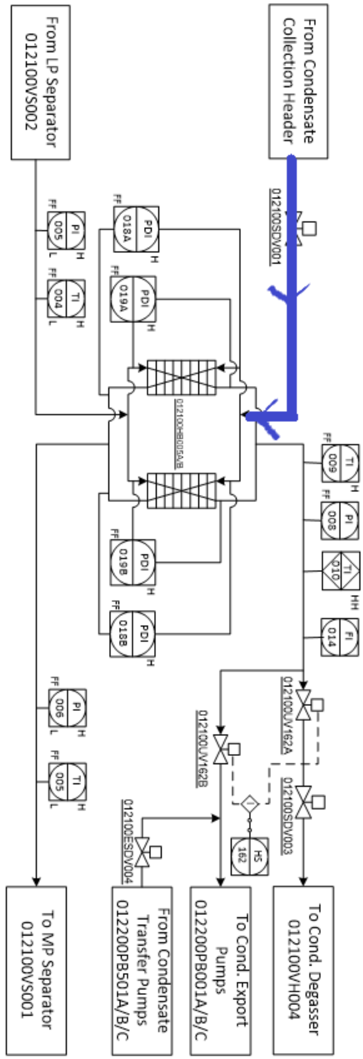


Figure 24 Condensate flow to Condensate Exchanger

The next step is identify the element on the process and determine the design intent. Then decide the Guide Word and Element for obtaining Deviation, as shown on the figure below.

After obtaining Deviation, the next step is determine cause, consequence and protection based on the arrangement. For the consequence which has possibility of gas leakage or explosion will use ALOHA software.

STUDY TITLE: Condensate process from condensate collection header to condensate exchanger											SHEET: 1 of 2	
Drawing No.: 11401			REV. No.:								DATE: 17 - 06 - 2016	
PART CONSIDERED:			Preheat the unstable condensate									
DESIGN INTENT: Normal pressure 25.1 (bar)			Material: Condensate				Activity: pre heated in condensate exchanger					
			Source: condensate collection header				Destination: condensate exchanger					
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required	
1	NO	Condensate	no condensate transfer to condensate exchanger	SDV-001 fails in controlled			no condensate flow on condensate exchanger will be delayed the process					
				Loss of power			no condensate flow on condensate exchanger will be delayed the process					
2	LESS	Condensate	Less condensate transfer to condensate exchanger	Pipeline leakage from condensate collection header trough condensate exchanger			no condensate flow on condensate exchanger will be delayed the process					

4.2.2. Risk Analysis

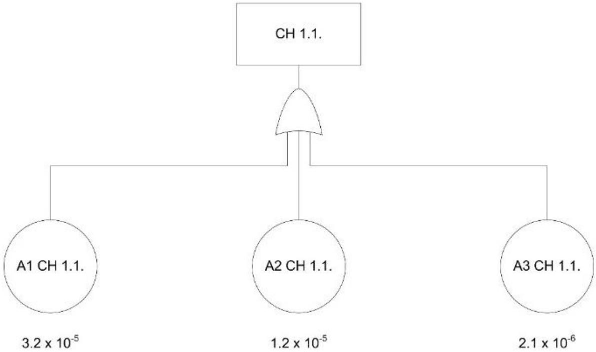
The second step is risk analysis. Risk analysis is analyze the level of frequency and consequence that maybe occurred on system. For example is the result of condensate process from condensate collection header to condensate exchanger from HAZOP.

Frequency value is decided by FTA method. For basic event value are obtained from OREDA 2002. After obtained the value of Failure Rates and Probability of Failure, the value will be matched to the risk matrix description of probability level.

The FTA method is start from the main event on HAZOP worksheet. For each cause will be given a code to simplify the process. For example, SDV 001fails in controlled.

A1 CH 1.1.

A	: First level contributor (It will following alphabet for the next level)
1	: First contributors (It will following numerical order for the next causes)
CH	: System which have to identify from HAZOP Worksheet (in one HAZOP code)
1	: Failure mode’s number, based on HAZOP worksheet
1	: Potential cause order



SDV-001 fails in controlled (CH 1.1.)

A1: Fail to open on demand
A2: Spurious Operation
A3: Structural Deficiency

The value of each event are decided based on gate type. Failure Probability for Basic Event will obtained from Failure Rates value. For example of CH 1.1. First calculate the value of each basic event:

- A1 CH 1.1.

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

  P: Failure Probability
  λ: Failure Rate (OREDA 2002: 3.46×10^{-6})
  T: Exposure Interval (OREDA 2002: 9.3247)

$P_{A1} = 1 - e^{-(3.46 \times 10^{\wedge}-6) \times 9.3247} = 3.2 \times 10^{-5}$

- A2 CH 1.1.

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

  P: Failure Probability
  λ: Failure Rate (OREDA 2002: 1.36×10^{-6})
  T: Exposure Interval (OREDA 2002: 9.3247)

  $P_{A2} = 1 - e^{-(1.36 \times 10^{\wedge}-6) \times 9.3247} = 1.2 \times 10^{-5}$

- A3 CH 1.1.

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

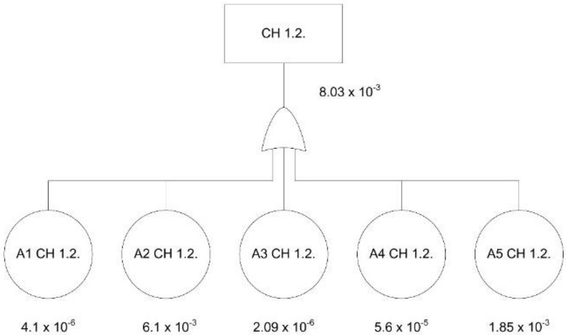
  P: Failure Probability
  λ: Failure Rate (OREDA 2002: 0.23×10^{-6})
  T: Exposure Interval (OREDA 2002: 9.3247)

  $P_{A3} = 1 - e^{-(0.23 \times 10^{\wedge}-6) \times 9.3247} = 2.1 \times 10^{-6}$

After finish with all basic event, then calculate the top event based on the gate.

CH 1.1. = $CH_{A1} + CH_{A2} + CH_{A3} - CH_{A1}CH_{A2} - CH_{A1}CH_{A3} - CH_{A2}CH_{A3} + CH_{A1}CH_{A2}CH_{A3}$

CH 1.1. = $(3.2 \times 10^{-5}) + (1.2 \times 10^{-5}) + (2.1 \times 10^{-6}) - (3.2 \times 10^{-5})(1.2 \times 10^{-5}) - (3.2 \times 10^{-5})(2.1 \times 10^{-6}) - (1.2 \times 10^{-5})(2.1 \times 10^{-6}) + (3.2 \times 10^{-5})(1.2 \times 10^{-5})(2.1 \times 10^{-6}) = 4.61 \times 10^{-5}$



Loss of Power (CH 1.2.)

A1: Breakdown

A2: Fail to start on demand

A3: Fail to Synchronize

A4: Low output

A5: Spurious stop

After Obtaining all the value of frequency, the next step is determine the level of consequence. To determine the level of consequence will used ALOHA software and ENI Risk Matrix Table of Asset Risk Matrix and People Risk Matrix.

ALOHA has function to knowing the area of an explosion or gas leakage based on chemical properties and environment condition. ALOHA result will be plotted to general arrangement drawing to knowing if there are any victim on that area or not. The complete result from ALOHA has attached on Attachment.

For example on HAZOP worksheet of Condensate process from condensate collection header to Condensate exchanger there are consequence of pipe leakage and explosion, then will be used ALOHA software to know the consequence.

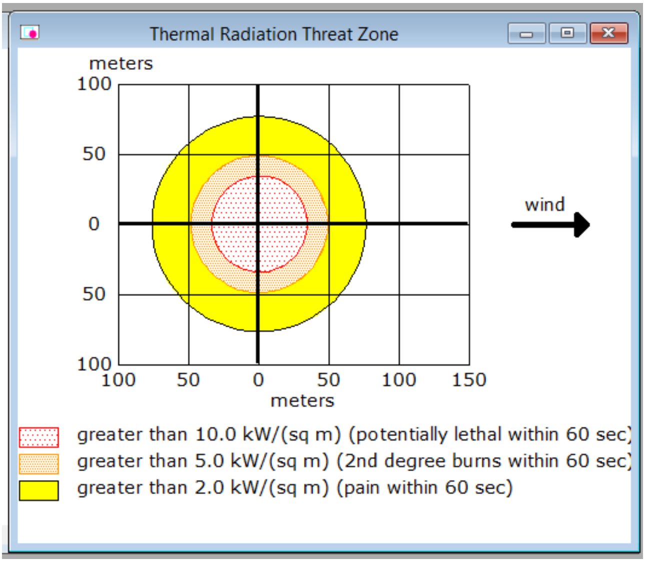


Figure 25 Threat Zone of Risk using ALOHA Software

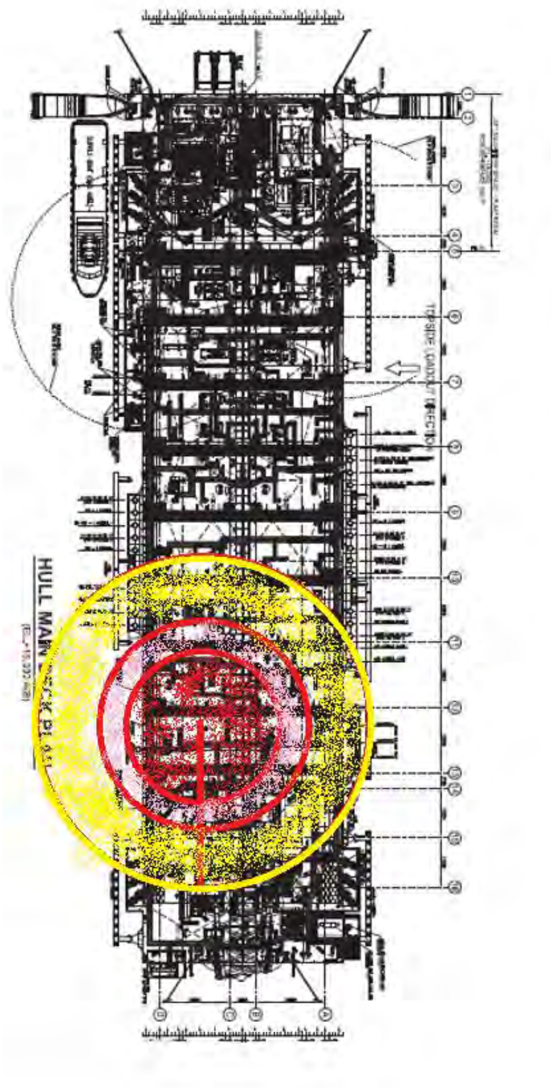


Figure 26 Threat Zone Result on Ship General Arrangement

4.2.3. Risk Evaluation

The third step is risk evaluation. Risk evaluation is evaluate the probability level and severity level of the risk. On this case, will be given an example from failure mode on SDV-001 fails in controlled. Based on risk analysis this failure mode has probability level on A level and severity level on 2 level. Then those result will be plotted on ENI Risk Matrix.

STUDY TITLE: Condensate process from condensate collection header to condensate exchanger							
Drawing No.: 11401			REV. No.:				
PART CONSIDERED:			Preheat the unstabilize condensate				
DESIGN INTENT: Normal pressure 25.1 (bar)			Material: Condensate				Activity: pre hea
			Source: condensate collection header				Destination: co
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences
1	NO	Condensate	no condensate transfer to condensate exchanger	SDV-001 fails in controlled	4.61×10^{-5}	A	no condensate flow on condensate exchanger will be delayed the process
							no condensate

Figure 27 Failure mode on SDC-001 Fails in Controlled

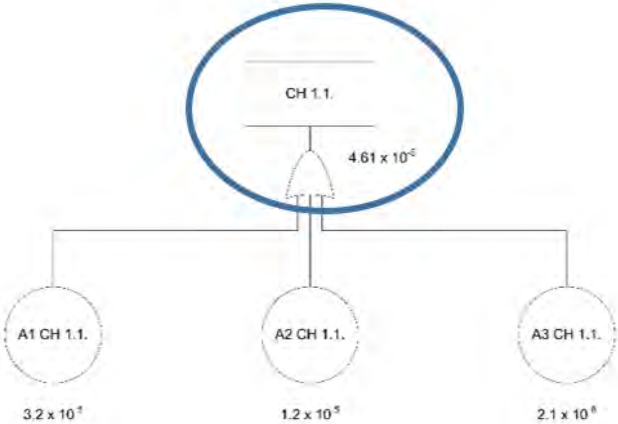


Figure 28Frequency of SDV-001 Fails in Controlled

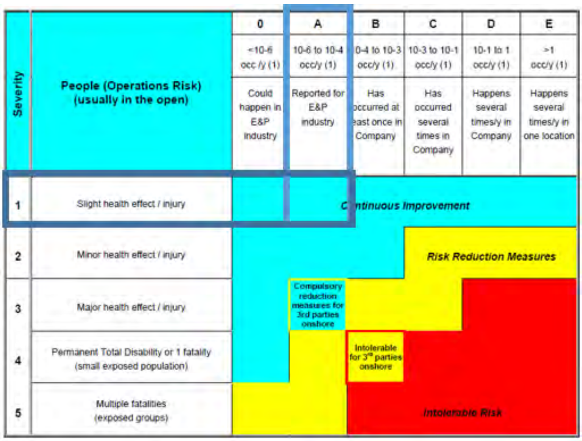


Figure 29 Probability and Severity Level at People Risk Matrix

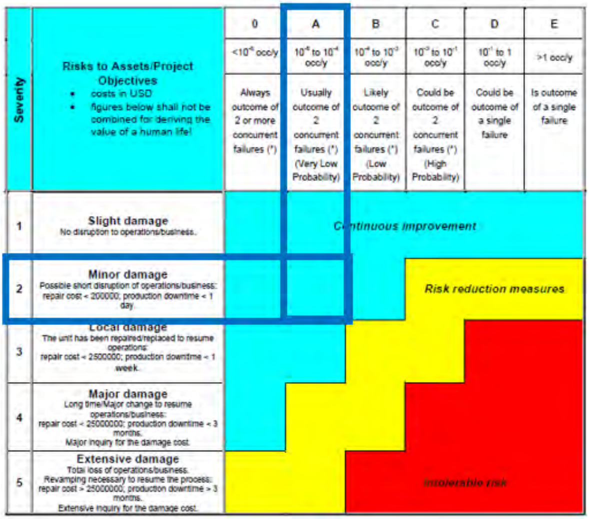


Figure 30 Probability and Severity Level on Asset Risk Matrix

From the figure above, there are a different value of severity level at People Risk Matrix and Asset Risk Matrix. From that different value we have to choose the higher value of severity because it present the worst effect of the severity value. The result will be on the figure below.

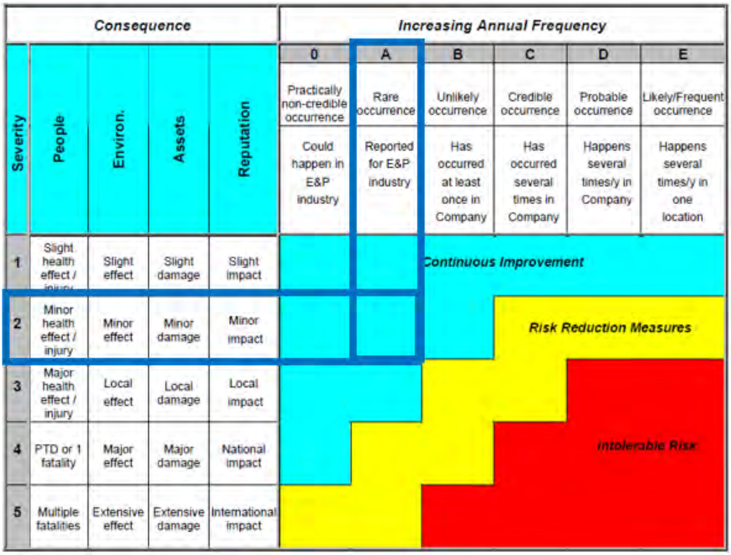


Figure 31 Result of the Failure on SDV-001 Fails in Controlled

Every color has a meaning, where:

- Continuous improvement (blue color): The level of risk is broadly acceptable and generic control measures are required aimed at avoiding deterioration.
- Risk reduction measure (yellow color): The level of risk can be tolerable only once a structured review of risk reduction measures has been carried out (where necessary, the relevant guidance from the local Authorities should be adopted for application of ALARP). ALARP is a concept that applies well only to personnel risk. For environmental risk the concept of BPEO is more frequently applied. Asset risk is often most easily judged on a basis of costs and benefits alone.

- Intolerable risk (red color): The level of risk is not acceptable and risk control measures are required to move the risk figure to the previous regions.

The result from risk matrix shown that the Failure on SDV-001 fails in controlled has a level of risk on continuous improvement (blue color) level. That is mean these is acceptable. If there is unacceptable risk, the risk must reduce, and the mitigation using LOPA method.

This figure below is the example worksheet of condensate process from condensate collection header to condensate exchanger. The other evaluation will be attached on Attachment.

STUDY TITLE: Condensate process from condensate collection header to condensate exchanger										SHEET: 1 of 2	
Drawing No.: 11401			REV. No.:							DATE: 17 - 06 - 2016	
PART CONSIDERED:			Preheat the unstable condensate								
DESIGN INTENT: Normal pressure 25.1 (bar)			Material: Condensate				Activity: pre heated in condensate exchanger				
			Source: condensate collection header				Destination: condensate exchanger				
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required
1	NO	Condensate	no condensate transfer to condensate exchanger	SDV-001 fails in controlled	4.61×10^{-5}	A	no condensate flow on condensate exchanger will be delayed the process	2	TI 004; PI 005	Continous Improvement	
				Loss of power	8.031×10^{-3}	B	no condensate flow on condensate exchanger will be delayed the process	2	TI 004; PI 005	Continous Improvement	
2	LESS	Condensate	Less condensate transfer to condensate exchanger	Pipeline leakage from condensate collection header trough condensate exchanger	7.4×10^{-6}	0	no condensate flow on condensate exchanger will be delayed the process	3	TI 004; PI 005	Continous Improvement	

STUDY TITLE: Condensate process from condensate collection header to condensate exchanger										SHEET: 2 of 2	
Drawing No.: 11401			REV. No.:							DATE: 17 - 06 - 2016	
PART CONSIDERED:			Preheat the unstable condensate								
DESIGN INTENT: Normal pressure 25.1 (bar)			Material: Condensate				Activity: pre heated in condensate exchanger				
			Source: condensate collection header				Destination: condensate exchanger				
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required
3	MORE	Condensate	More condensate transfer to condensate exchanger	SDV-001 fails in closed position	5.4×10^{-5}	A	Excessive pressure on condensate exchanger pipeline	2	TI 004; PI 005	Continous Improvement	

4.3. Mitigation

After all the risk assessment step, the last step is mitigation. Mitigation is a step to reduce or prevent the unacceptable risk to be happened. Mitigation in this thesis will be used in risk reduction measure level and intolerable risk level.

This Mitigation on this thesis will be using LOPA method. LOPA method using the scenario of risk on HAZOP worksheet. LOPA method will be reducing the probability of the event risk that occurred so the level on the risk matrix will be reduce too.

The first step on LOPA method is determine the scenario and the probability value that exist on the HAZOP worksheet. Next step is, list all the equipment for the detection of the failure that has been apply on the process system. The equipment is the IPL on the LOPA method. On the IPL of LOPA method there will be PFD value. The PFD value of IPL we can get it from OREDA.

The example of LOPA method will be shown in this figure below. This example of LOPA method is from failure mode “no condensate flow on pipeline from condensate exchanger to MP separator” scenario.

Scenario No. 1	No condensate flow on pipeline from condensate exchanger to MP separator		Node No. 1
Date: 20 June 2016	Description	Probability	Frequency (per year)
Consequence description/ Category	No condensate flow to MP separator		
Risk Tolerance Criteria	Action required		$>10^{-6}$
	Tolerable		$<10^{-4}$
Initiating event	No condensate flow on pipeline		7.4×10^{-5}
Frequency of Unmitigated Consequence			7.4×10^{-5}
Independent Protection Layers	Pressure indicator	4.6×10^{-6}	
	Temperature indicator	8×10^{-6}	
Total PFD		3.68×10^{-10}	
Frequency of Mitigated Consequence			2.72×10^{-15}
Risk Tolerance Criteria Met? (Yes/ No)		Yes	
Action required to meet Risk Tolerance Criteria	1. Pressure indicator installed		
	2. Temperature indicator installed		

Figure 32 Result of LOPA Method

From the picture above we know that the probability of failure mode on "no condensate flow on pipeline from condensate exchanger to MP separator" decrease from 7.4×10^{-5} to 2.72×10^{-15}.

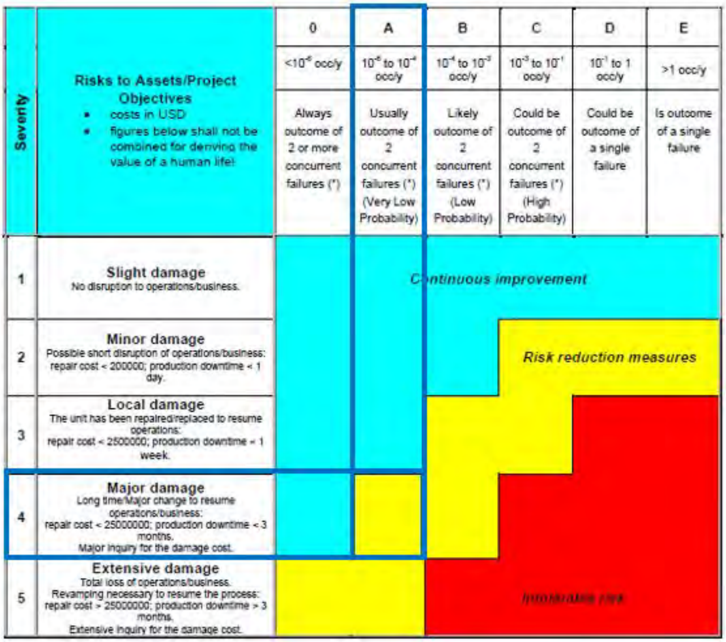


Figure 33 Risk Matrix result before the mitigation using LOPA method

From the picture above we know that the risk matrix before the mitigation using LOPA method. It shows that the result is on the Risk reduction measure level (yellow color), so the failure mode must be reduce to the continuous improvement level (blue color).

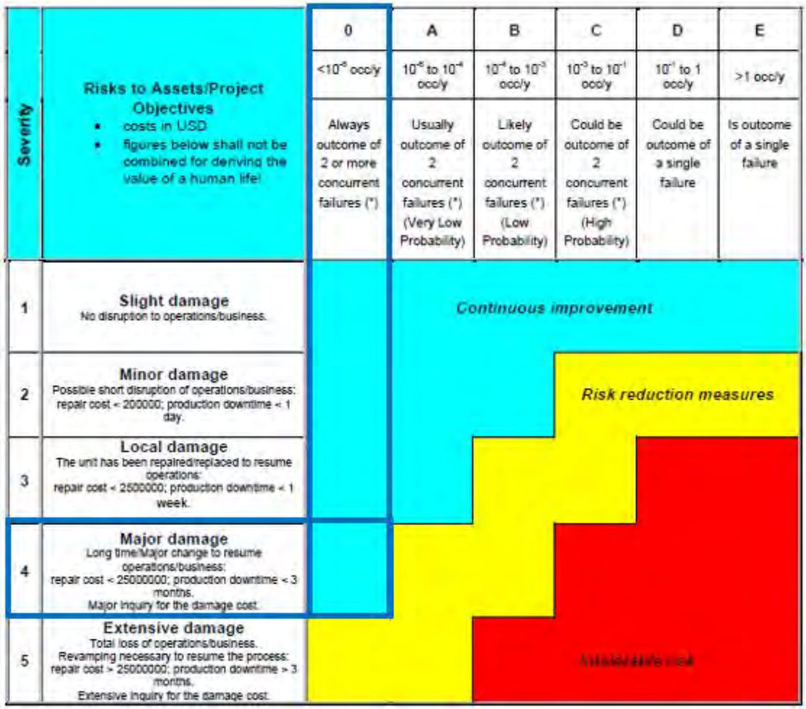


Figure 34 Risk Matrix level after the mitigation using LOPA

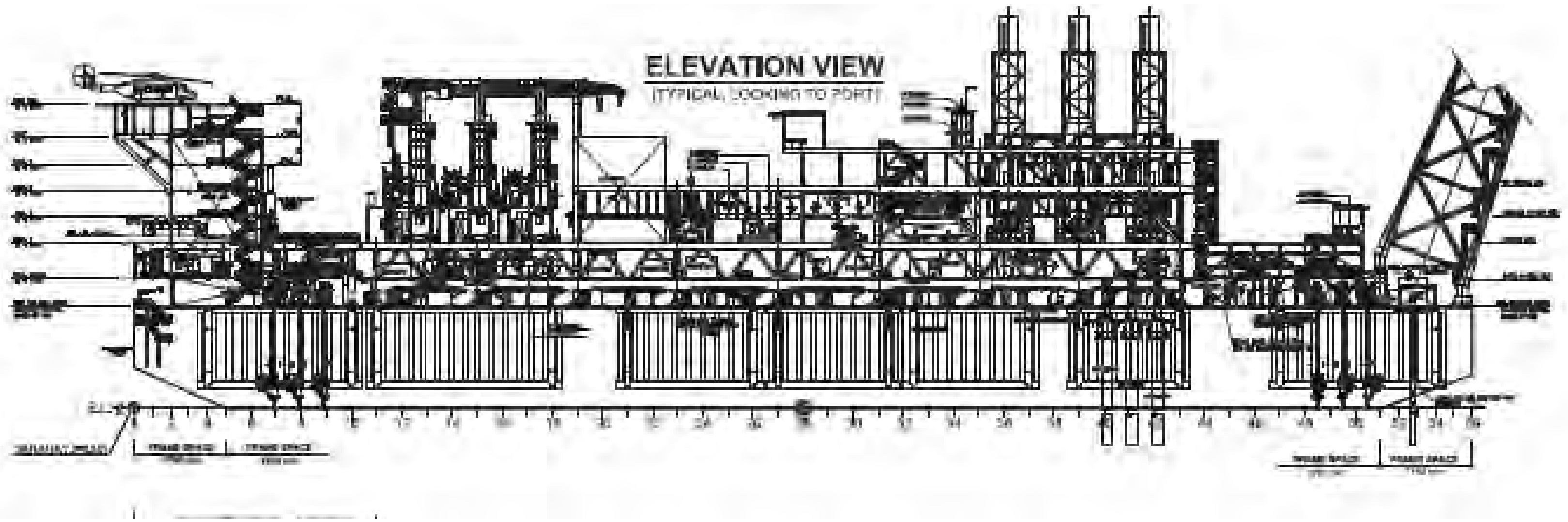
From the picture above we know that the risk matrix after the mitigation using LOPA method. It shows that the result is on continuous improvement level (blue color), because the probability value is 2.72×10^{-15} and fall in the 0 level of probability.

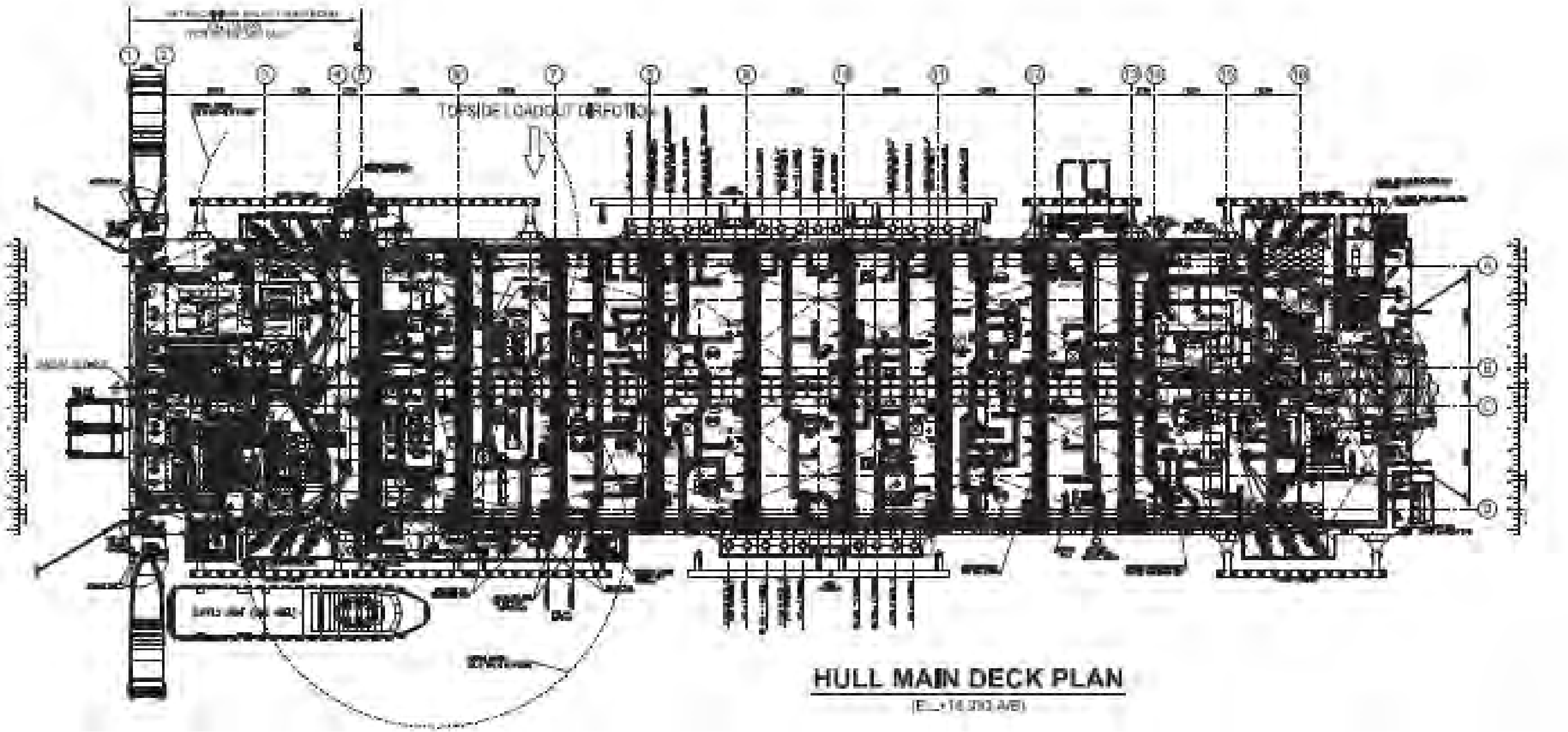
“This Page Intentionally Left Blank”

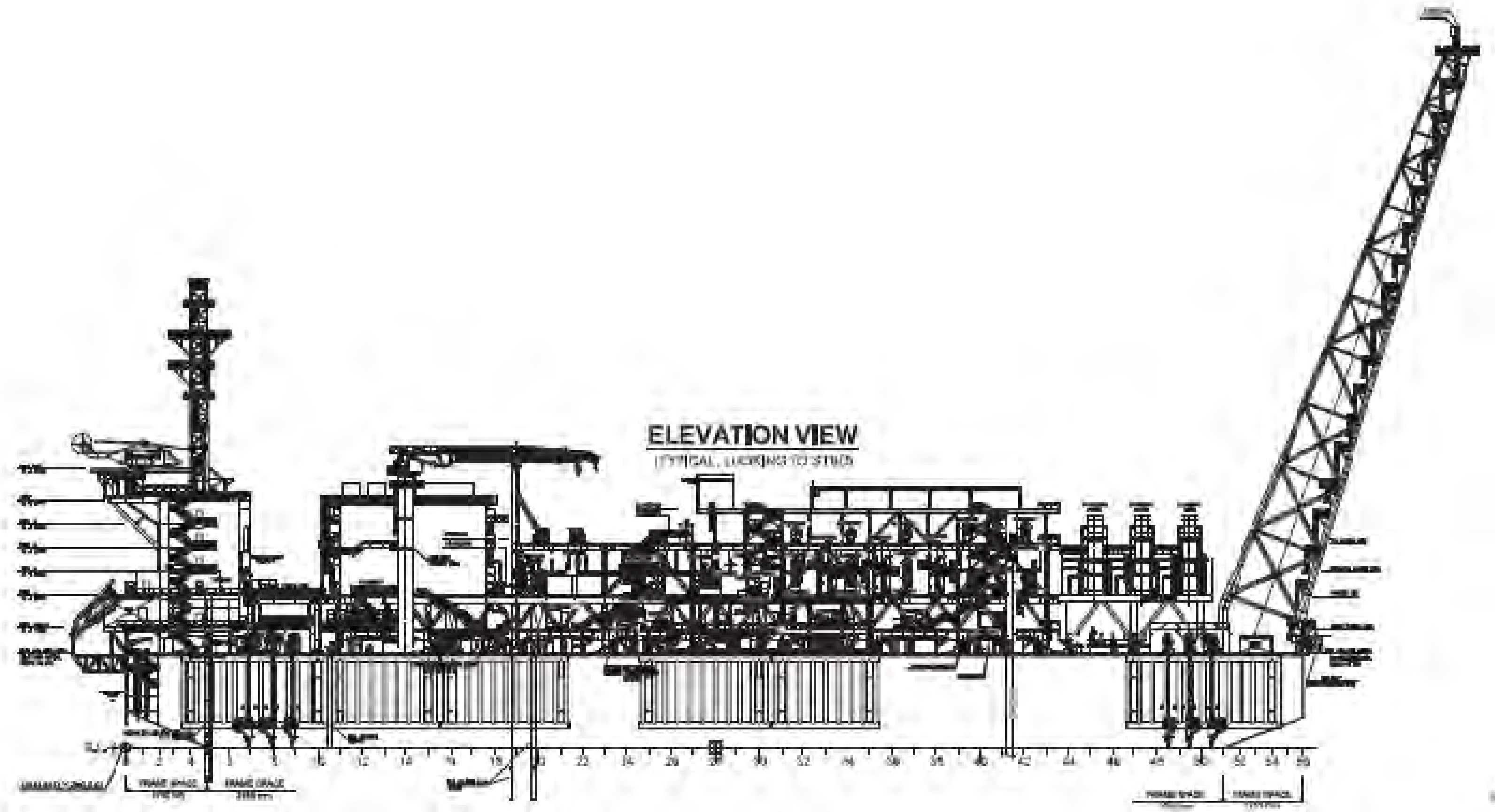
ATTACHMENT I

1. General Arrangement Jangkrik FPU

"This Page Intentionally Left Blank"


ELEVATION VIEW
(TYPICAL LOOKING TO PORT)


TOPSIDE LOADOUT DIRECTION
HULL MAIN DECK PLAN



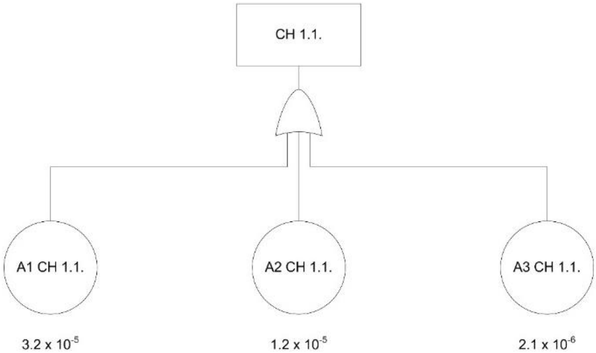
ELEVATION VIEW

"This Page Intentionally Left Blank"

ATTACHMENT II

1. HAZOP Analysis and risk evaluation result
2. Frequency analysis using FTA
3. Consequence analysis using ALOHA

FTA FREQUENCY ANALYSIS

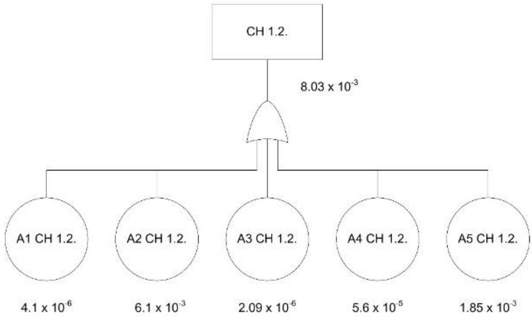


SDV-001 fails in controlled (CH 1.1.)

A1: Fail to open on demand

A2: Spurious Operation

A3: Structural Deficiency



Loss of Power (CH 1.2.)

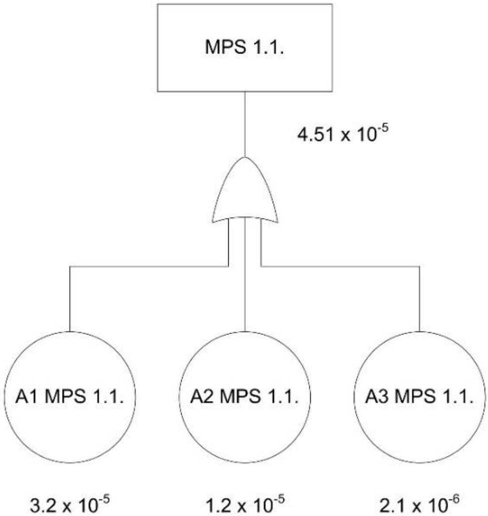
A1: Breakdown

A2: Fail to start on demand

A3: Fail to Synchronize

A4: Low output

A5: Spurious stop

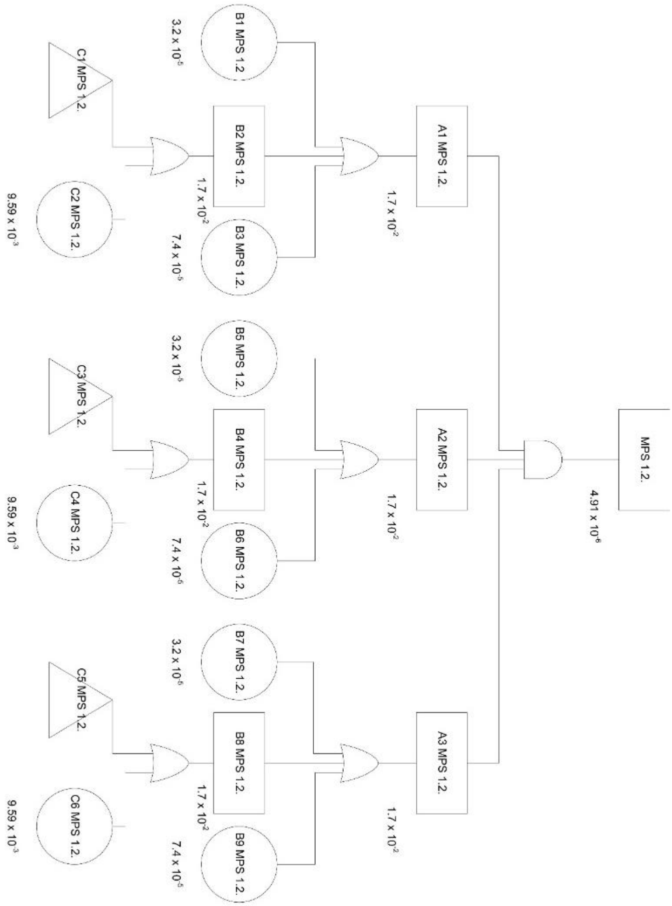


SDV-066 fails in controlled (MPS 1.1.)

A1: Fail to open on demand

A2: Spurious operation

A3: Structural deficiency



MPS 1.2.
4.91 x 10^{-6}
A1 MPS 1.2.
1.7 x 10^{-2}
A2 MPS 1.2.
1.7 x 10^{-2}
A3 MPS 1.2.
1.7 x 10^{-2}
B1 MPS 1.2.
3.2 x 10^{-5}
B2 MPS 1.2.
1.7 x 10^{-2}
B3 MPS 1.2.
7.4 x 10^{-5}
B4 MPS 1.2.
1.7 x 10^{-2}
B5 MPS 1.2.
3.2 x 10^{-5}
B6 MPS 1.2.
7.4 x 10^{-5}
B7 MPS 1.2.
3.2 x 10^{-5}
B8 MPS 1.2.
1.7 x 10^{-2}
B9 MPS 1.2.
7.4 x 10^{-5}
C1 MPS 1.2.
C2 MPS 1.2.
9.59 x 10^{-3}
C3 MPS 1.2.
C4 MPS 1.2.
9.59 x 10^{-3}
C5 MPS 1.2.
C6 MPS 1.2.
9.59 x 10^{-3}

Failure on flow system before condensate filter coalescer feed pumps (MPS 1.2.)

A1: Line 1 flow

A2: Line 2 flow

A3: Line 3 flow

B1: Fail to open on demand (ball valve)

B2: Fail on pump

B3: Failure on pipe (leakage)

B4: Fail to open on demand (ball valve)

B5: Fail on pump

B6: Failure on pipe (leakage)

B7: Fail to open on demand (ball valve)

B8: Fail on pump

B9: Failure on pipe (leakage)

C1: Loss of power

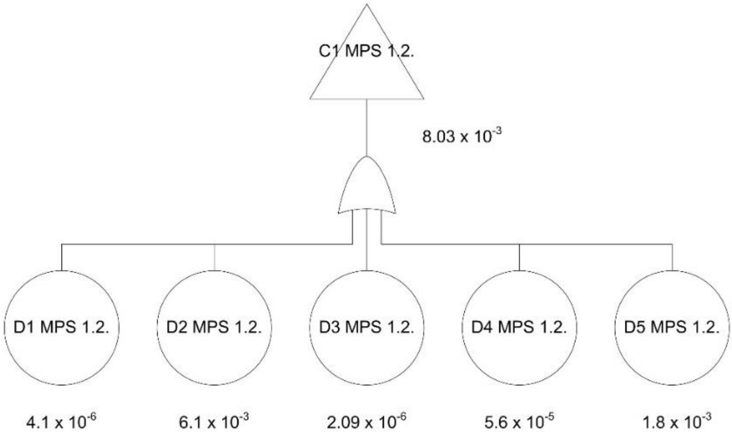
C2: Breakdown

C3: Loss of power

C4: Breakdown

C5: Loss of power

C6: Breakdown



C1: Loss of power (line 1)

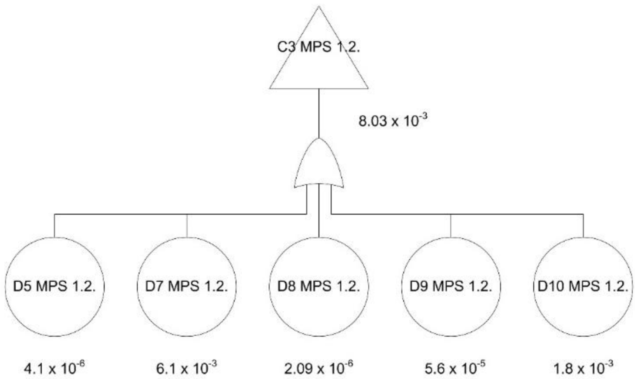
D1: Breakdown

D2: Fail to start

D3: Fail to synchronize

D4: Low output

D5: Spurious stop



C1: Loss of power (line 2)

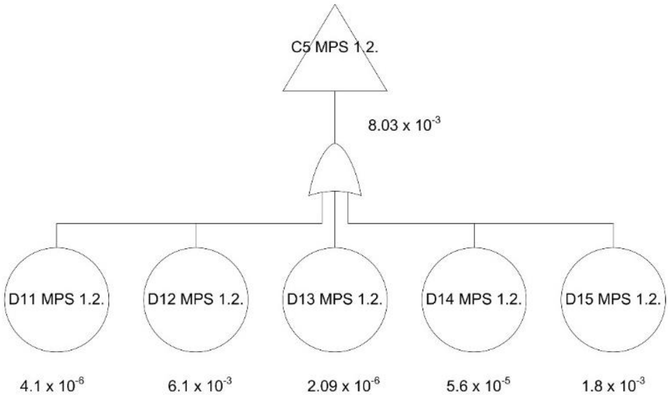
D1: Breakdown

D2: Fail to start

D3: Fail to synchronize

D4: Low output

D5: Spurious stop



C1: Loss of power (line 3)

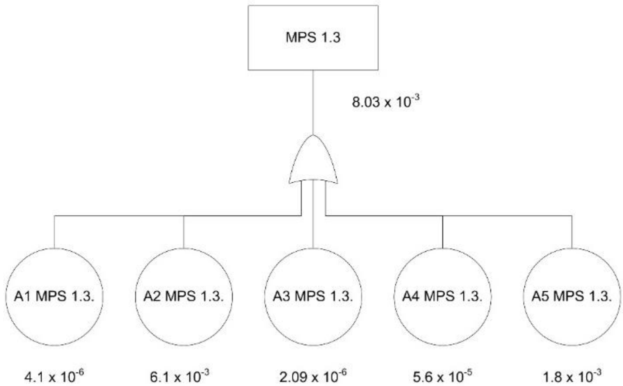
D1: Breakdown

D2: Fail to start

D3: Fail to synchronize

D4: Low output

D5: Spurious stop



Loss of power (MPS 1.3.)

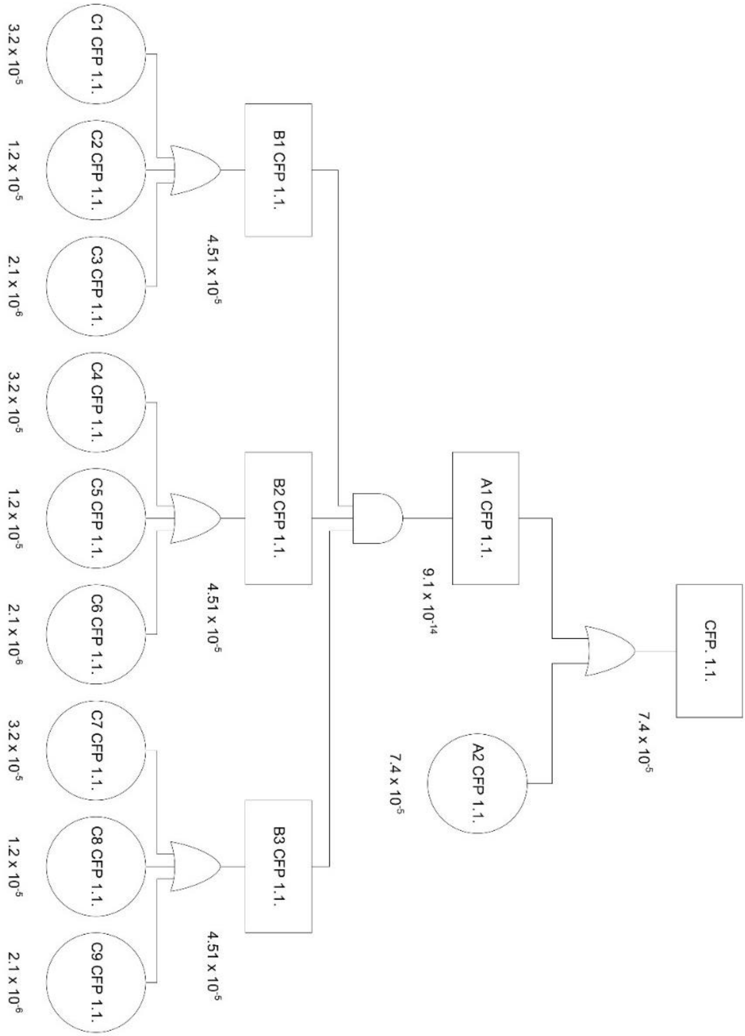
D1: Breakdown

D2: Fail to start

D3: Fail to synchronize

D4: Low output

D5: Spurious stop


C1 CFP 1.1.
3.2 x 10-5
C2 CFP 1.1.
1.2 x 10-5
C3 CFP 1.1.
2.1 x 10-6
C4 CFP 1.1.
3.2 x 10-5
C5 CFP 1.1.
1.2 x 10-5
C6 CFP 1.1.
2.1 x 10-6
C7 CFP 1.1.
3.2 x 10-5
C8 CFP 1.1.
1.2 x 10-5
C9 CFP 1.1.
2.1 x 10-6
B1 CFP 1.1.
4.51 x 10-5
B2 CFP 1.1.
4.51 x 10-5
B3 CFP 1.1.
4.51 x 10-5
A1 CFP 1.1.
9.1 x 10-14
A2 CFP 1.1.
7.4 x 10-5
CFP. 1.1.
7.4 x 10-5

Failure on flow system after condensate filter coalescer feed pumps (CFP 1.1.)

A1: Ball valve failure

A2: Pipeline leakage

B1: Line 1 flow

B2: Line 2 flow

B3: Line 3 flow

C1: Fail to open on demand

C2: Spurious stop

C3: Structural deficiency

C4: Fail to open on demand

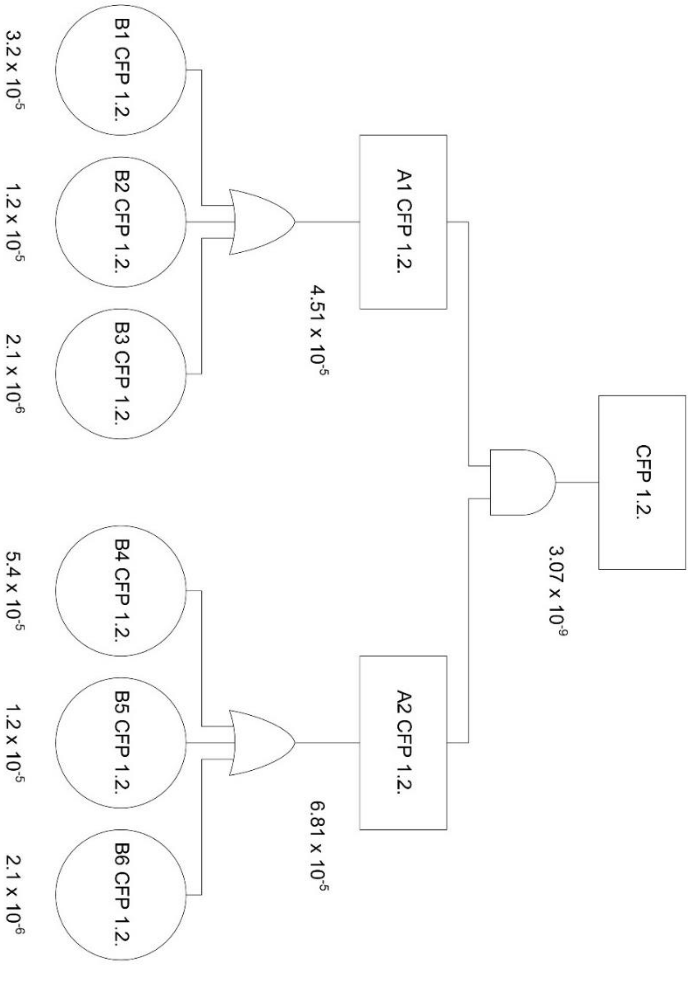
C5: Spurious stop

C6: Structural deficiency

C7: Fail to open on demand

C8: Spurious stop

C9: Structural deficiency


CFP 1.2.
3.07 x 10^{-9}
A1 CFP 1.2.
4.51 x 10^{-5}
A2 CFP 1.2.
6.81 x 10^{-5}
B1 CFP 1.2.
3.2 x 10^{-5}
B2 CFP 1.2.
1.2 x 10^{-5}
B3 CFP 1.2.
2.1 x 10^{-6}
B4 CFP 1.2.
5.4 x 10^{-5}
B5 CFP 1.2.
1.2 x 10^{-5}
B6 CFP 1.2.
2.1 x 10^{-6}

Failure on flow system before condensate filter (CFP1.2.)

A1: Line 1 flow

A2: Line 2 flow

B1: Fail to open on demand

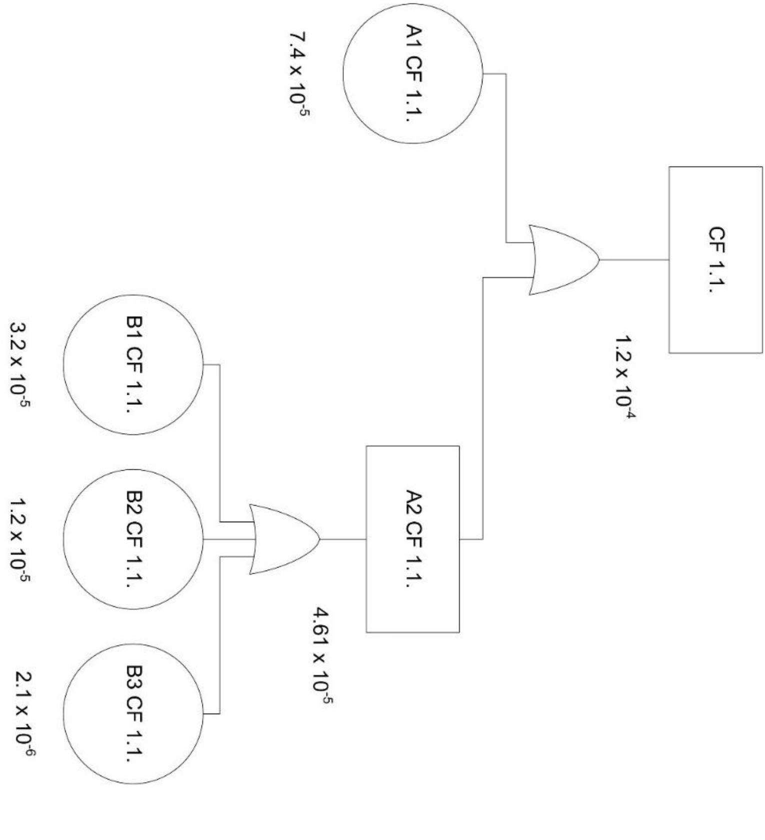
B2: Spurious stop

B3: Structural deficiency

B4: Fail to open on demand

B5: Spurious stop

B6: Structural deficiency


CF 1.1.
1.2 x 10^{-4}
A1 CF 1.1.
7.4 x 10^{-5}
A2 CF 1.1.
4.61 x 10^{-5}
B1 CF 1.1.
3.2 x 10^{-5}
B2 CF 1.1.
1.2 x 10^{-5}
B3 CF 1.1.
2.1 x 10^{-6}

Failure on flow system after condensate filter (CF 1.1.)

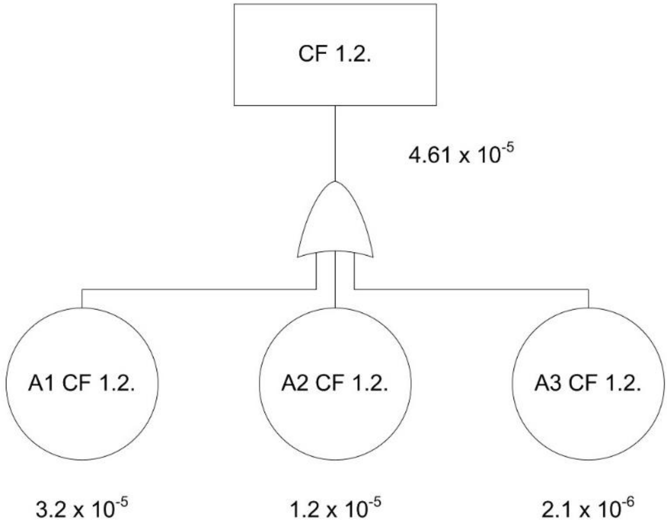
A1:Pipeline leakage

A2: Failure on ball valve

B1: Fail to open on demand

B2: Spurious stop

B3: Structural deficiency

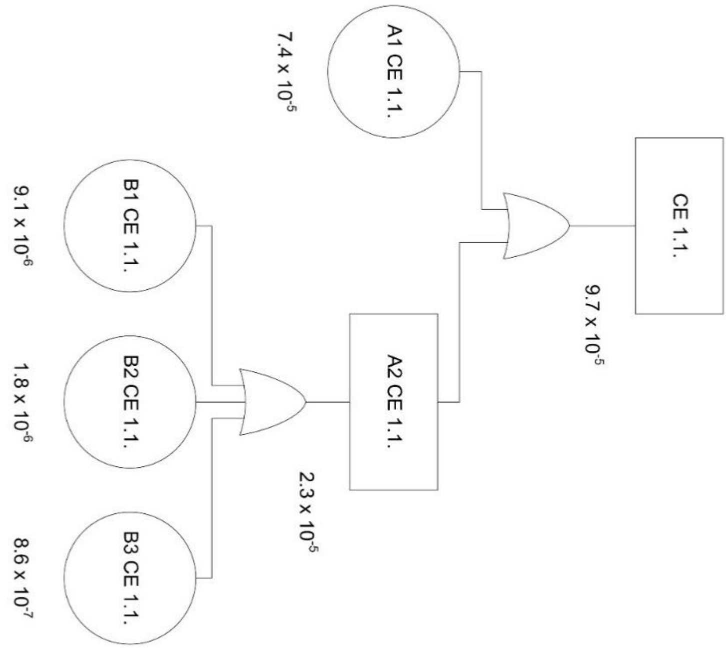


Failure on flow system before condensate heater (CF 1.2.)

A1: Fail to open on demand

A2: Spurious stop

A3: Structural deficiency


CE 1.1.
9.7×10^{-5}
A1 CE 1.1.
7.4×10^{-5}
A2 CE 1.1.
2.3×10^{-5}
B1 CE 1.1.
9.1×10^{-6}
B2 CE 1.1.
1.8×10^{-6}
B3 CE 1.1.
8.6×10^{-7}

Failure on flow system before condensate degasser (CE 1.1.)

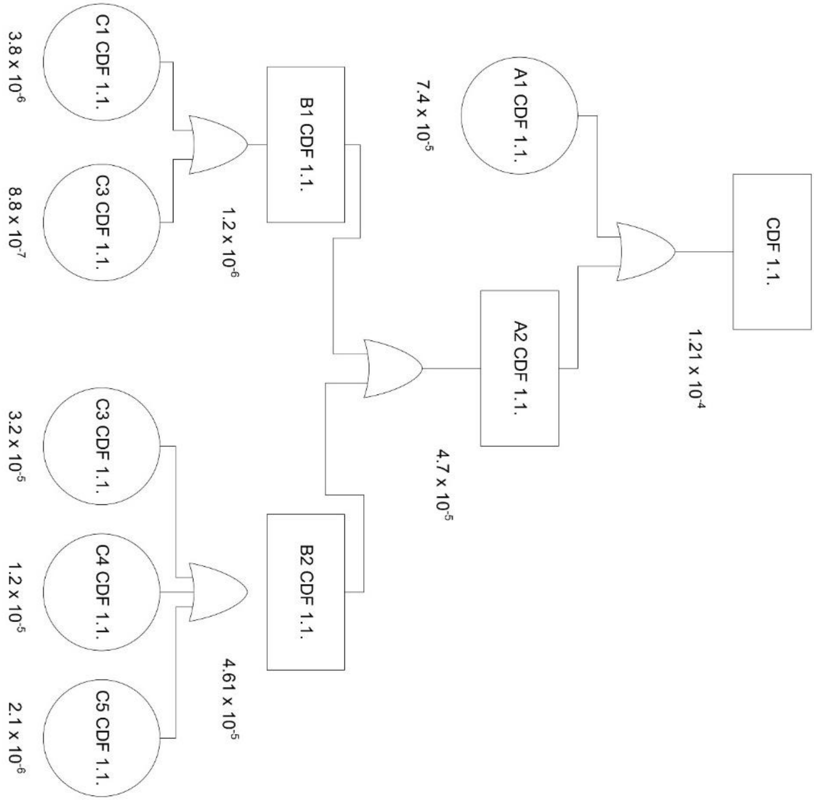
A1: Pipeline leakage

A2: Failure on globe valve

B1: Fail to open

B2: Spurious operation

B3: Structural deficiency


CDF 1.1.
1.21 x 10^-4
A1 CDF 1.1.
7.4 x 10^-5
A2 CDF 1.1.
4.7 x 10^-5
B1 CDF 1.1.
1.2 x 10^-6
B2 CDF 1.1.
4.61 x 10^-5
C1 CDF 1.1.
3.8 x 10^-6
C3 CDF 1.1.
8.8 x 10^-7
C3 CDF 1.1.
3.2 x 10^-5
C4 CDF 1.1.
1.2 x 10^-5
C5 CDF 1.1.
2.1 x 10^-6

Failure on flow system degasser condensate degasser (CDF 1.1.)

A1: Pipeline leakage

A2: Failure on pipeline

B1: Failure on butterfly valve

B2: Failure on ball valve

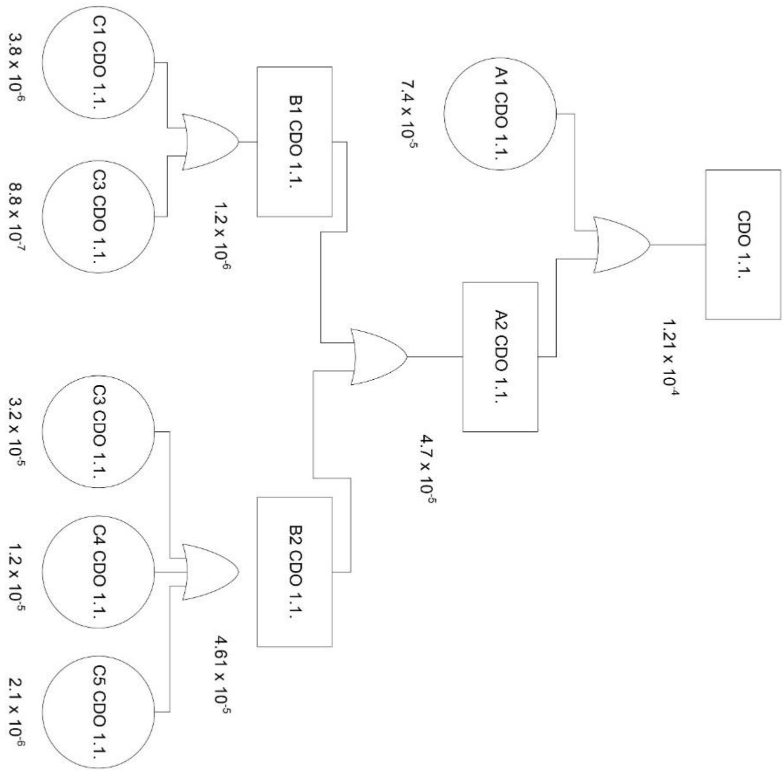
C1: Fail to regulate

C2: Leakage

C3: Fail to open on demand

C4: Spurious operation

C5: Structural deficiency


CDO 1.1.
1.21 x 10^-4
A1 CDO 1.1.
7.4 x 10^-5
A2 CDO 1.1.
4.7 x 10^-5
B1 CDO 1.1.
1.2 x 10^-6
B2 CDO 1.1.
4.61 x 10^-5
C1 CDO 1.1.
3.8 x 10^-6
C3 CDO 1.1.
8.8 x 10^-7
C3 CDO 1.1.
3.2 x 10^-5
C4 CDO 1.1.
1.2 x 10^-5
C5 CDO 1.1.
2.1 x 10^-6

Failure on flow system degasser condensate degasser (CDO 1.1.)

A1: Pipeline leakage

A2: Failure on pipeline

B1: Failure on butterfly valve

B2: Failure on ball valve

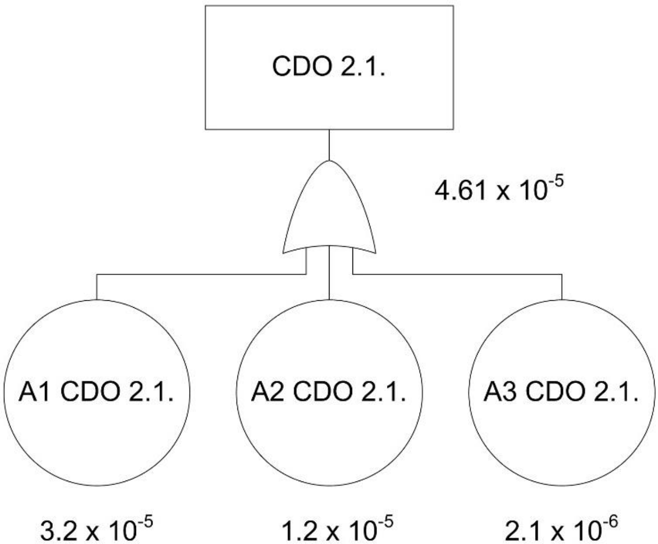
C1: Fail to regulate

C2: Leakage

C3: Fail to open on demand

C4: Spurious operation

C5: Structural deficiency



Failure on flow system from on spec condensate tank to ORF (CDO 2.1.)

A1: Fail to open on demand

A2: Spurious operation

A3: Structural deficiency

HAZOP ANALYSIS AND RISK EVALUATION RESULT

<table>
<tr><td colspan="9">STUDY TITLE: Condensate process from condensate collection header to condensate exchanger</td><td colspan="3">SHEET: 1 of 2</td></tr>
<tr><td colspan="3">Drawing No.: 11401</td><td colspan="6">REV. No.:</td><td colspan="3">DATE: 17 - 06 - 2016</td></tr>
<tr><td colspan="3">PART CONSIDERED:</td><td colspan="9">Preheat the unstabilize condensate</td></tr>
<tr><td colspan="3" rowspan="2">DESIGN INTENT: Normal pressure 25.1 (bar)</td><td colspan="4">Material: Condensate</td><td colspan="5">Activity: pre heated in condensate exchanger</td></tr>
<tr><td colspan="4">Source: condensate collection header</td><td colspan="5">Destination: condensate exchanger</td></tr>
<tr><td>No.</td><td>Guide Word</td><td>Element</td><td>Deviation</td><td>Possible Causes</td><td>Probability Failure</td><td>Probability Level</td><td>Consequences</td><td>Severity Level</td><td>Safeguards</td><td>Risk Level</td><td>Action Required</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">NO</td><td rowspan="2">Condensate</td><td rowspan="2">no condensate transfer to condensate exchanger</td><td>SDV-001 fails in controlled</td><td>4.61×10^{-5}</td><td>A</td><td>no condensate flow on condensate exchanger will be delayed the process</td><td>2</td><td>TI 004; PI 005</td><td>Continous Improvement</td><td></td></tr>
<tr><td>Loss of power</td><td>8.031×10^{-3}</td><td>B</td><td>no condensate flow on condensate exchanger will be delayed the process</td><td>2</td><td>TI 004; PI 005</td><td>Continous Improvement</td><td></td></tr>
<tr><td>2</td><td>LESS</td><td>Condensate</td><td>Less condensate transfer to condensate exchanger</td><td>Pipeline leakage from condensate collection header trough</td><td>7.4×10^{-6}</td><td>0</td><td>no condensate flow on condensate exchanger will be delayed the process</td><td>3</td><td>TI 004; PI 005</td><td>Continous Improvement</td><td></td></tr>
</table>

				condensate exchanger							

STUDY TITLE: Condensate process from condensate collection header to condensate exchanger										SHEET: 2 of 2	
Drawing No.: 11401			REV. No.:							DATE: 17 - 06 - 2016	
PART CONSIDERED:			Preheat the unstabilize condensate								
DESIGN INTENT: Normal pressure 25.1 (bar)			Material: Condensate				Activity: pre heated in condensate exchanger				
			Source: condensate collection header				Destination: condensare exchanger				
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required
3	MORE	Condensate	More condensate transfer to condensate exchanger	SDV-001 fails in closed position	5.4×10^{-5}	A	Excessive pressure on condensate exchanger pipeline	2	TI 004; PI 005	Continous Improvement	

STUDY TITLE: Condensate process from condensate exchanger to MP separator											SHEET: 1 of 1	
Drawing No.: 11402			REV. No.:								DATE: 17 - -06 - 2016	
PART CONSIDERED:			Separated gas and water from the incoming condensate									
DESIGN INTENT: Min. 13.1; Max. 16.5 (pressure, bar)			Material: condensate				Activity: separated gas and water from condensate					
			Source: condensate exchanger				Destination: MP separator					
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required	
1	NO	Condensate	No condensate flow on pipeline	Pipeline leakage	7.4×10^{-5}	A	No condensate flow to MP separator	4	TI 009; PI 008	Risk Reduction measure	Yes	
2	LESS	Condensate	Less condensate flow on pipeline	Pipeline leakage	7.4×10^{-6}	0	Excessive pressure on condensate exchanger pipeline	4	TI 009; PI 008	Continous Improvement	Yes	

STUDY TITLE: Condensate process from MP separator to condensate filter coalescer feed pumps											SHEET: 1 of 2
Drawing No.: 11403			REV. No.:							DATE: 17 - 06 - 2016	
PART CONSIDERED:			Prefilter and pressurize the condensate								
DESIGN INTENT: Suct.13.3; Diff. 2.5 (pressure, bar)			Material: condensate				Activity: transfer and pre-filter condensate				
			Source: MP separator				Destination: condensate filter coalescer feed pump				
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required
NO		Condensate	no condensate transfer to condensate exchanger	SDV-066 fails in controlled	4.51×10^{-5}	A	no condensate flow on condensate filter coalescer feed pump will be delayed the process	2	PI 053	Continous Improvement	
				Failure on flow system before condensate filter coalescer feed pumps	4.91×10^{-6}	A	no condensate flow on condensate filter coalescer feed pump will be delayed the process	3	PI 053	Continous Improvement	

					Loss of power	8.031×10^{-3}	B	no condensate flow on condensate filter coalescer feed pumps will be delayed the process	2		Continous Improvement	

STUDY TITLE: Condensate process from MP separator to condensate filter coalescer feed pumps										2 of 2	
Drawing No.: 11403			REV. No.:							DATE: 17 - 06 - 2016	
PART CONSIDERED:			Prefilter and pressurize the condensate								
DESIGN INTENT: Suct.13.3; Diff. 2.5 (pressure, bar)			Material: condensate				Activity: transfer and pre-filter condensate				
			Source: MP separator				Destination: condensate filter coalescer feed pump				
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required
2	LESS	Condensate	Less condensate transfer to condensate filter coalescer feed pumps	Pipeline leakage from MP separator trough condensate filter coalescer feed pump	7.4×10^{-6}	A	Excessive pressure on condensate filter coalescer feed pumps	3	PI 053	Continous Improvement	
3	MORE	Condensate	More condensate transfer to condensate filter coalescer feed pumps	SDV-066 fails in closed position	5`4 x 10^{-5}	A	Excessive pressure on condensate filter coalescer feed pumps	3	PI 053	Continous Improvement	

STUDY TITLE: Condensate process from condensate filter coalescer feed pumps to condensate filter										SHEET: 1 of 1	
Drawing No.: 11411			REV. No.:							DATE: 17 - 06 - 2016	
PART CONSIDERED:			Separate water from condensate								
DESIGN INTENT: Min. 17; Max. 22 (pressure, bar)			Material: condensate				Activity: filter water from condensate				
			Source: condensate filter coalescer pump				Destination: condensate filter				
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required
1	NO	Condensate	No condensate transfer to condensate filter	Failure on flow system after condensate filter coalescer feed pumps	7.4×10^{-5}	A	no condensate flow on condensate filter will be delayed the process	4	PI 060	Continous Improvement	
				Failure on flow system before condensate filter	3.07×10^{-9}	0	no condensate flow on condensate filter will be delayed the process	4	PI 060	Continous Improvement	
2	LESS	Condensate	Less condensate transfer to condensate filter	Pipeline leakage	7.4×10^{-6}	A	Less condensate flow on condensate filter will be delayed the process	4	PI 060	Continous Improvement	

STUDY TITLE: Condensate process from condensate filter to condensate heater											SHEET: 1 of 2	
Drawing No.: 11412			REV. No.:								DATE: 17 - 06 - 2016	
PART CONSIDERED:			Heated in the condensate									
DESIGN INTENT: Min. 1.5; Max.19.6 (pressure, bar)			Material: condensate				Activity: heating the condensate					
			Source: condensate filter				Destination: condensate heater					
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required	
1	NO	Condensate	No condensate transfer to condensate heater	Failure on flow system after condensate filter	1.2×10^{-4}	B	no condensate flow on condensate heater will be delayed the process	2	PI 029; TI 029	Continous Improvement		
				Failure on flow system before condensate heater	4.61×10^{-5}	A	no condensate flow on condensate heater will be delayed the process	3	PI 029; TI 029	Continous Improvement		
2	LESS	Condensate	Less condensate flow	Pipeline leakage before condensate heater	7.4×10^{-6}	A	no condensate flow on condensate heater will be delayed the process	3	PI 029; TI 029	Continous Improvement		

STUDY TITLE: Condensate process from condensate filter to condensate heater										SHEET: 2 of 2	
Drawing No.: 11412			REV. No.:							DATE: `7 - 06 - 2016	
PART CONSIDERED:			Heated in the condensate								
DESIGN INTENT: Min. 1.5; Max.19.6 (pressure, bar)			Material: condensate				Activity: heating the condensate				
			Source: condensate filter				Destination: condensate heater				
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required
2	LESS	Condansate (temperature)	Less condensate temperature	Condensate exhanger damaged	9.9×10^{-6}	0	Condensate exchanger not meet the temperature requirement	1	PI 029; TI 029	Continous Improvement	
3	MORE	Condensate (temperature)	More condensate temperature	Condensate exhanger damaged	9.9×10^{-6}	0	Condensate exchanger not meet the temperature requirement	1	PI 029; TI 029	Continous Improvement	

STUDY TITLE: Condensate process from condensate heater to LP separator										SHEET: 1 of 1	
Drawing No.: 11422			REV. No.:							DATE: 17 - 06 - 2016	
PART CONSIDERED:			For fonal Stabilization								
DESIGN INTENT: Min. 1; Max. 5 (pressure, bar)			Material: condensate				Activity: final stabilization				
			Source: condensate heater				Destination: LP separator				
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required
1	NO	Condensate	No condensate flow	Pipeline leakage	7.4×10^{-5}	A	no condensate flow on condensate heater will be delayed the process	2	PI 024; TI 024	Continous Improvement	
2	LESS	Condensate	Less condensate flow	Pipeline leakage	7.4×10^{-6}	0	no condensate flow on condensate heater will be delayed the process	2	PI 024; TI 024	Continous Improvement	

STUDY TITLE: Condensate process from LP separator to condensate exchanger											SHEET: 1 of 1	
Drawing No.: 11423			REV. No.:								DATE: 17 - 06 - 2016	
PART CONSIDERED:			Preheated the condensate									
DESIGN INTENT: Normal pressure 25.1 (bar)			Material: condensate				Activity: preheate condensate					
			Source: LP separator				Destination: condensate exchanger					
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required	
1	NO	Condensate	No condensate transfer to condensate exchanger	Failure on flow system before condensate exchanger	7.4×10^{-5}	A	no condensate flow on condensate exchanger will be delayed the process	3		Continous Improvement		
2	LESS	Condensate	Less condensate flow	Pipeline leakage	7.4×10^{-6}	0	low condensate flow on condensate exchanger will be delayed the process	3		Continous Improvement		

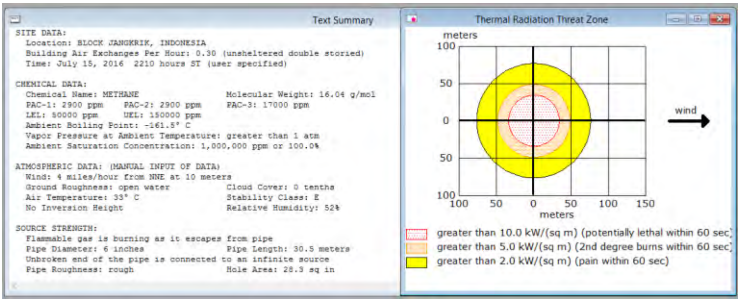
STUDY TITLE: Condensate process from condensate exchanger to condensate degasser											SHEET: 1 of 1	
Drawing No.: 11402			REV. No.:								DATE: 17 - 06 - 2016	
PART CONSIDERED:			To remove gasses from cpndensate which could otherwise form bubbles									
DESIGN INTENT: Min. 0.5; Max. 3.5 (pressure, bar)			Material: condensate				Activity: to remove gasses from condensate					
			Source: condensate exchanger				Destination: condensate degasser					
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required	
1	NO	Condensate	No condensate transfer to condensate degasser	Failure on flow system before condensate degasser	9.7×10^{-5}	A	no condensate flow on condensate heater will be delayed the process	2		Continous Improvement		
2	LESS	condensate	Less condensate transfer to condensate degasser	Pipeline leakage	7.4×10^{-6}	0	low condensate flow on condensate degasser will be delayed the process	3		Continous Improvement		

STUDY TITLE: Condensate process from condensate degasser to off spec condensate tanks										SHEET: 1 of 1	
Drawing No.: 60108			REV. No.:							DATE: 17 - 06 - 2016	
PART CONSIDERED:			Transfer the condensate								
DESIGN INTENT: Min. 0.05; Max. 12 (pressure, bar)			Material: condensate				Activity: transfer the condensate to off spec tank				
			Source: condensate degasser				Destination: off spec condensate tanks				
No.	Guide Word	Element	Deviation	Possible Causes	Probability Failure	Probability Level	Consequences	Severity Level	Safeguards	Risk Level	Action Required
1	NO	Condensate	No condensate transfer to off spec tanks	Failure on flow system degasser condensate degasser	1.21×10^{-4}	B	no condensate flow on condensate Off spec tanks will be delayed the process	2	TI 511; PI 522; LI 511 (Tank Monitoring)	Continous Improvement	
2	LESS	Condensate	Less Condensate transfer	Pipeline leakage	7.4×10^{-6}	0	Low condensate flow on condensate Off spec tanks will be delayed the process	3	TI 511; PI 522; LI 511 (Tank Monitoring)	Continous Improvement	

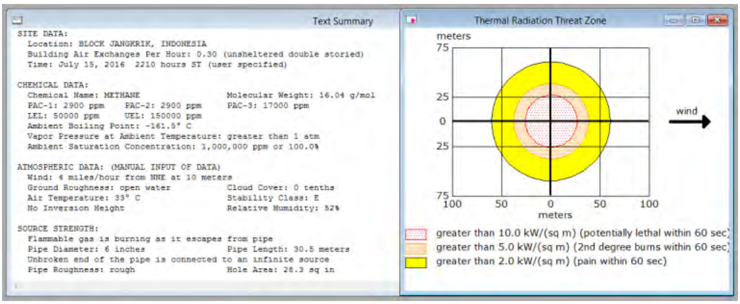
<table>
<tr><td colspan="11">STUDY TITLE: Condensate process from condensate degasser to on spec condensate tanks</td><td colspan="2">SHEET: 1 of 1</td></tr>
<tr><td colspan="3">Drawing No.: 60109</td><td colspan="8">REV. No.:</td><td colspan="2">DATE: 17 - 06 -2016</td></tr>
<tr><td colspan="3">PART CONSIDERED:</td><td colspan="10">Transfer the condensate</td></tr>
<tr><td colspan="3" rowspan="2">DESIGN INTENT: Min. 0.05; Max. 12 (pressure, bar)</td><td colspan="4">Material: condensate</td><td colspan="6">Activity: transfer the condensate to on spec tank</td></tr>
<tr><td colspan="4">Source: condensate degasser</td><td colspan="6">Destination: on spec condensate tanks</td></tr>
<tr><td>No.</td><td>Guide Word</td><td>Element</td><td>Deviation</td><td>Possible Causes</td><td>Probability Failure</td><td>Probability Level</td><td>Consequences</td><td>Severity People</td><td>Safeguards</td><td>Risk Level</td><td colspan="2">Action Required</td></tr>
<tr><td>1</td><td>NO</td><td>Condensate</td><td>No condensate transfer to off spec tanks</td><td>Failure on flow system degasser condensate degasser</td><td>1.21 x 10^{-4}</td><td>B</td><td>no condensate flow on condensate Off spec tanks will be delayed the process</td><td>2</td><td>TI 531; PI 524; LI 531 (Tank Monitoring)</td><td>Continous Improvement</td><td colspan="2"></td></tr>
<tr><td>2</td><td>LESS</td><td>Condensate</td><td>Less Condensate transfer</td><td>Pipeline leakage</td><td>7.4 x 10^{-6}</td><td>0</td><td>Low condensate flow on condensate Off spec tanks will be delayed the process</td><td>3</td><td>TI 531; PI 524; LI 531 (Tank Monitoring)</td><td>Continous Improvement</td><td colspan="2"></td></tr>
</table>

CONSEQUNECE ANALYSIS
USING ALOHA

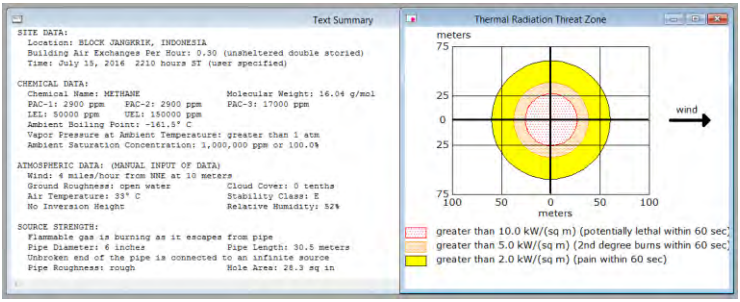
1. Condensate process from condensate collection header to condensate exchanger



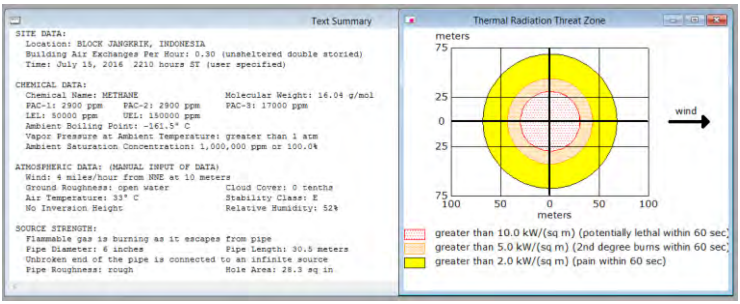
2. Condensate process from condensate exchanger to MP separator



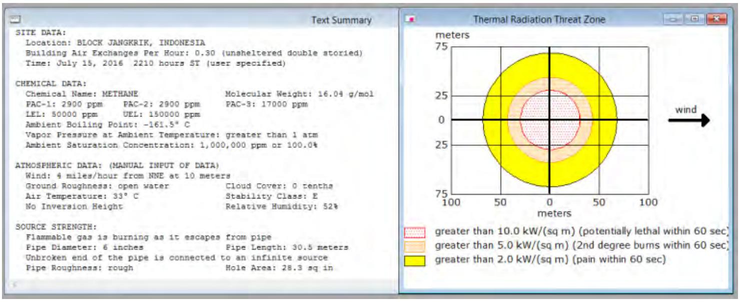
3. Condensate process from MP separator to condensate filter coalescer feed pumps



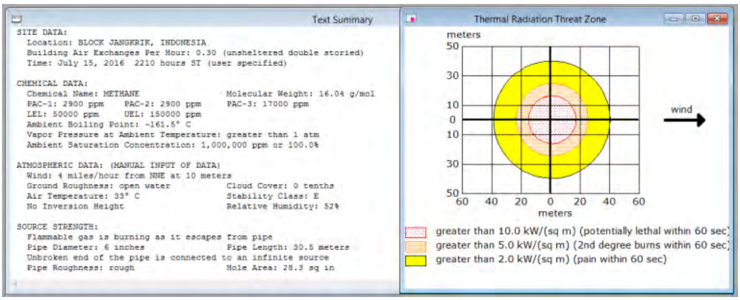
4. Condensate process from condensate filter coalescer feed pumps to condensate filter



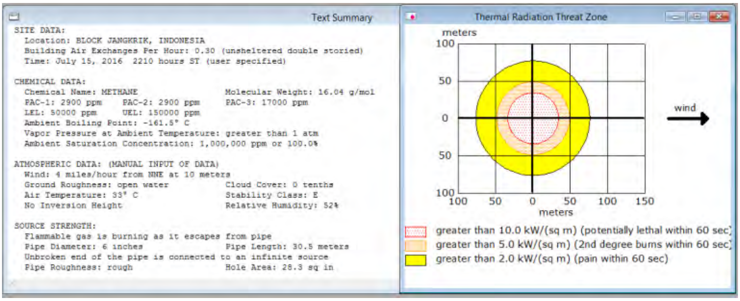
5. Condensate process from condensate filter to condensate heater



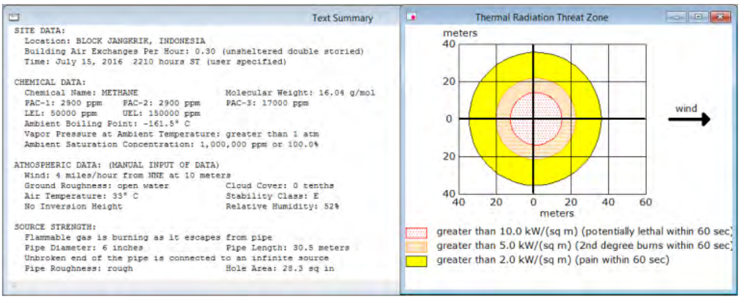
6. Condensate process from condensate heater to LP separator



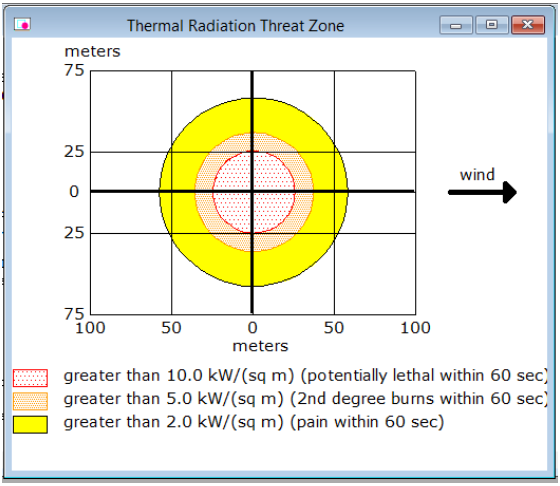
7. Condensate process from LP separator to condensate exchanger



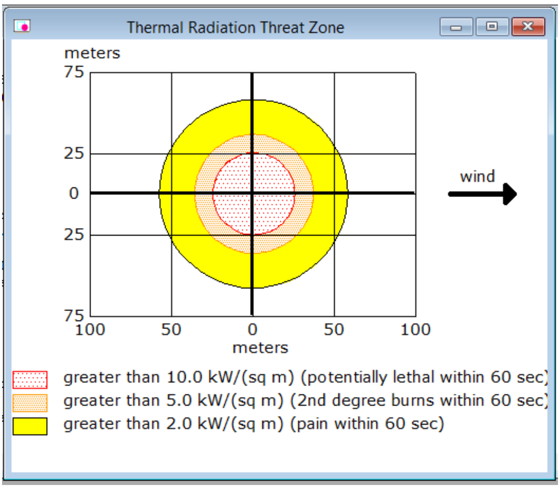
8. Condensate process from condensate exchanger to condensate degasser



9. Condensate process from condensate degasser to off spec condensate tanks



10. Condensate process from condensate degasser to off spec condensate tanks



MITIGATION

Scenario No. 1	No condensate flow on pipeline from condensate exchanger to MP separator		Node No. 1
Date: 20 June 2016	Description	Probability	Frequency (per year)
Consequence description/ Category	No condensate flow to MP separator		
Risk Tolerance Criteria	Action required		$>10^{-6}$
	Tolerable		$<10^{-4}$
Initiating event	No condensate flow on pipeline		7.4×10^{-5}
Frequency of Unmitigated Consequence			7.4×10^{-5}
Independent Protection Layers	Pressure indicator	4.6×10^{-6}	
	Temperature indicator	8×10^{-6}	
Total PFD		3.68×10^{-10}	
Frequency of Mitigated Consequence			2.72×10^{-15}
Risk Tolerance Criteria Met? (Yes/ No)		Yes	
Action required to meet Risk Tolerance Criteria	1. Pressure indicator installed		
	2. Temperature indicator installed		

CHAPTER V
CONCLUSION

Based on the result of the fire risk assessment of the FPU Jangkrik, we can conclude that:

1. There is one high risk inside the Floating Production Unit that is Condensate system inside the FPU.
2. Every system on the FPU that passed by Condensate will at the higher risk of fire, because the condensate its dangerous chemical fluid that has higher flash point.
3. There are many potential of fire caused by condensate flow. Every system is used to process the condensate until meet the specification will be a potential hazard in FPU.
4. There are many potential hazard on the condensate process inside the FPU such as Condensate process from condensate collection header to condensate exchanger, Condensate process from condensate exchanger to MP separator, Condensate process from MP separator to condensate filter coalescer feed pumps, Condensate process from condensate filter coalescer feed pumps to condensate filter, Condensate process from condensate filter to condensate heater, Condensate process from condensate heater to LP separator, Condensate process from LP separator to condensate exchanger, Condensate process from condensate exchanger to condensate degasser, Condensate process from condensate degasser to off spec condensate tanks, and Condensate process from condensate degasser to on spec condensate tanks.
5. There are many failure mode on every system process of condensate process.

6. Most result of risk matrix on every failure mode shows on the continuous improvement level (blue color).
7. There is one risk that unacceptable, the risk is when the pipe from the condensate exchanger to the MP separator leakage it can cause the major destruction of the FPU but there is no casualties, but on the risk matrix it shows that the failure mode on risk reduction measure level (yellow level).
8. After the mitigation using LOPA the risk that unacceptable turn to continuous improvement level (blue color), so the hazard can be tolerable.
9. The mitigation by add pressure indicator and temperature indicator to the system.
10. All of the other risk that can cause hazard and make a local loss but all of it is acceptable.

REFERENCES

Artana, K. B., & Dinariyana, A. A. (2013). *TEORI KEANDALAN SISTEM DAN APLIKASINYA.* Surabaya: Inti Karya Guna.

Francesca Rombaldoni. (2010). *HSE RISK MANAGEMENT AND RISK REPORTING.* Jakarta: ENI.

ISO (Intenational Organization for Standardization). (2009). *ISO 31000: Risk Management - Principles and Guidelines.* Switzerland: ISO.

Kontovas, C. A. (2005). *Formal Safety Assessment Critical Review and Future Role.* Greece: National Technical University of Athens.

Morris, M. A. (2011, November 30). Failure Modes and Effect Analysis based on FMEA 4th Edition. *Failure Modes and Effect Analysis based on FMEA 4th Edition*. ASQ The Global Voices of Quality.

Mullai, A. (2006). *Risk Management System - Risk Assessment Frameworks and Techniques.* Turku: DaGob.

Summers, A. E. (2002). Introduction to Layer of Protection Analysis. *Journal of Hazardous Materials*, 1-6.

Wilcox, R., Burrows, M., Ghosh, S., & Ayyub, B. M. (2000). Risk-based Technology Methodology for the Safety Assessment of Marine Compressed Natural Gas Fuel Systems. *International Cooperation on Marine Engineering Systems/ The Sociecty of Naval Architects and Marine Engineers*, 1-21.

Zaman, M. B. (2015). *Sistem Keselamatan Navigasi Kapal.* Surabaya: ITS Press.

WRITER'S BIOGRAPHY

The writer was born in Jakarta,on 18 November 1994, the writer is the first child in his family and has taken formal education in SDIT FAJAR HIDAYAH Bogor, SMPI Al – Azhar 19 Jakarta and SMAN 42 Jakarta. The Author was graduated from SMAN 42 Jakarta in 2012, having accomplished senior high school the writer continue his study to bachelor degree at Institut Teknologi Sepuluh Nopember in Department of Marine Engineering Double Degree Program at Faculty of Marine Technology – Institut Teknologi Sepuluh Nopember with Hochschule Wismar Germany. The author is registered with student number NRP. 4212 101 014 in Department of Marine Engineering, the writer took the bachelor thesis in Institut Teknologi Sepuluh Nopember, Surabaya. The writer was the second generation of Double Degree in Marine Engineering in Faculty of Marine Technology - Institut Teknologi Sepuluh Nopember.