Development of Asset Life Cycle Management System in Process Plant

by

Mohd Jeffri bin Mat Amin

Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

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Approved by,

____
(AP Dr Azmi bin Mohd Shariff)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MOHD JEFFRI BIN MAT AMIN

ABSTRACT

Managing engineering assets can be a challenging task and optimizing the assets usage is very critical. To ensure the assets is effectively manage and utilize, one have to make effective decision regarding the asset life cycle. The asset life cycle management refers to the effective management system monitoring the performance of the assets throughout their life cycle or “cradle-to-grave” ideology, which mean that the monitoring phase is to be done at beginning stage of purchasing the asset until its retirement time. The objective of this project is to develop the asset life cycle management system suitable to be implemented in processing plant with respect to their condition and environment. For this purpose, the author has identify and analyses a few model including those available in the literature as well as the models that already being implemented in other industries. The information obtained through studies and analyses has been squeeze and manipulate in order to come out with the technical framework of the asset life cycle management system in process plant. The framework developed involving five simple steps and suitable to be implemented with respect to the plant condition and environment. This project also focuses on selection of suitable maintenance strategies to be implemented for the specific equipment in order to have optimum strategies that are safe and cost effective. The outcome of this project would help the decision makers in the process plant to effectively monitoring the assets performance and effectiveness through the system developed.

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CHAPTER 1

INTRODUCTION

1.1 Background Of Study

The economic environment scenarios currently have changed the old industries interface. Each and every company survived in the competition trying to maximize every single penny that they are able to save in order for them to keep pace with their competition. Hence they are trying to find an alternative ways for them to reduce their operational cost and most importantly to increase and maximize their revenue and profit margin. For those are capable to look beyond others may give a thought on how to achieve these objective and for the long term period may contribute a lot to the organization in general by implementing asset life cycle management.

The visionary parties are looking for the area of improvement to be made in their organization. Studies were made to look for opportunities to reduce the cost of maintaining their asset, improve the performance and extend the life of those assets, speed up information and decision making, and gain competitive advantage by manipulating the asset life cycle. Hence it has brought to the recently fever for the companies to put a strong emphasis on to the area of Asset Life Cycle Management.

Managing of asset in the process plant is a challenging task to be done and the assets are very valuable and critical to the running of the plant. The asset life cycle management system considers the overall life of the asset or equipment starting from it being acquired in the industries tills its reach the retirement time. Asset usage in the plant need to be optimize without neglecting their performance, whereby regular monitoring are expected. For those who are directly involved with the plant management have to ensure that the asset perform at peak level and at the same time keep reduce their capital cost at lowest rate. The effectiveness of asset utilization rely on the effective of the decision taking regarding the asset life cycle phase.

The life cycle of an asset can be divided into a few phases but the most important phase need to be considered is during the middle life on an asset whereby asset is used in the production line. In this phase, the maintenance task is seem to be very important task to be carried out in order to ensure that the equipment is in good condition and more importantly to keep the production rate high as well as to ensure the plant is safe.

However, doing the maintenance task is involving a lot of money to be invested. Maintenance cost is very high and at some condition it is labeled the largest single controllable expenditure in the plant. While at some plant, the cost of plant maintenance is exceeding the value of net profit obtained. The maintenance cost alone already related to 40% of the total plant operational cost and it is clearly highlighted as the important finding new ways in managing the plant assets.

Currently the asset life cycle has been implemented in many industries such as mining, utilities, transportation and even government agencies that see the opportunity for them to reduce the cost and stay competitive in the global environment. Hence it is a time for process plant to also develop the asset life cycle system that can cater the need for fully monitoring whole equipment in plant and at the same time can provide a path to increase reliability of the plant by conducting the maintenance task wisely in the plant.

1.2. Problem Statement

Process plants facing a big problem regarding the equipment reliability since the ageing infrastructure have potential to end because of the failure of the equipment itself. To manage the whole asset used in term of the total performance is often difficult because there is no centralized or automated system to wholly monitoring the asset. Lack of monitoring the individual equipment may increase chances of equipment failure during the operational period and hence result in unplanned shutdown and any unwanted negative effect to the total effectiveness performance of the assets.

The processing plant seemed to be in need on the system that are relevant to be used and implemented in the condition and environment of the plant itself. The system looked have to be useful for the management to continuously monitor the plant generally and specifically to each of the equipment they have. Continuous monitoring in the plant is expected to contribute to the sustaining of plant performance and in the long term period may give a significant effect to the plant operation.

This project was aimed to develop the most suitable asset life cycle management system to be implemented in the process plant whereby the development process stages have to put consideration on every plant aspect and condition so as the system develop suit to the plant usage.

The asset life cycle management system take into consideration the whole life of an asset starting before the item being bought until its retirement time or simply consider as “cradle-to-grave” management of an item. However, for reality the most assets is already in service and the task that need to be fulfilled by the plants workers is to keep the reliability of the plant. One of the ways to achieve that target is by implementing maintenance task frequently with regard to the need of the plants and every each of equipment available. The maintenance task should be conducted in order to ensure that the plan is running well and avoid any damaged for the physical asset.

Maintenance task should be well scheduled according to the criticality and condition of the equipment whereby different type of equipment will need different kind of maintenance strategies to be performed. Every single aspect need to be considered in other to decided the most suitable maintenance strategies so as the plant is not only keep the reliability high but at the same time can reduce the cost of maintenance and reduce the operators workforce.

1.3. Objective and Scope of Study

1.3.1. Objective

The objectives of this study are:

- To study about the current asset life cycle management system implemented in the current industries.
- To provide the technical framework for the asset life cycle management system that is suitable to be used in process plant especially in the oil and gas industries.
- To develop optimum maintenance strategies to be implemented in process plant whereby, the maintenance used for the respective equipment is based on their failure probability, severity and risk.

1.3.2. Scope of Study

The scope of study, as outlined in the objective above, is including providing the technical framework for the asset life cycle management system that suits the process plant usage. In order to develop suitable framework to be used in process plant, a few system that already implemented in other industries has been referred.

Asset life cycle system consists of three phases which are beginning-of-life, middle-of-life and end-of-line. However, this project will only cover on middle-of-life phase, the time where equipment is put in the production line. At this stage, the reliability of the plant is very important in order to ensure the plant production rate is constant and to ensure the plant is in safe condition. And hence, maintenance task is seemed to be a good option to be implemented to achieve the reliability objective.

Maintenance task itself is a very wide definition whereby a few concept of maintenance is available in the literature. However, this project will only focus on four maintenance strategies which are Corrective Maintenance, Condition Based Maintenance, Time Based Maintenance, and Reliability centred Maintenance. Each and every strategy has its own advantages and disadvantages and suitable to be used in the certain condition based on the criticality of the equipment itself.

Selection and decision on the most suitable maintenance strategies to be used is very important criteria and has been given a priority in this project. The decision on maintenance strategies will be based risk assessment result using Failure Mode and Effect Analysis (FMEA) method. the FMEA sheet used in the study will provide the information about the Frequency and severity of the failure associated with single process unit. The value obtained of frequency and severity obtained is then needed t be put in the decision risk matrix that already being divided into 3 main categories. Maintenance strategies to be used for the respective method will be determined by the table whether it is suitable to used corrective maintenance, time based maintenance or condition based maintenance.

CHAPTER 2

LITERATURE REVIEW

2.1. Definition of Asset Life Cycle Management

In the challenging and globalization world today, every company needs to have strategy to keep them relevance to the continuously running competition. Industries seems to be pressured by their need to reduce the operational cost, meet tougher performance of their asset as well as to achieved their production target, the need to comply with regulation requirement, and maximize the return on asset. The visionary industries are looking for the opportunities to reduce the cost of maintaining asset, improve the performance and extend the life of the asset, speed up information and decision making, and gain competitive advantage throughout the asset life cycle. Hence it is put the strong need for the industries to look at the area of asset life cycle management for them to fully utilize their asset.

The term of asset have different in interpretation and usage depending on the domain of use. For instance, Asset is defined as "any physical core, acquired elements of significant value to the organization, which provides and request services for this organization" from an engineering form of view (Ourtani, Parlikad, MacFarlane, 2008).

While asset management has been defined as " a strategic, integrated set of comprehensive processes (financial, management, engineering, operating, maintenance) to gain greatest lifetime effectiveness, utilization and return from physical asset (production and operating equipment and structures)"(Mitchell and Carlson, 2001).

The asset lifecycle management has brought the more specific meaning as to manage the asset throughout their life cycle. The complete asset life cycle management considers ‘cradle-to-grave” life of a typical asset and can be divided into three interdependent process [5];

1. Beginning of Life (BOL): This involves the design and creation (manufacture) of the asset.
2. Middle of Life (MOL): when the asset moves into the usage stage, when it provides intended services to its user, and request services from the user in the form of maintenance, upgrade, etc;
3. End of Life (EOL): when the asset is eventually retired from it operation.

In effective asset life cycle management, coordinating these process and decisions made during these process are vital aspect to be considered, and this can be achieved through monitoring and capturing the information regarding key events throughout the asset’s life cycle.

2.2. Reliability

According to the J D Andrews and T R Moss reliability is defined as “the probability that an item (component, equipment, or systems) will operate without failure for a stated period of time under specified condition”.

This definition is referring to the quantitative reliability where its measure the performance probability of the system over specified period of time. The reliability assessment is carried out for the system that have been settled down in the steady state phase or useful life phase as has been shown in the reliability bath-tub.

The reliability bath tub consists of three phases as follow;

Phase I	known as burn phase where hazard rate will reduce as weak components are eliminated.
Phase II	Useful life of the system where hazard rate is remains approximately constant.
Phase III	Wear out phase when the system is approaching it retirement phase and hazard rate is keep increase.

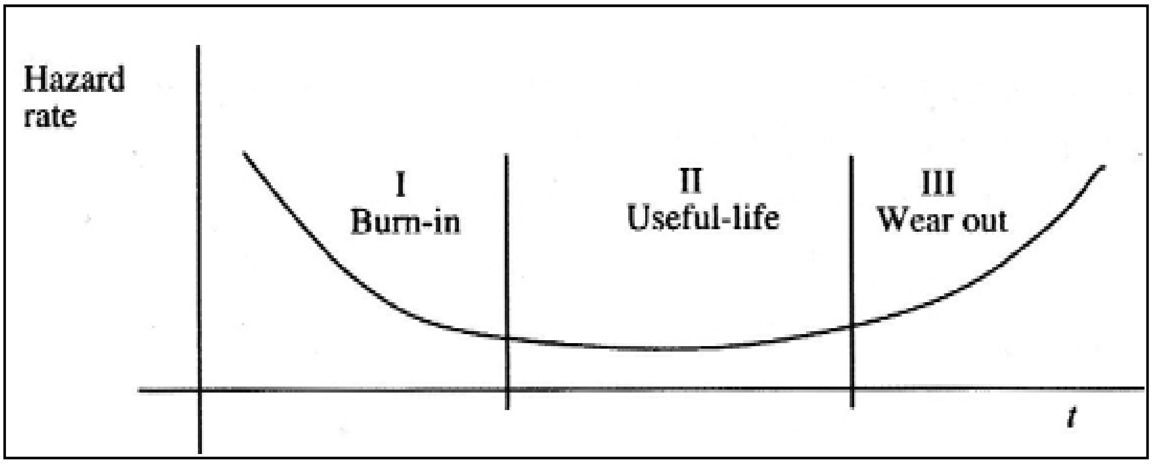


Figure 2.1: Reliability Bath-Tub Curve

Reliability of any system can be representing by the expression below;

$$R(t) = e^{-\mu t}$$

Where

R(t) = probability of successful operation for period of time t.

μ = failure rate

The most common parameters using in the reliability is the Mean Time Before Failure (MTBF) which is represent the predicted time between failures during the operation running. The reliability of a system is increased as the value of MTBF is increased.

$$MTBF = \frac{\sum t_i}{n}$$

Where

$\sum$ti = total operating times

N = number of failures

2.3. Risk Assessment

There are two types of risk assessment available which are either using quantitative or qualitative methods. Both methods are very important in determining potential hazard in the plant. According to Andrews and Moss, the qualitative method is used to identify and rank by important the potential hazard, plant areas, equipment types, or operating procedures that may critically affect the safety or availability of the plant.

A few important qualitative method used widely in industries are Hazard and Operability Study (HAZOP), Failure Mode and Effect Analysis (FMEA), while Fault Tree Analysis (FTA) and Event Tree Analysis are the example of quantitative methods used.

2.3.1 Hazard and Operability Studies (HAZOP)

Hazard and Operability studies (HAZOP) has been introduced to the chemical plants in order to identify and dealing with potential hazard created by industrial process that present to the operators and general public. According to the British Chemical Industry Safety Council, HAZOP is defined as "the application of a formal systematic critical examinations of the process and engineering intentions of the new facilities to assess the hazard potential of maloperation or malfunction of individual items of equipment and the consequential effects on the facility as a whole".

According to J D Andrews and T R Moss, the HAZOP studies is aimed to stimulate the imagination of designers and operators in a systematic manners so that they can identify the cause of potential hazard in the design. This methodology is flexible and applicable to be used in various range of industries regardless small or large organization.

The HAZOP study should be performing by specific HAZOP team that consist of expertise that familiar with the design and operation of the plant. The team need to consider each items available in the plant by applying a set of guide words to determines the consequences of operating conditions outside the design intention.

There are a few necessary term need to be clearly stated before the task can be proceed and there are;

- *Intention* : defines how the part is expected to function
- *Deviation* : Departures from the design intention which are discovered by systematic application of the guide words.
- *Causes* : The reasons why deviations might occur. Causes can be classified as realistic and unrealistic. Deviation due to the latter can be rejected.
- *Consequences* : the result of the deviations.
- *Hazards* : consequences which can cause damage, injury or loss.
- *Guide words* : words which are used to qualify the intention and hence deviations. The list of words are;

NO/ NOT	No flow, no pressure, etc
MORE	High flow, high pressure, etc
LESS	Low flow, low pressure, etc
AS WELL AS	Material in addition to the normal process fluids
PART OF	Process only part of the fluid
REVERSE	reverse flow of process fluids

Example of HAZOP record sheet is shown in the figure below,

ITEMS	GUIDE WORDS	DEVIATION	POSSIBLE CAUSE	CONSEQUENCES	SAFEGUARDS	ACTION REQUIRED

Figure 2.2: Example of HAZOP Datasheet

2.3.2 Failure Mode and Effect Analysis (FMEA)

A failure mode and effect analysis is a procedure in the operation management to systematically evaluate the potential failure modes within the system boundary. The objective of this method is to identify the items or strategies required to reduce the effect of failure and it can be performed to meet variety of objective such as to identify weak areas in the design or to identify critical equipment in the plant or to identify suitable maintenance strategies should be performed.

IDENTIFICATION	FUNCTION	FAILURE MODE	FAILURE EFFECT		FAILURE DETECTION METHOD	COMPENSATING PROVISIONS	SEVERITY	REMARKS
			LOCAL EFFECT	SYSTEM EFFECT				

Figure 2.3: Example FMEA Datasheet

The severity definition for use in process plant FMEA are as per below,

Level 1 - Minor - no significant effect

Level 2 -Major - some reduction in operational effectiveness.

Level 3 - Critical - Significant reduction of functional performance with an immediate change in system operating state.

Level 4 -Catastrophic - total loss of system involving significant property damage, death of operating personnel or environment damage.

2.3.3 Fault Tree Analysis

There are two different approaches to find a relationship between component failures and system failure where each of them know as forward analysis and backward analysis. Fault tree analysis is a deductive or backward approach where it trying to find the root causes that leads to the specific system failure mode.

The FTA can be expressed in term of combination between failure mode and also operator's action. The failure mode which is known as top event is developed into the branches below top event represents the causes for the failure. The development of FTA is executed until at one point, the component failure events or basic event are encountered. Moreover, the Fault tree analysis method can be used in both measurement of qualitative of quantitative method.

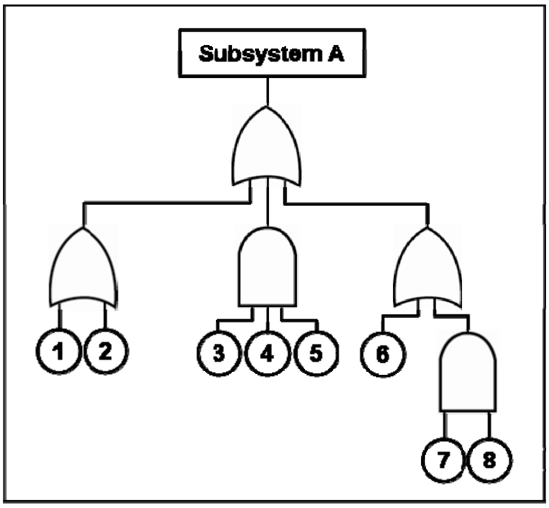


Figure 2.4: Example of Fault Tree Analysis

2.3.4. Event Trees Analysis

The event trees analysis begin with initiating an event until its come to the final result. This method provides information on how the failure can occur and also the probability of occurrence. There are a few steps of conducting ETA and there are as shown follows; [1]

1. Identify an initiating event of interest
2. Identify the safety functions designed to deal with the initiating event
3. Construct the events tree
4. Describe the resulting accident event sequences

If enough data are available, there should be a value assigned to each of the events and it is used to determine the probability of a certain sequence of events and to decide what important improvements are required.

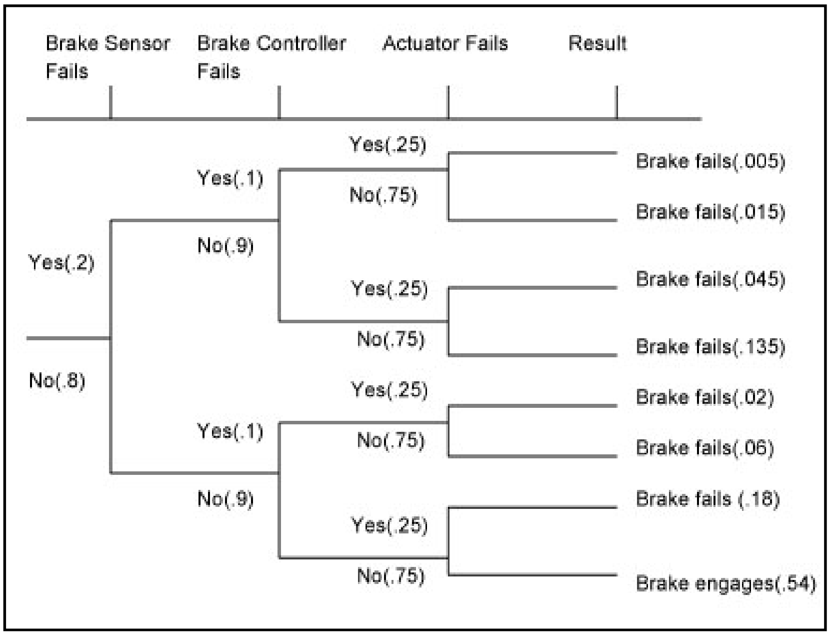


Figure 2.5: Example of Event trees Analysis for Brake Failure

2.4. Maintenance Strategies

Maintenance strategies can be divided into several approaches which lead to the varying maintenance cost and asset availability. A few types of strategies a=have been discussed below;

2.4.1. Corrective maintenance

This type of maintenance is the most simple strategies because its required no early analysis or detection of failure at the equipment and consist non of preventive maintenance at all. The concept of this strategy is by using the equipment until it reach the limit of its own life and broken or in other word the equipment is being put in the production line until it fails. Only then the decision is made whether the system or equipment should be should be repaired or replaced by the new one.

The corrective maintenance is not a cost saving type of maintenance as the damages that causes by the failures of the components may create more cost at the end than a different and more appropriate maintenance strategy. This type of strategies is significantly affecting the reliability performance as it may cause economic consequences for the network operator. It is only suitable to be implemented for the equipment which is non-critical and consequences of failure are not serious (Waeyenbergh & Pintelon, 2002).

2.4.2. Time based Maintenance

Time based maintenance is basic and simplest type of preventive maintenance strategies. The maintenance is carried out based on the fixed time intervals for inspection and conducting maintenance type of works. This time interval either obtained from manufacturers information datasheet or from the judgment of expertise and experience of network operators.

However, the time interval shows in the past shows that the time chosen is far on the safe side meaning that the time interval is to short between one maintenance work to another. Hence, the short interval is successfully achieved the objective of the maintenance but in other side it required much time as the maintenance work is conducted frequently. So it is suggested that the time interval should be make longer by decrease the frequency of inspection and maintenance work.

The time choose to do the inspection or maintenance work can be in any time interval whether it should be conducted daily, weekly, month or even on year basis.

2.4.3 Condition based Maintenance

Condition based maintenance is one of the preventive maintenance strategies where it try to maintained the equipment at the right time based on the condition of the equipment. Hence the real-time data regarding the condition of the equipment usually used in order to prioritize and optimized the maintenance resourced.

The system is continuously observed parameters condition in machinery, such that a significant change in indicative aspect that already decided like temperature, vibration and a few more that can indicate the developing failure in the system. Such condition monitoring will determined the condition or health of the equipment. The action of doing inspection or maintenance work will only take place when it is necessary to be conducted. Ideally the condition based maintenance allow the maintenance personal to only to the right thing at the right time, minimize the spare part cost, and reduce the downtime and time to be spent on maintenance task.

2.4.4 Reliability Centered Maintenance

Formal definition of Reliability Centered Maintenance can be referring to four main areas as follows (Deshpande & Modak, 2001);

1) It is a process used to determine the maintenance requirement of any physical asset in its operating context.
2) A process used to determine what must be done to ensure that any physical asset continuous to fulfill its intended functions in its present operating context.
3) RCM is a method for developing and selecting maintenance design alternatives based on safety, operational and economic criteria, RCM employs a systems perspective in its analysis of the system function, failures of functions and prevention of these failures.
4) RCM is a system consideration of system function, the way function can fail, and a priority based consideration of safety and economics that identifies applicable and effective PM task.

Or it is can simply conclude that the RCM methodology is completely described four unique features;

1) Preserve function
2) Identify failure modes that can defeat function
3) Priorities function need
4) Select only applicable and effective task

RCM focuses on “system approach. Complex, redundant systems have reliability directly engineered into their design. The reliability of the system can be reduced if maintenance task and frequencies are nit its integral components. Over maintenance reduces the system reliability on account of maintenance induced failure. For highly reliable system the system reliability very often is reduced due to human intervention under the pretext of Preventive Maintenance (Deshpande & Modak, 2001).

CHAPTER 3

METHODOLGY

This project consists of five (5) main steps that has been simplified in the figure 3.1 below,

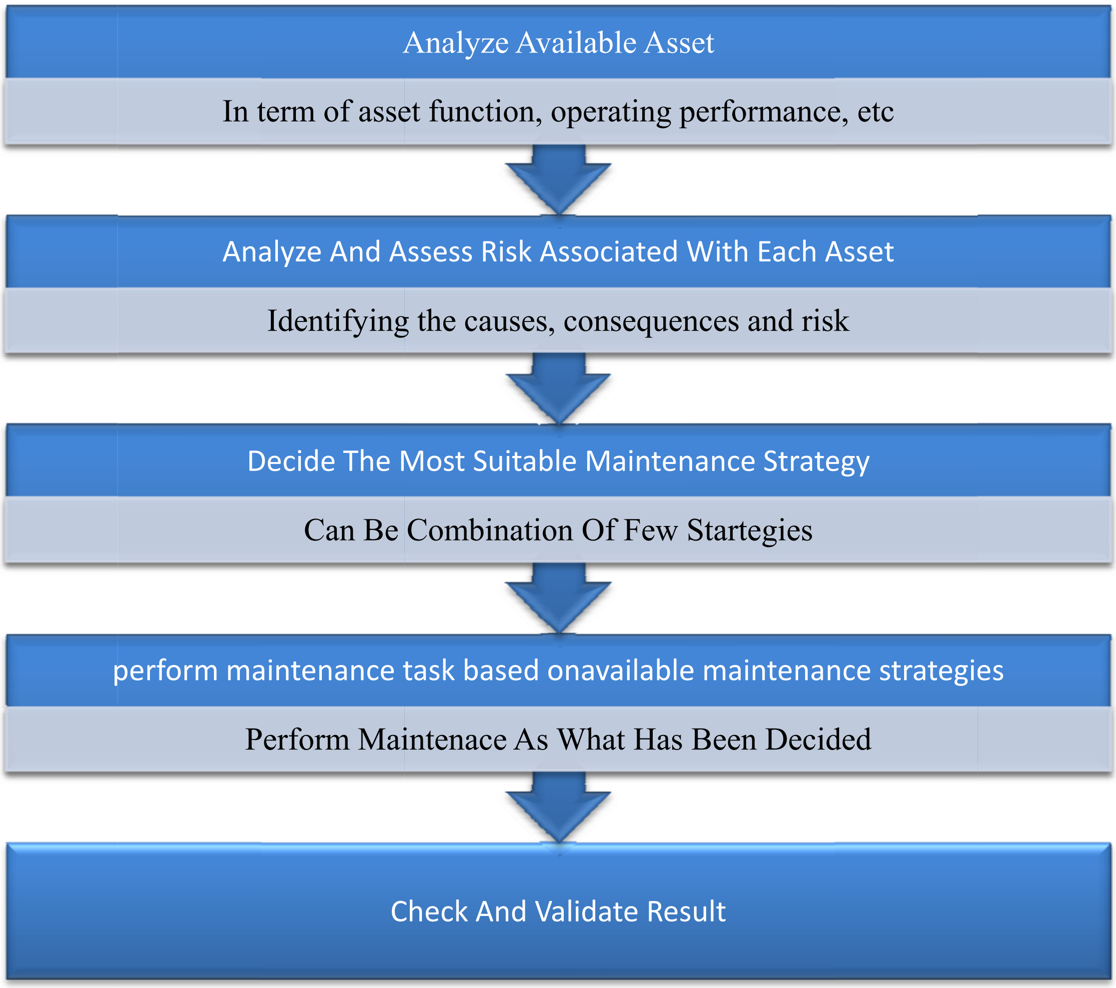


Figure 3.1: Methodology of the project

3.1 Analyze available asset

The first step that needs to be carried out in this system is to analyze the available asset in the process plant selected. One way to analyzed them is by referring to the Process Flow Diagram of the plant where it can provide a lot of important information about the plant. The PFD will show all main equipment used as well as their design parameters including Pressure, Temperature, Flow rate, mass balance and also controlling unit.

PFD is then further developed into mechanical flow diagram that shows all the equipment throughout plant including all those interconnecting pipe, materials, design and operating data, location of instruments and pressure relieving devices. The MFD also provides all the information on sizes, materials and layout to provide the scope for the first round requirement for equipments maintainability.

3.2 Analyze and Assess Failure Associated With Each Asset

The second step required in this system development is analyzing and assessing failure associated with each asset in the plant. Hence a few assessment tools that can measure the potential hazard in qualitative or quantitative outcome are required in this significant step. The overall objective of this step is to identify and rank by importance the potential hazards, plant areas, equipment types or operating procedures that may affect the plant reliability throughout its life cycle.

Even there a lot of assessment method available and commonly used in industries, this project will only used the Risk Table to assess the risk associated with the individual equipment. The Risk Table is used because it’s providing the important information like probability and severity of the failure along with risk value in form of quantitative measurement. The probability data is taken from the Reliability Data Handbook written by Robert Moss while the severity of the failure is however taken from plant historical data or from expertise who have vast experience in the chemical plant environment.

Shown below are the Risk Table used for this project;

Table 3.1: Example of Risk Table

No	Items	Probability			Severity		Risk Value
		μ	P	Value	Impact	Value	

μ is referring to the value of failure rate that can be obtained from reliability data handbook. The Probability of failure is then can be calculated based on the failure rates obtained.

The formula used to calculate the probability of failures is shown below;

$$P = 1 - R(t)$$

$$P = 1 - e^{-\mu t}$$

Where

R(t) = probability of successful operation for period of time t.

μ = failure rate

Each failure mode have their own frequency and severity of the failure depends on equipments and the failure it posses. The ranking of frequency criteria and probability can be obtained from table 3.2 and table 3.3 respectively.

Table 3.2: Frequency of Occurrence criteria

Value	Occurrence	Failure Probability
1	Very rare	< 0.2
2	Rare	0.2 < P <0.4
3	Occasional	0.4 < P < 0.6
4	Probable	0.6 < P < 0.8
5	Frequent	0.8 < P < 1.0

Table 3.3: Severity Evaluation Criteria

Value	Occurrence	Impact	Failure Severity
1	Minor	Type I	Discomfort: medication/accident 1-3 days **OR** loss < RM10 000
2	Moderate	Type II	Poor health 3-10 days **OR** loss RM10 000 – RM 100 000
3	Severe	Type III	Occupational disease: reversible in 10-30 days **OR** Loss RM100 000 – RM 1 million
4	Very Severe	Type IV	Permanent damage to health: >30 days/ involving several people

			OR Loss RM 1 million – RM 10 million
5	Catastrophic	Type V	Lethal exposure: Fatal accident **OR** loss > 10 million

the severity of failures whether in term of health of economic impact may differ from one company to another depends on company owns definition.

3.3.Decide The Most Suitable Maintenance Strategy

There are a few ways listed by the industries in order for them to choose suitable maintenance strategy to be implemented in their plant. Most of companies applied only one type of maintenance for the whole equipment in their plant.

However, applying one type of maintenance for all equipments is seemed not to be effective and always have some drawbacks either on reliability or monetary aspects. For example, if the plant is using corrective maintenance for all equipment in the plant, they will be facing a situation where some major equipment is broken down; there will be such a big impact to the reliability of the plant. This situation occur because corrective maintenance only being applied when the equipment already in failure mode and there is no initial indicator or initial step taken to prevent the equipment from failure. As a result, the plant will always come to the state where its operation is not smoothly run because of the failure that affects their production line.

Meanwhile, if time based maintenance were applied to all equipment in the plant, the maintenance task will be a burden to the plant operator because this type of maintenance need operators to continuously check the equipment on timely basis whether weekly, or monthly. This type of maintenance is suitable to be applied only to a major equipment where their failure will affect the production of the plant and not suitable for the minor equipment that have minimum effect for the plant.

Hence there is a need to find the most suitable way on deciding suitable maintenance task to be applied to each of equipment available in the plant. This project then suggests a decision matrix table to be referred in order to decide the most suitable maintenance strategies to be performed. The decision risk matrix table is shown in following figure 3.2 below;

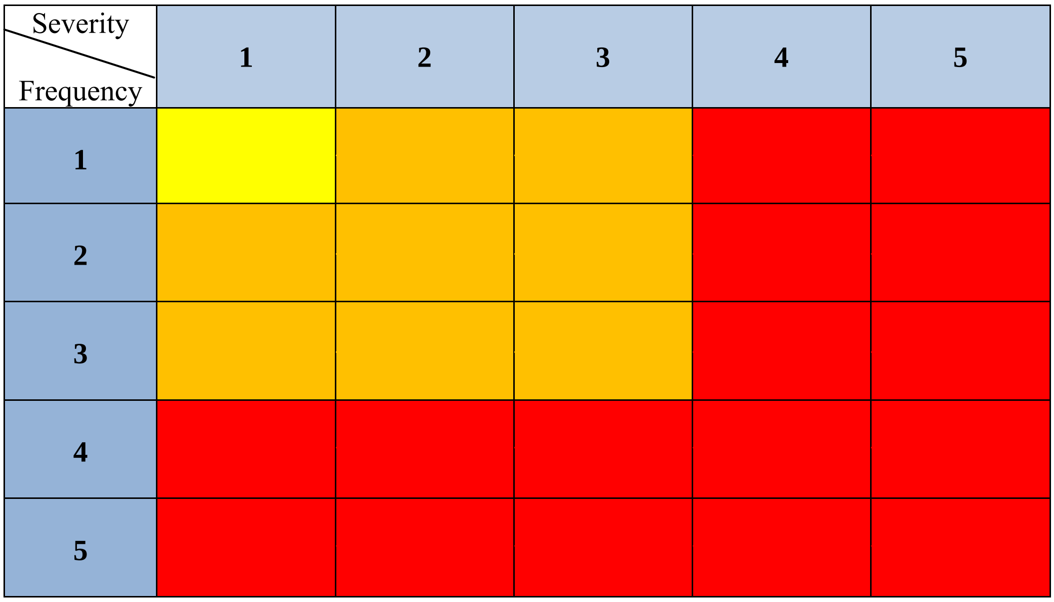
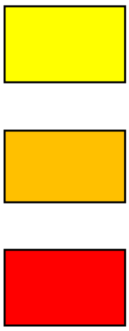


Figure 3.2: The decision risk Matrix



Corrective maintenance

Time based maintenance

Condition based maintenance

3.4.Perform Maintenance Task Based on Available Maintenance Strategies

This project will cover three types of maintenance strategies which are Corrective maintenance, Time Based Maintenance (TBM) and Condition Based Maintenance (CBM). All of the strategies listed is used based on different approach and can be used or implemented in different situation and condition. As what has been discussed in earlier, the decision to choose maintenance strategies were based on decision risk matrix above. If the equipment falls under low risk area which is in 1 X 1 areas, the equipment is categorized under low risk equipment and corrective maintenance is then the most suitable maintenance to be applied for this equipment. Same goes to other area whereby if the equipment fall within yellow and red area, are categorized under equipment that need time based and condition based maintenance respectively.

3.4.1. Corrective Maintenance

Corrective maintenance is the simplest maintenance strategies among all. This type of maintenance is also referred to reactive maintenance because the action will only be taken when there is problem or failures arise. There is no preventive action taken in this strategies, hence this type it only suitable to be applied for the equipment that have minimum risk to the plant operation.

3.4.2. Timed based Maintenance;

The time based maintenance strategies were applied for the equipment that has moderate risk of failure. This type of maintenance was based on timely basis either in weekly, monthly or annually. The time interval for the inspection is depending on the frequency of failure of the equipment. Time interval for equipments are not the same because equipment that fall under high frequency failure needs to be check more regular than those with lower frequency failure. The fixed time interval for inspection and maintenance work for the equipment falls within this type of maintenance can be divided into three group as shown below;

- ✓ Weekly inspection – maintenance is done weekly for equipment that has higher frequency of failure.
- ✓ Monthly – maintenance is done monthly for equipments that has moderate frequency of failure
- ✓ Annually – maintenance is done annually for equipment that has low frequency of failure.

However, equipment maintenance not necessary follows these three groups of fixed time interval since the maintenance should be done based on the frequency of failure that are different between one to another.

3.4.3. Condition Based Maintenance

Condition based maintenance seemed to be the most effective maintenance strategies to be applied. However, this type of strategies only suitable to be applied to equipments those are really critical to the plant operation. The maintenance is done based on the condition or performance of individual equipment. Hence, the critical equipment that falls under this category will be monitored regularly on a few parameters like temperature, pressure, vibration, etc. Any fluctuation on these parameters will give a warning sign to the plant management to perform the maintenance on the equipment.

3.5.Check and Validate Result

The last step of this system is to check and validate the result or outcome of the whole system developed by monitoring the performance of the plant. There are a few ways available in determining the outcome or result of this project. It decided to use two different methods which are Mean Time Before Failure and Overall Equipment Effectiveness throughout this respective project.

3.5.1. Mean Time between Failures (MTBF)

Mean time Before Failure (MTBF) is used to calculate the average time taken for an equipment to fail or a time interval between two failures. MTBF is given by the first moment of the failure density function [**2**], which are;

$$E(t) = MTBF = \int_{0}^{\infty} tf(t)dt = \frac{1}{\mu}$$

μ is referred to the failure rate of the equipment. The value of μ can be obtained from The Reliability Data Handbook, The MTBF calculation can be used to calculate for both single equipment or for the overall equipment performance. However, more component is being considered in the overall plant MTBF calculation will reduce the value of MTBF, hence indicate that the less time taken for the next failure to occur and low reliability of the plant. So in this project, the MTBF calculation will be only perform for the single equipment unit and not for the overall plant performance. The total performance of the plant will be calculating using Overall Equipment Effectiveness.

3.5.2 Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is a tool used specifically to measure on how effectively a manufacturing operation or specific equipment is utilized. The OEE measurement calculates the overall equipment performance regardless of the individual unit performance.

The OEE calculation can be an indicator to measure the efficiency of the plant and has been developed based on three separate measurable components whose are availability, Performance and Quality whereby all these components can be targeted for improvement. OEE can be calculated as formula shown below;

$$OEE = AE \times OE \times RE \times QE$$

Where

- Availability efficiency (AE) = Equipment uptime / Total Time
- Operational Efficiency (RE) = (Theoretical production time for actual units) / Production Time
- Quality Efficiency (QE) = (theoretical production time foe effective units) / (theoretical production time for actual unit)
- Rate Efficiency (RE) = (theoretical production time for actual units) / (production time)

CHAPTER 4

CASE STUDY AND DISCUSSION

In order to illustrate the suggested methodology, two case studies have been conducted in two different plant which are in polyethylene and Liquid Natural Gas (LNG) plant. All the detail of the typical polyethylene and LNG plant has been obtained. However, only a small portion of the plant is chosen to be studied for the case studies purpose. The polymerisation Unit and sulfinol Unit has been selected for both plant respectively.

4.1. Case Study 1: Polymerization area at Polyethylene Plant

For case study 1, the polymerization unit of typical polyethylene plant has been chose. The area of polymerization process is where the ethylene gas is polymerizing to form polyethylene powder before it being heated to melt and then being extruded to form the small polyethylene resins. This polyethylene plant was constructed early 90’s and still run the business of polyethylene up until now. This plant consists of five main areas, separated according to their task of function. The polymerization unit that is chosen for this case study is known as area 2, or also known as polymerization unit.

4.1.1. Analyze the asset

The first step that needs to be followed is to analyze the asset that available in this plant. For this respective case study, the area that being analyzed is only polymerization area. Process Flow Diagram of this area is shown in Figure 4.1 below;

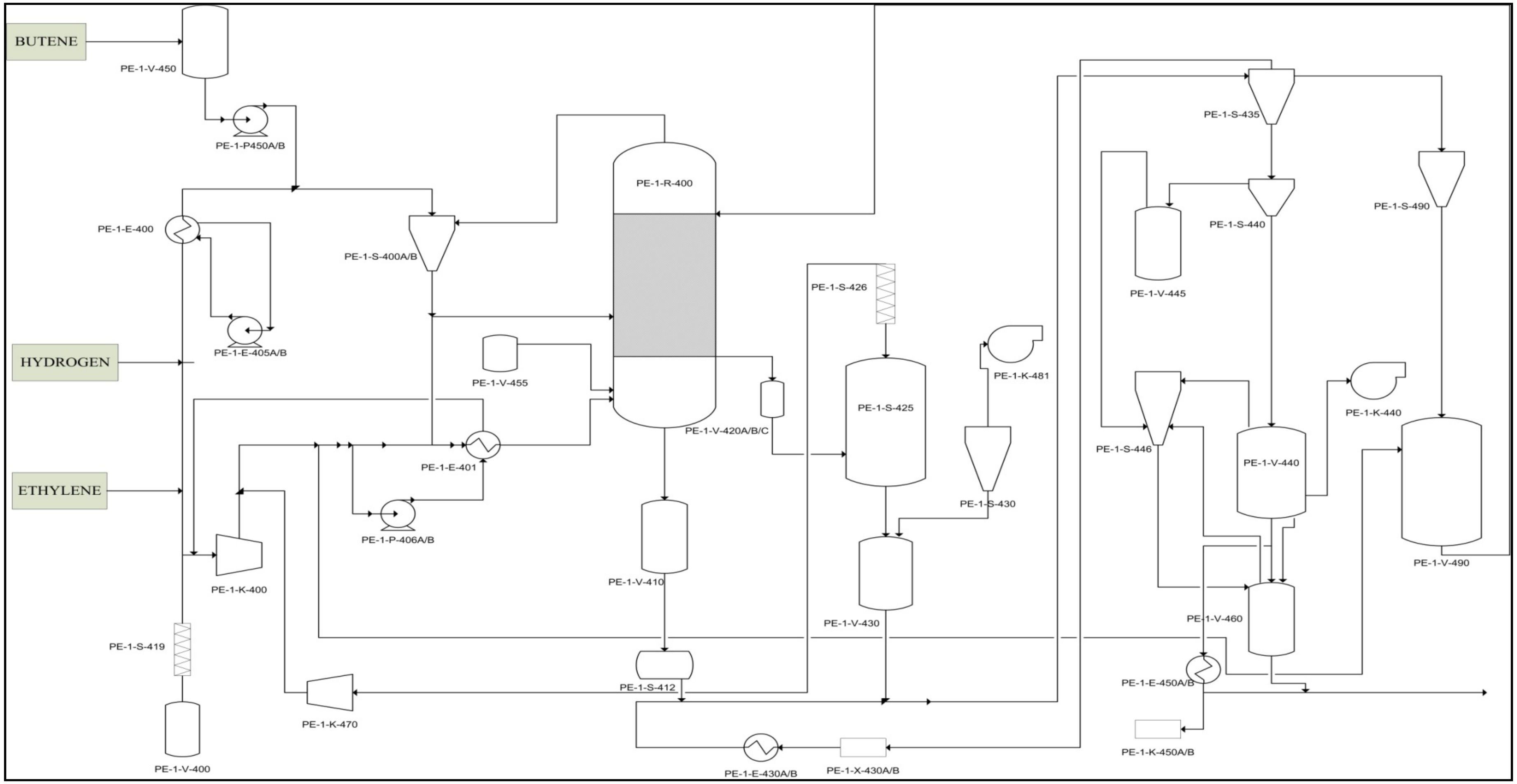


Figure 4.1: Process Flow Diagram of typical polyethylene plant

There are 44 main equipments available within this area and all of them are shown in the table below;

Table 4.1: list of equipment in the polymerization area

No	Equipment	Unit Area	Description
1	PE-1-E-400	Polymerization Unit	Heat Exchanger (Fixed Tube)
2	PE-1-E-401	Polymerization Unit	Heat Exchanger (Fixed Tube)
3	PE-1-E-430A	Polymerization Unit	Heat Exchanger (U-Tube)
4	PE-1-E-430B	Polymerization Unit	Heat Exchanger (U-Tube)
5	PE-1-E-450A	Polymerization Unit	Heat Exchanger (Fin Tube)
6	PE-1-E-450B	Polymerization Unit	Heat Exchanger (Fin Tube)
7	PE-1-K-400	Polymerization Unit	Compressor (Centrifugal)
8	PE-1-K-440	Polymerization Unit	Compressor (Centrifugal)
9	PE-1-K460A	Polymerization Unit	Blower
10	PE-1-K460B	Polymerization Unit	Blower
11	PE-1-K-470	Polymerization Unit	Compressor (Reciprocating)
12	PE-1-K-481	Polymerization Unit	Compressor (Centrifugal)
13	PE-1-P-405A	Polymerization Unit	Pump (Centrifugal, Water)
14	PE-1-P-405B	Polymerization Unit	Pump (Centrifugal, Water)
15	PE-1-P-406A	Polymerization Unit	Pump (Centrifugal, Water)
16	PE-1-P-406B	Polymerization Unit	Pump (Centrifugal, Water)
17	PE-1-P-450A	Polymerization Unit	Pump (Centrifugal, Gas)

18	PE-1-P-450B	Polymerization Unit	Pump (Centrifugal, Gas)
19	PE-1-R-400	Polymerization Unit	Reactor
20	PE-1-S-400A	Polymerization Unit	Cyclone
21	PE-1-S-400B	Polymerization Unit	Cyclone
22	PE-1-S-412	Polymerization Unit	Separator
23	PE-1-S-419	Polymerization Unit	Filter
24	PE-1-S-425	Polymerization Unit	Separator
25	PE-1-S-426	Polymerization Unit	Filter
26	PE-1-S-430	Polymerization Unit	Filter
27	PE-1-S-435	Polymerization Unit	Filter
28	PE-1-S-440	Polymerization Unit	Separator
29	PE-1-S-446	Polymerization Unit	Filter
30	PE-1-S-490	Polymerization Unit	Cyclone
31	PE-1-V-400	Polymerization Unit	Vessel (Oxygen)
32	PE-1-V-410	Polymerization Unit	Vessel (Powder)
33	PE-1-V-420A	Polymerization Unit	Vessel (Hopper, Additive)
34	PE-1-V-420B	Polymerization Unit	Vessel (Hopper, Additive)
35	PE-1-V-420C	Polymerization Unit	Vessel (Hopper, Additive)
36	PE-1-V-430	Polymerization Unit	Vessel (Powder)
37	PE-1-V-440	Polymerization Unit	Vessel (Degasser)
38	PE-1-V-445	Polymerization Unit	Vessel
39	PE-1-V-450	Polymerization Unit	Vessel (Butane)

40	PE-1-V-456	Polymerization Unit	Vessel (Carbon Dioxide)
41	PE-1-V-460	Polymerization Unit	Vessel (Hopper, Powder)
42	PE-1-V-490	Polymerization Unit	Vessel
43	PE-1-X-430A	Polymerization Unit	Rotary Valve
44	PE-1-X-430B	Polymerization Unit	Rotary Valve

4.1.2. Analyze and asses risk associated with assets.

This step will analyse the risk associated with all the equipment available in this polymerization area. The risk table is used in performing this step;

Table 4.2: Risk Table of polymerisation area

No	Equipment	Probability			Severity		Risk Value
		μ	P	Value	Impact	Value	
1	PE-1-E-400	11.4	0.095	1	Type II	2	2
2	PE-1-E-401	11.4	0.095	1	Type II	2	2
3	PE-1-E-430A	32.7	0.249	2	Type II	2	4
4	PE-1-E-430B	32.7	0.249	2	Type II	2	4
5	PE-1-E-450A	11.4	0.095	1	Type I	1	1
6	PE-1-E-450B	11.4	0.095	1	Type I	1	1
7	PE-1-K-400	5582	1.000	5	Type V	5	25
8	PE-1-K-440	1710	1.000	5	Type IV	4	20
9	PE-1-K460A	126	0.668	4	Type I	1	4

10	PE-1-K460B	126	0.668	4	Type I	1	4
11	PE-1-K-470	413	0.973	5	Type II	2	10
12	PE-1-K-481	1710	1.000	5	Type III	3	15
13	PE-1-P-405A	438	0.978	5	Type I	1	5
14	PE-1-P-405B	438	0.978	5	Type I	1	5
15	PE-1-P-406A	438	0.978	5	Type I	1	5
16	PE-1-P-406B	438	0.978	5	Type I	1	5
17	PE-1-P-450A	615	0.995	5	Type I	1	5
18	PE-1-P-450B	615	0.995	5	Type I	1	5
19	PE-1-R-400	3.33	0.029	1	Type V	5	5
20	PE-1-S-400A	4.6	0.039	1	Type I	1	1
21	PE-1-S-400B	4.6	0.039	1	Type I	1	1
22	PE-1-S-412	97	0.572	3	Type IV	4	12
23	PE-1-S-419	4.6	0.039	1	Type III	3	3
24	PE-1-S-425	97	0.572	3	Type IV	4	12
25	PE-1-S-426	1.8	0.016	1	Type III	3	3
26	PE-1-S-430	1.8	0.016	1	Type III	3	3
27	PE-1-S-435	1.8	0.016	1	Type III	3	3
28	PE-1-S-440	97	0.572	3	Type IV	4	12
29	PE-1-S-446	1.8	0.016	1	Type III	3	3
30	PE-1-S-490	4.6	0.039	1	Type III	3	3
31	PE-1-V-400	0.08	0.001	1	Type III	3	3

32	PE-1-V-410	0.32	0.003	1	Type III	3	3
33	PE-1-V-420A	138	0.701	4	Type I	1	4
34	PE-1-V-420B	138	0.701	4	Type I	1	4
35	PE-1-V-420C	138	0.701	4	Type I	1	4
36	PE-1-V-430	0.32	0.003	1	Type I	2	2
37	PE-1-V-440	0.32	0.003	1	Type II	2	2
38	PE-1-V-445	0.32	0.003	1	Type II	2	2
39	PE-1-V-450	0.08	0.001	1	Type III	3	3
40	PE-1-V-456	0.08	0.001	1	Type IV	4	4
41	PE-1-V-460	138	0.701	4	Type IV	4	16
42	PE-1-V-490	0.32	0.003	1	Type V	5	5
43	PE-1-X-430A	17.3	0.141	1	Type I	1	1
44	PE-1-X-430B	17.3	0.141	1	Type I	1	1

Where;

- μ is equipment failure rate (fault/million hours). The failure rate need to be converted in units of fault/year before it can be inserted in the formula in order to calculate the failure probability,(P).
- P represents the failure probability,
- Probability value represents the associated value for probability to be inserted in the decision risk matrix.
- Impact represents the severity of failure.
- Severity value represents the associated value for the severity to be inserted in the decision risk matrix.
- Risk Value is a result of multiplying probability value and severity value.

4.1.3. Decide the Most Suitable Maintenance Strategy

When the Risk Table is completely filled with required information, the project is then moved to the next step which is to decide the suitable maintenance strategy to be applied for certain equipment. In order to do that, the decision risk matrix needs to be referred. One can decide the suitable maintenance by matching the information of probability and severity values filled in the risk table with the decision risk matrix.

Based on the study case done earlier, maintenance strategies that suit to be applied on certain equipment is shown in the table below;

Table 4.3: List of Equipment with maintenance strategy

No	Corrective Maintenance	Time Based Maintenance	Condition Based Maintenance
1	PE-1-E-450A	PE-1-E-400	PE-1-K-400
2	PE-1-E-450B	PE-1-E-401	PE-1-K-440
3	PE-1-S-400A	PE-1-E-430A	PE-1-K-460A
4	PE-1-S-400B	PE-1-E-430B	PE-1-K-460B
5	PE-1-X-430A	PE-1-S-419	PE-1-K-470
6	PE-1-X-430B	PE-1-S-426	PE-1-P-405A
7		PE-1-S-430	PE-1-P-405B
8		PE-1-S-435	PE-1-P-406A
9		PE-1-S-446	PE-1-P-406B
10		PE-1-S-490	PE-1-P-450A
11		PE-1-V-400	PE-1-P-450B
12		PE-1-V-410	PE-1-R-400

13		PE-1-V-440	PE-1-S-412
14		PE-1-V-445	PE-1-S-425
15		PE-1-V-450	PE-1-S-440
16		PE-1-V-430	PE-1-V-420A
17			PE-1-V-420B
18			PE-1-V-420C
19			PE-1-V-456
20			PE-1-V-460
21			PE-1-V-490
22			PE-1-K-481

4.1.4. Perform maintenance strategy

After the maintenance strategies for each component has been decided, the maintenance is then need to be perform accordingly. For the equipment that fall under corrective maintenance, have to be maintained according to the basic or principle of corrective maintenance. Same goes to the equipment that fall under time based and condition based maintenance, whereby there need to be maintained according to the principle of their respective type of maintenance.

4.1.5. Check and Validate Result

The current MTBF for the equipments is shown in the table below;

Table 4.4: Table of Equipment with MTBF values

No	Equipment	MTBF	No	Equipment	MTBF
1	PE-1-E-400	10.014	23	PE-1-S-419	24.816
2	PE-1-E-401	10.014	24	PE-1-S-425	1.177
3	PE-1-E-430A	3.491	25	PE-1-S-426	63.420
4	PE-1-E-430B	3.491	26	PE-1-S-430	63.420
5	PE-1-E-450A	10.014	27	PE-1-S-435	63.420
6	PE-1-E-450B	10.014	28	PE-1-S-440	1.177
7	PE-1-K-400	0.020	29	PE-1-S-446	63.420
8	PE-1-K-440	0.067	30	PE-1-S-490	24.816
9	PE-1-K460A	0.906	31	PE-1-V-400	1426.941
10	PE-1-K460B	0.906	32	PE-1-V-410	356.735
11	PE-1-K-470	0.276	33	PE-1-V-420A	0.827
12	PE-1-K-481	0.067	34	PE-1-V-420B	0.827
13	PE-1-P-405A	0.261	35	PE-1-V-420C	0.827
14	PE-1-P-405B	0.261	36	PE-1-V-430	356.735
15	PE-1-P-406A	0.261	37	PE-1-V-440	356.735
16	PE-1-P-406B	0.261	38	PE-1-V-445	356.735
17	PE-1-P-450A	0.186	39	PE-1-V-450	1426.941
18	PE-1-P-450B	0.186	40	PE-1-V-456	1426.941

19	PE-1-R-400	34.281	41	PE-1-V-460	0.827
20	PE-1-S-400A	24.816	42	PE-1-V-490	356.735
21	PE-1-S-400B	24.816	43	PE-1-X-430A	6.599
22	PE-1-S-412	1.177	44	PE-1-X-430B	6.599

The value of OEE cannot be calculated in this case study, because it's required the continuous data from the plant. The collection of a few month real data is required in order to compare this method with the method that already implemented in the plant currently. The effectiveness of this method is only proven if the OEE of certain plant increase as they apply this method.

4.2. Case Study 2: Sulfinol Unit at Liquid Natural Gas plant.

For case study 2, the sulfinol unit of typical LNG plant was selected to be studied. The sulfinol unit is basically used to remove the acid gas which is predominantly carbon dioxide from natural gas in order to prevent freezing out and blockage in the liquefaction unit

4.2.1. Analyze the asset

The steps that need to be followed is just the same with the step in case study 1. The first step involve is analyzing the asset available in the respective area. Process Flow Diagram of the sulfinol unit is shown in Figure 4.2;

There are about 49 main equipments available in this section and all of them have been listed in the table below;

Table 4.5: List of Equipment in Sulfinol Unit

No	Equipment	Unit Area	description
1	911-RV-001	sulfinol Unit	Relief Valve
2	911-RV-005A	sulfinol Unit	Relief Valve
3	911-RV-005B	sulfinol Unit	Relief Valve
4	911-RV-005C	sulfinol Unit	Relief Valve
5	911-RV-009	sulfinol Unit	Relief Valve
6	911-RV-010	sulfinol Unit	Relief Valve
7	911-RV-011	sulfinol Unit	Relief Valve
8	911-RV-012	sulfinol Unit	Relief Valve
9	911-RV-018A	sulfinol Unit	Relief Valve

10	911-RV-018B	sulfinol Unit	Relief Valve
11	911-RV-018C	sulfinol Unit	Relief Valve
12	911-RV-018D	sulfinol Unit	Relief Valve
13	911-RV-018E	sulfinol Unit	Relief Valve
14	911-RV-025	sulfinol Unit	Relief Valve
15	911-RV-026	sulfinol Unit	Relief Valve
16	911-RV-033	sulfinol Unit	Relief Valve
17	911-RV-034	sulfinol Unit	Relief Valve
18	C-91101	sulfinol Unit	gas Absorber
19	C-91103	sulfinol Unit	regenerator
20	E-91101	sulfinol Unit	solvent cooler
21	E-91102A	sulfinol Unit	heat exchanger (rich sulfinol)
22	E-91102B	sulfinol Unit	heat exchanger (rich sulfinol)
23	E-91102C	sulfinol Unit	heat exchanger (rich sulfinol)
24	E-91105	sulfinol Unit	regenerator (condenser)
25	E-91106A	sulfinol Unit	regenerator (reboiler)
26	E-91106B	sulfinol Unit	regenerator (reboiler)
27	E-91106C	sulfinol Unit	regenerator (reboiler)
28	E-91106D	sulfinol Unit	regenerator (reboiler)
29	P-91101A	sulfinol Unit	pump (solvent)
30	P-91101B	sulfinol Unit	pump (solvent)
31	P-91101C	sulfinol Unit	pump (solvent)
32	P-91102A	sulfinol Unit	pump (booster)
33	P-91102B	sulfinol Unit	pump (booster)

34	P-91102C	sulfinol Unit	pump (booster)
35	P-91103A	sulfinol Unit	pump (reflux)
36	P-91103B	sulfinol Unit	pump (reflux)
37	P-91104	sulfinol Unit	pump (drain vessel)
38	P-91105	sulfinol Unit	pump (drain vessel)
39	P-91108	sulfinol Unit	pump (water)
40	S-91101	sulfinol Unit	filter (solvent)
41	S-91106	sulfinol Unit	recycle filter
42	S-91110A	sulfinol Unit	filter (carbon)
43	S-91110B	sulfinol Unit	filter (carbon)
44	S-91111	sulfinol Unit	filter (solvent)
45	S-91112	sulfinol Unit	recycle filter
46	V-91101	sulfinol Unit	flash vessel
47	V-91103	sulfinol Unit	reflux drum
48	V-91105	sulfinol Unit	drain vessel
49	V-91107	sulfinol Unit	feed gas vessel

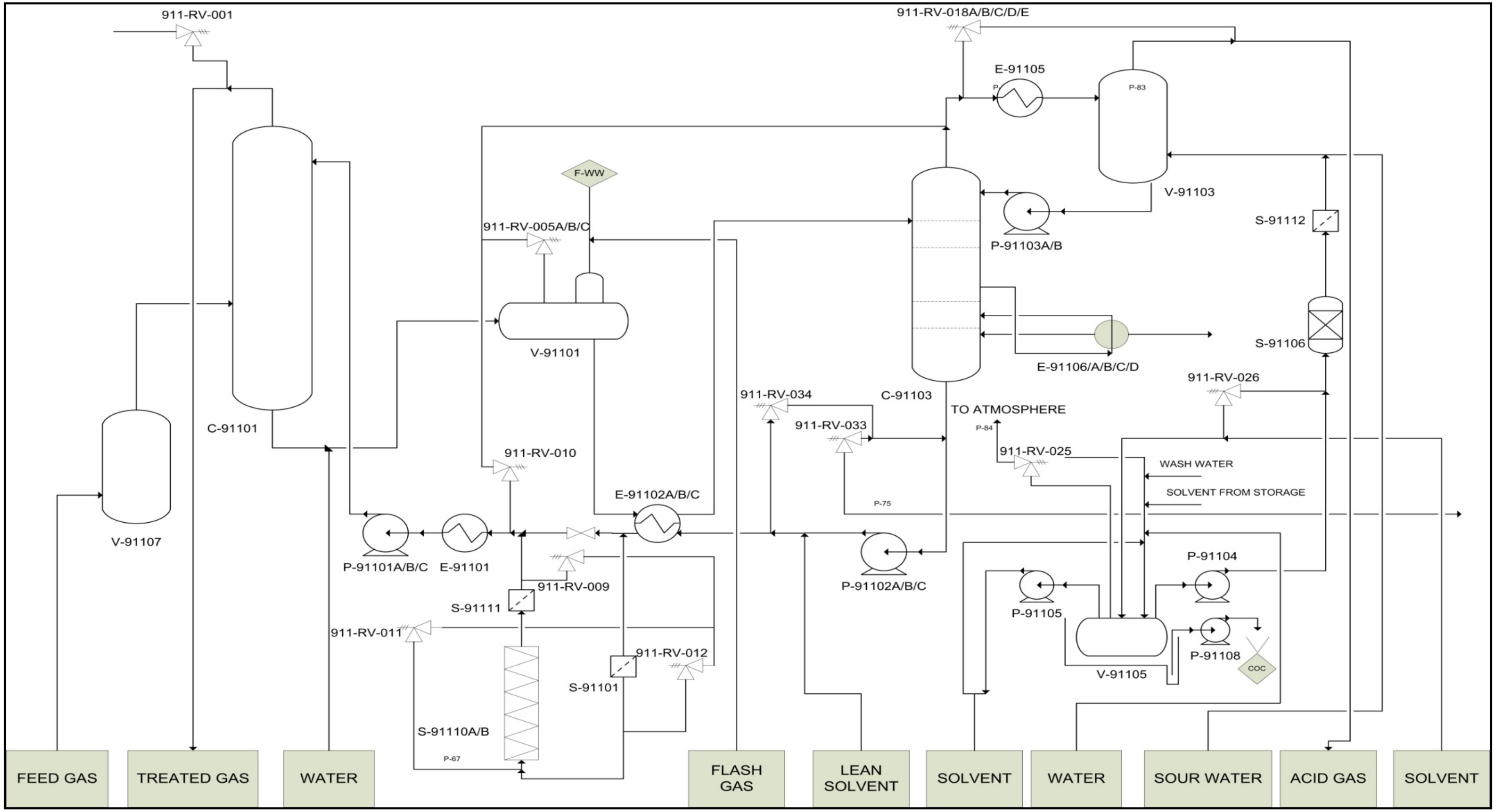


Figure 4.2: Process Flow Diagram of Sulfinol Unit in LNG plant

4.2.2. Analyze and asses risk associated with assets.

This step will analyse the risk associated with all the equipment available in this polymerization area. The risk table is used in performing this step;

Table 4.6: Risk Table of Sulfinol Unit

No	Equipment	Probability			Severity		Risk Value
		μ	P	Value	Impact	Value	
1	911-RV-001	23	0.182	1	Type V	5	5
2	911-RV-005A	23	0.182	1	Type III	3	3
3	911-RV-005B	23	0.182	1	Type III	3	3
4	911-RV-005C	23	0.182	1	Type III	3	3
5	911-RV-009	23	0.182	1	Type V	5	5
6	911-RV-010	23	0.182	1	Typ3 V	5	5
7	911-RV-011	23	0.182	1	Type V	5	5
8	911-RV-012	23	0.182	1	Type V	5	5
9	911-RV-018A	23	0.182	1	Type III	3	3
10	911-RV-018B	23	0.182	1	Type III	3	3
11	911-RV-018C	23	0.182	1	Type III	3	3
12	911-RV-018D	23	0.182	1	Type III	3	3
13	911-RV-018E	23	0.182	1	Type III	3	3
14	911-RV-025	23	0.182	1	Type V	5	5
15	911-RV-026	23	0.182	1	Type V	5	5

16	911-RV-033	23	0.182	1	Type V	5	5
17	911-RV-034	23	0.182	1	Type V	5	5
18	C-91101	16	0.131	1	Type V	5	5
19	C-91103	91.3	0.551	3	Type V	5	15
20	E-91101	0.67	0.006	1	Type III	3	3
21	E-91102A	32.7	0.249	2	Type I	1	2
22	E-91102B	32.7	0.249	2	Type I	1	2
23	E-91102C	32.7	0.249	2	Type I	1	2
24	E-91105	28.5	0.221	2	Type IV	4	8
25	E-91106A	26	0.204	2	Type I	1	2
26	E-91106B	26	0.204	2	Type I	1	2
27	E-91106C	26	0.204	2	Type I	1	2
28	E-91106D	26	0.204	2	Type I	1	2
29	P-91101A	22	0.175	1	Type I	1	1
30	P-91101B	22	0.175	1	Type I	1	1
31	P-91101C	22	0.175	1	Type I	1	1
32	P-91102A	88	0.537	3	Type II	2	6
33	P-91102B	88	0.537	3	Type II	2	6
34	P-91102C	88	0.537	3	Type II	2	6
35	P-91103A	26	0.204	1	Type I	1	1
36	P-91103B	26	0.204	1	Type I	1	1
37	P-91104	250	0.888	5	Type III	3	15

38	P-91105	250	0.888	5	Type III	3	15
39	P-91108	438	0.978	5	Type III	3	15
40	S-91101	64	0.429	3	Type II	2	6
41	S-91106	64	0.429	3	Type III	3	9
42	S-91110A	1.2	0.010	1	Type I	1	1
43	S-91110B	1.2	0.010	1	Type I	1	1
44	S-91111	64	0.429	3	Type IV	4	12
45	S-91112	64	0.429	3	Type III	3	9
46	V-91101	97	0.572	3	Type V	5	15
47	V-91103	68	0.449	3	Type IV	4	12
48	V-91105	98	0.576	3	Type IV	4	12
49	V-91107	138	0.701	4	Type IV	4	16

Where;

- μ is equipment failure rate (fault/million hours). The failure rate need to be converted in units of fault/year before it can be inserted in the formula in order to calculate the failure probability,(P).
- P represents the failure probability,
- Probability value represents the associated value for probability to be inserted in the decision risk matrix.
- Impact represents the severity of failure.
- Severity value represents the associated value for the severity to be inserted in the decision risk matrix.
- Risk Value is a result of multiplying probability value and severity value.

4.2.3. Decide the Most Suitable Maintenance Strategy

The most suitable maintenance strategy for equipment is then decided by referring to the information of probability and severity collected in the risk table. Maintenance strategies that suit to be applied on each equipment is shown in the table below;

Table 4.7: List of Equipment with maintenance strategy

No	Corrective Maintenance	Time Based Maintenance	Condition Based Maintenance
1	P-91101A	911-RV-005A	911-RV-001
2	P-91101B	911-RV-005B	911-RV-009
3	P-91101C	911-RV-005C	911-RV010
4	P-91103A	911-RV-018A	911-RV-011
5	P-91103B	911-RV-018B	911-RV-012
6	S-91110A	911-RV-018C	911-RV-025
7	S-91110B	911-RV-018D	911-RV-026
8		911-RV-018E	911-RV-033
9		E-91101	911-RV-034
10		E-91102A	C-91101
11		E-91102B	C-91103
12		E-91102C	E-91105
13		E-91106A	P-91104
14		E-91106B	P-91105
15		E-91106C	P-91108
16		E-91106D	S-91111

17		P-91102A	V-91101
18		P-91102B	V-91103
19		P-91102C	V-91105
20		S-91101	V-91107
21		S-91106	
22		S-91112	

4.2.4. Perform maintenance strategy

The maintenance strategies for all equipment should be done accordingly as shown in the table above.

4.2.5. Check and Validate Result

The current MTBF for the equipments is shown in the table below;

Table 4.8: Table of Equipment with MTBF values

No	Equipment	MTBF	No	Equipment	MTBF
1	911-RV-001	4.963	26	E-91106B	4.391
2	911-RV-005A	4.963	27	E-91106C	4.391
3	911-RV-005B	4.963	28	E-91106D	4.391
4	911-RV-005C	4.963	29	P-91101A	5.189
5	911-RV-009	4.963	30	P-91101B	5.189

6	911-RV-010	4.963	31	P-91101C	5.189
7	911-RV-011	4.963	32	P-91102A	1.297
8	911-RV-012	4.963	33	P-91102B	1.297
9	911-RV-018A	4.963	34	P-91102C	1.297
10	911-RV-018B	4.963	35	P-91103A	4.391
11	911-RV-018C	4.963	36	P-91103B	4.391
12	911-RV-018D	4.963	37	P-91104	0.457
13	911-RV-018E	4.963	38	P-91105	0.457
14	911-RV-025	4.963	39	P-91108	0.261
15	911-RV-026	4.963	40	S-91101	1.784
16	911-RV-033	4.963	41	S-91106	1.784
17	911-RV-034	4.963	42	S-91110A	95.129
18	C-91101	7.135	43	S-91110B	95.129
19	C-91103	1.250	44	S-91111	1.784
20	E-91101	170.381	45	S-91112	1.784
21	E-91102A	3.491	46	V-91101	1.177
22	E-91102B	3.491	47	V-91103	1.679
23	E-91102C	3.491	48	V-91105	1.165
24	E-91105	4.005	49	V-91107	0.827
25	E-91106A	4.391			

The value of OEE cannot be calculated in this case study, because it’s required the continuous data from the plant. The collection of a few month real data is required in order to compare this method with the method that already implemented in the plant currently. The effectiveness of this method is only proven if the OEE of certain plant increase as they apply this method.

4.3. Discussion

As what has been discussed in the earlier part of this chapter, it is known that two case studies has been conducted and being performed in two different process plant which are in polyethylene plant and liquid natural gas plant. Small area in those two plant was selected and being thoroughly studied in order to illustrate the method suggested in this project and also as a medium to study on how feasible this method to be applied.

Based on those two case studies performed, it seemed that the five main steps of the suggested method used during this studies is feasible to be used and reliable in differentiate the types of equipment with regards to the risk associated with individual item in the plant. According to the result obtained during those studies, equipment were grouped into three categories according to the type of maintenance strategies to be performed which are corrective maintenance, time based maintenance and condition based maintenance.

A polymerisation area of typical polyethylene plant has been studied for case study 1. Some amount of 44 types of equipment has been selected during this study. The result shown 6 equipment falls under corrective maintenance, while 16 and 22 equipment falls under time based and condition based maintenance.

From this result, it is notice that, the equipment that falls under the corrective maintenance has least number compared to other types of maintenance and also the equipment grouped in this category is considered not very critical to the plant operation. The list of equipment in this category has the lowest frequency of failure and the same time has minimum severity to the plant since the equipment is usually come in pairs and it means that the equipment got a backup if it is fail to operate. This small number of equipments in this group indicates that only a small proportion of the equipment in the process plant has lowest frequency and minimum severity of failure.

Meanwhile, sixteen equipments were grouped in the time based maintenance. Majority of the equipment in this group is stand alone and do not have any backup if any failure occurs. However, the frequency of failure for equipment is this category is moderate while the severity of failure is whether in type 2 or type 3 only which is not as severe as the failure resulted from the failure of the equipment that falls under condition based maintenance.

Most of equipment that has been studied in the polymerisation area in this typical polyethylene plant falls under the condition based maintenance. According to the method suggested, equipment being grouped in this category has the maximum value of failure occurrence and the same time has posses the most severe effect to the plant if any failures occur to these equipments. Referring to the risk table that has been constructed in the case study, the equipments within this group has the probability of failure higher than 0.8 and severity of failure is in type 4 and type 5.

In spite of that, the second case study conducted in the sulfinol unit in liquid natural gas plant are using the same method has been used for the first case study.49 equipment has been chosen to be studied in this respective case study and the number of equipment that falls under corrective maintenance, time based maintenance and condition based maintenance are 7equipments, 22 equipments, and 20 equipment respectively. The same pattern is shown in this study for the corrective maintenance where equipment that falls within this group has the least number of equipment. This small number of equipment within this category is again proving that only small portion of equipment available in the plant is not critical to the plant operation.

At the end of both case study, the Mean Time before Failure (MTBF) are calculated for all the equipment based on their current failure probability. The MTBF value that has been calculated has wide range of value and they are different between one equipment to another. The MTBF calculated represent the time estimated for the equipment to be broken. And hence, it is noticed that the equipment that falls under corrective maintenance will have higher MTBF value compared to equipment within the time based and condition based maintenance.

It is expected the value of MTBF of the equipment will be increase as the method suggested being implemented in the process plant. For example current MTBF for the PE-1-K-470 is 0.276, which is means that the equipment PE-1-K-470 is expected to be broken in the interval of 0.276 years after its pervious failure. However, implementation of this method in the plant, has categorized the equipment PE-1-K470 into the time based maintenance, which made the respective equipment to be maintained on specific time interval. The MTBF after the implementation of this method is expected to increase compared to MTBF before this method being implement in the plant.

The MTBF calculation however, only represents the performance of the individual equipment based on its criticality and not considering the performance of the whole plant collectively. In order to calculate the overall plant performance, new criteria has been introduced which is called Overall Equipment Effectiveness (OEE). The calculation of OEE however cannot be demonstrated in these two case studies since the calculation of this value need this method to be first implement in the plant. The calculation of OEE will indicate the reliability of the overall equipment in the plant collectively. The OEE calculation was based on the percentage value and that means a good plant will have the highest percentage of OEE. Same goes to the implementation of this method whereby this method can be considered succeed if the OEE of the plant achieved its highest percentage after this method being applied in the plant.

CHAPTER 5

CONCLUSION

There are three main objective has been highlighted in the earlier chapter of this project and it seem that all of them had been successfully achieved. The first targeted objective in this project is to study the asset life cycle management system that being applied in the industry currently. A few model of asset life cycle management system has already being studied for the last few months. In this research it is found that the asset life cycle itself means that the life span of the equipment which is started as early as the purchasing time up until their retirement period or until they are broken down or being replace by another equipment. however, it seem that to develop that kind of system may required a lot of time but yet the efficiency or effectiveness of the system is in doubt. Hence, after taking consideration of that factors and referring to the system that already being implemented, it is decided to have smaller scope of study which only focusing on the Middle-of-Life of an equipment where the time they being put in the production line.

As the scope of studies has being identified, the focus has move to the second objective of the project which is to develop the framework of asset life cycle management system in process plant. The framework development were based on the condition and environment of the process plant provided that it is simple and suitable to be implemented in the plant to cater the need of the plant engineers who are always have limited time during their working hour. Hence the framework of the system has been develop with five(5) main steps to be followed; (1) Analyze the asset, (2) Analyze and assess risk associated with asset, (3) Decide maintenance strategies, (4) perform maintenance task, (5) Check and validate result. The steps involve in this framework has been develop in such a simple steps in order to have a system that can be implemented in process plant working environment and at the same time provide the workable system that are useful to cater the plant needs.

When dealing with middle-of-life of the equipment, it is always being regards to have an equipment to work at their highest performance in order to get the highest return from the plant production. However, the equipment will only performed best when there is no defect on the equipment and hence there is a need to do the maintenance work for each of equipment available in the plant. Another problem arise is that, there are a lot of maintenance strategies available and currently implemented in the process plant; which one of them can give the best impact to the plant operation. Each of the maintenance strategies has their own advantages and disadvantages. This project is then manipulates the advantages of each strategy and come out with optimum strategies based on the equipment failure probability, severity and risk. This maintenance strategy decides the best maintenance method to be implemented for the certain equipment whether it is corrective maintenance, time-based maintenance or condition-based maintenance. The maintenance strategy is only decided when all the information regarding the equipment risk has been filled in the risk table and being matched with the information in the decision risk matrix.

The entire three objectives listed already being achieved while asset management system has successfully developed. Two case studies have been carried out in polymerization area and sulfinol unit in typical polyethylene and Liquid Natural Gas plant respectively. The case studies results show that the system is workable to be implemented in the process plant. However, the effectiveness of this method is not yet proven since there is a need to have a collection of data for a few months, before and after this method being implemented in the certain process plant. This method will be proven effective if implementation of this method in process plant giving a higher MTBF and OEE reading compared to the period before it’s being implemented.

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APPENDIX A

Sample of calculation

$$P = 1 - R$$
$$P = 1 - e^{-\mu t}$$

Where

P = probability

R = reliability

μ = failure rate

t = time

Example of calculation for equipment PE-1-E-400

μ = 11.4 failures/Mh

Convert the failure rate to the unit of failures/year

μ = (11.4/1000000) X (365*24)

= 0.09987 failures/year

Reliability, R = Exp (-μt)

= Exp (-0.09987*1)

= 0.9050

Probability of failures, P = 1- R

= 1- 0.9050

= 0.095

Mean Time Before Failure = 1/ μ

= 1/0.09987

=10.013 years