การบริหารความเสี่ยงสำหรับโรงงานอุตสาหกรรมปิโตรเคมี

นาย กฤตพล ศรีเจริญ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต

สาขาวิชาการจัดการทางวิศวกรรม ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต

คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2553

ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

RISK MANAGEMENT IN PETROCHEMICAL PLANT

Mr. Krittapol Sricharoen

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Engineering Management
The Regional Centre for Manufacturing Systems Engineering
Faculty of Engineering
Chulalongkorn University
Academic Year 2010
Copyright of Chulalongkorn University

Thesis Title	RISK MANAGEMENT IN PETROCHEMICAL PLANT
By	Mr. Krittapol Sricharoen
Field of Study	Engineering Management
Thesis Advisor	Associate Professor Parames Chutima, Ph.D.

Accepted by the Faculty of Engineering, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

.... Dean of the Faculty of Engineering
(Associate Professor Boonsom Lerdhirunwong, Dr. Ing.)

THESIS COMMITTEE

....Chairman
(Professor Sirichan Thongprasert, Ph.D.)

....Thesis Advisor
(Associate Professor Parames Chutima, Ph.D.)

....Examiner
(Associate Professor Jirapat Ngaoprasertwong)

....External Examiner
(Associate Professor James Wallbank, D.Eng.)

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

กฤตพล ศรีเจริญ : การบริหารความเสี่ยงสำหรับโรงงานอุตสาหกรรมปิโตรเคมี (RISK MANAGEMENT IN PETROCHEMICAL PLANT)

อ.ที่ปรึกษาวิทยานิพนธ์หลัก : รศ.ดร.ปารเมศ ชุติมา, 221 หน้า

งานวิจัยนี้มีจุดประสงค์เพื่อที่จะศึกษาความเสี่ยงในโรงงานอุตสาหกรรมปิโตรเคมีแห่งหนึ่ง การริเริ่ม งานวิจัยดังกล่าวจำเป็นที่จะต้องค้นคว้าหาข้อมูลสนับสนุนเพิ่มเติม จุดประสงค์หลักของงานวิจัยนี้คือ เพื่อ ลดและป้องกันความเสี่ยงที่มีผลต่อกระบวนการผลิตในฝ่ายผลิตของบริษัทที่ใช้เป็นกรณีศึกษา รวมไปถึงเสนอแนะวิธีการป้องกันความเสี่ยงดังกล่าว

กลุ่มบริหารจัดการความเสี่ยงที่ถูกคัดเลือกมาจะทำการบริหารจัดการการประเมินความเสี่ยงจากหน่วยผลิตที่ทำการเลือกมาเพื่อเป็นต้นแบบ ขั้นตอนดำเนินการได้ถูกแบ่งออกเป็น 3 ขั้นตอนเพื่อการประเมินอย่างละเอียด FMEA (Failure Mode and Effect Analysis) ถูกนำมาใช้เพื่อการประเมิน กลุ่มบริหารจัดการความเสี่ยงได้ทำการระบุความเสี่ยงขึ้นมาทั้งสิ้นรวม 16 หัวข้อ จากนั้นได้นำการวิจัยโดยใช้เทคนิคพาเรโต้ (Pareto Analysis) มาคัดเลือกหัวข้อความเสี่ยงลำดับที่มีความสำคัญ เพื่อทำการแก้ไขจำนวนทั้งสิ้น 4 หัวข้อ เพื่อหามาตรการป้องกันความเสี่ยง มาตรการป้องกันความเสี่ยง 3 มาตรการได้ถูกจัดทำขึ้นเพื่อลดค่า RPN ในกลุ่มความเสี่ยงหลัก ผลที่ได้จากการให้คะแนน RPN หลังจากมาตรการป้องกันความเสี่ยงถูกนำไปใช้ พบว่าลดความเสี่ยงลงได้ถึง 80-90% รวมถึงการลดอัตราการเกิดอุบัติการณ์, ค่าเสียหายจากอุบัติการณ์ และการสูญเสียโอกาสในการผลิตลงได้

ผลของการนำมาตรการป้องกันความเสี่ยงไปใช้ อาจไม่สามารถบ่งชี้ได้อย่างชัดเจนว่าสิ่งที่ได้นำเสนอไปนั้น สามารถลดอัตราและผลกระทบทางการเงินที่ได้รับจากอุบัติการณ์ แต่การมีมาตรการป้องกันเพิ่มขึ้น ทำให้สามารถติดตาม บ่งชี้ และวิเคราะห์อุบัติการณ์เพื่อลดความน่าจะเป็นของการเกิดดังกล่าว

ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต ลายมือชื่อนิสิต K. S.

สาขาวิชาการจัดการทางวิศวกรรม............. ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก Paran

ปีการศึกษา......2553........................

ศูนย์วิทยทรัพยากร จุฬาลงกรณ์มหาวิทยาลัย

##5071630421: MAJOR ENGINEERING MANAGEMENT
KEYWORDS :RISK MANAGEMENT/ RISK ANALYSIS/ FMEA

KRITTAPOL SRICHAROEN: RISK MANAGEMENT IN PETROCHEMICAL PLANT. ADVISOR: ASSOC. PROF. PARAMES CHUTIMA, PH.D. 221 pp.

The purpose of this research is to study the risks in petrochemical plant. The extended research on its characteristics will be necessary. The objectives of this research are to minimize and prevent the risks of a process unit in operation department of the case company. Preventive methods will also be recommended.

Risk management team will be selected to evaluate the risks from selected production unit to be model unit. The considered process will be broken down into 3 processes. FMEA (Failure Mode and Effect Analysis) will be used to assess the risk sensitivity from 16 risks identified. Pareto analysis is also applied. The assessment of the RPN (Risk Priority Number) using Pareto Analysis shows that there are in total of 4 critical risks. The preventive actions can be organized, using linkage between each critical risk and its root cause. Three preventive actions would resolve the intensity of these risks to lower the RPN value of the critical risks. The results show that the RPN after applying preventive actions has reduced by 80-90 % including the decreasing of the incident, cost of incident (COI) and loss production opportunity (LPO).

The implementation results of the preventive action may not clearly indicate that the proposed actions significantly reduce the rate and financial impacts from incidents but with the additional preventive actions, incident can be tracked, identified and analyzed to reduce occurrence and probability and mitigate the consequences of incidents.

The Regional Centre for Manufacturing Systems Engineering Student's Signature....K. sri

Field of Study: ...Engineering Management... Advisor's Signature...

Academic Year: .....2010......................

ACKNOWLEDGEMENTS

The author would like to express his greatest gratitude and appreciation to his advisor, Asst. Prof. Dr. Parames Chutima for his invaluable guidance, providing value suggestions and his kind supervision throughout this study. In addition, he is also grateful to Professor Sirichan Thongprasert, as the chairman, Assistant Professor Jirapat Ngaoprasertwong as the members of the thesis committee.

Finally, the author most sincere appreciations are dedicated to his family members, special person and friends for their moral supports, understandings and kind assistants as a part of this thesis completion. Thank you to everyone that was involved in any step of the thesis, without them, it would not have been possible to complete.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

CONTENTS

Page

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

LIST OF TABLES

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

LIST OF FIGURES

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

CHAPTER I

INTRODUCTION

1.1 Background of the research

Today, world-class competitiveness is a necessary for all companies. The undeniable global competition characterized by both a technology push and a market pull, and the rapidly evolving technology and increased customer requirements put forward a lot of challenges for management. All companies have tried to gain more competitive advantage in any ways as they can. To reach this target, all factors need to be concerned both external and internal factors. The external factors such as market situation, politics condition or economics crisis are hardly changed by the company but one thing that the most companies can manage and control by themselves is the internal factor such as operation management, human resource management, financial management, etc. In this research will be focused on operation management.

One of these challenges in operation management concerns the production equipments, machines or process failure. In order to be able to extend the life span of machines for good reliability and safety, some control and repair tasks need to implement when they breakdown, failure or at set intervals and these are generally referred to as maintenance planning. Proper maintenance planning can help to keep the life cycle cost down and ensures that operation equipments can utilize smoothly without problems. Moreover, proper maintenance planning also contributes to the overall performance and reliability of the company.

Maintenance planning is also the processes that are conducted so as to keep process, machines or equipments under acceptable standards with a view to controlling and preventing unexpected malfunctions and potential causes as much as possible so that production activity could go on regularly according to the plan. Although the company has how much good maintenance planning, the failures still occur.

Risk management has become a major role in this situation. Risk is a thing that can occur and affect to any process in the company. It must be considered to avoid the failure in any aspect. Repetitive failures can cause the company to lose seriously about plant reliability, plant safety and customer dissatisfaction. Risk management can be applied in many departments including operation or production. Risk can be divided into two main groups which are internal risks and external risks. Internal risks or operational risks are the uncertainties within the company especially operation, so these risks could be controlled by the risk management. In difference, external risks are the uncertainties that beyond the company's influence which they are very difficult to handle.

This research is conducted to study the cause of failure in the company and to suggest area of improvement throughout Failure Modes and Effects Analysis (FMEA) tool. FMEA is an approach of product or process analysis that is conducted to analyze and identify potential failures that could affect process performance. FMEA is a tool to help developing process standard and to improve production management in terms of quality, cost and time. It is a bottom up technique in which study is made of how components or processes can fail by analyzing and identifying potential failures that affect to the product quality and process performance.

The implementation of FMEA to the process will enable the company to identify the important areas in which to control the process and where to install safeguarding properly. It provides a systematic thinking of the process and its environment that will almost always improve understanding of how the process might fail. It also supports the necessary for an alternative process or improvement to the existing processes.

1.2 Background of the case company

The case company was established following the resolutions of shareholders' meetings of Rayong Refinery Public Company Limited (RRC) and Aromatics

(Thailand) Public Company Limited (ATC) on September 13, 2007 to merge refinery business and petrochemical business.

- Refinery Business

With a Complex Refinery and modern Condensate Splitter, the company is highly flexible in the selection of feed stocks, able to choose from a wide variety of crude oil and condensate. In addition, the plant can reduce a high rate of sulfur from oil products, thereby able to add value to low-value hydrocarbon products i.e. heavy crude to become high quality petroleum and aromatics products in accordance with market demand.

- Aromatics Business

Aromatics manufacturing technology is from UOP Company Limited. The technology has been continuously improved and developed until achieving global acceptance. Both plants have been designed for exchange of raw materials and products to maximize production of Paraxylene and Benzene.

The last decades, industrial processes are becoming more and more complex. Expanding product and production requirements led to further optimization of the concerned processes. Due to continuously increasing competition, the necessity for increased productivity force process installations to operate to their limits.

The case company set up new petrochemical plant (Aromatics 2 or AT) for aromatics business in RIL Industrial Estate. Continuous of the production process in 24 hours per day is very important because the company has to produce both main products and by-products to meet customer's contract volume in selling both domestic and export demand. Figure 1.1 shows the business work flow of AT.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

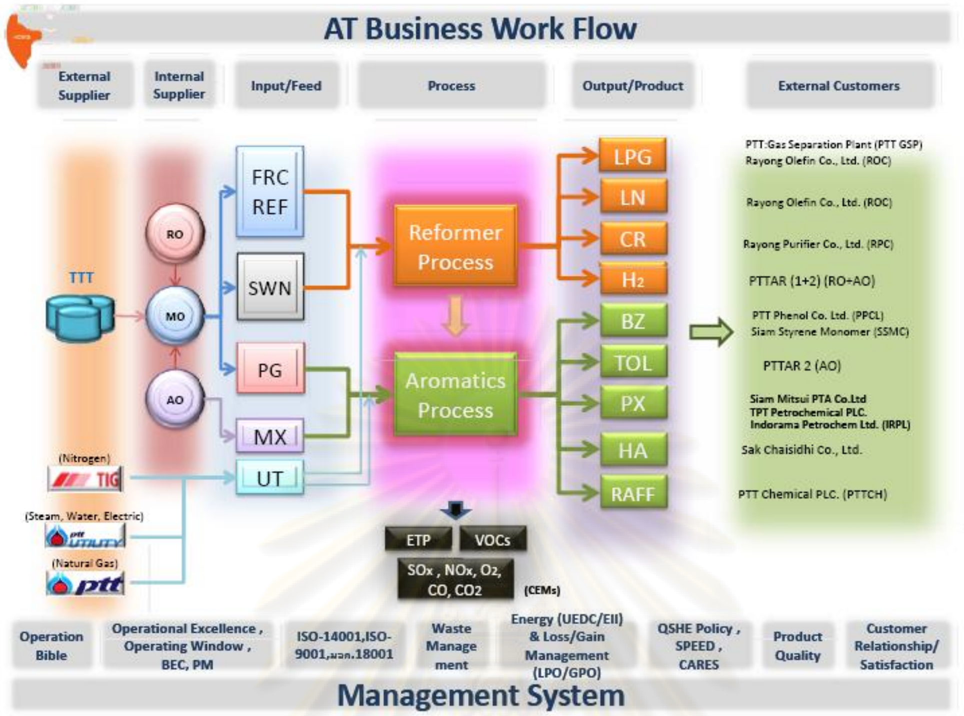


Figure 1.1 Aromatics 2 (AT) Business Workflow

The case company entered into commercial operation on 1st February 2009 and the complex comprises an upstream condensate hydrotreater/reformer followed by a relatively ‘standard’ UOP aromatics complex. This contains Parex, Tatoray, Sulfolane, Olefin Reduction & Aromatics Fractionation units. The plant is designed to produce 616,000 tons/year of paraxylene, 363,000 tons/year of benzene and 60,000 tons/year of toluene. It entered into commercial operation on 1st February 2009.

The case company is operated from a blast resistant control room using DCS with an Emerson Fieldbus system to reduce the length of cabling and number of interface modules. There is a totally separate interlock/shutdown system and emergency isolation valves have been installed on a number of high-hazard vessels. The process facilities are divided into Reformer and Aromatics sections, both of which employ UOP technology. There is no novel equipment and the new catalysts have already been proven by UOP. The plant is highly integrated with 2 other production sites, namely AR1 and AR2. This is illustrated in Figure 1.2.

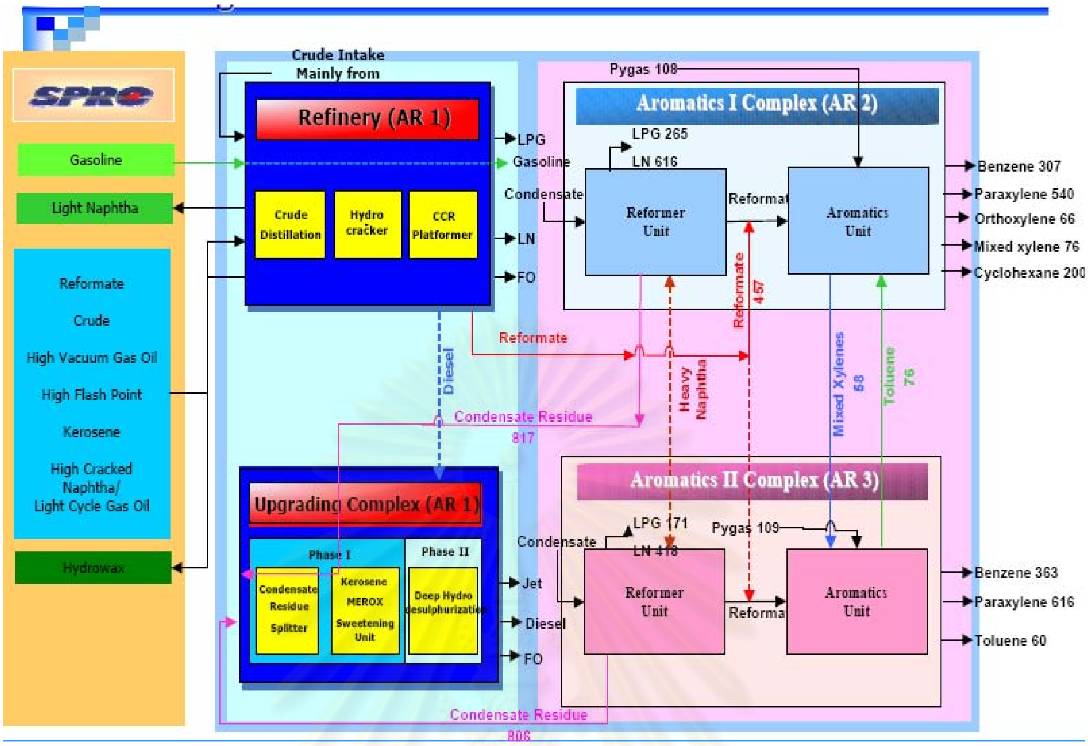


Figure 1.2 Plant Configuration

1.3 Statement of problem

Since the start up from January 2009, AT faced many problems from equipment failure or machine breakdown which had affected to discontinuation of the production process. Our Reliability Team has recorded the number of plant incidents occurred from January 2009 to July 2009 as shown in Figure 1.3.

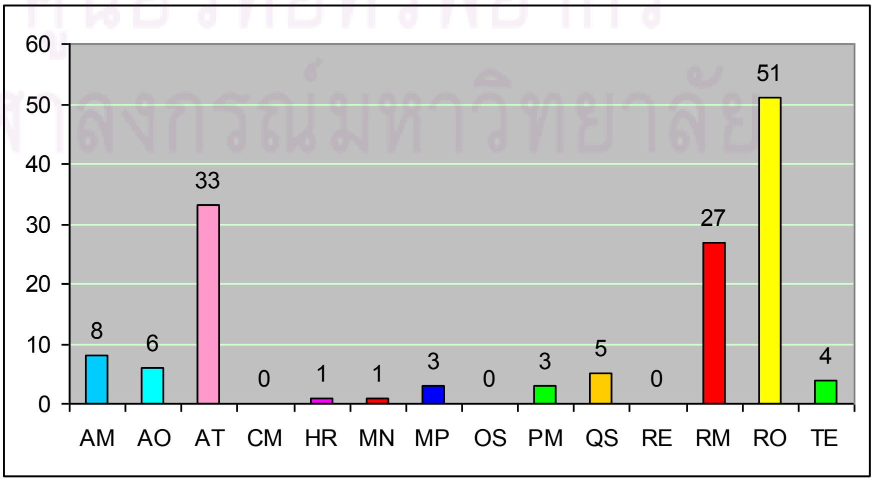


Figure 1.3 Total plant incident reports

We can classify these incidents into 3 groups by using impact criteria which are asset impact, people impact and environment impact in Table 1.1.

Table 1.1 Summary of Incident and Near Miss: YTD 2009 (Update till 31 July 2009)

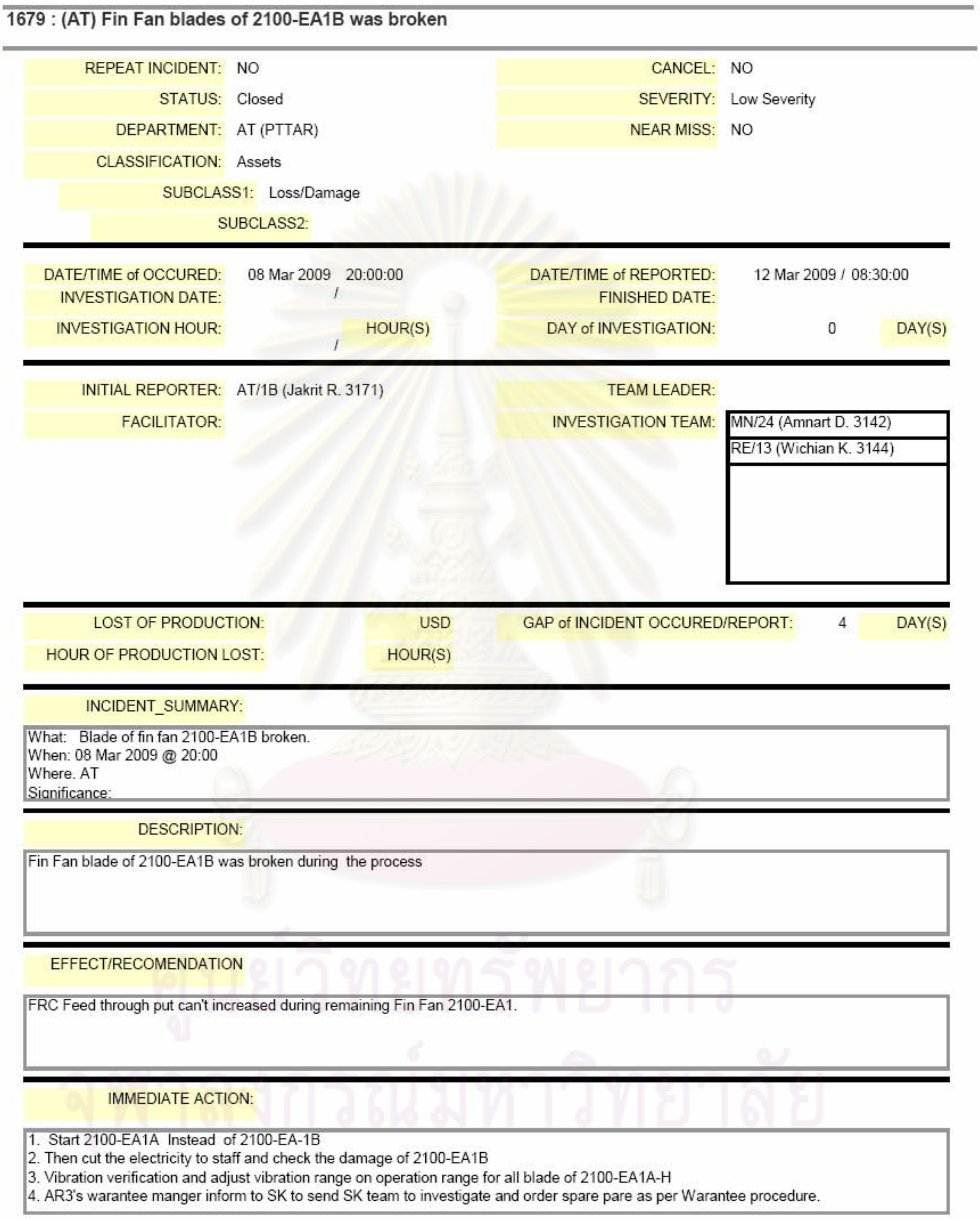
Assets						People			Environment				Total
Department	Ope/relia	Loss/ damage	Fire	Loss property	Product Quality	First Aid	LTI	Medical Treatment	Spill	Smell Complaint	Reputation	Legal non-compliance	
AM	8	1	0	0	0	0	0	0	0	0	0	0	9
AO	4	1	0	0	1	2	0	0	0	0	0	0	8
AT	36	3	1	1	3	2	0	1	0	0	0	0	47
CM	0	0	0	0	0	0	0	0	0	0	0	0	0
HR	0	0	0	1	0	0	0	0	0	0	0	0	1
MN	0	1	0	0	0	0	0	0	0	0	0	0	1
MP	1	1	2	1	0	0	0	0	0	0	0	0	5
PM	0	0	0	2	0	1	0	0	0	0	0	0	3
OS	0	0	0	0	0	0	0	0	0	0	0	0	0
QS	0	3	0	0	0	1	0	0	0	0	1	0	5
RE	0	0	0	0	0	0	0	0	0	0	0	0	0
RM	20	1	1	0	8	1	1	0	11	3	0	0	46
RO	45	4	4	1	1	6	0	0	1	1	0	1	64
TE	2	1	2	0	2	0	0	0	0	0	0	0	7
Total	116	16	10	6	15	13	1	1	12	4	1	1	196

According to the data from Table 1.1, this table shows the summary of incidents and near miss of each department. There are 14 departments which are Aromatics Movement (AM), Aromatics One operations (AO), Aromatics Two operations (AT), Commercial (CM), Human Resource (HR), Maintenance (MN), Project (MP), Procurement (PM), Operation development (OS), Quality and Safety (QS), Reliability and Engineering (RE), Refinery Movement (RM), Refinery Operations (RO) and Technology (TE). The highlight in Table 1.1 shows AT's cases. It shows that most incidents come from operation and reliability (incidents are 33 cases and near miss are 3 cases). It means that there are some problems in production process. Although the case company has central maintenance and preventive maintenance is set up monthly program to take care of electrical, instrumental and mechanical equipments, plant incidents still occur periodically. From Figure 1.3 and Table 1.1, it will see that RO and RM also have high incidents as well but they have their own standard procedure to cope with this situation as RRC before amalgamation. That is the main reason for AT to deal with this happening by doing something. Table 1.2 shows the summary incidents of AT only.

Table 1.2 Summary of Incident Report for AT

ID	INCIDENT TITLE Total: 58 Record(s).	OCCURRED DATE
1653	(AT) 2440 H2A tripped.	10 Feb 2009
1670	(AT) PX off spec (ortho xylene) purity 99.55 wt%.	01 Feb 2009
1673	(AT) Unit 2250 hot shut down	17 Mar 2009
1674	(AT) Steam lost due to problem at PTTUT.	11 Mar 2009
1677	(AT) 2200-H3 burner trip	05 Feb 2009
1679	(AT) Fin Fan blades of 2100-EA1B was broken	08 Mar 2009
1681	(AT) AR3 Total plant shut down due to power blackout	12 Mar 2009
1685	(AT) Steam condensate return from AR3 to PTTUT off spec	20 Feb 2009
1687	(AT) PX off-spec purity 99.31%	03 Mar 2009
1689	(AT) Load chemical 3 DT-129 into 3 DT 190 (TK-65)	19 Feb 2009
1692	(AT) CCR hot shut down due to X-ray activitie	19 Feb 2009
1694	(AT) CCR hot shutdown	06 Feb 2009
1698	(AT) CCR hot s/d	24 Mar 2009
1700	(AT) Workers sustained injury to his chin while working at PSA project.	15 Mar 2009
1710	(AT) ขโมยเข้าตัดสายไฟ AR3	31 Mar 2009
1717	(AT) Steam lost due to problem at PTTUT.	10 Apr 2009
1718	(AT) Steam lost due to problem at PTTUT.	10 Apr 2009
1719	(AT) Analyzer house have wire burn	12 Apr 2009
1724	(AT) 2250 CCR Hot shutdown due to oxygen analyzer leakage	20 Apr 2009
1736	(AT) 2100-E13 Tube Leak	28 Apr 2009
1739	(AT) Parex E S/D from 2500-PV18A malfuntion.	05 May 2009
1740	(AT) Steam lost due to problem at PTTUT.	02 May 2009
1745	(AT) Dust flew into contractor eye	12 Jun 2009
1746	(AT) Parex E S/D from 2500-PV18A malfuntion.	02 May 2009
1751	(AT) 2250-UNIT S/D(Oxygen Low Low)	06 May 2009
1757	(AT) PTT-UT : Electric blink & Boiler , 2 Gas Turbine Trip	14 May 2009
1758	(AT) CCR HOT S/D	17 May 2009
1759	(AT) 2500-FV18A stuck,Parex adsorption section shutdown.	15 May 2009
1760	(AT) 2200C2 shutdown while changing from VSD mode to Soft starter mode	20 May 2009
1762	(AT) 2100-E13 Tube Leak (Deethanizer Overhead Condenser Leakage)	18 May 2009
1772	(AT)กระจกรถยนต์หนีบนิ้วชี้ขวา	27 May 2009
1780	(AT) Ground fault ที่ Feeder SE-B1-L (6.6 kV)	04 Jun 2009
1785	(AT) CCR HOT S/D pressure 2200-C2 (2nd stage) swing	11 Jun 2009
1786	(AT) 2500-FI20 low low flow consequence to shutdown Parex unit	11 Jun 2009
1789	(AT)Parex unit was shutdown according to the 2500-FV18A stick (Chamber	11 Jun 2009
1793	(AT) AR3 total plant shutdown due to power blackout	18 Jun 2009
1794	(AT) CCR Hot S/D	21 Jun 2009
1797	(AT) CCR hot s/d	24 Jun 2009
1799	(AT) CCR hot s/d	26 Jun 2009
1802	(AT) 2250-UNIT HOT S/D	29 Jun 2009
1805	(AT) 2250-Unit Hot S/D	03 Jul 2009
1814	(AT) 3/4"vent at chamber circulation line was cracked	19 Jun 2009
1819	(AT) Unit 2250 Hot shutdown	15 Jul 2009
1821	(AT) CCR hot s/d	19 Jul 2009
1823	(AT) Unit 2250 Hot Shut Down	22 Jul 2009
1824	(AT) UNIT-2500 Shut-Down due to 2500-FT020 cracked	22 Jul 2009
1827	(AT) CCR Hot s/d	29 Jul 2009
1832	(AT) CCR Hot s/d	02 Aug 2009
1835	(AT) CCR Hot S/D	05 Aug 2009
1841	(AT) Power blackout consequence to total plan shutdown	10 Aug 2009
1852	(AT) หลังมือได้รับบาดเจ็บจากถูกท่อความร้อนในขณะทำการเปลี่ยน Sigthglass ที่	19 Aug 2009
1855	(AT) Steam hammering	11 Aug 2009
1865	(AT) Benzene off spec.	27 Aug 2009
1866	(AT) 2500-FaLL20 LOW	27 Aug 2009
1870	(AT) Power dip from EGAT consequence to power generator frequency dip to	31 Aug 2009
1872	(AT) ไฟฟ้า Trip	03 Sep 2009
1876	(AT) 2500-PV14A Failure	05 Sep 2009
1891	(AT) 2200-C-2 shutdown due to contractor off emergency shutdown switch (	17 Sep 2009

There are some examples for AT incidents. Figure 1.4 shows one case from broken blade of fin-fan:



1679 : (AT) Fin Fan blades of 2100-EA1B was broken

REPEAT INCIDENT:	NO	CANCEL:	NO
STATUS:	Closed	SEVERITY:	Low Severity
DEPARTMENT:	AT (PTTAR)	NEAR MISS:	NO
CLASSIFICATION:	Assets		
SUBCLASS1:	Loss/Damage		
SUBCLASS2:			

DATE/TIME of OCCURED:	08 Mar 2009 20:00:00	DATE/TIME of REPORTED:	12 Mar 2009 / 08:30:00
INVESTIGATION DATE:	/	FINISHED DATE:	
INVESTIGATION HOUR:	/ HOUR(S)	DAY of INVESTIGATION:	0 DAY(S)

INITIAL REPORTER:	AT/1B (Jakrit R. 3171)	TEAM LEADER:	
FACILITATOR:		INVESTIGATION TEAM:	MN/24 (Amnart D. 3142) RE/13 (Wichian K. 3144)

LOST OF PRODUCTION:	USD	GAP of INCIDENT OCCURED/REPORT:	4 DAY(S)
HOUR OF PRODUCTION LOST:	HOUR(S)		

INCIDENT_SUMMARY:

What: Blade of fin fan 2100-EA1B broken.
When: 08 Mar 2009 @ 20:00
Where. AT
Significance:

DESCRIPTION:

Fin Fan blade of 2100-EA1B was broken during the process

EFFECT/RECOMENDATION

FRC Feed through put can't increased during remaining Fin Fan 2100-EA1.

IMMEDIATE ACTION:

1. Start 2100-EA1A Instead of 2100-EA-1B
2. Then cut the electricity to staff and check the damage of 2100-EA1B
3. Vibration verification and adjust vibration range on operation range for all blade of 2100-EA1A-H
4. AR3's warantee manger inform to SK to send SK team to investigate and order spare pare as per Warantee procedure.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Figure 1.4 Incident report of fin-fan's broken blade

<u>Incident Description:</u>

- What: Blade of fin fan 2100-EA1B broken.
- When: 08 Mar 2009 @ 20:00
- Significance:

Health and Safety:	None
Environmental:	None
Operation:	Can not increase throughput

- What happened:

2100EA1B, Automatic Fan, was tripped by motor overloading in the night of Sunday 08th Mar due to one (1) blade broke out at the shaft end bolted to fan hub.

- What went wrong:

- Material defect since fabrication/ erection.

This failure should be caused by material defect since fabrication/ erection as commented by Lead Corrosion Engineer, RE/24.

- The vibration switch was not working resulting from improper setting.
- The existing vibration switch is not effective enough to protect machine from this kind of failure. The severe damage to Fin Fan unit i.e. most of the blades were damage as a consequence event may be minimized if the vibration switch can function efficiently to tripped the machine right after the broken of first blade.

- What can be done:

- Recalibrate the vibration switches (including the switches on other finfan coolers) to ensure their integrity.
- Set preventive maintenance program to do function test on vibration switches.
- Replace new set of fin-fan blades

Another case is about control valve malfunction. These groups of control valves always fail repeatedly as shown in Figure 1.5 and Figure 1.6 respectively.

1746 : (AT) Parex E S/D from 2500-PV18A malfuntion.

REPEAT INCIDENT:	NO	CANCEL:	NO
STATUS:	Final	SEVERITY:	Medium Severity
DEPARTMENT:	AT (PTTAR)	NEAR MISS:	NO
CLASSIFICATION:	Assets		
SUBCLASS1:	Operation Reliability		
SUBCLASS2:			

DATE/TIME of OCCURED:	02 May 2009 13:00:00	DATE/TIME of REPORTED:	04 May 2009 / 08:00:00
INVESTIGATION DATE:	/ 10 Jun 2009	FINISHED DATE:	10 Jun 2009
INVESTIGATION HOUR:	4 / HOUR(S)	DAY of INVESTIGATION:	0 DAY(S)

INITIAL REPORTER:	AT/22 (Amorn T. 3120)	TEAM LEADER:	AT (Anutin C. 3007)
FACILITATOR:	OS/15 (Supiab P. 1404)	INVESTIGATION TEAM:	RE/5 (Jesada P. 1349) RE/4 (Pirote S. 1339) OS/16 (Deacha R. 2558, 2562) RE/52 (Akardech P. 2428) RE/41 (Chonlavit S. 1336)

LOST OF PRODUCTION:	610000 USD	GAP of INCIDENT OCCURED/REPORT:	2 DAY(S)
HOUR OF PRODUCTION LOST:	HOUR(S)		

INCIDENT_SUMMARY:

===

Refer to incident no. 1759

DESCRIPTION:

- While normal operation , 2500PIC18A was stick and malfunction. This make Parex Chamber 2500-V1 was low low pressure (2500PLL5) reading then the UV6,7,8 around the chamber was close follow the ESD logic.
- The flow to Raffinate Column & Extract Column was upset and force the Parex Unit to do short Ciculation
- Then Effect to Isomar Unit was loss feed from Parex and make the isomar do the reactor circulation and total reflux.

EFFECT/RECOMENDATION

- The Px product loss about 624 ton. (by send the mixed xylene from U2440 to 2945TK65)
- Ball and seat damaged

IMMEDIATE ACTION:

- Switch to use 2500PV18B , then isolate 2500PV18A , then start up parex and isomar again.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Figure 1.5 Incident report of control valve malfunction

1759 : (AT) 2500-FV18A stuck,Parex adsorption section shutdown.

REPEAT INCIDENT:	NO	CANCEL:	NO
STATUS:	Final	SEVERITY:	High Severity
DEPARTMENT:	AT (PTTAR)	NEAR MISS:	NO
CLASSIFICATION:	Assets		
SUBCLASS1:	Operation Reliability		
SUBCLASS2:			

DATE/TIME of OCCURED:	15 May 2009 20:00:00	DATE/TIME of REPORTED:	16 May 2009 / 09:00:00
INVESTIGATION DATE:	/ 17 Jun 2009	FINISHED DATE:	17 Jun 2009
INVESTIGATION HOUR:	2 / HOUR(S)	DAY of INVESTIGATION:	0 DAY(S)

INITIAL REPORTER:	AT/22 (Amorn T. 3120)	TEAM LEADER:	AT (Anutin C. 3007)
FACILITATOR:	RE/55 (Wittaya S. 1361)	INVESTIGATION TEAM:	RE/5 (Jesada P. 1349) OS/16 (Deacha R. 2558, 2562)

LOST OF PRODUCTION:	1346000 USD	GAP of INCIDENT OCCURED/REPORT:	1 DAY(S)
HOUR OF PRODUCTION LOST:	HOUR(S)		

INCIDENT_SUMMARY:

What : Parex chamber pressure low low shutdown parex and isomar 2500-V1 and 2500-V2
When : 13 May 2009 (20:00)
Where: AR3
Significance:

DESCRIPTION:

While switching 2500FV18B to use 2500FV18A for tuning PID after replacement the Valve finish , The 2500FV18A was not correct action and fail to closed. And the vibration occur along the line of 2500FV18A/B make the gasket of the upstream 2500PSV3B break and force process to Parex Unit to do shutdown due to H/C release out

EFFECT/RECOMENDATION

Investigate after vibration found that
- Support Piping of 2500FV18A/B was misalignment
- Suction Bellow of 2500P2C Was damaged.
- 2500FV18A Steam Valve was bend

IMMEDIATE ACTION:

- shutdown the parex unit and other unit

Figure 1.6 Incident report of control valve malfunction

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Incident Description:

- What : Parex chamber pressure low low shutdown parex and isomar 2500-V1 and 2500-V2
- When : 15 May 2009 (20:00)
- Significance:

Safety:	None
Environment:	Flaring at Valve 2500-V1 and 2500-V2
Operations:	Px product loss about 624 ton.

- What happened?

At approximately 20:00 on 15 May 2009, the Parex unit was manual shut down because there was a leak from inlet flange of 2500 PSV03B while the operation was switching over valve from 2500 FV018B to 2500 FV018A. The leak was caused by vibration generated from valve 2500FV018A malfunction.

- Consequence:

1. Immediately changing of circulation flow to 1300 – 2200 m3/hr (normal 1700 m3/hr) also pressure fluctuation from 5 – 11.3 barg (normal 8.8 barg).
2. High piping vibration resulting to HC leakage at PSV inlet flange which is connected to circulation pipe.

- Immediate action:

1. Shutdown chamber circulation pumps to reduce system pressure and change operation mode to short circulation bypass chamber
2. Spray water to eliminate HC cloud and mitigate smell to community nearby
3. Survey defected piping and related equipment
4. The control valve was switched over to standby one when it show the problem sign
5. The damaged valve was send to shop for repair by lapping method and keep as spare

- Possible cause

- Valve defect (just the previous 2500FV018A V-ball valve).

One of the main problems is that the production and maintenance departments do not demonstrate what effects preventive maintenance has on profitability. It is profitable to find the optimum points for preventive maintenance under different conditions. When the number of failures is viewed, it is evident that the case company must be aware of the failure rates of its facilities. To prevent the equipments with increasing failure rates, risk management by using FMEA can help to analyze and reduce the risk of unexpected failures.

1.4 Objective

To develop standard contingency procedure for reducing and controlling operational risks for AT production department.

1.5 Scope of Study

This study will focus on the avoidable incidents of equipments failure which causes considerable financial impact to the case company. This study will analyze and update all existing risks of operations and to reduce probability and prevent incidents through comprehensive risk assessments.

In this research, the study will mainly focus on the problem of equipments related to process reliability and operational risk. This study will focus on production department based on selected unit to be case study and then will apply to the next units if it has been accomplished by using process FMEA.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

1.6 Expected benefits

The expectation of this thesis is to understand the causes of failure related to the production department of the company including successfully develop risk management and procedure, improving efficiency, productivity and profitability and also control and reduction of operational risk in the production process. Benefits that will be received are

1. Standard contingency procedure for production department
2. Adopting improved procedures for production department
3. Implementation of new risk management in production department
4. Increase productivity by reducing defects
5. Guidance for failure reduction to other models (units)

1.7 Research Procedure (methodology)

1. Study the material related to thesis topic such as from literature review and journals.
2. Study theoretical tools or techniques that related to thesis topic from books and journals.
3. Collect the data related to the scope of study and analyze causes of the problem.
4. Gather information about other factories or journals that have case study or problem.
5. Establish the risk management procedure and implementation.
6. Summary the improvement of study on risk management of the company.
7. Write up the thesis

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

1.8 Organization of Thesis

The first chapter describes the overview of the case company business and its existing problems in production. This chapter also includes the objective, scope of study, expected benefits and the research methodology of the thesis. In chapter two, risk management and its detail approaches will be discussed. Studying the relevant literatures, journals and researches in the past are denoted in chapter two. Chapter three will be started with the explanation of process overview and the selected unit to be model. This chapter also shows the detailed methodology of the thesis and how it will be conducted.

In chapter four, the content will show the result and analysis of the risks. This chapter will show the results of the risk management process step by step along with the analysis of the information from the results. It will show critical risk evaluation and then the preventive actions and how to response these risks. In chapter five, the implementation will be discussed and proposed. This chapter is also about the conclusion of the total process of the risk management and the recommendations within this thesis.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

CHAPTER II

THEORIES AND LITERATURE REVIEW

2.1 Risk Management

Risk management is starting important for all size of many companies due to the limitation of resource. Effective utilization of resource is very to the one who mange the company which need to investigate the risk in many aspects to achieve desired objective.

The appropriate framework of risk management may start from planning, identification, analysis, response and control, which depends on each organization . The successful of risk management is also the achievement of the objective for each company, or the ability to finish task within the limitation of resources, which generally are budget, time and technical .Utilization of systematic risk management helps the organization to (Mills, 2001)

- Identify, assess, and rank risks, making the risk explicit.
- Focus on the major risk of the company.
- Make informed decision on the provision for adversity, e.g. mitigation measures.
- Minimize potential damage should the worst happen.
- Control the uncertain aspects of construction phases.
- Clarify and formalize the company’s role and the roles of others in the risk management process.
- Identify the opportunities to enhance performance.

Risk management is now an important thing, and it is unavoidable even the company is already studied for feasibility, which ensure the successful of the business. Without the appropriate management on limited resource, it can bring the company to the risk, which is the source of failure. Risk can happen any time due to uncertainly and limited resource. It needs to be efficiently and effectively managed to reduce the problem in order to achieve the objective.

In general, risk management is a system or process to manage the risk, which is the source of the failure or the situation that diverge the desired objective. It is difficult to specify all risk factors the even affect to specified business. The simple way to classify risk is the source, which can be classified into

- Internal risk factors
- External risk factors

2.2 Standard of risk Management

Risk management is widely recognized as a process or system to minimize obstacle or barrier in order to meet the business objective, which is now recognized as an important part of business. There are a number of risk management standards and guidelines, which are currently used in various fields. (Kloman, 2003)

1. Australia/New Zealand Risk Management Standard 4360:2004**:** This standard has been established since 1995.The important of this standard is to combine opportunity and harm into risk. All employees and stakeholders are encouraged to participate in risk management, which has to be notified for the responsibility. Steps of risk management are clearly identified, and analysis should be done on both qualitative and quantitative techniques.

2. Canadian Risk Management Guideline CAN/CSA-Q850-97**:** This guideline focuses on affecting of risk on stakeholders, which follows Australia/New Zealand Risk Management Standard as a guideline. Recommendation on the guideline is to establish a risk management team, which constitutes of

multidisciplinary group of internal and external experts including representative from all levels of stakeholders.

3. British Standard BS-6079-3:2000: This standard was setup as a guide to the management of business related project risk in the fields of economic and general welfare of society, which includes setting the context, identifying risk, risk analysis, risk evaluation and risk treatment. The British Standard, which is a conventional framework, confirms the following three levels if risk decision making:

    1. Strategic (long-term goals)
    2. Tactical (medium-term goals)
    3. Operational (short-term goals)

2.3 Various Process of Risk Management

Risk management is defined in various ways. According to (Flanagan and Norman, 1993), “risk management is a discipline for living with the possibility that future events may causes adverse effects”. Risk management involves six tasks as follows (California Department of Transportation [Caltrans], 2003):

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

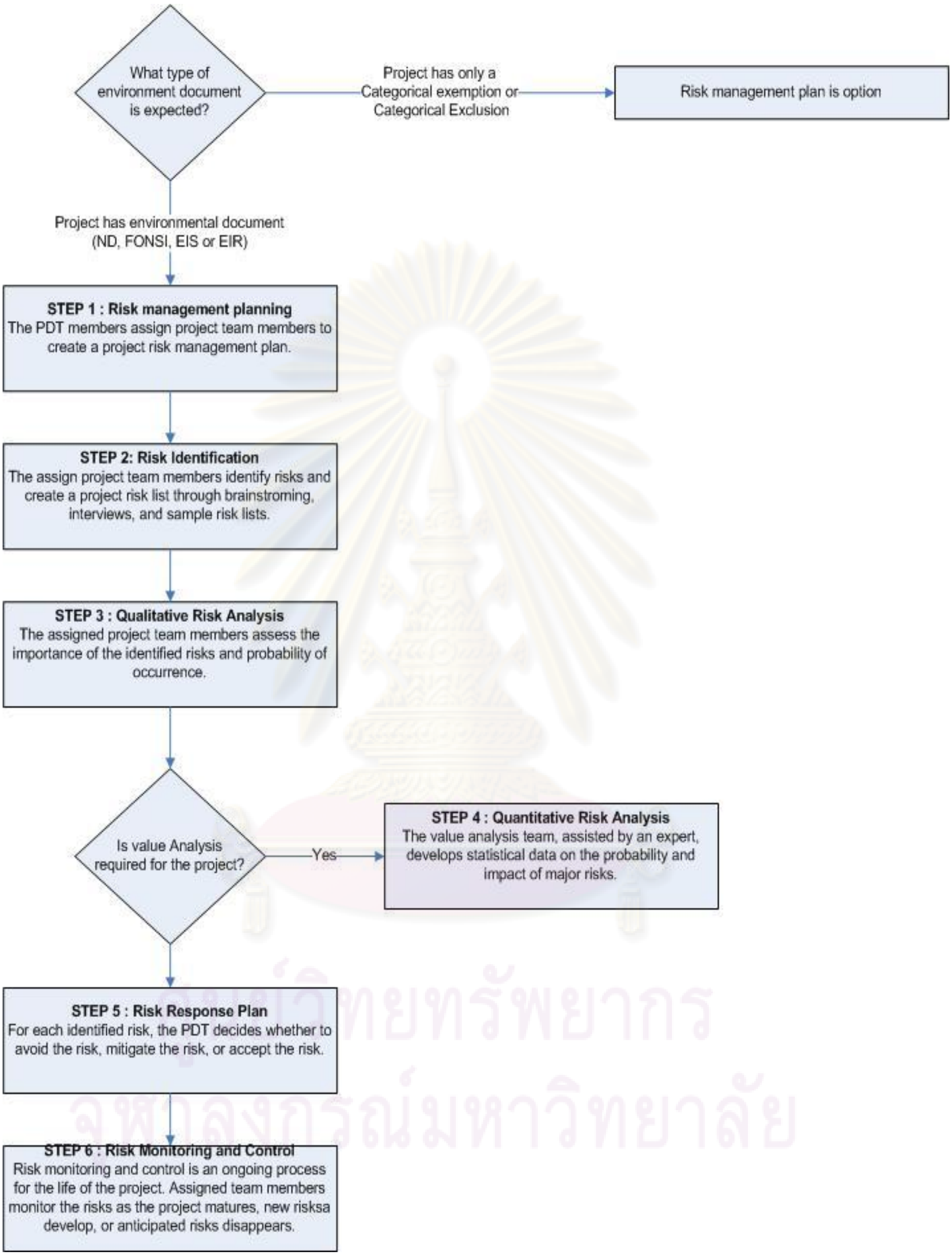


Figure 2.1 Risk Management Process Flow chart (Caltrans, 2003)

2.3.1 Risk Management Planning

When starting risk management for any project, team has to be established to create the plan in order to deal with associated risk. Activity planning for risk management is established for the project.

2.3.2 Risk identification

It involves as identifying the source, type, its potential and characteristic. To identify risk, there are many sources to find out the risk in the project:

- Experience from the precedent or previous project.
- Brainstorming from the expert and involved people.
- Existing of recorded data.
- Gathering during project operation.

2.3.3 Risk Analysis

The objective of risk analysis is to find its probability and effect, which will occur during manage the project. To measure the degree of risk for its probability and effect, it can be measures in the form of level e.g. low, medium, and high, or in the form of source for each objective.

Analysis on the risk can be classified into two categories. Qualitative risk analysis evaluate how important of the risk to the objective and prioritize for further analysis, while quantitative risk analysis is numerically estimation of probability to meet cost and schedule objective.

2.3.4 Risk Response planning

Response to the risk is the creation of appropriate strategy to manage each risk, and decide the action plan to manage the strategy. Strategy and action plan for each risk generally compose of:

- **Avoidance:** Elimination of the risk or to protect the objective from its impact.
- **Transference:** Relocation of the risk to another party, which is more capable to deal with associated risk.
- **Mitigation:** Reduction of probability or the effect from risk to an satisfactory point.
- **Acceptance:** Accept the occurrence of unavoidable risk, as well as prepare to deal with the risk**.**

2.3.5 Risk Monitoring and Control

Monitoring and control for the risk are expected to keep track of the risk in the project, and make sure that the response plan is still effective. Periodic review of the risk in the project is to deal with reoccurrence of unexpected risk.

Flanagan and Norman (1993) clarified risk management as “a discipline for living with the possibility that future events may cause adverse effects”. According to (Flanagan and Norman, 1993), explanation and process of risk management, which constitutes of several stages, are clarified as follows:

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

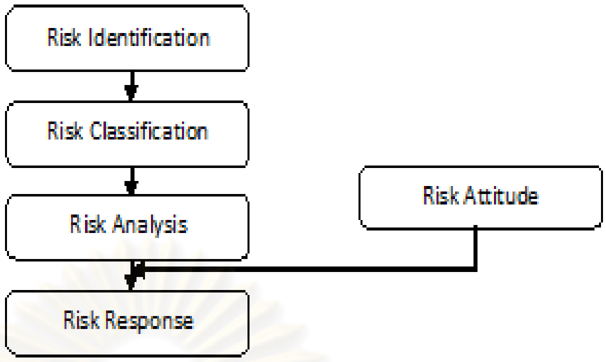


Figure 2.2 The Risk Management Framework

Source Flanagan and Norman (1993)

One of the most well-known risk management processes, which was first established in 1995 by Australia and New Zealand. Australia and New Zealand Standard for risk management designs risk management as “the possibility of something happening that impacts on your objectives. It is the chance to either make a gain or a loss It is measured in term of likelihood and consequence”. Risk management standard from the Australia and New Zealand standard on risk management (AS/NZS 4360:2004) is illustrated as follows:

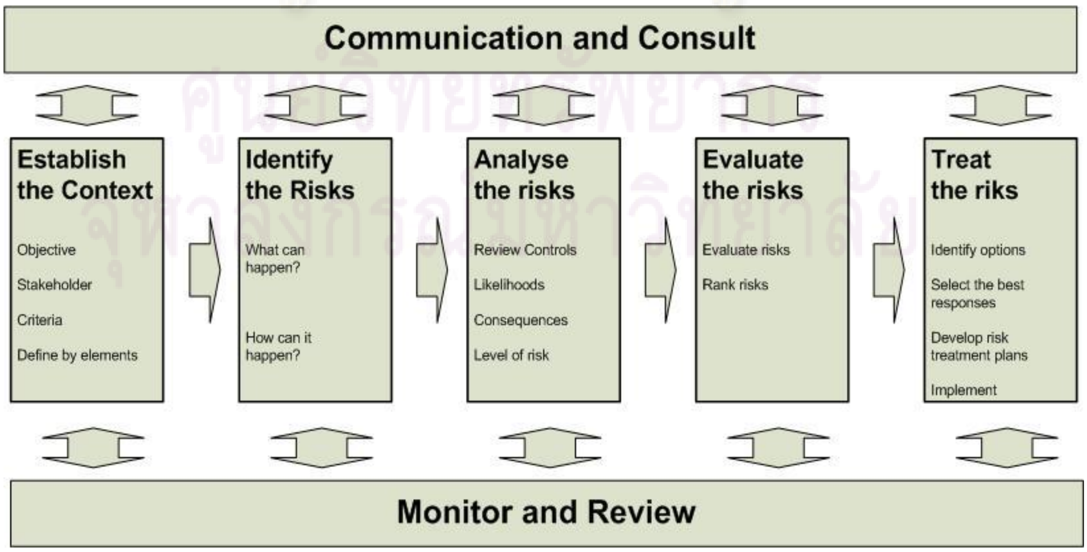


Figure 2.3 Risk Management Process Diagram

Source Boardleaf Capital International (2004)

Establish the Context

The Strategic and organization context preparation is required for risk Management. Business characteristics and objective have to be clarified in order to indicate intrinsic risk in the business. From AS/NZS 4360:2004 standard, the context for risk management fall into two parts:

1. Descriptive
2. Creative

Identify the Risks

Potential risks are identified what would be the source of risk and how the occurred, which affect the business. Identification of potential risks, which might affect the business by brainstorming is preferable for further analysis.

Analysis the risks

Potential risks are prioritized by rating in order to assign a significant of each factor. Significant of each risk is described in more than detail to clarify the characteristic. Likelihood and its consequence are measured to analyze the level of risk.

Evaluate the risks

Evaluation of the significant risks is ranked with its priority. Commonly, risks with high priority are to be firstly considered. Risk evaluation classified the risk what plan is suitable to each risk.

Treat the risk

Risk treatment is to determine what should be done in order to deal with risk. Risk treatment is expected to find the most appropriate plan to avoid the risk or at least to reduce their effect. Alternative response plans to the risk need to consider the characteristic of each risk.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Monitoring and review

Monitor and review of the outputs from previous stage need to be verified to ensure that the change of risk might not affect the business, and the situation must be brought up to date.

Communicate and consult

Involving of related parties to risk management is an important thing to achieve successful outcome. Communicate and consult of related parties to each stage of risk management need to be concerned.

2.4 Analytical Tools

In risk management, there are the requirements of the tool to deal with the risk. Requirements of the tool are to find out what and how the risk can occur, and also why it occurs. Analytical tools help identify the potential risks, and also prioritize the problem areas, the tools that relate to risk management generally compose of (Kloman, 2003):

- Assumption analysis
- Brainstorming , check lists
- Criticality analysis
- Cumulative frequency plots (S curves)
- Decision analysis
- Delphi technique
- Expert interviews
- Event tree analysis
- Faults tree analysis
- HAZOP study
- Influence diagrams
- Monte Carlo simulation
- Prompt lists
- Risk registers

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

- Databases
- Sensitively analysis

Important alternative tools for risk management are described as follows:

2.4.1 Root cause Analysis (RCA)

In general, Root cause Analysis is a process to find the source of problem and how to make action to deal with the problem. According to (Andersen and Fagerhaug, 2006), "Root Cause Analysis is a structure investigation that aims to identify the true cause of problem, and the actions necessary to eliminate it". Four major steps are involved with RCA as the following (Rooney and Vanden Henvel, 2004);

1. **Data collection:** The first step of analytical tool is mostly data collection, which spends a lot of time to gather the data. Without the information and consideration of situation, the potential factors cannot be identified.

2. **Cause Factor Charting:** This step provides the structure in order to organize and analyze the collected data and information from the first step. Charting is simply a sequence diagram with logic test, which should be created as soon as the data and information are collected. It describes the event, which leads to the occurrence with the condition surrounding the event.

3. **Root Cause Identification:** Requirement of decision diagram called Root Cause Map is needed in this step. Root Cause Map helps identify the underlying reasons for each factor why they exist, and also facilitated to determine the cause.

4. **Recommendation:** Generation and Implementation: Recommendation for the identification of the root cause is needed in order to prevent the recurrence of the root cause of casual factor**.** Implementation of recommendation is also needed otherwise the attempt to perform the analysis is waste.

ศูนย์วิทยทรัพยากร จุฬาลงกรณ์มหาวิทยาลัย

2.4.2 Pareto Diagram

Pareto Diagram has been established by Alfredo Pareto, which his objective is to study the distribution of wealth in Europe. For the principle of Pareto, Andersen and Fagerhaug (2006) stated that "most effects, often 80 percent, are the result of small number of causes, often only 20 percent". Dr. Joseph Juran identified Pareto principle, which can be simplify into the world "vital few and useful many", which means most of important factors normally come from a small part of the whole.

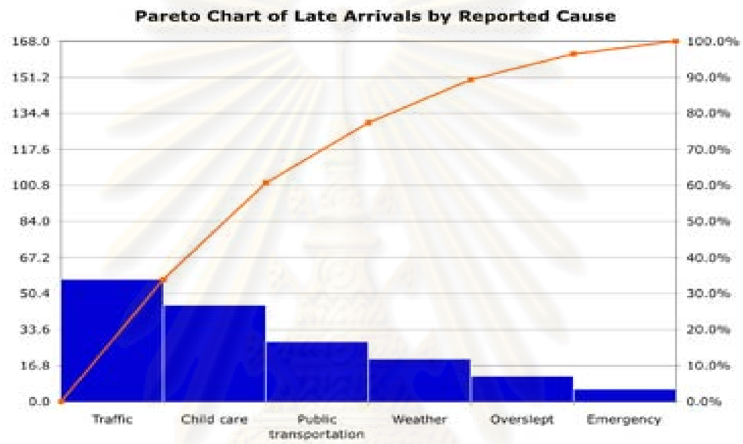


Figure 2.4 Pareto diagram

Source Besterfield et al., (2002)

Possible data classifications of Pareto diagram are types of filed failure, problems, complaints, causes, types of nonconformities, etc.(Besterfield et al., 2002).

The purpose of Pareto Diagram is to display the cause or factors that lead to the problem by rank those causes or factors by the degree of importance. The use of Pareto principle is a never-ending process. When the vital few target factor is corrected, next vital few will then be corrected, which is a continuous process.

There are five steps to construct Pareto diagram (Besterfield et al., 2002):

1. Determine the method if classifying the data. There are many criterions to classify the data:
    - Problem
    - Cause
    - Nonconformity
    - Etc.
2. Determine the unit of frequency to be used to rank the characteristics, which could be the unit of monetary.
3. Collect data for an appropriate time interval or use historical data.
4. Summarize the data for an appropriate time interval or use historical data.
5. Construct the diagram and find the vital few.

2.4.3 Fishbone Diagram

Interchangeable name of Fishbone Diagram is Cause-and –Effect Diagram. It is a process to identify the cause of factor, which affects to the desired objective, e.g. quality. Ishikawa summarized that process did not refer only to manufacturing, it also related to design, purchasing, sales, personal, and administration. There are six categories involve in fishbone diagram, which are normally called “five M’s and one E”.

- Men
- Materials
- Methods
- Machines
- Measurements
- Environment

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

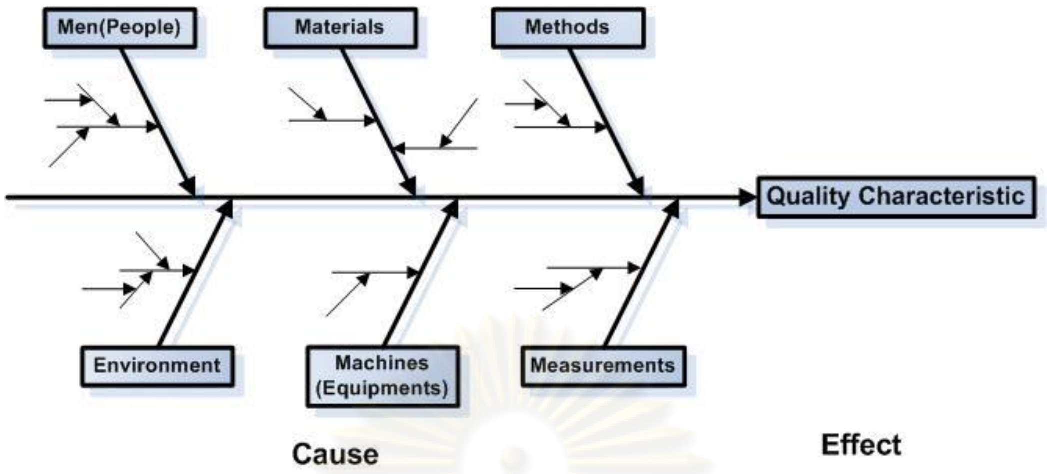


Figure 2.5 Cause and Effective Diagram (Fishbone Diagram)

According to (Brussee, 2005), “the purpose of fishbone diagram is to identify all the inputs variables that could be causing the problem of interest”. The objective of this approach is to find the problem or cause of factor in order to prevent them before they actually occur, which shall be called “vanguard control” (Ishikawa and Lu, 1988). Due to the number of cause of factor is infinity, the important thing is to find the truly important one that will severely affect to the objective by brainstorming, which is a suitable way. Fishbone Diagram is a useful process, which has nearly unlimited application in many fields. According to (Besterfield et al., 2002), fishbone diagram is useful to:

1. Analyze actual condition for the purpose of product or service quality improvement, more efficient use of resources, and reduced costs.
2. Eliminate conditions causing nonconformities and customer complaints.
3. Standardize existing and proposed operations.
4. Educate and train personnel in decision-making and corrective-action activities.

2.4.4 Failure Mode and Effect Analysis (FMEA)

FMEA is one the most famous analytical tool to systematically identify and analysis the failure and its effect to desired objectives. According to (Besterfield et al., 2002), "Failure Mode and Effect Analysis is an analytical Technique (a paper test) that combines the technology and experience of people in identifying foreseeable failure modes of a product or process and planning for its elimination".

In FMEA, three major criteria are used to prioritize the importance of failure cause:

1. Severity (S)
2. Occurrence (O)
3. Detection (D)

Utilization of S and D probability criteria with S is to develop the risk prioritization numbers. Severity (S) is an assessment how serious of the effect of the potential failure mode, which is applied only to the effect of the failure, excludes the potential failure mode. Occurrence (O) is a possibility, which one of the specified causes/mechanisms will occur. Detection (D) is a relative measure of the assessment of the ability to detect either a potential cause/mechanism or the subsequent failure mode. All of three criteria will then be calculated as "Risk Priority Number (RPN)", which is used to rank the importance of various concerns.

RPN = (S) x (O) x (D)

According to (Besterfield et al., 2002), to execute FMEA, there are four stages to consider.

1. Specifying Possibilities
    - Functions
    - Possible Failure Modes
    - Root Causes
    - Effects
    - Detection/Prevention

2. Quantifying Risk
    - Probability of Causes
    - Severity of Effect
    - Effectiveness of Control to Prevent Cause
    - Risk Priority Number
3. Correction High Risk Causes
    - Prioritizing Work
    - Detailing Action
    - Assign Action Responsibility
    - Check Points on Completion
4. Re-evaluation of Risk
    - Recalculation of Risk Priority Number

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

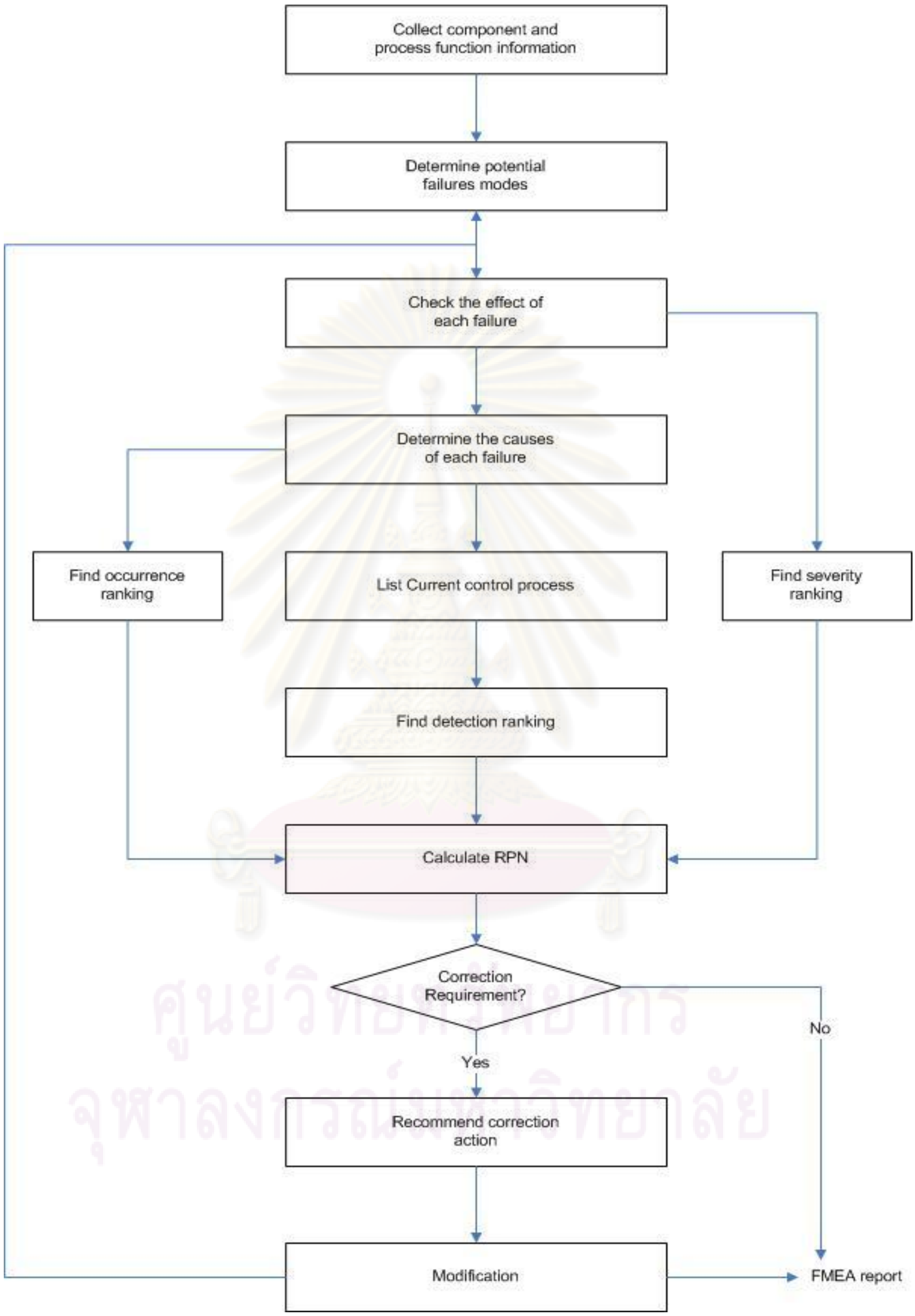


Figure 2.6 The FMEA Procedure

Source Teng and Ho (1996)

2.5 Literature Review

There are many studies and literatures supporting FMEA as the useful and effective technique.

Vermillion (2002) explained that service companies who frequently conduct FMEA and evaluate their success typically experience:

- Minimized customer defection and increased customer satisfaction
- Increased consistency in service quality
- Reduction of costly design changes
- Reduced transaction costs and increased profit
- Reduced liability

FMEA is differentiated over other types of failure analysis method in that it is particularly adept at:

- Identifying cause and effect of known and potential failures before they occur
- Providing documentation of failures which can be tracked over time
- Making accountability easier to pinpoint
- Facilitating continuous improvement
- Creating a common language that can be easily understood by both technical and non technical people in the organization

According to (Mouss et al., 2000), they explained that the FMEA is a method of critical analysis which consists of identifying an inductive and systematic way the risks of abnormal operations of a system then to seek the origins and their consequences. It allows;

- Identification of the failure modes of all the components of a system
- The possible investigation into the failure causes, for each mode of failure
- The evaluation of the effects on the system and the user for each combination cause mode of failure
- The search of possible detections, for each combination cause-mode of failure

FMEA was always used for the studies of the diagnosis prepared within the framework of the plant maintenance. The diagnosis uses the link between the effects of a failure, perceived like a addition of detection test allotted to each combination cause-mode of failure as Figure 2.7 shown below

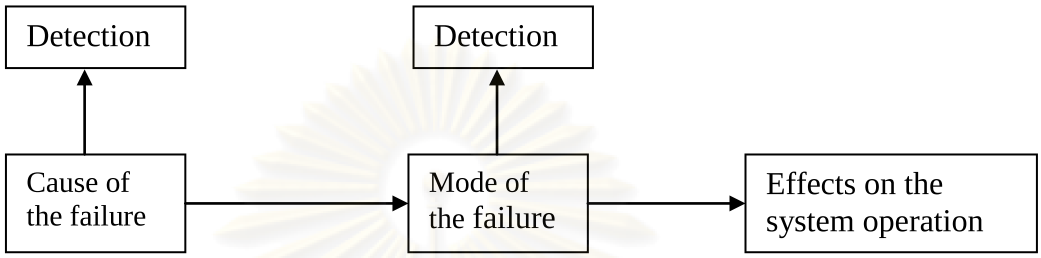


Figure 2.7 Failure Mechanism

The realization of an FMEA first of all requires the determination of the level of decomposition. A system could be the subject of a hierarchical decomposition in as much of level of decomposition must be compatible with the knowledge of all the modes of failure, and their effects. The results of these analyses are then presented in the form of a table with columns gathering the main analyzed criteria.

Casper (1999) explained that FMEA is a reliability engineering tool that the system safety community has adopted as a safety tool for analyzing system failures that could cause a hazard. FMEA is an analytical tool to identify all the ways that a component can fail and what are the effects of the failure on the system. The company should use FMEA for analyzing systems at the lowest level to determine the hazard associated with component failure and how the failures affect the overall mission performance of the safety critical system. He further recommended that FMEA should be used after other hazard analysis techniques have identified safety critical systems that need further analysis. The process for performing FMEA is accomplished in steps. The quality of FMEA is determined by how these steps are performed. The steps are as follows:

- Define the system and the scope and boundaries of the analysis
- Construct a functional block diagram showing the relationship between the different system levels.
- Assess each functional block and determine if its failure would affect the rest of the system.
- .Use a bottom-up type approach to determine the effects of failure of each component. List the modes or ways that the component can fail.
- For each failure mode, determine the worst credible effect and determine a severity and probability of occurrence.
- Identify whether the failure is a single point failure. (A single point failure is a failure of a single component that could cause complete failure of mission or loss of the system.)
- Determine corrective actions. These can prevent the failure or mitigate the effects of the failure.
- Document the failure on the worksheet.

FMEA is good for specific, critical or hazardous subsystems to know what can fail and what the result of the failure will be. FMEA is very systematic approach and it looks at every component to determine failure effects.

According to (Bonacum and Brown, 2002), they explained that Failure Mode and Effects Analysis (FMEA) is one of over one hundred analytical tools that is part of the broad management practice of system safety. System safety aims to identify, assess and control risks or hazards before they cause harm. FMEA has been part of the system safety toolbox for decades. It has received increased attention as we focus more on preventive of problems and trying to proactively understand "what could go wrong " before it does.

Lueck (1996) explained that the best time to start FMEA is before a failure is designed into a product or manufacturing process. FMEA can help to reduce crises during product development and launch and thus reduce costs, since early, upfront changes tend to cost less that late, downstream ones. The corrective action review and evaluation can avoid creating new concerns and the cost impact of changes can be evaluated during development. FMEA can also be used to develop new equipment or to evaluate the operations of the existing equipment and systems. FMEA is an interactive process of continuous improvement that involves team effort. Functional areas involved include design, materials, manufacturing, assembly, packing, shipping, service, recycling, quality, reliability, vendor and customers.

Stamatis (1997) explained that the propensity of managers and engineers to minimize the risk in a particular design and/or process has forced the company to look at reliability engineering to not only minimize but also to define the risk. FMEA has extracted the basic principles without the technical mathematics and has provided us with a tool that anybody can committed to continual improvement can utilize.

Wilcox (1996) explained that the marine industry is recognizing the powerful techniques including FMEA that can be used to perform risk analysis of marine systems. The safety of a ship design is often questioned when relatively new technologies are used that have not had a successful history of safe operation or an established engineering system. The need for better understanding of the safety performance of new marine designs has prompted the application of established risk analysis techniques to develop an improved assessment of design safety. FMEA is one of the reliability and safety analysis tools adopted by the marine community for system safety analysis.

Rotodaro and Oliveira (2001) showed that FMEA is a useful tool for service companies to prevent any failure during the services operation because the service companies must be able to develop and error free services to the customers. According to service definition, the customer is always present during the process and delivery of the service. If something goes wrong, it will happen in the presence of the customer. This study showed the use of FMEA as a prevention tool in the services offered by a Medical clinic restaurant. FMEA is proved to be effective in preventing error or any failure during the service operation.

Villacourt (1992) provides the guideline for use of FMEA in the semiconductor industry. Steps of FMEA were taken during the design phase of the equipment life cycle to ensure that reliability requirements have been properly implemented. He ensures that FMEA is a proactive approach to solve potential failure modes and using FMEA can help cut down cost and avoid the embarrassment of discovering problems such as defects, failures, downtime, scrap loss in the field. According to his study, there are many companies in semiconductor industry successfully use FMEA in design and process. For example, Ford Motor Company requires their suppliers to perform detailed FMEA on all design and process. Texas Instruments and Intel Corporation have implemented extensive training on FMEA as part of their total quality educational programs.

Scipioni et al., (2002) reports the usefulness of FMEA methodology and its implementation in a food company. FMEA known as “Hazard Analysis and Critical Control Points (HACCP) can be used to assure product quality and improve operational performance of the production cycle by identifying, monitoring, and controlling areas of food production process which may be critical in terms of the likelihood of problems or contamination. The work was developed in an Italian confectionery industry in cooperation with part of the internal staff, chosen as FMEA team member, and was focused on the study of water biscuit production line. There are two main tasks completed by the FMEA team in two complementary operations, the control of exterior qualitative aspects and the implementation and integration of the obtained results in the food control system built in the company on the basis of HACCP.

Hawkins and Woolons (1998) explained that there are five basic failure modes in associated with mechanical equipment. The failure modes are categorized according to the type of equipment and energy:

1. fluid flow equipment (leakage and distorted flow)
2. structural systems 9fracture and excessive deflection)

3. thermodynamic systems (bearing seizure and reduced accuracy of relative movement)
4. kinematics systems (bearing seizure and reduced accuracy of relative movement)
5. material properties (incorrect material or geometry)

These failure modes originate at the lowest level of aggregation where faults are considered on individual parts. Failure modes are not normally considered below this level. The cause of the failure modes may be identified such as environmental effects including temperature, contamination and fatigue.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

CHAPTER III

CURRENT SITUATION AND METHODOLOGY

This chapter will give the details of the background of the case company, core business processes, management functions, existing practices related procedures and work instructions, past incidents which will reveal some failures and detailed methodology of the thesis. This given information is the information needed to understand the risk management process and to enable processing the risk and its RPN rating.

3.1 The case company process

Overall details of the process units are as follows and there is a block flow diagram appended.

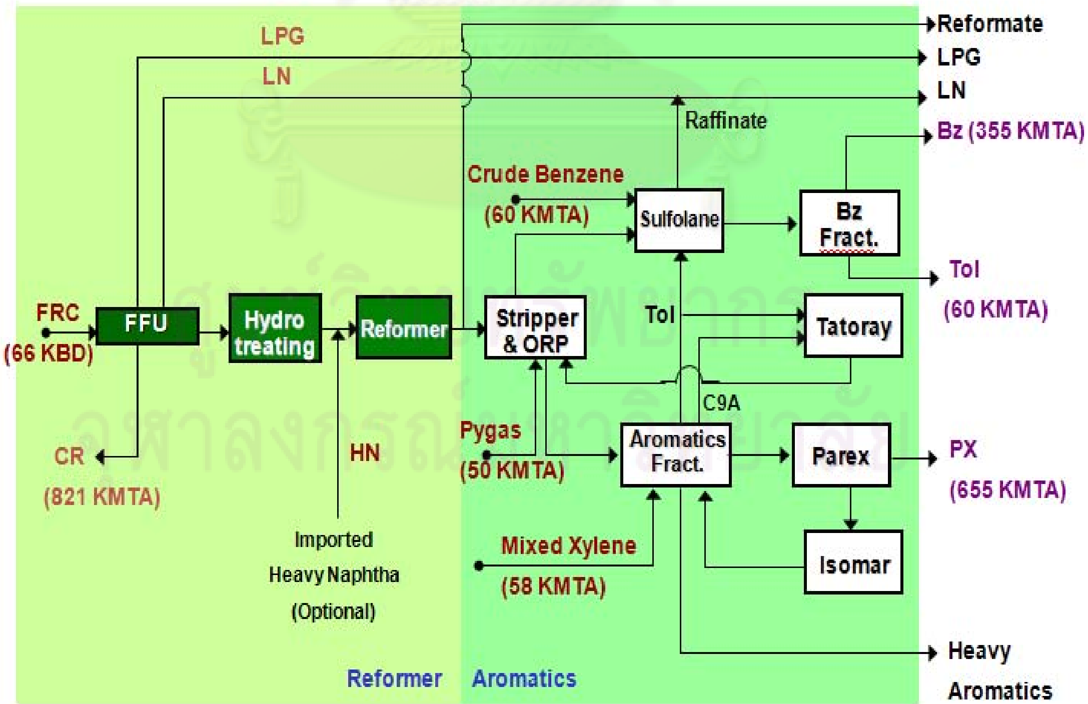


Figure 3.1 AR3 Process Flow Diagram

3.1.1 Feed Fractionation (2100)

The condensate feedstock is filtered and passed to a large depentanizer column. The overheads from this are further processed in debutanizer and deethanizer columns to produce fuel gas, LPG and light naphtha. The bottoms from the first column pass to the naphtha splitter that recovers heavy naphtha for routing to the hydrotreater and the CCR Platformer. All 3 liquid streams from Unit 2100 are treated in mercury adsorbers.

3.1.2 Heavy Naphtha Hydrotreater (2150)

The heavy naphtha stream is processed to remove catalyst poisons (sulphur and nitrogen compounds). The hydrogenation reactor operates at around 32 bar/220oC and this unit has 2 hydrogen compressors. The sweetened product passes to the CCR Reformer via another mercury adsorber.

3.1.3 CCR Platformer (2200/2250)

This unit is used to convert the sweet, paraffinic compounds in the feedstock to aromatics. This is a standard UOP plant that is designed to run at very high severity in order to maximize the production of aromatics. The reaction takes place in 4, stacked reactors at low pressure (4-5 bar) but moderate temperatures of about 550oC. Consequently this unit has a large fired heater. The catalyst flows (by gravity) down the reactor stack and is withdrawn from the bottom for continuous regeneration (the removal of carbon deposits). Effluent from the reactors is cooled and passed to a separator where the light ends (including excess hydrogen) are removed. The hydrogen is recovered by 2 reciprocating compressors (2200-C3) and is used in the hydrotreating, olefins reduction, Isomar and Tatoray units. The liquid reformate is then passed to the olefins reduction unit (2450) for further processing.

3.1.4 Tatoray Unit (2380)

The objective of this plant is to convert unwanted toluene into more benzene and mixed xylenes. It is a catalytic process that operates at about 30 bar/500oC.
The products are then separated in a train of distillation columns. The light ends are removed in a large stripper column, where the bottoms pass to the aromatics fractionation unit. The plant has one centrifugal compressor.

3.1.5 Aromatics Fractionation Unit (2440)

This is a distillation process used to separate the mixed xylene fraction from the heavier aromatics (that are exported). It includes the large xylene splitter column where the reboiler is a fired heater. The toluene fraction is also removed and returned to the Tatoray unit.

3.1.6 Parex Unit (2500)

This plant uses a solid, zeolitic adsorbent to separate the important para-xylene product from the mixed xylene stream. The large adsorbent vessel contains a number of chambers, each of which has several beds of solid adsorbent. There are multiple nozzles on the vessel and a proprietary rotary valve is used to control the flow of 4 major streams to and from the adsorption chambers.

ศูนย์วิทยทรัพยากร

3.1.7 Isomar Unit (2320)

จุฬาลงกรณ์มหาวิทยาลัย

This plant is designed to maximise PX production by catalytically converting unwanted C8s (mainly ortho- and meta-xylene) to more PX. The feed to the unit is the raffinate from the Parex unit, which contains very little PX. The Isomar unit then re-establishes an equilibrium distribution of the xylene isomers (about 30% PX).

The raffinate from the Parex unit is first vapourized in a fired ‘charge heater’ before the stream is piped, together with hydrogen, into the top of the large reactor. The vapour is passed radially through the fixed bed of catalyst at about 410oC and

10.5 kg/cm2. Heat is recovered from the effluent, which is then cooled and routed to a separator to remove the gas phase.

The gas phase contains some hydrogen that is recycled to upstream of the reactor by a centrifugal compressor 2320-C1. The Ebara machine is driven by a 4.1 MW ABB motor and the unit has deluge protection. This also applies to the lube oil console that is located outside the compressor house at ground level. The local control cabinet is pressurized with indicator and rotameter visible on the front.

Liquid from the separator is piped to a de-heptanizer (5.0 barg and 249oC at the bottom) where the light ends are removed. The C8 stream from the bottom of this column is recycled back to the Aromatics Fractionation unit.

3.1.8 Sulfolane (Unit 2540)

This employs an extractive distillation (ED) process to separate high purity aromatics from the steam of mixed hydrocarbons from the Tatoray unit. The plant involves ED and solvent recovery/regenerator columns. The solvent (Sulfolane) enters the top of the ED column and absorbs aromatics as it descends. The solvent/aromatics mixture from the bottom passes to the Solvent Recovery column where the aromatics are separated under vacuum by steam stripping. They then pass to the benzene/toluene separation section. The hydrocarbon raffinate from the top of the ED column is returned to the refinery.

3.2 Management functions

There are dedicated production teams at each of the sites and these undertake routine maintenance activities. In addition, there are centralized Maintenance, Engineering (Inspection) and Safety functions that provide services to each production site.

3.2.1 Operations Department

Organization: During the commissioning of the plant during 2008 (by the contractors) the case company had a full operational team in place. This included the managers of Commissioning, Technical, Process Control, Tank Farm, Laboratory and Maintenance. At AR3 there are separate teams for the Operations (of the units) and Oil Movements. They are of similar structure and, for example for plant operations there is an overall Shift Manager with Shift Supervisors for each of the Reformer and Aromatics areas. The latter then have teams of Panel, Chief and Field Operators. Each area also has a Maintenance Manager with Mechanical, Electrical and Instrument Supervisors. This is a conventional structure for facilities such as this.

Operating Instructions: General procedures were provided by UOP and were then expanded (in English) by the EPCC contractors. Before the plant was commissioned the AR3 team completed the detailed Thai version, which incorporates lessons learned from the AR2 plant. There is an action to make a detailed review of the procedures after some operating experience has been obtained.

Basic Equipment Care Program: The Operations department has a Basic Equipment Care (BEC) program that allows operators to undertake simple maintenance tasks. The case company has responded that the operators are well trained (they must be BEC certified) and are the area owner and so no permit is required. In addition, all BEC tasks are first approved by the Area Supervisor.

Every 3 months the operators complete a BEC checklist. This is a visual inspection of the critical items of equipment such as PSVs, TRVs, mixers, pumps, lubrication systems, tank drain and roof valves, bund drain valves (normally closed), etc.

Interlock Isolation: The bypassing of an interlock system requires the prior approval of the shift manager and full details are recorded in a dedicated logbook. The bypass is undertaken from the engineer's panel and cannot be done by the panel. This also applies to the various startup bypasses on the panel, where the keys have been removed and are held by the Shift Manager.

The status of the interlock system is indicated on the DCS panel, where it was noted that 1 bypass had been made for some time. In instances such as this we recommended that long term bypassing of interlocks be referred to the MOC procedure.

Equipment Isolation: In order to isolate equipment, details of the valves to be operated and the locations of blinds are first marked up on a copy of the P&ID. Details of the blinds inserted and then removed when the job is completed are recorded on a ‘Blind & Valve List.’

3.2.2 Maintenance Department

Organization: Maintenance for the case company has been rationalized and there is now a centralized Maintenance department to handle large repair jobs and turnarounds. This is complemented by local Field Execution teams within the Production department at each of the 3 sites. The latter are responsible for routine, day-to-day maintenance activities and some minor repairs. These 2 groups work together closely and all activities are planned centrally with Senior Maintenance Planners dedicated to each of the sites. . The team was established well before the commissioning of the plant and so had ample time to gather equipment data and develop the maintenance programs.

Maintenance Policy: This is common throughout the case company and generally follows Shell’s Asset Management philosophy. The plant is designed for major turnarounds after 4 years of operation and so the first will be in 2012. There is an additional Reliability Centered Maintenance (RCM) program, which is handled by the Reliability Engineering group. The maintenance program is managed by SAP software and both the schedule and equipment database for AR3 have already been installed. As noted elsewhere, the case company has a Basic Equipment Care program that allows process operators to undertake simple maintenance tasks. There is a preventive maintenance system in place. This management system identifies the schedule for servicing machinery, testing interlocks, for repainting equipment, and turnaround planning. There is an acceptance that some breakdown maintenance will be required.

Condition Monitoring: There is an extensive condition-monitoring program that is managed by the centralized Rotating Equipment Engineering group in the Reliability & Engineering Department.

3.2.3 Engineering/Technical Services

Organization: Engineering is handled by the central Asset Management department, which contains Reliability & Engineering section. This includes Reliability, Project, Rotating Equipment Engineers, together with Inspection. There is also a separate Technology department that contains process engineering and process control specialists, together with the laboratory.

3.2.4 Inspection Services

Organization: It is located in the Reliability and Engineering Department and is divided into 5 groups, one of which is dedicated to inspecting the 2 aromatics plants. This contains a Lead Process Inspector and 2 Inspection Engineers. Another of the groups specializes in corrosion engineering.

The inspection group has an impressive array of NDT equipment including magnetic particle, ultrasonic, dye penetrant, alloy analyzer, portable and bench hardness testers, A-Scan ultrasonic, etc. More is hired with the specialist contractors as required.

3.3 Current Procedure and Work Instructions

The case company adopts internationally recognized management system in all areas of its operation to achieve overall excellence. The purpose of the Aromatics and Refining Management System is to provide a structure against which the main business processes can be specified and managed that ensures that the business processes are continually improved.

The objectives of this approach to manage the case company include:

- Demonstrate its ability to consistently provide high quality product that meets stakeholder and applicable statutory and regulatory requirements
- Manufacture and deliver product via the most efficient, environmental friendly and safe production processes
- Enhance stakeholder satisfaction through the effective management system
- Focus on reducing and controlling the impact on environment as well as the hazard risks to employees and concern parties
- Enhance the learning culture
- Receptacle for capturing aromatics and refining management best practices
- Develop and enhance human resources capability on both staff and management level towards the high performance organization
- Demonstrate of the completeness of the overall business process
- Communicate the managed way to all level of staff in organization.

3.3.1 Current risk management

The risk management in the case company is included into the corporate policies. It is the approach for the most hazard identification as a big picture. Mostly, it concerns about Enterprise Risk Management (ERM) and serves for strategic management as well.

For efficiently operation of Risk Management, the case company has laid down the risk management policy as the following.

- Manage the risks of the company at the acceptable level
- Risk management is everybody responsibility in the company such as the committee, management team and all staff
- Embed risk management system into the routine tasks to become organization culture
- Continually improve and develop risk management system to be more efficiently and effectively
- Regularly report risks to management committee and management team

The Risk Management process of the case company covers as the following steps;

1. **Objective Setting**

"To create sustainable value for organization under uncertain circumstances"

2. **Event Identification (Risk Identification)**

The major consideration is focused on the prevention of the external and internal uncertainties in four main types.

- Hazard Risk

  It includes the risk from fire and other property damage, windstorm and other natural perils, theft and other crime, personal injury, business interruption, disease and disability (including work-related injuries and diseases), and liability claims.

- Financial Risk

  It includes the risk from price (e.g. asset value, interest rate, foreign exchange, commodity), liquidity (e.g. cash flow, call risk, opportunity cost), credit (e.g. default, downgrade), inflation/purchasing power, and hedging/basis risk.

- Operational Risk

It includes the risk from business operations (e.g. human resources, product development, capacity, efficiency, product/service failure, channel management, supply chain management, business cyclicality), empowerment (e.g. leadership, change readiness), information technology (e.g. relevance, availability), and information/business reporting (e.g. budgeting and planning, accounting information, pension fund, investment evaluation, taxation).

- Strategic Risk

It includes the risk from reputational damage, competition, customer wants, demographic and social/culture trends, technological innovation, capital availability, and regulatory and political trends.

Although the case company has its own ERM (Enterprise Risk Management), the key focus of the case company is operational risks. Many events, both external and internal, can lead the case company to confront with the risks such as reliability risks, environmental risks and hazardous risks. In addition, there are many points of concern which are needed to be taken into account. The points to be focused are flammable liquid, high pressure, high temperature, oil spill, emission, etc.

3. Risk Assessment

Risk level is a combination of likelihood (probability) of that event occurring and the impact (consequence) of an event. Risks can be both upside or downside, i.e. Opportunities or Threats. The risk owner is responsible to assess their own risk and provide the outcome for management to consider an appropriate method to response with the risk.

4. **Risk Response:**

For the risk that has been assessed and ranked at the medium and high level, the risk owner function is responsible for setting the risk management plan with the suitable specific target date and summarize into the risk register for further risk management.

5. **Monitoring:**

Risk and Investment Management Manager will report the HIGH risk management progress to the Risk Management Committee (RMC) at least one per quarter prior the board meeting.

3.3.2 The case company Risk Assessment Matrix (RAM)

To assess the risks, tailor made Risk Assessment Matrixes. It is widely used in the case company business processes to provide practical tools for day-to-day risk based decision-making weighing threats against costs.

RAM is considered for the impact or consequence on

- Personal and Safety
- Asset/Financial Loss
- Environment Impact
- Reputation
- Customer
- Staff morale

For ease of understanding and consistency implementation in day-to-day decision-making weighing threats against costs, RAM has been tailor made as detailed in this document for following business processes:-

1. Integrated Management System Audit Finding Category
2. Document Requirement
3. SHE Severity
4. Incident Investigation Severity
5. Investment Priority

6. Maintenance Priority Code
7. Risk and Reliability Management

Table 3.1 and Table 3.2 are the example of Risk Assessment Matrix in the case company and their criticalities to be assessed.

Table 3.1 Risk Assessment Matrix (RAM): Risk and Reliability Management

Impacts or Consequences							Likelihood				
							0.01%	0.1%	1%	10%	100%
							1 Improbable	2 Unlikely	3 Possible	4 Likely	5 High
Severity	**Safety and Health**	**Asset or Financial Loss**	**Environmental l Impact**	**Reputation**	**Customer**	**Staff's Morale**	Never heard in R&P industry / Very hard to occur next year	Has occurred in R&P industry / Unlikely to occur next year	Has occurred in R&P in last ten years / Possible to occur next year	Has occurred several times in R&P in last five years / Likely to occur next year	Has occurred several times in the company/ Anticipate to occur next year
1	First aid, medical treatment	Value <10K USD	Slight environmental effect within fence (local)	No public awareness	Minimal impact to customers	Minimal impact to staff's morale	N	N	N	L	L
2	**Minor injury, LTI**	Value up to 100K USD	Minor environmental effect/Large contamination	Local public awareness	Verbal complaints	Short-term impact, less than 3 months	N	N	L	M	MH
3	**Permanent partial disability Major injury**	Value up to 1M USD	Significant release outside fence	Limited nation public	Official letter complaint/ Supply interruption	Long-term impact. More than 3 months	L	L	M	MH	H
4	**Permanent total disability (death)**	Value up to 10M USD	Severe environmental Damage Major emission	Widely national public awareness	Purchase less or turn to other supplier	Protesters rally or official complaint	L	M	MH	H	E
5	**Multiple fatalities Large exposed**	Value >10M USD	Massive effect to large area	International public awareness	Stop purchase	Employees strike	M	MH	H	E	E

Table 3.2 Risk and Reliability Management Criticality

Risk &Reliability Management Criticality			
Criticality	**Assessed Risk**	**Description of Category**	**Action Recommended.**
Negligible	N	Not susceptible under any foreseen conditions	Cost effective. No inspection, Breakdown maintenance
Low	L	Susceptible to malfunction or degradation under upset conditions	Improve Monitoring, Planned maintenance PM/CM
Medium	M MH	Susceptible to malfunction or degradation under normal conditions	Opportunity Inspection, Planned maintenance PM/CM, Condition monitoring
High	H	Very susceptible to malfunction or degradation	Extensive Monitoring, Detailed RCM, RCA analysis, Consider redesign,
Intolerable	E	Intolerable and Extreme criticality items	Recommend re-designed

3.3.3 Incident Investigation and Analysis

The case company is committed to preventing incidents that involve aromatics and refinery operations and equipment reliability, so it has set as one of its goals to continually improving all aromatics and refinery processes. This procedure describes how the investigation and analysis processes are to be used to improve aromatics and refinery processes. This procedure incorporates the use of a risk assessment matrix to rate an incident's potential outcome and determine the depth of investigation that is required.

It is important that all incidents must be reported so that corrective action can be established before a similar occurrences result in a serious accident. The primary objective of an incident investigation is to determine and document the root causes and contributing causes of an incident. Recommendations and corrective action plans are then developed with the intent of preventing such incidents in the future. In order to make continuous improvement in the investigation process, the following approach shall be focused.

1. Focus on incident's potential consequences rather than its actual consequences.
2. Focus on effective solution by using root cause analysis technique in preventing the risk recurring.
3. Emphasis to have no repeat incidents or similar case in other areas, and use the solution to minimize the risk and loss.
4. Utilize team-based approach by enhance trust and create NO blaming culture in the investigation process in order to obtain fact-findings and the real root causes.
5. Promote incident reporting system as a proactive mechanism for risk management, prioritization and error reduction strategy.
6. Use line responsibility concept, line function to take the lead in incident investigation.
7. Allocate responsibilities for incident investigation appropriately through qualified people.
8. Meet all relevant statutory and Group requirements on incident reporting.

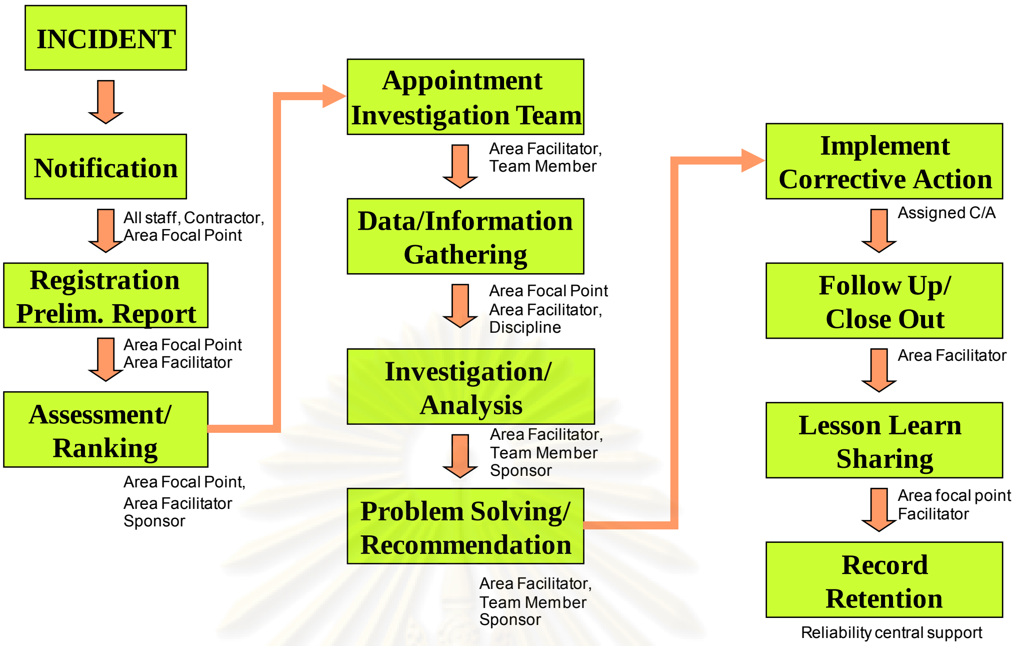


Figure 3.2 Incident Investigation process

3.4 Past Incidents

As already mentioned in Chapter I, the new plant was first commissioned in June 2008 and, following a few teething troubles it finally entered into commercial operation on 1st February 2009. Since the startup there have been reported many incidents.

- Incident Type

The case company requires investigation of the incidents or near misses, which meet the Risk Assessment criteria. Incidents are abnormal occurrences in business operations that fall into one of the following categories in Table 3.3.

Table 3.3 Incident types and scope

Incident Type	Scope
People	Includes all people injuries, first aid, medical treatment, restricted work cases, recordable cases, permanent partial disability, fatality and occupational illness.
Asset/Financial Loss	Includes equipment Trip, Fire, Loss & Damage, and Operation Reliability.
Environmental	Includes Legal Non-Compliance, Complaints, and Spill or Release.
Reputation	Includes internal and external public concerns; local media, national or international public attention.
Customer	Includes customer awareness, product waiver, verbal/letter complaint, contract termination or not comply with legal and international public concern.

- Incident Severity

The severity level is classified as LOW, MEDIUM and HIGH following the Risk Assessment Matrix (RAM). However, low severity is split into two categories for no investigation and investigation. The first low severity group means not required to set up investigation team but facilitator needs to input data gathered from the incident into the database. This information includes potential root cause, immediate action, lessons learn and 10 recommended practices violation. The second low severity group is required full investigation due to have high potential consequence judged by RAM. Incident investigation team needs to be set up to do the whole incident investigation process.

The severity of an incident dictates how deep the investigation and analysis process is required, along with how many and the various disciplines that will need to be involved as either a member of an Investigation Team or to provide technical or other support for the investigation. The actions required for each severity level are as follows:

Table3.4 Incident Severity

Severity	Details
Low	**No investigation is required:** No full investigation and root cause analysis is required. Problem could review internally and fix by area owner.
	Investigation is required: Investigation team will be set up when incident having high potential consequence after judged by RAM.
Medium	Full investigation is required.
High	Full incident investigation with high priority. Immediate corrective action to reduce risks e.g. stop activity.

Of all the incidents through the year 2009, the case company use COI and LPO as the measurement to control and improve the operational availability. In the Asset Management System Performance, both indicators are one of the key performance indicators of the case company and shall be continuously monitored against the KPI's targets.Cost of Incidents (COI) is an indicator of gaps in reliability and also tells the bottom line impact of unplanned incidents to the company. All operated and non operated assets and equity affiliates should be reported for all Cost of Incidents. This indicator shows the impact such as lost revenues or reduced gross margins, incremental expenses associated with repairs or replacement and portion of capital incurred in lieu of repair or replacement (e.g. upgrade instead of replace).

LPO is a Lost Production Opportunity cost measured is $USD. This is the monetary value of reduced, lost, or off-specification production attributed to a production unit event of unplanned maintenance, process difficulties, feed shortage and product ship delay and equipment malfunction.

In year 2009, the total incidents of the company had 282 records and AT had total incidents 62 times which are about 22% of the overall incidents and about 25 cases had created LPO and COI about 12,684,002 $USD and 12,165,883 $USD respectively, mostly from operation reliability. Therefore the risk analysis will be focused on operation cases which occurred during Year 2009.This problem is a major concern to the management of the company because it is not only cost the company in financial aspect but also the image and the opportunity to expand its business.

The incident report were translated and summarized into summary report as shown in Table 3.5.

Table 3.5 AT Summary Incident Report of year 2009

	INCIDENT BY PARAMETER REPORT						
ID	INCIDENT TITLE	OCCURRED DATE	SEVERITY	CLASSIFICATION	SUBCLASS 1	LPO(USD)	COI(USD)
1681	(AT) AR3 Total plant shut down due to power blackout	12 Mar 2009	High Severity	Assets	Operation Reliability	1,900,000	1,900,000
1689	(AT) Load chemical 3 DT-129 into 3 DT 190 (TK-65)	19 Feb 2009	Low Severity	Assets	Loss/Damage		1,600
1710	(AT) ขโมยเข้าตัดสายไฟ AR3	31 Mar 2009	Low Severity	Assets	Loss of Property		2,689
1736	(AT) 2100-E13 Tube Leak	28 Apr 2009	Medium Severity	Assets	Operation Reliability	922,000	390,795
1739	(AT) Parex E S/D from 2500-PV18A malfunction.	05 May 2009	High Severity	Assets	Operation Reliability	1,157,000	1,157,000
1746	(AT) Parex E S/D from 2500-PV18A malfunction.	02 May 2009	Medium Severity	Assets	Operation Reliability	610,000	610,000
1757	(AT) PTT-UT : Electric blink & Boiler , 2 Gas Turbine Trip	14 May 2009	Medium Severity	Assets	Operation Reliability	571,000	571,000

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

1759	(AT) 2500-FV18A malfunction consequence to Parex adsorption section shutdown.	15 May 2009	High Severity	Assets	Operation Reliability	1,346,000	1,346,000
1762	(AT) 2100-E13 Tube Leak (Deethanizer Overhead Condenser Leakage)	18 May 2009	Medium Severity	Assets	Operation Reliability	382,000	390,795
1786	(AT) Pusharound annubar flow 2500-FI20 failure consequence to shutdown Parex unit	11 Jun 2009	Medium Severity	Assets	Operation Reliability	338,000	338,000
1793	(AT) AR3 total plant shutdown due to power blackout	18 Jun 2009	High Severity	Assets	Operation Reliability	587,000	587,000
1814	(AT) 3/4"vent at chamber circulation line was cracked	19 Jun 2009	Low Severity	Assets	Loss/Damage		
1824	(AT) UNIT-2500 Shut-Down due to 2500-FT020 cracked	22 Jul 2009	Medium Severity	Assets	Operation Reliability	214,000	214,000
1841	(AT) Power blackout due to loss power supply from PTTUT consequence to total plan shutdown	10 Aug 2009	High Severity	Assets	Operation Reliability	1,637,000	1,637,000

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

1866	(AT) Chamber circulation control valve stuck (2500-PV18A, Globe Valve from AR2)	27 Aug 2009	Medium Severity	Assets	Operation Reliability	427,000	427,000
1870	(AT) Power dip from EGAT consequence to power generator frequency dip to VSD system.	31 Aug 2009	Medium Severity	Assets	Operation Reliability	143,000	143,000
1872	(AT) ไฟฟ้า Trip	03 Sep 2009	High Severity	Assets	Operation Reliability	102,000	102,000
1876	(AT) 2500-PV14A Failure	06 Sep 2009	Medium Severity	Assets	Operation Reliability	237,000	237,000
1898	(AT) 2200C2 immediately shut down	21 Sep 2009	Medium Severity	Assets	Operation Reliability	560,000	560,000
1927	(AT) 2380-C4 tripped during load propane to refrigerant unit	17 Oct 2009	Medium Severity	Assets	Operation Reliability	180,000	180,000
1939	(AT) 2500-P2C tripped during switch over 2500-P2B to 2500-P2A	26 Oct 2009	Medium Severity	Assets	Operation Reliability	174,000	174,000
1966	(AT) Helper got first aid case while helping the fitter assembling pipe line 10" at 2945-TK57B	21 Nov 2009	Low Severity	People	First aid	2	2

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

1970	(AT) 2200-C2 tripped due to intermediate power supply damaged	24 Nov 2009	Medium Severity	Assets	Operation Reliability	638,000	638,000
1972	(AT) 2200-C2 Tripped due to intermediate power supply defected	25 Nov 2009	Medium Severity	Assets	Operation Reliability	484,000	484,000
2005	(AT) GTG #2 and AUX boiler tripped from bud tie 6.9 fail	14 Dec 2009	Medium Severity	Assets	Operation Reliability	75,000	75,000
Total=	25					12,684,002	12,165,883

From the above incident summary reports, it can be observed that the failure mode came from the problem of process and equipment reliability (operation reliability). In order to assess all these risks, process FMEA is used to analyze the existing processes. The focus of the process FMEA is to minimize production failure effects on the system by identifying the key variables. In the case company, there are many units to operate and the incidents can occur to every unit both the difference time and the same time.

For the continuous process, all production units are running in risk equally. In this research, the selected unit will be used as a model to study failure reduction in the case company by using process FMEA approach. In the future, this approach will be used to apply what studied on this model to others.

3.5 Risk Management Process

Risk Management is used to identify and solve the critical risks that could impact the case company. The Australian and New Zealand standard on risk management (ASINZS 4360:2004) is the latest version of risk management standard. It provides systematically steps to facilitate the case company to manage the risks which composes of major steps as the following:

1. Establish the Context
2. Identify Risks
3. Analyze Risks
4. Evaluate Risks
5. Treat Risks
6. Monitoring and Review Risks

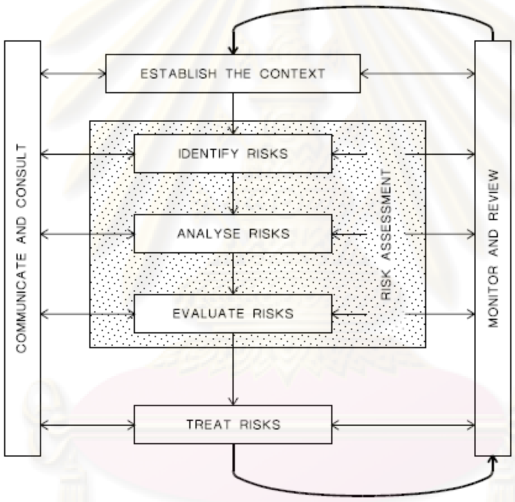


Figure 3.3 Risk Management Standards (AS/NZS 4360:2004)
Source Standards Australia and Standards New Zealand (2004)

For the case company, its enterprise risk management has been broken down to operational risk and it is suitable for day to day operation and decision making activities. In this level, the concernment will be focused on maintaining operational availability and reducing incident chance. Moreover, in this level the consideration will relate to equipment, material and man.

3.5.1 Establish the Context

Establishment the context of risk management enables the organization to understand the environmental of the business sector we operate. Risk Management

Context identifies the risk categories of relevance to the enterprise and the degree of coordination throughout the organization including the adoption of common risk matrix. The objective of this stage is to understand the external operating environment and internal organization culture. The objective is set to identify the principal risks and developing appropriate solutions to manage them are effectively as possible. The case company also has the objective which is “To create sustainable value for organization under uncertain circumstances”. As the major risk assessment is time-consuming and costly, it is worthwhile to do a preliminary scoping and pilot study.

3.5.2 Risk Management Team

To identify and assesses the significant of risks, the case company set up the team from multi-discipline members assigned to review the operating performance of a production unit or area identify reliability risks threats, manage and communicate reliability risks, and follow up on related action items. Members is a cross functional team which comprises of members nominated from various departments include production day staff, production support, technology, inspection, maintenance, HSSE, engineering, laboratory. Production Team members may be own or contract staff. The Meeting schedule will be set up monthly or ad hoc as emergency case.

The following key roles and responsibilities of the team are:

- Approve ranking of Top-10 Reliability Risk in their own area
- Drive action plan of Top-10 Reliability Risk e.g. Zero Unplanned SD actions
- Approve as effective Incident investigation report (high severity)
- Approach to solving risk problems.
- Review & comment bad actor, expired MOC to treat the risks.
- Advise closing gap for KPI performance monthly
- Identify and evaluate the significant risks faced by the organization
- Encourage goo d risk management practice within the organization.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

- Key risk indicators will be identified and closely monitored on a regular basis.

3.5.3 Risk Identification Process

Risk identification session started by discussion about the generic risks that usually occurred in the case company by using Brainstorming technique. In order to reduce oneself thinking where the ideas are not creative and the group is being invaded with one strong-minded person, the nominal group method is applied. The nominal brainstorming method requires that the team will have to generate the ideas individually and then present it to the team and then it can be discussed later.

The case company identified risks using 3 main approaches as follows:

1. **Process Oriented Identification**

   Risks are identified by the Project Teams during projects design e.g., EIA Study and is on-going in accordance with the Management of Changes Procedure or may arise from periodic review or audit.

2. **Area / Business Unit Oriented Identification**

   Risks are identified by risk identification and Risk Assessment Working Groups by brainstorming.

3. **Risk Identification based on Job/Task Analysis**

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

3.5.4 Risk Assessment Process

After risks are identified by Brainstorming, the next step is to assess the risks, which the assessment can be subdivided into two steps, risk analysis and risk evaluation.

- Analyze Risks

Identified potential risks from the previous step need to be analyzed in order to indicate their characteristics. In risk analysis step, the objective is to identify the significant of those risks that affect the organizational objective. Impact of potential risks does not have the same significant to the objective, which depends on their likelihood and consequence. Risk analysis determines how often identified risks are likely to occur and the magnitude of their consequences. The significance of risk is expressed as a combination of its consequence or impact on the objectives of the organization and the likelihood of those consequences occurring. Consequence and likelihood may be accounted for using a qualitative, semi-qualitative or quantitative approach. The qualitative approach is most common and is briefly described below. The likelihood criteria are expressed as a probability of the annual occurrence on a descriptive scale from Rare to Almost certain. Consequences are rated in terms of the potential Impact on the key criteria, such as Performance, cost, schedule, identified during the context step. The impact is then also described on a scale from insignificant to catastrophic.

The Risk Management Standard, AS/N ZS 4360: 2004 explains each analysis as the following;

Qualitative analysis uses descriptive scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur. These scales can be adapted or adjusted to suit the Circumstances, and different descriptions used for different risks. Quantitative analysis is used as an initial screening activity to identify risks which require more detailed analysis where the level of risk does not justify the time and effort required for a fuller analysis or where the numerical data are inadequate for a quantitative analysis.

Quantitative analysis uses numerical values (rather than the descriptive scales used in qualitative and semi-quantitative analysis) for both consequences and likelihood using data from a variety of sources. Consequences may be estimated by modeling the outcomes of an event or set of events, by extrapolation from experimental studies or past data. Consequences may be expressed in terms of monetary, technical or human criteria. In some cases more than one numerical value is required to specify consequences for different times, places, groups or situations.

Likelihood is expressed as a probability, a frequency, or a combination of exposure and probability. The way in which likelihood and consequence are expressed and the ways in which they are combined to provide a level of risk will vary according to the type of risk and the cont ext in which the level of risk is to be used.

With the widespread use of risk analysis, a number of generic techniques and approaches have evolved. Some of the more common techniques, which look at very different aspects of system safety analysis, are:

• Failure mode and effect analysis
• Hazard and operability study (HAZOP)
• Fault tree analysis
• Event tree analysis
• Monte Carlo simulation
• Probabilistic risk analysis
• OSH Method of hazard identification
• Short cut risk-analysis method

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

The Failure Mode and Effect s Analysis (FMEA) is selected to be a risk assessment tool in this research. FMEA is a good approach to assess the risk using the RPN (Risk Priority Number) and analyzing the scores. The FMEA that will be used in this process will be the process FMEA (PFMEA) because the process FMEA provides a structured, qualitative, analytical framework which taps the multi-disciplined experience of the team to brainstorm answers to such questions as

- How can this process, function, facility, or tooling fail?
- What effect will process, function, facility, or tooling failures have on the end product (or customer)?
- How can potential failures be eliminated or controlled?

Process FMEA can be used to assess and improve any process both new processes and current processes. The most common use of the PFMEA involves manufacturing processes including the process steps, process equipment, process conditions, tooling/fixtures, operator errors, material quality and so on.

Process FMEA reveals process problems related to the manufacture of the product. For example, a piece of automated assembly equipment may feed the wrong parts, resulting in products not being assembled correctly. In a chemical manufacturing process, temperature and mixing time could be sources of potential failures, resulting in an unusable product. It is helpful when conducting a process FMEA to think in terms of the five elements of a process: people, materials, equipment, methods, and environment. This methodology identifies potential or known failure modes and provides follow-up and corrective actions before the first or subsequent production runs.

FMEA uses severity, occurrence, and detection rankings to calculate RPN, although the definitions of the ranking scale for each may be different. Many companies have different customized ranking scales for their own process FMEA. The ranking scales presented in this research are suggestions and can be used as starting points to develop customized ranking scales specifically designed for a particular company.

- Risk Evaluation

After analyze the risks, the FMEA established the Risk Priority Number (RPN) which is the product of Severity, Occurrence and Detection quantifying the impacts of risks. By using this quantitative analysis, the risk management team can evaluate the causes of risks by the magnitude of the RPN number. Risk evaluation is about deciding whether particular risks are acceptable or not to taking into account. The outcome is a list of risks with agreed priorities ratings from which decisions can be made about acceptable levels of tolerance for particular risks and where greatest effort should be focused.

3.5.5 RISK TREATMENT

Risk treatment is the process to take action to the risk. Action to the risk is controlled by its result. The objective of risk treatment is to response identified risks by designating what will be done, and who will be responsible for the risks that have been identified. Risk treatment converts the earlier analysis into actions to reduce risk. Risk reduction should focus on reducing the severity, the probability of occurrence, or both. The previous plan and strategy which were in management plan before risk management process started have to be modified if the identified risks dominate the current control.

Risk treatment choices are evaluated in terms of feasibility, costs and benefits with the aim of choosing the most appropriate and practical way of reducing risk to a tolerable level. The option chosen should provide a Risk Action Plan to deal with risks before they arise and a Contingency Plan that provides for recovery if a risk eventuates. Risk Action Plans will manage different risks in different ways. They may seek to reduce the likelihood of occurrence, minimize the consequences, transfer/share risk and retain risk.

There is a potential benefits in using the quantitative analysis, like FMEA which provides the information on the aggregate affect of the potential risks. The values do not only show what the risks are but also systematically quantifying their severity, detection and occurrence.

Until the top management appreciate the effect, it is difficult to make a right decision to accept/share/transfer/eliminate these risks. Once the management of the case company knows the levels of risks, it can make better decision to formulate the strategies for the forthcoming strategic plan.

From general risk management standard, possible response options include:

1. Risk Avoidance: Exposure to risks might be eliminated by introducing remote operations or by replacing dangerous facility or through using a less risky process. Poor technology should be overtaken by something better. Costly retrofitting to meet safety standards can be avoided through adequate risk identification and consideration of alternative. It will always be cheaper to mitigate risks at an early stage.

2. Risk Mitigation: Level of the risks can be reduced by controlling probability of risk occurring e.g. through the introduction of some control system to trip when parameter reaches a critical value or/and impact of its consequence. Reduction of risk level can be managed by implementation of strategic plan or any control system.

3. Risk Transfer: Risk can be transferred from the organization to another party.
Level of transferred risks is not changed, but the responsibility is transferred to the others. Transferring of risk may be in part or total. Risk transfer moves the responsibility to another party or sharing the risks through a contract. Transfer of risk can significantly increase if another party cannot manage that risk.

4. Risk Acceptance: Not all risk can be reduced or even transferred. There may be residual risks which retained by the organization. Any response strategic plan cannot be implemented to deal with the risk. Risk in this case must be carefully considered and retained in the company. Once the risks are evaluate to identify their natures, risk treatment options are formulated to each significant potential risk in order to create further action plan.

5. Duplicate Resource: Duplication of operations enhances reliability by introducing redundancy. This is the commonest approach in many cases, and is a very effective

option. The likelihood of experiencing the risk is thereby reduced, provided any standby or backup unit does not share a common element with the main unit.

6. Transform the risk: This is another form of mitigation in which the risky process is transformed into one that poses less of a treat or may be more easily treated.

3.5.6 MONITORING AND REVI EWS

Continuous monitoring and review of risks ensures that new risks are detected and managed. Action plans are implemented and managers and stakeholders are kept informed. The availability of regular information on risks can assist in identifying trends, likely trouble Spots or other changes that have arisen. Ongoing review is essential to ensure that the management plan remains relevant. Factors that may affect the likelihood and consequences of an outcome may change, as may the factors that affect the suitability or cost of the treatment options. It is therefore necessary to repeat the risk management cycle regularly. Actual progress against risk treatment plans provide an important performance measure and should be incorporated into the organization's performance management, measurement and reporting system. Monitoring and review also involves learning lessons from the risk management process, by reviewing events, the treatment plans and their outcomes.

3.5.7 COMMUNICATE THE RISKS

When the risk is established, the creditability of the chosen message-bearers is important. Since all parties to the process bring their own biases. There are four conceptual approaches to risk communication.

- The top -down transmission of expert opinion to a non -expert audience;
- An interactive exchange of information and opinion among individual, groups or organizations;
- An exchange of information within a wider cultural or institutional context;
- A political process of empowering risk bearing groups society.

In the view of risk communication, its effectiveness hinges on trust. Trust is hard to gain, but easy to lose. If the source of communication is not trusted, perhaps because the present evidence contradicts past message, then it is unlikely that the new massage will be trusted.

Australian/New Zealand Risk Management Standard suggests t he objectives of good communication are clarity, objectivity, timeliness, regularity. Although these objectives are sound in principle, they are difficult to achieve in practice. The basic rules of communication include:

• Write clarity and simple;
• Avoid hiding adverse information and be open;
• Take the initiative, especially when one has negative information;
• Avoid "killer words" such as perfectly safe, risk-free, which are never true;
• Quantify risks as far as possible;
• Acknowledge that there are no dumb questions;
• Be frank when dealing with the media;
• Be aware of factors that inspire trust;
• Put data in context and choose risk comparison carefully;
• Remember that other will decide what is acceptable to them.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

CHAPTER IV

RESULT AND ANALYSIS

In this chapter, it will be started with the selected unit which is used to be a pilot model. It contains general overview, process performance, process principles, process variables and process flow with control. The analysis in this chapter will conduct gap analysis between the current practice and the system to be developed. This chapter is about methodology to study the present process of the case company and to identify the potential causes of possible failures which are significant to the production performance, production opportunities and incident cost by using risk analysis tool, FMEA. The conducting of process FMEA will be explained in this chapter step by step.

FMEA is the method used for identifying the causes of failure in the case company. FMEA methodology, FMEA boundaries, process flow chart and causes & effect diagram are utilized to systematically analyze the problem in the process FMEA form.

4.1 GENERAL OVERVIEW

The selected unit from the case company is the first unit from Aromatics side. The importance of this unit is to remove olefins from reformate feed. Olefins will make the main product quality out of selling specifications.

Olefins represent a problem to some catalytic or adsorbent systems. The Olefin Reduction Process (ORP) is used to convert the olefin and alkenylbenzene species present in reformate and similar materials into their hydrogenated products.

Removal of olefins has been traditionally accomplished by using an acid clay catalyst to combine the olefin with an aromatic molecule. The product of the reaction is a heavy species which may be removed by distillation. The heavy products are typically disposed in a heavy stream that has fuel oil value. The ORP converts the olefins into their aliphatic analog, e.g. heptene would convert into heptane. Alkenyl benzene species are converted to their alkyl benzene analog, e.g. methyl styrene would be converted into methyl ethyl benzene.

The hydrogenation is carried out selectively to convert olefinic material without converting the aromatic molecules back into naphthenes. From an economic view point the cost of hydrogen and catalyst used in the process is offset by the recovery of useful feedstock that would be lost in alkylation and the elimination of the replacement of non-regenerable clay systems currently used for removal of olefins. Disposal of the clay is also eliminated.

4.2 PROCESS PERFORMANCE

The Olefin Reduction Process can be placed in most locations that utilize clay. The Figure 4.1 below shows the ORP incorporated into a fully integrated aromatic complex:

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

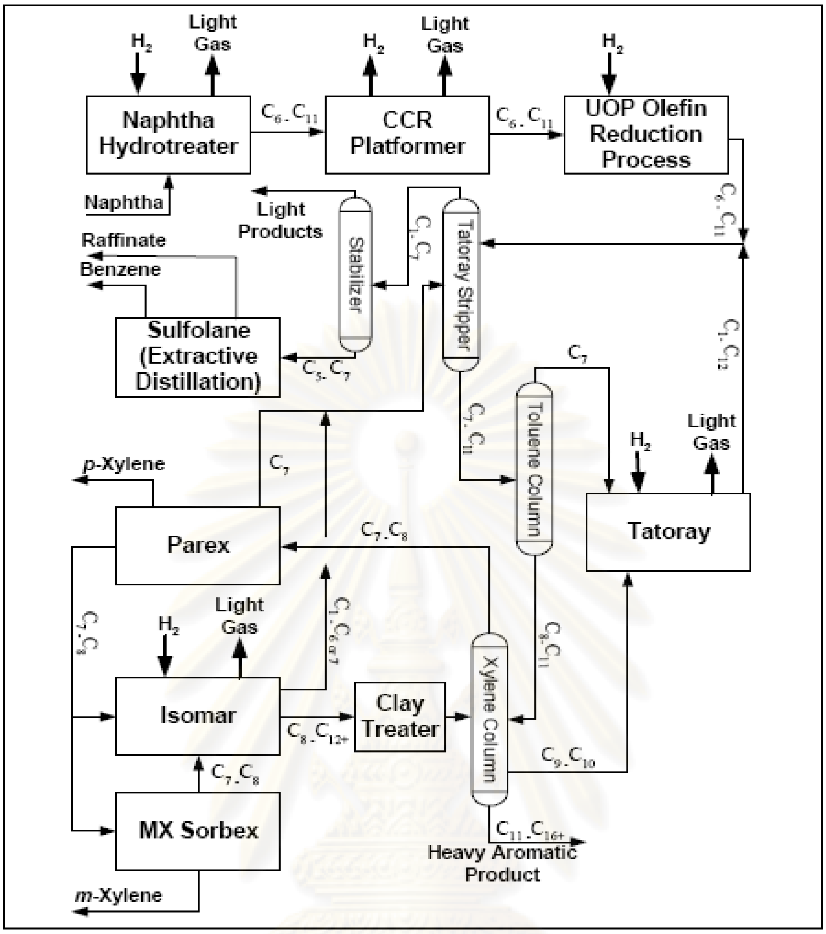


Figure 4.1 the ORP incorporated into a fully integrated aromatic complex

Naphtha is normally fed to a hydro-treating unit to remove sulfur and nitrogen species which are detrimental to the Platforming unit catalyst. Some feed contaminants are also removed in the naphtha hydro-treating unit which can contribute to fouling of the unit. Normally the sulfur and nitrogen leave the unit in the gas phase as H2S and ammonia.

In the Platforming unit some of the charge is converted from naphthene and paraffin material to aromatics. Typically very little non-aromatic material is left in the fraction that boils with the C8 aromatics and heavier. Some quantities of nonaromatic material are left in the fraction that boils with the toluene and benzene. In the lighter fraction of the product, boiling with benzene and toluene, the bromine reactive species are typically normal olefins or iso-olefins. The olefins in the C8 aromatic and heavier

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

fractions are typically olefins that are attached to the aromatic rings, the alkenylbenzene materials.

The Olefin Reduction Process will saturate the olefins that are analogs of paraffin to the corresponding paraffin. The alkenyl benzene molecules get converted to their corresponding aromatics.

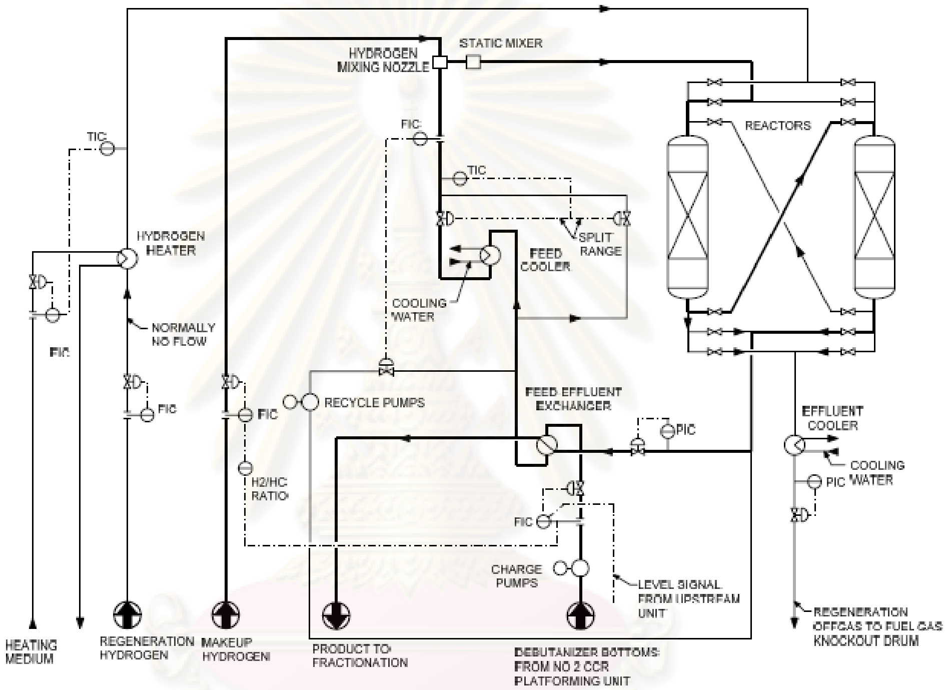


Figure 4.2 the process unit flow scheme

4.3 PROCESS PRINCIPLES

A. REACTION CHEMISTRY

The main reaction in the Olefin Reduction Process is hydrogenation. Isoparaffin and normal paraffin are hydrogenated to their corresponding paraffin. Alkenyl benzene species are hydrogenated to their corresponding aromatic molecule. Multi-ring aromatic molecules are hydrogenated to the corresponding monocyclic molecules.

1. Conversion of Normal Olefins

n-2-heptene + H2 = normal heptane + heat (30 kcal/g-mole)

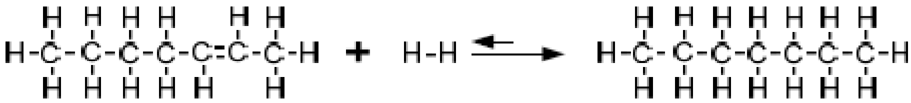


Figure 4.3 Conversion of Normal Olefins

2. Conversion of Iso-Olefins

2methyl 1-hexene + H2 = 2methyl hexane + heat (28 kcal/g-mole)

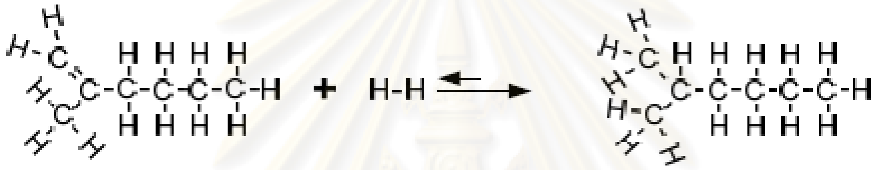


Figure 4.4 Conversion of Iso-Olefins

3. Conversion of Alkenyl Benzene

Styrene + H2 = ethyl benzene +heat (28 kcal/g-mole)

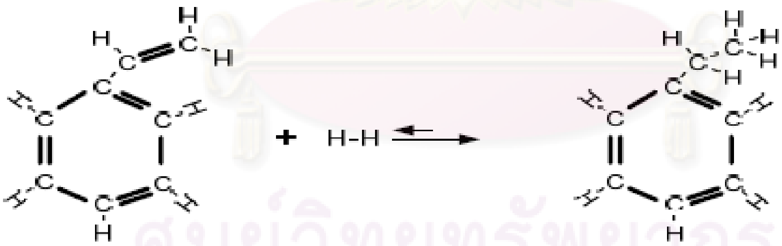


Figure 4.5 Conversion of Alkenyl Benzene

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

4. Conversion of Multi-Cyclic Rings

Naphthalene + 2H2 = tetralin (1234 tetrahydronaphthalene) + heat (30 kcal/gmole)

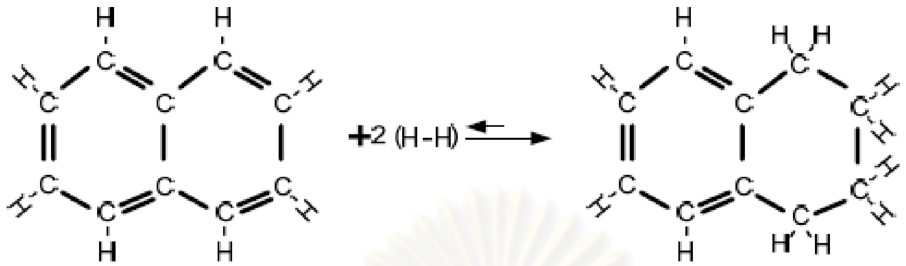


Figure 4.6 Conversion of Multi-CyclicRings

5. Conversion of Aromatic Rings

Ethyl benzene + 3H2 = ethyl cyclohexane + heat (28 kcal/g-mole)

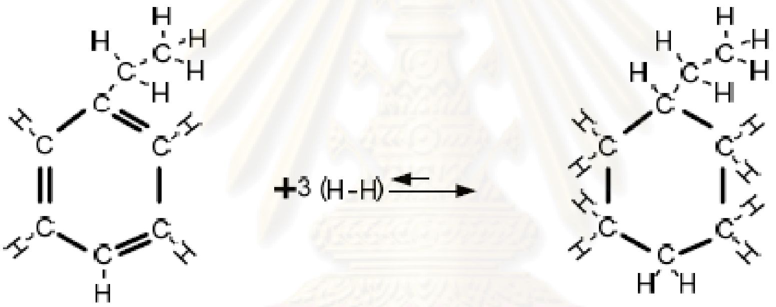


Figure 4.7 Conversion of Aromatic Rings

4.4 PROCESS VARIABLES

The operation of the Olefin Reduction Process (ORP) is controlled using temperature, pressure, the flow through the reactors and the ratio of H2 to the reactants. Although sample points are provided in the unit to determine the quality of the product from the olefin reduction unit, an efficient operation is best obtained when the operator monitors the end products after further processing.

The function of the ORP is to remove as much of the bromine reactive materials in the feed as possible while not saturating aromatics. As was the case with clay treating performed previously it is not normally required to remove all the olefin reactive species present in the charge.

The purpose of the ORP is not to remove all of the olefin reactive species present in the charge to the unit. ORP is to maintain the product quality of: the benzene fraction after extraction, the feed to the *para*-xylene production unit, the para-xylene product and the C7/C9 charge to the transalkylation unit.

To most efficiently operate the ORP the various product qualities should be monitored and the bromine index measured out of the ORP reactors should be controlled to hold the product qualities in specification. Some species like tertiary olefins are very difficult to remove with the ORP and attempting to make a product with 0 Bromine index would require excessive severity which would reduce cycle length of the catalyst and hydrogenate more aromatics than necessary. Normally one of the products will control the required outlet bromine index of the ORP.

1. PRESSURE

In the ORP unit pressure should be maximized at the reactors to maintain the maximum solubility of the hydrogen in the process liquid. The design reactor outlet pressure is approximately 22 kg/cm2 g (315 psig). The operator needs to adjust this value to maintain good operation of the makeup hydrogen valve and the feed control valve. The goal of the operator should be to maintain the highest pressure in the reactor circuit consistent with the operation of the upstream equipment. Yields are improved with higher pressures that force more of the hydrogen into the liquid phase.

If the feed or makeup hydrogen control valves are operating significantly closed there is pressure available. The Pressure Indicator Controller (PIC) on the outlet of the reactors should be operated such that the makeup hydrogen and feed control valves are mostly open but still in a controllable range. This is to say the pressure drop across the makeup hydrogen and feed control valves will be minimized. The normal pressure drop across the reactors is approximately 3.5 bar (50 psi). When one of the reactors is taken off line for regeneration the set point of the pressure controller at the outlet of the reactor may need to be increased to allow the feed and make up gas control valves to remain in control.

2. FLOW

Normally the flow through the reactor is not adjusted during normal operation. A recycle of product is used to maintain a high velocity through the catalyst bed. Normally the WHSV through the beds is 5/hr. When one of the reactors is taken off line for regeneration, the WHSV increases to 10/hr. Reduction in WHSV can lead to poor selectivity and additional aromatic saturation.

3. TEMPERATURE

The normal range of temperature for the operation of the ORP is from 45 °C (113 °F) to 110 °C (230 °F). As the catalyst ages the temperature of the reactor will need to be increased to maintain the activity of the catalyst. The End of Run (EOR) temperature of 110 °C (230 °F) should not be exceeded as high temperatures may lead to permanent poisoning of the catalyst. Higher temperatures will cause more hydrogenation of aromatics. As result of this effect, running at the lowest temperature which still makes the product quality acceptable should be the operating goal. When one of the reactors is taken off line for regeneration the reactor remaining on line will require an increase in temperature to maintain the hydrogenation of the bromine reactive species.

Although it may be obvious, it is important that the two reactors be out of phase with each other. When the unit if first put into operation both catalyst beds are fresh. Since the mechanism for deactivation is sulfur adsorption, the reactor in the second position will begin deactivating from the beginning as the first reactor does not adsorb enough sulfur to protect the second reactor. When the unit is put into operation it is recommended that the first reactor be taken into regeneration after maybe 2 months. Although the first reactor will not be deactivated, it should be regenerated so that the two reactors will be on different schedules for regeneration.

While it may appear to make sense to hold one of the reactors off line in a standby mode this is not expected to be useful as operating with 2 reactors in series should allow a lower operating temperature which will provide the best yields and longest ultimate catalyst life.

4. H2/REACTANTS

The unit is designed with hydrogen to hydrocarbon ratio set point controller. The purpose of this controller is to maintain the ratio of hydrogen to fresh feed entering the unit. In order to estimate the initial set point of the controller you must know the feed composition and feed Bromine Index or Bromine Number. Bromine Index is Bromine number multiplied by 1000.

The charge should be analyzed to determine the bromine number and composition. A first assumption is that one mole of hydrogen will be consumed for each mole of Br2 that is determined by Bromine index. Bromine Number reports results in grams of Br/100 g of sample. The naphthalene in the charge must also be considered as it consumes hydrogen. Each mole of naphthalene will consume 3 moles of hydrogen. Although the intention is not to hydrogenate the aromatics in the charge an allowance must be made for some hydrogenation. A starting value for this estimate may be 0.5% of the benzene and 0.25% of the toluene.

4.5 PROCESS FLOW AND CONTROL

1. Liquid Feed Entering the Unit

The Olefin Reduction Unit can be located is several locations depending on the complex flow scheme and processing objectives. Locations can include the debutanized product from the reforming process unit, or the heavy aromatic stream for a reformate splitter. In the first case there may be value in hydrogenating the olefins that co-boil with the benzene and toluene as when they will be subsequently fed to a naphtha cracker. In the second case there may be value in no hydrogenating the benzene and toluene co-boiling materials when they will be blended into gasoline. Other locations are possible depending on the desire to convert olefins in a process stream to their analogous hydrogenated species.

Generally the feed is received directly from upstream fraction. As such there is generally no need to have a separate feed surge drum for the unit. The surge capacity in the upstream unit is used to protect against significant swings in flow rate that may upset the ORP. Tank should be avoided such that oxygen and moisture contamination is avoided. Normally the charge must be pumped to a pressure sufficient to allow for dissolution of most of the hydrogen required by the process. Normally the pump is located near the source of the charge. Feed is directed to the unit on flow control. If the flow control is not stable then the ratio of hydrogen to the feed cannot be controlled very accurately. If the flow is low and the hydrogen is high then more of the aromatic species will be hydrogenated and a yield loss will occur. If the feed deviates high then the amount of hydrogen input to the unit will be to low to meet the requirements of the hydrogenation of the olefins.

2. Feed is cooled by the Product

The Feed-Effluent exchanger recovers heat from the fresh feed into the product from the unit to reduce the required heat input to downstream storage. The fresh feed cools through the heat exchanger and the product form the unit is heated.

3. The Recycle Stream Joins the Feed

The feed is joined by a recycle stream between the feed-effluent exchanger and the feed cooler. A recycle stream is used to improve the superficial velocity of the charge through the reactor. The additional flow also helps to dissolve the hydrogen gas in the stream entering the reactor. The recycle is a pumped stream taken from the outlet of the reactor. The flow of the recycle stream is controlled upstream of its junction with the fresh feed by a total flow controller located down stream of the feed cooler.

4. Feed Temperature Control

A water cooled heat exchanger is used to cool the combined recycle and feed to the target charge temperature. This is accomplished by splitting the feed through and around the water cooled exchanger. Split range control directs more of the combined feed and recycle through the water cooler if the temperature is too high, and allows more to bypass the exchanger if it is too low. The temperature sensing point is located sufficiently downstream of the feed cooler to allow the feed to properly mix before the temperature is measured.

5. Control of Liquid Flow to the Reactor

As mentioned previously, the total flow of feed and recycle is controlled using a sensing point downstream of the feed cooler. The fresh feed enters the unit on flow control and the recycle flow is adjusted to maintain the proper space velocity to the reactor.

6. Makeup Hydrogen control

Make up hydrogen is brought into the unit on flow control. The flow of hydrogen is reset by a ratio controller that sets the makeup hydrogen flow to a multiple of the fresh feed flow. The ratio controller should provide some stability for small variations in fresh charge flow. The ratio controller receives a signal from the fresh feed controller and calculates a set point for the makeup hydrogen controller.

7. Mixed Hydrogen and Liquid Charge to the Reactors

The hydrogen enters the combined liquid charge and recycle stream in a mixing nozzle. The mixed stream passes through a static mixer to promote dissolution of the makeup hydrogen into the liquid charge stream. At the inlet to the reactor some of the hydrogen gas may not be fully dissolved.

Two reactors are provided. Normally both reactors are operated in series with the one regenerated last in the second position. Using two reactors in series allows the process to perform at lower temperature and make up hydrogen flow than if only one reactor is in operation. When the lead reactor is at its end of useful life then it is taken off line for regeneration. A freshly regenerated reactor is placed back on line in the second position using the piping manifold around the reactors. A sample point with appropriate piping is provided at the outlet of the reactors.

8. Reactor Pressure Control

A pressure controller and control valve is provided at the outlet of the reactor to maintain the pressure of the unit. The pressure of the reactors should be maximized consistent with the pressure available from the feed pump and make up hydrogen supply.

4.6 FMEA Methodology

Process FMEA is applied to eliminate or minimize all possible causes that have impact to the existing production. Process FMEA Table will be used in documentation and facilitating the FMEA process for tracking and identification purpose. A number is assigned in the header of process FMEA worksheet. The FMEA concept is team approach, so the FMEA team must be cross-functional and they must be willing to contribute to the procedure. To apply FMEA technique to address the problem in the research point process of the case company, the FMEA team is formed to analyze the potential causes of failure.

The FMEA team members will have various responsibilities. The FMEA team brainstorms to determine all potential causes of failure for each process step that could potentially lead to the problem. To organize brainstorming, cause and effect diagram known fishbone diagram will be used. Current process control and recommended corrective action for each assumption need to be filled in process FMEA worksheet. It is important to make an assignment of responsibility and the completion date to the appropriate members.

In addition, FMEA team is expected to decide severity, occurrence and detection ranking for evaluation criteria and ranking. The Risk Priority Number (RPN) which is the degree of risk of each failure is represented by the product of these three ranked indices. RPN value should be used to rank the concerns in the process. Special concentration should be given for higher RPN because this means that the FMEA team needs to find preventive and/or corrective action to reduce this higher risk.

The leader of FMEA team implements corrective action to reduce the high risk failure modes according to its priority from the RPN. FMEA is a living document and never ends because new potential causes and corrective actions are updated on new FMEA revisions as the research goes on. Once the actions have been implemented, it is required for the team to continue documenting the FMEA actions for an evaluation of effectiveness as part of the FMEA documentation. Severity, Occurrence and Detection are re-assessed after these actions have been taken and revised RPN is reviewed to determine whether further actions are required. Once the FMEA team has a consensus that the FMEA does not require any changes then the FMEA files will be kept in a folder for documentation and history tracking purposes. It is important to update the FMEA as the design or process changes so that the assessment changes or new information becomes known.

4.6.1 Data sources and collection

Investigation of any failure should start as soon as possible because the quality and quantity of the evidence begin to decline immediately after the incident. Data quality is the most important to the success of this process. High quality of data would help investigation in term of cause elimination. Data should be collected as soon as an incident occurred and also throughout the investigation process.

There are several sources of data to be utilized such as incident report history, operation log book, process trend, physical evidence, procedure, field walk around, equipment status history, interviews, tests, complaint information and expert advice. Any checklist related to the incident shall also consider, for examples: Alarm Checklist, PSV Checklist, Reading Sheets, etc.

The data required for using FMEA in this research includes historical data from January to December 2009.

4.6.2 Current practice Analysis

As already mentioned in chapter 3, these were the existing practices known to the case company participants.

- **Operating and Maintenance Procedures:** The licensors are responsible for writing these procedures, but they usually use vendor package information which is written with some knowledge of the end use of the package and so have many generalizations. The Operations and Maintenance Supervisors must edit these draft procedures and make them suitable for operator work. Their initial use is as training information, and therefore must be completed well before commissioning. In addition they must be eventually translated into Thai language.

- **Operator Training:** The case company provides operator 'on-the-job training before and after plant start up. This requires the new operator to have a 'buddy' until the Supervisor is comfortable with the new operator's performance by verbal examination. The training includes fire response and First Aid training. The employees who will operate this new plant will be given thorough classroom training and spend some months in existing operations before commissioning begins.

- **Permit to Work:** The plant has a rigorous permit system that requires the Shift Manager to sign hot work permits following the explosive test and ensure gas tests are done for confined space entry.

- **Safe Work Practices:** The case company has comprehensive Safe Work Practices. These are the guides to every day work by operators and maintenance people to ensure that no uncontrolled loss of containment occurs due to manpower error. These procedures are in place ready for this new project. These are clearly effective, as the existing plant has worked 5 million man-hours without a lost time injury.

- **LO/LC:** The P&IDs show that block valves around PSVs to be LO or LC and a few inlets to the flare header.

- **Maintenance:** There is a preventive maintenance system in place. This management system identifies the schedule for servicing machinery, testing interlocks, for repainting equipment, and turnaround planning. There is an acceptance that some breakdown maintenance will be required.

4.6.3 FMEA procedure

The process of conducting a failure mode and effects analysis (FMEA) is systematic. There are ten steps to follow:

Step 1: Define the FMEA boundaries and scope of FMEA including a description of the process under review.

Step 2: Assemble the FMEA team consisting of a multidisciplinary group of people. Team members should include a subject matter expert, a leader and a facilitator who understand the FMEA process.

Step 3: Review the process by using a detailed flowchart of the process or using process flow diagram (PFD).

Step 4: Brainstorm to determine failure modes for each process step including a review related to categories such as people, methods, equipment, materials, and the environment of the process.

Step 5: Identify the potential causes of each failure modes at the point provides some insight into probability.

Step 6: Identify the potential effects of each of the failure modes in terms of their impact on the performance of the product or process.

Step 7: Assess each of the failure modes in terms of the combined severity, occurrence and ability to detect the failure.

Step 8: Develop and prioritize strategies and action to reduce risk associated with the most significant failure modes.

Step 9: Assign responsibility for implementing corrective actions and take action to eliminate or reduce the high-risk failure modes.

Step 10: Monitor to evaluate if the risk reduction strategies have reduced risk.

4.6.4 Process Boundary Definition

The scope of FMEA will need to be clearly defined to all the team members. FMEA boundaries include a description of the process under review. The scope of FMEA will focus on the process from ORP as explained in details earlier. In this research, the process boundary, as shown in Figure 4.1, is the ORP unit. The process starts from incoming two sources of feed and ends at the treated product.

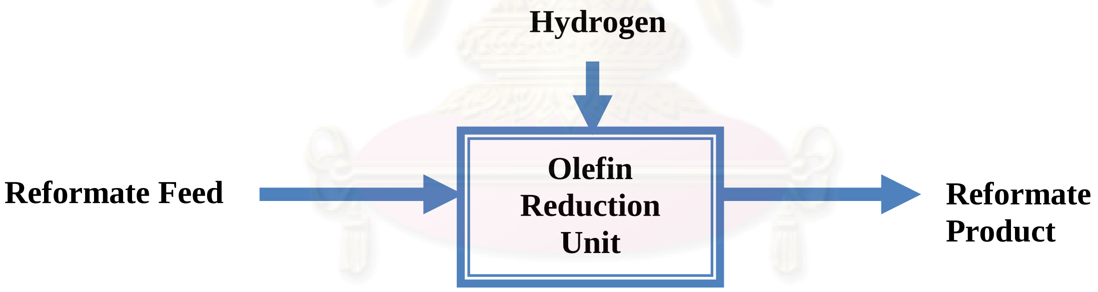


Figure 4.8 Process Boundary of ORP

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

4.6.5 Working Team

Failure Mode and Effects Analysis (FMEA) is a team function and cannot be done on an individual basis. The composition of the FMEA team is cross-functional and multi-disciplined for each study. The knowledge that is required for a specific problem is often unique to that problem and may require personnel from other specialized departments as well.

A working Team is formed in order to develop and conduct risk analysis of selected unit for prototype model. A team comprises of many people from different related departments such as Process Technology Department, Production Department, Reliability Engineering Department and Maintenance Department. The following representatives should be participated such as Process Engineers, Operation Specialists, Mechanical Engineers, Electrical Engineers and Instrument Engineers. A team will have a monthly meeting to ensure all problems and initiatives will be discussed to come up with appropriate action plans. In addition, to get the best practice and solution, the team might comprise the plant superintendent (staff member responsible for all plant performance), the plant engineer, a suitable representative of the technical support departments, a supervisor or foreman and possibly an operator or a tradesperson or both.

The risk analysis using process FMEA is a systematic evaluation performed to identify causes that could result in undesirable consequences. To be effective, the team must involve the members who will be responsible for EFD input and development. The team needs to be multi-disciplined with sufficient authority to make on-the-spot decisions when appropriate. The expertise of the team, within their own disciplines, is fundamental to the success of the research.

The FMEA team should be a catalyst to stimulate ideas between the design engineer, operations manager, maintenance manager, and a representative of the maintenance personnel (technician). The team members should have a thorough understanding of the systems operations and the mission's requirements. A team leader should be selected that has FMEA experience. If the leader does not have experience, then a FMEA facilitator should be sought.

Investigation team member shall be anyone whom involved or witnessed to an incident. They shall fully participate, cooperate and contribute team to determine the facts and root causes in the investigation process and also come up with corrective actions. They also help team identify risk assessment of all corrective actions.

The team member has role and responsibility as the following;

- Specific Process Area Team

  A primary function is to coordinate FMEA process with specific Plant/Process Area. The team shall consist of Operations Specialist, Maintenance, Process Engineer, Area Inspector, Rotating Engineer and Reliability Focal Point.

  - Develop and review FMEA Plans.
  - Convene meeting to discuss progress on initiatives at agreed time interval.
  - Discuss and identify developing issues which may require attention.
  - Identify areas of required improvement.
  - Establish a clear definition of the problem.
  - Determine priorities for initiatives.
  - Determine where ad hoc (rapid deployment) teams and Task Force Teams are required to address a specific problem or bad actor.
  - Develop and issue minutes of meeting to member and Team Sponsor.
  - Produce report on progress/status of FMEA initiatives at agreed interval.

- Task Force Team

  A primary function is to develop corrective action plan to a specific problem or area of unreliability. Team shall contain multi-disciplinary persons with experience/ knowledge in the problem being address.

  - Participate.
  - Contribute knowledge and experience.
  - Be open-minded for discussion, negotiation and compromise.
  - Share adequate information with colleagues.
  - Define problem within unit or area boundaries.
  - Define required results/develop/deliverables to be produced.
  - Identify root cause of problem, utilizing all information available.
  - Determine if additional information is required.
  - Develop corrective action plan.

- Issue plans to core team or team sponsor (if not initiated by Core Team) for review and approval for implementation.
- Review progress. Measure improvement.
- Issue close out report to core team.
- Participate actively in the meetings
- Prepared for the meetings, completely scheduled activities/responsibilities.
- Supplies information as identified by the team/action plan.
- Follows up on action plan items as identified by the Team/action plan.
- Take minutes of meeting when requested.

It is helpful also to have members in the team who have different levels of familiarity with the product or process. Those who are most familiar with it will have valuable insights, but may overlook some of the most obvious potential problems. Those who are less familiar with the process or product will bring unbiased, objective ideas into the FMEA process. Be aware that those with an emotional investment in the process or product may be overly sensitive during the critiquing process and may become defensive. Deciding whether to include these emotionally invested people on the team must involve weighing the disadvantages against the advantages that their experience and knowledge will bring to the process.

4.6.6 Failure mode Identification

Potential Failure Mode is defined as the manner in which the process could potentially fail to meet the process requirements and/or design intent as described in the Process Function/Requirements column. It is a description of the nonconformance at that specific operation. It can be a cause associated with a potential failure mode in a subsequent (downstream) operation or an effect associated with a potential failure in a previous (upstream) operation. However, in preparation of the FMEA, the assumption may be made that the incoming stream are correct.

Normally, there are four types of Failure Modes which always occur. The first and second types apply often and are the most commonly seen, and the third and fourth types are typically missed when performing the FMEA.

1. No Function: Process operation is totally non-functional or inoperative.

2. Partial/Over Function/Degraded Over Time: Degraded performance meets some of the specifications or some combination of the specifications but does not fully comply with all attributes or characteristics. This category includes over function. A degraded function over time is not generally a Failure Mode type in a PFMEA.

3. Intermittent Function: Complies but loses some functionality or becomes inoperative often due to external impacts such as temperature, pressure and environmental. This Failure Mode provides the condition of: on, suddenly off, recovered to on again function or starts/stops/starts again series of events.

4. Unintended Function: This means that the interaction of several elements whose independent performance is correct, adversely impacts the product or process. This will result in an unwanted outcome or consequence by the product, and hence the expression "unintended function". This type of failure mode is not common in process FMEA.

Each Failure Mode must have an associated function. A good check to discover “hidden” functions is to match all possible failures with the appropriate functions. A failure mode at one operation can be an effect of the failure mode in upstream or downstream operation. The FMEA team must list each potential Failure Mode for the particular operation in terms of a component, subsystem, system, or process characteristic. The assumption is made that the failure could occur, but may not necessarily occur.

In the case company, the failure mode will use in the scope after the meeting by using failure reference from many sources provided in Appendix as the following issues;

Process 1: Reformate to Reactor Inlet

Parameter: Flow

Parameter: Temperature

Parameter: Pressure

Process 2: Reactor Operation and Reactor Effluent

Parameter: Flow

Parameter: Temperature

Parameter: Pressure

Process 3: General Issues

Parameter: Operations

Parameter: Instrumentation

Parameter: Services/Utilities

Parameter: Operating Procedure

The process parameters were applied to each process of the system to generate failure modes from the normal operation. The first considered was “General Issues” and this allowed extensive coverage of the hazard, reliability and safe work practices associated with the existing plant. The general issues are the overall factors showing the possible risks that can happen to the selected unit. The “Possible Cause” and “Potential Consequence” scenarios were then discussed and documented into FMEA worksheets. A cause needed to be one that would occur within the process being considered. In contrast, the consequences were global taking into account what happens to upstream and downstream of the process and even outside of the FMEA scope.

The "Current Controls" that reduce the risk associated with the specific cause/consequence scenarios were then discussed and also documented. Indicators whether field mounted or part of the DCS were not considered as protection systems but alarms were. Much reliance is placed upon malfunction alarms triggered by transmitter failure.

4.6.7 Cause and Effect Analysis

FMEA team members will brainstorm all potential causes of failure for each process step of the production unit that affect to the incident. This process will be facilitated by using process flow diagram of the selected unit. Team members come to the brainstorming meeting with a list of their ideas. In addition to the ideas members bring to the meeting, others will be generated as a result of the synergy of the group process.

Cause and Effect diagram technique will be used to categorize the team's ideas. The ideas would be classified into 5 categories of cause and effect diagram which are material, man, measurement, method and machine. The information from this analysis will be used to fill in the columns of the process FMEA Table in relationship to the potential effects of failure and current process control. Recommended actions need to be filled in process FMEA Table. Responsibility and Target Completion Date is also important when assigning to appropriate team member.

All decision making activities shall be supported by fact only. All perceived reliability issues shall be supported by documentation, data and statistics. This documentation can be in the form of incident reports, non-conformance reports, bad actor reports and maintenance index. It is requested that each of the team members provide necessary information to support the FMEA.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

The information shall be used for Pareto analysis, objective setting and brainstorming activities. Supporting information shall be provided by industry benchmarking companies such as Solomon Associates Inc.

4.6.8 List Potential Effects for Each Failure Mode

With the failure modes or risks listed on the FMEA Worksheet, the FMEA team reviews each failure mode and identifies the potential effects of the failure should it occur. For some of the failure modes, there may be only one effect, while for other modes there may be several effects.

This step must be thorough because this information will feed into the assignment of risk rankings for each of the failures. For a Process FMEA, downstream users can include an operation or a service (dealer) operation. Place all effects for the Failure Mode being analyzed in one field or box. Each must be considered when assessing the potential effect of a failure. Identify the consequences of each Failure Mode for:

- Operator safety
- Upstream users
- Downstream users
- Machines/equipment

The risks that have been identified are discussed among the team on why it should be a risk and what the causes and effects of the risks are. The failure modes or risks that were identified will be explained individually to gain better picture of each of them. By doing so, the score of FMEA rating will be more effective. The following items are the conclusion from failure mode identifying and possible causes from the team meeting. The cause check list will see in Appendix.

<u>Process 1</u>: Reformate to Reactor Inlet

1.1 Failure Mode: No Flow of Reformate

Potential Causes:

- 1.1.1 FV2 closes due to loss of instrument air or mechanical failure
- 1.1.2 FIC2 malfunctions
- 1.1.3 LIC8 malfunctions at the debutanizer bottom in unit 2200
- 1.1.4 Debutanizer bottoms pump trips
- 1.1.5 TIC2 malfunctions and shuts both control valves
- 1.1.6 Operator closes block valves around the control valve FIC2 in error

1.2 Failure Mode: No Flow of Hydrogen

Potential Causes:

- 1.2.1 FV 4 fails closed due to loss of instrument air or malfunctions
- 1.2.2 FIC 4 malfunctions
- 1.2.3 FY 2 malfunctions
- 1.2.4 Block valve around FIC 4 closes
- 1.2.5 Check valve downstream of FIC 4 jams close or is installed back to front

1.3 Failure Mode: Higher Temperature

Potential Causes:

- 1.3.1 TIC2 malfunctions and causes exchanger bypass to open
- 1.3.2 Loss of cooling water flow through E2

1.4 Failure Mode: Lower Temperature

Potential Causes:

- 1.4.1 TIC2 malfunctions and causes exchanger bypass to close

1.5 Failure Mode: Higher Pressure

Potential Causes:

1.5.1 Fire outside heat exchanger E1 or E2

1.5.2 TIC2 malfunctions and shuts both control valves

1.6 Failure Mode: Higher Pressure (H2 Line)

Potential Causes:

1.6.1 FIC 4 malfunctions or bypass opens

1.7 Failure Mode: Lower Pressure

Potential Causes:

1.7.1 Pin hole leak in E1A/B/C

1.7.2 Tube fracture in E1A/B/C

1.7.3 Pin hole leak in cooling heat exchanger E2 and tube fracture in E2

Process 2: Reactor Operation and Reactor Effluent

2.1 Failure Mode: No Flow

Potential Causes:

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

2.1.1 Incorrect spectacle blinds position and block valve open

2.2 Failure Mode: Higher Temperature

Potential Causes:

2.2.1 Bypass around E1A/B/C is closed at end of run condition where reactor effluent 110 ºC will heat debutanizer feed to <110 deg ºC

2.3 Failure Mode: Lower Temperature

Potential Causes:

2.3.1 TIC2 malfunctions and causes exchanger bypass to close

2.4 Failure Mode: Higher Pressure

Potential Causes:

2.4.1 PIC 1 malfunctions or PV 1 fails closed due to loss of instrument air or mechanical failure

2.5 Failure Mode: Lower Pressure

Potential Causes:

2.5.1 PIC 1 stuck opened or bypass opens in error

Process 3: General Issues (overall factors)

3.1 Failure Mode: Operation

Potential Causes:

3.1.1 Misdirected flow due to incorrectly opened valve(s)

3.2 Failure Mode: Instrumentation

Potential Causes:

3.2.1 Check valve on instrumentation take off at flare header is plugged.

3.2.2 Instrument vent check valve in incorrect position

3.2.3 Valve mechanical malfunction

3.2.4 Control loop malfunction

3.2.5 Fin fan vibration

3.2.6 Fin fan motor trips

3.3 Failure Mode: Services / Utilities

Potential Causes:

3.3.1 Pump trips on electrical overload when handling maximum demand

3.4 Failure Mode: Operating Procedure

Potential Causes:

3.4.1 Incorrect operating practices

4.6.9 Assigning Severity, Occurrence, and Detection Rankings

Each of these three rankings is based on a 5 or 10-point scale, with 1 being the lowest ranking and 5 or 10 the highest. It is important to establish clear and concise descriptions for the points on each of the scales, so that all team members have the same understanding of the rankings. The scales should be established before the team begins the ranking process.

Since the case study company has their own evaluation criteria about the score of severity, occurrence from Risk Assessment Matrix (RAM) as this greatly assisted the team in knowing when to make a recommendation (action item) and then helping in prioritize actions later. The author will use those criteria in rating the score in order to prevent the confusion when implement this FMEA process to the case study company at the first time. For the score of detection, it is designated from the team agreement in the meeting which will relate with rating scale of severity and occurrence.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Table 4.1 Risk Assessment Matrix from the case company

Impacts or Consequences							Likelihood				
						Technical	0.01%	0.1%	1%	10%	100%
						Non-Tech.	1 Improbable	2 Unlikely	3 Possible	4 Likely	5 High
Severity	Safety and Health	Asset or Financial Loss	Environmental Impact	Reputation	Customer	Staff's Morale	Never heard in R&P industry / Very hard to occur next year	Has occurred in R&P industry / Unlikely to occur next year	Has occurred in R&P in last ten years / Possible to occur next year	Has occurred in R&P in last five years / Likely to occur next year	Has occurred in PTTAR / Anticipate to occur next year
1	First aid, medical treatment	Value <10K USD	Slight environmental effect within fence (local)	No public awareness	Minimal impact to customers	Minimal impact to staff's morale	L	L	L	ML	M
2	Occupational Illness RWC/LTI <20 days	Value up to 100K USD	Minor environmental effect/Large contamination	Local public awareness	Verbal complaints	Short-term impact, less than 3 months	L	L	ML	M	M
3	LTI >20 days	Value up to 1M USD	Significant release outside fence	Limited nation public	Official letter complaint/ Supply interruption	Long-term impact. More than 3 months	L	ML	M	M	H
4	Partial Disability	Value up to 10M USD	Severe environmental Damage Major emission	Widely national public awareness	Purchase less or turn to other supplier	Protesters rally or official complaint	ML	M	M	H	E
5	Total disability / Death	Value >10M USD	Massive effect to large area	International public awareness	Stop purchase	Employees strike	M	M	H	E	E

From this risk matrix, it needs to be changed and applied to use with criteria ranking. RPN to be used in this thesis is calculated by the multiplication of S (severity), O (occurrence), D (detection) using scaled 1-5 for each factor. Therefore the highest possible risk of each failure mode is 125 and the lowest is 1. The criteria of ranking the scale for severity, occurrence and detection are described in Table 4.2, Table 4.3, and Table 4.4 respectively.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Table 4.2 Ranking scale for severity of potential failure mode

Process FMEA Severity		
Severity Rating	**Severity**	**Comment**
1	Very low	Minimal equipment damage with negligible plant Downtime, Value < 10K USD
2	Low	Some equipment damage with possible Downtime, Value up to 100K USD
3	Moderate	Some equipment damage and Downtime within 1 week, Value up to 1M USD
4	High	Major damage to equipment and Downtime within 30 days, Value up to 10M USD
5	Very high	Downtime in access of > 30 days, Value > 10M USD

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Table 4.3 Ranking scale for probability and frequency of occurrence

Process FMEA Occurrence		
Occurrence Rating	**Occurrence**	**Comment**
1	Improbably	Never heard in R&P industry / Very hard to occur next year
2	Unlikely	Has occurred in R&P industry / Unlikely to occur next year
3	Possible	Has occurred in R&P in last ten years / Possible to occur next year
4	Likely	Has occurred in R&P in last five years / Likely to occur next year
5	High	Has occurred in the case company / Anticipate to occur next year

Table 4.4 Ranking scale for detection

Process FMEA Detection		
Detection Rating	**Detection**	**Comment**
1	Very High	The detection of the existence of a defect is almost a certainty
2	High	There are controls to detect defects, but there is a small chance of defects not being detected
3	Moderate	There is only a small chance of detecting an existing defect
4	Low	Controls in place will not generally detect the existence of a defect
5	Very Low	A defect will almost certainly escape detection

4.6.10 Risk Analysis using FMEA

The next step is to bring major failure modes and the potential causes as identified in cause-effect analysis or fish bone diagrams into FMEA worksheet. Some of the potential causes are filtered out because the working team concluded that the severity or occurrence of the potential effects and causes are not significant. The failure modes will be worked out in order of functions or processes that they are in. The level of severity, occurrence, and detection to each potential cause are rated to evaluate the risk priority number. The rating criteria of the severity, occurrence and detection are according to detail described in Table 4.2 – Table 4.4.

Current process controls that prevent the causes of each failure mode must be identified in column G of the FMEA worksheet. The detection rating is evaluated according to the rating as described in Table 4.4, whether the current process control are effective in preventing the process from each failure mode.

The significant high RPN will be taken into consideration for further solution and improvement in the next preventive plans. The significant high RPN is any values that are larger than the acceptable RPN. The acceptable RPN is determined by multiplying the case company acceptable rating criteria of the severity, occurrence and detection, therefore any values that are larger than the acceptable value will be consider as high RPN. This is the first consideration criteria for the case company to screen the key potential failure modes. The FMEA team agrees to pursue failures on RPN value > 18 based on maximum score for the RPN is 125 (5*5*5 from severity, occurrence and detection). In addition, RPN score at 18 come from acceptable level of severity at 2, occurrence at 3 and detection at 3. It means that the RPN of failure that has higher score than 18 must be addressed and taken into consideration to find solution and improvement.

The acceptable RPN works out as follows:

2(S) x 3(O) x 3(D) = 18

Therefore any potential causes that have RPN of 18 and above will be taken into consideration for further solution and improvement along with the system.

Recommended actions will be proposes to reduce or eliminate the risk associated with the failure mode. A high RPN needs the immediate attention since it indicates extreme negative effect addressed to its failure mode. The recommended actions include but should not be limited to the following; inspection, testing, monitoring, redesign, re-rating, preventative maintenance, etc. The recommended actions will be described in column J of the FMEA worksheet. The expected RPN indicates whether the countermeasures are effective in reducing risk. The re-assigned scores of RPN components are written in column M, N, O and P respectively. The PFMEA worksheets will be shown in Table 4.5.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Table 4.5 FMEA Work Sheet

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
1. 2450: Reformate to Reactor Inlet To cool down reformate to reactor inlet temperature (about 45 deg C) and properly mix the reformate with the H2 at 22 barg	1.1 No Flow	1.1.1.1. Loss of flow through the cooling system and into the reactor which causes loss of net flow forward from the unit and possible upset to the downstream unit	**2**	1.1.1 FV2 closes due to loss of instrument air or mechanical failure	**3**	1.1.1.1.1. Operator training and procedures 1.1.1.1.2. Reliable instrument air supply from 2 air compressors with 1 auto start turbine driven air compressor,and an air receiver with 10 mins hold up 1.1.1.1.3. Positioner alarm on FV 2 1.1.1.1.4. FIC 2 fitted with	**1**	**6**	323				

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

100

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						bypass							
		1.1.1.2. Olefin flow to the reactor is reduced,leading to excess H_2 with hydrogenation of aromatics, causing a very small net product loss from the complex leading to minor increase in outlet temperature of reactor	**2**		**3**	1.1.1.2.1. Ratio controller will close off H_2 flow 1.1.1.2.2. TIC 2 will maintain inlet temperature of reactor	**1**	**6**					
		1.1.1.3. Loss of production from CCR upstream	**2**		**3**	1.1.1.3.1. Flow indicator on DCS	**2**	**12**					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

101

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		1.1.1.4. Potential overpressure upstream of FV2	**2**		**3**	1.1.1.4.1. Piping design to withstand shut in pressure of the pump	**1**	**6**					
		1.1.1.5. Potential overpressure of pump seal and casing leading to loss of containment and fire if ignited	**2**		**3**	1.1.1.5.1. Double mechanical seal specified 1.1.1.5.2. Pumps designed to API 610 standards 1.1.1.5.3. Fire and gas detection	**1**	**6**					
		1.1.2.1 Loss of flow through the cooling system and into the	**2**	1.1.2 FIC2 malfunctions	**3**	1.1.2.1.1 TIC 2 will maintain inlet temperature of	**1**	**6**					

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		reactor which causes loss of net flow forward from the unit and possible upset to the downstream unit				reactor 1.1.2.1.2 Controller loop failure or transmitter failure sounds alarm in control room, and causes the controller to hold in the last position							
		1.1.2.2 Olefin flow to the reactor is reduced, leading to excess H2 with hydrogenation of aromatics, causing a very small net product loss from the complex leading	2		3	1.1.2.2.1. Ratio controller will close off H2 flow 1.1.2.2.2. TIC 2 will maintain inlet temperature of reactor	1	6					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

103

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		to minor increase in outlet temperature of reactor											
		1.1.2.3 Loss of production from CCR upstream	**2**		**3**	1.1.2.3.1 Flow indicator on DCS	**2**	**12**					
		1.1.2.4 Potential overpressure upstream of FV2	**2**		**3**	1.1.2.4.1. Piping design to withstand shut in pressure of the pump	**1**	**6**					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		1.1.2.5 Potential overpressure of pump seal and casing leading to loss of Containment and fire if ignited	**2**		**3**	1.1.2.5.1. Double mechanical seal specified 1.1.2.5.2. Pumps designed to API 610 standards 1.1.2.5.3. Fire and gas detection	**1**	**6**					

105

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		1.1.3.1 . Loss of flow through the cooling system and into the reactor which causes loss of net flow forward from the unit and possible upset to the downstream unit	2	1.1.3 LIC8 malfunctions at the debutanizer bottom in unit 2200	3	1.1.3.1.1 TIC 2 will maintain inlet temperature of reactor 1.1.3.1.2 Controller loop failure or transmitter failure sounds alarm in control room, and causes the controller to hold in the last position	1	6	Consider changing the cascade scheme such that LIC 8 will control the rundown of the reformate and FIC2 will be on straight flow Controller				

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

106

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		1.1.3.2 . Olefin flow to the reactor is reduced,leading to excess H2 with hydrogenation ofaromatics, causing a verysmall net product lossfrom the complex leadingto minor increase in outlet temperature of reactor	2		3	1.1.3.2.1. Ratio controller will close off H2 flow 1.1.3.2.2. TIC 2 will maintain inlet temperature of reactor	1	6					
		1.1.3.3. Loss of production from CCR upstream .	2		3	1.1.3.3.1 Flow indicator on DCS	2	12					
		1.1.3.4. Potential overpressure upstream of FV2	2		3	1.1.3.4.1. Piping design to withstand shut in	1	6					

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						pressure of the pump							
		1.1.3.5. Potential overpressure of pump seal and casing leading to loss of containment and fire if ignited	**2**		**3**	1.1.3.5.1. Double mechanical seal specified 1.1.3.5.2. Pumps designed to API 610 standards 1.1.3.5.3. Fire and gas detection	**1**	**6**					
		1.1.4.1. Loss of flow through the cooling system and into the reactor which causes loss of net flow forward from the unit and	**2**	1.1.4 Debutanizer bottoms pump trips	**2**	1.1.4.1.1 spare pump provided for reformate	**2**	**8**					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

108

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		possible upset to the downstream unit											
		1.1.4.2. Olefin flow to the reactor is reduced,leading to excess H2 with hydrogenation of aromatics, causing a very small net product loss from the complex leading to minor increase in outlet temperature of reactor	**2**		**2**		**2**	**8**					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

109

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		1.1.4.3.Loss of production from CCR upstream	**2**		**2**		**2**	**8**					
		1.1.4.4. Potential overpressure of pump seal and casing leading to loss of ontainment and fire if ignited	**2**		**3**	1.1.4.4.1. Double mechanical seal specified 1.1.4.4.2. Pumps designed to API 610 standards 1.1.4.4.3. Fire and gas detection	**1**	**6**					
		1.1.5.1. Lost of flow through the cooling system and into the reactor which causes loss of net flow forward	**2**	1.1.5 TIC2 malfunctions and shuts both control valves	**3**	1.1.5.1.1 Controller loop failure or transmitter failure sounds alarm in control room,	**2**	**12**					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

110

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		from the unit and possible upset to the downstream unit				and causes the ontroller to hold in the last position 1.1.5.1.2. FIC4 controls hydrogen ratio and FY2 will stop hydrogen flow 1.1.5.1.3 .TAH on TI 11 to TI 16 in reactors							
		1.1.5.2. Olefin flow to the reactor is reduced,leading to excess H2 with hydrogenation of aromatics, causing a very small net product loss from the complex leading to minor increase in outlet temperature of reactor	**2**		**3**		**2**	**12**					

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		1.1.5.3. Loss of production from CCR upstream	**2**		**3**		**2**	**12**					
		1.1.5.4. Potential overpressure of pump seal and casing leading to loss of containment and fire if ignited	**2**		**3**		**2**	**12**					
		1.1.5.5. Upstream piping will see potential overpressure from debutanizer pump or a recycle pump	**2**		**3**	1.1.5.5.1. Piping is designed for pump shut off head	**2**	**12**					
		1.1.5.6 .Loss of complete flow to the reactor	**2**		**3**	1.1.5.6.1. TAH on TI 11 to TI 16 in reactors	**2**	**12**					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		leading to excess H_2 accumulation in reactor with excess saturation material in reactor due to excess residence time,leading to slight increase in reactor temperature				1.1.5.6.2. FIC 4 controls hydrogen ratio and FY 2 will stop hydrogen flow							
		1.1.5.7. Possible H_2 blowby to downstream units	2		3	1.1.5.7.1.TAH on TI 11 to 16 in reactors 1.1.5.7.2. FIC 4 controls hydrogen ratio and FY 2 will stop hydrogen flow 1.1.5.7.3. H_2 will be released safely through the Tatoray stripper	1	6					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

113

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						overhead							
		1.1.5.8. Possible H2 blowby in upstream units, with possible H2 release to reformate tankage,causing the floating roof to sink	**2**		**2**	1.1.5.8.1. Install a check valve between battery limit double block valves from unit 2200	**2**	**8**					
		1.1.5.9. Loss of flow through recycle pumps with ossible damage to pump	**2**		**2**	1.1.5.9.1 Relatively lowhead and spare pumps provided	**2**	**8**					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		1.1.5.10. Possible reverse flow from recycle pump ischarge at 43 barg back to debutanizer through minimum flow return line	**2**		**2**	1.1.5.10.1 Debutanizer bottom pump system has check valve	**2**	**8**					
		1.1.6.1. Loss of flow through the cooling system and into the reactor which causes loss of net flow forward from the unit and possible upset to the downstream unit	**2**	1.1.6 Operator closes block valves around the control valve FIC2 in error	**2**	1.1.6.1.1 Operator training and procedures	**2**	**8**					

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		1.1.6.2 . Olefin flow to the reactor is reduced,leading to excess H2 with hydrogenation of aromatics, causing a very small net product loss from the complex leading to minor increase in outlet temperature of reactor	**2**		**3**		**1**	**6**					
		1.1.6.3. Loss of production from CCR upstream.	**2**		**3**		**2**	**12**					
		1.1.6.4. Potential overpressure upstream of FV2	**2**		**3**		**1**	**6**					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

116

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		1.1.6.5. Potential overpressure of pump. seal and casing leading to loss of containment and fire if ignited	**2**		**3**		**1**	**6**					
	1.2 No Flow (H2)	1.2.1.1 Hydrogenation of olefins stops leading to partial poisoning of Parex adsorbent and yield loss	**2**	1.2.1 FV 4 fails closed due to loss of instrument air or malfunctions	**3**	1.2.1.1.1 FIC 4 indicates flow and bypass provided	**1**	**6**					
						1.2.1.1.2 Clay treating downstream							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

117

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						1.2.1.1.3 Reactor temperature indicators TI 11 to TI 16 indicate loss of reaction							
						1.2.1.1.4 Daily sampling							
		1.2.2.1 Hydrogenation of olefins stops leading to partial poisoning of Parex adsorbent and yield loss	2	1.2.2 FIC 4 malfunctions	3	1.2.2.1.1 Clay treating downstream	1	6					
						1.2.2.1.2 Reactor temperature indicators TI 11 to TI 16 indicate loss of reaction							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

118

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						1.2.2.1.3 Malfunction on FIC 4 sounds alarm							
		1.2.3.1 Hydrogenation of olefins stops leading to partial poisoning of Parex adsorbent and yield loss	2	1.2.3 FY 2 malfunctions	3	1.2.3.1.1 FIC 4 indicates flow and bypass	1	6					
						1.2.3.1.2 Clay treating downstream							
						1.2.3.1.3 Reactor temperature indicator TI 11 to TI 16 indicate loss of reaction							
						1.2.3.1.4 Daily sampling							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

119

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						1.2.3.1.5 Malfunction on FIC 4 sounds alarm							
		1.2.4.1 Hydrogenation of olefins stops leading to partial poisoning of Par exeadsorbent and yield loss	2	1.2.4 Block valve around FIC 4 closes	2	1.2.4.1.1 FIC 4 indicates flow and bypass provided	1	4					
						1.2.4.1.2 Reactor temperature indicators TI							
						1.2.4.1.3 Daily sampling							
						1.2.4.1.4 Malfunction on FIC 4 sounds alarm .							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

120

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						1.2.4.1.5 Operator training and procedures							
		1.2.5.1 Hydrogenation of olefins stops leading to partial poisoning of Parex adsorbent and yield loss	2	1.2.5 Check valve downstream of FIC 4 jams close or is installed back to front	2	1.2.5.1.1 FIC 4 indicates bypass provided	1	4					
						1.2.5.1.2 Clay treating downstream							
						1.2.5.1.3 Reactor temperature indicators TI 11 to TI 16 indicate loss of reaction							
						1.2.5.1.4 Daily sampling							
						1.2.5.1.5 Malfunction on FIC 4 sounds alarm.							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

121

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						1.2.5.1.6 Operator training and procedures.							
						1.2.5.1.7 Field P&ID review is specified as part of startup procedures which includes to verify the direction of every check valve in the process							
	1.3 Higher Temparatur e	1.3.1.1 Hydrogenation of aromatics with loss of hydrogenation of olefins i.e. loss of selectivity and loss of	**2**	1.3.1 TIC2 malfunctions and causes exchanger bypass to open	**3**	1.3.1.1.1 Daily product sample analysis	**1**	**6**					
						1.3.1.1.2 Malfunction on TIC2 sounds alarm							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

122

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		production				1.3.1.1.3 TI3 indicates higher temperature							
						1.3.1.1.4 Clay treating downstream and sulfolane unit extracts the byproducts							
						1.3.1.1.5 Parex will remove non aromatics							
		1.3.1.2 Minor poisoning of Parex unit	2		3	1.3.1.2.1 Daily product sample analysis	1	6	Configure TDAHL on TI3 with a difference from TIC2 set point of 5 deg C				
						1.3.1.2.2 Malfunction on TIC2 sounds alarm							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

123

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						1.3.1.2.3 TI3 indicates higher temperature							
		1.3.2.1 Hydrogenation of aromatics with loss of hydrogenation of olefins i.e. loss of selectivity and loss of production	2	1.3.2 Loss of cooling water flow through E2	3	1.3.2.1.1 Daily product sample analysis	1	6					
						1.3.2.1.2 Spare turbine driven CW pumps							
						1.3.2.1.3 Malfunction on TIC2 sounds alarm							
						1.3.2.1.4 Clay treating downstream and sulfolane unit extracts the byproducts							
						1.3.2.1.5 Parex will remove non aromatics							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
	1.4 Lower Temparatur e	1.4.1.1 Loss of hydrogenation of olefins and minor poisoning of Parex unit	2	1.4.1 TIC2 malfunctions and causes exchanger bypass to close	3	1.4.1.1.1 Daily product sample analysis	1	6					
						1.4.1.1.2 Malfunction on TIC2 sounds alarm							
						1.4.1.1.3 Clay treating downstream and sulfolane unit extracts the byproducts							
						1.4.1.1.4 Daily product sample analysis							
						1.4.1.1.5 Spare turbine driven CW pumps							
						1.4.1.1.6 Malfunction on TIC2 sounds alarm							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

125

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						1.4.1.1.7 TI3 indicates lower temperature							
		1.4.1.2 Gradual build up of H2 in reactor circuit with possibility of 2 phase flow in the reactor effluent and recycle system	2		3	1.4.1.2.1 Daily product sample analysis	1	6					
						1.4.1.2.2 Malfunction on TIC2 sounds alarm							
						1.4.1.2.3 TI3 indicates lower temperature							
						1.4.1.2.4 Downstream unit can tolerate some additional H2							
	1.5 Higher Pressure	1.5.1.1 Rupture of heat exchanger	3	1.5.1 Fire outside heat exchanger E1 or E2	1	1.5.1.1.1 PSV 301A/B	1	3					
						1.5.1.1.2 Firefighting system							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

126

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						1.5.1.1.3 Fire and gas detection							
		1.5.2.1 Upstream piping will see potential overpressure from debutanizer pump or a recycle pump	**2**	1.5.2 TIC2 malfunctions and shuts both control valves	**3**	1.5.2.1.1 Piping is designed for pump shut off head	**2**	**12**					
	1.6 Higher Pressure (H2 Line)	1.6.1.1 Excess of flow of H2 at 36 barg with potential to overpressure the reactor	**3**	1.6.1 FIC 4 malfunctions or bypass opens	**2**	1.6.1.1.1 Reactor is designed for 43 barg	**1**	**6**					
						1.6.1.1.2 PIC 1 controls unit pressure by allowing excess flow to the stripper							
						1.6.1.1.3 Malfunction on FIC 4 sounds alarm							

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						1.6.1.1.4 FIC 4 has limited capacity - 1							
	1.7 Lower Pressure	1.7.1.1 Some feed will bypass reactors and debutanizer bottoms will enter Tatoray unit stripper with no significant consequences	**1**	1.7.1 Pin hole leak in E1A/B/C	**2**		**3**	**6**					
		1.7.2.1 Hydrogenation of aromatics with loss of hydrogenation of olefins i.e. loss of selectivity and loss of production and	**2**	1.7.2 Tube fracture in E1A/B/C	**2**	1.7.2.1.1 Clay treating downstream and sulfolane unit extracts the by products	**1**	**4**					
						1.7.2.1.2 Parex will remove non aromatics							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		loss of production				1.7.2.1.3 Sampling of stripper column bottoms identified high bromine index							
						1.7.2.1.4 10/13ths rule							
						1.7.2.1.5 E1A/B/C is designed for 43 barg							
		1.7.2.2 Minor poisoning of Parex unit	2		2	1.7.2.2.1 Sampling of stripper column bottoms identified high bromine index	3	12					
		1.7.3.1 Reformate and trace H2 enters	2	1.7.3 Pin hole leak in cooling heat	2	1.7.3.1.1 Analyzer provided	1	4					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

129

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		cooling water system		exchanger E2 and tube fracture in E2		1.7.3.1.2 Gas detection at cooling water top distributor							
						1.7.3.1.3 Operator training and procedures to track down source of leak							
						1.7.3.1.4 10/13ths rule							
						1.7.3.1.5 E2 is designed for 34 barg							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

130

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
2 . 2450: Reactor Operation and Reactor Effluent (Not Regeneration) Intention: To pass make up H2, reformate and recycle making a total feed of 440 sm3/h through 2 reactors in series or a single reactor while the other is being regenerated and passing	2.1 No Flow	2.1.1.1 No reactor flow	2	2.1.1 Incorrect spectacle blinds position and block valve open	2	2.1.1.1.1 Drawing error	2	8	Amend P&ID to show correct position of spectacle blinds for reactor 1 followed by reactor 2 in series, and add a note to highlight various perating cases.				
		2.1.1.2 Recycle pump will have no flow and downstream system will reach shut off head of up to 43 barg, causing pump	2		2	2.1.1.2.1 Operator training and procedures	2	8	65				

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

131

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
the reactor effluent via feed preheating exchangers to the Tatoray stripper. About 2/3 of the reactor effluent is recycled		damage if it continues											
	2.2 Higher Temparature	2.2.1.1 Potential for reactor temperature to be greater than design inlet for run	1	2.2.1 Bypass around E1A/B/C is closed at end of run condition where reactor effluent t 110 deg C will heat debutanizer feed to <110 deg C	2	2.2.1.1.1 Cooler E2 and TIC will reduce reactor inlet temperature	2	4					
						2.2.1.1.2 Bypass around E1 A/B/C is provided to be opened at end of run condition							

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
	2.3 Lower Temparature	2.3.1.1 Loss of hydrogenation of olefins and minor poisoning of Parex unit	**3**	2.3.1 TIC2 malfunctions and causes exchanger bypass to close	**1**	2.3.1.1.1 Cooler E2 and TIC will reduce reactor inlet temperature	**1**	**3**					
						2.3.1.1.2 Bypass around E1 A/B/C is provided to be opened at end of run condition							
						2.3.1.1.3 Malfunction on TIC 2 alarm							
		2.3.1.2 Gradual build up of H2 in reactor circuit with	**2**		**1**	2.3.1.2.1 Cooler E2 and TIC will reduce reactor inlet temperature	**1**	**2**	Refer To 2450-R5				

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		possibility of 2 phase flow in the reactor effluent and recycle system				2.3.1.2.2 Bypass around E1 A/B/C is provided to be opened at end of run condition							
						2.3.1.2.3 Malfunction on TIC 2 alarm							
						2.3.1.2.4 Downstream unit can tolerate some additional H2							
	2.4 Higher Pressure	2.4.1.1 Equipment upstream of PIC1 will be exposed to	**2**	2.4.1 PIC 1 malfunctions or PV 1 fails closed due	**2**	2.4.1.1.1 Design pressure of equipment is 43 barg	**2**	**8**					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

134

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		shut off pressure of the debutanizer pump		to loss of instrument air or mechanical failure		2.4.1.1.2 H2 controller will stop importing H2through FIC 4							
		2.4.1.2 Equipment upstream of PIC1 could be exposed to net gas compressor discharge of 36 barg	**2**		**2**	2.4.1.2.1 System is designed for 43 barg	**2**	**8**	Review the pressure balance in the system to ensure that the recycle pump discharge pressure cannot go above 43barg				
		2.4.1.3 Possible upset to upstream and downstream units	**2**		**2**	2.4.1.3.1 Not known	**2**	**8**	Ensure upstream and downstream unit can withstand the no flow scenario				

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

135

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
	2.5 Lower Pressure	2.5.1.1 Reactors lose pressure reaching as low as 5 barg, loss of solubility of H2 and causing 2 phase flow in the reactor leading to yield loss.	2	2.5.1 PIC 1 stuck opened or bypass opens in error	2	2.5.1.1.1 Operator training and procedures for bypass	2	8					
						2.5.1.1.2 Potential for PDAH 8 to sound alarm							
						2.5.1.1.3 FIC 2 limits reformate and H2 flow to Tatoray unit							
						2.5.1.1.4 Bypass is provided to allow repair of faulty PIC							
		2.5.1.2 Slight 2 phase flow downstrea m of	2		2	2.5.1.2.1 Spare pump provided to allow repair of damaged pump	2	8					

136

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		reactor leading to cavitation in recycle pump due to gas				2.5.1.2.2 FIC 3 indicates lower flow if gas is present							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
3. General Issue	3.1 Operation	3.1.1.1 Potential contamination or injury	**2**	3.1. 1 Misdirected flow due to incorrectly opened valve(s)	**2**	3.1.1.1.1 LO and LC valves are identified and sealed by padlock with the key retained by the shift manager	**2**	**8**					
	3.2 Instrumentation error	3.2.1.1 Cannot be maintained without plant shutdown	**2**	3.2.1 Check valve on instrumentation take off at flare header is plugged.	**1**	3.2.1.1.1 Relocate block valve downstream of check valves,upstream of connection to flare header. See drawing 2450-101/102. This applies to the level instruments and Control	**2**	**4**					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

138

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						valve vents							
		3.2.2.1 Instrument vent will hold a head of liquid	2	3.2.2 Instrument vent check valve in incorrect position	2	3.2.2.1.1 Check valve shown on standard drawings 8-138, 8-139 and 8-140 should be free draining in both directions from check valves	2	8					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		3.2.3.1 Process not under control	**3**	3.2.3 Valve mechanical malfunction	**5**	3.2.3.1.1 None	**5**	**75**	Alarm sounds in the DCS alarm when valve positioner senses the valve is fully opened or fully closed or not responding properly. This applies to field bus system but not the hardwired ESD system				
		3.2.4.1 Process not under control	**2**	3.2.4 Control loop malfunction	**1**	3.2.4.1.1 Alarm soundsin the DCS alarm when signal input from the transmitter is outside the	**1**	**2**					

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						range of 4 - 20 mA.This applies to field bus system but not the hardwired ESD system							
						3.2.4.1.2 Alarm sounds in the DCS as a result of any general fault in the control loop and output is locked in position. This applies to field bus system but not the hardwired ESD system							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

141

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
						3.2.4.1.3 In the event of a malfunction, the valve output changes from auto to manual and holds the last position. This applies to field bus system but not the hardwired ESD system							
						3.2.4.1.4 If a control valve is not responding to the controller signal a positioner alarm sounds							

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommende d Actions	SEV	OCC	DET	RPN
						3.2.4.1.5 FIs part of a control loop have a transmitter and if this fails an alarm will sound.Single instruments not part of a control loop will not sound an alarm unless requested							
		3.2.5.1 Loss of cooling with potential for over pressure	**2**	3.2.5 Fin fan vibration	**2**	3.2.5.1.1 Each fin fan is fitted with a vibration switch that sends a signal to a common alarm	**2**	**8**	Need for PM Plan Need Patrol check				

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

143

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		3.2.6.1 Loss of cooling with potential for over pressure	**2**	3.2.6 Fin fan motor trips	**2**	3.2.6.1.1 a running status alarm to indicate when it is started and stopped	**2**	**8**					
	3.3 Loss of Services / Utilities	3.3.1.1 Process upset that can be extensive	**3**	3.3.1 Pump trips on electrical overload when handling maximum demand	**5**	3.3.1.1.1 None	**5**	**75**	1. Emergency Procedure 2. Management of Change				
		3.3.1.2 Spare pump may be started and also trip	**4**		**4**	3.3.1.2.1 None	**5**	**80**	Pump trip sounds alarm and running status light alerts the control operator that a pump has stopped or has been started				

144

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommende d Actions	SEV	OCC	DET	RPN
									Pumps can be started from the control room				
	3.4 Lack of Operating Procedure	3.4.1.1 Potential for loss of containment from bleeds and vents	**2**	3.4.1 Incorrect operating practices	**3**	3.4.1.1.1 P&IDs state that all vents and bleeds shall be capped or plugged or blank flanged	**2**	**12**	Establish checklists of items that need to be checked occasionally				
		3.4.1.2 Tank bund drain valves left open following rain	**3**		**3**	3.4.1.2.1 SOP will require bund drain valves to be closed when unattended	**1**	**9**	Refer To 2450-R54				
		3.4.1.2 Bypass valves around level control valves are left	**2**		**2**	3.4.1.2.1 A Standard Operating Procedures (SOP) will define the handling of	**3**	**12**	Ensure operating personnel review SOPs before training and commissioning				

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		unattended and gas blowby occurs to downstream units				control valve bypass valves			begins				
		3.4.1.3 Pressure gauges break off due to vibration or impact releasing hydrocarbons	**1**		**3**	3.4.1.3.1. None	**5**	**15**	Training of operators requires that the valve under a Pressure Indicator (PI) will only be cracked open				

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

According to the RPN ranking from Table 4.5, there are 3 sets of failures, effects and causes that have high RPN over acceptable level which are listed in Table 4.6.

Table 4.6 Summary of process FMEA that the RPN value is higher than 18

Item	Failure mode (Risk)	Causes of failure	S	O	D	RPN
1	3.2 Instrumentation error	3.2.3 Valve mechanical malfunction	3	5	5	75
2	3.3 Loss of Services / Utilities	3.3.1 Pump trips on electrical overload when handling maximum demand (process upset)	3	5	5	75
3	3.3 Loss of Services / Utilities	3.3.1 Pump trips on electrical overload when handling maximum demand (equipment failure)	4	4	5	80

From Summary of process FMEA that the RPN value is higher than 18, 3 items of high-risk area from 3 processes are addressed. Therefore, the FMEA team called the meeting to take proper actions to find the solutions for those failures. At last, the action plan is created for each related departments. In addition, items and standard contingency procedure of action plan are represented as the action to improve the failures and standard procedure generated to solve the problems respectively.

4.6.11 Critical risk evaluation

The failure modes or risks that were identified and analyzed using the PFMEA scoring system will be evaluated and allocated. The tool that will be used to separate these risks is the Pareto analysis. According to Pareto principle 20:80, this is based on the concept that about 20 percent of the causes account for 80 percent of the problems obtained in any process. This is the intensive screening for the case company to best select the critical risks.

In this case, the Pareto analysis will be applied to "80% of the total RPN score will be 20% of the number of failure modes" In order to do Pareto analysis, the following steps will have to be carried out.

1. Reorder the RPN of all risks from highest to lowest.
2. Calculate the total cumulative RPN of all risks.
3. Determine 80% of the total cumulative RPN.
4. Determine the specific total number of risk that means 80% against the total number of risks, which should meet 20%.
5. Determine the RPN score accumulating down of the risk that matches 80% of the total cumulative RPN (cross checking of 20%)
6. The risks that are within that 80% of the accumulative will be 20% of the total number of risks, and these risks will be the critical risks that needed to be managed.

This method of evaluating the sensitivity of the RPN of the risk, the critical risks can be determined and therefore can be managed accordingly. The Pareto analysis method might not be exactly 80% to 20% because the number of samples in this research might be too small. The actual number of the Pareto analysis might be an approximate of the actually theoretical 80-20 number but with a small-scale sample size, it is considered acceptable.

4.6.12 Pareto Analysis

The Pareto analysis of the risks will be carried out in this section. The calculation and the critical risks will be determined at the end of this section.

1. All the risks in every process reordered from the highest to the lowest of RPN
2. The cumulative RPN of all the failure modes is 771
3. 80% of the cumulative RPN (771) is approximately 617

4. The total number of failure mode is 16, so 20% of the total number of failure mode is 3.2

5. The accumulating score cross checking of both 80% and 20%:

a. At risk number 3, the accumulative RPN at that point is 230 (75+75+80)

b. 230/617 = 40% (< 80% theory)

From the calculation result, the vital few causes will be taken into account. The 20% of those 16 potential causes are the first 3 items (3.2) but 80% of score summary of these 3 items is only 40% which is less than 80% as theory. In this case, the team decided to set a cut-off RPN, where any failure modes with an RPN above that point require further attention. Any failure mode that has RPN above 18 creates an unacceptable risk. This decision sets the cutoff RPN at 18. By the way, the next items which have scored less than 18 will be obtained to further study FMEA by focusing mainly on the item that has no control system.

Table 4.7 Summary of critical risk (failure mode) from Pareto analysis

Item	Failure mode (Risk)	Causes of failure	S	O	D	RPN
1	3.2 Instrumentation error	3.2.3 Valve mechanical malfunction	3	5	5	75
2	3.3 Loss of Services / Utilities	3.3.1 Pump trips on electrical overload when handling maximum demand (process upset)	3	5	5	75
3	3.3 Loss of Services / Utilities	3.3.1 Pump trips on electrical overload when handling maximum demand (equipment failure)	4	4	5	80
4	3.4 Lack of Operating Procedure	3.4.1 Incorrect operating practices	1	3	5	15

According to acceptable RPN, all items from item 1 to item 3 have severity, occurrence and detection rating higher than acceptable rating in each ranking scale.

These critical risks will be brought to discuss among FMEA team in the meeting and then the RPN score will be recalculated for improvement. After that, the implementation will be applied.

4.6.13 Take action to eliminate or reduce the high-risk failure modes

In the meeting, the FMEA team discussed about the critical risks. The approach that the team decided to manage these risks is to break the critical risks down to the root cause and then solve it. To identify the root cause, the FMEA team decided to use a cause and effect diagram known as fishbone diagram. Fishbone diagram is a useful tool to find the root cause of the problem and an easy way to look at them. The FMEA team decided to break all the risks into these diagrams first so all of them can be prevented correctly and to the right source and right root cause.

Item 1: Instrumentation error

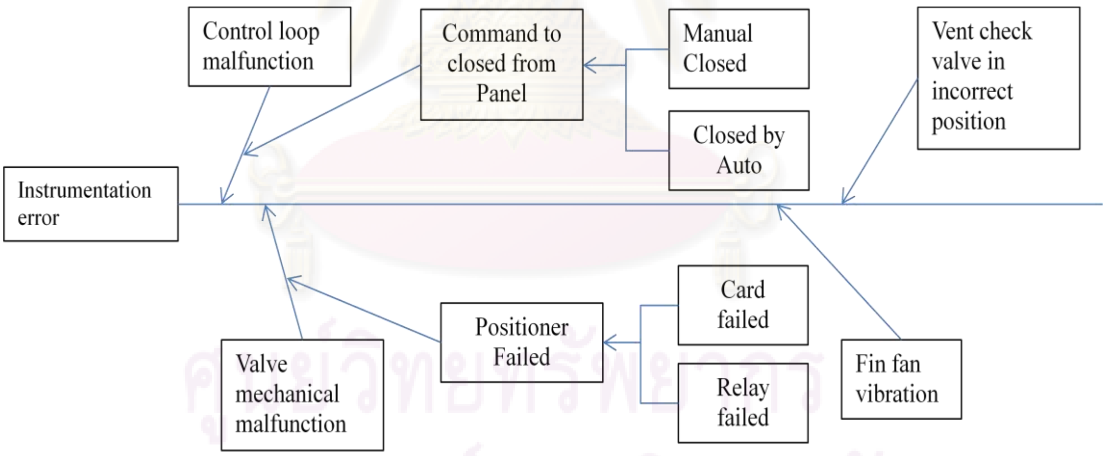


Figure 4.9 Fishbone diagram of item 1

There are four main causes to the risks item 1(Figure 4.9). The discussion about this risk has concluded that the risk would not occur if it is properly documented and properly controlled and supervised. The team has concluded that the preventive program such as Basic Equipment Care program and also controlling and monitoring program have to be reviewed and improved. Poor documentation is one of the causes that the FMEA team must concern.

Item 2-3: Loss of Services / Utilities

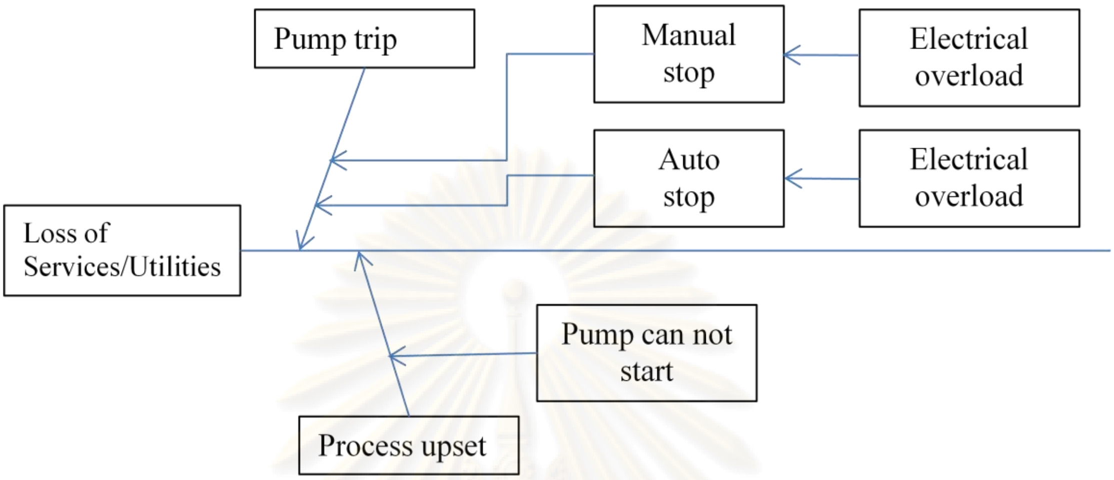


Figure 4.10 Fishbone diagram of item 2-3

This critical risk has 2 main causes which are process upset and equipment failure. The FMEA team agreed to manage this risk by using management system like work instruction or work procedure as preventive action plan. Another assistant is the alarm from Distributed Control System (DCS). This sound will alert panel operator to quick action in handling emergency case.

Item 4: Lack of Operating Procedure

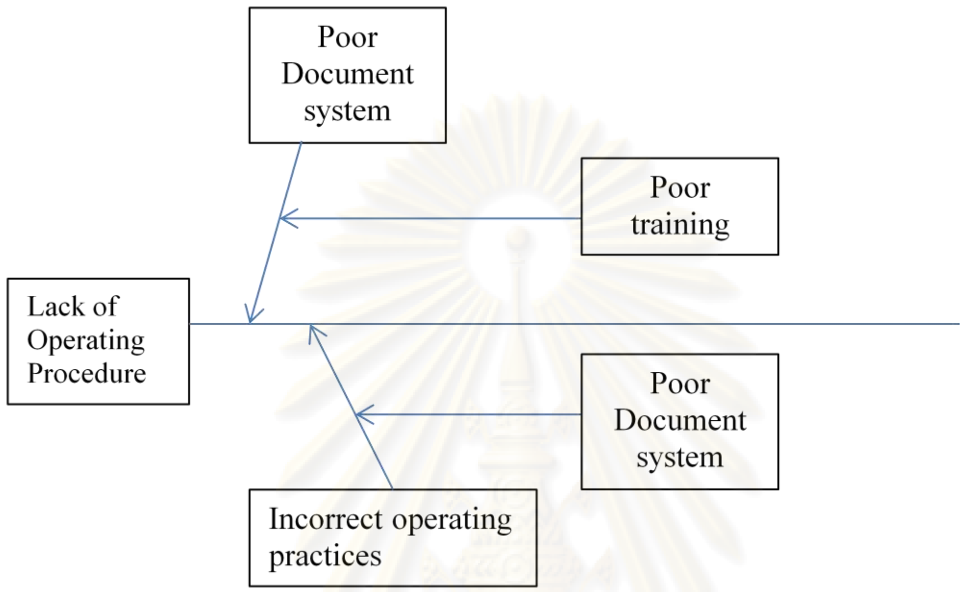


Figure 4.11 Fishbone diagram of item 4

This risk from the lack of operating procedure is one of the critical risks that the FMEA team pretty concerned. The FMEA team felt that this risk is the main root cause of other risks in the case company. To lower more RPN score, more effort to solve this problem is really needed to be taken good care.

In order to reduce the score, at least one of the severity, occurrence or detection will have to be changed. According to Table 4.6 and 4.7, SOD rating of each item from item 1 to item 3 has high rating score over the acceptable value. The detection rating of all causes is 5 which mean that the detection system is very low. Therefore, the FMEA team can have meeting to take proper actions to find the solutions for those failures. In order to achieve a lower ranking, generally the planned process control has to be improved. Increasing failure detection will simply make it easier to detect failures once they occur. There are two types of process controls to consider which are;

1. Prevention: Prevent the Cause or Failure Mode/Effect from occurring or reduce their rate of Occurrence.
2. Detection: Detect the Cause and lead to corrective actions.

The team discussed about process control and considered to manage the critical risk by using the preventive actions or preventive controls. The initial occurrence rankings will be affected by the prevention controls provided they are integrated as part of the process intent. The initial rankings for detection will be based on the process Detection controls that either detect the cause of failure or detect the failure mode. Once the process controls have been identified, review all preventive controls to determine if any occurrence rankings need to be revised.

From all the 4 cause of failure modes, the FMEA team has summarized and then prepares the preventive actions for them. The preventive actions are listed and explained as the following;

1. Review and improve the Operation of the "Basic Equipment Care" Program

This program allows process operators to undertake simple maintenance tasks. They are organized from inside the Production department and these non-routine jobs are being done without the benefit of the work procedure. To improve BEC, the purpose of BEC must be clarified and truly be understood to all production operators. The following objectives must let them know are

- To improve plant reliability by operation staff looking after their equipment
- To build up ownership of operation staff to taking cares their equipment.
- To reduce cost by operation staff perform BEC task, which is, reduce number of contractor.
- Operation staff will have multi skill to do both operation job and basic maintenance job.

To make BEC more efficient, it has been identified that the shift team under BEC currently performs BEC activities in the task list. It is recommended that for the tasks that currently being performed, structured refresher training shall be conducted. For new tasks, which are to be performed under BEC, a series of proper training modules per each task is to be developed. The training modules consist of a simplified predefined theory and knowledge required to perform the tasks. Competency is verified by assessing the job done against steps written in Task Analysis. Competency is verified on site. To develop skills for the Basic Equipment Care Tasks, the content of training required is drawn up through Task Analysis methodology. Training Supervisor / Supervisors of various Process Areas, together with the respective discipline Engineers and Technicians, will provide the resources for delivering the training.

A good system for requesting, distributing/tasking and recording of tasks under the Basic Equipment Care Activities done is necessary. It was defined that the existing SAP software was the most suitable system. Alternatively, the logging /recording in share drive are also used for certain tasks or activities. The current practice where any job was done by the plant operator is keyed into SAP and closed by immediate Supervisors.

Effecting SOD: Lower occurrence and detection (item 1, 3 and 4)

2. Provide Emergency Training and procedure to Process Operators.

The operation department has to set up a process emergency training exercise to each shift once per month. This program involves a review of the procedure and the field operators have checklist of the duties they have to perform. The emergency procedure provides the necessary step by step to operate process safely. The activities involved must be carefully co-coordinated to avoid damage to equipment and the production of excessive amounts of off spec. Material. The shut down procedure is provided to highlight the steps required for a complete shutdown. Since this unit is part of a larger integrated complex, other parts will be affected and may be shutting down at the same time.

An emergency condition may arise from a number of causes or combination of causes and its effect on the plant will depend on the situations prevailing at the time. Hence it is not possible to give hard and fast rules to cover every possible situation. For each unit within the complex a procedure is given for the complete shutdown of that unit in a crash shutdown situation. This procedure is followed when a major emergency prevails, requiring a complete shutdown of that unit including de-pressurization. The discussion on the crash shutdowns is followed by procedures, which cover the more common emergencies arising from utility or mechanical failure. These may make reference to the complete crash shutdown procedures for the affected unit(s), but the extent to which the complete crash shutdown procedure is followed or modified will depend both upon the original failure and the circumstances prevailing at the time. In general it is the intention to bring the unit to a sustainable condition, while the problems with that particular equipment are being resolved. The procedures provide a basic framework for dealing with any emergency and they must be known and understood by all members of the operating team.

In addition, the bullet point procedure is made for guideline for an emergency failure of equipments. The plant condition may arise from a number of causes or combination of cause and its effect on the plant will depend on the situations prevailing at the time. Hence it is not possible to give harm and fast rules to cover possible situation. This procedure is followed when the emergency is occurring and needs the fast reminding to activate the cause.

Effecting SOD: Lower severity and occurrence (item 1, 2, 3 and 4)

3. Bad Actor List Development

Bad Actor is individual of equipment which has incurred significant impact to the case company as per RAM due to failure to operate as per operational requirements, or other equipment that show multiple failures >2 times per year. This Work Instruction provides guidelines for the development of the Bad Actor list detailing the format for presentation, timing of submission and distribution list. It is intended that this Work Instruction ensure consistency of reports and continual maintenance of the Bad Actor List.

The output from this Work Instruction will be a list of equipment that have been identified as performing unreliable, Bad Actor, hence requiring detailed review and development of a corrective action plan. Bad Actor lists will be created: one list per production unit. Each bad actor list will be divided into four sections.

1. Static Equipment
2. Rotating Equipment
3. Instrumentation
4. Electrical Equipment

The list will only show the Top-Ten (10) bad actors in each equipment category. A detailed description of the reason for the equipment being established as a bad actor will also be incorporate in the list.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Table 4.8 Bad Actor List Standard Form (sample table)

No	Equip Tag	Mnt. Cost (US$)	LPO Cost (US$)	No of failures	Details	Action Required	Priority	Asset owner	Target
1.									
2.									
3.									

Effecting SOD: <u>Lower severity, occurrence and detection</u> (item 1, 2 and 3)

At last, the preventive actions are created for each related departments by focal point person of each discipline. In addition, items and standard procedure of action plan are represented as the action to improve the failures in Table 4.7 and standard procedure generated to solve the problems respectively.

For the corrective actions, among the FMEA team has discussion to do it as well. The recommendation for item 1 and 3 is to issue the Management of Change (MOC) by setting the alarm sounds in the DCS alarm when the valve positioner senses the valve is fully opened or fully closed or not responding properly for item 1 and pump trip sounds alarm and running status light alerts the control operator that a pump has stopped or has been started for item 3.

The MOC is applied to all changes at the case company that may affect Safety, Health, or Environment. While the main intent refers to “Not-In-Kind” Changes to the equipment, processes, procedures, feeds, chemicals, and technology, it also covers any Changes that may affect the safety, health or environment of company personnel, contract personnel, and/or the outside community. The MOC is required for any temporary or permanent Change to any physical equipment, control and safeguarding systems, feed-stocks, chemicals and catalyst, operating windows, and operating practices and procedures, and emergency response procedures.

Effecting SOD: Lower occurrence and detection (item 1, 2 and 3)

4.6.14 Implementation

The implementation of the preventive action plans is discussed among the FMEA team in the meeting. During the meeting, all the implementation plans have been discussed and summarized that there were only some preventive action plans that could not be fully implemented because of the limitation of inappropriate timing and other factors within the case company. Mostly, these preventive actions are the time consuming process and also they are needed to have time for collecting the data to do analysis. The following preventive actions were carried out to implementation:

Preventive action 1: Review and improve the operation of the BEC program
Preventive action 2: Provide emergency training and procedure to process operations
Preventive action 3: Bad actor list development

Preventive action 1: Review and improve the operation of the BEC program

According to BEC system in the past, it has less motivation to do this activity. To get more effectiveness, BEC will be included in yearly performance evaluation and to be stated in individual performance charter.

By reviewing typical activities on a shift and comparing with the pacesetter level, it is recommended that a minimum 20% of shift time is an achievable and reasonable target to set for BEC Program. The percentage of BEC is based on a monthly man-hour of operators that available to perform BEC tasks compares to the contribution time spent. That is, on the average, about 1 hr should be spent on BEC Program activities per Operator per shift. This is not withstanding unplanned activities such as plant upset that require urgent attention by the Operators. Conversely, there may also be instances where a BEC Program activity takes more than 20% time on certain shifts.

Moreover, it has been identified that the shift team under BEC currently performs BEC activities in the Task Listing. It is recommended that for the tasks that currently being performed, structured refresher training shall be conducted. For new tasks, which are to be performed under BEC, a series of proper training modules per each task is to be developed. The training modules consist of a simplified predefined theory and knowledge required to perform the tasks. Competency is verified by assessing the job done against steps written in Task Analysis. Competency is verified on site.

A good system for requesting, distributing/tasking and recording of tasks under the BEC activities done is necessary. It was defined that the existing SAP-M software was the most suitable system. Alternatively, the logging /recording in share drive are also used for certain tasks or activities.

Preventive action 2: Provide emergency training and procedure to process operations

The emergency training and emergency procedure are created into standard practices and documents. The emergency training or emergency case scenario called “dry run” is used to be common practice to shift operation. It is indicated by using shift KPI. For the emergency procedure, an overview of the required action is given followed by a more detailed and complete checklist of the necessary steps to ensure the emergency is safely contained.

In any emergency case whether large or small, it is essential to recognize the potential consequence and to act swiftly and safely. The consequences of the prevailing emergency are listed and should serve as a guide for further actions. The plant is instrumented such that it can be rapidly shut down and rendered completely safe. Not every emergency will require such drastic action, and the correct measures, taken promptly, will prevent most major upsets escalating into an emergency. The example of the emergency training for handle emergency case is shown in Figure 4.12 and Figure 4.13.

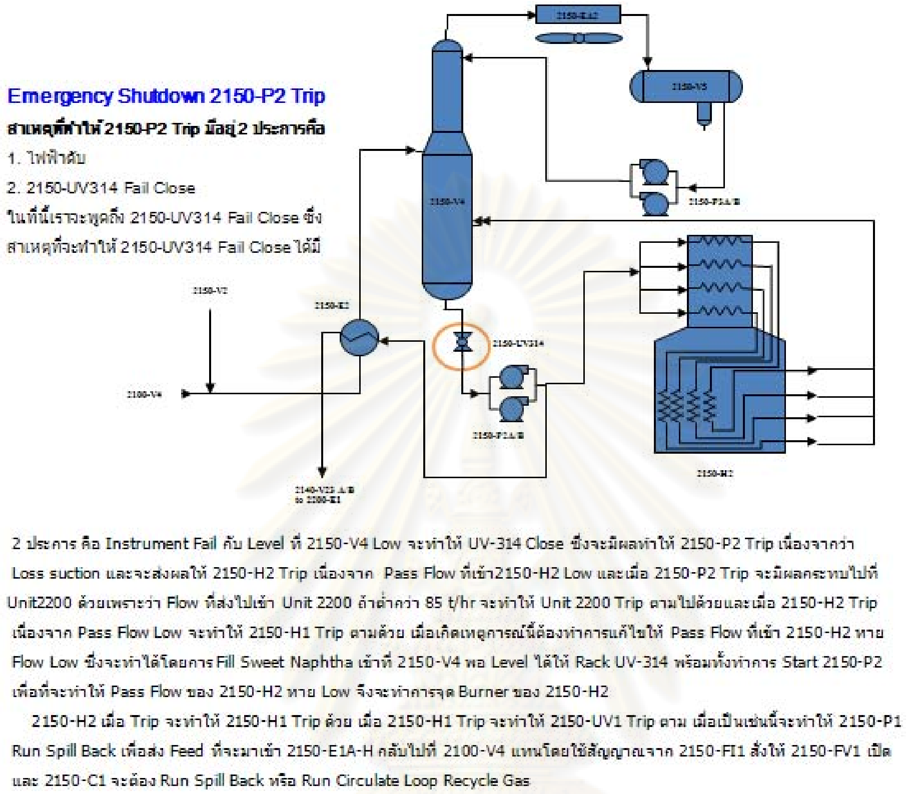


Figure 4.12 Emergency Shutdown Exercise Desktop

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Figure 4.13 Emergency Shutdown Exercise on site

Preventive action 3: Bad actor list development

After implementation, the FMEA team got the top ten risk ranking of equipment failure or incident each month from the meeting. These items will be followed up by each item leader to complete each item as tentative in the meeting.

Table 4.9 Top ten risk ranking for AT

Item	Unit	Reliability Risk	Leader	Finished Target	%Complete
1	2100	Fouling 2100-V1, 2100-E3A/B and 2100-E10 (2100-V7) problem	TE/2	Q2/2011	
2	2100	Corrosion of OVHD section of 2100-V7(Equipment &Piping)	TE/2	Q4/2011	
3	VSD	RIT VSD 2200-C2 and 2320-C1	RE/3	Q2/2011	
4	2200	Bypass Valve of 2200-FV25 (BFW) Passing : Already issued MOC	AT/1B	Q1/2011	
6	PTTUT	PTT UT reliability - Aux boiler Improvement	AT/1A	Q2/2011	
7	2500	PAREX chamber Vent Valve crack and leaks	TE/2	Q1/2012	
8	2250	U2250 CCR - HCl dew point corrosion in some existing line at temp <138 C	RE/2	Q2/2011	
9	2200	Potential Plugging of CFE spray bar of PLF at AR3 (consider ranking)	TE/2	Q1/2012	
10	2200	2200-LT11 (2200-V15) often error	RE/3	Q1/2011	
11	All	Equipment Criticality Classification	RE/5	Q1/2011	
12	All	CUI (Corrosion Under Insulation) Program	RE/2	Q4/2012	
13	All	PM Compliance Improvement	MN/5		
14	All	RCM-AT 2011 master plan and implementation.	RE/1	Q4/2011	
15	All	AR3 SIL Assessment Workshop and SIFpro Implementation	MN/3	Q2/2011	
16	All	Install instrument (DCS) for critical machine and process.	RE/3	Q3/2011	

4.6.15 Recalculation RPN rating score

Once all suggested preventive actions have been taken to improve the process, new rankings for severity, occurrence, and detection should be determined, and a resulting RPN calculated. After FMEA team discussion, each item of failure mode should be re-scored. There is no target RPN for FMEAs. It is up to the FMEA team and the company to decide on how far the team should go with improvements.

The rescoring of the critical risk should reveal the difference that the preventive actions and how effective they are. The larger the range of difference between the RPN score means the more effective the preventive actions are. According to the preventive action, the risk team can use this information to reconfigure the score of the RPN. In the 6th meeting, the score of the new RPN is collected and is summarized to the following:

Table 4.10 Rescoring of failure modes and new RPN

Item	Failure mode (Risk)	Causes of failure	S	O	D	RPN
1	3.2 Instrumentation error	3.2.3 Valve mechanical malfunction	2	2	2	8
2	3.3 Loss of Services / Utilities	3.3.1 Pump trips on electrical overload when handling maximum demand (process upset)	2	1	4	8
3	3.3 Loss of Services / Utilities	3.3.1 Pump trips on electrical overload when handling maximum demand (equipment failure)	2	1	4	8
4	3.4 Lack of Operating Procedure	3.4.1 Incorrect operating practices	1	1	3	3

In Table 4.10, the failure modes were rescored and the new RPN were calculated. The result shows that most of the risk management team feels that the failure modes have been managed and should reduce. The evidence is shown in the decreasing RPN. All of the RPN in the failure modes of item 1-4 have reduced to below acceptable level (18). This means all the risks are no longer critical if all the preventive actions were implemented. After all the new RPN is calculated, comparing the old and the new RPN into percentage will show the decreasing percentage between them.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Table 4.11 Percentage comparison of old and new RPN

Item	Failure mode (Risk)	Causes of failure	Old RPN	New RPN	% corrective
1	3.2 Instrumentation error	3.2.3 Valve mechanical malfunction	75	8	89
2	3.3 Loss of Services / Utilities	3.3.1 Pump trips on electrical overload when handling maximum demand (process upset)	75	8	89
3	3.3 Loss of Services / Utilities	3.3.1 Pump trips on electrical overload when handling maximum demand (equipment failure)	80	8	90
4	3.4 Lack of Operating Procedure	3.4.1 Incorrect operating practices	15	3	80

The comparing percentage shows the improvement between the new and the old RPN. From the percentages showing in Table 4.11, it can be concluded that the FMEA team believe that the preventive actions will be effective and will be improving and solving the failure modes to gain a better performance. The FMEA team's efforts resulted in more than 70 percent reduction in the resulting RPN from the original FMEA total RPN for critical items. The 4 items addressed were below the target of 18 points.

Table 4.12 FMEA Worksheet after RPN rescoring

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
3. General Issue	3.2 Instrumentation	3.2.3.1 Process not under control	**3**	3.2.3 Valve mechanical malfunction	**5**	3.2.3.1.1 None	**5**	**75**	Alarm sounds in the DCS alarm when valve positioner senses the valve is fully opened or fully closed or not responding properly. This applies to field bus system but not the hardwired ESD system	**2**	**2**	**2**	**8**
	3.3 Services /Utilities	3.3.1.1 Process upset that can be extensive	**3**	3.3.1 Pump trips on electrical overload when	**5**	3.3.1.1.1 None	**5**	**75**	1. Emergency Procedure 2. Management of Change	**2**	**1**	**4**	**8**

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

165

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
		3.3.1.2 Spare pump may be started and also trip	**4**	handling maximum demand	**4**	3.3.1.2.1 None	**5**	**80**	Pump trip sounds alarm and running status light alerts the control operator that a pump has stopped or has been started	**2**	**1**	**4**	**8**

ศูนย์วิทยทรัพยากร จุฬาลงกรณ์มหาวิทยาลัย

Table 4.12: FMEA Worksheet after RPN rescoring (continue)

Process Description	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Recommended Actions	SEV	OCC	DET	RPN
									Pumps can be started from the control room				
	3.4 Part of Operating Procedure	3.4.1.3 Pressure gauges break off due to vibration or impact releasing hydrocarbons	**1**		**3**	3.4.1.3.1. None	**5**	**15**	Training of operators requires that the valve under a Pressure Indicator (PI) will only be cracked open	**1**	**1**	**3**	**3**

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The purpose of this research is to improve the case company plant performance and availability by reducing the incident rate for Aromatics two site (AT). The risk management of the case company is a combination of many expert people from each responsibility area that come together to work as one working team. These incidents cause the case company higher cost of incident (COI) and also loss production opportunity (LPO).

From the study of this thesis, the team for risk management must be established before starting risk management process. The team is established by selecting the representative from related department, which the representative should have enough experience in order to ensure that all processes of risk management are appropriately managed.

The Australian and New Zealand Risk Management Standard (AS/NZS 4360:2004) is conducted and all steps are explained as the following;

1. Goals and Context of the project are established by the agreement of the team to specify the objective and the circumstance of the current situation.
2. Identify Risks in various aspects by brainstorming. As mention earlier, rules of brainstorming must be strictly followed.
3. Analyze Risks and Estimate Risk Level by consideration of likelihood and consequence. Experience of estimator is very important for this step.
4. Evaluate Risks by indicate the causes of significant potential risks in order to decide the action plan.

5. Treat Risks by the use of risk treatment option and propose the feasible action plans to deal with significant potential risks.
6. Continuously Monitor and Review the risks after they are managed from the previous step into acceptable level.

Risk analysis in this research is conducted by the risk management standard of ASINZS 4360:2004 by focusing on the likelihood and consequence. The result from this analysis is in the form of risk level to show the significant by the product of likelihood and consequence. The risk analysis methods used in this research is FMEA. FMEA is a type of qualitative risk management. The type of FMEA used will be process FMEA (PFMEA) which means that the process of the case company will have to be separated out to be analyzed process by process.

FMEA is the process to analyze the defect, which might happen through the process or design starting from raw material, production and utilization by specify the severity, probability of occurrence and detection including action plan. The similarity of FMEA to the risk estimation of this study is the consideration on ranking the level of risk. Risk level of FMEA is in the form of Risk Priority Numbers (RPN) which is the result of severity, probability of occurrence and detection.

A working team is formed in order to conduct risk analysis of selected unit to be case study and the future model of all remaining units. A working team conducted a gap analysis of the current practice to determine the additional requirement to the current system. A working team brainstormed possible potential causes, effects and failure modes of the 3 main processes of the selected unit (ORP unit). The 3 main processes of ORP unit are input process, output process and overall issues of this process.

The brainstormed potential causes are classified into categories on fishbone diagrams which are as follows,

• Man
• Machine
• Process

• Substance
• Environment

The next step is to bring major failure modes and the selected major potential causes as identified in fish bone diagrams into FMEA worksheet. The FMEA analysis is the analyzing of the failure mode that could happen in each process. Using the past experience, judgment and estimation of the risk management team, the FMEA analysis can be completed. To analyze the risks, risk criteria for each variables of FMEA will be needed. The Risk Priority Number (RPN) consists of 3 variables, which are Severity (S), Occurrence (O) and Detection (D) rating from 1-5. These 3 factors multiplying together will create a RPN score. This score can be used to analyze the sensitivity of the risks and respond to them with suitable actions.

The acceptable RPN is determined as 18 and any significant high RPN above this value will be taken into consideration for further solution and improvement. The case company also used the Pareto analysis to be another tool and technique to verify critical failure modes. From FMEA study, there are 3 factors which have high RPN and 1 factor which has RPN score less than 18 but among the FMEA team, they has agreement to take care of it. All these 4 factors are required recommended actions to reduce or eliminate the risk associated with the failure mode.

The recommended actions in the Process FMEA (PFMEA) worksheet are as follows;

- Alarm sounds in the DCS alarm when valve positioner senses the valve is fully opened or fully closed or not responding properly. This applies to field bus system but not the hardwired ESD system
- Emergency Procedure
- Management of Change
- Pump trip sounds alarm and running status light alerts the control operator that a pump has stopped or has been started
- Training of operators requires that the valve under a Pressure Indicator (PI) will only be cracked open

The preventive actions that are plan out to be implemented will cover more than one critical risk. The preventive actions can be summarized in to the following:

- Review and improve the Operation of the “Basic Equipment Care” Program
- Provide Emergency Training and procedure to Process Operators.
- Bad Actor List Development

Comparing between the pre-implementation and post-implementation, incident rate, COI and LPO are reduced. It clearly indicate that the recommended actions and preventive actions significantly reduce the incident rate and financial impacts caused by major incident, but with the FMEA worksheet, the incidents can now be tracked, identify and analyze, in order to reduce occurrence probability and mitigate the consequences of the incidents. This is the advantage of the case company to have tracking approach to follow up all recorded failure modes that have happened to prevent repeatedly occur. Table 5.1 shows incident summary in year 2009 and the total incidents of AT are 79 cases.

Table 5.1 Summary of Incident and Near Miss: (Jan-Dec) YTD 2009

Incidents Separated by Classification YTD												Total
Department	Asset					People			Environment			
	Operation Relia	Loss,damage	Loss property	Fire	Product qaulity	First Aid	Med	LTI	Complaint	Spill	Non-compliance	
AM	12	2	0	0	0	0	0	0	0	0	0	14
AO	19	1	0	1	2	4	0	0	0	1	0	28
AT	58	7	1	2	3	4	1	0	1	2	0	79
BD	0	1	0	0	0	0	0	0	0	0	0	1
CS	0	0	0	0	0	0	0	0	0	0	0	1
HR	0	0	1	0	0	0	0	0	0	0	0	1
MN	0	1	0	0	0	2	1	0	0	0	0	4
MP	1	2	1	2	2	0	0	0	0	1	0	9
PA	0	1	0	0	0	0	0	0	0	0	0	1

PM	0	2	2	0	0	1	1	0	0	0	0	6
QS	0	5	0	0	0	1	0	0	0	0	0	7
RE	0	2	0	0	0	0	0	0	0	0	0	2
RM	28	3	0	2	22	3	0	1	3	14	0	76
RO	75	14	2	6	1	12	0	0	2	5	1	118
TE	2	1	0	4	4	0	0	0	0	0	0	11
Total	195	42	7	17	34	27	3	1	6	23	1	358

In Table 5.2, it shows the comparison of incidents between year 2009 and year 2010 after implementation. The total incidents showed obviously decreasing.

Table 5.2 Compare total incidents between year 2009 and year 2010

Dept	Total Incidents YTD 2009	Total Incidents YTD 2010
AO	28	33
AT	79	36
RO	118	60
MO	90	91
MN	4	6
PM	6	14
TE	11	7
HR	1	1
RE	2	0
SP	-	5
CS	1	0
MP	9	5
OS	-	0
QS	7	4
FP	-	1
Total	356	265

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

From Table 5.2, the incidents of operation are 58 cases from total 79 cases in year 2009. In year 2010, all incidents of AT are reduced to 10 cases from total 36 cases. The details of incidents, COI and LPO will show in Table 5.3.

Table 5.3 AT Summary Incident Report of year 2010

ID	INCIDENT TITLE	OCCURRED DATE	SEVERITY	CLASSIFICATION	SUBCLASS 1	LPO (USD)	COI (USD)
2136	(AT) 2320-C1 Compressor tripped due to IGCT power supply of VSD failed	07 Apr 2010	Medium Severity	Assets	Operation Reliability	570,000	570,000
2156	(AT) Parex unit shutdown due to 2500-ME1A/B rotary valve stopped	05 May 2010	Medium Severity	Assets	Operation Reliability	297,940	297,940
2185	(AT) 2320 - C1 trip during transfer direct online to VSD step	26 May 2010	Medium Severity	Assets	Operation Reliability	22300	22300
2192	(AT) 2200-C2 tripped while electrician reset alarm VSD	28 May 2010	Medium Severity	Assets	Operation Reliability	148,900	148,900
2196	(AT) 2200-C2 tripped by VSD during PTTUT have a problem with frequency dip	30 May 2010	Medium Severity	Assets	Operation Reliability	149,000	149,000
2228	(AT) CCR Hot S/D due to Oxgen analyzer failure from lightning	27 Jun 2010	Low Severity	Assets	Operation Reliability		2,272
2256	(AT) Loss HP	16 Jul 2010	Medium	Assets	Operation	249,000	249,000

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

	Steam from PTT UT (Supply to Reformer,Aromatic,utilities area)		Severity		Reliability		
2305	(AT) 2200PIC-036 failed closed while plant normal running	05 Oct 2010	Medium Severity	Assets	Operation Reliability	569	4,569
2350	(AT) 2440-FV13H cannot control flow due to positioner was malfucntion	16 Oct 2010	Medium Severity	Assets	Operation Reliability		8,000
2382	(AT) 2500-FI20 Flow low low due to 2500PV18A failure	05 Dec 2010	Low Severity	Assets	Operation Reliability	408,000	408,000
2384	(AT) 2380-V6 LPG Leak	05 Dec 2010	Medium Severity	Assets	Loss/Damage	434,000	434,000
Total	**11**					2,279,709	2,293,981

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

5.2 Recommendations

Recommendations to the risk management are ways to improve it in the future with time. The results of this research will be helpful for management of the case company because they indicate that for future improvement the case company needs to implement preventive action program in the production department. With the limited time, the risk management of a whole unit could not be 100% completed because there was a lot more study details into the factors that were influencing them.

As mention earlier, risk management is the process that requires dedication almost full time from the team and it is the process that requires continuous commitment. Due to the risk management system requires the various members to set up team, participants of risk management must be the staff from the related departments such as engineering, production and technology department which have their own normal work to response. In the period that the participants have more work in hand, they will relocate the dedication from risk management to their normal work. This will result in ineffective risk management.

These are some of the factors that should be improved over time to gain more effective risk management.

1. Training and understanding of FMEA

Risk analysis by using FMEA is a new method to the case company, especially in operation department. It can easily be misunderstood easily. It is helpful for FMEA team members to have some understanding of the FMEA process before starting the practice, extensive training is not necessary if team members have previous experience working on problem-solving teams. It is important that FMEA team members know the basics of working on a team because they will be using those skills as FMEA team members. Knowledge of consensus-building techniques, team project documentation, and idea generating techniques such as brainstorming are all necessary for FMEA team members. In addition, team members should be comfortable using continuous-improvement problem solving tools, such as flowcharts, data analysis, and graphing techniques.

2. Risk management team should be founded into a new section

Risk management is a process that requires long term commitment due to the life of the project and the change of risk. It is difficult for normal staffs to manage their normal work and the risk in the same time. Risk management team should be founded into a new section in order to achieve effective risk management.

3. Continuous improvement use of FMEA

The FMEA used in these risk meeting is the first FMEA ever used in the history of the company, which there were confusion and misunderstandings. The FMEA tables and criteria will need to improve over time to be more accurate and gain more insight to the project. The criteria of the FMEA will need to be updated to fit the projects at hand and the past risks will need to be reviewed to gain better understanding of the projects in the future.

4. Input more tools and techniques

In each process of risk management, there are tools and techniques used to gain faster and better results. In the future, these tools and techniques will have to improve. With better tools and techniques, the risk management process will get more accurate and more effective.

5. Ranking scale and acceptable RPN

The ranking scale used for severity, occurrence and detection is 1-5 which do not have a smooth transition between levels when compared to the scale of 1-10. The reason that 1-5 is chosen instead of 1-10 is that at the start of the thesis, most of the members in the working team are not familiar with risk analysis and FMEA, therefore to simplify the method, the author chose the scale of 1-5.

The acceptable RPN can be modified or further improved through changing the combination rating of each factor can be changed to suit the case company's future goal or requirements changes. In this thesis, for simplicity reason, the acceptable RPN of value 18 was used by choosing the rating of each factor as
2 (Severity) x 3(Occurrence) x 3 (Detection).

REFERENCES

Andersen, B. and Fagerhaug, T. 2006. Root Cause Analysis: Simplified Tools and Techniques. ASQ Quality Press. Milwaukee, Wisconsin.

Australia/New Zealand Standard. Standards ASINZS 4360: RISK MANAGEMENT. [Online]. 2004. Available from: http://www.ucop.edu/riskmgt/erm/documents/ [2004, August, 31].

Besterfield, D.H., Besterfield-Michna, C., Besterfield, G.H. and Besterfield-Sacre, M. 2002.Total Quality Management. Prentice-Hall, USA, 3rd edition.

Brussee, W. 2005. All About Six Sigma: The Easy Way to Get Started. McGraw-Hill; 1st edition

Broadleaf Capital International. 2004. Tutorial Notes: The Australian and NewZealand Standard on Risk Management, ASINZS 4360:2004. Broadleaf Capital International Ply Ltd.

Bonacum, D. and Brown, D. 2002. Failure Mode and Effect Analysis (FMEA): Team Instruction Guide. Kaiser Permanente, March.

California Department of Transportation. 2003. Project Risk Management Handbook. Caltrans Office of Statewide Project Management Process Improvement.

Casper, J.H. 1999. Preparing Hazard Analyses for JSC Ground Operations. Occupational Safety and Quality Assurance Branch, Revision C, April.

Flanagan, R. and Norman, G. 1993. Risk Management and Construction. Wiley Blackwell Scientific Publication, Great Britain.

ศูนย์วิทยทรัพยากร จุฬาลงกรณ์มหาวิทยาลัย

Ford Design Institute. 2004 Failure Mode and Effect Analysis: FMEA Handbook with Robustness Linkages. Dearborn, MI.

Hawkins, P.G. and Woollons, D.J. 1998. Failure Modes and Effects Analysis of Complex Engineering Systems using Functional Models. Artificial Intelligence in Engineering 12, pp. 375-379, Elsevier Science.

Ishikawa, K. and Lu, D. J. 1988. What is Total Quality Control: The Japanese Way. Prentice-Hall. USA.

Kloman, F. 2003. Risk Management Reports. Risk Management Reports and Seawrack Press, Inc.

Lueck, D. 1996. Stop Failure in Its Tracks. CIRAS News, Iowa State University, Volume 31, No. 1.

Mcdermott, R.E., Mikulak, R.J. and Beauregard, M.R. 2009. The basics of FMEA. 2nd edition, Taylor & Francis Group, LLC.

Mills, A. 2001. A Systematic Approach to Risk Management for Construction. Structural Survey, Vol. 19, No.5, pp. 245-252.

Mouss, H., Mouss, D., Mouss, N. and Chebira, S. 2002. Application of Neutral Networks to Industrial Diagnosis of an Agro-Alimentary Production System. University de Batna, Laboratoire d’ Automatique et Productique 1, Rue Chahid Boukhlouf-0500 Batna, Algerie.

Mraz, M. 2005. FMEA – FMECA. University of Ljubljana, Faculty of Computer and Information Science Ljubljana, Bernhard Huber, Management Center Innsbruck, Ljubljana.

Rooney, J. J. and Vanden Henvel, L. N. 2004. Root Cause Analysis for Beginners. Quality Progress, pp. 45-53.

Rotondaro, R.G. and Oliveira, C.L. 2001. Using Failure Modes Effect Analysis (FMEA) to Improve Service Quality. University of Sao Paulo, Av. Professor Almeida Prado, No. 128, Trav. 2, Sao Paolo, Brazil.

Scipioni, A., Saccarola, G., Centazzo, A., and Arena, F. 2002. FMEA methodology design, implementation and integration with HACCP system in a food company. Food Control 13, p.495-501, Elsevier Science.

Stamatis, D.H. 1997. TQM Engineering Handbook. USA, Marcel Dekker.

Teng, S.H. and Ho, S. Y. 1996. Failure Mode and Effects Analysis: An integrated approach for product and process control. International Journal of Quality & Reliability Management, Vol. 13, No.5, pp. 8-26.

Vermillion, D. 2002. Improving Customer Satisfaction in the Service Industry using Failure Modes & Effects Analysis. November 18, for OPERMGT 345, 001.

Villacourt, M. 1992. Failure Modes and Effects Analysis (FMEA): A Guide for Continuous Improvement for the Semiconductor Equipment Industry. Technology Transfer, SEMATECH, September 30.

Wilcox, L.R. 1996. Risk-Informed Regulation of Marine Systems Using FMEA. U.S. Coast Guard Marine Safety Center, Washington, D.C.

APPENDICES

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Appendix A: FMEA Checklists

CHECKLIST FOR ENABLERS

Definition

- Enabling events / conditions (enablers) must be present or active for the scenario to proceed.

Do not by themselves initiate a hazard scenario.

Examples of Enablers

- Alarms disabled
- Safeties bypassed
- Procedures not followed
- PM not performed
- Failure of inerting
- Extreme ambient conditions
- Process being in a particular mode, phase or step
- Etc.

CHECKLIST FOR SAFEGUARDS

Types

Type	Meaning	Example
Prevention	Act of causing an event not to happen	Cathodic protection
Detection / Indication	Act of discovering or identifying an accident in progress	Flammable gas detectors
Mitigation	Act of causing a consequence to be less severe	Water sprays

Categories of Safeguards

- Human vs Automated
- Administrative vs Procedural vs Engineered

- Passive vs Active

Deciding on Appropriate Safeguards

Guidelines for Safeguards

- Specify “what” and “where”
- Clearly identify safeguards
- List safeguards separately
- Include safeguards both within the node and in other nodes
- Credit only confirmed safeguards
- Include only appropriate safeguards
- Record only credible safeguards
- Consider recording set points
- Follow a standard convention for recording safeguards in the worksheet
- Be careful when taking credit for human safeguards
- Consider the failure of safeguards as causes of hazard scenarios
- Use a global safeguards list

Suggested Guidelines for Appropriate, Credible Safeguards

- Equipment safeguards such as pressure relief / control devices, block valves, rupture disks, interlocks, automatic shutoffs, and automatic bypasses

  - Unless determined otherwise by the PHA team

  - Possible reasons for invalidating these safeguards include:

  - Poor design

  - Inadequate preventive maintenance

  - Potential for bypass

  - Testing taking place

- Alarms, monitoring trends of key process parameters, standard operating procedures, and operator attention may be used as safeguards, if there is a consensus among the team

  - Allowed by company procedures
  - Specific action should be identified, e.g. referencing a procedural step

- Emergency response may be used as a safeguard

- Unless rejected by the team as not appropriate

- Usually, training should be included as a safeguard only if it is unique / special and there is documentation
  - Specific training should be identified
  - Normal operator training is not considered a safeguard unless determined otherwise by the team

<u>Definition of Independent Protection Layer (IPL)</u>

A safeguard that acts regardless of the:

- Initiating event, or
- Action or failure of any other safeguard associated with the scenario, or
- Any other element of the scenario

<u>Typical Criteria for IPLs</u>

In order to be considered an IPL, a safeguard must be:

- Effective
- I.e. Prevents the undesired consequence when it functions as designed
- Independent
- Auditable
- Effectiveness and reliability can be audited

CHECKLIST FOR CONSEQUENCES

<u>Types</u>

- People
- Environment
- Property / equipment
- Process
- Adjacent installations
- Public relations
- Etc

<u>Guidelines for Consequences</u>

- Record only allowable consequences
- Be specific
- Select consequence endpoints
- Use the selected endpoint consistently
- Use appropriate level of detail

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

- Specify unprotected, worst-case consequences
- Address conditional modifiers
- Qualify consequences
- Do not combine different types of consequences
- Record multiple consequences separately
- Identify chemicals as needed
- Identify consequences wherever they occur
- Identify both immediate and delayed consequences

CHECKLIST FOR CAUSES

Types of Causes

- Equipment failures
- Human failures
- External events
- Types of Equipment Failures
- Mechanical, e.g. pumps, valves
- Structural, e.g. foundations, supports, hangers
- Electrical, e.g. switches, motors
- Electronic, .g. circuit boards
- Programmable (i.e. computers, including software)
- Any other equipment
- Information to Identify for Equipment Failures
- Equipment name, i.e. "what"
- Identifier, i.e. "which"
- Failure mode, i.e. "how"
- Failure mechanism, i.e. "why"

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Types of Human Failures

Type	Meaning	Example
Omission error	Action is not performed	Failure to execute a step in a procedure
Commission error	Action is performed incorrectly	Operator closes the wrong valve
Extraneous act	Non-required action is performed instead of or in addition to required act	Technician closes block valves under both relief valves
Violations (deliberate acts)	Action that is prohibited, or different from that prescribed	Operator disables an alarm

Sources of Human Failures

- Design
- Construction
- Operation
- Maintenance
- Management
- Etc.

Information to Identify for Human Failures

- Type of failure, i.e. "what"
- Identifiers, i.e. "which"
- Person(s) involved, i.e. "who"
- Optionally, underlying reason for the failure, i.e. "why"

<u>Types of External Event</u>

Type	Examples
Natural events	Flooding, lightning, tornadoes, hurricanes, earthquakes
Human induced	Vehicle impacts, dropped objects from lifting devices
Utility failures	Electricity, instrument air, plant nitrogen, cooling water, steam, etc.
Knock-on or domino effects	Propagation of an incident to affect adjacent equipment or processes e.g. fires or explosions in adjacent facilities

Information to Identify for External Events

- Event / factor, i.e. "how"
- Reason, as appropriate, i.e. "why"
- Effect, i.e. "what"
- Identifiers, as appropriate, i.e. "which"

<u>Sources of Common Cause Failure</u>

- Utilities, e.g. electrical power, instrument air, etc.
- People, e.g. designers, manufacturers, constructors, operators, mechanics, etc.
- Control systems, e.g. DCS
- Similar technologies or the same type of redundant equipment
- External factors, e.g. lightning
- Common location
- Process corrosion, plugging or fouling, e.g. plugging of relief valves and sensors
  in a shutdown system
- Single elements, e.g. common process taps, common conduit, single energy sources, single field devices, etc.
- Maintenance, e.g. tools, procedures, calibration, training

- Susceptibility to mis-operation, e.g. training, procedures, activity under abnormal
  stress
- Environmental factors
- Electrical, e.g. power spikes, voltage surge, high current levels, static discharge, radio-frequency radiation
- Mechanical, e.g. shock, vibration
- Chemical, e.g. corrosive atmosphere, salt air, humidity, water
- Physical, e.g. temperature, fire
- Usage, heavy or infrequent

Guidelines for Causes

- Let the team brainstorm
- Address all types of causes
- Record causes when first identified
- Group equipment failures as appropriate
- Be complete
- Be specific
- Clearly identify equipment, controls, instrumentation, etc.
- Provide appropriate level of detail
- Decide on credible causes
- Consider multiple failures
- Address previous incidents
- Focus on causes that originate within the node but do not exclude causes from
- other nodes/facilities

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Appendix B: FMEA Common Failure Mode of Industrial Equipments

- **Common Failure Mode of Centrifugal Pumps**

THE CAUSES	Insufficient Discharge Pressure	Intermittent Operation	Insufficient Capacity	No Liquid Delivery	High Bearing Temperatures	Short Bearing Life	Short Mechanical Seal Life	High Vibration	High Noise Levels	Power Demand Excessive	Motor Trips	Elevated Motor Temperature	Elevated Liquid Temperature
Bent Shaft					●	●	●	●		●			
Casing Distorted from Excessive Pipe Strain					●	●	●	●		●		●	
Cavitation	●	●	●	●	●		●	●	●				●
Clogged Impeller	●		●	●				●		●			
Driver Imbalance						●	●	●					
Electrical Problems (Driver)						●	●	●		●	●	●	
Entrained Air (Suction or Seal Leaks)	●	●	●					●	●			●	
Hydraulic Instability					●	●	●	●	●				
Impeller Installed Backward (Double-Suction Only)	●		●							●			
Improper Mechanical Seal							●						
Inlet Strainer Partially Clogged	●		●					●	●				●
Insufficient Flow through Pump													●
Insufficient Suction Pressure (NPSH)	●	●	●	●				●	●				
Insufficient Suction Volume	●	●	●	●	●			●	●				●
Internal Wear	●		●					●		●			
Leakage in Piping, Valves, Vessels	●		●	●									
Mechanical Defects, Worn, Rusted, Defective Bearings					●		●			●			
Misalignment					●	●	●	●		●		●	
Misalignment (Pump and Driver)								●		●	●		●
Mismatched Pumps in Series	●		●			●		●		●			
Noncondensables in Liquid	●	●	●					●	●			●	
Obstructions in Lines or Pump Housing	●		●	●				●				●	●
Rotor Imbalance						●	●	●					
Specific Gravity Too High	●									●		●	
Speed Too High										●	●		
Speed Too Low	●		●	●								●	
Total System Head Higher Than Design	●	●	●	●	●		●					●	●
Total System Head Lower Than Design					●		●	●	●	●			●
Unsuitable Pumps in Parallel Operation	●		●	●	●			●	●		●		●
Viscosity Too High	●		●							●		●	
Wrong Rotation	●			●						●		●	

- **Common Failure Modes of Rotary-Type, Positive-Displacement Pumps**

	THE PROBLEM										
THE CAUSES	No Liquid Delivery	Insufficient Discharge Pressure	Insufficient Capacity	Starts, But Loses Prime	Excessive Wear	Excessive Heat	Excessive Vibration and Noise	Excessive Power Demand	Motor Trips	Elevated Motor Temperature	Elevated Liquid Temperature
Air Leakage Into Suction Piping or Shaft Seal		●	●				●			●	
Excessive Discharge Pressure			●		●		●	●	●		●
Excessive Suction Liquid Temperatures			●	●							
Insufficient Liquid Supply		●	●	●	●		●		●		
Internal Component Wear	●	●	●				●				
Liquid More Viscous Than Design								●	●	●	●
Liquid Vaporizing in Suction Line		●	●	●			●				●
Misaligned Coupling, Belt Drive, Chain Drive					●	●	●	●		●	
Motor or Driver Failure	●										
Pipe Strain on Pump Casing					●	●	●	●		●	
Pump Running Dry	●	●			●	●	●				
Relief Valve Stuck Open or Set Wrong		●	●								
Rotating Element Binding					●	●	●	●	●	●	
Solids or Dirt in Liquid					●						
Speed Too Low		●	●						●		
Suction Filter or Strainer Clogged	●	●	●				●			●	
Suction Piping Not Immersed in Liquid	●	●		●							
Wrong Direction of Rotation	●	●								●	

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

- **Common Failure Mode of Reciprocating Positive- Displacement Pumps**

THE CAUSES	THE PROBLEM								
	No Liquid Delivery	Insufficient Capacity	Short Packing Life	Excessive Wear Liquid End	Excessive Wear Power End	Excessive Heat Power End	Excessive Vibration and Noise	Persistent Knocking	Motor Trips
Abrasives or Corrosives in Liquid			●	●					
Broken Valve Springs		●		●			●		
Cylinders Not Filling		●	●	●			●		
Drive-Train Problems							●		●
Excessive Suction Lift	●	●							
Gear Drive Problem							●	●	●
Improper Packing Selection			●						
Inadequate Lubrication						●	●		●
Liquid Entry Into Power End of Pump						●			
Loose Cross-Head Pin or Crank Pin								●	
Loose Piston or Rod								●	
Low Volumetric Efficiency		●	●						
Misalignment of Rod or Packing			●						●
Non-Condensables (Air) in Liquid	●	●	●				●		●
Not Enough Suction Pressure	●	●							
Obstructions in Lines	●						●		●
One or More Cylinders Not Operating		●							
Other Mechanical Problems: Wear, Rusted, etc.					●	●	●	●	
Overloading					●				●
Pump Speed Incorrect		●				●			
Pump Valve(s) Stuck Open		●							
Relief or Bypass Valve(s) Leaking		●							
Scored Rod or Plunger		●							●
Supply Tank Empty	●								
Worn Cross-Head or Guides			●			●			
Worn Valves, Seats, Liners, Rods, or Plungers	●	●		●					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

- **Common Failure Mode of Centrifugal Fans**

THE CAUSES	Insufficient Discharge Pressure	Intermittent Operation	Insufficient Capacity	Overheated Bearings	Short Bearing Life	Overload on Driver	High Vibration	High Noise Levels	Power Demand Excessive	Motor Trips
	THE PROBLEM									
Abnormal End Thrust				●			●			
Aerodynamic Instability		●	●	●	●		●	●		
Air Leaks in System	●	●	●							
Bearings Improperly Lubricated						●	●	●		●
Bent Shaft				●	●	●	●		●	
Broken or Loose Bolts or Setscrews				●			●			
Damaged Motor							●			
Damaged Wheel	●		●	●						
Dampers or Variable-Inlet Not Properly Adjusted	●		●							
Dirt in Bearings				●			●			
Excessive Belt Tension				●			●			●
External Radiated Heat				●						
Fan Delivering More Than Rated Capacity						●	●			
Fan Wheel or Driver Imbalanced				●			●			
Foreign Material in Fan Causing Imbalance (Plate-Out)				●			●	●		
Incorrect Direction of Rotation	●		●			●	●			
Insufficient Belt Tension							●	●		
Loose Dampers or Variable-Inlet Vanes							●			
Misaligment of Bearings, Coupling, Wheel, or Belts				●		●	●	●	●	
Motor Improperly Wired						●	●	●		●
Packing Too Tight or Defective Stuffing Box						●	●		●	●
Poor Fan Inlet or Outlet Conditions	●		●							
Specific Gravity or Density Above Design						●	●		●	
Speed Too High		●		●	●	●	●			●
Speed Too Low	●	●	●					●		●
Too Much Grease in Ball Bearings				●						
Total System Head Greater Than Design	●		●	●		●			●	
Total System Head Less Than Design		●					●			●
Unstable Foundation		●		●			●	●		
Vibration Transmitted to Fan from Outside Sources				●			●	●		
Wheel Binding on Fan Housing				●		●	●	●		●
Wheel Mounted Backward on Shaft	●		●							
Worn Bearings							●	●		
Worn Coupling							●			
120-Cycle Magnetic Hum							●	●		

- **Common Failure Modes of Blowers and Fluidizers**

	THE PROBLEM									
THE CAUSES	No Air/Gas Delivery	Insufficient Discharge Pressure	Insufficient Capacity	Excessive Wear	Excessive Heat	Excessive Vibration and Noise	Excessive Power Demand	Motor Trips	Elevated Motor Temperature	Elevated Air/Gas Temperature
Air Leakage into Suction Piping or Shaft Seal		●	●			●				
Coupling Misaligned				●	●	●	●		●	
Excessive Discharge Pressure			●	●		●	●	●		●
Excessive Inlet Temperature/Moisture			●							
Insufficient Suction Air/Gas Supply		●	●	●		●		●		
Internal Component Wear	●	●	●							
Motor or Driver Failure	●									
Pipe Strain on Blower Casing				●	●	●	●		●	
Relief Valve Stuck Open or Set Wrong		●	●							
Rotating Element Binding				●	●	●	●	●	●	
Solids or Dirt in Inlet Air/Gas Supply				●						
Speed Too Low		●	●					●		
Suction Filter or Strainer Clogged	●	●	●			●			●	
Wrong Direction of Rotation	●	●							●	

- **Common Failure Modes of Centrifugal Compressors**

	THE PROBLEM								
THE CAUSES	Excessive Vibration	Compressor Surges	Loss of Discharge Pressure	Low Lube Oil Pressure	Excessive Bearing Oil Drain Temp.	Units Do Not Stay in Alignment	Persistent Unloading	Water in Lube Oil	Motor Trips
Bearing Lube Oil Orifice Missing or Plugged				●					
Bent Rotor (Caused by Uneven Heating and Cooling)	●						●		
Build-up of Deposits on Diffuser		●							
Build-up of Deposits on Rotor	●	●							
Change in System Resistance		●							●
Clogged Oil Strainer/Filter				●					
Compressor Not Up to Speed			●						
Condensate in Oil Reservoir								●	
Damaged Rotor	●								
Dry Gear Coupling	●								
Excessive Bearing Clearance	●								
Excessive Inlet Temperature			●						
Failure of Both Main and Auxiliary Oil Pumps				●					
Faulty Temperature Gauge or Switch				●	●				●
Improperly Assembled Parts	●						●		●
Incorrect Pressure Control Valve Setting				●					
Insufficient Flow		●							
Leak In Discharge Piping			●						
Leak In Lube Oil Cooler Tubes or Tube Sheet								●	
Leak in Oil Pump Suction Piping				●					
Liquid "Slugging"	●						●		
Loose or Broken Bolting	●								
Loose Rotor Parts	●								
Oil Leakage				●					
Oil Pump Suction Plugged				●					
Oil Reservoir Low Level				●					
Operating at Low Speed w/o Auxiliary Oil Pump				●					
Operating in Critical Speed Range	●								
Operating in Surge Region	●								
Piping Strain	●					●	●	●	●
Poor Oil Condition					●				
Relief Valve Improperly Set or Stuck Open				●					
Rotor Imbalance	●						●		
Rough Rotor Shaft Journal Surface					●		●		●
Shaft Misalignment	●					●			
Sympathetic Vibration	●						●	●	
Vibration					●				
Warped Foundation or Baseplate							●		●
Wiped or Damaged Bearings					●				●
Worn or Damaged Coupling	●								

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

- **Common Failure Modes of Reciprocating Compressors**

THE CAUSES	Air Discharge Temperature Above Normal	Carbonaceous Deposits Abnormal	Compressor Fails to Start	Compressor Fails to Unload	Compressor Noisy or Knocks	Compressor Parts Overheat	Crankcase Oil Pressure Low	Crankcase Water Accumulation	Delivery Less Than Rated Capacity	Discharge Pressure Below Normal	Excessive Compressor Vibration	Intercooler Pressure Above Normal	Intercooler Pressure Below Normal	Intercooler Safety Valve Pops	Motor Over-Heating	Oil Pumping Excessive (Single-Acting Compressor)	Operating Cycle Abnormally Long	Outlet Water Temperature Above Normal	Piston Ring, Piston, Cylinder Wear Excessive	Piston Rod or Packing Wear Excessive	Receiver Pressure Above Normal	Receiver Safety Valve Pops	Starts Too Often	Valve Wear and Breakage Normal
Air Discharge Temperature Too High		●																●						
Air Filter Defective		●																	●	●				●
Air Flow to Fan Blocked	●	●				●																		
Air Leak into Pump Suction							●																	
Ambient Temperature Too High	●	●				●									●									
Assembly Incorrect																								●
Bearings Need Adjustment or Renewal					●	●	●								●									
Belts Slipping					●				●	●														
Belts Too Tight			●			●									●									
Centrifugal Pilot Valve Leaks																●								
Check or Discharge Valve Defective						●																		
Control Air Filter, Strainer Clogged				●																				
Control Air Line Clogged																					●			
Control Air Pipe Leaks																					●	●		
Crankcase Oil Pressure Too High																●								
Crankshaft End Play Too Great					●																			
Cylinder, Head, Cooler Dirty	●	●																						
Cylinder, Head, Intercooler Dirty						●												●						
Cylinder (Piston) Worn or Scored	●	●			●	●		●	●	●		●H	●L	●H	●L	●	●		●H	●H				
Detergent Oil Being Used (3)								●																
Demand Too Steady (2)																							●	
Dirt, Rust Entering Cylinder		●																	●	●				●

The header cell spanning all problem columns reads: THE PROBLEM

- **Common Failure Modes of Steam Traps**

THE CAUSES	THE PROBLEM: Trap Will Not Discharge	Will Not Shutoff	Continuously Blows Steam	Capacity Suddenly Falls Off	Condensate Will Not Drain	Not Enough Steam Heat	Traps Freeze in Winter	Back Flow in Return Line
Back-Pressure Too High				●				
Boiler Foaming or Priming		●				●		
Boiler Gauge Reads Low	●							
Bypass Open or Leaking	●		●					
Condensate Load Greater Than Design		●						
Condensate Short-Circuits					●			
Defective Thermostatic Elements						●		
Dirt or Scale in Trap			●		●			
Discharge Line Has Long Horizontal Runs							●	
Flashing in Return Main				●				●
High-Pressure Traps Discharge into Low-Pressure Return								●
Incorrect Fittings or Connectors				●				●
Internal Parts of Trap Broken or Damaged	●	●	●		●			
Internal Parts of Trap Plugged	●				●			
Kettles or Other Units Increasing Condensate Load		●						
Leaky Steam Coils		●						
No Cooling Leg Ahead of Thermostatic Trap						●		●
Open By-Pass or Vent in Return Line				●				
Pressure Regulator Out of Order	●							
Process Load Greater Than Design		●						
Plugged Return Lines				●				
Plugged Strainer, Valve, or Fitting Ahead of Trap	●							
Scored or Out-of-Round Valve Seat in Trap						●		
Steam Pressure Too High	●							
System is Air-Bound					●			
Trap and Piping Not Insulated							●	
Trap Below Return Main				●				●
Trap Blowing Steam into Return				●				
Trap Inlet Pressure Too Low				●	●			
Trap Too Small for Load		●						

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

- **Common Failure Modes of Control valves**

	THE CAUSES	THE PROBLEM: Valve Fails to Open	Valve Fails to Close	Leakage through Valve	Leakage Around Stem	Excessive Pressure Drop	Opens/Closes Too Fast	Open/Closes Too Slow
Manually Actuated	Dirt/Debris Trapped in Valve Seat		●	●				
	Excessive Wear		●	●				
	Galling	●	●					
	Line Pressure Too High	●	●	●	●	●		
	Mechanical Damage	●	●					
	Not Packed Properly				●			
	Packed Box Too Loose				●			
	Packing Too Tight	●	●					
	Threads/Lever Damaged	●	●					
	Valve Stem Bound	●	●					
	Valve Undersized					●		●
Pilot Actuated	Dirt/Debris Trapped in Valve Seat	●	●	●				
	Galling	●	●					
	Mechanical Damage (Seals, Seat)	●	●	●				
	Pilot Port Blocked/Plugged	●	●	●				
	Pilot Pressure Too High		●				●	
	Pilot Pressure Too Low	●		●				●
Solenoid Actuated	Corrosion	●	●	●				
	Dirt/Debris Trapped in Valve Seat	●	●	●				
	Galling	●	●					
	Line Pressure Too High	●	●	●	●			●
	Mechanical Damage	●	●	●				
	Solenoid Failure	●	●					
	Solenoid Wiring Defective	●	●					
	Wrong Type of Valve (N-O, N-C)	●	●					

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Appendix C: Meeting Agenda

Agenda

- ❑ Safety / Reliability talk — 2 min
- ❑ Meeting Objectives by AT — 3 min
- ❑ Introduction FMEA — 30 min.
- ❑ Request for advice or comment.
  - Top -10 Reliability Risk Ranking — 30 min.
  - Monthly KPI performance closing gap action — 15 min.
- ❑ Request to approve.
  - Area Core Team — 5 min.
  - KPI Team — 5 min.
  - Reliability Risk Team — 5 min.
  - Equipment Criticality Classification Team — 10 min.
- ❑ AOB

TE, RE, MN recommendation for reliability risk and improvement

SPEED Social Responsibility & Caring ◆ Professionalism ◆ Ethics ◆ Engagement ◆ Diversity & Teamwork

AT : Top -10 Reliability Risk Ranking

Item	Unit	Reliability Risk	Leader	Finished Target	%Complete
1	2100	Fouling 2100-V1, 2100-E3A/B and 2100-E10 (2100-V7) problem	TE/2		
2	2100	Corrosion of OVHD section of 2100-V7(Equipment &Piping)	TE/2		
3	VSD	RIT VSD 2200-C2 and 2320-C1	RE/3		
4	2200	Bypass Valve of 2200-FV25 (BFW) Passing : Already issued MOC	AT/1B		
6	PTTUT	PTT UT reliability - Aux boiler Improvement	AT/1A		
7	2500	PAREX chamber Vent Valve crack and leaks	TE/2		
8	2250	U2250 CCR - HCl dew point corrosion in some existing line at temp <138 C	RE/2		
9	2200	Potential Plugging of CFE spray bar of PLF at AR3 (consider ranking)	TE/2		
10	2200	2200-LT11 (2200-V15) often error	RE/3		
11	All	Equipment Criticality Classification	RE/5		
12	All	CUI (Corrosion Under Insulation) Program	RE/2		
13	All	PM Compliance Improvement	MN/5		
14	All	RCM-AT 2011 master plan and implementation.	RE/1		
15	All	AR3 SIL Assessment Workshop and SIFpro Implementation	MN/3		
16	All	Install instrument (DCS) for critical machine and process.	RE/3		

SPEED Social Responsibility & Caring ◆ Professionalism ◆ Ethics ◆ Engagement ◆ Diversity & Teamwork

Appendix D: Standard Emergency Procedure

[redacted]

Company Limited

Aromatics Two Operations

HC-WI-AT-XXXX

[redacted]

BULLET POINT PROCEDURE

Prepared by:	[redacted]
	[redacted]
Division	[redacted]

Reviewed/Approved by:	[redacted]
	[redacted]
	Operations Specialists

Distribution List

Copy No.	**Controller/Holder**	**Location**
00	TQA/MS Coordinator AR3 Process Team	EDMS

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Amendment List

Revision	Date	Page/ Section	Reason	By
0	[redacted]	All	First release	[redacted]
1	[redacted]	Page 22	Create Procedure Loss of Trunk Radio	[redacted]
2	[redacted]	All	Revised font and wording	[redacted]

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

TABLE OF CONTENTS

PAGE

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

1. Purpose/Objective

This bullet point procedure is made for guideline for an emergency failure of equipments. The plant condition may arise from a number of causes or combination of cause and its effect on the plant will depend on the situations prevailing at the time. Hence it is not possible to give harm and fast rules to cover possible situation. This procedure is followed when the emergency is occurring and needs the fast reminding to activate the cause.

The plant is an instrumented such that it can be rapidly shut down and rendered completely safe. Not every emergency will require such drastic action, and the correct measures, taken promptly, will prevent most major upsets escalating into an emergency.

The emergency condition may only affect one part of the complex and although this is shutdown it may be possible to continue operation on the rest of the complex.

General

All the SMOC were in operation needs to be stop incase of an upset to the unit.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

2. Scope

The emergency condition may only affect one part of the complex and although this is shutdown it may be possible to continue operation on the rest of the complex (even at reduced throughput). Again this will depend very much on conditions prevailing at the time but some general guidelines are given below.

3. Roles and Responsibility

Shift manager, Panel Operator, Senior Operator and Area Operators to coordinate work place are healthy and safely.

4. Business Workflow Activity

N/A

5. Detailed Activities

5.1 U-1000 CDU-BULLET

5.1.1 CDU FURNACE TRIP

- Inform the other panels and the outside operators of the situation.
- Reduce throughput of the CDU to 16,000 T/D and LCR under reflux to minimum~10-15% OP.
- Fix flow rate to HVU and reduce FOT of F-1101.
- Start the tempered water system and be careful hammering.
- Partially bypass the HVU and VBU.
- Keep monitoring C-1101 pressure and vacuum loading.
- Close the burner cook valves then start purging the furnace.
- If there is too much backpressure in the slops line, line up the slops to crude tankage.
- Let HDS automatically tripped by V1303 low level and bypass the unit.
- Switch MD from CDU to C1351, when the level in the C1351 starts dropping.
- Reduce the reflux flows to maintain the temperatures in the column or stop LCR/MCR/TCR respectively to maintain top temperature above 100 ^{o}C
- Close SEAL OIL bleed to V-1002 and line up flushing oil to U-4460.
- If the cooling of the C1351 top starts to drop, take in import naphtha from panel 2.
- If the F1001 cannot be put on line again within a few hours, put the CDU/HVU/VBU on crude circulation from the crude tank to the slops line to the crude tank.

5.1.2 P-1001 CDU FEED PUMP FAILURE

- Inform the other panel man and the outside operators of the situation.
- Reduce F1001 FOT to minimum firing.
- Raise P1001 suction pressure.
- Restart P1001 urgently.
- Balance pressure V1002 to C1001 by 100 % manual output 10PC003
- Adjust F1001 feed to minimum, and monitor feed coils flow against the tripped setting
- Open the crude bypasses over the E1001, E1003, E1009 and E1010A/B/C/D
- If 12,000 T/D cannot be reached due to some feed coil low flow. Keep the feed coil flow above the tripped setting.
- Adjust HDS feed to balance V1303 level. If V1303 level can't be controlled, HDS will have to be shutdown and bypassed.
- If P1001 couldn't be recovered in time, the CDU shutdown has to be considered

If all above doesn't work, shut down CDU/HVU/VBU/HDF and keep the units circulating.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

5.1.3 P1002 FAILURE

- Inform the other panel man and outside operators of the situation.
- Restart P1002 or the spare P1002 urgently (If succeed, restart F-1001 as soon as possible).
- If not succeed, manually shutdown F1101, manually increase C1101 pressure to 1 bara by gradually close steam to ejectors and stop P1107.
- Shutdown VBU
- Close fuel gas burner valves of F1001/1101/1201
- Stop P1003, P1101 when C1001 and V1101 low level respectively.
- Switch off power supply to electrical grids of V1001
- Shutdown P1001
- Put VBU/HVU on hot residue circulation
- Slops HGO, LGO and KERO
- Let HDS automatically tripped by V1303 low level and bypass the unit.
- Stop all refluxes as required.
- Reduce firing F1351 and start circulating HGO to C1351. Open the import naphtha from panel 2 and KERO to MCR. Close Cl352 draw off.
- If the P1002 cannot be restarted within a few hours, then dilution HVU and VBU with gas oil and keep the units circulating to bring the temperatures down.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

5.1.4 P-1003 FAILURE

- Inform the other panel man and outside operators of the situation.
- Restart P1003 urgently.
- If not succeed, manually trip CDU furnace
- Then immediately bypass HDS and put on hot H2 stripping, and routing MD from CDU to HDF
- Shutdown HVU and increase C1101 pressure to 1 bara by reducing steam to ejectors and stop P1107 if necessary.
- Shutdown F1201 and put loop P1202>F1201>V1202>C1201 in circulating
- Stop P1002, P1001 and turn off electrical grids of V1001
- Keep all reflux on circulation to cool down C1101 then shutdown TCR, MCR and LCR pumps respectively.
- Stop P1101 when V1101 is low level.
- Keep HDF reflux circulating to cool down the top temperature. Shutdown TCR, MCR pumps when C1351 top temperature is below 100^{o}C. Import naphtha from P-2 to control the top column temperature if necessary.
- If P1003 cannot be restarted within 30 minutes, put HVU/VBU on circulation as follows: P1202>F1101>C1101>V1101>P1101>V1201>P1201>F1201>V1202>C1201 and add flushing oil for diluting.

NOTE: Monitor for CDU/HGO color, if not clear divert to slops.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

5.1.5 P1004 FAILURE LCR PUMP

- Inform the other panel man and outside Operators of the situation.
- Restart the P1004 or P1004S urgently.
- Reduce the return temperature of the MCR and increase the reflux flow to maximum.
- Maximize TCR cooling by close the E1001 bypass and maximise the reflux flow.
- Max cooling E1004 (start the rest of fin-fan)
- Reduce FOT of F1001 around 10-15^{o}C by 5^{o}C each step
- Reduce CDU feed to maintain column temp
- If top temperatures of the column cannot be maintained, reduced striping steam to C1001.
- Check LGO (MCR) color. If black diverts to HF slops T5710 (Over flow from LCR compartment.
- Monitor color of middle distillate feed to HDS if above 6. Bypass the HDS
- Divert HDF products to slop T5711.
- Divert the naphtha to T5232 in case the top temperature 10TC100 remains above 185^{o}c

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

5.1.6 P-1005 FAILURE MCR PUMP

- Inform the other panel man and the outside operators of the situation.
- Restart the P1005 or the spare pump urgently.
- Reduce the return temperature of the LCR and increase the reflux flow to maximum.
- Ask for panel 2 to take more LCR duty.
- Maximize TCR for cooling by close the E1001 bypass and maximise the reflux flow.
- Max cooling E1004 (start the rest of fin-fan)
- Reduce FOT of F1001 around 10-15^{o}C by 5^{o}C each step
- Reduce CDU feed to maintain column temp
- If top temperatures of the column cannot be maintained, reduced striping steam to C1001.
- Divert naphtha to T5232 in case the top temperature 10TC100 remains above 185^{o}c.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

5.1.7 P1007 FAILURE TCR PUMP

- Inform the other panel man and the outside operators of the situation.
- Restart the P1007 or the spare pump urgently.
- Introduce cold import naphtha from panel 2 to the TCR.
- Check all El051's are running, panel2.
- Reduce the return temperature of MCR, LCR and increase the reflux flow.
- Inform panel 2 for maximum MCR, LCR duty.
- Reduce the FOT 5 ^{o}C each for 10-15 ^{o}C of F1001 and reduce feed if the temperatures in the column cannot be maintained.
- Divert the naphtha to T5232 in case the top temperature 10TC100 cannot be controlled below 185oc.

5.1.8 CDU OVERHEAD NAPHTHA PUMP P1052 FAILURE

- Inform the other panel man and outside operators of the situation.
- Restart the P-1052 or the spare pump urgently.
- Increase cooling on TCR by closing bypass over El001, maximise reflux flow, reduce MCR return temperature and increase MCR flow with HDF as the same.
- Reduce the FOT of F1001.
- Increase the feed to the platformer by I5FRC003.
- If no P1052 flow can be established: Reduce the HCU reactor temperatures by 20'C. Reduce HCU intake by 30%.
- Reduce the CDU throughput to minimum. Trip K1051.
- Put F1101 on minimum firing only and increase the pressure in C1101 to 1 bar, stop P1107.
- Put the F1201 on minimum firing only and flush the unit with hot HVU feed.
- Slops the HGO, LGO and KERO. Put the residue to slops when the CDU/FOT < 200 * C.
- Put the seal oil on internal circulation.
- Let the HDS trip on low flow and bypass the unit.
- Trip the F1001, 1101/1201/1351. Reduce the refluxes and stop when required.
- Switch HGO from E1360 back to C1351 when low level at bottom, open KERO to MCR closes the draw off to Cl352.

If P1052 out of service for a few hours, start crude circulation to the crude tank.

5.2 U-1101 HVU-BULLET

5.2.1 LP STEAM FAILURE HVU

CONSUMERS - Ejectors J1101/2
- Vent pipe V1109
- Air preheater E1107

- Inform the other panel man and the outside operators of the situation.
- If the loss of vacuum is partial only the unit can stay on line.
- Reduce the FOT of F1101 5^{o}c and observe the vacuum.
- If the loss is longer then,
- Reduce CDU through put to minimum and maximise the CDU T90%.
- Partial bypass CDU/LR.
- Reduce HVU feed to above minimum.
- Reduce further the F1101 FOT to 380 ^{o}C.
- Bypass the DEKA air preheater, F1103, partially to raise the flue gas outlet temperature above 150^{o}C.
- Reduce the VBU cracking and observe no flooding on top section C1201.

5.2.2 P1101 FAILURE

- Inform the other panel man and the outside operators of the situation.
- Restart the P1101 or the spare pump urgently.
- If P1101 isn't available or can't be restarted, shutdown F1101. Isolate fuel gas, waste gas and fuel oil.
- Bypass HVU when the FOT drops below 400 ^{o}C.
- Trip F-1201 and put VBU on internal circulation.
- Keep the refluxes going until low levels are reached. Then stop all reflux pumps.
- Reduce the CDU intake to minimum.

5.2.3 P-1104 FAILURE LCR PUMP

- Inform the outside operators and other panel of the situation.
- Restart P1104 or the spare P1004S urgently, if not successful then,
- Maximum cooling capacity of the MCR by increase flow to maximum and reduce return temperature start fin fan E1103 if stop.
- Maximum cooling capacity of the TCR, CFR and VGO under reflux, introduce FOS to V1104 if low level.
- Reduce F1101 FOT to 380 ^{o}C or minimum firing if top column is cannot control.
- Reduce feed rate HVU to minimum.
- Reduce CDU feed to minimum.
- Adjust HDS feed or bypass.
- Reduce VBU cracking and observe top section is not flooding.

Note: If HDS bypass, VBU must be switched to un-cracking mode

5.2.4 P-1105 FAILURE MCR PUMP

- Inform the outside operators and other panel of the situation.
- Restart P1105 or the spare P1004S urgently, if not successful then,
- Maximum cooling capacity of LCR by increase flow to maximum and reduce return temperature.
- Maximum cooling capacity of the TCR, CFR and VGO under reflux, introduce FOS to V1104 if low level.
- Reduce F1101 FOT to 380 ^{o}C or minimum firing if top column can't control.
- Increase the column pressure if top column pressure can't be controlled.
- Reduce feed rate HVU to minimum.
- Reduce CDU feed to minimum.
- Adjust HDS feed or bypass.
- Reduce VBU cracking and observe top section is not flooding.

Note: If HDS bypass, VBU must be switched to un-cracking mode

5.2.5 P-1106 Failure TCR/CFR/VGO Under reflux pump

- Inform the outside operators and other panel of the situation.
- Restart P1106 or the spare urgently, if not succeed then:
- Maximum cooling capacity of LCR by increase flow to maximum and reduce return temperature.
- Maximum cooling capacity of MCR by increase flow to maximum and reduce return temperature.
- Reduce F1101 FOT to 380 ^{o}C or minimum firing if top column is cannot control.
- Reduce feed rate HVU to minimum.
- Reduce CDU feed to minimum.
- Adjust HDS feed or bypass.
- Reduce VBU cracking and observe top section is not flooding.

Note: If HDS bypass, VBU must be switched to un-cracking mode

5.2.6 P-1107 Failure Liquid ring pump

- Inform the outside operators and other panel of the situation.
- Restart P1107 or the spare urgently, if not succeed then:
- Minimum firing F1101, reduce steam to ejectors and divert waste gas to flare.
- Manual 11PIC015 and open 100% to let gas easy flow to flare.
- Minimum feeds to CDU/HVU and the rest of LR partial bypass HVU.
- Reduce VBU cracking and observe C1201 top section not loading (VBU partial bypass is recommended).
- Maximum cooling capacity of the LCR by increase flow to maximum and reduce return temperature.
- Maximum cooling capacity of the MCR by increase flow to maximum and reduce return temperature.
- Maximum cooling capacity of the TCR/CFR/VGO under reflux by increase flow to maximum and reduce return temperature.
- If top column still can't be controlled, trip F1101 firing.
- Adjust HDS feed or bypass.

NOTE: IF HDS BYPASS, VBU MUST BE SWITCHED TO UN-CRACKING MODE

5.3 U-1200 VBU-BULLET

5.3.1 P-1201 failure VBU feed pump

- Inform the outside operators and other panel of the situation.
- Restart P1201 or the spare urgently, if not succeed then,
- Minimum feeds to CUD.
- Bypass HVU/VBU.
- Trip F1101/1201.
- Put VBU on internal circulation.
- Maximum cooling C1101.
- Keep V1101 level as must as possible but not flooding C1101.

NOTE: Closely monitor V1201 level; it may be over filling that possibly carries residue to C1001 through the vapor line**.**

5.3.2 P1202 TRIP

- Inform the outside operators and other panels of the situation.
- Restart the P1202 or the spare pump.
- If not successful, trip the F1201; isolate the fuel oil and fuel gas burner valves.
- Reduce crude feed as per SRF limited due to lost preheat.
- Bypass the unit and switch 12LRCA002 to 12FRC037.
- Stop the steam supply to C1201.
- If P1202 cannot be restarted within 15 minutes, introduce FOS into furnace coils or steam out the coils.

5.3.3 P-1203 failure VBU / TCR

- Inform the outside operators and other panels of the situation.
- Restart the P1203 or the spare pump if not successful then,
- Trip F1201.
- Bypass VBU.
- Reduce V1202 pressure to minimum.
- Put VBU on internal circulation to cool down the unit and feed coils.
- Reduce CDU feed rate to prevent F1001 SRF not over firing.

5.3.4 Control Valve 12PCV003 STUCK

Effect: High pressure 12-PRCA-003, F1201 coil flows low; F1201 may trip in the event of the above:

- Reduce crude feed intake to the CDU to maintain F-1001 not to exceed the firing limit.
- Request outside operator to open cracking section bypass line 12-HIC-043 - 12-FRC-037.
- Open 12-FRC-037 100 %.
- Control 12-PRCA-003 pressure below 10 bar using 12-HIC-043.
- Request Instrument Technician or Instrument trained operators to check 12-PRCA-003.
- Put 12-PRCA-003 on manual 100 % open, send outside operator to check control valve action.
- Request outside operator to monitor and radio in 12-PRCA-003 valve position.
- Close 12-PRCA-003 to 20 %, maintain pressure below 10 bar using 12-HIC-043.
- Open 12-PRCA-003 to 100 %, continue "stroking" the control valve position between 20-100 % to try and clear any blockage.
- If the blockage cannot be cleared bypass the cracking section fully and gas oil wash the unit ready for 12-PRCA-003 removal.

NOTE: DO NOT STROKING VALVE BELOW THE STUCKED POSITION.

5.4 U-1300 HDS-BULLET

5.4.1 BLACK MATERIAL IN HDS FEED VESSEL V-1303

- Inform the other panel man and outside operators of the situation.
- Reduce HDS reactor temperature to 300^{o}C.immediately.
- Trip the P1301 and bypass the reactor section. If MD color more than 6.0.
- Stop the slop injection to HDS if slop is on feeding
- Check the colour of CDU/ HGO/LGO/KERO, if some black divert to slops.
- In the CDU check the 10TRC091 and compare with 10TI106 (feed inlet C1001) reduce if higher than required.
- Increase LCR/LCR under reflux in the C1001 and increase the duty (E1451) if level in V1003 is dropping.
- In the VBU check the top temperature of the C1201, top reflux flow and temperature.
- Dump the V1303 content if black and refill with FOS and the hot material from CDU that not black.

- Restart F1301 and P1301 to prepare for cut in conditions
- Check the 10QRA006 for improvement on colour.
- Reintroduce the Middle Distillate when the colour is acceptable.
- Check the colour of the rundown products and switch back to on grade when colour is OK.

5.4.2 K-1301 TRIP

- Inform the outside operators and other panel area.
- Bypass the unit.
- Try to restart urgently, if not successful, then,
- Rectify the cause of trip.
- Stop the slops injection.
- If can’t restart compressor within 20 minutes after tripped then:
- Depressure the unit by using low rate depressurizing till reach the N2 pressure.
- Reduce crude feed to meet the MD ~ 7000 td.
- Uncracking the VBU.
- Reduce the VGO produced.
- Shutdown HDS feed pump; P-1301.
- Shutdown wash water pump; P-1302.
- Introduce N2 purging to the reactor section.
- Monitoring on the reactor temperature for dropping.

5.4.3 P1301 FAILURE

- Inform the outside operators and other panels.
- Check if the backflow protection has tripped.
- Bypass the HDS and then switch VBU to un-cracking mode.
- Stop the slops injection
- Close the fuel gas burner valves.
- If the Pump cannot be restarted within reasonable time.
- Reduce crude feed to reach MD~7000 t/d.
- Fully hot H2 stripping mode.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

5.4.5 HDS HHPS V1304 INLET TEMPERATURE CONTROLLER FAILURE 13-TRCA-001.

A: BYPASS CLOSED RESULTING IN LOWER TEMPERATURE TO V1304.

- Inform the other panel man and the outside operators.
- Take the TRCA-001 to manual.
- Check the trend of output 13TRCA001 and adjust.
- Check and compare the 13-TI-064/065 and adjust TRCA001 output to meet the temperature required.
- Provide more heat input to F1351. Check the flame pattern.

B: BYPASS OPENS RESULTING IN A HOTTER TEMPERATURE TO V1304.

- Inform the other panel man and the outside operators of the situation.
- The bypass valve opening might trip the feed by LL flow or back flow protection.
- Take the TRCA-001 to manual.
- Check the trend of output 13TRCA001 and adjust.
- Check and compare the 13-TI-064/065 and adjust TRCA001 output to meet the temperature required.
- Increase the HDF MCR and TCR refluxes to assist the temperature controllers.
- If the top temperature of the HDF cannot be controlled below 185^{o}c switch the Naphtha to slops.
- Check the levels of the V1306 and V1307, if uncontrollable reduce the CDU feed.
- Check the adip column, especially the 13TDIA903.

5.4.6 HOT LP SEPARATOR V1305 LEVEL FAILURE LEADING TO OVERFILL 13-LRCA-005.

- Inform the other panel man and outside operators of the situation.
- Take the level controller 13-LRCA-005 to manual and check for the trend output and adjust to meet the required.
- Take the level controller 13-LRCA-003 to manual and check for the trend output and adjust to meet the required.
- Inform to outside operator and let them to confirm the sight-glass of V-1305 for level.
- If the 13-LZA-006 failure to LL and could not rectify then,
- Bypass the HDS
- Reduce crude feed to meet the MD ~ 7000 td.
- Stop the slops injection.

- Rectify the cause of the failure of the level instrument.

5.4.7 LOSS H2 Grid

- Communicate-Inform Shift Manager, other Panels and Outside Operators.

Case: PLF, PSA-H, HMU TRIPPED

- Bypass HDS, Close 13PCV011 H2 supply to HDS.
- Reduce crude intake to meet MD ~ 7000 t/d.
- Crude intake reduction will depend on the nature and expected duration of the hydrogen producing/purifying unit.
- VBU un-cracking mode.
- Switch products to LF slops, once HDF temp have been normalized test for H2S, Copper strip on spec then check with OM to switch to component tank.
- Stop any slops injection to CDU or HDS.

Case: PSA-P TRIPPED

- Secure HDS unit.

5.5 U-1350 HDF-BULLET

5.5.1 HDF FURNACE F1351 TRIP

- Inform the outside operator and other panels of the situation.
- Close the fuel oil and fuel gas burner valves and start the purge sequence.
- Restart the furnace.
- If not successful or expected to be shut down for a period expanding 1 hour, reduce the intake of the CDU.
- Maximize the heat input to C-1351 such as 13TRCA001, 13TIC511, and 13UC501/502.
- Reduce cooling duty of MCR/TCR.
- Adjust the TCR to maintain the top temperature above 100 degree.
- Stop the refluxes to maintain the temperature profile in the column.
- Switch the seal oil to internal circulation and make up to use FOS instead.
- Switch VBR diluents to use FOS instead.

5.5.2 P-1351 FAILURE.

- Inform the outside operator and other panels of the situation.
- The column C-1351 will fill up at bottom section.
- Restart pump as soon as possible, if not successful then,
- Reduce feed to HDS and maximize the temperature 13TRCA001.
- Reduce crude intake.
- Reduce cooling duty of MCR/TCR but observe the top temperature is not above 185^{o}C (13TRCA516).
- Maximize the heat in/out to C-1351 at F1351 FOT, 13UC-501/502, 13TIC-511.
- Manual LGO draw off 13 FIC504 and open 100 %.
- Partially slops the CDU/HGO, LGO as required if V-1303 level goes up to quick.
- If the above could not met and C-1351 flooding for long then,
- Bypass the HDS and put on HOT H2 STRIPPING MODE.
- Slops all CDU products HGO, LGO and kero.
- Shut down F1351.
- Shut the HDF down.
- Put Seal oil system on close circulation and line up FOS to service.
- Switch VBR diluents to use FOS instead.

5.5.3 P-1356 FAILURE

- Inform the outside operator and other panels of the situation.
- Restart pump as soon as possible, if not successful then,
- F-1351 will trip with LL flow to feed coils.
- Partially bypass CDU/HGO to slops.
- Reduce the cooling duty of MCR and TCR.
- Maximize the heat input to C-1351, 13TC001, 13TC511 and 13UC501/502.
- Check the products for H2S.
- Slops the HDF products as required.
- Switch VBR diluents to use FOS instead.
- Switch the seal oil system to use FOS instead.

5.6 V-3825 Loss of CRS-LR.

- Inform the outside operator and other panels of the situation.
- Introduce CDU LR to V3825 as level control.
- Inform utilities panel for increase RFG consumption.
- Furnace is on dual firing increase RFG firing and monitor common stack SO2 Emission.
- Adjust condition within SO2 control limit.
- If common stack SO2 cannot control under Furnace dual firing on Max. FG and Min. FO.
    - Take out FO firing F1351, F1751, F1101, F1001, F1201 and F1401 as following to 100% FG.
    - If CR-LR cannot restart consider taking out oil guns and cleaning.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

5.7 Loss of Trunk Radio

Conventional mode

Conventional mode is the direct communication on group of radio users assign to the same channel without repeater and central controller.

The conventional system will be used as a backup in case of emergency situation. It is the responsibility for user to switch radio to conventional channel when the trunk radios totally fail and the fail-soft mode cannot use to communicate to talk group users.

The light red flash will appear (No beep sound) and "out of range" word will indicate on radio display channel when the conventional mode zone C is selected.

Note: The conventional channel will provide for each of 5 channels service [redacted]. All radio users are defaulted and assigned the talk group for area communication in channel detail below;
The conventional mode channel details the assigned talk group below;

Channel	[redacted] Assign for Conventional Owner
CONVEN1	Panel 1 & 4
CONVEN2	Panel 2 & 3
CONVEN3	RTL, RAIL, Panel 5, JETTY
CONVEN4	EMER, SEC
CONVEN5	RM, PSM, CTM

It is necessary to set up the mandatory emergency tier exercise with practice for the trunk radio partial or totally fail to increase operational capability include ensure that all back up mode has good reliability when the fail-soft mode or conventional mode is used for communication.

BIOGRAPHY

Krittapol Sricharoen was born in Bangkok, Thailand 1973. He graduated from Faculty of Engineering, Chulalongkorn University, Thailand in 1995 with a Bachelor's degree in Chemical Engineering. He continues to study in Engineering Business Management for Master's degree at Regional Centre for Manufacturing Systems Engineering, Chulalongkorn University (Thailand) and University of Warwick (United Kingdom). He had been working on PTT Aromatics and Refining Public Company Limited during his Master's degree.