Failure Risk Analysis in Amine Contactor Unit Using Failure Mode and Effect Analysis (FMEA) Method at PT X

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Abstract. PT X is an oil and natural gas company. One necessary production process is contaminant separation. The separation is done through a sweetening process using an amine contactor unit. The process involves hydrocarbon gases, H_2S, and CO_2. This process could potentially fail. Thus, it should be managed because chemical materials can harm occupational health, safety, and the environment. FMEA is a method to assess the risk of failures. Risk assessment begins by identifying potential hazards, then analyzing them based on hazard probability levels, risk severity levels, and the effectiveness of control measures, called detection. The assessment of the three main components in the amine contactor unit (pipes, valves, instruments) found potential failures: leaks, corrosion, and faulty pressure differential instruments. The highest risk priority number (RPN) from each component was in the gas inlet pipe, gas inlet valve, and instrument level control valve.

Keywords: Gas, Failures, H_2S, FMEA, RPN

1 Introduction

Industrial growth in Indonesia has increased rapidly, especially in the mining sector, such as oil and gas. As an industrial sector that contributes to the country's economy, efforts are needed to maintain and increase the production of oil and gas reserves. PT X is a company in the oil and gas sector founded in 1997. The product of PT X is natural gas produced for the needs of power plants. In the natural gas industry, accidents such as fire, explosion, and exposure to hazardous materials and chemicals can occur. Natural gas contains H_2S and CO_2, which are categorized as acidic gases. In the raw natural gas management process, PT X has a processing unit with a potentially high-risk level in the initial process, namely the amine contactor unit. An *amine contactor* is a gas production unit that absorbs H_2S gas levels in natural gas using the chemical compound Methyl Di-Ethanol Amine (MDEA). That chemical compound may cause corrosion in the piping system and equipment made of iron. As a result, pressure and fluid flow in the equipment have potential safety hazards and process failures, such as damage to piping and other components that can cause explosions, fires, and environmental pollution. The risk of this

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hazard can threaten the safety of workers around the unit area, damage equipment, and disrupt the running of the production process. It will be detrimental to the company. Accidents in amine contactor units are usually caused by operational failures, either from old machines or small leaks on the sidelines [6]. Therefore, it is necessary to analyze the risk of failure in the system or component to prevent process failures using the failure mode and effect analysis method (FMEA). FMEA can analyze various error considerations from the equipment or components used in the system to minimize the risk or impact of a failure rate by assessing the system's performance [5].

2 Method

The FMEA technique uses several parameters to determine the component or equipment failure risk score, such as severity, occurrence, and detection. Assessment references for each parameter can be seen in Table 1 for severity rating classification, Table 2 for occurrence rating classification, and Table 3 for etection rating classification. Those rating classifications are determined based on discussion with Health, Safety, and Environment (HSE) division in PT X (Table 1-3). Then, a failure's severity, occurrence, and detection score are multiplied to determine the risk score, or in FMEA, known as risk priority number (RPN), as seen in equation 1. Based on RPN, PT X can determine which potential failures need more attention and get priority for implementing the control measures.

$$\text{Severity x Occurance x Detection} = \text{RPN} \tag{1}$$

Table 1. Severity Rating

Score	Severity	Description
1	No impact	No impact on components and tools.
2	Very small	The damage has no impact on the component or the tool has very minor problems
3	Small	The damage does not impact components or tools experiencing minor problems
4	Very low	Damage to components or tools results in minor problems, but the production system is still operating (can still be handled by the operator)
5	Low	Damage to components or tools causes the production process to decrease but the machine can still operate (can still be handled by the operator)
6	Moderate	Damage to components or tools resulting in decreased production performance, but still able to operate (handled by mechanics)
7	High	Damage to components or tools resulting in shutdown (1 minute – 15 minutes)
8	Very High	Damage to components or tools can disrupt the system very serious so that the production process experiences a shutdown
9	Dengerous	Damage to components or tools that can cause work accidents and the production system stops for an unspecified time
10	Very Dengerous	Causes component damage that can cause accidents suddenly a and endanger work safety

Table 2. Occurrence Rating

Score	Occurrence	Description
1	Never happened	Never happened
2	Very rarely happened	Almost never happened in ≥ 210384 /hour (24 years)
3	Small	Very rarely happened in time ≤ 157788 - 210384 /hour (18-24 years)
4	Rarely happened	Rarely happened in time ≤ 113958 – 157788 /hour (13-18 year)
5	Low	Low occurs within time ≤ 70128 - 113958 /hour (8-13 year)
6	Moderate	Medium occurs within ≤ 8766 – 43830 /hour (1-5 year)
7	Often occurs	Fairly high within ≤ 4380 - 8766 /hour (6 month-1 year)
8	Very High	High occurs within ≤ 730 - 8766 /hour (1 month-6 month)
9	Often occurs	Very high occurs within ≤ 168 - 730 /hour (1 week – 1 month)
10	Occurs so frequently that damage cannot be avoided	Almost any time ≤ 24 - 168 / hour (1 day – 1 week)

Table 3. Detection Rating

Score	Detection	Describtion
1	Almost Certain	The ability of the tool/control system used to detect potential failures is almost certain
2	Very High	The ability of the control device/system used to detect potential failures is very high
3	High	The ability of the tool/control system used to detect high potential failures
4	Medium High	The ability of the tool/control system used to detect potential failures is moderate to high
5	Moderate	The ability of the tool/control system used to detect potential failures is moderate
6	Low	The ability of the tool/control system used to detect potential failures is low
7	Very Low	The ability of thethe control system used to detect potential failures is very low
8	Small	The capability of the control system/tools used to detect potential failures is small
9	Very Small	The capability of the control devices/systems used to detect potential failures is very small
10	There is no chance to be foundi	There is no control device/system capable of detecting a potential failure

3 Results and Discussion

The amine contactor unit is divided into three main components. There are pipes, valves, and instruments. Risk assessment, which FMEA carries out, was also separated by those three components. Based on the method described above, in each component, it has been identified what potential failures can occur, what the effects are, and what are the levels of severity (refer to Table 1). Through FMEA, it has also been traced what are the failure effects and how are the probability or occurrence levels of those events (refer to Table 2). Not only based on the assessment of those two aspects (severity and occurrence), through FMEA, it has also been identified what are current control processes or detections for each potential failure and how effective the current control processes are (refer to Table 3).

The pipe component is divided into several parts, as listed in Table 4. The failures found in this component include gas leak, excess pressure, damaged valve (stuck), corrosion, and MDEA liquid leak. Some of the effects of those failures include leaks in connecting pipes, gas out, environmental pollution, poisoning and death, fire, or unit shutdown. PT X should be aware of the highest failure potential in each sub-component. In the gas inlet pipe, amine inlet pipe, and amine outlet pipe, valve damage is the highest potential failure because it can cause unit shutdown. This damage can occur because of the age of the valve, especially in the valve handle, which must be routinely maintained [9]. Whereas at the gas outlet pipe, the highest potential failure is corrosion. Corrosion can occur due to the frequent passage of gas [9]. Corrosion of the pipes can also cause unit shutdown.

Table 4. RPN in Each Component

Component	Sub-Component	RPN
Pipes	Gas Inlet Pipe	266
	Gas Outlet Pipe	202
	Amine Inlet Pipe	188
	Amine Outlet Pipe	183
Valve	Amine Inlet Valve	148
	Gas Inlet Valve	216
	Amine Outlet Valve	172
Instrument	Level control valve (LCV)	258
	Pressure safety valve (PSV)	237
	Level transmitter	96
	Flow transmitter	90
	Pressure Differential Indicator Transmitter (PDIT)	48

Based on Table 4, the highest RPN is in the gas inlet pipe. A detailed description of the FMEA risk assessment for gas inlet pipes can be seen in Table 5. The inlet pipe has four potential failures, namely, H_2S gas leaks, excess pressure, valve damage, and corrosion. PT X should carry out several controls to minimize the risks. Measuring pipe thickness every three years, routine monthly inspections, and calibrating fire detectors regularly [3] are control measures that PT X can adapt to minimize these risks. Through FMEA, those control measures effectively minimize risk because the RPN is reduced to 12.

Like the previous component, the valve component is divided into several parts shown in Table 4. Amine inlet valve, gas inlet valve, and amine outlet valve are three sub-components with similar potential failures with pipe components. One potential failure not found in pipe components was H_2S gas leaks. This failure has the highest risk in the gas inlet valve sub-component. The effect can cause a fire which will spread to other units and cause poisoning [7]. H_2S is a toxic gas and substance. Exposure exceeding ten ppm will cause dizziness and even death [1]. The highest RPN is in the valve gas inlet can be seen in Table 6.

In the instrument component, there are five sub-components, consisting of a level control valve (LCV), pressure safety valve (PSV), level transmitter (LV), flow transmitter (FT), and pressure differential indicator transmitter (PDIT). The identified failure modes on the instrument components differ from the two previous components. Several modes of failure for this component are diaphragm valve leak, rich amine leaking, corrosion, broken valve spring in PSV, gas leak, stuck flooter, error flow transmitter reading, eroded orifice, and the pressure difference between Upstream V-104 and Downstream V-104 cannot be read.

An amine contactor is a unit that continuously operates for 24 hours. Thus, the flow of MDEA never stops. This continuous fluid friction can cause corrosion of the instrument. Corrosion can cause a diaphragm valve leak. This condition can cause overpressure because the liquid passes to the regenerating amine [3]. In addition, corrosion can cause eroded orifice, which can cause inaccurate readings.

The usage age of an instrument is also important to be monitored because the older the instrument is, the lower its performance will be. The valve spring in PSV can also be damaged as it gets old. This hazard must be avoided because the amine contactor unit contains dangerous gas. If the gas leak, it can cause fire and even death [10]. Apart from usage age, the volume of liquid also needs to be controlled. The volume should be, at most, the required volume. When the fluid volume is insufficient or excessive, it can cause the flooter to get stuck and cause a leak or even make an alarming error. Alarms are also an essential part of an instrument, especially in warning workers if conditions are not as required. PDIT is one of the instruments in the amine contactor unit that measures two negative pressures in pipes. Error alarm conditions can send wrong signals and data to the control room.

FMEA results show that the highest RPN is at LCV show in Table 4. A detailed description of the risk assessment of the LCV instrument can be seen in Table 7. Control measures that can be carried out include routine checking every 3 - 6 months, routine inspections every month, and checking the lifetime of tools with a calibration period.

Based on historical records at PT X, failure can occur in two conditions. First, when there is a flow of gas entering under high-pressure conditions. Second, when the valve handle is damaged, both conditions caused the system to shut down and needed some attention because it was very detrimental to the company. Corrosion is a potential cause of failure from the three main components in the amine contactor unit. Three factors can cause corrosion: (1) Weather variation. Seasonal changes will cause corrosion outside the pipe wall, which can be controlled with an anti-rust coating to protect the pipe from hot or rainy weather. (2) Pipe life. This factor can cause corrosion on the inside of the pipe. Since 1997, PT X has never inspected the inner pipe wall. (3) Frequent passage of gas in pipes is also a cause of corrosion.

Table 5. FMEA assessment of gas inlet pipes

Mode of failure	Effect of failure	S	Cause of failure	O	Current process control	D	RPN	Recommended action	S	O	D	RPN
Leaking gas	Fire	9	Leaking pipe	1	Routine maintenance	3	27	Routine checking of pipe thickness every three years, routine inspection every month, checking the gas detector during the calibration period	4	1	3	**12**
	Poisoning and death	9	Tool or instrument fault	1	Routine inspection	3	27					
Over pressure	Connecting pipe experienced a leak	9	Error /damage to the reader	1	Routine maintenance	2	18					
	H_2S gas came out	9	The instrument pressure detector and gas detector were not read	1	Routine Inspection	2	18					
	Facility shut down	8	Error during the operation process	2	routine maintenance	2	32					
The valve was damaged (stuck)	Experiencing shut down	8	damage to handle valve	2	Maintenance and routine inspection	3	48					
Corrosion	Experiencing shutdown	8	Weather	1	Routine maintenance	3	24					
			Frequent passage of gas	2	Routine corrosion inspection	3	48					
			Usage age	1	Routine maintenance and routine corrosion inspection	3	24					
			Total				266					

Note: S is Severity, O is Occurrence, D is Detection, and RPN is Risk Priority Number

Table 6. FMEA assessment of gas inlet valves

Mode of failure	Effect of failure	S	Cause of failure	O	Current process control	D	RPN	Recommended action	S	O	D	RPN
H_2S gas leaking	poisoning and death	9	errors in tools or instruments	1	Routine maintenance	3	27	Routine checking of pipe thickness every 1-2 years, routine inspection every month, checking the gas detector during the calibration period	4	1	3	**12**
	valve not functioning properly	9	damage to the valve handle	2	Routine inspection	3	54					
	fire	9	leaking valve	1	Routine maintenance	3	27					
Corrosion	Gas leaking	9	frequent gas passage	2	Routine maintenance	2	36					
	Shut down facility	8	weather	1	Routine corrosion inspection	3	24					
			Lifes	2	Routine maintenance	3	48					
			Total				216					

Note: S is Severity, O is Occurrence, D is Detection, and RPN is Risk Priority Number

Table 7. FMEA assessment of Instrument level control valve (LCV)

Mode of failure	Effect of failure	S	Cause of failure	O	Current process control	D	RPN	Recommended action	S	O	D	RPN
Diaphragm valve leak	fluid passing	8	exposed to H2S carried by Amine	2	Routine maintenance	3	48	Routine checking every 3 - 6 months, carrying out routine inspections every month, checking the lifetime of tools that have a calibration period	2	1	3	**6**
	exceeds liquid capacity	7	spilled liquid	2	Routine calibration	3	42					
	leaking	8	damage to valve	1	Routine maintenance	3	24					
Liquid amine leaking	valve not functioning properly	8	Lifes	2	Routine maintenance	3	48					
Corrosion	has shutdown	8	Friction occurs	2	Maintenance and routine corrosion checking	3	48					
			exposed to H2S carried by Amine	2	Routine inspection	3	48					
			Total				258					

Note: S is Severity, O is Occurrence, D is Detection, and RPN is Risk Priority Number

4 Conclusion

The risk identification and assessment of the amine contactor using the FMEA method were performed. Based on the results of identifying the amine contactor, three leading equipment, and components have a risk of process failure. First is Pipe. Potential risks are identified in the gas inlet pipe tools and components, including pipe leaks, valve damage, and corrosion. The second is Valves. Potential risks are identified in the gas inlet valve tools and components, including leaks and corrosion. Finally is the Instrument. Potential risks in the instrument level control valve are identified, including the diaphragm leaking valve, liquid amine leaking, and corrosion. Recommendations for control measures that can be taken to minimize the occurrence of process failures in the amine contactor unit are providing a maintenance schedule for components or tools, carrying out regular and routine inspections, and checking the calibration date on the instrument. Through the FMEA method, the recommendation to improve the control measure can reduce the risk, which can be seen in each component's final RPN.

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