Hazard and Operability Study and Risk Management Case Study: Phosphoric Acid Concentration Process in Petrochemical Plant - Indonesia

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***Abstract*— A Phosphoric Acid evaporation system happens in concentration process. The biggest potential harm can happen in evaporation system as a result of the leak in the Heat Exchanger, so harm and risk evaluation is needed. Harm evaluation is done by dividing the node into Heat Exchanger, Lower Evaporator, and Upper Evaporator, Guide World that obtained based on Control Chart. Risk appraisal that based on the Risk Matrix is consists of Likelihood and Consequences appraisal. Based on the analysis done, there are two instruments have potential harm and high risk such as Flow Transmitter Steam Inlet and Pressure Transmitter in Evaporator. Both of them five value of Likelihood and three points of Consequences. In order to lower the risk, the replacement of Specification Instrument is needed so that the instrument will be in accordance with the properties of fluid that very corrosive and abrasive. It needs a re-calibration once in every week when the Shut down Cleaning Process happens. It also needs a Redundant System in Heat Exchanger. Emergency Response Plan is about how to handle emergency situation and minimalist the risk.**

***Index Term*— risk management, heat exchanger, evaporator, HAZOP.**

I. Introduction

Petrochemical Plant Gresik is the biggest fertilizer company in Indonesia. It has three production units consist of Production Unit I with Nitrogen fertilizer as the specialty, Production Unit II with Phonska and SP36 fertilizer as the specialty, and Production Unit III that produces Phosphoric fertilizer, Phosphoric Acid, Sulfuric Acid, AlF_3, Gypsum, and Ammonium Sulfide. Phosphoric Acid is used as the basic material of Phonska fertilizer, SP-36 fertilizer, and Aluminum Fluoride. The production process of Phosphoric Acid is divided into three steps, reduction, filtration, and concentration [1].

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Evaporation system occurs in the concentration step. This system consists of some components that support the Phosphoric Acid. This process will increase the concentration of Phosphoric Acid, so it can reaches the set point. The use of heat exchanger is expected to make the concentration of Phosphoric Acid reaches until 48%t. While the concentration of inlet is expected to reach until 45 %. The components supporting the evaporating system sometimes can have downtime condition, stuck, or even trip. Stuck condition in the evaporating system that usually happens is a leak caused by steam in heat exchanger that can affect the evaporator (D-2501). The trip condition also sometimes happens in the pump that used as Phosphoric Acid carry-over in evaporating system. Both of these problems can cause a bad impact in the production process, harm, and risk. In order to prevent the bad condition, HAZOP method can be used in the instrument of production process [1,12].

By doing HAZAD study the danger point of each loop controller can know the level of danger. For loop control of the process can be guaranteed that when the level of risk at a safe level as indicated by the green color of the risk matrix, then the function condition of safety integrity can be guaranteed. Conversely, if the state of a particular loop is at a moderate level or danger it can be ascertained that the condition was integrity safety level can be improved by redesigning. So that the safety integrity level can be maintained according to the needs of the system design or specific control loop [2,5].

II. Materials and Methods

The process consists of some main process using equipments such as Heat Exchanger E-2501, Unit Evaporator D2501 and Circulation Pump P-2501. That equipment can be divided into some Node Instrument Loop Control that later the potential harm and risk will be identified shown in Figure 1. In this process, the data that consists of maintenance data, process data, Piping and instrument Drawing (P&ID), and Probability failure demand (PFD) from evaporating system in Phosphoric Acid are collected. The maintenance data is processed for likelihood and Mean Time to Failure (MTTF) the maintenance data and period of time used is 4 years 3 months started from January 2010 until March 2014 [1,5,6].

The process data obtained from some transmitters by the recorder and indicator controller in its plant is also needed. The process data is based on the monthly data record of March 2014. In the real situation, Phosphoric Acid evaporation system has ever experienced a shutdown condition in March 22nd-23rd, 2014.

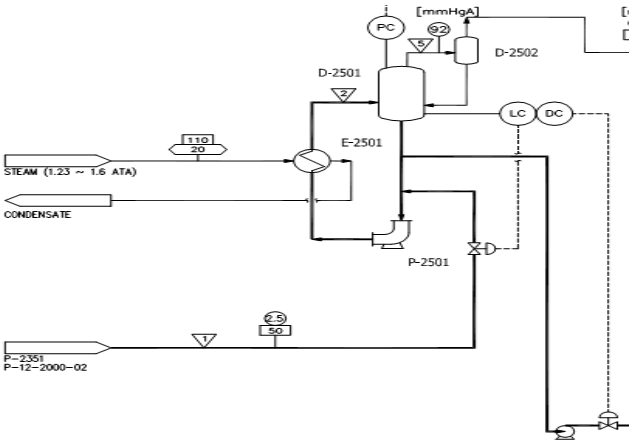

Fig 1. P&ID of phosphoric acid evaporating system [1]

HAZOP method is a method to analyze and identify the potential harm in the process of the plant systematically. HAZOP method is used to evaluate the process done in the plant, especially those which don't stay in line with the operation design. HAZOP method has some steps that begin with plant flow process analysis. After it has been analyzed, the node can be determined in the plant by either P&ID (Piping and Instrument Diagram) or PFD (Process Flow Diagram) that later the guide word from every single instrument in the node also can be determined. After it has been determined, the problems that could be happened along the operability process must be identified. If there are some problems occurred, the causal of the problems and the solution in the form of recommendation should be determined. Briefly, this diagram will explain the HAZOP study shown in Figure 2. [4,6,7].

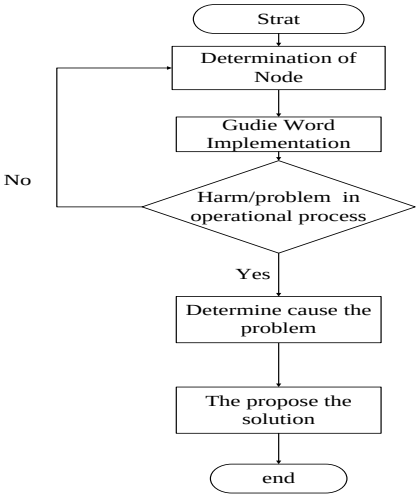

Fig 2. Flowchart of HAZOP study [6]

Risk is a possibility that could be happened after the work done can cause a loss as a consequence. In the other word, risk is a compilation between likelihood value and consequence value. After doing the harm identification, the next step that must be done is predicting the risk by risk assessment in the second step and risk management analysis in the third step. The criteria of the risk can be obtained from likelihood equation. In this equation, the value used is from maintenance data. Likelihood equation is shown [5,8,9].

$$LE = OT/MTTF \quad (1)$$

Where
LE= Likelihood equation
OT= operation time, in hour
MTTF = mean time to failure

TABLE I
RISK MATRIX STANDARDS [1]

Likelihood	Consequences				
	Tool C Category 1	Tool B Category 2	Tool A&B Category 3	Tool A Category 4	Tool A &L Category 5
1.(Brand New / Excellences)	L 1	L 2	L 3	L 4	M 5
2.(Very Good / Serviceable)	L 2	L 4	M 6	M 8	M 10
3.(Acceptable/Barely Acceptable)	L 3	M 6	M 9	M 12	H 15
4.(Below Standard / Poor)	L 4	M 8	M 12	H 16	H 20
5.(Bad or Unusable)	M 5	M 10	H 15	H 20	H 25

Where:
L (green color) = Low *risk*
M (yellow color) = Moderate *risk*
H (red color) = High *risk*

Control chart is a statistic graph used to explain the control boundary of the process that consists of upper boundary, lower boundary, and centre boundary. Control chart shows whether the process is in or out of control. The example of control chart shown in Figure 3.

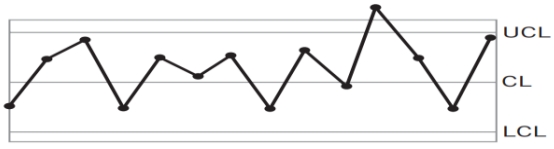

Fig 3. Control Chart [3,9]

Control chart $\bar{x}$ equation is influenced by the middle standard deviations value, so the equation below can be used [3,10].

$$UCL = \bar{\bar{x}} + A_3\bar{s} \quad (2)$$

$$CL = \bar{\bar{x}} \quad (3)$$

$$LCL = \bar{\bar{x}} - A_3\bar{s} \quad (4)$$

Where:

$\bar{\bar{x}}$ = the average of mean ($\bar{x}$)
$\bar{s}$ = the average of standard deviation(s)
$A_3 = 3/(c_4\sqrt{n})$
With C_4 as a constant that forms control chart variable (Douglas, 2009). The equation that used to determine the control chart is shown below [3,11].

$$UCL = \bar{s} + 3\frac{\bar{s}}{c_4}\sqrt{1 - c_4^2} \quad (5)$$

$$CL = \bar{s} \quad (6)$$

$$LCL = \bar{s} - 3\frac{\bar{s}}{c_4}\sqrt{1 - c_4^2} \quad (7)$$

Average is the middle value that can be obtained from the data provided [2,10].

Emergency Response Plan analysis is done in the potential risk that can influence the production process. Lacking is one of the example if the potential failure that can influence a big impact to the production process. Harm evaluation and risk management that have been arranged can be formed into an assessment table in the form of worksheet table. This table contains harm evaluation, risk analysis, and recommendation as a handling.

III. Results and Discussion

Before determining the guide word and deviation from each instrument, the node is needed so that the classification will be easier. After the node is determined, a control chat can be made from each instrument. From the control chart, the guide word and the deviation shown in the Table 2. The Piping and instrument drawing of heat exchanger shown in Figure 4.

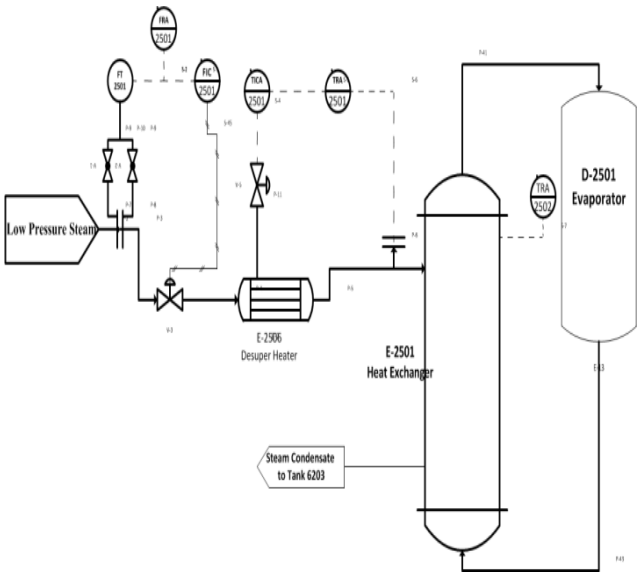

Fig. 4. P&ID of Heat Exchanger [1]

Based on the data process from node in heat exchanger, here below is the control chart for TR 2501 shown in Figure 5.

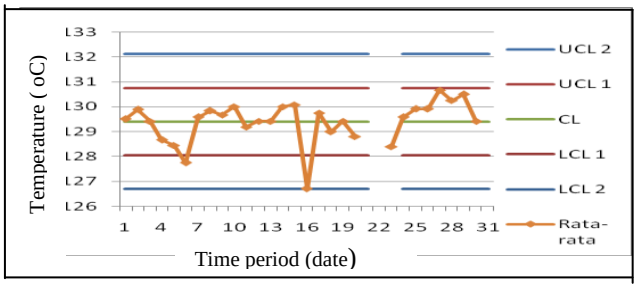

Fig 5. Control chart of TR-2501 with two boundaries HE

From the control chart, the guide world from each instrument can be determined and resulting the following Table II [8-10].

TABLE II
Guide word and deviation of Heat Exchanger

Instrument	Guide Word	Deviation
Flow Transmitter (FT 2501)	More	More Flow
	Less	Less Flow
Flow Indicator Controller (FIC 2501)	More	More Flow
	Less	Less Flow
Temperature Indicator Controller (TIC 2501)	As well as	As well as Temperature
Temperature Recorder (TR 2501)	Low	Low Temperature
Temperature Recorder (TR 2502-2)	High	High Temperature
	Low	Low Temperature

The Piping and instrument drawing of evaporator is shown in Figure 6.

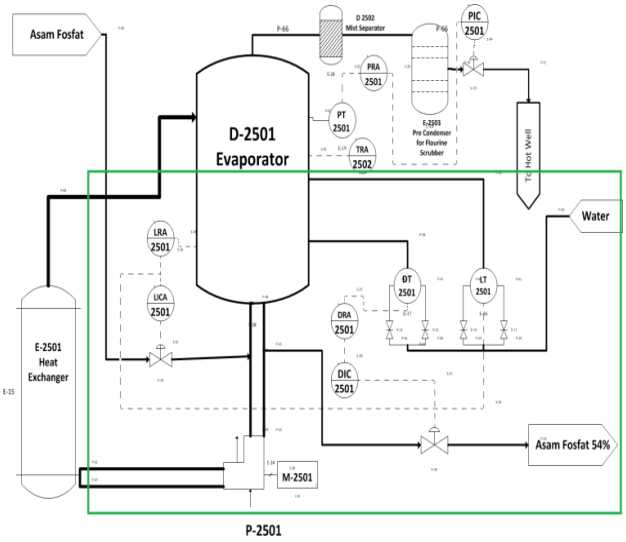

Fig 6. P&ID of Evaporator [1]

Based on the data process of node in the bottom evaporator, the control chart of PT-2501 is shown Figure 7.

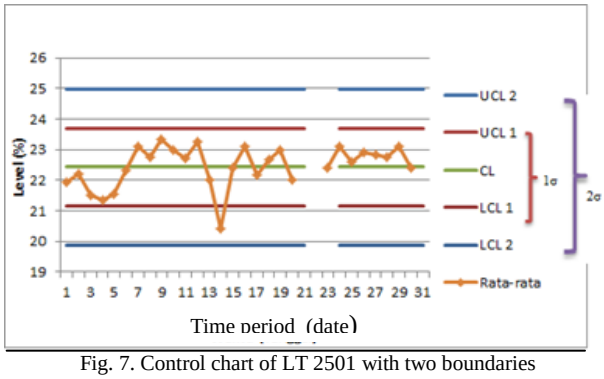

Fig. 7. Control chart of LT 2501 with two boundaries

Guideword in the upper part of evaporator results a deviation explained in Table III.

TABLE III
GUIDE WORD AND DEVIATION OF BOTTOM EVAPORATOR

Instrument	Guide Word	Deviation
Level Transmitter (LT 2501)	More	More Level
Level Indicator Controller (LIC 2501)	More	More Level
Density Indicator Controller (DIC 2501)	More	More Density
Monitor (M 2501) / P2501	Less	Less Flow
	More	More Flow

P&ID upper of Evaporator shown Fig.8.

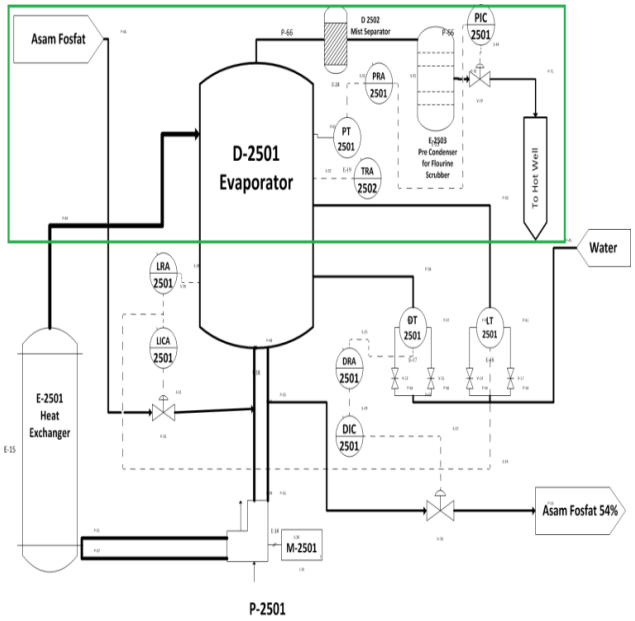

Fig 8. P&ID the upper part of evaporator [1,13]

Based on the data process of node in the upper evaporator, the control chart of PT 2501 is shown Figure 9.

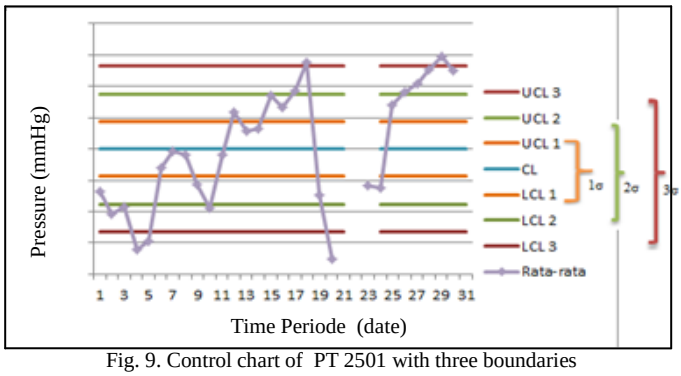

Fig. 9. Control chart of PT 2501 with three boundaries

TABLE IV
GUIDEWORD AND DEVIATION OF THE UPPER EVAPORATOR

Instrument	Guide Word	Deviation
Temperature Recorder (TR 2501-1)	Low	Low Temperature
	High	High Temperature
Pressure Transmitter (PR 2501)	Low	Low Pressure
	High	High Pressure
Pressure Indicator Controller (PIC 2501)	Low	Low Pressure

Risk Assessment, Likelihood determination is based on the calculation of the operation duration versus the Mean Time to Failure (MTTF). The MTTF value is determined from the maintenance data. Likelihood determination of some instruments that found in each is shown in the Table V–VII.

TABLE V
LIKELOHOOD CRITERIA DETERMINATION OF HEAT EXCHANGER
GUIDEWORD AND DEVIATION OF THE UPPER EVAPORATOR

Tax No. Instrument	MTTF (hr)	Likelohood (LL)	Criteria of LL
FT -2051	3100	6.04	5
FIC-2051	4328	2.16	2
TIC-2051	1680	1.29	1
TR -2051	168	4.29	5
TR -2052	4932	2.04	2

TABLE VI
DETERMINATION OF LIKELOHOOD CRITERIA FOR BOTTOM EVAPORATOR

Tax No. Instrument	MTTF (hr)	Likelohood (LL)	Criteria of LL
LT -2051	1645	11.38	5
LIC-2051	2280	2.21	2
DIC-2051	504	1.43	1
M -2051 P-2501	3672	1.18	1

TABLE VII
DETERMINATION OF LIKELOHOOD CRITERIA FOR UPPER EVAPORATOR

Tax No. Instrument	MTTF (hr)	Likelohood (LL)	Criteria of LL
TR -2051-1	4280	3.03	5
PT-2051	2085	6.95	5
PIC-2051	13008	1.00	1

Determination of Consequent; Consequences are determined on qualitative that based on how much the loss and how it affects either the production process or the instrument related to the production process. Consequences determination of some instruments that can be divided into some nodes can be expressed in Table VIII-Table IX.

TABLE VIII
CONSEQUENCES CRITERIA HEAT EXCHANGER

Instrument	Deviation	Consequences criteria
FT 2501	More Flow Less Flow	3
FIC 2501	More Flow Less Flow	4
TIC 2501	As well as Temperature	1
TR 2501	Low Temperature	2
TR 2502-2	High Temperature	2
	Low Temperature	3

TABLE IX
CONSEQUENCES CRITERIA IN BOTTOM EVAPORATOR

Instrument	Deviation	Conequences criteria
LT 2501	More Level	1
LIC 2501	More Level	2
DIC 2501	More Density	3
M 2501 (P-2501)	Less Flow	3
	More Flow	5

TABLE X
CONSEQUENCES CRITERIA OF UPPER EVAPORATOR

Instrument	Deviation	Conequences criteria
TR 2501-1	Low Temperature High Temperature	4
PT 2501	Low Pressure High Pressure	3
PIC 2501	Low Pressure	1

To determine the risk criteria of each instrument, the criteria of likelihood must be combined with the criteria of consequences by risk matrix. In the risk matrix, the risk level has been classified into combination between likelihood and consequences. Each risk level is expressed in a different color. Here below is the risk analysis result with risk matrix that has been classified into some nodes shown in Table XI-Table XIII.

TABLE XI
RISK MATRIX OF HEAT EXCHANGER

Likelihood	Consequences				
	Tool C Category 1	Tool B Category 2	Tool A&B Category 3	Tool A Category 4	Tool A&L Cate Gory 5
1. (Brand New / Excellences)	(1) L 1				
2 (Very Good/ Serviceable)		(1) L 4	(1) M 6	(1) M 8	
3. (Acceptable/ Barely Accept.)					
4. (Below Standard / Poor)					
5. (Bad / Unusable)		(1) M 5	(1) H 15		

Table VIII is shows that some heat exchangers have high risk. The high level of risk is caused by Flow Transmitter (FT 2501.

TABLE XII
RISK MATRIX OF BOTTOM EVAPORATOR

Likelihood	Consequences				
	Tool C Category 1	Tool B Category 2	Tool A&B Category 3	Tool A Category 4	Tool A&L Category 5
1. (Brand New/ Excellences)			(2) L 3		(1) M 5
2. (Very Good/ Serviceable)		(1) L 4			
3.(Acceptable/ Barely Accept.)					
4. (Below Standard / Poor)					
5. (Bad / Unusable)	(1) M 5				

From Table XI, shows that most of the instruments have low level of risk. And Table XII

TABLE XIII
RISK MATRIX OF UPPER EVAPORATOR

Likelihood	Consequences				
	Tool C Category 1	Tool B Category 2	Tool A&B Category 3	Tool A Category 4	Tool A&L Category 5
1. (Brand New / Excellences)	(1) L 1				
2 .(Very Good/ Serviceable)					
3 .(Acceptable / Barely Accept.)				(1)M 12	
4 .(Below Standard / Poor)					
5. (Bad / Unusable)			(1) H 15		

Table XIII shows that there are three instruments, but one of it has high risk. This condition is caused by Pressure Transmitter (PT 2501) on the evaporator [1].

Emergency Response Plan (ERP) is guidelines of emergency situation handling in a plant that happens in the work hours. ERP is the effort done by the company to handle the emergency situation of the factory, from the initial handling up to rehabilitation. It is consists of some procedures. Emergency situation such as the leak of hazardous and poisonous material can leads to damage in the company assets, threaten people's health, and also damage the environment. So, ERP is done by the company to handle the emergency situation of the factory, from the initial handling up to rehabilitation.

Based on the evaluation result, it can be seen that the highest risk and harm potential in the heat exchanger happens in the Flow Transmitter (FT 2501) steam inlet. While in evaporator, the highest risk and harm happens in Pressure Transmitter (PT-2501).There are two instruments in Phosphoric Acid evaporating system that have high harm potential and risk. Both of the instruments have the same score and risk condition. It is 15 for the score and in High Risk condition. These two instruments are FT 2501, placed in node of heat exchanger, and PT 2501, placed in node of the upper part of the evaporator. Comparing these two instruments, FT 2501 has bigger consequences because it can experience a leak and it takes a lot of time to heat the Phosphoric Acid, so it can interrupt the process. While PT 2501 has consequence that can leads to a failure in production process, so shutdown can be happened in evaporating system. Therefore, recommendations need to be done in order to prevent the emergency situation.

When the emergency situation happens suddenly, ERP needs to be done. ERP is about the procedure to handle the emergency situation and some parties that related and responsible. The provision of ERP is all the human resource in the factory must be able to handle the emergency situation. Moreover, the facilities provided in the company such as phone operator to build communication among the employees, fire truck from fire department, and medical equipment from medical team of Houspital Petrochemical Plant (RSPG)[1,14].

IV. Conclusion

Based on the evaluation of the result and discussion that has been done, the conclusion is instrument that has harm potential and high risk is Flow Transmitter, Heat Exchanger, and Pressure Transmitter. Flow Transmitter has five score of likelihood, meaning the risk happens more than four times every month. While Pressure Transmitter has five score of likelihood and both of it have three score of consequences. In order to lower the risk, the replacement of Specification Instrument is needed so that the instrument will be in accordance with the properties of fluid that very corrosive and abrasive. It also needs a re-calibration once in every week when the Shutdown Cleaning Process happens. Then, Redundant System needs to be added in Heat Exchanger E-2501, because the biggest harm potential happens in the Phosphoric Acid evaporating system that caused by the leak. So, ERP is needed to handle the emergency situation and lower the risk.

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