Reliability And Safety Study In Furnace "Hydro treate Thermal Distillated " At Oil Refinery Plant Cilacap-Indonesia

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Abstract - Low Pressure Stripper Reboiler 018F102 is furnace located in unit 18 Hydro treaded Thermal Distillate, Fuel Oil Complex (FOC) II, PT. PERTAMINA Refinery Unit IV Cilacap. Furnace 018F102 serves to heat the bottom product of the column low pressure stripper 018C102 until the temperature reaches 317 ^{O}C. The role of the reboiler is very important, so the reliability of the reboiler must be maintained. Reliability calculation is performed to develop maintenance strategy, so that can know the level of security of an instrument (SIL). Thus, the damage and failure of the instruments, as well as the risks posed can be predicted earlier and anticipated. From the evaluation, the recommendation of scheduling preventive maintenance and the consequence of labor risk borne by the company. Level of reliability on Low Pressure Stripper Reboiler 018F102 with operating time of 500 hours, 1000 hours and 2000 hours is 0.58; 0.49 and 0.32. While the safety level is in SIL 1. The risk consequences of the workforce covered by the company within 6 years (2009-2015) is IDR 42,569,783,34.

Keywords: rebuilder, reliability, safety, SIL
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I. INTRODUCTION

The rapid development of industrial sector in Indonesia caused the increasing of energy demand. The energy crisis that hit the early world of the 21st century caused world oil prices to climb to a record USD 120 per barrel for the first time since August 22, 2008. Demand for petroleum and gas as one of natural resources for fuel is increasing (Wildan, 2011) . One of the state-owned companies engaged in the field of petroleum namely PT. Pertamina (Persero). PT. Pertamina has seven processing units, one of which is PT. Pertamina Refinery Unit (RU) IV Cilacap. PT. Pertamina RU IV Cilacap process crude oil (crude oil) into the form of fuel (fuel oil), non fuel, and petrochemicals. Refinery at PT. Pertamina RU IV Cilacap currently produces 348,000 barrels / day from its maximum capacity of 548,000 barrels / day. This plant is very strategic because it supplies 44% of national fuel needs or 75% of fuel needs in Java. When a process failure occurs at PT. Pertamina RU IV Cilacap, it will have an impact on the inhibition of fuel supply (Pertamina, 2008).

The process of producing processed crude oil requires a very complex control system and instrument, where each part of the process is very important and connected to each other. One of the most important process equipment is heating to heat the product in a process. One such instrument is a reboiler, where the reboiler can be either a furnace (kitchen) or a heat exchanger. The main function of the reboiler is to reheat the raw material of a process, for example in a process in a distillation unit (Pertamina, 1997). The role of the reboiler is very important, so the

reliability of the reboiler must be maintained. One way to maintain the reliability of an instrument is to perform maintenance on the unit. The types of maintenance232that is often used to maintain and maintain the performance of reboiler is by doing a systematic treatment. Reliability calculation is done to develop maintenance strategy, so it can know the security level of an instrument (SIL). If this is further assessed based on data reliability and SIL levels, we can conduct a review of the security system as well as the risks to be incurred. Thus, the damage and failure of the

Therefore, it is necessary to evaluate the reliability of each reboiler component. Evaluation is done by calculating the value of reliability, safety, and risk management. From these evaluations can be done recommendation scheduling preventive maintenance and the consequences of labor risk borne by the company. Based on the problem, in this final project conducted Reliability and Safety Analysis at Low Pressure Stripper Reboiler 018F102 Unit Hydrotreated Thermal Distillate Fuel Oil Complex II at PT. Pertamina RU IV Cilacap

II. MATERIAL AND METHODS

2.1. Furnace

Furnace is a process equipment used to raise the temperature of a fluid by using combustion heat from liquid fuel and gas fuel burning in the burner. The combustion process inside the furnace is done by the principle of fire triangle using fuel, lighters and air. The main purpose of furnace is to heat the fluid in accordance with the prescribed temperature, in order to be processed in the next process (Basuki, 2009). The process of heat transfer that occurs using radiant heat radiating in the crude oil that flows in the tube. The main room where radiant heat that takes place inside the furnace is called a radiant fire-box or combustion chamber. Liquid or gaseous fuels (or a combination of both) are fed into the furnace after being mixed with combustion air inside the burner and ignited. Heated crude oil is generally flown first through the convection section located between the combustion chamber and the chimney, in order to utilize the heat contained in the combustion gases.

2.2. *Reliability* (Keandalan)

Reliability is the possibility of a component or system to operate or perform its functions. The function has been specified in certain operating conditions and in certain environments for a specified time period as well. Thus, reliability is the possibility of not failing or being able to perform its function over a period of time (t) or more. To calculate the value of reliability can be used the formula as below (Ebeling, 1997):

$$R(t) = 1 - F(t) = \int_0^{\infty} f(t)dt \qquad (2.1)$$

With:
F(t) adalah Cumulative Distribution Function (CDF)
R(t) adalah Reliability Function
f(t) adalah Probability Density Function (PDF).

2.3. *Safety Integrity Level* (SIL)

Safety Integrity Level is a security level of an instrument component that configures with Safety Instrumented System (SIS) such as sensor, logic solver, and final element. SIL can also be defined as the relative level of risk reduction. SIL is the required performance measurement for the safety of instrumentation function (SIF). Safety Instrumented Function is a safety function with a specific level of safety

integrity, which is required to achieve functional security. An SIF may consist of safeguards aimed at securing a process unit, machinery from more fatal damage and operator safety. To know the value of SIL used in a component then first know the value of failure rate then determine Probability Failure on Demand (PFD). PFD

$$PFD = \frac{\lambda Ti}{2} \quad (2.2)$$

Which:
= component failure tate
Ti = *test interval*

After knowing the value of PFD from each component, then look for SIL value level by looking at range of PFD and Risk Reduction Factor (RRF) value. RRF is the level of risk reduction of a component. The amount of RRF is formulated in the following equation.

$$RRF = \frac{1}{PFD} \quad (2.3)$$

In accordance with equation 2.3, the magnitude of RRF is inversely proportional to the value of PFD. Thus, the greater the value of the PFD will be the smaller the level of risk reduction in a component, and vice versa. The SIL value is not a mathematical calculation, but only a conversion value of the PFD and RRF values obtained in accordance with IEC 61508 standard as shown in Table 2.1.

Table 2.1: Level Value of *Safety Integrity Level* (SIL)

Safety Integrity Level (SIL)	*Probability of Failure on Demand* (PFD)	*Risk Reduction Factor* (RRF)
4	< 0,0001	>10.000
3	0,001-0,0001	1.000-10.000
2	0,01-0,001	100-1.000
1	0,1-0,01	10-100

In the safety standard of IEC 61508/61511 or ISA-TR 84.00.02-2002, SIL is grouped into 4 levels with SIL 4 definition being the highest and reliable SIL value. SIL 4 has a high level of security so that the risk of failure rate is also smaller. While SIL 1 is the lowest SIL value, so it has a low level of security because it has a high failure rate.

The research methodology undertaken in this final project is as follows:

2.4. Literature Study

The study of literature is done by collecting theories that can support the completion of the writing of the final task. The author conducts literature studies by reading books relating to the reliability and safety of the system. The author also browsing on the internet so that the material obtained more varied, such as international journals, and various other references. The author also conducted a field study to find out the real conditions in the company.

2.5. Data Colection

At this stage, data collection related to the topic of Final Assignment is taken. The data are data of company damage in 2009 until 2015, P & ID (Piping and Instrumentation Diagram), PFD (Process Flow Diagram), and Process manual data.
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The data used in this final project is not only written data, but also data from the interview with the instrument technician in the field.

2.6. Data Processing for TTF and TTR

Time To Repair (TTR) data is obtained from daily report of PT. Pertamina

weibull 1-3 data distribution, exponential distribution, normal distribution, to lognormal distribution.

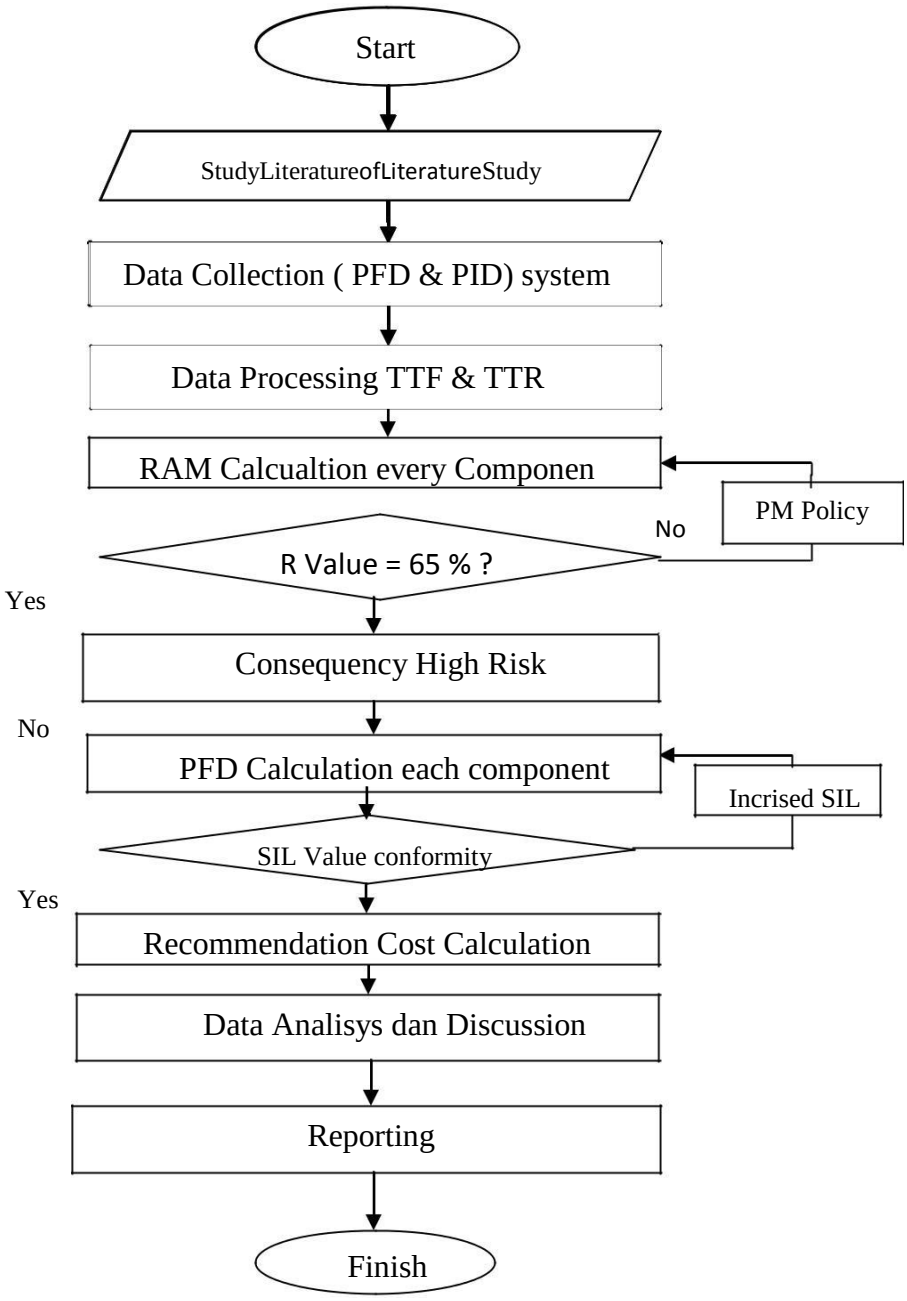

Figure 2.1. : Flowchart research methodology

2.7. Calculation of Reliability, Availability, Maintainability each component

At this stage calculation of reliability, availability, and maintainability of each component. Based on the distribution test using Reliasoft Weibull 6 ++ software assistance can be calculated reliability, availability, and maintainability in accordance

with the recommended distribution results Software Reliasoft Weibull ++ Version 6. The results of reliability can be plotted in a graph relationship between the value of reliability with the operational time. Similarly, the value of availability and maintainability can be calculated using the existing equations in accordance with each recommended distribution. If the component reliability value has reached the

2.8. High Risk Consequent

Determining the consequences of risk is divided into two, which are time-based and cost-based. Time-based losses can be found using the MTTR equation. As for cost-based losses can be calculated based on information obtained from the company

2.9. PFD Calculation Component

Having obtained the value of each component's lambda failure rate, the Probability Failure on Demand (PFD) value is calculated to obtain the SIL level for each component. After knowing the value of PFD from each component, then can find the level of SIL value by looking the range of PFD value according to standard of IEC 61508. If SIL value have fulfilled then do recommendation of cost calculation, if SIL value have not fulfill then need to do SIL increase. Increased SIL can be done by evaluating Safety Instrumented System (SIS) of the plant that has been built.

III. RESULTS AND DISCUSSION

This chapter discusses the reliability and safety techniques of Low Pressure Stripper Reboiler 018F102. Low Pressure Stripper Reboiler 018F102 is furnace in unit 018 Thermal Disitillate HDT, Fuel Oil Complex (FOC) II, PT. Pertamina Refinery Unit IV Cilacap. Furnace is a process equipment used to raise the temperature of a fluid by using combustion heat from liquid fuel or burning gas fuel in the burner. The combustion process inside the furnace is carried out by the principle of fire triangle (fire triangle) using fuel, lighters and air. The air is supplied from the fan ID, then comes out along with the combustion gas on the chimney. In the furnace there is a tube arrangement that functions as a place to flow the heated fluid. The burning flame will heat the outer side of the tube, the heat is absorbed and transferred to the fluid that flows in it.

In the 018 Hydro treated Thermal Distillate FOC II unit, the furnace includes essential equipment in a process that serves to heat the bottom product of the column low pressure stripper 018C102 to a temperature of 317 ° C. Heated Gas Oil (HGO) from 019 Visbreaker and Light Gas Oil (LGO) units derived from the Crude Distillation 011 unit, where crude oil (LGO / HGO) is heated first by furnace 018F101. Bottom product of column low pressure stripper 018C102 is pumped using low pressure stripper bottom pump 018P103 to low pressure stripper reboiler 018F102 to be heated. Once heated, it is returned to column 018C102 to sharpen the fraction separation.

Table 3.1: Component in low pressure stripper reboiler 018F102

Component	Control System		
	HTD	*Fuel Oil*	*MP Steam*
Transmitter	FT 040	PT 023	PT 022
Controller	FIC 040	PIC 023	PDIC 022
Aktuator	FV 040A	PV 023	PV 022

3.1. Maintenance Data

Data collected in the form of data between the time of component damage or (maintenance) company in 2009 to 2015, PFD (Process Flow Diagram), P & ID
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(Piping and Instrumentation Diagram), and Process manual data. Reliability and safety analysis is performed on the instrumentation system components. The components of the instrumentation system in the low pressure stripper reboiler 018F102 are shown in Table 3.1.

TTF data. Table 3.2 is an example of maintenance data, Table 3.3 is the result of TTR and TTF data processing on component FT 040.

Tabel 3.2: Maintenance Data in FT 040

No.	Actual Start	Actual Com-pletion	TTR (Hours)	TTF (Day)	TTF (Hours)
1.	27/09/2010	02/10/2010	15	0	0
2.	05/01/2012	05/01/2012	10	460	11040
3.	29/10/2012	29/10/2012	8	298	7152
4.	02/04/2014	08/04/2014	8	520	12480
5.	29/01/2015	30/01/2015	8	296	7104
Amount			49	1574	37776
Rate			9,8	314,8	7555,2

From the data processing obtained the most appropriate test results of the distribution as shown in Table 3.3.

Tabel 3.3: Data Processing from TTR dan TTF pada FT 040

Data Processing TTR		Data Processing TTF	
Distribution	*Ranking*	*Distribution*	*Ranking*
Exponential 1	4	Exponential 1	4
Exponential 2	1	Exponential 2	5
Normal	2	Normal	3
Lognormal	2	Lognormal	2
Weibull 2	3	Weibull 2	1
Weibull 3	1	Weibull 3	5

Based on the result of TTR data processing on FT 040 component, there are 2 suitable distributions, that is Exponential 2 and Weibull 3 distribution. However, after implementation suggestion from software Reliasoft Waybull ++ Version 6, the most suitable distribution is Exponential 2 with value = 0.2615 and value = 6.4255. As for TTF data processing results, the most suitable distribution is Weibull 2 with value = 3.8112 and = 1.04E + 04. From the distribution and parameters are then used to find the function of reliability as a function of time (R (t)), availability (A (t)), and maintainability (M (t)).

3.3. Analisys Relialibility in Low Pressure Stripper Reboiler 018F102

After the reliability value obtained on each component, it can be calculated system reliability value on Low Pressure Stripper Reboiler 018F102 using a series system configuration equation.

Where;

R_1 = R (FT 040)
R_2 = R (FIC 040)
R_3 = R (FV 040A)
R_4 = R (PT 023)
R_5 = R (PIC 023)
R_6 = R (PV 023)
R_7 = R (PT 022)
R_8 = R (PDIC 022)
R_9 = R (PV 022)

Reliability value in operation 500 hours as;

R_1 = 0,999990
R_2 = 0,995379
R_3 = 0,855545
R_4 = 0,956173
R_5 = 1
R_6 = 0,873445
R_7 = 0,999999
R_8 = 0,874740
R_9 = 0,941344

$R_S = P(E_1 \cap E_2 \cap E_3 \cap E_4 \cap E_5 \cap E_6 \cap E_7 \cap E_8 \cap E_9)$

$= P(E_1)\, P(E_2)\, P(E_3)\, P(E_4)\, P(E_5)\, P(E_6)\, P(E_7)\, P(E_8)\, P(E_9)$

$= (R_1)\, (R_2)\, (R_3)\, (R_4)\, (R_5)\, (R_6)\, (R_7)\, (R_8)\, (R_9)$

It shows that reliability value on Low Pressure Stripper Reboiler 018F102 with operational time for 500 hours is 0.58563. Based on the same equation, the calculation of reliability at 1000 hours and 2000 hours. At the operational time of 1000 hours, obtained reliability value of 0.496308, while at the operating time 2000 hours is 0.321973. The following graph shows the reliability of all components of the constituent control system on Low Pressure Stripper Reboiler 018F102 as in Figure 3.1.

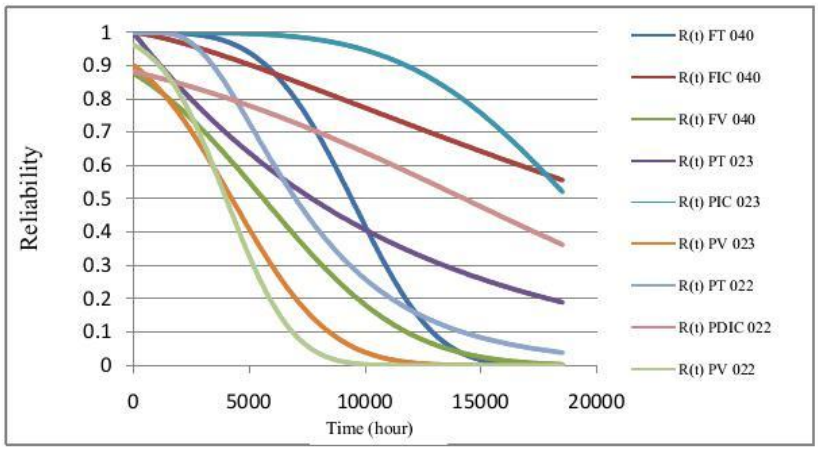

Figure 3.1.: Grafik Reliability System

In Figure 3.1 shows that the PV 022 component has a relatively low reliability degradation versus time. While the PIC 023 component shows that its reliability value is highest against time. Based on the results of data processing has been done, the instrument compiler Low Pressure Stripper Reboiler 018F102 has an increased rate of failure (wear out period). To avoid failure of the instrument prior to its operation, and to detect the beginning of damage, it is necessary to preventive maintenance on each component. The reliability value of each control system component in Low Pressure Stripper Reboiler 018F102 can be improved after preventive maintenance.

The recapitulation results for the maintenance measures of each component of the control system on Low Pressure Stripper Reboiler 018F102 are shown in Table 4.4 below

Table 3.4: Interval Maintenance Base Implemented Preventive Maintenance

No.	Component	Maintenance Interval
1	FT 040	8600 operation hour
2	FIC 040	16700 operation hour
3	FV 040A	4300 operation hour
4	PT 023	5600 operation hour
5	PIC 023	17400 operation hour
6	PV 023	3500 operation hour
7	PT 022	6000 operation hour
8	PDIC 022	11200 operation hour
9	PV 022	3400 operation hour

Thus, the maintenance action on each component that is scheduled systematically and refers to preventive maintenance is more effective to do. Preventive maintenance is done before reaching the operating hours of each component in order to prevent failure. Based on Table 3.4, it is expected to be a

3.4. Hight Risk Consequent

Determining the consequences of risk is divided into two, which are time-based and cost-based. Time-based losses can be found using the MTTR equation. Before determining the highest risk, onsequences, it is necessary to calculate the probability / likelihood value. The following table shows the likelihood value of each component of the constituent control system on the Low Pressure Stripper Reboiler 018F102 for a period of 6 years as shown in Table 3.5.

Table 3.5: Likelihood value in 6 years

Component	MTTF	Likelihood (6 Tahun)
FT 040	7555,2	6,956797967
FIC 040	14912,0	3,524678112
FV 040A	5059,2	10,38899431
PT 023	11104,0	4,733429395
PIC 023	18744,0	2,804097311
PV 023	3898,0	13,48383787
PT 022	9120,0	5,763157895
PDIC 022	17164,8	3,062080537
PV 022	3737,6	14,06250000

The likelihood value provides information on how often a component fails during operation. The value depends on the MTTF value of each component. Based on Table 3.5, the PV 022 component has the greatest likelihood value of 14.0625. It shows that the PV 022 component has been damaged 14 times in 6 years. While the lowest likelihood value is on the PIC 023 component of 2.8040. That is, the PIC 023 component is damaged approximately 3 times over a period of 6 years. Any damage that occurs will result in a loss in terms of time. The following table shows the likelihood and MTTR values of each component of the control system on Low Pressure Stripper Reboiler 018F102 as shown in Table 3.6.

Tabel 3.6 : Likelihood and MTTR value

Component	MTTR	Likelihood (1 year)
FT 040	9,80	1,159466328
FIC 040	6,67	0,587446352
FV 040A	7,80	1,731499051
PT 023	7,60	0,788904899
PIC 023	6,67	0,467349552
PV 023	3,08	2,247306311
PT 022	13,50	0,960526316
PDIC 022	4,75	0,510346756
PV 022	3,33	2,343750000

Based on Table 4.6, PT 022 component has the average time of the greatest improvement, which is 13.5 hours. While the PV component 023 has the average of the smallest repair time of 3.08 hours. The length of time needed to repair the damaged component causes the operating hours of the company to be reduced.

3.5. Analisys Safety in *Low Pressure Stripper Reboiler* 018F102

Safety analysis on Low Pressure Stripper Reboiler 018F102 is done by calculating PFD (Probability Failure on Demand) value to determine safety level or

Table 3.7: Calculation PFD (Probability Failure on Demand)

System	λ (t)	PFD	PFD *average*	RRF	SIL
HTD	2,20598E-05	0,094857	0,25901076	3,860844	SIL 1
	1,11767E-05	0,093325			
	3,29433E-05	0,070828			
FUEL OIL	1,49387E-05	0,041828	0,27137138	3,684987	SIL 1
	1,96645E-05	0,171081			
	3,34068E-05	0,058462			
MP STEAM	1,83 E-05	0,054825	0,1850055	5,405245	SIL 1
	9,71 E-06	0,054375			
	4,46 E-05	0,075806			

As in the previous explanation, Low Pressure Stripper Reboiler 018F102 has 3 control systems with 3 constituent components. Based on the PFD calculation table as shown in Table 3.7, the RRF (Risk Reduction Factor) value can be calculated using equation (2.3). The RRF value indicates the risk reduction level of a component. In Table 4.7 it appears that the smaller the value of PFD, the greater the level of risk reduction in a component. As in the Steam MP control system, its PFD value is 0.185 with a RRF of 5.40. The control system on Low Pressure Stripper Reboiler 018F102 is included in SIL 1, because the PFD value of each control system lies between 0.1-0.01. That is, within a period of approximately 10 years occurred at least 1 time failure. This indicates that the safety level of Low Pressure Stripper Reboiler 018F102 is low.

The safety level of an instrument component that configures with Safety Instrumented System (SIS) such as sensor, logic solver, and final element used are still made in 1980s. Currently, the solenoid used is still 1oo1, and the safeguard used is only an alarm indicator. Therefore it is necessary to support safeguard to increase its SIL value, such as replacing solooid 1oo2 or me-redundant control system components at Low Pressure Stripper Reboiler 018F102. So the PFD equation can be calculated, and the results obtained as shown in Table 3.8.

Tabel 3.8 : Increased level SIL

Sistem	PFD Initial	PFD Initial average	SIL	PFD New	PFD New average	SIL
HTD	0,094857	0,25901076	SIL 1	0,011997	0,0302989	SIL 2
	0,093325			0,011612		
	0,070828			0,006688		
FUEL OIL	0,041828	0,27137138	SIL 1	0,002332	0,0459149	SIL 2
	0,171081			0,039025		
	0,058462			0,004557		
MP STEAM	0,054825	0,18500550	SIL 1	0,004007	0,0156119	SIL 2
	0,054375			0,003942		
	0,075806			0,007662		

3.6. Cost Calculation and Risk Labor Cost per Year

Labor costs are calculated on the basis of the number of workers making improvements, along with the salaries the workers receive each time they make

Table 3.9: Labor Cost

Component	Amoun Labor	Total cost Per/hour (IDR)
FT 040	2	95.000
FIC 040	2	80.000
FV 040A	3	110.000
PT 023	2	105.000
PIC 023	2	80.000
PV 023	3	120.000
PT 022	3	100.000
PDIC 022	2	80.000
PV 022	3	130.000
TOTAL (IDR)		900.000

Based on Table 4.9, the total wage of hourly workers is Rp 900.000,00. Furthermore, to calculate the consequences of labor risk using the RTK equation. The result of labor risk consequences is shown in Table 3.10 below.

Table 3.10: Consequen of Risk Labor

Component	Consequent of RTK
FT 040	6476778,907
FIC 040	1879828,326
FV 040A	8913757,116
PT 023	3777276,657
PIC 023	1495518,566
PV 023	4989020,010
PT 022	7780263,158
PDIC 022	1163590,604
PV 022	6093749,999
TOTAL	42569783,340

From Table 3.10, the labor risk consequences incurred by the company within 6 years (2009-2015) amounted to IDR 42,569,783,34.

4. CONCLUSIONS

Based on the research that has been done, it can be concluded as follows. Reliability level on Low Pressure Stripper Reboiler 018F102 with operating time of 500 hours, 1000 hours and 2000 hours is 0.58; 0.49 and 0.32; The Safety Integrated Level on Low Pressure Stripper Reboiler 018F102 is at SIL level 1. Recommended related reliability at Low Pressure Stripper Reboiler 018F102 Thermal Distillate Unit HDT Fuel Oil Complex II at PT. Pertamina RU IV Cilacap is conducting preventive maintenance or scheduled maintenance actions to extend life time and prevent damage to system components. Of the 9 components analyzed, the following are the most appropriate scheduling treatments:

- FT 040 must be preventive maintenance before 8600 hours of operation.
- FIC 040 must be preventive maintenance before 16700 hours of operation.
- FV 040 must be preventive maintenance before 4300 hours of operation. 241
- PT 023 should be preventive maintenance before 5600 hours of operation.
- PIC 023 must be preventive maintenance before 17400 operating hours.
- PV 023 should be preventive maintenance before 3500 hours of operation.
- PT 022 should be preventive maintenance before 6000 hours of operation.

While the recommendations that can be given related to safety at Low

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REFERENCES

Dhillon, B. S. 20**05.** *Engineering Maintenance.* Boca Raton : CRC Press, 2005.

Ebeling,Charles E. 1997**.** *An Introduction to Reliability and maintainability Engineering.* [penyunt.] The McGraw. New York : Hill Companies, 1997.

Emerson. 2005. *Basic Fundamentals Of Safety Instrumented Systems*. Emerson Process Management

Ingrey, Andy, Lereverend, Patrict dan Hildebrandt, Andreas. 2007. *Manual Safety Integrity Level (SIL) IEC 61508/ 61511.* s.l. : Central Association of the Elektrotechnik und Elektroindustrie (ZVEI) e.V., 2007.

ISA-TR84.00.02. 2002. *Safety Instrumented Functions (SIF)-Safety Integrity Level (SIL) Evaluation Techniques.* North Carolina : ISA-The Instrumentation, Systems, and Automation Society, 2002. Vol. Part 2. ISBN: 1-55617-803-4.

Basuki Rahman, Fradikta Eri dan Irfin Zakiyah. 2009**.***Evaluasi Furnace Tipe Box, Sebagai Proyeksi Perhitungan Desgn Furnace Tipe Silinder Vertikal Terhadap Kebutuhan Jumlah Tube dan Diameter dengan Kapasitas Produksi 3800 Barrel/ Hari di Pusdiklat Migas Cepu.* Bandung : SNTKI, 2009. ISBN 978-979-98300-1-2.

Irfansyah, Wildan. 2011**.***Verifikasi Safety Integrity Level Menggunakan Metode Semi-kuantitatif IEC 61511 Studi Kasus: Tangki Timbun-Filling Shed Terminal LPG.* Surabaya : Jurnal Teknik Sistem Perkapalan.

Kececioglu, Dimitri (1991), "Reliability Engineering Handbook Volume I", PTR Prentice Hall, Englewood Cliffs, New Jersey.

Kern, Donald Q. 1988. *Process Heat Transfer.* s.l. : McGraw-Hill Book Company, 1988.

Levitt, Joel (1997), "The Handbook of Maintenance Management "Industrial Press Inc, 200 Madison Avenue New York .

Montgomery, Douglas C., 1999, "Introduction to Statistical Quality Control 6th Edition". United States of America. [6]

Musyafa, A., Erna Zulfiana. 2013. Risk Management and Hazard and Operability Study on Steam Turbine Power Plant Unit-5 in the Power Generation Paiton, East Java–Indonesia, Advances in Natural and Applied Sciences, 7(5) December 2013, Pages: 510-518 [11].

Musyafa, A. ,at.al., " Hazad And Operability Study and Analysis of Safety Integrity Level Case Study: Ammonia Refrigerant Compressor at Petrochemical Plant" Advances in Natural and Applied Sciences, 9(8) July

Musyafa, A., at.al. "Reliability and Maintainability Assessment of the Steam Turbine Instrumentation System for optimization Operational Availability System at Fertilizer Plant", Australian Journal of Basic and Applied Sciences, 8(13) August 2014, Pages: 132-139, 2014.

Air Compressor System in Ammonia Plant PT. Petrokimia Gresik", Australian Journal of Basic and Applied Sciences, 9(11) May 2015, Pages: 853-862, 2015.

Nelson, W.L. 1985**.** *Petroleum Refinery Engineering.* s.l. : Mc Graw-Hill Book

—. 2008. *Mengenal Lebih Ddekat Produk-Produk PT. Pertamina (Persero).* Jakarta : Divisi Komunikasi Korporat, 2008.

Robin E. MCdermott, Raymond J. Mikulak, Michael R. Beauregard. (1996) "The Basic Of FMEA" Resource Engineering. INC, USA [1].

Ramakumar, R. (1993). "Engineering Reliability: Fundamental and Applications". Prentice Hall International, Inc. New Jersey [5].

Ronny D. Noriyati, et.al..." Reliability Assessment of Cooling Pump For Parts Inventory Planning in Power Plant System, Paiton-Indonesia". Australian Journal of Basic and Applied Sciences, 8(13) August2014, Pages: 140-146 AENSIISSN: 1991-8178. Journal home page:www.ajbasweb.com, 2014.

Standards Association of Australia," Australian Standard: Risk Management AS/NZS 4360" [7].

SINTEF, 2009, Industrial Management. "Offshore Reliability Data Handbook 4th Edition". OREDA Participants, 2000 [9].

Silvana D. Costa. et. al. "Evaluation Safety Integrity Level Using Layer of Protection Analysis in Recycle Gas First Stage Cycle Compressor at PT. Pertamina Persero" **.,** Australian Journal of Basic and Applied Sciences, 9(20) June 2015, Pages: 154-163, 2015.

Silvana D. Costa. et. al.,2017, Human Factor and Reliability Assessment on Boiler System At Refinery Processing Unit IV , PT . Pertamina -Indonesia Human Factor and Reliability Assessment on Boiler System At Refinery Processing Unit IV , PT . Pertamina – Indonesia, Wulfenia, Vol 24, No. 2;Feb 2017, Pp:12-23.