Human Factor and Reliability Assessment on Boiler System At Refinery Processing Unit IV, PT. Pertamina -Indonesia

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Abstract: Boiler unit is functioning equipment converts water into steam in the temperature and pressure set point. Activities of the process contain a potential hazard. One of the causes of the danger is the human factor and the failure of the instrument. Analysis was performed on humans who contribute to the failure of the instrument. By utilizing historical data plus the observation instrument maintenance and workers through questionnaires, the values; Mean Time to Failure (MTTF), failure rate, and Probability Failure on Demand (PFD) for each instrument can be known. The correlation between the two variables can be aproach with regression method, in which the human factor and the failure of the instrument is represented by the value of the PFD.

It is known that the failure of the instrument is affected by internal and external factors on the performance of the operator. Internal factors include; confidence, attention, problem solving skills, work under pressure, negligence, and stress due to work piling up. External factors include; information and standards provided by the company (procedures), education and training, communication, time, and evaluation of instrument failure on boiler equipment. Correlation deviation caused by the human factor to the failure of the instrument indicated by the value of the measurement uncertainty (μ). The most dominant factor of the factor to the failure of the instrument boiler operator is the task load of stress that has the smallest value of μ among other factors = 0.087. This is consistent with the internal factors μ its value is smaller than other external factors with the value of μ = 0.095.

Keywords: Boilers, Human Factors, Failure Instrument, Safety

1. Introduction

PT. Pertamina Persero Processing Unit IV Cilacap is one of the processing units owned by PT Pertamina with production capacity, most notably 348,000 barrels / day. The production is supplying 34% of the fuel oil (BBM) or 60% national fuel needs in Java [1]. One of the important components of

the processing unit is a boiler. Boiler is a component that is used to convert water into steam (steam) through the heating process [2]. The main constituent parts of the boiler economizer, among others, the steam drum, superheated and reheated [3].

In addition, the process also has the potential to cause harm, either of the components used, as well as from outside. Factors danger from the outside can be caused from human and environmental factors. The danger can be detrimental to workers and companies [3]. Losses could be material, social, and even death. In addition, 15% of the causes of accidents caused by the operation and maintenance [4]. In the operation and maintenance which became the subject is a human. This is because the safety system in a plant that is less [5]. Lack of safety systems can be caused by lack maintiability instruments, operation errors, and so on which can cause the instrument to fail. Based on the above problems, it is necessary to the analysis of human influence on the failure of the instrument on the boiler at the PT. Pertamina (Persero) Processing Unit IV Cilacap so that it can be seen how much the human influence on the failure of the instrument.

2. Material and Methods

Study Process Boilers, the initial phase includes understanding the material on the processes that occur in the boiler. The literature was obtained from the internet, scientific journals, and books of knowledge that support this research. In addition, the material on the boiler is also obtained from PT. Pertamina Processing Unit IV Cilacap.

Data Collection, this study took the data associated with the existing processes in the boiler such as Process Flow Diagrams (PFD), Piping and Instrument Diagrams (P & ID), as well as data maintenance of each component in the boiler. In addition, data collection by observation through questionnaires Cosmos as a maintenance worker in the field of materials to determine the human impact on the failure of the instrument in the plan.

Calculation of MTTF and PFD, the instruments maintenance of data obtained from the plan will be processed to produce the Mean Time to Failure (MTTF) and the rate of failure (failure rate) instrument. In accordance with the standard ISA-TR84.00.02-2002 that the failure rate also affects Probability Failure on Demand (PFD), the chances of failure on the instrument during the time interval which is owned by such instruments [6, 7].

$$\lambda = \frac{1}{MTTF} \tag{1}$$

$$PFD = \frac{\lambda \times TI}{2} \tag{2}$$

Contribution Operator to the Instrument Failure, human Influence Against Failure Analysis Instruments at this stage, the analysis aimed to determine the relationship between the human impact on the existing failure in the instrument. The method used is the linear regression method. Regression was used to

determine the shape of the functional relationship between two variables or two factors. In regression analysis, there are two types of variables [8], including the response variable (dependent variable), i.e. variables whose existence implemented by other variables. This variable is denoted by the symbol Y. The second variable is the predictor variables (independent variables), which is a variable that is not influenced by other variables. The emblem of the independent variable is X. For a simple linear regression equation form can be described by the following equation [8, 9].

$$Y = a + b\,X + \in \tag{3}$$

Where:

$$b = \frac{n\sum_{i=1}^{n} x_i \cdot y_i - \left[\sum_{i=1}^{n} x_i\right]\left[\sum_{i=1}^{n} y_i\right]}{n\sum_{i=1}^{n} x_i^{\,2} - \left[\sum_{i=1}^{n} x_i\right]^2} \tag{4}$$

$$a = \frac{\sum_{i=1}^{n} y_i - b\sum_{i=1}^{n} x_i}{n} = y - b \cdot x \tag{5}$$

ε (residual factor) is the residual. While uncertainties can be used to determine the following equation [10].

$$U = \sqrt{\frac{SSR}{(n - Var)}} \tag{6}$$

where:

$$SSR = \left(y_i - a - b \cdot x_i\right)^2 \tag{7}$$

In this discussion, Probability Failure on Demand (PFD) will be the dependent variable (yi) where the PFD would represent a failure of the instrument. While the independent variables (xi) is the human factor, among which self-confidence, attention, skill, problem solving, pressure, omission, task load stress, procedures, education and training, communication, and evaluation [11].

3. Discussion

Data analysis was conducted on data that have been obtained previously, the relationship between human influences with the failure of existing instruments in the boiler PT. Pertamina Processing Unit IV Cilacap. From the analysis, it can be seen that the human factor has the most effect on the failure of the instrument. So it can be concluded from this study.

3.1. Safeguard System on Boiler

Any failure or damage suffered by an instrument will have an impact on the performance or the performance of the instrument. Safeguards system is a system that protects the security of the instrument is working on a process. This system works on certain conditions that harm, such as the condition of the level or in the steam drum water level in the boiler is a low-high-low or high. The following are some of the safeguards system of the boiler instrument 052B-104.

Table 1. Instrument maintenance data as safeguards boiler system

Tag Number	*Service Description*	*Result*
052PSL-413	Fuel Oil Press	Good
052PDSL-408	Diff ATM STM/Fuel Oil	Good
052PSL-414	Fuel Gas Low Press	Good
052PSH-414	Fuel Gas High Press	Good
052FSL-404	Combustion Air Flow	Good
052LSL-402	Level Drum Low	Good
052LSH-401	Level Drum High	Good
052PSL-432	Air Inst Low Press	Good
052HS-413	Emergency Shutdown I/P	Good
052HS-414	Emergency Shutdown Ctrl PNL	Good
052XV-406	Fuel Gas Shut Off VLV	Good
052XV-407	Fuel Oil Shut Off VLV	Good
052XV-409A	In div Shut Off VLV FO	Good
052XV-409B	Incdiv Shut Off VLV FO	Good
052XV-409C	In div Shut Off VLV FO	Good
052XV-410A	In div Shut Off VLV FG	Good
052XV-410B	In div Shut Off VLV FG	Good
052XV-410C	In div Shut Off VLV FG	Good
052XV-411A	In div Pilot Gas	Good
052XV-411B	In div Pilot Gas	Good
052XV-411C	In div Pilot Gas	Good

Based on the data maintenance in Table 1, the instrument safeguards system of the boiler is not a failure or replacement. This is caused by the instrument in this system is maintained by periodically checking that is 4 months. Because the instrument is an instrument which safeguards system is critical, which is an instrument that only work at certain times (hazard conditions). Moreover, this can be due to the instrument in this system is an instrument that does not operate in a sustainable manner or continuously (uncontained).

3.2. Boiler Control System on 052B-104 Tag Number

A system has a control system that aims to produce the best output in accordance with the given input. In boilers 052B-104, there are four nodes are analyzed, namely Fuel Oil Supply node, the node Fuel Gas Supply, Boiler Feed Water Supply nodes, and nodes High Pressure (HP) Steam Output. Here is the calculation of the Mean Time To Failure (MTTF) of each instrument in the fourth node.

3.2.1. Node of Fuel Oil Supply

Fuel Oil supply is input in the form of oil that will be used in the combustion process in the burner chamber. Before the oil into the burner, oil spray (spray) by using high-pressure steam.

Table 2. PFD Instrument on Fuel Oil Supply node

Tag Number	MTTF)	*Failure Rate*(λ)	*Test Interval* (TI)	(PFD)
052PV-408	10662	9,38E-5	8760	0,411
052FT-407	35448	2,82E-5	8760	0,124
052HIC-411	21552	4,64E-5	8760	0,203
052PIC-491	26352	3,79E-5	8760	0,166
052PT-408	26256	3,81E-5	8760	0,167
052PIC-408	21552	4,64E-5	8760	0,203

3.2.2. Node of Fuel Gas Supply

Fuel gas supply that is input in the form of air that will be used in the process of combustion in the burner.

Table 3. PFD Instrument on Fuel Gas Supply node

Tag Number	MTTF	*Failure Rate*(λ)	*Test Interval* (TI)	PFD
052PT-416	9960	1,00E-4	8760	0,440
052HIC-412	26352	3,79E-5	8760	0,166
052FIC-412	20448	4,89E-5	8760	0,214
052FT-408	13140	7,61E-5	8760	0,333
052PT414A	28992	3,45E-5	8760	0,151
052PV-412	9248	1,08E-4	8760	0,474

3.2.3 Node of Boiler Feed Water Supply

Boiler Feed Water Supply or commonly known as boiler feed water, the input of water is converted into steam.

Table 4. PFD Instrument on Boiler Feed Water Supply node

Tag Number	(MTTF)	*Failure Rate*(λ)	*Test Interval* (TI)	PFD
052FT-406	35184	2,84E-4	8760	0,124
052FIC-406	16692	5,99E-5	8760	0,262
052FV-406	16980	5,89E-5	8760	0,258
052LG-428	26352	3,79E-5	8760	0,166
052HIC-405	26256	3,81E-5	8760	0,167

3.2.4. Node of High Pressure Steam

High Pressure Steam (HP Steam) is the output of the boiler in the form of high-pressure steam that will be used in the production process.

Table 5. PFD Instrument on High Pressure Steam node

Tag Number	(MTTF)	*Failure Rate*(λ)	*Test Interval* (TI)	(PFD)
052FT-402	16692	5,99E-4	8760	0,262
052TT-477	35136	2,85E-5	8760	0,125
052TT-404	20448	4,89E-5	8760	0,214

3.3. Relationship Personal factor and the Instruments failure

in analyzing the influence of human relationships with these human failures, the method used is the regression method with yi is Probability Failure on Demand (PFD) instrument and xi is the factor of human internal or external factors. Here are the results of the calculation of failure rate relationships with internal and external human factors.

Table 6. Relationship of PFD and Internal Human Factor

x_i	y_i	x_i^2	$x_i \cdot y_i$	E
30	0,474	900	14,208	0,0385
35	0,440	1225	15,392	0,0102
28	0,411	784	11,503	0,0250
28	0,333	784	9,333	0,0065
28	0,262	784	7,347	0,0001
30	0,262	900	7,872	0,0002
26	0,258	676	6,707	0,0009
31	0,214	961	6,640	0,0057
28	0,214	784	5,998	0,0015
26	0,203	676	5,284	0,0006
26	0,203	676	5,284	0,0006
22	0,167	484	3,670	0,0001

23	0,167	529	3,837	0,0006
29	0,166	841	4,820	0,0098
35	0,166	1225	5,817	0,0298
22	0,166	484	3,657	0,0002
26	0,151	676	3,928	0,0059
473	4,258	13389	121,297	0,1360

PDF relationships and internal personal factors indicated by Table 6, from the above data obtained values of a, b, y, and μ by equation (4), the obtained value of b. as follows, $b = 0{,}012$ and by using equation (5), the obtained value a following; $a = -0{,}092$ Having obtained the values of a and b substitution into equation (3) is obtained: $y = -0{,}092 + 0{,}012 \cdot x$ Furthermore substitution into equation 6, it is obtained: $U_{internal} = 0{,}0953$ = 9,53 %

Table 7. Relationship PFD and External Human Factors

x_i	y_i	x_i^2	$x_i \cdot y_i$	E
25	0,474	625	11,840	0,0488
20	0,440	400	8,795	0,0360
20	0,411	400	8,216	0,0259
17	0,333	289	5,667	0,0072
20	0,262	400	5,248	0,0002
20	0,262	400	5,248	0,0002
20	0,258	400	5,159	0,0001
25	0,214	625	5,355	0,0015
20	0,214	400	4,284	0,0013
25	0,203	625	5,081	0,0025
19	0,203	361	3,861	0,0021
20	0,167	400	3,336	0,0069
19	0,167	361	3,170	0,0068
22	0,166	484	3,657	0,0072
25	0,166	625	4,155	0,0075
18	0,166	324	2,992	0,0068
21	0,151	441	3,173	0,0099
356	4,258	7560	89,237	0,171

Relationships of PDF and personal external factors shown in Table 7, from the data in Table 7, obtained values of a, b, y, and μ by the following equation; $b = 0{,}001$; $a = 0{,}239$;

$y = a + b \cdot x$; $y = 0{,}239 + 0{,}001 \cdot x$ And,

$U_{eksternal} = 0{,}1067$ = 10,67 %

Internal and external factors influence human can be represented in Figure 1 and Figure 2.

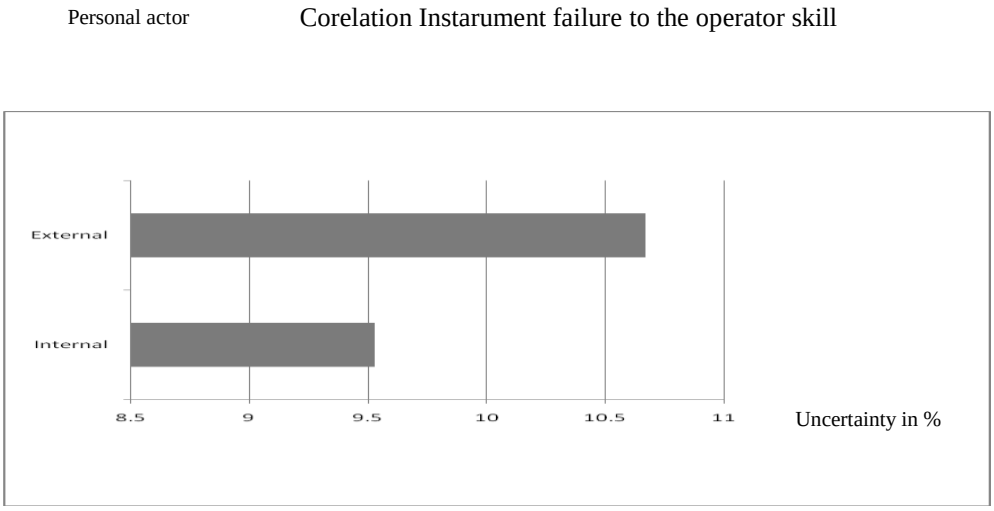

Figure 1. Internal and External human factor and uncertainty

Figure 1 shows that external factors humans have μ value greater than the value of μ that is owned by the human internal factor that is equal to 0.1067. This means that the human external factors influence the smaller the instrument failure of the boiler PT. Pertamina, Processing Unit IV Cilacap. This is caused by the questions on the questionnaire, which means positive with the largest value is 5, while the expected value of the value of the human factor is the smallest value that one. To that end, a smaller value of μ represents a greater influence on the failure of the instrument.

In addition, the appendix has been carried out calculations with the relationship between the failure of the instrument every human factors. This calculation uses a simple linear regression analysis, the dependent variable is denoted instrument failure y and the independent variable is the human factor which is symbolized by the notation x. The results are shown in the Appendix for each human factor can be seen in Table 8.

Table 8. Relationship of Human Factors Rated and uncertainty

Factor	μ
Self Confidence	0,1063
Attention	0,1042
Skill	0,1038
Problem Solving	0,1012
Pressure	0,1055
Omission	0,0997
Task Load Stress	0,0866
Procedure	0,1056
Education and Training	0,1041
Communication	0,106
Timing	0,1045
Evaluation	0,1067

The value of the measurement uncertainty in the value of the uncertainty factor is the operator whose members contributed to the failure of the instrument. Because the value of the questionnaire opposite to the desired value as human error, or in other words the higher the value the greater the questionnaire each factor no effect on the failure of the instrument (not indicate human error). So that the value of μ is the smallest of the human factor will provide the greatest influence on the failure of the instrument on the boiler PT. Pertamina, Processing Unit IV Cilacap. Furthermore, the results of Table 8 above are represented in Figure 2.

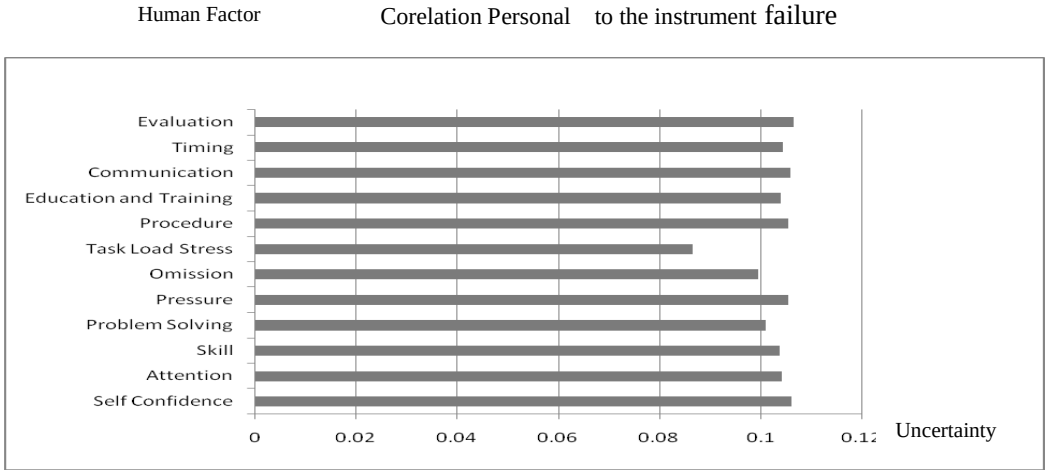

Figure 2. Relationship Human Factors and uncertainty

The obtained value of μ for each factor, the factors that have the highest value of μ is the Factor Evaluation (Evaluation) of 0.1067. While the factors that have the most low U value is the stress factor is piling up (Task Load Stress) of 0.0866.

4. Analysis

Based on data analysis, instrument failure also caused by human factors. Human factors consist of internal factors (individual) and external factors. By comparing the correlation value of each statement of the correlation values in the table with a confidence level of 95% ($\alpha = 0.05$) with n as many as 17, which is 0,482. Correlation value of each statement that meets the human factor influence on the failure of this instrument is a correlation value greater than 0.482. Internal factors that satisfy them are trust, attention, ability, problem solving, working under pressure, negligence, and the stress is piling up. And external factors among which are the companies providing the information and standard procedures, training, communication, time, and evaluation of instrument boiler failure.

By regression analysis, it is obtained each major influence every human factor to the failure of the instrument. Large effect (deviation) of the human instrument failure can be demonstrated through the value of U. The human factor that has the highest value of U is a factor evaluation (evaluation) of 0.1067. While the factors that have the most low U value is the stress factor is piling up (task load stress) of 0.0866. In accordance with the previous explanation that the value of U is the smallest of the human factor that will provide the greatest influence on the failure of the instrument on the boiler PT. Pertamina,, Processing Unit IV Cilacap, because scores on the questionnaire opposite to the desired value as human error, so that the higher the value the greater the questionnaire each factor has no effect on the failure of the instrument. To that end, the task load stress factor is the greatest influence on the failure of the instrument on the boiler PT. Pertamina, Processing Unit IV Cilacap compared with other human factors. This is comparable with the internal factors that have a U value which is smaller than the external factors is 0.0953. This means that the overall internal factors have a greater influence on the failure of the instrument, especially in the boiler.

Figure 2 shows the factors working for a diagram showing the pressure and the stress factor due to the piling work, it appears that the second statement has a proportional relationship to the statement that has been given to the respondent is someone who is able to work under pressure will not feel stress due to work piling up. However, from the results obtained through questionnaires given, it appears that the value of U on factors work under pressure (pressure) by a factor of stress due to work piling showed contradictory results. U value on factors work under pressure (pressure) has a high value is 0.1055. Unlike, occupational stress factors accumulate have lowest U value is 0.0866 of respondents obtained answers to the perception of each. In fact, someone prefers not agree on the time given in the statement

that a person is able to work under pressure. Because it could be someone still influenced on the assessment of him as a person before the work. As has often been pointed at someone's curriculum vitae will demonstrate the advantages possessed. But for occupational stress factors accumulate, 23.53% of respondents said not agree to strongly disagree if the respondent does not feel stress from piling statement. This is based on the respondents' assessment of the performance or the performance of which has been done by the respondent.

5. Conclusion

The failure of the instrument on the boiler PT. Pertamina, Processing Unit IV Cilacap influenced by human factors. It can be seen from some of the factors that influence the failure of instruments, both internal (individual) or from external workers. Internal factors included the confidence (self-confidence), attention (attention), ability (skills), problem solving (problem solving), work under pressure (pressure), negligence (omission), and the stress is piling up (task load stress). And external factors among which are the information and standards provided by the company (procedures), training (education and training), communication (communication), time (timing), as well as an evaluation of the failure of the instrument (evaluation) in the boiler PT. Pertamina, Processing Unit IV Cilacap.

Large effect (deviation) of the human instrument failure can be demonstrated through the value of U. The most influential factor from human to instrument failure of the boiler in the PT. Pertamina,, Processing Unit IV Cilacap is the task load of stress that have a U value of the smallest among other factors is equal to 0.0866. This is consistent with the internal factors that have a U value smaller than the external factor that is equal to 0.0953.

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