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Risk Indentification on Superheater Pipeline Boiler of 600 MW Power Plants Using a Risk Based Inspection (RBI) Method

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Abstract— Steam power plants are the most efficient type of power generation and can make a significant contribution to the demand for electricity resources. Steam power plants, in general, utilize energy derived from seawater to be process into steam in boilers so that often many pipe failures have occurred due to thinning due to corrosion caused by inappropriate water quality in small units and difficult to detect continuously. In general, inspection planning related to pipe thinning in steam power plants shows a minimal trend compared to inspections in the oil & gas industry. Moreover, it has no basic policy as to how inspection intervals and piping methods will be carry out. In this study, it carried out with the aim of conducting a risk assessment of boiler pipe failure so that it can provide a more optimal overview of the inspection plan. Analysis using Risk Based Inspection (RBI) will be used as a research reference to create the most effective and efficient inspection system as to minimize the impact and expenses cost in pipeline maintenance. After RBI assessment, the inspection plan for superheater pipeline on boiler line will be held every 2 years.

Keyword: Risk Based Inspection, Steam Power Plant, Superheater Pipeline Boiler

INTRODUCTION

Steam power plant in general is a type of power plant that utilizes steams as a turbine drives. One of the important components of the power plant is the piping system. Some equipment cannot be separated from the piping system, especially in the boiler system. Furthermore, cooling water piping system and auxiliary piping system are included in the system that needs to be supported by a good piping system too (Xin'an Yuan et al, 2017). One of the subsections of boiler piping system is superheaters, shown in the following figure 1. in the blue square.

Basically, superheaters in boiler pipeline are used to heat wet-steam that has formed before to be dry steam to ensure the safety of the turbin blades. This line operates on a high temperatures when steams through inside the line and a flue gas through pass on the outside of the line (Tong Liu et al, 2022).

Thinning and piping leakage on the superheater pipeline is a problem that is bound to be encountered, due to production process which can disrupt operations. The damage and leaks are usually repaired with identical material specifications and dimensions at the time of annual overhaul, by checking the thickness of each line.

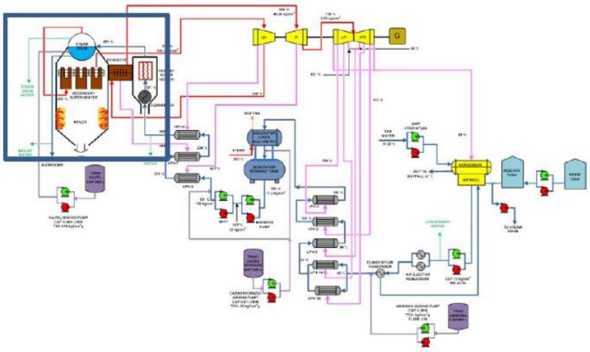

Figure 1. Single line diagram of pipeline

Thinning and piping leakage on the superheater pipeline is a problem that is bound to be encountered, due to production process which can disrupt operations. The damage and leaks are usually repaired with identical material specifications and dimensions at the time of annual overhaul, by checking the thickness of each line. It is not very effective because it prolongs the downtime, which results in KWH loss. It shows that one of the contributing factors is the lack of standard piping inspection procedures. Initial maintenance activities are needed to mapping pipeline materials that have certain history, or pipeline materials that require more attention. Then recorded the data. From the data that has been collected, further analysis of the remaining life, risk level, and corrosion rate can be used to estimate further pipeline inspection plan.

In this study, the equipment that will be analyzed is the superheater pipeline on boiler line which is used in the process of further evaporation of wet-steams into dry-steam in the power plant. In general, inspection planning related to pipe thinning in steam power plants shows a minimal trend compared to inspections in the oil & gas industry. Analysis using Risk Based Inspection (RBI) will be used as a research reference to create the most effective and efficient inspection system as to minimize the impact and expenses cost in pipeline maintenance.

METHOD

Risk Based Inspection (RBI)

Risk Based Inspection (RBI) is an inspection method based on risk analysis which includes probability of failure, possibility impact of the risk, and the relation to the current operating system (Noori et al, 2006). This method calculates the probability of hazard as a basis for determining priorities and as a reference for management inspection program (hameed et al, 2021). Therefore, RBI method allows change in inspection and maintenance scheme to enhance the higher safety of the equipment high risk by trying to do repairs or maintenance with better equipment for the risk it becomes lower. The main goal of RBI is to improve operating time of equipment to becomes longer by minimizing failure or at least at the same risk before (Perera et al, 2021). RBI defines risk as equation 1

$$Risk = PoFxCoF \quad (1)$$

For, PoF is Probability of Failure, and CoF is Consequences of failure (Seo, J. K, et al, 2015).

Probability of Failure (PoF)

Probability of Failure (PoF) is the possibility of an equipment or component to failure. Losses due to occurance of failure will affect the resistance of material being analyzed, determined by its current operating conditions.

Then the results of the remaining life (RL) are projected on the table 1 below. In RL, it is chosen from the results of the lowest RL which is the highest risk ranking to most likely to fail.

Table 1. Probability of Failure Category by Remaining Life

Remaining Life (RL) in Years	Probability of Failure (PoF)	
RL <= 4	Almost Certain	5
4 <RL <= 6	Likely	4
6 <RL <= 8	Moderate	3
8 <RL <= 10	Unlikely	2
RL>= 10	Rare	1

Consequence of Failure (CoF)

Consequence of Failure (CoF) is possibility impact or effect of the risk when equipment is failure. There are three things that need to be assessed to determine CoF, which will be explained in each table below.

Table 2. Stand by Availability (S)

Stand By Availability	rating	
Emergency Shutdown	High	5
Reduction max 20%	Medium High	4
Reduction max 10%	Medium low	3
Reduction max 5%	low	2
There is no reduction	Very low	1

If there is a pipe failure and costs are required for repairing by the time, it can be shown that on rating of financial models (F)

Table 3. Financial Model (F)

Financial Model		rating	
Repair Time (M)	Cost (B)		
M>= 7 days	B >= 1billion	High	5
5 <=M < 7 days	0,5 billion<=B<1	Medium High	4
3<=M < 5 days	30 – 50% BTR	Medium low	3
1 <=M < 3 days	10-30% BTR	low	2
M <= 1 day	B<10% BTR	Very low	1

Finally, to determine CoF, Safety and Environment are important. It shown on the table 4 below

Table 4. Stand by Availability (S)

Location (L)	rating	
Public Areas, densely populated	High	5
Public Area, far from residential	Medium High	4
General Location	Medium low	3
Inside Cluster, no fenced and security	low	2
Cluster, fenced, there is security	Very low	1

RESULT

Data of thickness collected during overhaul periodic inspection from year 2017, 2019, 2021 respectively. Then do the calculation of the corrosion rate, which is the amount of metal released per unit time on the certain surface of the component. The corrosion rate is closely related to the corrosion resistance of a material. From the calculation of the corrosion rate that has been done, it shows an error which is a negative corrosion rate value. This indicates the possibility of an error in data retrieval, or the occurrence of a deposition in the pipeline which will result in an increase in the flow rate of the pipeline or pressure on the pipe so that corrosion will occur easily. The result shown on the following figure 2.

Reheater										
Lokasi	Posisi	Thickness Kiri			Thickness Tengah			Thickness Kanan		
		2017	2019	2021	2017	2019	2021	2017	2019	2021
Reheater cross over	SB14 atas T1	5,210	5,398	5,543	5,255	5,420	5,535	5,190	5,407	5,530
	RL	-0,188	-0,145	-0,167	-0,165	-0,115	-0,140	-0,217	-0,123	-0,170
	SB14 front T1	5,340	5,382	5,834	5,255	5,365	5,836	5,460	5,350	5,833
	RL	-0,042	-0,452	-0,247	-0,110	-0,471	-0,291	0,110	-0,483	-0,187
	SB14 rear T1	4,680	4,473	4,860	4,695	4,454	4,872	4,660	4,439	4,879
	RL	0,207	-0,387	-0,090	0,241	-0,418	-0,088	0,221	-0,440	-0,110
	SB30 front T1	5,365	5,063	5,808	5,320	5,056	5,804	5,380	5,050	5,806
	RL	0,302	-0,745	-0,221	0,264	-0,748	-0,242	0,330	-0,756	-0,213
	SB30 rear T1	5,035	4,198	4,944	5,085	4,188	4,904	5,050	4,180	4,949
	RL	0,837	0,000	0,046	0,897	0,000	0,091	0,870	0,000	0,051
	SB48 front T1	4,650	4,461	4,625	4,645	4,444	4,623	4,660	4,435	4,623
	RL	0,189	-0,164	0,013	0,201	-0,179	0,011	0,225	-0,188	0,018
	SB62 front T1	5,515	5,212	5,723	5,545	5,204	5,711	5,550	5,197	5,728
	RL	0,303	-0,511	-0,104	0,341	-0,507	-0,083	0,353	-0,531	-0,089
	SB62 rear T1	4,900	4,350	4,767	5,000	4,340	4,749	4,980	4,360	4,774
	RL	0,550	0,000	0,067	0,660	0,000	0,126	0,620	0,000	0,103
	SB64 atas T1	4,780	4,484	4,514	4,690	4,473	4,514	4,700	4,477	4,514
	RL	0,296	-0,030	0,133	0,217	-0,041	0,088	0,223	-0,037	0,093
	SB64 front T1	4,600	4,537	4,619	4,660	4,537	4,616	4,610	4,523	4,614
	RL	0,063	-0,082	-0,010	0,123	-0,079	0,022	0,087	-0,091	-0,002
	SB64 bawah T1	5,130	4,394	4,548	5,105	4,375	4,539	5,195	4,365	4,529
	RL	0,736	0,000	0,291	0,730	0,000	0,283	0,830	0,000	0,333

Figure 2. thickness data

The result shown that there are several points that must be inspected immediately because the remaining life less than 4 years based on the PoF table shown below.

Table 5. PoF of the data

Remaining Life (RL) in Years	Probability of Failure (PoF)	
RL <= 4	Almost Certain	5
4 <RL <= 6	Likely	4
6 <RL <= 8	Moderate	3
8 <RL <= 10	Unlikely	2
RL>= 10	Rare	1

Subsequently, CoF are determined by 3 different table which has been shown before. From the data, we can calculate the result by the table respectively shown below.

Table 6. Stand by Availability (S) from the data

Stand By Availability	rating	
Emergency Shutdown	High	5
Reduction max 20%	Medium High	4
Reduction max 10%	Medium low	3
Reduction max 5%	low	2
There is no reduction	Very low	1

If there is maintenance by the failure of the boiler pipeline, it will completely stop or emergency shutdown, so the rating of the S is high.

Table 7. Financial Model (F) from the data

Financial Model		rating	
Repair Time (M)	Cost (B)		
M>= 7 days	B >= 1billion	High	5
5 <=M < 7 days	0,5 billion<=B<1	Medium High	4
3<=M < 5 days	30 – 50% BTR	Medium low	3
1 <=M < 3 days	10-30% BTR	low	2
M <= 1 day	B<10% BTR	Very low	1

If there is failure, because of the boiler pipe consists of hundreds of pipes, it will take a long time to inspect it, so the rating of the F is high.

Table 8. Stand by Availability (S) from the data

Location (L)	rating	
Public Areas, densely populated	High	5
Public Area, far from residential	Medium High	4
General Location	Medium low	3
Inside Cluster, no fenced and security	low	2
Cluster, fenced, there is security	Very low	1

The location of power plants is inside the cluster, fenced, and there is security, so the risk rating of failure is very low.
Then, CoF is ranked according to the average result of the data before shown in the following table

Table 9. CoF from the data

	ranking					CoF
	1	2	3	4	5	
S					x	
F					x	Significant D
L	x					

The RBI calculation method is carried out by multiplying POF and COF to produce a different risk rating for each segment with the following results. CoF x PoF were plotting into 5x5 matrix to determine risk condition of the pipe.

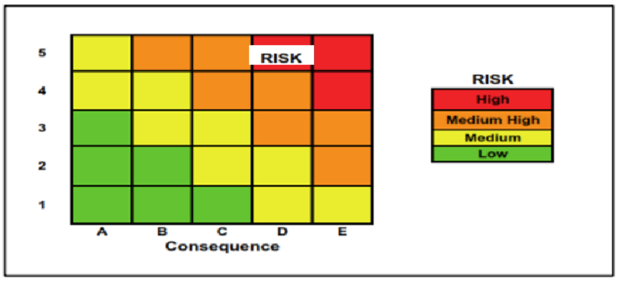

Figure 3. RBI result

DISCUSSION

Based on these results, we can determine the inspection planning, i.e., how the risk target determined. Meanwhile, the inspection schedule has been determined to comparison from the data with certain level confidence below:

1. Code 4 = no confidence or no data
2. Code 3 = predictable deterioration and incomplete data
3. Code 2 = predictable deterioration, standard accepted defect data, and complete data
4. Code 1 = no active failure mechanism, stable operating environment, and complete data

Risk		Confidence Level			
		4	3	2	1
9	High Risk	1	2	6	N/A
8		2	4	6	N/A
7		3	4	6	N/A
6	Medium Risk	4	4	8	8
5			6	8	8
4		6	6	8	10
3	Low Risk	6	8	10	10
2		8	10	10	15
1		8	10	15	15

Figure 3. Inspection interval

the confidence level used no 4 because of lack of data, the data collected with 2 years interval so we cannot assess whether there has been an improvement which results in data changes at the intervals. From the table, the inspection interval is 2 years.

CONCLUSION

According to the RBI method for the boiler superheater piping system, it shows a high probability of failure (PoF) with rating no 5 based on remaining life and medium-high or significant D for Consequence of Failure (CoF) with rating 4. Corrosion related to high operating system effect the PoF. The inspection plan for superheater piping system is recommended to be 1 year from the date of RBI inspection, which is every 2 years.

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