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Failure Analysis of High Pressure Heater in PT. PJB UP Paiton

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Abstract— The aim of this paper is to analyze the cause of harm in high pressure heater in PT. PJB UP Paiton and to prevent it from happening again. In PT. PJB UP Paiton, several problem related to high pressure heater had occurred before. When the high pressure heater harmed, tube plugging usually applied to fix the trouble. Through this process, the high pressure heater was not fully recovered. The efficiency and failure rate of high pressure heater is decreased and increased respectively. Hence, a root cause failure analysis is conducted to accurately determine the cause of the problem. The result shows that the cause of failure in high pressure heater are the increase of feedwater velocity, the increase of extraction steam velocity, change of flow patter and heat transfer inside high pressure heater and radial displacement tube that over limit. Based on this result, redesign of high pressure heater is performed by increasing the capacity of feedwater flow in high pressure heater and decreasing the feedwater velocity.

Index Terms— High Pressure Heater, redesign, root cause failure analysis.

I. INTRODUCTION

High pressure heater is a kind of heat exchanger that has utilized to feedwater pre-heater before boiler in rankine cycle. In PJB PU Paiton limited companies, there are several problems that occurred in high pressure heater. These problems are not only disturb the overall process, but also decreasing the power plant overall efficiency overtime. There are several factor that may harm the high pressure heater such as leakage or corrosion [1][2]. To overcome this problem, several studies already suggest a few solution i.e. thermal analysis, flow analysis and numerical analysis [3-5]. Meanwhile, in this work, problem identification in many different aspects are conducted to get a better understanding on the problem. The aim of this work is to analyze the problem that became the root cause failure in high pressure heater system and prevent any further problem.

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II. REVIEW OF HIGH PRESSURE HEATER

One of the ways to increase efficiency in rankine cycle is the usage of regenerative system. Regenerative system works by increasing the feedwater temperature before entering boiler, this heating process would decrease the fuel usage in boiler. In this case, High Pressure Heater (HPH) is used as the regenerative system. HPH using hot fluid from extraction steam turbine to heat the feedwater. The exact position of high pressure heater in the plant can be seen at Figure 1.

III. METHODOLOGY

To maintain the feedwater heater in good condition, a few steps of feedwater heater analysis are conducted. These analysis consist of three main steps, which are problem identification, troubleshooting analysis and implementation.

A. Problem Identification

Problem Identification is performed to get a better understanding at what might cause the problem in high pressure heater. In this step, several method is utilized. First, operation data analysis is performed. Operation data analysis based on the difference between design data and actual data. Second, maintenance data analysis is performed. This analysis is performed based on maintenance data record to observe any other equipment or variable that may affect the high pressure heater performance. Then numerical analysis is performed, this analysis is based on numerical calculation using Gambit and Fluent. Finally, Failure mode of high pressure heater is examined to determine the root cause of failure in high pressure heater. Finally, any possible cause of failure in high pressure heater is listed and analyzed.

B. Troubleshooting

Based on the result of problem identification, solution can be formulated in this step. Simply put, this step consist of any possible solution that would be formulated to troubleshoot any possible cause of failure in high pressure heater.

C. Implementation

The last step of this work is to implement the solution that was formulated in troubleshooting step. The implementation itself is not limited to the high pressure heater, external variable can also be adjusted according to the proposed solution. Test of the implemented solution also performed to know whether the implementation has been a success or not. Finally, evaluation is conducted to measure how effective the solution is.

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IV. RESULTS

A. *Problem Identification Analysis*

1) *Operation Data Analysis*

Based on Sumitomo Corporation Instruction and Maintenance Manual: Operation Manual Volume O – I, most influential parameter toward the high pressure heater are the feedwater velocity, extraction steam velocity and the temperature difference between feedwater inlet and outlet.

Operation data about feedwater velocity in high pressure heater is taken and can be seen below

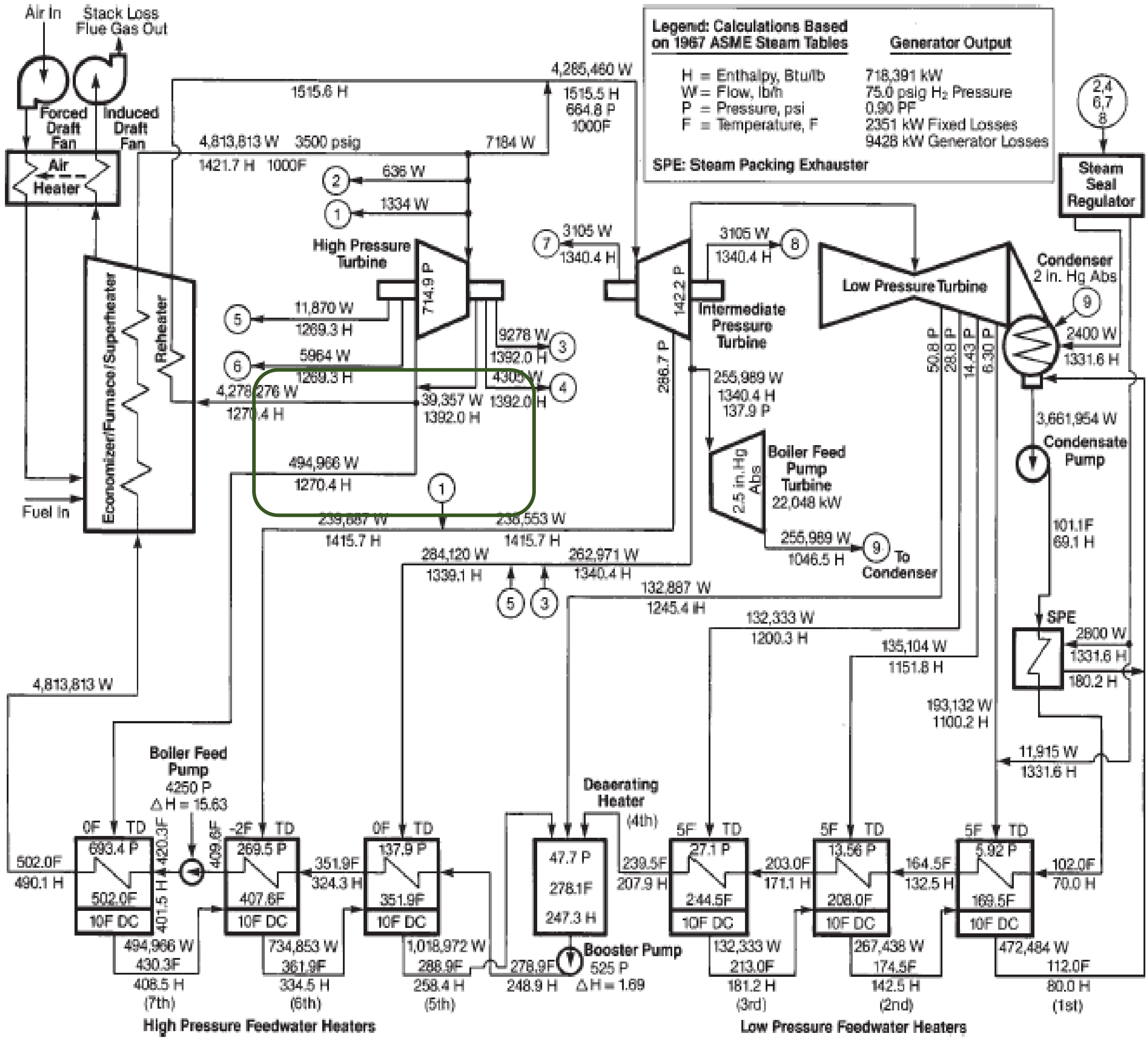

Fig. 8 Supercritical pressure, 3500 psig turbine cycle heat balance (English units).

Fig. 1. High Pressure Heater in Plant

Table 1. Feedwater velocity

HPH	Velocity (m/s)				
	Max. Allowance	Design	Commissioning	Actual	Actual no Plug
5	3.00	2.60	2.48	3.64	2.84
6	3.00	2.68	2.56	2.97	2.92
7	3.00	2.83	2.72	3.14	3.11

Table 1 shows that the actual feedwater velocity exceeds the limit. This condition can be caused by leakage in the valve before the high pressure heater.

Increased extraction steam velocity can also cause a problem to high pressure heater. This increase can be caused by several factor such as shell delta pressure or decrease of feedwater temperature that entering the high pressure heater.

The third cause that might possibly harm the high pressure heater is the difference between inlet feedwater and outlet feedwater.

2) *Maintenance Data Analysis*

Based on Serious Inspection that performed at 2003 and 2004, the rotor at high pressure, intermediate pressure and low pressure turbine also radial spill strip, blade cover and nozzle diaphragm has been through over clearance as much as 161%. This condition affirm that there was an excessive flow of feedwater to high pressure heater.

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3) Numerical Analysis

Numerical analysis was conducted by utilizing Gambit and Fluent. This analysis focused on how fluid flow behavior and heat transfer affect the high pressure heater tube. The result shows that high pressure heater tube failure may be caused by the increased mass flow rate of steam, tube radial displacement that exceed maximum allowed total clearance, change in flow pattern and heat transfer and the vibration caused by those three major factors.

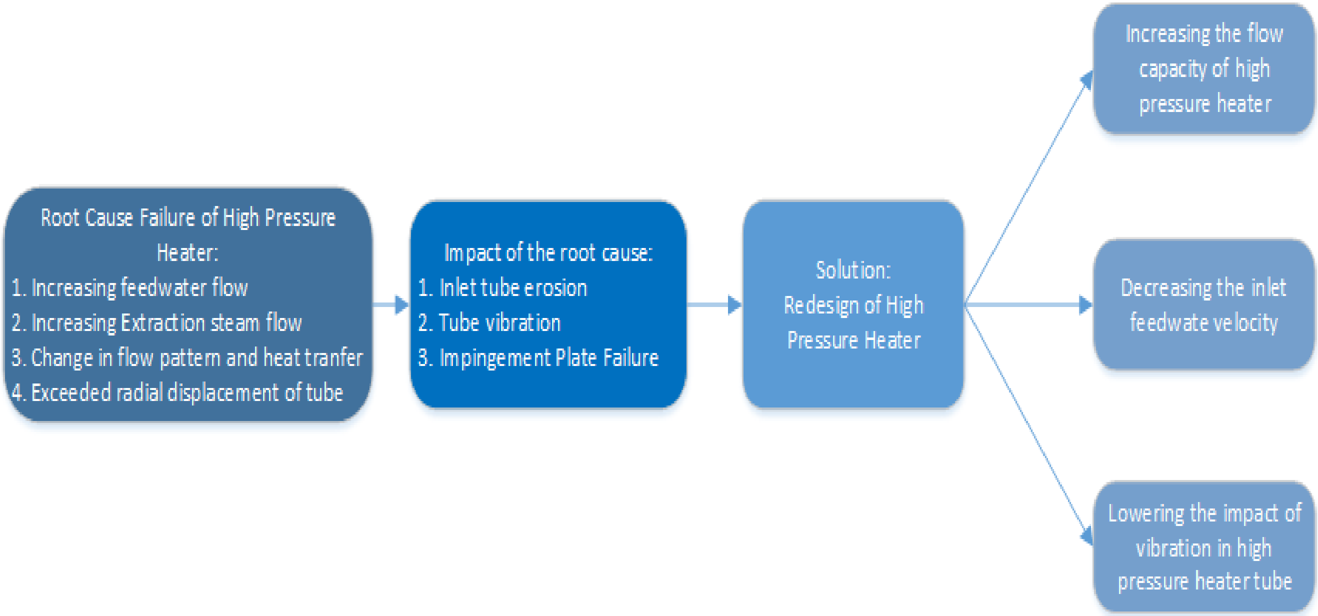

Fig. 2. Troubleshooting analysis heater is the difference between inlet feedwater and outlet

ITEM		HPH 5	Suralaya	Design T22 V=2,07	Design SA-556 V=2,07	Design T22 V=1,93	Design SA-556 V=1,93
Type		Horizontal Closed tubular type					
Feed water flow (kg/h)		1,149,020.00	1,156,036.00	1,351,152.00			
Total heating surface (m²)		780.00	1,186.00	1,047.20	1,047.20	1,123.90	1,123.90
Number of tube passes		2	2	2	2	2	2
Feed water velocity in tube (m/s)		2.600	1.910	2.070	2.070	1.930	1.930
Tubes	Quantity (U-tube)	1,242	1,579	1,884	1,884	2,022	2,022
	Outer diam. (mm)	15.875	15.875	15.875	15.875	15.875	15.875
	Thickness (mm)	1.900	2.108	2.108	2.108	2.108	2.108
	Eff. Length (mm)	6,294.0	7,530.0	5,572.7	5,572.7	5,572.7	5,572.7
Shell	Inner diam. (mm)	1,450.0	1,650.0	1,425.0	1,425.0	1,475.0	1,475.0
	Thickness (mm)	16.00	25.00	19.00	19.00	20.00	20.00
Channel	Inner diam. (mm)	R750 Spheri.	R837.5 Spheri	R 712.5 Spheri	R 712.5 Spheri	R737.5 Spheri	R737.5 Spheri
	Thickness (mm)	80.00	135.00	169.00	169.00	174.00	174.00
Baffle	Quantity (main baffle)	6	9	10	10	10	10
	Thickness (mm)	16.00	16.00	9.52	9.52	9.52	9.52
	Spacing (center-center) (mm)	970	900	440	440	440	440
Tube arrangement	Pattern (°)	60	60	60	60	60	60
	Pitch (mm)	20.640	38.104	20.640	20.640	20.640	20.640
Tubesheet thickness (mm)		330.00	550.00	314.32	314.32	314.32	314.32
Overall heater length (mm)		8,505	9,770	8,857	8,857	8,913	8,913

Fig. 3. New design for high pressure heater unit 5.

4) Failure Analysis of High Pressure Heater

Failure mode that could possibly occurs in high pressure heater can be seen at Figure 4. While considering the result from operation data analysis, maintenance data analysis and numerical analysis, there are three major possible cause of high pressure heater failure. First is tube vibration, tube vibration caused by increased stream velocity entering the high pressure heater. Tube vibration can also occurred when total clearance of radial displacement exceeds the maximum allowance. Other than that, tube vibration may also occur when there is a change in flow pattern and heat transfer in high pressure heater.

The second one is inlet tube erosion caused by the over clearance. And the third is impingement tube failure that caused by increased steam and drains velocity and hit the impingement baffle.

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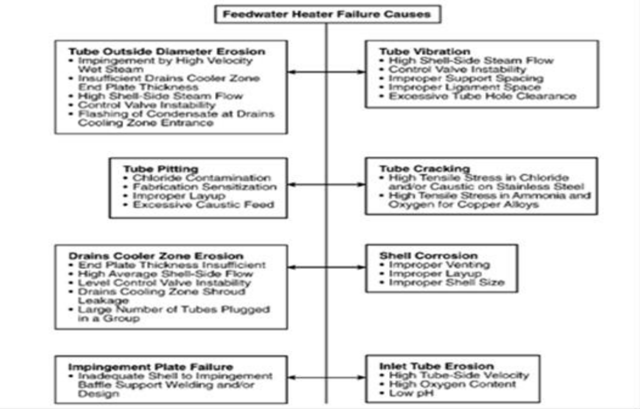

Fig. 4. High pressure heater failure mode

B. Troubleshooting Analysis

Based on the result of problem identification analysis, troubleshooting analysis is performed to generate solution. Since most of the root cause failure of high pressure heater are about design and operation condition, high pressure heater re-design is proposed. Parameters that would contribute in designing new high pressure heater be feedwater flow capacity and high pressure heater efficiency.

Detailed process diagram in redesigning the heat pressure heater can be seen at Figure 2. First, the value of feedwater flow capacity in high pressure heater is increased to 1.351.000 kg/h. This capacity is adjusted to the maximum amount of required steam toward next process. The, inlet feedwater velocity should be decreased to 2.6 m/s, 2.68 m/s and 2.83 m/s for high pressure heater unit 5, 6 and 7 respectively. This can be done by adding more tube or increasing the tube diameter in high pressure heater.

To maintain the high pressure heater efficiency, the Terminal Temperature Difference (TTD) and Drain Cooler Approach (DCA) should be calculated and maintained at the existing design value. Input parameter used for high pressure heater re-design can be seen at Table 2.

Table 2. Input parameter for re-design

Parameter	Existing High Pressure Heater			New design of High Pressure Heater		
Feedwater flow rate (kg/h)	1.149.020			1.351.000		
High Pressure Heater	5	6	7	5	6	7
Velocity (m/s)	2.6	2.68	2.83	2.6	2.68	2.83
TTD (ºC)	2.8	0	0	2.8	0	0
DCA (ºC)	5.6	5.6	5.6	5.6	5.6	5.6
Feedwater temperature rise (ºC)	13.6	39.5	46.0	13.6	39.5	46.0

Based on this input parameter, final engineering design of high pressure heater can be developed. The result can be seen at Figure 3.

C. Implementation Analysis

After re-designing the new high pressure system and fabrication of new high pressure heater, new high pressure system for unit 5, 6 and 7 is installed. Commissioning and performance test also conducted to analyze the new high pressure heater performance.

Table 3. High pressure heater performances

Parameter	Value		
	Old	Test(Old)	Test(New)
Total feedwater temp. rises (ºC)	99.1	97.8	103.0
HPH 7 feedwater outlet temp. (ºC)	250.0	255.3	254.0
HPH 6 feedwater outlet temp. (ºC)	204.0	210.8	205.0
HPH 5 feedwater outlet temp. (ºC)	164.5	170.4	171.0
HPH 5 feedwater temp. rises (ºC)	13.6	12.9	20.0
HPH 6 feedwater temp. rises (ºC)	39.5	41.5	34.0
HPH 7 feedwater temp. rises (ºC)	46.0	43.7	49.0
HPH 5 TTD	3.0	-	-3.4
HPH 5 DCA	4.9	-	12.0
HPH 6 TTD	0.0	-	-2.8
HPH 6 DCA	5.6	-	36.8
HPH 7 TTD	0.0	-	2.0
HPH 7 DCA	5.6	-	47
Feedwater flowrate (kg/h)	1.149.020	1.151.429	1.279.456

According to Table 3, the feedwater temperature rises of high pressure heater unit 5 and 7 are higher compared to their older units. This shows that the performance of newly installed high pressure heater unit 5 and 7 are better.

D. Evaluation

Evaluation process took place about a year after the implementation process. In the last three years before new high pressure heater was implemented, there are several problem happen in high pressure heater system. According to PT. PJB UP Paiton maintenance history, there are about 58 problems occurred in the past three years. But a year after the new high pressure heater was installed, no problem had occurred. This clearly shows that the new high pressure heater design more reliable.

V. CONCLUSION

This paper present a systematic failure analysis of high pressure heater in PT. PJB UP Paiton. It reveal two major cause of high pressure heater failure, feedwater flow rate and tube vibration. The root cause of tube vibration itself is increased feedwater flow rate. Hence, the high pressure heater flow rate capacity is greatly considered. After several analysis, high pressure heater is redesigned with higer flow rate capacity to overcome the problem. The new high pressure heater also has better performance when implemented. The new design also proved to be more reliable after a year of evaluation.

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