"Performance Analysis of Regenerative Feed Water Heating system in 270 MW Thermal Power Plant"

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Abstract - *The development of any country relates on capital energy consumption. The demand for power generation on the large scale is increasing day by day. Owing to their major contribution towards power production thermal plant shave vital role to play in the development of nation due to the scarcity of power, every power plant needs to be operated at maximum level of efficiency. The feed water heaters from a part of the regenerative system to increase the overall thermal efficiency of the plant In the present world, that parameter which directly or indirectly influences the performance of a heater has been studied the factor such as inlet temperature ,saturation temperature, terminal tap difference, drain cool approach & Temperature raise are studied The data for the performance of a test and the subsequent calculations are collected from HP heaters of 4 Units having capacity 270 MW RPL (Rattan India Power limited, 270 MW Thermal Power Station, Amravati, Maharashtra)*

Key words: **Feed water heater, power station, Regenerative, Thermal, turbines, operational cost**

1. INTRODUCTION

The Regenerative Cycle starts from turbine. The regenerative feed heating system cycle starts from the condenser at L.P end and ends at economizer inlet H.P end. Various auxiliaries like condenser, pump, main ejectors, gland steam condenser, drain cooler, H.P heaters etc. are situated in the system. The L.P heaters drain cooler and gland steam condenser are located in the condensate cycle between condensate pump & in the deaerator. The H.P heaters are located in the feed water cycle between deaerator and the boiler. The six extractions from the turbine are provided to 3 horizontal L.P heaters, deaerator and 2 Horizontal H.P heaters.

1.1 Extraction Drain System

The turbine extraction lines are connected to extraction drain points to drain condensate during warming up of pipes, during heater out condition and during turbine drip operation. The function of L.P heater is to increase the temperature of the feed water condensate discharged from drain cooler. The function of H.P heater to increase the temperature of the drain to the maximum desired required range. The function of deaerator is the dissolved gases like oxygen, CO_2, NH_2 which are harmful and present in feed water, are eliminated and heats the incoming feed water & Acts as a reservoir to provide a sudden and instantaneous demand.

1.2 Basic Feed Heating System

For the basic feed heating system for each process in vapor power cycle. it is possible to assume a hypothetical (or)ideal process which represents the basic intended operation. For basic feed system we used Rankin cycle in this when all these four processes are ideal, the cycle is an ideal cycle called Rankin cycle. For the purpose if analysis, the Rankin cycle is assumed to be carried out in a steady flow operation, applying steady flow engineering equation (SFEE) to each of the process on the basis of the process on the basis of unit mass of fluid, and neglecting changes in kinetic and potential energy.

2. Power plant working Cycle

The thermal cycle for the plant has been designed in accordance with the latest trends and concepts prevailing so as to achieve optimum heat rate. The regenerative feed heating system plays vital role in improving the thermal cycle efficiency. Feed heating system for KWU turbine cycle is shown in Fig.1.

It consists of three low-pressure heaters, gland steam condenser, drain cooler, deaerator and two high-pressure heaters. In addition to this the condensate passes through inter-coolers of main ejectors used for extraction of non-condensable gases from the condenser. The condensate extraction pumps (2x100%) take suction from condenser hot well and delivers the condensate to deaerator through the tube systems of main ejector, gland steam cooler, drain cooler and low pressure heaters. Boiler feed pumps (3 x 50%) take suction from deaerator and pump the feed water to boiler through high-pressure heaters. The condensate/feed water gets heated up progressively by bled

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 04| Apr -2016 www.irjet.net p-ISSN: 2395-0072

steam from turbine extractions together with gland leak-off steam.

2.1 LP Heaters

L.P. Heaters No. 1, 2 & 3 get heating steam from LP turbine. Quick closing non-return valves (swing check type) are provided in extraction lines of LP heaters No. 2 & 3 to prevent back flow of steam into the turbine during trip. Also the LP heater No. 2 & 3 are provided each with drain control valves (2 Nos.), one for maintaining heater level at normal value and second control valve provides alternate path to condenser through flash box by maintaining heater level at higher set point. No level is maintained in LP heater 1. Its drain is connected through a siphon to condenser.

Whenever level in LP heater Nos. 1, 2 & 3 reaches very high set point, the respective motorized block valve in extraction line closes along with the opening of drip valve in extraction line (drip valves only in LPH-2 & 3). Drip from next higher pressure heater is diverted to condenser through flash box by alternate drip control valve. Affected LP heater is isolated by closing condensate line isolating valves and opening bypass valves across it.

2.2 H P Heaters

Two horizontal HP heaters No. 5 & 6 are provided in the system. HP heater No. 5 gets heating steam from IP turbine and HP heater No. 6 from cold reheat line (after CRH NRV). Hydraulically operated non-return valve is provided in extraction line to HPH-5 and motorized block valves near heater ends of HPH 5 & 6.

HP heaters shall be automatically isolated on feed water and steam side under heater very high-level condition. Quick opening group protection valves (FD16 & 17) are also provided for bypassing HP heaters during very high heater level condition. Normal level of HP heater No. 6 is controlled through control valves cascading the drip to HP heater 5 and another valve cascading to deaerator and alternate drain control valve is provided to condenser through flash box operating on high level.

2.3 Deaerator

Deaerator is designed to operate under variable pressure between 55% to 100% load on turbine and during this range, steam is drawn from turbine extraction, i.e. IPT exhaust. During start-up of turbine, deaerator is provided with steam supply from cold reheats line as well as external steam source, i.e. auxiliary PRDS header.During initial start-up, pegging of deaerator is done through a control valve connected to auxiliary steam header at a pressure of 3.5 ata. till about 15-20% boiler MCR load, depending upon the type of start-up (viz. cold, warm or hot).

After this, the steam supply to deaerator is switched over to cold reheat line through a control valve and pegging is maintained at 3.5 ata. up to about 55% turbine load. Thereafter the steam supply to deaerator is automatically switched over to turbine extraction and this is in service up to full load. During HP/LP bypass operation also, the deaerator is pegged from cold reheat line at a pressure of 3.5 ata.Normal level in the hot well is maintained by positioning the hot well control valve and excess return dump valve

The minimum flow requirements of ejector, condensate pump and gland steam condenser is approximately 210 T/hr. and the same is achieved by condensate recirculation control valve.This valve is a regulating type and remains open during start-up when main condensate valve is closed. As the load on the turbine increases, main condensate control valve opens and the minimum recirculation control valve closes proportionately to maintain minimum flow of 210 T/hr.

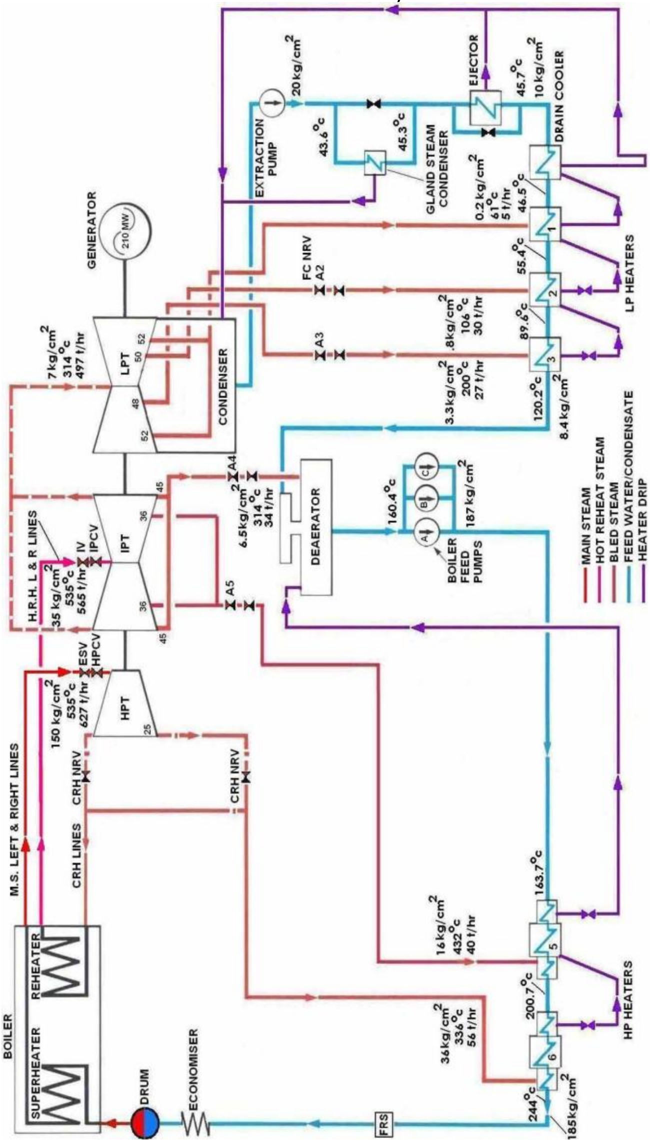


Fig. 1: Power Plant working cycle

3. Feed Water Heater

Feed water heater is a power plant component used to pre-heat water delivered to a steam generating boiler. Preheating the feed water reduces the irreversibility's involved in steam generation and therefore improves the thermodynamic efficiency of the system.[4] This reduces plant operating costs and also helps to avoid thermal shock to the boiler metal when the feed water is introduced back into the steam cycle.

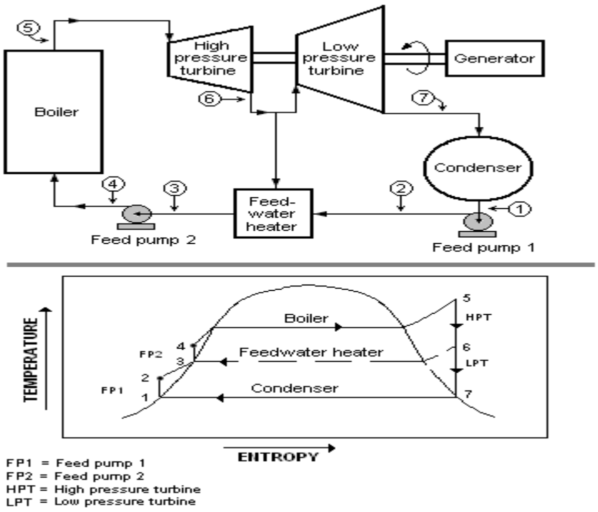


Fig. 2 : Feed water heater Flow diagram with T-S Diagram

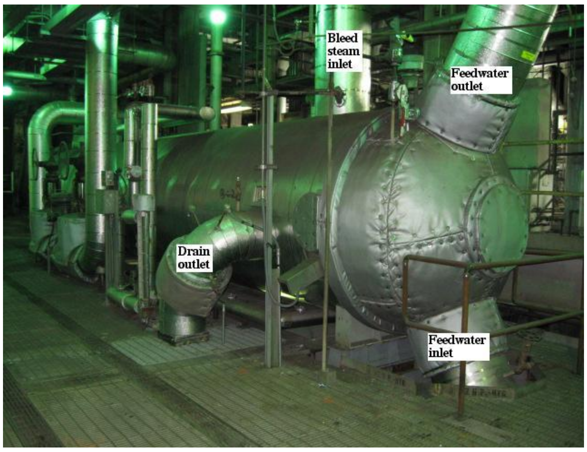


Fig. 3 : Feed water Heater in UNIT 2, RPL Plant

3.1 Heaters Heating Zone

Zones are separate areas within the shell in a feedwater heater.
Desuperheating Zone : The incoming steam enters this zone, giving up most of its superheat to the feedwater exiting from the heater.
Condensing Zone: All feed waters have this zone. All of the steam is condensed in this area, and any remaining non condensable gases must be removed. A large percentage of the energy added by the heater occurs here.
Sub cooling Zone: The condensed steam enters this zone at the saturation temperature and is cooled by convective heat transfer from the incoming feedwater.

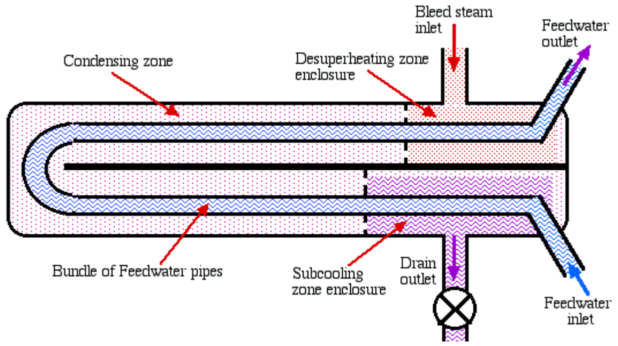


Fig. 4 : Feed water Heater Heating Zone

4. HP Heater performance Parameter

The performance of feed water heaters can be analyzed by monitoring the terminal temperature difference (TTD), drain cooler approach temperature (DCA), the pressure drop on the feed water side and the temperature rise across the heater. To monitor these it is desirable to carry out a simplified routine performance test on feed water heaters at a specified frequency. This will help in identifying the level of deviations and trending of performance.

A) Terminal Temperature (TTD)
Formula :-

TTD = T sat- T (fw out)

Where, T (sat) = Saturation temp taken at the heater shell pressure, o C ,T (fw out) = Temperature of feed water leaving the heater, o C

B) Drain Cooler Approach Temperature (DCA)
Formula :-

DCA = T (drain temp) - T (feed water entering)

Where,T (drain) = temp of the drain leaving the heater, o C
T(fw in) = Temp of feed water entering the heater, o C

C) Temperature Rise (TR)
Formula :-

TR = Feed water oulet temp. - Feed water Inlet Temp.

D) Extraction Steam Flow
Formula :-

Extraction Flow = FW Flow*(Enthalpy of FW after HPH-6- Enthalpy of FW before HPH-6) / (Enthalpy of extraction steam to HPH-6 - Enthalpy of HPH-6 Drain)

5. Data Collection

The performance test data from instruments will be recorded using sample format as given in Format

Test Setup:

1. Unit should be in operation at normal full feed water flow and steady state condition.
2. Ensure the heater drains are cascading as per the specified cycle conditions.
3. Ensure venting of steam side and waterside to remove non-condensable gases. Operation of the feed water heater shall be brought to the steady state condition prior to initiating the test run. It shall be kept at this condition throughout the test run.
4. First test run is conducted at heater water level at normal design value. Subsequently, other test runs are conducted by varying the heater levels above and below the normal level.

5.1 Sample computation

HP Heater 5 & 6 Performance parameter data sheet

Observation data /Reading noted during test run of all 4 units.

HP Heater- 6 Performance Monitoring data sheet						
		Test Value				
Sl. No	**Parameters**	**Design**	**Unit# 2**	**Unit# 3**	**Unit #4**	**Unit#5**
1	**Load(in MW)**	**270**	271.10	273.16	271.18	270.57
2	**FW Temp before HPH -6 (in °C)**	**201.1**	204	205	205	204
3	**FW Temp after HPH -6 (in °C)**	**246**	249	249	250	248
4	**Enthalpy of FW before HPH-6 (in KJ/kg)**	**857.234**	870.46	874.993	874.993	870.46
5	**Enthalpy of FW before HPH-6 (in Kcal/kg)**	**205.079**	208.244	209.328	209.328	208.244
6	**Enthalpy of FW after HPH-6 (in KJ/kg)**	**1066.37**	1080.82	1080.82	1085.686	1075.9802
7	**Enthalpy of FW after HPH-6 (in Kcal/kg)**	**255.1124**	258.56	258.56	259.733	257.4115
8	**Extraction Steam pressure to HPH-6 (in kg/cm²)**	**37.74**	38.09	39	38.98	38.27
9	**Extraction SteamTemperature HPH -6 (in °C)**	**343.4**	353	342	350	349
10	**Drain Temperature of HPH -6 (in °C)**	**206**	211	216	211	209
11	**Enthalpy of Ext Steam to HPH -6 (in KJ/kg)**	**3082.33**	3106.78	3077.48	3097.411	3096.55
12	**Enthalpy of Ext Steam to HPH -6 (in Kcal/kg)**	**737.375**	743.248	736.239	741.00	740.8014
13	**Enthalpy of HPH-6 Drain (in KJ/kg)**	**879.421**	902.293	925.202	902.293	893.1705
14	**Enthalpy of HPH-6 Drain (in Kcal/kg)**	**210.387**	215.859	221.34	215.85	213.677
15	**FW Flow (in TPH)**	**796.6**	753.9	893.3	736	839
16	**Saturation temp.**	**246.9**	247.5	248.	248.06	247.62

HP HEATER-6 PERFORMANCE INDICES						
Sl. No	**Parameters**	**Design**	**Unit# 2**	**Unit #3**	**Unit #4**	**Unit #5**
1	**Terminal temp. diff. (TTD)**	**-0.20**	-1.5	-0.27	-1.94	-0.38
2	**Drain cooler approach (DCA)**	**4.80**	7	11	6	5
3	**EXTRACTION FLOW**	**75.630**	76.939	85.428	70.641	78.2577
4	**FW TEMP RISE**	**44.9**	45	40	45	44

HP Heater- 5 Performance Monitoring data sheet						
		Test Value				
Sl. No	**Parameters**	Design	Unit# 2	Unit# 3	Unit #4	Unit #5
1	**Load(in MW)**	**270**	**271.10**	**273.16**	**270.57**	**271.18**
2	**FW Temp before HPH -5 (in °C)**	**167.3**	**173.25**	**171.25**	**169.88**	**173.23**
3	**FW Temp after HPH -5 (in °C)**	**201.1**	**204**	**205**	**205**	**205**

4	Enthalpy of FW before HPH-6 (in KJ/kg)	707.275	733.46	812.02	718.680	733.372
5	Enthalpy of FW before HPH-5 (in Kcal/kg)	169.204	175.466	194.26	171.933	175.44
6	Enthalpy of FW after HPH-5 (in KJ/kg)	857.23	870.46	874.99	870.46	874.99
7	Enthalpy of FW after HPH-5 (in Kcal/kg)	205.079	208.244	209.32	208.244	209.32
8	Extraction Steam pressure to HPH 5(in kg/cm²)	16.16	16.75	17	16.90	16.94
9	Extraction SteamTemperature HPH -5 (in °C)	427.2	441	427	438	430
10	Drain Temperature of HPH -5 (in °C)	172.2	176	176	176	176
11	Enthalpy of Ext Steam to HPH -5 (in KJ/kg)	3313.69	3343	3312.3	3336.44	3318.98
12	Enthalpy of Ext Steam to HPH -5 (in Kcal/kg)	792.7488	798.42	792.41	798.191	794.0153
13	Enthalpy of HPH-5 Drain (in KJ/kg)	728.725	745.55	754.361	745.55	745.55
14	Enthalpy of HPH-5 Drain (in Kcal/kg)	174.3361	178.060	180.4691	178.063	178.0630
15	FW Flow (in TPH)	796.60	753.9	893.3	839	736.4
16	Saturation temp.	201.85	205.56	204.35	204.85	205.4
	HP HEATER-5 PERFORMANCE INDICES					
Sl. No	Parameters	Design	Unit #2	Unit #3	Unit #4	Unit #5
1	Terminal temp. diff. (TTD)	-0.20	1.56	-0.65	-0.15	0.4
2	Drain cooler approach (DCA)	4.90	2.75	4.75	6.12	2.77
3	EXTRACTION FLOW	46.2182	39.833	21.990	49.1266	40.5050
4	FW TEMP RISE	33.8	30.75	33.75	34.12	31.77

5.2 Calculation:

Following sample calculation considering unit # 2 Data
HPH 5 Performance parameter Calculation

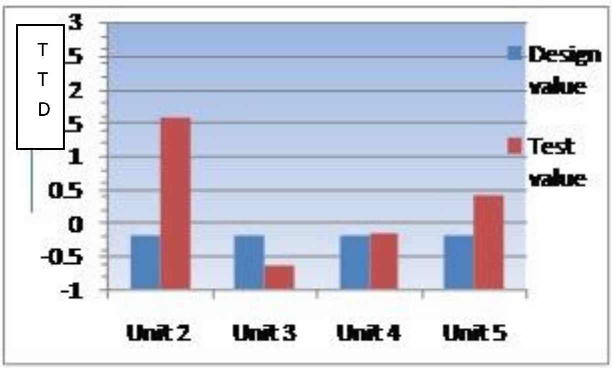
1) Terminal Temperature (TTD)
TTD = t sat – t fw out
= 205.56- 204=1.56 ° C.
2) Drain Cooler Apporach Temperature (DCA)
DCA = t drains - t fw in
= 176 – 173.25 = 2.75 ° C.
3) Temperature Rise (TR)
TR = t fw out – t fw in
= 204 -173.25 = 30.75 ° C.
4) Extraction Steam Flow
EXTRACTION FLOW= FW Flow*(Enthalpy of FW after HPH-5- Enthalpy of FW before HPH-5) / (Enthalpy of extraction steam to HPH-5 - Enthalpy of HPH-5 Drain)
= 753.9 * (870.46 – 733.45) / (3343 – 745.55)
= 39.822 TPH

HPH 6 Performance parameter Calculation

1) Terminal Temperature (TTD)
TTD = t sat – t fw out
= 247.5 – 249 = -1.5 ° C.
2) Drain Cooler Apporach Temperature (DCA)
DCA = t drains - t fw in
= 211 – 204 = 7 ° C.
3) Temperature Rise (TR)
TR = t fw out – t fw in
= 249 - 204 = 45 ° C.
4) Extraction Steam Flow
EXTRACTION FLOW= FW Flow*(Enthalpy of FW after HPH-6- Enthalpy of FW before HPH-6) / (Enthalpy of extraction steam to HPH-6 - Enthalpy of HPH-6 Drain)
= 753.9 * (1080.82 – 870.46) / (3106.78 – 902.293)
= 76.9398 TPH

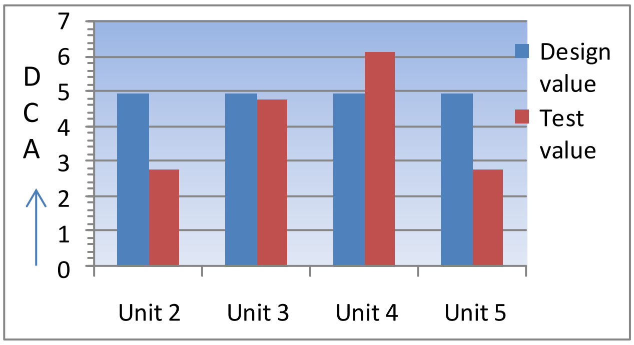
7. Result Analysis by graph

Following Graph showing the individual parameter (TTD and DCA) of each unit representing HP heater 5 Performance Curve. HP Heater 5 Performance curve using TTD analysis of 4 Units.



In the above graph it shows that TTD of unit 2 is on higher side it means that its heater level is not proper, may be heat partition leaks and its tube internally fouled. All other unit test value of TTD is in acceptable limit.

- HP Heater 5 Performance curve using DCA analysis of 4 Units.



In the above graph of HP Heater 5 shows that DCA of unit 2 is on lower side it means that

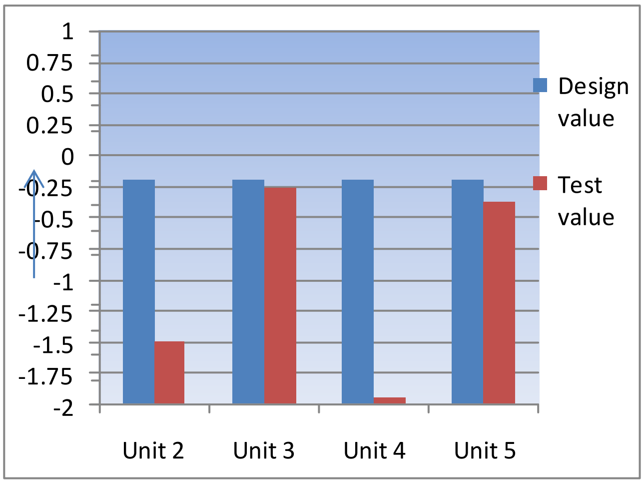
1. Heater shell side drain valve not proper.

2. Heater isolation valve break or damage, water level is increased due to that proper venting not possible.

3. In unit 4 DCA is more, means its drain valve is passing and hence heater efficiency is lower than other units.

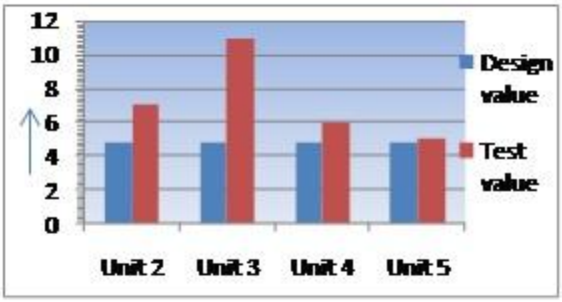
Following Graph showing the individual parameter (TTD and DCA) of each unit representing HP heater 6 Performance Curve.

- HP Heater 6 Performance curve using TTD analysis of 4 Units.



In the above graph it shows that TTD of unit 3 & 4 is in good condition. But in unit 2 & 4 the TTD test value is far lower than design value it shows that firstly Heater shell side venting is not proper, the cascading valve is passing, level not maintained properly

- HP Heater 5 Performance curve using DCA analysis of 4 Units.



In the above graph shows that in Unit 3 DCA test value is on higher side it shows that

1 .Excessive Feed water drains Bypass.

2. Low water level maintained during operation

3. May be Excessive number of tube plugged

7.1Fault Analysis:

An increase in either the TTD or DCA, and/or a decrease in the temperature rise indicate the problem with the heater. This deterioration in the performance could be the result of any or all of the following causes:

1. Fouled heater tubes (either steam or water side or both).

2. Internal leakage (leakage through the water box partition plate resulting in a partial internal bypassing of the heater, or, tube-to-tube sheet leakage resulting in feed water leaking to the steam side).

3. External leakage (through the bypass valve).d. Plugged tubes (reducing the heat transfer area, while increasing tube velocity).

7.2 Recommendation:

Based on the above discussions, following are the recommendations for feed water heaters:

1. All the HP Heater tubes shall be welded to tube sheets & then roller expanded. LP Heater tubes shall be roller expanded to tube sheet.

2. The water box or channel section of all heaters shell should be of carbon steel, fabricated or forged construction. Water box should be of hemispherical

shape. Sufficient space area should be provided in between water box & tube plate for efficient & smooth entry of feed water & ease maintenance of the tubes.

3. Water box of all the HP Heaters & LP Heaters shall be welded to the tube plate.

4. The shells of all the heaters shall be welded to the tube plate.

5. All connections for drains, feed water & steam at the heaters shall be welded to leak-tight.

6. In the HP Heaters the steam leaving the de-super heater section at the full duty shall be above the saturation temperature by a sufficient margin to ensure that no condensation will occur in the tubes under normal operating conditions & steam leaving the de-superheating section will not cause droplet impingement in the condensing section.

7. To avoid excessive velocity in the drain cooling section during emergency draining operation to condenser & lower heater, a separate drain cooler bypass connection shall be provided on the shell of the heater.

8. All openings on the HP Heater channel shall be self-sealing type.

9. The fouling factors on the tube side & the shell side in different zone shall be as per HEI standards.

10. Periodical checking should be done to avoid any leakage or accumulation of non-condensable gases. For this proper venting has to be ensured during the operating condition of the heaters.

8 Conclusions

From the above calculations it is evident that efficiency of the HP heaters is on higher side kept for HPH-5as per Parameter. The efficiency of the HPH-5 may be lower due to sale formation or increase flow velocity due to more number of tube diameters in the tube bundle. However efficiency can be improved by HP jet chemical cleaning of the tubes and replacement of the tube bundle the cycle efficiency of the plant can be improved.

The efficiency of power plant increase with increase in number of heaters, but it is not economical to have large number of heaters to increase to increase the efficiency on the basis of the techno-economic study the numbers of heaters generally used in 270 MW units are 6 to 7 thus the efficiency increases by 5 to 6 approximately.

The operation and maintenance of the heaters in the current power plant must be increased such that there is no much deviation in the design and calculations values. It is also observed that with thisoperation and maintenance the heaters are giving the efficiency of about 75% - 80%.

Advantages of Regenerative Feed water heating System

1. It improves the cycle efficiency.
2. The metal temperature of boiler tube reduces by taking feed heaters in service and hence increases the boiler tube life and reduces the outage due to tube leakages.
3. Extractions from last stages of turbine also act as moisture extractor and hence reduce the blade damage due to water droplets impact.
4.Cost per unit of electrical power reduces by using with feed heaters.

Disadvantages of Regenerative Feed water heating System

1. Increase cost of pipe frame work and also increase mechanical losses with the some steam input less work is achieved.
2. Strength of turbine decreases due to the holes provided for extraction of steam from different stages.
3. The temperature of the flue gases may reach to dew point temperature Decreases the extent of heat extraction from the gases economizer, Regenerative feed heating involves the process of improving the efficiencies of turbine and to produce move work.

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