International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur

PERFORMATIVE ANALYSIS OF REGENERATIVE FEED HEATING SYSTEM IN STEAM POWER PLANT

S Kamalesh
Mechanical department
St john s college of eng& tech
Yerrakota ,yemmignoor ,india
Kamaljntu2012@gmail.com

Naveen Kumar Nagali
Mechanical department
Adhiyamaan college of eng
Hosur ,india
nagallinaveen@gmail.com

B Madhu Babu
Mechanical dept.
Jntua
Anantapur india
madhubabu3319@gmail.com

Abstract

The development of any country directly 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 power plants have a vital role to play in the development of nation. Due to the scarcity of poor every power plant needs to be operated at maximum level of efficiency. In case of thermal power plants this applies equally to all its auxiliaries.

The feed water heaters form a part of the regenerative system to increase the overall thermal efficiency of the plant. In the operation and maintenance of a power plant the feed water heaters are virtually neglected compared with other components. To realize the effect of feed water heating and an attempt is made in this project work to find the improvement in cycle efficiency due to FWH. Two units of different configuration with same capacity (210MW) are considered for the analysis. In general an improvement of (5-6%) efficiency is possible due to repetition.

The actual gain in efficiency depends on the number of FWH'S and the performance of heater. The improvement in efficiency of the two units considered for the analysis indicated the above the factor. Hence an effective analysis is required to the number of FWH to be used. Also the maintenance of heater in the form of removal of scale or corrosion plays important role in the overall performance of the plant.

The performance of regenerative cycle of feed water heating system of 210MW and find some of the troubles and suggesting suitable remedies in regenerative cycle and high lighting the modification for optimum performance.

Index Terms—heating system,regenerative ,efficiency,capacity,capital,energy

I. INTRODUCTION

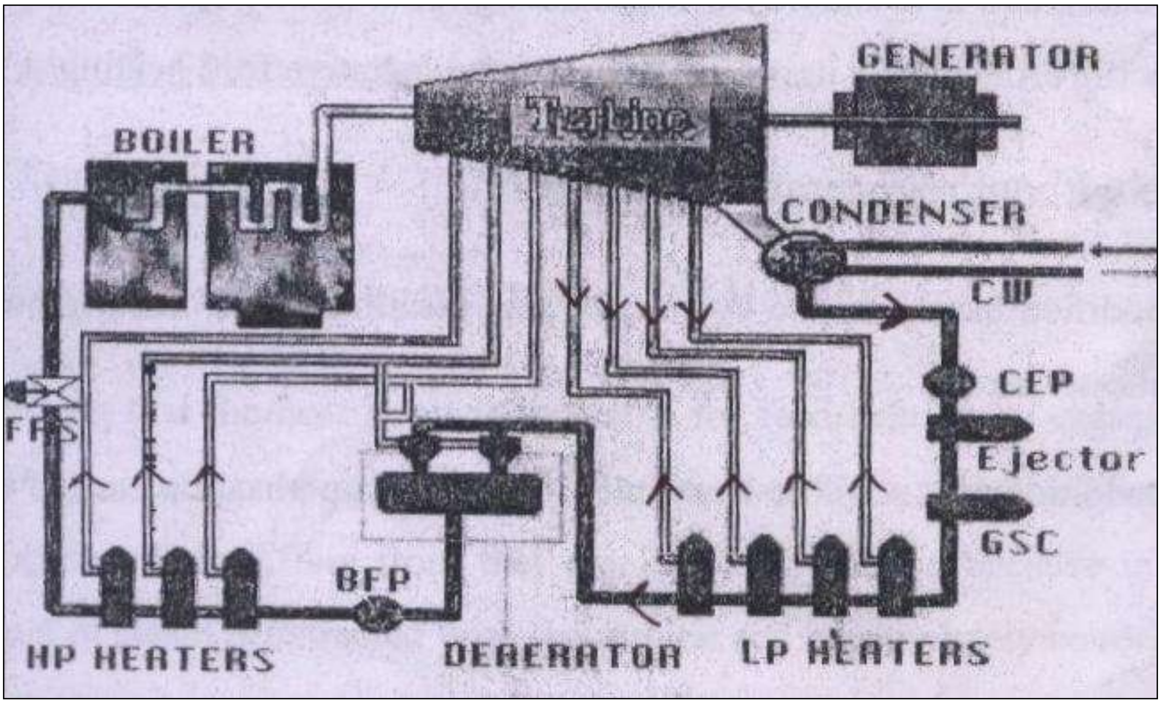
This paper describes the Performative Analysis of Regenerative Feed Heating System in Steam Power Plant. HP Heaters, LP Heaters and Deaerator play a vital role in Regenerative Feed Heating System. This analysis describes that how the efficiency increases with regenerative feed heating. The result we get will also have its effect on the condenser i.e. the load on the condenser will also be decreased.

International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur

II. BACKGROUND INFORMATION

REGENERATION

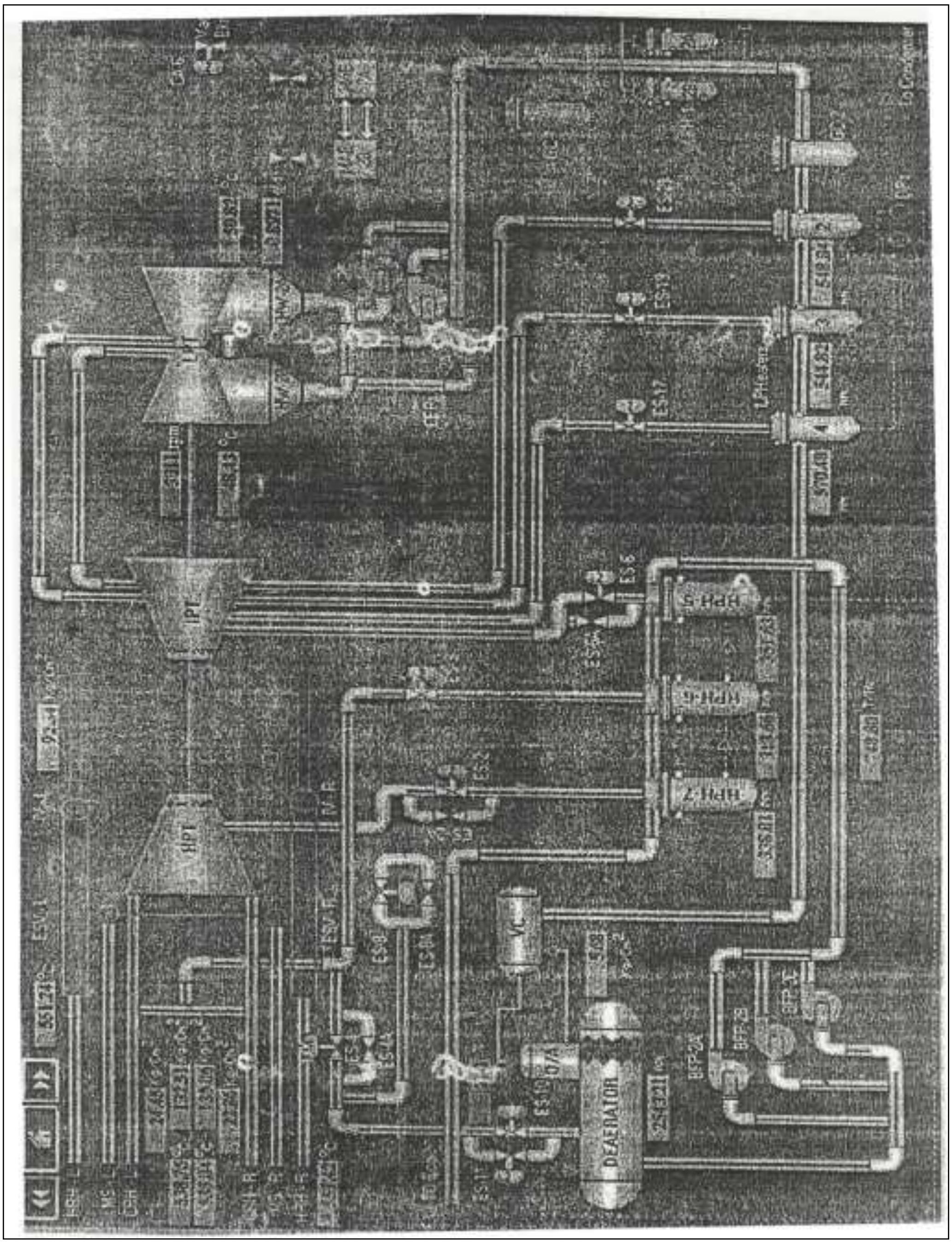
When heat is absorbed or picked up in between the fluid flow and is sent back to its source, the process is called regeneration, e.g. in the feed heating, heat is coming from the boiler drum and is sent back to boiler drum again. The process is regenerative because a part of the working fluid after partial expansion is utilized to heat the other parts of working media in the cycle. Another example of regenerative heating is Ljungstrom air heater in boiler.



Regenerative System

REGENERATIVE FEED HEATEING

A small fraction of the steam expanding through the turbine is bled off from different stages of turbine before reaching the condenser, and used to heat water in feed heaters. This process is called regenerative feed heating. Some torque is sacrificed in the process, but energy is saved. The bled steam is also called as extraction steam.

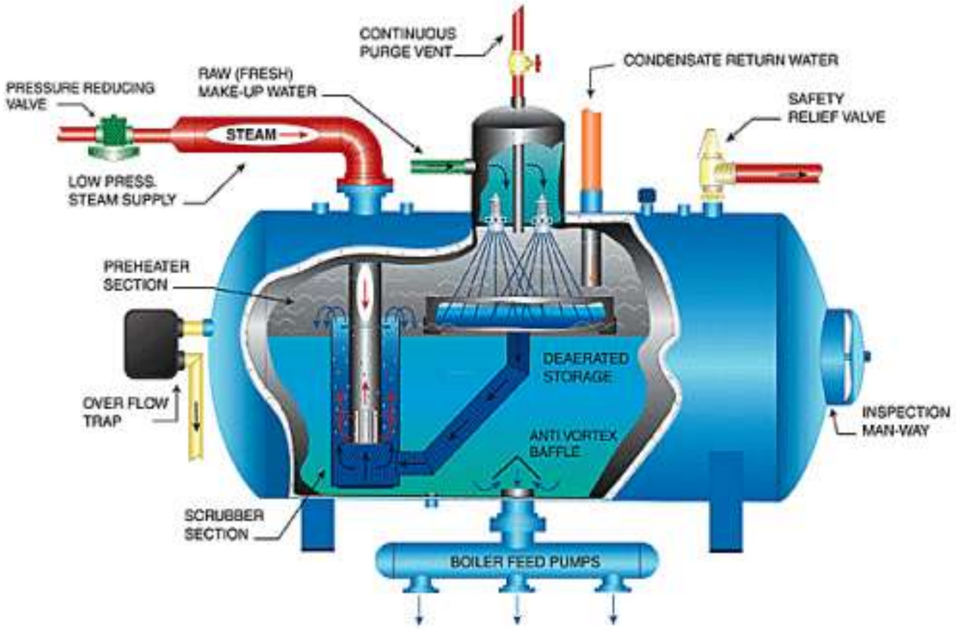


Feed Heating System

FUNCTION OF DEAERATOR (D/A)

The function of deaerator is to remove dissolved oxygen and other gases from the condensate feed water, which are corrosive in nature. To heat-up incoming condensate water. To act as a reservoir for providing condensate water, whenever need arises.

International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur



DEAERATOR

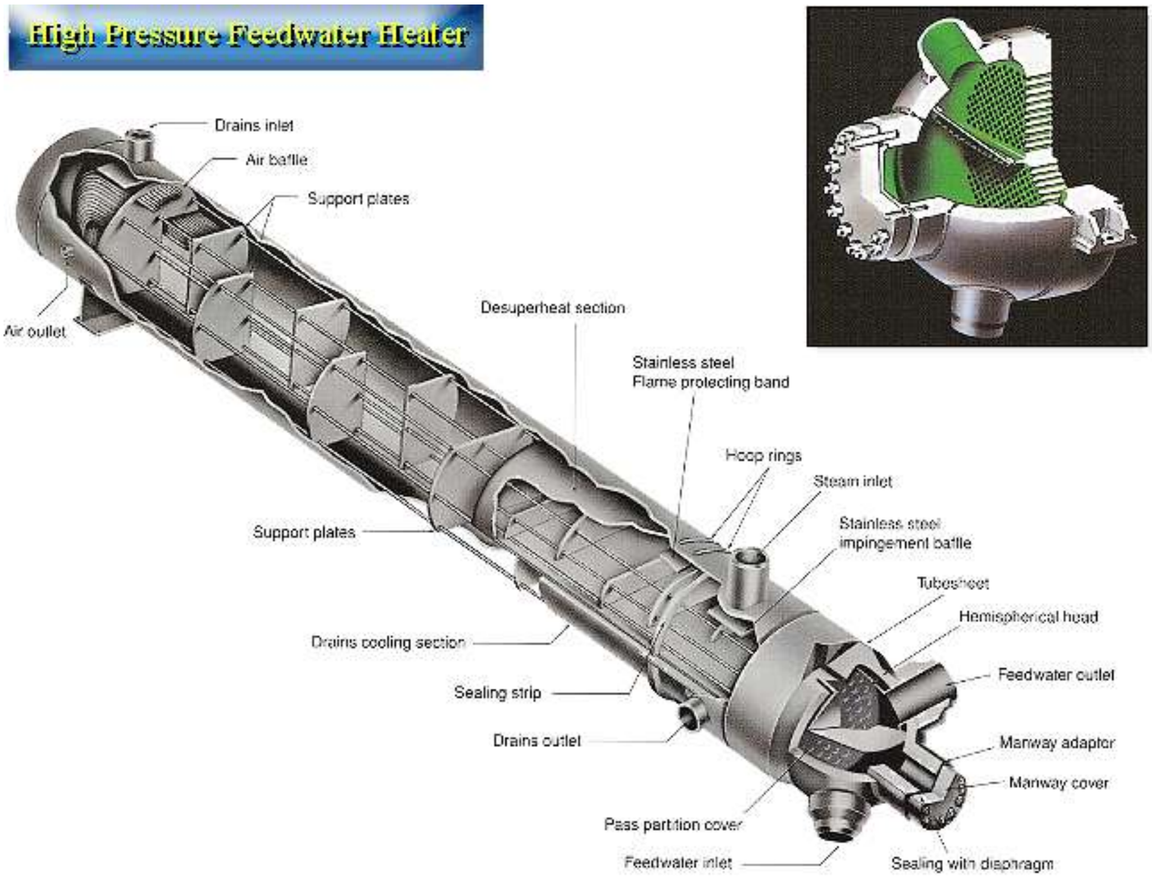
MATERIAL USED FOR DEAERATOR CONSTRUCTION

Material D/A shell /dish	A285 Gr. C
FST shell / dish	A 285 Gr. C / IS 2002 Gr. 2A
Trays	SS 304
Fabricated nozzles	A 285 Gr. C

WORKING OF HP HEATER

The feed water enters into the lowest pressure HP heater. After gaining heat in this heater the feed water passes to the next higher pressure heater and finally to boiler through feed regulating station and the economizer. In case of any trouble in the HP heater they can be by-passed individually, as well as in groups from the feed water side.

International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur

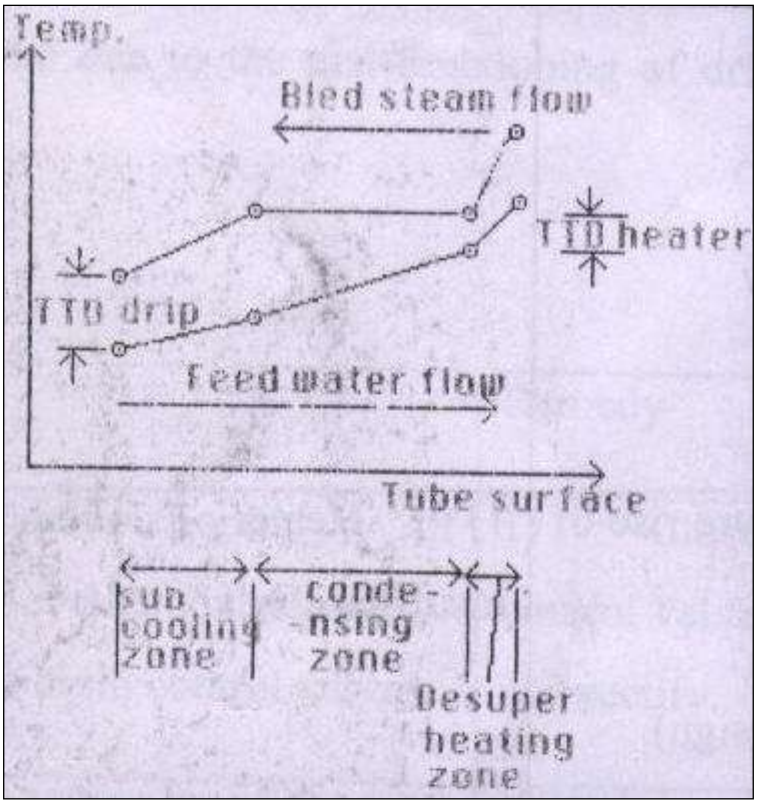


HP HEATER

PERFORMANCE OF HEATERS:

Temperature difference between feed water outlet and bled steam saturation temperature is known as TTD. The TTD must be near to the design valve of heater for better heat transfer. In case of direct contact heaters the TTD is zero. Higher TTD represents the fouling of heater tubes from both sides (inside and outside) and blanketing of heater tubes by non-condensable gases. To remove non-condensable gases venting arrangement is provided in each heater. The HP heaters can be vented to the Deaerator or condenser. The LP heater can be vented to condenser.

International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur



Graph of T.T.D

TTD is the measure of heater performance. If there is an increase in the resistance to heat transfer, the bled steam saturation temperature will be unaffected but, the feed water outlet temperature will be reduced. Accordingly the TTD will increase and thus will cause a reduction of the bled steam flow. Typical value of the TTD is 80°C for a HPH in case of 500 MW units.

EFFECTIVENESS OF HEATER

Effectiveness of heater should be near to the design value of the heater. The value of effectiveness of heater is near 85%.

$$\text{Effectiveness} = \frac{\text{Feed water temperature rise}}{\text{(Saturation temp. corresponding to the bled steam pressure)- (Feed Water inlet temperature).}}$$

International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur

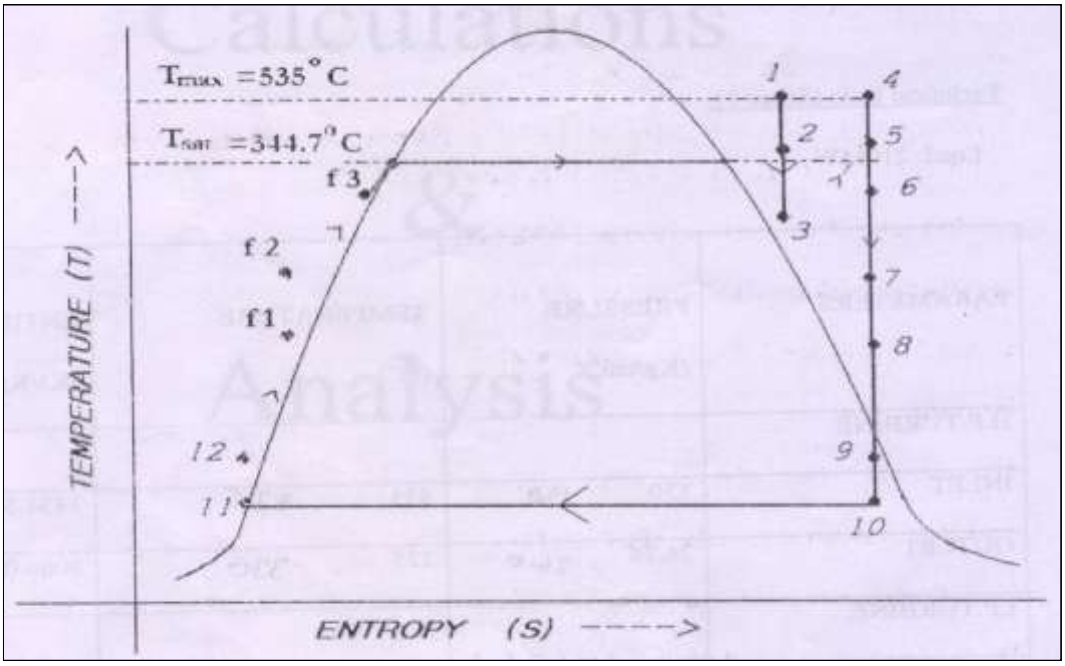
CYCLE EFFICIENCY (WITH REGENERATION)

TECHNICAL DATA:

LOAD: 210MW

PARAMETERS	PRESSURE (Kg/cm^2)	TEMPERATURE(°C)	ENTHALPY(KJ/Kg)
H.P.TURBINE			
INLET	130	535	3434.55
OUTLET	26.74	325	3066.02
I.P.TURBINE			
INLET	23.44	535	3542.3
OUTLET	1.2848	184	2842.47
L.P.TURBINE			
INLET	1.2848	184	2842.47
OUTLET	-0.9	57.7	2605.988

Total mass of steam entering into H.P.Turbine = 623 tones/hour.
Total feed water flow in the circuit = 623 tones/hour.



Rankine Cycle with Regeneration and Reheating

International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur

Let us assume that equivalent amount of steam entering into the turbine.

where
m = mass of steam at the inlet of H.P.Turbine
m1 = mass of extraction steam in H.P.H7
m2 = mass of extraction steam in H.P.H6
m3 = mass of extraction steam to Deaerator
m4 = mass of extraction steam in H.P.H5
m5 = mass of extraction steam in L.P.H4
m6 = mass of extraction steam in L.P.H3
m7 = mass of extraction steam in L.P.H2
m8 = mass of extraction steam in L.P.H1
h1 = Enthalpy of steam at the inlet of H.P.Turbine
h2 = Enthalpy of extraction steam in H.P.H7
h3 = Enthalpy of extraction steam in H.P.H6 & Enthalpy of extraction steam to Deaerator & Enthalpy of steam at the exit of H.P.Turbine
h4 = Enthalpy of steam at the inlet of I.P.Turbine
h5 = Enthalpy of extraction steam in H.P.H5
h6 = Enthalpy of extraction steam in L.P.H4
h7 = Enthalpy of extraction steam in L.P.H3
h8 = Enthalpy of extraction steam in L.P.H2 & Enthalpy of extraction steam in L.P.H1
h9 = Enthalpy of extraction steam in L.P.H1
h10 = Enthalpy of steam at the outlet of L.P.Turbine.

Heaters	Quantity of Extraction steam (Tons/hr)	Mass Fraction	Pressure (Kg/cm^2)	Temperature (°C)	Enthalpy (KJ/Kg)
H.P.H7	32.447	m1 = 0.052070	42.83	382	3168.22
H.P.H6	47.278	m2 = 0.075880	26.74	325	3066.02
H.P.H5	17.661	m3 = 0.028348	13.15	447.3	3361.5
Deaerator	6.5	m4 = 0.010433	26.74	325	3066.02
L.P.H4	25.4	m5 = 0.040770	7.078	363.5	3192.252
L.P.H3	22.53	m6 = 0.036164	3.06	263.5	2995.296
L.P.H2	26.67	m7 = 0.042810	1.409	182	2838.827
L.P.H1	8	m8 = 0.012840	-0.88	54	2243.22

International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur

III. MAIN RESULT CALCULATIONS

WORK DONE BY H.P.TURBINE:

WH.P.T = m (h1-h2) + (m-m1)(h2-h3)

WH.P.T = 1 (3434.55-3168.22) + (1-0.05207)(3168.22-3066.02)

WH.P.T = 363.208 KJ/Kg.

WORK DONE BY I.P.TURBINE:

WI.P.T = (m-m1-m2-m3)(h4-h5) + (m-m1-m2-m3-m4)(h5-h6) + (m-m1-m2-m3-m4-m5)(h6-h7) + (m-m1-m2-m3-m4-m5-m6)(h7-h8)

WI.P.T = (1-0.05207-0.07588-0.01433)(3542.3-3361.5) + (1-0.05207-0.07588-0.010433)(3361.5-3192.25) + (1-0.05207-0.07588-0.010433-0.028348-0.04077-0.036164)(2995.296-2838.83)

WI.P.T = 571.2398 KJ/Kg.

WORK DONE BY L.P.TURBINE:

WL.P.T = (m-m1-m2-m3-m4-m5-m6-m7) (h8-h9) + (m-m1-m2-m3-m4-m5-m6-m7-m8)(h9-h10)

WL.P.T = (1-0.05207-0.07588-0.010433-0.028348-0.04077-0.036164-0.04281)(2838.8278-2605.988) + (1-0.05207-0.07588-0.010433-0.028348-0.04077-0.036164-0.04281-0.01284) (2605.988-2243.22)

WL.P.T = 420.246KJ/Kg.

Total Work done by Turbine WTurbine = WH.P.T + WI.P.T + WL.P.T

= 363.208 + 571.2398 + 420.246

= 1354.69KJ/Kg.

CALCULATIONS FOR WORK DONE BY PUMP:

Temperature of feed water before B.F.P = 165.7°C
Pressure of feed water before B.F.P = 8 Kg/cm²
Enthalpy (Hf1) = 700.44 KJ/Kg
Temperature of feed water after B.F.P = 173.1°C
Pressure of feed water after B.F.P = 160 Kg/cm²
Enthalpy (Hf2) = 740.79 KJ/Kg

Work done by pump Wpump = m(hf2 - hf1)
= 1(740.79 – 700.44)
= 40.35 KJ/Kg.

Net Work Done Wnet = WTurbine - Wpump
= 1354.69 -40.35
= 1314.34 KJ/Kg.

CALCULATIONS FOR HEAT INPUT (Qin):

Heat Input Qin = Qf3-1 + Q3-4
Where
Qin = Total Heat supplied
Qf3-1 = Heat supplied to rise the feed water temperature to super heat condition
Q3-4= Heat supplied during reheating of steam
Mass of feed water at the inlet of Economizer = 1
Temperature of feed water before Economizer = 250.9°C
Pressure of feed water before Economizer = 160 Kg/cm²
Enthalpy = 1090.44 KJ/Kg
Temperature of feed water after super heating = 535°C
Pressure of feed water after super heating = 130 Kg/cm²
Enthalpy = 3434.55 KJ/Kg

Where
Qf3-1 = m(hf3 – h1)
= 1(3434.55 – 1090.44)
Qf3-1 = 2344.11 KJ/Kg.

Mass of steam at the inlet of reheating = (1-0.05207-0.069-0.04601)
Temperature of steam before reheating = 325°C
Pressure of steam before reheating = 26.74 Kg/cm²
Enthalpy = 3066.02 KJ/Kg
Temperature of steam before reheating = 535°C
Pressure of steam before reheating = 24.49 Kg/cm²

Enthalpy = 3541.75 KJ/Kg

Heat supplied during reheating of steam

Q3-4 = (m-m1-m2-m3)(hf3-h1)

= (1-0.05207-0.07588-0.010433)(3542.3-3066.02)

Q3-4 = 410.37 KJ/Kg.

Total Heat supplied Qin = Qf3-1 + Q3-4

= 2344.11 + 410.37

Qin = 2754.48 KJ/Kg

Efficiency (η) = Wnet/Qin

= 1314.34 / 2754.48

η = 47.7%

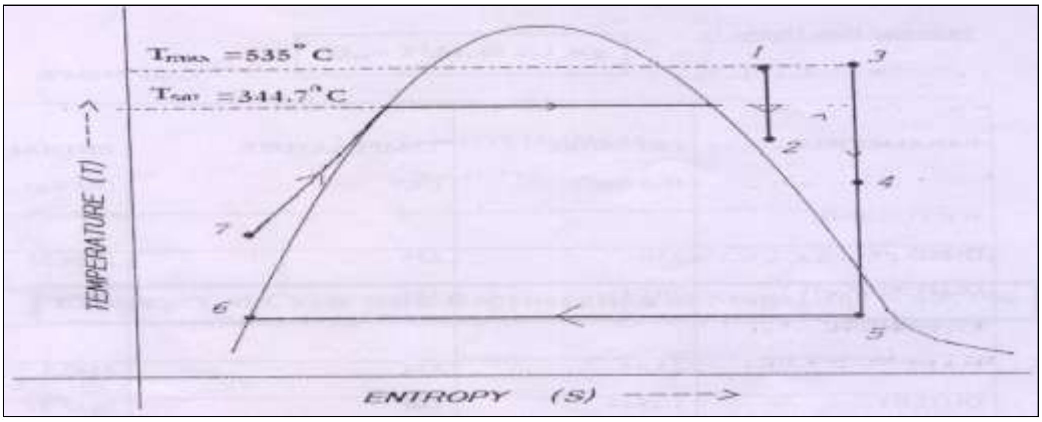
Efficiency of cycle with regeneration of stage1 (η) = 47.7%

CYCLE EFFICIENCY (WITHOUT REGENERATION)

TECHNICAL DATA:

LOAD: 210MW

PARAMETERS	PRESSURE (Kg/cm²)	TEMPERATURE(°C)	ENTHALPY(KJ/Kg)
H.P.TURBINE			
INLET	130	535	3434.55
OUTLET	26.74	325	3066.02
I.P.TURBINE			
INLET	23.44	535	3542.3
OUTLET	1.2848	184	2842.47
L.P.TURBINE			
INLET	1.2848	184	2842.47
OUTLET	-0.9	57.7	2243.22



Rankine Cycle without Regeneration and with Reheating

H1 = Enthalpy of steam at the inlet of H.P.Turbine.
H2 = Enthalpy of steam at the exit of H.P.Turbine.
H3 = Enthalpy of steam at the inlet of I.P.Turbine.
H4 = Enthalpy of steam at the outlet of I.P.Turbine & Enthalpy of steam at the inlet of L.P.Turbine.
H5 = Enthalpy of steam at the outlet of L.P.Turbine.

CALCULATIONS:

WORK DONE BY H.P.TURBINE:

WH.P.T = m(h1-h2)
WH.P.T = 1(3434.55-3066.02)
WH.P.T = 368.53 KJ/Kg.

WORK DONE BY I.P.TURBINE:

WI.P.T = m (h3-h4)
WI.P.T = 1(3542.3-2842.47)
WI.P.T = 699.83 KJ/Kg.

WORK DONE BY L.P.TURBINE:

WL.P.T = m(h4-h5)
WL.P.T = 1(2842.47-2243.22)
WL.P.T = 599.25 KJ/Kg.
Total work done by Turbine WTurbine = WH.P.T + WI.P.T + WL.P.T
= 368.53+699.83+599.25
WTurbine = 1667.61 KJ/Kg.

CALCULATIONS FOR WORK DONE BY PUMP:

Temperature of feed water before B.F.P	=	52°C
Pressure of feed water before B.F.P	=	9.8 Kg/cm^2
Enthalpy (Hf1)	=	218.535 KJ/Kg
Temperature of feed water after B.F.P	=	62°C
Pressure of feed water after B.F.P	=	160 Kg/cm^2
Enthalpy (Hf2)	=	272.611 KJ/Kg

Work done by pump Wpump = m(hf2 - hf1)
= 1(272.611-218.535)
Wpump = 54.076 KJ/Kg.

Net Work Done Wnet = WTurbine - Wpump
= 1667.61 – 54.076
Wnet = 1613.534 KJ/Kg.

International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur

CALCULATIONS FOR HEAT INPUT (Qin):

Qin = Q7-1 + Q2-3
Where
Qin = Total Heat Supplied
Q7-1 = Heat supplied to rise the feed water temperature to super heat condition
Q2-3 = Heat supplied during reheating of steam

Mass of feed water at the inlet of economizer	=	1
Temperature of feed water before economizer	=	62°C
Pressure of feed water before economizer	=	160 Kg/cm^2
Enthalpy	=	272.611 KJ/Kg
Temperature of feed water after super heating	=	535°C
Pressure of feed water after super heating	=	130 Kg/cm^2
Enthalpy	=	3434.55 KJ/Kg

Where

Q7-1 = m(hf3-h1)
= 1(3434.55 – 272.611)
Q7-1 = 3161.939 KJ/Kg.

Mass of steam at the inlet of reheating	=	1
Temperature of steam before reheating	=	325°C
Pressure of steam before reheating	=	26.74 Kg/cm^2
Enthalpy	=	3066.02 KJ/Kg
Temperature of steam before reheating	=	535°C
Pressure of steam before reheating	=	24.49 Kg/cm^2
Enthalpy	=	3542.3 KJ/Kg.

Where

Q2-3 = m(hf3 – h1)
= 1(3542.3 – 3066.02)
Q2-3 = 476.28 KJ/Kg.

Total Heat Supplied Qin = Q7-1 + Q2-3
= 3161.939 + 476.28
Qin = 3638.219 KJ/Kg.

Efficiency (η) = Wnet / Qin
= 1613.534 / 3638.219
η = 44.34%

International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur

IV IMPLEMENTATION DETAILS OF THE PROPOSED METHOD CALCULATIONS:

WORK DONE BY H.P.TURBINE:
WH.P.T = m(h1-h2)
WH.P.T = 1(3434.55-3066.02)
WH.P.T = 368.53 KJ/Kg.

WORK DONE BY I.P.TURBINE:
WI.P.T = m (h3-h4)
WI.P.T = 1(3542.3-2842.47)
WI.P.T = 699.83 KJ/Kg.

WORK DONE BY L.P.TURBINE:
WL.P.T = m(h4-h5)
WL.P.T = 1(2842.47-2243.22)
WL.P.T = 599.25 KJ/Kg.
Total work done by Turbine WTurbine = WH.P.T + WI.P.T + WL.P.T
= 368.53+699.83+599.25
WTurbine = 1667.61 KJ/Kg.

CALCULATIONS FOR WORK DONE BY PUMP:

Temperature of feed water before B.F.P	=	52°C
Pressure of feed water before B.F.P	=	9.8 Kg/cm²
Enthalpy (Hf1)	=	218.535 KJ/Kg
Temperature of feed water after B.F.P	=	62°C
Pressure of feed water after B.F.P	=	160 Kg/cm²
Enthalpy (Hf2)	=	272.611 KJ/Kg

Work done by pump Wpump = m(hf2 - hf1)
= 1(272.611-218.535)
Wpump = 54.076 KJ/Kg.

Net Work Done Wnet = WTurbine - Wpump
= 1667.61 – 54.076
Wnet = 1613.534 KJ/Kg.

CALCULATIONS FOR HEAT INPUT (Qin):
Qin = Q7-1 + Q2-3
Where
Qin = Total Heat Supplied
Q7-1 = Heat supplied to rise the feed water temperature to super heat condition
Q2-3 = Heat supplied during reheating of steam
Mass of feed water at the inlet of economizer = 1

Temperature of feed water before economizer = 62°C
Pressure of feed water before economizer = 160 Kg/cm^2
Enthalpy = 272.611 KJ/Kg
Temperature of feed water after super heating = 535°C
Pressure of feed water after super heating = 130 Kg/cm^2
Enthalpy = 3434.55 KJ/Kg

Where

Q7-1 = m(hf3-h1) = 1(3434.55 – 272.611)
Q7-1 = 3161.939 KJ/Kg.

Mass of steam at the inlet of reheating = 1
Temperature of steam before reheating = 325°C
Pressure of steam before reheating = 26.74 Kg/cm^2
Enthalpy = 3066.02 KJ/Kg
Temperature of steam before reheating = 535°C
Pressure of steam before reheating = 24.49 Kg/cm^2
Enthalpy = 3542.3 KJ/Kg.

Where

Q2-3 = m(hf3 – h1)
= 1(3542.3 – 3066.02)
Q2-3 = 476.28 KJ/Kg.

Total Heat Supplied Qin = Q7-1 + Q2-3
= 3161.939 + 476.28
Qin = 3638.219 KJ/Kg.

Efficiency (η) = Wnet / Qin
= 1613.534 / 3638.219
η = 44.34%

IV. RESULTS

One unit (210 MW) of stage -1 and one unit of stage -2 are considered for the present analysis. The feed water heating system of the two units considered are not the same but have some differences. The effects of those factors are observed in the results.

η (With Regeneration)	47.7%
η (Without Regeneration)	44.34%

The two units considered results same efficiency without feed water heating. It is clearly observed from the above results that there is considerable increment in the efficiency due to regenerative feed water heating.

For certain reasons which are to be diagnosed the efficiency of stage-2 has shown less improvement than the other units considered. The unit of stage-1 has gained an efficiency of 3.36% where as the unit of stage-2 has gained only 1.17%. Two observations made at the plant which might be more possible reasons for the above differences are

The stage-2 unit has only 6 feed water heaters [3LPH + 1DA + 3HPH] where as stage-1 has 8 feed water heaters [4LPH + 1DA + 3HPH]

V. CONCLUSION

The following conclusions can be made from the present work for much more better performance of the plant.

1) The tubes of the feed water heaters must be periodically cleaned using water jets & chemicals.
2) Replacement of damage or worn-out components.
3) The excessive use of tubes dummies must be taken care, so as to increase the effective heat transfer.
4) Effective instrumentation is needed to evaluate the total system & sub-systems performance.
5) Optimization of deaerator performance is needed.
6) By taking proper steps for the above mentioned reasons, the overall efficiency of the plant will be improved considerably & components can be made compact & also the loads on condenser can be reduced and hence there will be an increased power output.

REFERENCES

1. John r.howell & richard o.buckius, fundamentals of engineering thermodynamics, mc graw hill publications.
2. P.k. nag, engineering thermodynamics; tata mc graw hill publications.
3. Vanwylanand sonntag, fundamentals of classical thermodynamics.
4. Aapplied thermodynamics by td eastop and mc conley.
5. Aarora and domukundwar, power plant engineering, dhanapat rai & co.,
6. Ww.f.stoecker (1989), “design of thermal systems: mc graw hill, 3rd edition.
7. B.k. hodg (1990), “analysis and design of thermal systems”, prentice hall inc.,
8. R.k. rajput, thermal engineering.
9. Rrogers and mayhew, engineering thermodynamics.