

Performance Analysis of Regenerative Feed Heating in A Steam Power Plant

Ch.vijaya kumar¹M.tech(cad/cam),Dhananjaya kumar² M.E
^{1,2}Mechanical,Gnit/Jntuh,India

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 Unit 1 VTPS(Vijayawada Thermal Power Station)

Keywords: Feed water, power station, Regenerative, Thermal, turbines, operational cost

I. 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, main ejectors, 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 Functions of 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, CO₂, NH₂ 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 Advantages Of Regenerative Feed Heating System:

It improves the cycle efficiency. 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. Extractions from last stages of turbine also act as moisture extractor and hence reduce the blade damage due to water droplets impact. Cost per unit of electrical power reduces by using with feed heaters.

1.3 Disadvantages Of Regenerative Feed Heating System:

Increase cost of pipe frame work and also increase mechanical losses with the some steam input less work is achieved. Strength of turbine decreases due to the holes provided for extraction of steam from different stages. 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.

1.4 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. The work and heat quantities can be evaluated in terms of the properties of the fluid. Usually, the pump work is small compared to the turbine work, and is sometimes neglected then $h_4=h_3$ and the cycle efficiency approximately becomes

$$\eta = \frac{h_1 - h_2}{h_1 - h_4}$$

In the direction opposite to the steam flow. In turbine, the steam is thus headed before entering into the boiler; such a system is known as Regenerative heating. The ideal regenerative cycle has efficiency equal to that efficiency of Carnot cycle with same heat supply and heat rejection temperatures.

All the heat added from an external source (θ_1) is at constant temperature (T_1), and all the heat rejected (θ_2) is at the constant temperature (T_2) both being reversible then

$$\theta_1 = h_1 - h_4 = T_1 (s_1 - s_4)$$

$$\theta_2 = h_2 - h_3 = T_2 (s_2 - s_3)$$

$$s_4 - s_3 = s_1 - s_2$$

$$s_1 - s_4 = s_2 - s_3$$

$$\theta_1 = \theta_2 \Rightarrow 1 - T_2/T_1 = 1 - T_2/T_1$$

The efficiency of the ideal regenerative cycle is equal to Carnot cycle efficiency writing the steady flow energy equation for the turbine.

$$h_1 - W_t - h_2 + h_4 - h_4 = 0$$

$$W_t = (h_1 - h_2) - (h_4 - h_4)$$

The pump work remains the same as in the Rankin cycle

$$W_p = h_4 - h_3$$

The network output of the ideal regenerate cycle is thus less, and hence its steam rate will be more. Although it is more efficient when compared with the Rankin cycle

II. Regenerative Cycles With Feed Water Heaters:

2.1 Regenerative Cycle With Single Feed Water Heater:

The steam at p_1 pressure enters the turbine at point A. Let a small amount of wet steam of m Kg after partial expansion at pressure p_2 be drained from turbine at point B and enters the feed water heater. The remaining steam at pressure p_3 is further expanded in turbine and leaves at point "c". The steam is then condensed in the condenser. The condensate from the condenser is pumped into the feed water heater where it mixes up with steam extracted is just sufficient to cause the steam leaving the feed water to be saturated.

$$\eta_{\text{cycle}} = \frac{W_t}{Q_1} = \frac{(h_1 - h_2) + (1 - m)(h_2 - h_3)}{(h_1 - h_6)}$$

W_t = Turbine work

h_1 = Enthalpy of steam entering the turbine at A

h_2 = Enthalpy of bled steam

h_3 = Enthalpy of steam leaving the turbine at C

h_{f1} = sensible heat of feed water leaving the feed water heater.

h_{f3} = Enthalpy (or) sensible heat of steam leaving the condenser.

m = Amount of bled steam per kg of steam supplied

Where $m = \frac{h_{f2} - h_{f3}}{h_2 - h_{f3}}$

$$\text{Efficiency of cycle including the effect of bleeding} = \frac{\text{Total work done}}{\text{total heat supplied}} = \frac{(h_1 - h_2) + (1 - m)(h_2 - h_3)}{(h_1 - h_2)}$$

2.2 Regenerative Cycle with Two Feed Water Heaters:

The steam at pressure p_1 enters the turbine at point "A". Let a small amount of steam after partial expansion p_2 be drained from the turbine at point B_1 enters the feed water heater 2. The remaining steam equal to $(1 - m_1 - m_2)$ Kg is further expanded in the turbine and leaves it a point "c". The steam is then condensed in the condenser, The condensate from the condenser is pumped in to the feed water where it mixes with the steam extracted from the turbine.

Let us consider 1 Kg steam

h_1 = Enthalpy of steam entering the turbine at A

h_2 = Enthalpy of steam bled at B to L.P heater

h_3 = Enthalpy of steam bled at B_1 to H.P heater

h_4 = Enthalpy of steam leaving the turbine at C

h_{f2} = Enthalpy of feed water leaving the feed water heater 1

h_{f3} = Enthalpy of feed water leaving the feed water heater 2

h_{f4} = Enthalpy of steam leaving the condenser.

m_1 = Amount of steam bled at B per kg of steam supplied

m_2 = Amount of steam bled at B_1 per kg of steam supplied

Here $m_1 = \frac{h_{f2} - h_{f3}}{h_2 - h_{f3}}$
 $m_2 = \frac{(1 - m_1)(h_{f3} - h_{f4})}{h_3 - h_{f4}}$

Technical Data:

HPH7:Vertical coil type with integral de

Quality of extraction steam	Kg/hr	32441
Pressure of extraction steam(max)	ata	42.83
Enthalpy of extraction steam	Kcal/kg	756.68
Qty. of feed water	t/hr	662
Temp. of feed water at inlet	°C	222.3
Temp. of feed water at outlet	°C	245.7
Size of tubes(D.S.Zone)	mm	OD 32x4
No .of spiral coils in de-superheating zone	.....	32
Surface area:		
De-superheating zone:	Mm ²	84.5
Condensating zone:	Mm ²	602
Drain cooling zone:	Mm ²	84.5
Design pressure on shell side	atg	32
Design pressure on water side	atg	265
Design pressure on shell side	°C	250
Design pressure on water side	°C	250
Test pressure on the shell side	atg	48
Test pressure on water side	atg	400
Overall height	mm	9625

Superheating and drain cooling zones

S.no					
1	NO. Of heaters	.....	3		
2	Type	.....	Vertical		
3	HP HEATERS		HPH5	HPH6	HPH7
4	Inlet FW flow	t/hr	662	662	662
5	FW inlet temp	°C	169.3	184.8	221.73
6	FW outlet temp	°C	184.8	221.73	244.6
7	EXtern.Steam flow	t/hrs	17.66	41.28	32.44
8	Steam(turbine end)	Ata	13.15	28.853	42.83
9	Steam temp(turbine end)	°C	453	330	383
10	TTD	°C	2.0	4.5	2.5
11	DCA	°C	10	15	7.5
12	TR	°C	.....	.....	.....

Design Data:

Test Data:

S.NO.	Description	Units	Run 1	Run 2	Run 3
1	Load	MW	209	211	209
2	Ms pressure	Kg/cm ²	128.98	118.8	129.02
3	Fw flow	t/hr	687.10	701.97	684.92
4	HPH5 shell pressure	Kg/cm ²	11.41	11.61	11.32
5	HPH6 shell pressure	Kg/cm ²	25.01	25.50	25.08
6	HPH7 shell pressure	Kg/cm ²	39.02	39.87	39.04
7	FW temp HPH5 IN	°C	162.52	161.95	162.45
8	FW temp HPH5 OUT	°C	179.01	179.01	178.78
9	FW temp HPH6 OUT	°C	220.68	221.58	221.05
10	FW temp HPH7 OUT	°C	245.32	246.34	245.48
11	Drain temp HPH5	°C	183.07	210.29	235.1
12	Drain temp HPH6	°C	183.51	210.95	236.01
13	Drain temp HPH7	°C	182.76	210.38	235.25

The extract from the test data (Run-1) is consolidated in the table given below:

S. No.	Description	Design °C	Design °C	Deviation °C	HR deviation Kcal/KWh
1	HPH7 TTD	2.5	2.2	-0.3	-0.57
2	HPH7 DCA	7.5	14.2	6.7	1.6
3	HPH7 TR	.....	.....	.....	.....
4	HPH6 TTD	4.5	4.4	-0.1	-0.19
5	HPH6 DCA	15	31.3	16.3	3.89
6	HPH6 TR	.....	.....	.....	.....
7	HPH5 TTD	2.0	8.7	6.7	12.78
8	HPH5 DCA	10	20.5	10.5	2.51
9	HPH5 TR	.....	.....	.....	.....

IV. Calculation & Analysis:

1) Terminal Temperature Difference (TTD):

$$TTD = T_{\text{sat}} - T_{\text{(fw out)}}$$

◦ Where, $T_{\text{(sat)}}$ = Saturation temp taken at the heater shell pressure, °C

$T_{\text{(fw out)}}$ = Temperature of feed water leaving the heater, °C

2) Drain cooling approach (DCA):

$$DCA = T_{\text{(drain temp)}} - T_{\text{(feed water entering)}}$$

Where, $T_{\text{(drain)}}$ = temp of the drain leaving the heater, °C

$T_{\text{(fw in)}}$ = Temperature of feed water entering the heater, °C

3) Temp rise across heater (TR):

$$TR = T_{\text{(feed water entering)}} - T_{\text{(feed water leaving)}}$$

Model calculations -1 For HPH - 7:

Pressure = 39.02 bar

$T_{\text{sat}} = 248.029$ °C (from steam tables)

$T_{\text{fw out}} = 245.32$ °C

$TTD = 248.029 - 245.32 = 2.71$ °C

$T_{\text{drain}} = 235.10$ °C

$T_{\text{fw in}} = 220.88$ °C

$DCA = 235.10 - 220.88 = 14.22$ °C

$T_{\text{fw out}} = 245.32$ °C

$T_{\text{fw in}} = 245.32 - 220.88 = 24.4$

Model calculations -1 For HPH - 6:

Pressure = 25.01 bar

$T_{\text{sat}} = 223.97$ °C (from steam tables)

$T_{\text{fw out}} = 211.88$ °C

= 3.1 °C

$TTD = 223.97 - 211.88 = 3.1$ °C

$T_{\text{drain}} = 210.29$ °C

$T_{\text{fw in}} = 179.01$ °C

$DCA = 210.29 - 179.01 = 31.28$ °C

$T_{\text{fw out}} = 210.88$ °C

$T_{\text{fw in}} = 179 - 01$ °C

$TR = 210.88 - 179.01 = 41.87$ °C

Model calculations -1 For HPH - 5:

Pressure = 11.4 bar

$T_{\text{sat}} = 187.68$ °C (from steam tables)

$T_{\text{fw out}} = 179.01$ °C

$TTD = 187.68 - 179.01 = 8.67$ °C

Model calculation : 2

Using the amount of heat lost by the feed water and the amount of heat gained by the steam the performance of the HP heaters can be analyzed. It is known that the amount of heat gained should be equal to the amount of heat lost but the case being heaters or any other mechanical components the heat transfer is not that much perfect as it is effected by many losses.

Model calculations -2 For HPH - 7:

External steam flow = 32 t/hr

Steam pressure = 37.5 bar

Steam temperature = 383 °C

Drain pressure = 37.5 bar

Drain temperature = 235 °C

Using mollier's diagram,

The enthalpy of steam is $h_{\text{steam}} = 3170$ KJ/kg

The enthalpy of drain is $h_{\text{drain}} = 2820$ KJ/kg

$$h_{\text{steam}} - h_{\text{drain}} = 3170 - 02820 = 350 \text{ KJ/kg}$$

$$\begin{aligned} \text{Amount of heat lost} &= \text{flow} \times \text{enthalpy} \\ &= 32 \times 350 \times 10^3 \text{ KJ/hr} \\ &= 11200 \times 10^3 \text{ kJ/hr} \end{aligned}$$

$$\begin{aligned} \text{As there is under cooling, the amount of heat lost in the drain is} &= m \text{ cp} (T_{\text{sat}} - T_{\text{drain}}) \\ &= 662 \times 1 \times (246 - 235) \end{aligned}$$

$$= 7282 \times 10^3 \text{ kJ/kg}$$

$$\begin{aligned} \text{Total amount of heat lost} &= (911200 + 7282) \times 10^3 \\ &= 662 \times 1 \times (245 - 221) \\ &= 15888 \times 10^3 \text{ kJ/hr} \end{aligned}$$

Model calculations -2 For HPH - 6:

External steam flow = 41 t/hr

Steam pressure = 21 bar

Steam temperature = 330 °C

Drain pressure = 25 bar

Drain temperature = 210 °C

Drain flow = 73 t/hr

Using molli's diagram,

The enthalpy of steam is $h_{\text{steam}} = 3070 \text{ kJ/kg}$

The enthalpy of drain is $h_{\text{drain}} = 2825 \text{ kJ/kg}$

The enthalpy of drain leaving heater H drain = 3170 kJ/kg

$$\begin{aligned} \text{Heat lost by steam (Q1)} &= \text{flow} \times \text{enthalpy} \\ &= 41 \times 3070 = 125870 \times 10^3 \end{aligned}$$

$$\begin{aligned} \text{Heat lost by the drain leaving heater 7 (Q2)} &= 32 \times 3170 \\ &= 101400 \times 10^3 \text{ kJ/hr} \end{aligned}$$

$$\begin{aligned} \text{Heat lost by drain (Q3)} &= 73 \times 2825 \\ &= 206225 \times 10^3 \text{ kJ/hr} \end{aligned}$$

$$\begin{aligned} \text{Heat lost} &= (Q1 + Q2) - Q3 \\ &= (125870 + 101400) - 206225 \times 10^3 \text{ kJ/hr} \\ &= 21085 \times 10^3 \text{ kJ/hr} \end{aligned}$$

$$\begin{aligned} \text{Due to under cooling heat lost in drain} &= m \times C_p \times (T_{\text{sat}} - T_{\text{drain}}) \\ &= 662 \times 1 \times (224 - 210) \\ &= 9268 \times 10^3 \text{ kJ/hr} \end{aligned}$$

$$\begin{aligned} \text{Total heat lost} &= (21085 + 9268) \times 10^3 \text{ kJ/hr} \\ &= 30353 \times 10^3 \text{ kJ/hr} \end{aligned}$$

$$\begin{aligned} \text{Heat gain by the feed water} &= m \times C_p \times (F_{\text{wo}} - F_{\text{wi}}) \\ &= 662 \times 1 \times (221 - 179) \\ &= 27084 \times 10^3 \text{ kJ/hr} \end{aligned}$$

Model calculations -2 For HPH - 5:

External steam flow = 17 t/hr

Steam pressure = 11.5 bar

Steam temperature = 453 °C

Drain pressure = 11.5 bar

Drain temperature = 183 °C

Drain flow = 90 t/hr

Using molli's diagram,

The enthalpy of steam is $h_{\text{steam}} = 3380 \text{ kJ/kg}$

The enthalpy of drain is $h_{\text{drain}} = 2780 \text{ kJ/kg}$

The enthalpy of drain coming from heater 6 H drain = 2825 kJ/kg

$$\begin{aligned} \text{Heat lost by steam (Q1)} &= \text{flow} \times \text{enthalpy} \\ &= 17 \times 3380 = 57460 \times 10^3 \end{aligned}$$

$$\begin{aligned} \text{Heat lost by the drain leaving heater 7 (Q2)} &= 73 \times 2825 \\ &= 206225 \times 10^3 \text{ kJ/hr} \end{aligned}$$

$$\text{Heat lost by drain (Q3)} = 90 \times 2780$$

$$= 250200 \times 10^3 \text{ kJ/hr}$$

$$\text{Heat lost} = (Q_1 + Q_2) - Q_3$$

$$= (57460 + 206225) - 250200 \times 10^3 \text{ kJ/hr}$$

$$= 13485 \times 10^3 \text{ kJ/hr}$$

$$\text{Due to under cooling heat lost in drain} = m \times C_p \times (T_{\text{sat}} - T_{\text{drain}})$$

$$= 662 \times 1 \times (186 - 183)$$

$$= 1986 \times 10^3 \text{ kJ/hr}$$

where m = mass flow rate of steam
 cp = 1.000 kJ/kg-k

Observations and analysis:

From the above calculations it is evident that efficiency of the HP heaters is on higher side kept for HPH-5. the efficiency of the HPH-5 may be lower due to scale 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.

Extraction steam parameter HPH-5:

Pressure of extraction steam pr = 13 bar
 Enthalpy of extraction steam hes = 3361.33 kJ/kg
 Quantity of feed water flow Qf = 662 t/hr
 Temperature of feed water at inlet Tfi = 169.3° c
 Temperature of feed water at outlet Tout = 186.0 °c
 Quantity of extraction steam (Qes) = 17.661 t/hr
 Quantity of drip from HPH-6 (Q d) = 202° c
 Enthalpy of drip from HPH-5 = 778.116 kJ/kg
 Enthalpy of drip from HPH-6 = 869.8 kJ/kg
 Heat lost by extraction steam HPH-5 = Qe (hes - hfd)
 = 17.661(3361.33 - 778.116)X10³
 = 45622.14X10³ kJ/kg
 Heat lost by drip coming from HPH-6 = Qsd (hdri - hdrip)
 = 79.719(869.8 - 778.116)X10³
 = 7308.96X10³ kJ/kg
 Total heat lost by extraction steam & drip:
 = (45622.4+7308.96)X10³
 =52931.1 x 10³ kJ/hr
 Heat gained by feed water = Qfdw (Tout - Tin) x 10³
 = 662 x 4.1868 (186 - 169.3) x 10³
 = 46,286.75 x 10³ kJ/hr
 Efficiency of HPH - 5(n) = Heat gained/heat lost
 = (46,286.75/52,931.1) x 100
 = 87.45 %

Extraction steam parameter HPH-6:

Pressure of extraction steam p r = 28 bar
 Enthalpy of extraction steam hes = 3071.72 kJ/kg
 Quantity of feed water flow Qfw = 662 t/hr
 Temperature of feed water at inlet Tfi = 186° c
 Temperature of feed water at outlet Tout = 222.3 °c
 Quantity of extraction steam (Qes) = 47278 kg/hr
 Quantity of drip from HPH-7 (Q d) = 32441 t/hr
 Temperature of drip from HPH-6 (Td) = 202° c
 Temperature of drip from HPH-7 (Td) = 233° c
 Enthalpy of drip from HPH-6 h d = 869.8 KJ/kg
 Enthalpy of drip from HPH-7 h d = 1013.7 KJ/kg
 Heat lost by extraction steam HPH-6 = Qes (hes - hfd)
 = 47.278(3071.72 - 869.8)X10³
 = 104102.37X10³ kJ/kg
 Heat lost by drip coming from HPH-7 = Qsd (hdri - hdrip)

$$= 32441(1013.7 - 869.8) \times 10^3$$

$$= 4668.26 \times 10^3 \text{ kJ/kg}$$

Total heat lost by extraction steam & drip:

$$= (104102.37 + 4668.26) \times 10^3$$

$$= 108770.63 \times 10^3 \text{ kJ/hr}$$

$$\text{Heat gained by feed water} = Q_{fdw} (T_{out} - T_{in}) \times 10^3$$

$$= 662 \times 4.1868 (222.3 - 1876) \times 10^3$$

$$= 10041.37 \times 10^3 \text{ kJ/hr}$$

$$\text{Efficiency of HPH - 6(n)} = \text{Heat gained/heat lost}$$

$$= (100611.37 / 108770.63) \times 100$$

$$= 92.5 \%$$

Extraction steam parameter HPH-7:

pressure of extraction steam $p_r = 42 \text{ bar}$
 enthalpy of extraction steam $h_{es} = 3168.06 \text{ kJ/kg}$
 quantity of feed water flow $Q_{fw} = 662 \text{ t/hr}$
 Temperature of feed water at inlet $T_{fi} = 222.3^\circ \text{ c}$
 Temperature of feed water at outlet $T_{out} = 245.7^\circ \text{ c}$
 Quantity of extraction steam (Q_{es}) = 32441 kg/hr
 Temperature of drip from HPH-7 (T_d) = 233° c
 Enthalpy of drip from HPH-7 (h_{fd}) = 1013.7 kJ/kg
 Heat lost by extraction steam HPH-7 = $Q_{es} (h_{es} - h_{fd})$
 $= 37441(3168.06 - 1013.7) \times 10^3$
 $= 69889.6 \times 10^3 \text{ kJ/kg}$

$$\text{Heat gained by feed water} = Q_{fdw} (T_{out} - T_{in}) \times 10^3$$

$$= 662 \times 4.1868 (245.7 - 222.3) \times 10^3$$

$$= 64856.88 \times 10^3 \text{ kJ/hr}$$

$$\text{Efficiency of HPH - 7} = \text{Heat gained/heat lost}$$

$$= (64856.88 / 69889.6) \times 100$$

$$= 92.8 \%$$

$$\text{Total efficiency of the turbine (HP,IP,LP)} = ((87.45 + 92.5 + 92.8) / 3) \times 100$$

$$= (272.75 / 3) \times 100$$

$$= 90.91\%$$

V. Conclusion:

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 210 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 this operation and maintenance the heaters are giving the efficiency of about 75% - 80%.

References

Examples follow:

Journal Papers:

- [1]. Drbal. westra K. and boston P...1995.power plant Engineering.springer
- [2]. Szargut J., 2004, Economic effect of the regenerative heating of feed water in a steam power plant (in polish).energetyka no.5, pp.266-268
- [3]. Szargut J., 1999, Application of steam from regenerative bleeds for the production of network in large steam power plants.ArchiwumEnergetvki.XXVIII, No.1-2.pp.83-93

Books:

- [4]. R.k raj put,ThermalEgg,Laxmipublication (P) LTD (ISBN-978-81-318-0804-7), eighth Edition,andP.no:644
- [5]. P.K nag,Egg Thermodynamic, McGraw-hill (ISSBN-10:0-07-026062-1),Fourth Edition,P.no:457,532,449
- [6]. AroraDomkundwar, power plant Engg.Dhanpatrai&co.(P) LTD,First Edition,P.no:19.1-19.11,22.1-22.70
- [7]. R.SKhurmi&J.KGupta,ThermalEngg,S.chanpublishing(ISBN: 81-219-2573-8),FirstEditon,P.no:569,573.



CH.vijaya kumar M.Tech (CAD/CAM), Asst.Professor in Guru Nanak Inst Of Technology, Ibrahimpattam, R.R Dist-501506, Emid:vijaya_kumar580@yahoo.com, Cell:9652898481.



Dhananjaya kumar M.E, Asso.pofessor in GNIT. Emid:drawookar@yahoo.co.in,cell:08050565245