International Journal for Modern Trends in Science and Technology
Volume: 03, Issue No: 01, January 2017
ISSN: 2455-3778
http://www.ijmtst.com

Optimization of Steam Consumption in Turbine with Energy Auditing

Ch. Ramesh[1] | P Siva VNB Gupta[2] | Dr.T. Jayananda Kumar[3]

[1]PG Scholar, Department of Mechanical Engineering, Godavari Institute of Engineering and Technology, Rajahmundry, Andhra Pradesh, India.
[2]Assistant Professor, Department of Mechanical Engineering, Godavari Institute of Engineering and Technology, Rajahmundry, Andhra Pradesh, India.
[3]Professor and HOD, Department of Mechanical Engineering, Godavari Institute of Engineering and Technology, Rajahmundry, Andhra Pradesh, India.

To Cite this Article
Ch. Ramesh, P Siva VNB Gupta and Dr.T. Jayananda Kumar, "Optimization of Steam Consumption in Turbine with Energy Auditing", *International Journal for Modern Trends in Science and Technology*, Vol. 03, Issue 01, 2017, pp. 38-46.

ABSTRACT

In steam power plants the power is generated using the heated steam within the turbine. The power is generated in mega watts. Steam is generated using Coal as a fossil fuel. Steam turbines operate at low efficiency. All the super heat energy in steam is converted into work leaves the Turbine with high available energy. As most part of the heat in steam is not recovered to improve the efficiency of the cycle, regenerative feed water heaters are provided which utilize the total steam energy (including later heat) of the bleed Steam.

Energy audit plays an important role in identifying energy conservation opportunities in the industrial sector, while they do not provide the final answer to the problem; they do help to identify potential for energy conservation and induces the companies to concentrate their efforts in this area in a focused manner. An effort is made in this work for developing methodology of energy audit in thermal power plant on system based. The paper shows all the performance equation of component involves in the thermal power plant according to the system base.

Condensers are cleaned with acid to remove scales and sludge to produce vacuum. This help the reduce the steam consumption in turbine. An analysis is carried out to calculate steam consumption in 4 turbine generators and cooling water flow in condenser this will enhance the efficiency of condenser.

KEYWORDS: *Stream power plant, Cooling water pump, Air pre-heaters, condenser, economizer, high pressure and Pulverizer etc.*

I. Literature Survey

In Steam Power plants the steam conditions are major factors for power generation. The [10]Pof Dev Kumar Patel optimising process operating conditions can considerably improve turbine water rate, which in turn will significantly reduce energy requirement. Various operating parameters affect condensing and back pressure turbine steam consumption and efficiency. This paper contain the effect of operating condition of turbine back pressure turbine inlet steam temperature and advantage of improving inlet steam temperature by reheat cycle on the efficiency of steam turbine and total energy production of power plant.

The [11]Prof Iran Sunit was done the power output of turbine , thermal efficiency and specific steam consumption in conventional steam power plants. Three cycles i.e regenerative cycle, super heater cycle and cogeneration cycle are considered to formulate the data and obtain a better result in steam turbine power plants.

As per the study carried out by [11]M. J. Poddar and Mrs. A.C.Birajdar, the share of energy costs in total production costs can get improves profit levels in all the industries. It can be achieved by improving the efficiency of industrial operations and equipments. Energy audit plays an important role in identifying energy conservation opportunities in the industrial sector, while they do not provide the final answer to the problem, they do help to identify potential for energy conservation and induces the companies to concentrate their efforts in this area in a focused manner.

The study carried out by [2]Ch.Kiran kun and G.Srinivasa Rao performance analysis from the energy audit will shown the clear and need of energy audit in a steam power plants. From the energy audit we can get improve the performance

II. Introduction

Power plants are where power is produced such as in the electricity generating stations and jet engines. The workings of these power plants are based on the turbine used. Steam has been a popular mode of conveying energy since the industrial revolution.Steam power plants play a key role in electric power generation. Therefore the Rankine steam power cycle is one of the most important cyclic processes used in industry.

1.2 Operation:

Power plants are one of the main sources of electricity in both industrialized and developing countries. These plants have drawn flak on consumption of non-renewable sources of energy at a rapid rate and also since they release huge amounts of greenhouse gases into the atmosphere..

Functioning of thermal power plant:

In a thermal power plant one of coal, oil or natural gas is used to heat the boiler to convert the water into steam. The steam is used to turn a turbine, which is connected to a generator. When the turbine turns, electricity is generated and given as output by the generator, which is then supplied to the consumers through high-voltage power lines.

Detailed process of power generation in a thermal power plant:

1) **Water intake**: Firstly, water is taken into the boiler through a water source. If water is available in a plenty in the region, then the source is an open pond or river. s

2) **Boiler heating**: The boiler is heated with the help of oil, coal or natural gas. Furnace is used to heat the fuel and supply the heat produced to the boiler. The increase in temperature helps in the transformation of water into steam

3) **Steam Turbine**: The steam generated in the boiler is sent through a steam turbine. The turbine has blades that rotate when high velocity steam flows across them. This rotation of turbine blades is used to generate electricity.

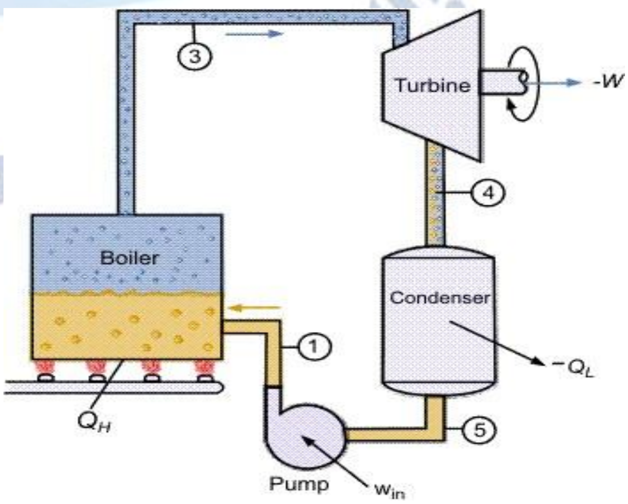
4) **Generator**: A generator is connected to the steam turbine. When the turbine rotates, the generator produces electricity which is then passed on to the power distribution systems.

5**)** **Special mountings**: There is some other equipment like the economizer and air pre-heater. An economizer uses the heat from the exhaust gases to heat the feed water. An air pre-heater heats the air sent into the combustion chamber to improve the efficiency of the combustion process.

6) **Ash collection system**: There is a separate residue and ash collection system in place to collect all the waste materials from the combustion process and to prevent them from escaping into the atmosphere.

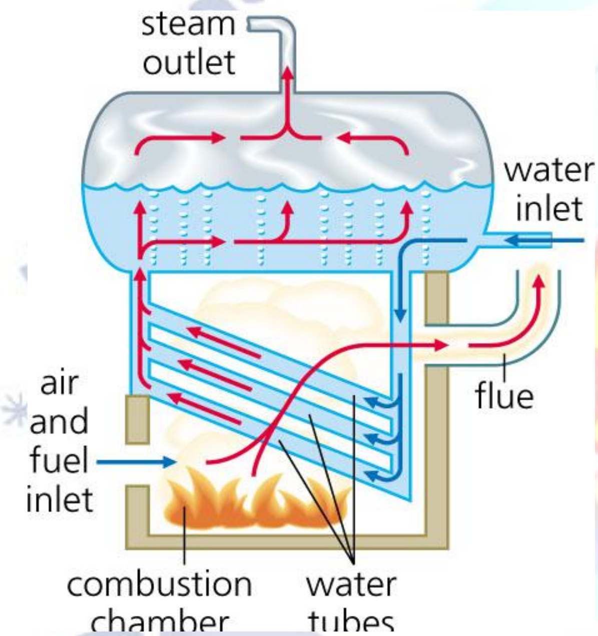
BOILER:

Now that pulverized coal is put in boiler furnace. Boiler is an enclosed vessel in which water is heated and circulated until the water is turned in to steam at the required pressure. Coal is burned inside the combustion chamber of boiler. The products of combustion are nothing but gases. These gases which are at high temperature vaporize the water inside the boiler to steam.



WATER TUBE BOILERS:

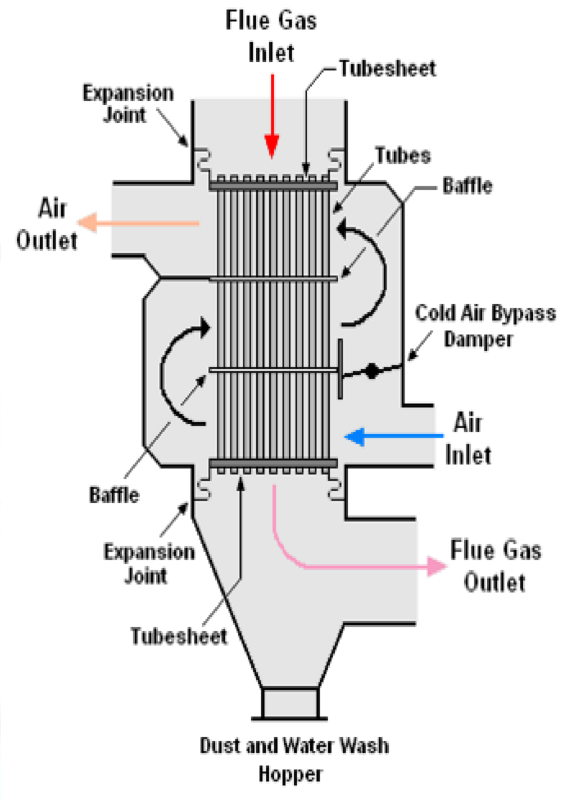
In these boilers water is inside the tubes and hot gases are outside the tubes. This water circulates through the tubes connected external to drums. Hot gases which surround these tubes will convert the water in tubes in to steam. As the movement of water in the water tubes is high, so rate of heat transfer also becomes high resulting in greater efficiency. They produce high pressure, easily accessible and can respond quickly to changes in steam demand.. Large heating surfaces can be obtained by use of large number of tubes. We can attain pressure as high as 125 kg/sq cm and temperatures from 315 to 575 centigrade.



AIR PRE HEATER:

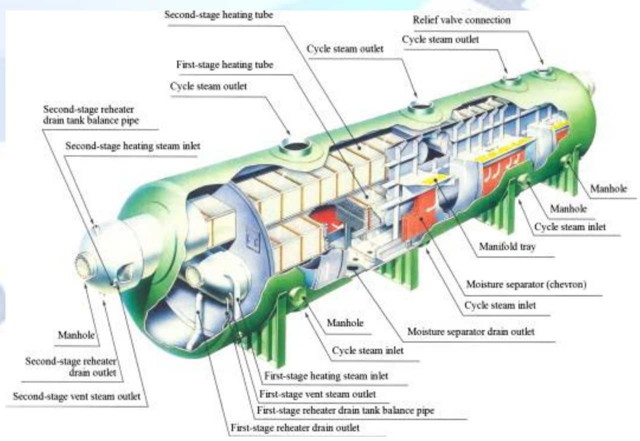
The remaining heat of flue gases is utilized by air pre heater. It is a device used in steam boilers to transfer heat from the flue gases to the combustion air before the air enters the furnace. Also known as air heater or air heating system. It is not shown in the lay out. But it is kept at a place nearby where the air enters in to the boiler.

The purpose of the air pre heater is to recover the heat from the flue gas from the boiler to improve boiler efficiency by burning warm air which increases combustion efficiency, and reducing useful heat lost from the flue. As a consequence, the gases are also sent to the chimney or stack at a lower temperature, allowing simplified design stack (to meet emissions regulations, for example).After extracting heat flue gases are passed to electrostatic precipitator.



REHEATERS:

Power plant furnaces may have a re-heater section containing tubes heated by hot flue gases outside the tubes. Exhaust steam from the high pressure turbine is rerouted to go inside the re-heater tubes to pickup more energy to go drive intermediate or lower pressure turbines. This is what is called as thermal power.



III. Analysis of HP Heaters

TURBO GENERATOR - 1 LOG SHEET:

Turbine Speed	2987 Rpm	
CW-Part Cond I/L	1.991 Kg/C	2.576 Kg/C
CW Temp at Cond I/1 L/R	35.77 Deg.	35.73 Deg.
CW Temp at Cond O/L L/R	45.04 Deg.	41.46 Deg.
R-W Temp at HPH 3/4 0/L	174.5 Deg.	215.2 Deg.
R-W Flow Through heat	281.8 T/Hr.	
Condenser Vacuum	-0.59 T/Hr.	
Main Steam Temp	521.4	
CEP DICSH Flow	74.52 T/Hr.	
Temp Turbine Exhaust	72.52 Deg.	
Vibration TURB -FRONT-V/H	20.23 U/M	49.98 U/M
Vibration TURB -REAR-V/H	53.88 U/M	23.82 U/M
Vibration GEN FRONT- v/H	75.33 U/M	117.1 U/M
Vibration GEN -REAR-V/H	27.27 U/M	30.73 U/M
TURB-FRONT-V/H(Housing)	8.674 IJ/M	
TURB-REAR-V/H(Housing)	8.900 U/M	
GEN-FRONT-V/H(Housing)	25.02 U/M	
VIBR GEN-REAR-V/H(Housing)	10.59 U/M	
Axial Displacement	-0.19 MM	
Casing Expansion	17.6 MM	
Differential Expansion	-0.27 U/M	
TUR THRUST BRG Temp(1&2)	59.01 Deg.	85.86 Deg.
TUR THRUST BRG Temp(3&4)	54.40 Deg.	54.23 Deg.
TUR JOURNAL BRG Temp(FS)	57.33 Deg.	78.48 Deg.
GEN JOURNAL BRG Temp(FS)	69.25 Deg.	82.15 Deg.
Lo Temp At Oil Cooler O/P	48.51 Deg.	
Power Actual Va/M	39.99 MVV	
Gland Steam Temp	182.1Kg	
Gland Steam Pressure	-250 MB	
Lube Oil Header Pressure	2.702 Kg	
Governing Oil Header Pressure	138.0 Kg	
Main Steam Pressure	88.15 Kg	
Turbine Frist Steam Pressure	66.22 Kg	

TUR Extraction ¾ Pr.	12.89Kg
Steam flow from MS HDF	283.3 T/hr
TUR casing Temp (top/bottom)	---
Piston	367.5 deg.
Exhaust steam temp.	74.34 deg.
Load	40
Speed	2982
MS Pr.	188.1
MS temp.	529.9
MS flow	283.4
1st Pr.	66.2
HP oil Pr.	138.0
LB oil Pr.	2.7
BX Steam temp.	73.8
CEP Pr.	18.9
CEP flow	76.8
Vacuum	-0.593

Calculation of Turbine Heat Rate:

Main Steam Pressure	90.5Kg/cm^2
Main Steam Temp.	528^{0}c
Main Steam Flow	238.8T/hr.
Condenser power generation	55MW
CEP flow	200-210 T/hr.
Average flow	205 T/hr.
Vacuum	-0.89
Exhaust temp.	51^{0}c
Cooling water temp.	L=33.4/44.3 , L=34.4/43.7
Feed water flow	218-225 T/hr.
AVG flow	2.22 T/hr.
HPH_3	114^{0}C
H_3, H_4	117^{0}C, 230^{0}C

EXTRACTION STEAM:

HPH_4 26.2 kg/cm^2 (OV 24.5 Kg
381.4^{0}C (388^{0}C)

HPH_3 11.4 Kg/cm^3
289.3^{0}C (320^{0}C)

HPH_2 1.09Kg/cm^2
358^{0}C

LPH_1 -0.05 kg/cm^2
105^{0}C

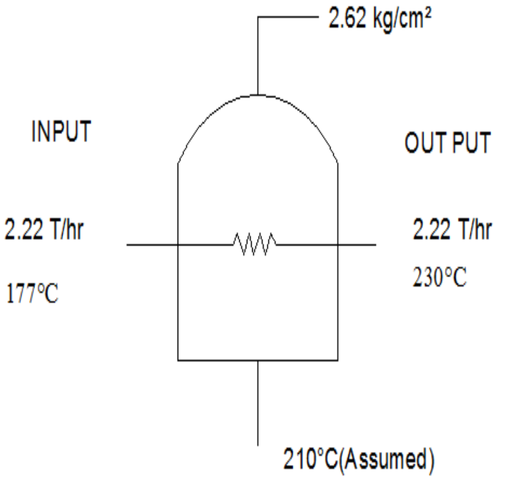
CONDENSER TEMP:

CPH_I inlet 60.2^{0}C

CPH_I outlet 90^{0}C

CALUCULATIONS:

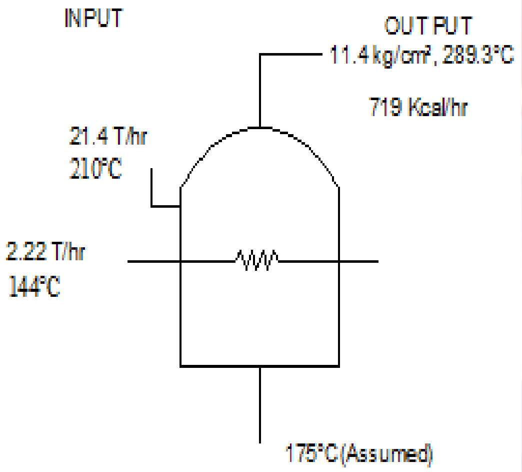
Extraction at HPH_4



Saturation temp. at 2.6 kg/cm^2=288^{0}C

Extraction at HPH_4

Extraction at HPH_3

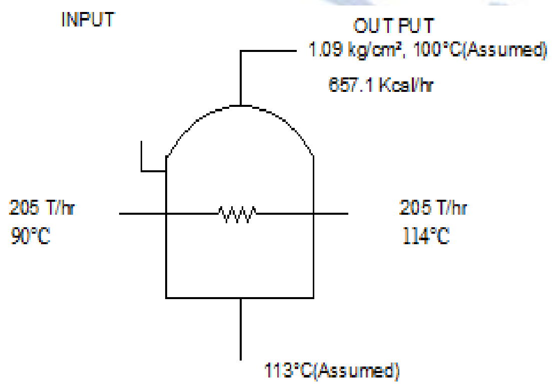


Saturation temp. at 11.4 kg/cm^2=190^{0}C

Extraction at HPH_3

Extraction at LPH_2

M.(ΔT) = M(657.1-assumed tem.), m=9T/hrD

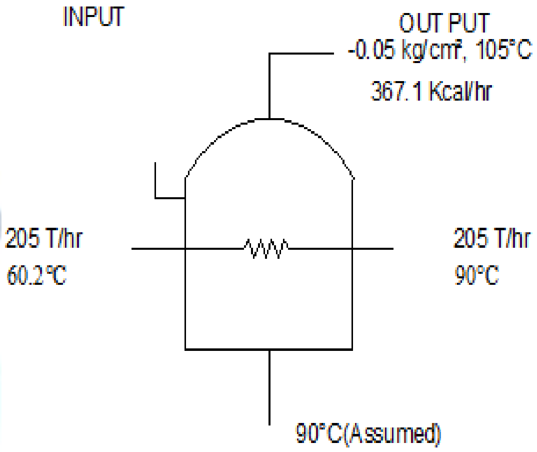


Extraction at LPH_2

Extraction at LPH_1

205(90-60.2) = 9(113-90)+M(637.1-90)

M=10.8 T/hr



Extraction at LPH_1

IV. Boiler Heat Input When Both Heater are in Service

The data from the boiler heat heat in[put when both are in service

Temperature of feed water inlet of boiler = 232.8^{0}C

Enthalpy of feed water at inlet to boiler = 1003.46KJ/Kg

Temperature of steam at outlet boiler = 530.15^{0}C

Enthalpy of superheated steam = 3457.31KJ/Kg

Increase of enthalpy in boiler(heat addition) = 3457.31-1003.46 =2453.85kJ/Kg

Efficiency of boiler(η) =0.83(Assumed)

Heat input to boiler = ΔH/η=2453.85/0.83

= 2956.44kJ/Kg

Steam flow rate for 67.79 MW of power = 248.01T/hr.

Total heat input = 248.01x10^{3}x2956.44

= 733228.12MJ/hr.

V. BOILER HEAT INPUT WHEN BOTH HP HEATERS ARENOT IN SERVICE

Temperature of feed water inlet of boiler = 134.7^{0}C

Enthalpy of feed water at inlet to boiler= 566.41KJ/Kg

Enthalpy of superheated steam = 3457.31KJ/Kg

Increase of enthalpy in boiler (heat addition) = 3457.31-566.41 = 2890.9kJ/Kg

Efficiency of boiler (η)= 0.85(Assumed)

Heat input to boiler for same 67.79 MW of power = ΔH/η

= 2890.9/0.85

= 3401.06kJ/Kg

Steam flow rate for 67.79 MW of power = 225.98T/hr.

Total heat input = $225.98 x 10^3 x 3401.06$

= 768571.27MJ/hr.

Steam flow requirement when both the heaters are in service IS 248.01T/hr. when there is no HP heater. steam flow required to generate same power is 225.98T/hr. through the steam flow required to generate same power is less when there are no HP Heater, water enter the boiler at a lower temperature that is 134.7^{0}C instead of 232.8^{0}C so the actual heat input required in the boiler to convert it into steam is higher-when there are no HP heaters in service.

VI. GENERATE SAME POWER OUTPUT

The data from the different parts of the steam power plant, the energy production from the boiler, turbine and condenser. The cost of expenditure of for the input coal also given.

Heat input to boiler when there no HP Heater in service =768571.27MJ/hr.

Heat input to boiler when both HP Heater are in service = 733228.12MJ/hr.

Additional heat input = 768571.27- 733228.12

= 35343.15MJ/hr.

Calorific value of coal = 3150Kcal/Kg

Extra coal required when there are no HP Heaters = $35343.15 x 10^3/13185.9$

= 2680Kg/hr.

= 2.68T/hr

Coal served due to HP heater in service = 2.68x24 T/day

= 2.68x24x365 T/day

= 23480.08 T/year

Cost of coal = Rs900/T

Total saving = Rs23480.08x900

= Rs21132072.49

Cost of both HP heaters = Rs2Cr (approx.)

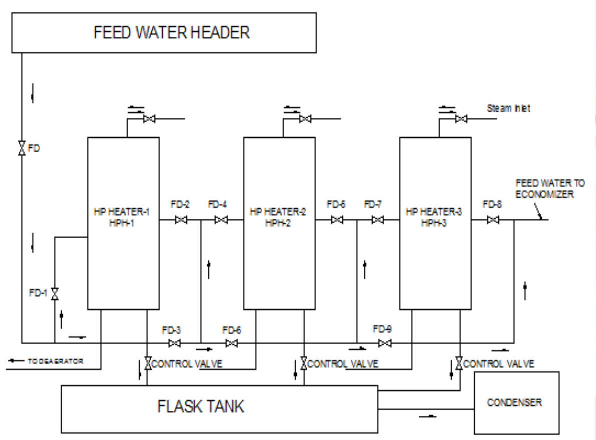
Payback period = 1yr

VII. EXPERIMENTION

Charging of high pressure heater 1/ 2 of turbo generator:

1. Feed water is charged through heater as confirmed by opening of valve in the boiler feed pump discharged heaters and feed water header at 16.5 m elevation for the corresponding turbo generator.
2. FD valve '0' meter level in feed water line before HP heater-1 is to be open.
3. Heater by-pass valve FD-3 and FD-6 are kept open.
4. Check feed water flow through heater in the indicator provided in MCR corresponding control panel.
5. Valve before and alter control valve to HP heater 1 & 2 drip line to flash tank are open.
6. Valves before and after control valve HPH-2 to HPH-l cascade line or open.
7. Valves before and alter control valve in HPH-l & 2 drip line to deaerator (near deaerator)
8. Stand pipes top and bottom isolated valves, level switches top and bottom isolation valves, level controller top and bottom isolation valves (both normal and high level controllers) are all keep open.
9. Stand pipe vents and drain valves kept closed.
10. Heater -l & 2 vent valves are opened.
11. Heater -l & 2 shell drains and tube drain valves are closed.
12. Drain valves after FD -l and FD-S are kept crack open.

13. Feed water inlet and outlet valves of HPH-l (FD-1.2) inlet and outlet valves of HPH-2 (FD-4, 5) are loosened.
14. IBV of FD-1.2. 3.4. 5 valves are opened.
15. Drain valves alter FD-l & FD-S are closed.
16. Main vales FD-l, 2, 4 and 5 are opened from control room through operation of respective open push buttons, opening valve is confirmed by "open service"
17. 13ata valve to HPH-l of corresponding Ta is opened from 13 ata header at 16.5 elevation from the header in service.
18. HP heater are charged above a turbine load 35-40 MW and removed below 30MW load.
19. HP heater-1 charged by keeping FD-l, 2 opened, FD-3 closed and slowly opening Exhaust valve from the control panel is inching mode of operation.
20. HP heater-2 id charged by keeping FD-4, 5 open, FD-6 closed and slowly opening valve from control panel id inching mode of operation.
21. HP heater 1& 2 levels are checked in indication between =50 mm.
22. Feed water flow and temperature of feed water inlet and outlet for HP heater 1&2 are observed in control panel indicator log book for TG.



VIII. Data Observations and Cost Analysis

The data observation shows the numerical value of HP heater when its expansion the turbo generator.

The data analysis was done with different parameter in boiler and condenser etc.

Boiler Heat Input of HP Heater:

Temperature of feed water at inlet of boiler = 232.8^{0}C

Enthalpy of feed water at inlet to boiler = 1003.46kj/kg

Temperature of steam at outlet boiler = 530.15^{0}C

Enthalpy of superheated steam = 3457.31kj/kg

Increase of enthalpy in boiler (heat additional) = 3457.31-1003.46

= 2453.85kj/kg

Efficiency of boiler (E) = 0.83 (assumed)

Heat input to the boiler = Heat addition / E = 2453.85 / 0.83

= 2956.44kj/kg

Total heat input to turbine= 248.01 x 1000 x2956.44

= 733228.12Mj/hr

Technical Data of HP Heaters:

S.NO	CONTENT	UNITS	VALUES
1	QUANTITY OF EXTRACTION STEAM	KG/HR	27615
2	PRESSURE OF' EXTRACTION STEAM	ATA	13.324
3	ENTHALPY OF EXTRACTION	KCAL/KG	719.2
4	QUALITY OF FEED WATER	KG/HR	336560
5	PRESSURE OF FEED WATER	ATA	143.29
6	TEMPERATURE OF FEED WATER AT INLET	C	140.9
7	TEMPTER OF' FEED WATER AT OUTLET	C	190
8	SURFACE AREA	M	420
9	SURFACE OF TUBES : OD THICKNESS	---	5/8"X16BG
10	VELOCITY	M/SEC	1.59S

Technical date of HP heaters

IX. Result Analysis

In the Result analysis the steam power plant audit done with HP heaters and the additional HP heaters. it will shows improve the efficiency and reduce cost of the steam production per unit power production.

Analysis in the following tables show the data analysis of steam power plant with HP heaters and additional HP heaters to the plant.

Before	After
5 Nos. of HP heater in	8 Nos. HP heaters in service

service	
Feed water average temp. =179^{0}C	Feed water average temp. =220^{0}C
Boiler main steam total flow =1100 ton/Hr.	Boiler main stream total flow=1160 ton/hr.
Enthalpy of stream at 101Kg/cm2, 540^0 C= 840 M cal/ton	Efficiency of boiler = 85.5
Heart input to boiler = (840-179)/0.85= 777.647M Cal/ton of stream	Heart input to boiler-(840-220)/0.85= 729.41 M cal/ton of stream
Total heat input = 1100x777.64 = 855411.76 M Cal/hr.	Total heat input 1160X 729.4 = 846117.64 M Cal/hr.

Reduction in total heat input to the boiler = 855411-846117= 9294cal/hr. assuming a loss of heat of 20% due to increase in flue gas temperature, heat transfer loss etc.

Net savings in heat input = 9294*0.8 =7435.2MCal/Hr.

Coal calorific value = 2900MCal /Ton

Reduction in the coal input to the boilers = 7435.2 / 2900 = 2.564 Tons / Hr.= 2.564 * 24 *365= 22461 Tons / annum.

At Rs.1200/- per tons of coal, total

Cost of 4 No. of heaters including installation cost = Rs4Crores .

Life of the heater expected is maximum 10 years and minimum it can go up to 20 years

Talking's minimum life of 10 years into account.

Results:

Expected savings in 10 years at present rate= Rs2.7Crores*10 = Rs27Crores

Net savings in next 10 years = Rs27-4Crores

= Rs 23Crores or

= Rs2.3Crores/annum

X. Conclusion

The turbine heat rate consumption is actually according to our data is 2693 kacl/kwh but to reduce that consumption we use condenser, normally condenser are used to reduce consumption and to create vacuum as life increase, the efficiency decreases by forming scale, sludge to walls so by acid cleaning of condenser to the walls the scales are removed from effective cleaning of the condensers we get the better efficiency then by this heat consumption rate is made low.

By effective cleaning of condenser the vacuum created is high therefore steam generated is high so we observed that TG1 and TG4 readings

TG-1-0.59

TG-4-0.86

So in TG4 not exaction of steam occurs so in TG4 efficiency is high. steam consumption is low.

From the reviews concluded that there are so many ways to reduce the energy consumption, energy cost reduction etc. which we are getting from energy auditing . Hence there is a need to prefer energy auditing of every plant once in anyear. For the research, it is found that it is also possible to do auditing at different load conditions and by comparison we get the actual consumption as well as wastage.

Thus the study showed that cogeneration steam power plants are more efficient as compared to conventional steam power plants as it preserves the quality of environment while enhancing the profitability, productivity or usefulness of energy input. The turbine efficiency improves and the specific steam consumption is low. The low grade waste heat from the process heater is used for doing work and also generates power and electricity.

By this the steam consumption is made to be low by cleaning condensers withacid

REFERENCES

[1] VikasDuhan, Jitender Singh "Energy Audit of Rajiv Gandhi Thermal Power Plant Hisar" JRPS International Journal for Research Publication & Seminar Vol 05 Issue 02 March -July 2014

[2] Ch.Kiran Kumar, G.Srinivasa Rao "Performance Analysis from the Energy Audit of A Thermal Power Plant," IJETT - Volume4 Issue6- June 2013

[3] A G Vinchurkar, Dr R RLakhe, Dr R L Shrivastava, "Energy management and optimizing energy in thermal power station," IJAERD, Volume 1,Issue 7,July 2014

[4] Jinendra K Gugaliya,*, Naveen Bhutani, and Mohan S Kumar, "Energy Assessment for Power Plants" Proceedings of the 6th International Conference on Process Systems Engineering (PSE ASIA), 25 - 27 June 2013, Kuala Lumpur

[5] Ms.ShradhaChandrakantDeshmukh, Ms.Varsha Arjun Patil ,"Energy conservation and Audit in TPS" International Journal of Scientific and Research Publications, Volume 3, Issue 8, August 2013.

[6] Namdeo D. Adate, R. N. Awale, "energy conservation through energy efficient Technologies at thermal power plant," International Journal of Power System Operation and Energy Management ISSN (PRINT): 2231 – 4407, Volume-2, Issue-3,4. 2013

[7] K.R. Shanmugam, Praveen Kulshreshtha, "Efficiency analysis of coal-based thermal power generation in India during post-reform era" Int. J. Global Energy Issues, Vol. 23, No. 1, 2005

[8] S.C.Arora and S. Domkundwar "A Course in Power Plant Engineering". Dhanphat Rai & Co. (P) Ltd. Educational & Technical Publication

[9] Energy Efficiency: A Worldwide Review" World Energy Council, Energy Efficiency Policies and Indicators, published on July 2004 .

[10] Mr. Santosh MahadeoMestry, "Technical paper on major energy saving potential in thermal power plant & effective implementation of EC Act

[11] Dr.Ivan sunitrout, Abhisekgaikward, Vinodkumarvarma, Mohmmadtariq " Thermal analysis of steam power plant " Journal of Mathmatical and Civil Engineering (IOSR-JMCE) Volume 7 , Issue 2 (May-Jun 2013).

[12] Dr Dev kumar patel "Improve steam turbine efficiency by use of Re heat rankine cycle " IJESRT,(120RPubicaton imapct factor 3785, July 2015 .