"STUDY OF BOILER AND THERMAL ENERGY ANALYSIS AT THERMAL POWER STATION"

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ABSTRACT

Energy conservation means, the need is to use energy efficiently and effectively. Energy Audit is a technical survey of a plant in which the machine/section wise/ department wise pattern of energy consumption studied and attempts to balance the total energy input correlating with production. As a result of the study the areas where the energy is wastefully used and the improvements are felt, are identified and corrective measures are recommended so that the overall plant efficiency could be improved. Fundamental understanding of the process is essential if we are to improve the overall efficiency of the system. So in this project we are going to carry out the audit and study particular department of a power plant. We planned to study the thermal energy audit for boiler of a power plant named Suryalaxmi thermal power station (STPS). Suryalaxmi thermal power station is located at Nagardhan, Ramtek & it's power generation capacity is 25MW. The power plant is commissioned in August 2012. After meeting the captive requirements, the company plans to save the surplus power.

KEYWORDS

Boiler, Boiler Specifications, Analysis of coal, heat Balance Sheet, Efficiency.

1. INTRODUCTION

The most evident problem in this world is the reduction of non-renewable energy sources. Therefore, energy security is the major concern of today's world. Improving efficiency of the energy systems is an essential option for the security of future energy. Now days power demand increases is extremely very high compared to the rate at which generation capacity increase. Boiler is a heart of power plant, so its efficiency is directly affected to the all over efficiency of the plant. It is quite obvious that approximately 65% to 70% power generation comes out from thermal power plant uses coal as fuel available from various parts of India, where transportation is also made easy and timely. Power is one of the basic infrastructures necessary for the Industries and socio economic development in the State.

Power consumption per capital indicates the industrial and economical growth of the country and thereby represents the living standard of the people of the same. The whole world is in grip of electrical energy crisis and pollution due to the power plants. the overall power scene in India shows heavy shortages in almost all the states.

2. DESCRIPTION ABOUT THE PLANT

The Thermal Power plant, uses 30 tones per hour fuel fired AFBC(atmospheric fluidized bed combustion) boiler, the company generates and sales electricity. The plant has been setup for the capacity of 25 MW at Nagardhan, Ramtek. The power plant commissioned in August 2012. After meeting the captive requirements, the company plans to sale the surplus power. This plant is basically setup to meet the power requirment of suryalaxmi cotton mill and the excess energy produced will be utlize for selling purpose. The basic layout of a thermal power plant is shown in below figure;[1]

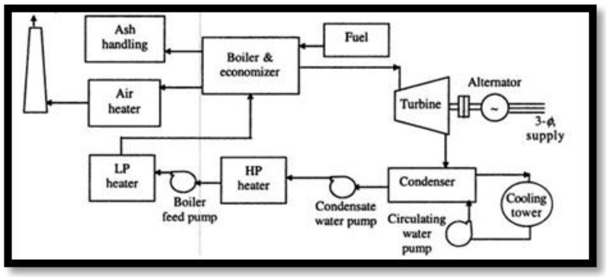


Fig .Basic **l**ayout of Thermal Power Plant

3. BOILER INTRODUCTION

A boiler is comprised of two basic systems. One system is the steam water system also called the waterside of the boiler. In the waterside, water is introduced and heated by transference through the water tubes, converted to steam, and leaves the system as steam. Boilers must maintain a chemical balance. The manner in which this is done can interact with the feed water control system.

The amount of blow down must be considered in the feed water control scheme, especially if the blow down is continuous. Often, the blow down flow is divided by the concentration ratio times the feed water flow. Continuous blow down is the common method for controlling the chemical concentration. On large boilers this may be done automatically by measuring the boiler water conductivity to control the blow down rate. The blow down rate may also be achieved by combining the conductivity with ratio control of blow down, rationing blow to feed water flow.

4. BOILER SPECIFICATIONS

Specification of Atmospheric Fluidized Bed Combustion (AFBC) boiler at Thermal power plant are [2]

Sr. No.	Unit	Value
1	Boiler type	AFBC
2	Power generation capacity	25 MW
3	Max. continuous rating at main steam stop valve	110 TPH
4	Steam pressure at main steam stop valve	110 Kg/cm^2
5	Steam pressure at turbine inlet	108 Kg/cm^2
6	Steam temperature at main steam stop valve outlet	510±5℃
7	Steam temp. control range for design performance of fuel	50-100% MCR
8	Surface area of boiler	5507 m^2
9	Surface temp. of boiler	70℃
10	Feed water temperature at HP heater outlet	230℃
11	Fuel firing rate	30 T/hr
12	Steam flow rate	110 T/hr
13	Feed water temperature	230℃
14	Feed water temperature at deareator outlet	140℃
15	Feed water temperature at HP heater outlet	200℃
16	Boiler turn down ratio	1:4
17	Flue gas temp. leaving Air pre heater	140℃
18	Fuel	100% coal
19	Fuel size	Less than 6 mm
20	Bed material size	2360℃
21	Ambient temperature	30℃
22	Fusion temperature	Less than 1100℃
23	Condition of bed material	Dry
24	Deareator operating temp.	170℃
25	Feed water temperature at economizer inlet with HP heater in line for MCR generation	230℃

5. Analysis of coal

There are two methods for analysis of coal;

1) **Proximate analysis**- The proximate analysis determines the fixed carbon,

volatile matter, and moisture and ash percentages.

2) **Ultimate analysis**- The ultimate analysis of coal involves determination of the weight percent of carbon as well as sulphur, nitrogen and hydrogen.

a) Measurement of moisture

- Determination of moisture is carried out by placing a sample of powered coal of 1 gm crucible and it is placed in the oven kept at 100℃.
- Then the sample is cooled to room temperature and weighed again.
- Ash present in coal sample is 11%.

b) Measurment of ash

- The coal sample of 1 gm is heated in furnace at 900℃ for 1 hour until all the carbon is burned.
- Then the sample is cooled to room temperature and weighed again.
- The loss in weight represents ash.
- Ash present in coal sample is 44%.

c) Measurement of Carbon, Hydrogen, Nitrogen, Sulphur (CHNS)

- Determination of CHNS is carried out by placing a sample of powered coal of 1 gm crucible in combustion chamber and it is heated at 110℃.
- Leco CHNS analyzer used for the analysis.
- Infrared and thermal conductivity cells used to detect of individual compounds.

d) Measurement of gross calorific value (GCV)

A bomb calorimeter consists of a small cup to contain the sample , oxygen, a stainless steel bomb,water, stirrer, a thermometer, insulating container and ignition circuit connected to bomb.

By using stainless steel for the bomb, the reaction will occur with no change in volume.

Analysis of coal	Instrument	Result
Carbon	Leco CHNS analyzer	34.3%
Hydrogen	Leco CHNS analyzer	2.8%
Oxygen	O2 Analyzer	6.4%
Sulphur	Leco CHNS analyzer	0.51%
Nitrogen	Leco CHNS analyzer	0.7%
Ash	Furnace	44.0%
Moisture	Oven	11.0%
GCV of coal	Bomb calorimeter	3400 Kcal/kg
GCV of fly ash	Bomb calorimeter	889 Kcal/kg
GCV of bottom ash	Bomb calorimeter	395 Kcal/kg

Table. Analysis of coal sample

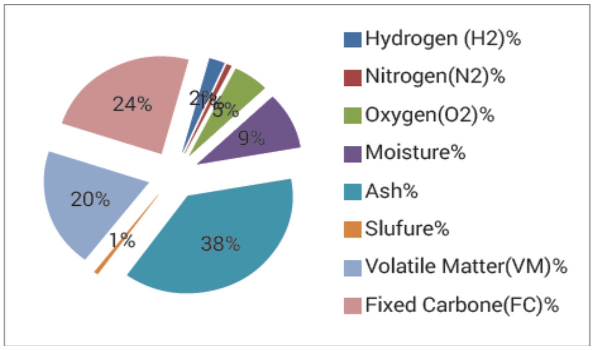


Fig. Coal Analysis Chart

6. Performance of boiler for 10MW & 20MW

For calculating the performance of boiler the fallowing parameter required. This Parameter taken from power plant for the calculation of 10MW.[3]

1) Steam temperature = 510 ℃
2) Steam pressure= 108 kg/cm^2
3) Steam flow = 51.66 T/hr
4) Fuel firing rate = 12.70 T/hr
5) Ambient temperature = 30℃
6) Temperature of flue gases = 190℃
7) Feed water temperature = 153 ℃
8) Humidity in ambient air = 0.0204 kg/kg of air
9) Ratio of bottom ash to fly ash = 30:70
10) GCV of bottom ash = 889 kcal/kg

11) GCV of fly ash = 395 kcal/kg GCV of coal = 3400 kcal/kg
12) %CO2 in flue gas = 14%
13) %CO in flue gas = 0.5%

Boiler efficiency[4]

η =100–(L1+L2+L3+L4+L5+L6+L7+L8)

Where,
L1- Loss of heat due to dry flue gas (Sensible heat)

L2- Loss due to hydrogen in fuel (H2)

L3- Loss of heat due to moisture in fuel (H2O)

L4- Loss of heat due to moisture in air (H2O)

L5- Loss of heat due to carbon monoxide (CO)

L6- Loss of heat due to radiation and convection

L7- Loss of heat due toun-burnt carbon in fly ash

L8- Loss of heat due to un-burnt carbon in bottom ash.

For 10 MW		
As per given values		
1. Theoretical air required	(11.6x34.8)+{34.8(2.9-6.4/8)}+(4.35x0.9)}/100	
	=4.70Kg/Kg Fuel	
	%CO2at theoretical condition	
	Moles of C/(moles of N2+moles of C)	
	Where	
	Moles of N2	
	=(wt. of N2 in Theo. Air/mol. Wt. of N2)+ (wt. of N2 in Fuel/mol. wt. of N2	
	(4.70/28)x(77/100)+(0.009/28)	
	=0.12957	
	Where moles of C	0.343/12
	0.343/12	
	(CO2)t-(0.0285/0.1295+0.0285)	
	=18.03%	CO2 measure 14%
2. Exess Air Supplied	=7900[(CO2)t+(CO2)a]/(CO2)ax(100-(CO2)t	
	=7900[18.03-14)/14(100-18.03)	
	=27.74%	
OR		

%Of excess air	=(4.60/21-4.60)x100	=27.90%
3. Actual Mass of Air	={1+27.74/100}x Theoretical Air	
	={1+27.74/100} x4.70	=6.0Kg/Kg Fuel
4. Mass of Dry Flue gas	= Mass of CO2 +Mass of N2+Mass of N2 comb. Air supplied + Mass ofO2+Mass0fS2	
	=(0.348x44/12)+0.009+(6x77/100) + (6-4.70)x23/100+(.0034x64)/100	
	=6.204Kg/Kg	
5. Losses Due To		
Dry flue gas (sensible heat)(L1)	={M x Cp x (Tf-Ta)/GCV of Coal} x100	
	={6.204x0.23x(190-30)/3400}x100	
	=6.71%	
Hydrogen in fuel (H2)(L2)	={9xH2x{584+Cp(Tf-Ta)}/GCV of Fuel}x100	
	={9x0.028x{584+0.45(190-60)}/3400}/100	
	=4.86%	
Moisture in fuel (H2O)(L3)	={m x{584+Cp(Tf-Ta)}/GCV of Fuel}x100	
	={0.1181x{584+0.45(190-60)}/3400}x100	
	=2.12%	
Moisture in air (H2O)(L4)	={AAS x H. F .x Cp(Tf-Ta)}/GCV of Fuel}x100	
	={6.0x0.024x0.45(190-30)/3400}x100	
	=0.26%	
Carbon monoxide(CO)(L5)	={(%CO x C)/(%CO+%CO2)}x{(5744/GCV Of Coal)}x100	
	={(0.55x.348)/(0.55+14)}x{(5744/3400)}x100	
	=2.22%	
Radiation and convection(L6)	For power station boiler =0.4to1%	
	$=\{0.584x\{(Ts/55.55)^4-(ta/55.55)^4\}x (Ts-Ta)^{1.25}x(196.85Vmx68.9/68.9)^{0.5}\}$	
	=0.50%	
Unburnt in fly ash(L7)	=Total ash collected/kg of fuel burnt x GCV of fly ash)/(GCV Of Fuel)}x100	
	={(3.90)/(3400)}x 100	=0.11%
Unburnt in bottom ash(L8)	=(Total ash collected per kg of fuel burnt x G.C.V Of bottom ash/GCV Of Fuel)x100	

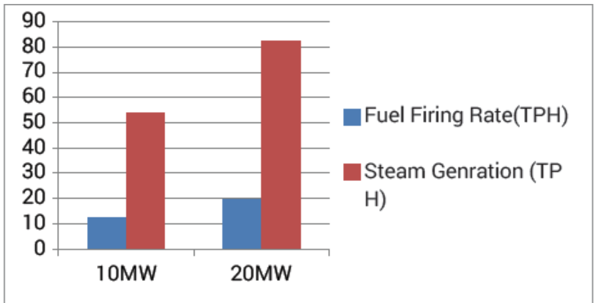
	=(62.136/3400)x 100	=1.82%
Efficiency of Boiler	=100-(L1+L2+L3+L4+L5+L6+L7+L8)	
	=100-18.60	
	=81.40%	

Parameter taken from power plant for the calculation of 20MW.[5]

1) Steam temperature = 510 ℃
2) Steam pressure= 108 kg/cm^2
3) Steam flow = 82.5 T/hr
4) Fuel firing rate = 19.79 T/hr
5) Ambient temperature = 30℃
6) Temperature of flue gases = 210℃
7) Feed water temperature = 195 ℃
8) Humidity in ambient air = 0.0204 kg/kg of air
9) Ratio of bottom ash to fly ash = 30:70
10) GCV of bottom ash = 889 kcal/kg
11) GCV of fly ash = 395 kcal/kg GCV of coal = 3400 kcal/kg
12) %CO2 in flue gas = 16.5%
13) %CO in flue gas = 0.5%

For 20 MW		
As per given values		
1. Theoretical air required	(11.6x34.8)+{34.8(2.9-6.4/8)}+(4.35x0.9)}/100	
	=4.70Kg/Kg Fuel	
	%CO2at theoretical condition	
	Moles of C/(moles of N2+moles of C)	
	Where	
	Moles of N2	
	=(wt. of N2 in Theo. Air/mol. Wt. of N2)+ (wt. of N2 in Fuel/mol. wt. of N2	
	(4.70/28)x(77/100)+(0.009/28)	
	=0.12957	
	Where moles of C	0.343/12
	0.343/12	
	(CO2)t-(0.0285/0.1295+0.0285)	
	=18.03%	CO2 measure 14%
2. Exess Air Supplied	=7900[(CO2)t+(CO2)a]/(CO2)ax(100-(CO2)t	
	=7900[18.03-14)/14(100-18.03)	
	=27.74%	

OR		
%Of excess air	=(3.80/21-3.80)x100	=22.09%
3. Actual Mass of Air	={1+22.09/100}x Theoretical Air	
	={1+22.09/100}x4.70	=5.73Kg/Kg Fuel
4. Mass of Dry Flue Gas	= Mass of CO2 +Mass of N2+Mass of N2 comb. Air supplied + Mass of O2+Mass 0f S2	
	=(0.348x44/12)+0.009+(5.73x77/100)+ (5.73-4.70)x23/100+(.0034x64)/100	
	=5.69Kg/Kg	
5. Losses Due To		
Dry flue gas (sensible heat)(L1)	={M x Cp x (Tf-Ta)/GCV of Coal} x100	
	={5.69x0.23x(201-30)/3400}x100	
	=6.71%	
Hydrogen in fuel (H2)(L2)	={9xH2x{584+Cp(Tf-Ta)}/GCV of Fuel}x100	
	={9x0.028x{584+0.45(190-60)}/3400}/100	
	=4.86%	
Moisture in fuel (H2O)(L3)	={m x{584+Cp(Tf-Ta)}/GCV of Fuel}x100	
	={0.1181x{584+0.45(210-60)}/3400}x100	
	=2.29%	
Moisture in air (H2O)(L4)	={AAS x H. F .x Cp(Tf-Ta)}/GCV of Fuel}x100	
	={5.73x0.024x0.45(201-30)/3400}x100	
	=0.31%	
Carbon monoxide(CO) (L5)	={(%CO x C)/(%CO+%CO2)}x{(5744/GCV Of Coal)}x100	
	={(0.55x.348)/(0.55+17.2)}x{(5744/3400)}x100	
	=1.82%	
Radiation and convection(L6)	For power station boiler =0.4to1%	
	={0.584x{(Ts/55.55)^4-(ta/55.55)^4}x (Ts-Ta)$^{1.25}$x(196.85Vmx68.9/68.9)$^{0.5}$}	
	=0.50%	
Unburnt in fly ash(L7)	=Total ash collected/kg of fuel burnt x GCV of fly ash)/(GCV Of Fuel)}x100	
	={(2.90)/(3400)}x100	=0.08%
Unburnt in	=(Total ash collected per kg of	



bottom ash(L8)	fuel burnt x G.C.V Of bottom ash/GCV Of Fuel)x100	
	=(41.136/3400) x100	=1.20%
Efficiency of Boiler	=100-(L1+L2+L3+L4+L5+L6+L7+L8)	
	=100-17.43	
	=82.57%	

7. CALCULATIONS FOR COST SAVING

1	**Actual 4 tone steam is required for generation of 1 MW power,**		
	As per my calculation		
	10MW	51.66TPH	
	20MW	82.5TPH	
	As per std. Values		
	10MW	40TPH	
	20MW	80TPH	
	Costing of Coal for 1 tone –Rs 3545/-		
	10MW	Rs 41334.7/	Excess costing
	20MW	Rs 8862/	Excess costing
	We save Rs 32472.7/- during 80% load on Boiler. After all the auxiliary regarding 80% load on boiler the Costing is Rs 31632/- per hrs. i.e. we can save Rs 840.7/- Rs Per Day 840.7x24 = 20176.8/- Rs Per Month 20176.8x30=605304/- Rs Per Year 20176.8x355=7162764/- We can save Rs 7162764/-per year.		
	Similarly,		
2	**By Efficiency**		
	10MW	81.40%	Efficient
	20MW	82.33%	Efficient
	0.93%more efficient during 80% loads on Boiler.		
3	**For feed water temperature**		
	10MW	153°C	
	20MW	195°C	
	Difference in both Is 22°C		
	Ultimately Temperature difference needs Coal for rising temperature		
	Nearly 300 t o400 kg of coal to be require for raising the temp.		
	=0.350x3545		
	1240/- Rs per day 1240x30=37200/- 1240x355=440200/-		
	We save Rs Per Year 440200/- during 80% load on Boiler		

8. RESULTS AND DISCUSSION

The losses of AFBC boiler are obtained and studied in details to find out energy saving opportunity. The heat losses in boiler are found to be as follows:

Sr. No	Losses	10MW	20MW
1	Dry Flue Gas Loss	6.71%	6.58%
2	Loss Due To Hydrogen In Fuel	4.86%	4.89%
3	Loss Due To Moisture in Fuel	2.12%	2.29%
4	Loss Due To Moisture in Air	0.26%	0.31%
5	Partial Combustion of C To CO	2.22%	1.82%
6	Surface Heat Loss	0.50%	0.50%
7	Loss Due To Unburnt in Fly Ash	0.11%	0.08%
8	Loss Due To Unburnt in Bottom Ash	1.82%	1.20%
9	Total Losses	18.60%	17.67%
10	Efficiency	81.40%	82.33%

9. Comparison FFR & Steam generation

According to this figure we can easily get idea about fuel firing rate and steam generation for the 1MW generation boiler takes 51.66 TPH steam similarly 12.70 TPH coal is needed and for 20MW boiler takes 82.5 TPH steam and 19.79 TPH coal respectively. As per the load is rises the fuel firing rate is reduce and required steam for generation also reduces.

Fig. Comparision FFR & Steam generation

10. Comparision of specific fuel ratio

According to this figure we get idea about specific fuel ratio, Specific fuel ratio is the ratio of steam generation Vs fuel consumption by this figure we conclude that for 10MW generation SFR maximum and for 20MW it is low i.e for 10MW 4.25 and 20MW 4.16. At the maximum load on boiler the temperature and auxiliaries are more than the efficiency is more, ultimately it affects the specific fuel ratio.

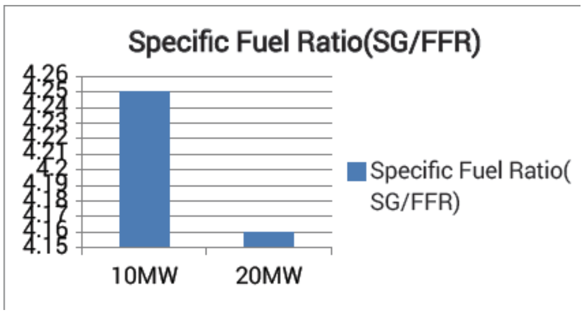


Fig. Comparision of specific fuel

11. Conclusion

With the help of the detailed information that is collected and studied by us we calculated the balance sheets on the basis of the required parameters and various losses which affect the performance calculations of a plant. By indirect method heat losses are studied in details. Heat lost due to unburnt carbon in fly ash is one of the major sources of energy loss. We can calculate Efficiency at 10MW generation is 81.20% and for 20MW 82.57% i.e. boiler on maximum load is more efficient nearly 1%. When load raises specially SF ratio decreases also reduce in boiler losses upto 0.93% more efficiency.(i.e.82.57%).

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