Investigation of Boiler Performance in a Power Plant

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Abstract-- ***In any modern power plant, the efficiency calculation and loss analysis of a boiler are the first steps to maintain and improve the overall power plant efficiency. The efficiency of the boiler was calculated by the losses or indirect method which is more complicated and more accurate than the direct method. The specific objective of this paper is to calculate the efficiency of a boiler and to identify and analyse the losses involved in the boiler. Boiler's performance deviations were analysed and the causes for these deviations are found. To minimise these deviations the possible remedial measures were found and also aims to suggest methods which would aid in the reduction of the specific fuel consumption and the carbon footprint, apart from calculating the efficiency and analysing the losses involved in a boiler.***

Keywords: ***Boiler performance, Carbon footprint, Power plant, Specific fuel consumption.***

I. INTRODUCTION

A. BOILER

A steam generator is popularly known as boiler. It is a closed vessel made of high quality steel in which steam is generated from the water by the application of heat. The water receives heat from the hot gases through the heating surfaces of the boiler. The hot gases are formed by the burning fuel, may be coal, oil or gas. Heating surface of the boiler is that part of boiler which is exposed to hot gases on one side and water or steam on the other side. The steam, which is collected over the water surface, is taken from the boiler through super heater and then suitable pipes for driving engines or turbines or for some industrial heating purpose. A boiler consists of not only the steam generators but also a number of parts to help for the safe and efficient operation of the system as a whole. The capacity of the boilers used for power generation is considerably large compared with other boilers. Due to the requirements of high efficiency, the steam for power generation is produced at high pressure and in very large quantities. They are very large in size and are individual design depending the type of fuel to be used.

B. POWER PLANT

A power station also referred to as a generating station, power plant, powerhouse or generating plant is an industrial facility for the generation of electric power. A thermal power station is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated; this is known as a Rankine cycle. Thermal power plants generate more than 80% of the total electricity produced in the world. Ennore thermal power station is one of the oldest thermal plants in Tamil Nadu coming under "Tamil Nadu Electricity Board (TNEB)".It was started in 1970. It is one of the four major thermal power plants of Tamil Nadu established by TANGEDCO. Presently it has an installed capacity of 450-MW. The necessary coal arrives through ship to the Ennore Port from Orissa. The coal used is bituminous coal. The Station presently consists of two 60-MW and three 110-MW units.

II. REVIEW OF POWER PLANT

Sebastian Tier et al. (2002) calculated the boiler efficiencies, state properties, amount of various types of losses, heat loads and mass flow are dealt with in detail. It helped us get an idea as to how one must begin to create solutions to eliminate or minimise them. Also, the indirect method has been dealt with in detail in this paper. Indirect method determines the efficiency of a boiler by the sum of the major losses and by the fuel power of the boiler. The indirect method provides a better understanding of the effect of individual losses on the boiler efficiency. Genesis Murehwa et al. (2012) shown the weakness of depending on energy analysis only power plants as a performance measure that will help improve efficiency. Exergy analysis was undertaken at the thermal power plant which highlighted the areas that could be addressed to improve the efficiency. A recommendation of retrofitting and replacement was done for the system.

Ongoing work in development of intelligent power plant is expected to improve stability of steam headers, responsiveness to steam demand, increase power generation flexibility, minimize operations cost, improve overall plant efficiency, increase fuel cost savings and reduce CO2 Emission. R.K. Kapooria et al. (2008) investigated and analysed the various important characters affecting the thermal power plant's overall efficiency and other related of the Rankine cycle have been discussed. The efficiency of a simple Rankine cycle is improved by using intermediate reheat cycle, enabling improved thermal conditions of the working fluid. However, it cannot reach the thermal conditions as in the case of the Carnot cycle where heat addition and heat rejection occurs at a specified temperature range. The regeneration is vital to improve the efficiency as it uses the sensible heat of exhaust steam for the preheating of feed water. Inclusion of a FWH also introduces an additional pressure level into the Rankine cycle as seen in the T-s diagram. Hence, the extraction pressure level is another parameter under the control of the designer.

The control of steam condenser pressure i.e. condenser vacuum and supply of condenser tube cooling water is another parameter which affects the steam thermal power plant efficiency. Amit Kumar Jain (2012) discussed about modern approach towards efficient operation of boilers. Higher product quality, better reliability, better availability of plants, optimization of cost and efficient working of boilers is the chief concern now a days. Generally the production can be increased by the efficient use of boilers and hence there is a lot of scope to minimize the boiler operation cost. Thus in this paper an attempt is made to understand the way by which boilers can be used efficiently. Nabil M. Muhaisen et al. (2012) clearly showed the changes of efficiency levels that related to the steam boilers. The efficiency levels were based on the changes of the temperature of the used feed water for the boilers along with the changes of the temperature of the exhaust gases. The humidity levels of the used fuel within the boiler are also being considered. This research has also indicated that the efficiency of the steam power plant will increase and showing higher level of effectiveness when applying good, reliable working conditions.

III. PERFORMANCE ANALYSIS AND PLANT EFFICIENCY

Performance monitoring is done to find out the deviation of equipment and machines from the actual designed condition and to optimize the unit. Performance analysis is done for the units to

- Make availability of units
- Less Maintenance
- Safety for operating personnel
- Economic operation
- Minimising generating cost
- Running at high efficiency

3.1 Efficiency and Loss Analysis in Boiler

- *Experimental work involved at the site consists of measurements related to Coal, Air, Flue gas, Steam flow and feed water flow at hourly reading. The experimental work was conducted at ETPS Unit III & IV by taking the reading from logbook of boiler section.*
- *The measurements of the contents of the coal (i.e. Ash, G.C.V fixed carbon, sulphur etc.) was taken from the chemical laboratory of ETPS.*
- *The efficiency calculations test was conducted at plant load 55 MW. In ETPS, the efficiency calculations are done by direct method. But we calculate the efficiency of the boiler by 'Indirect or Losses Method'.*

3.2 Advantages of Losses Method over Direct Method

The efficiency can be measured easily by measuring all the losses occurring in the boilers using the principles to be described. The disadvantages of the direct method can be overcome by this method, which calculates the various heat losses associated with boiler. The efficiency can be arrived at, by subtracting the heat loss fractions from 100. An important advantage of this method is that the errors in measurement do not make significant change in efficiency. Thus if boiler efficiency is 90%, an error of 1% in direct method will result in significant change in efficiency i.e. 90 + 0.9 = 89.1 to 90.9. In indirect method, 1% error in measurement of losses will result in Efficiency = 100 – (10 + 0.1) = 90 + 0.1 = 89.9 to 90.1

IV. EFFICIENCY CALCULATIONS

The following is a test report from the laboratory of a test conducted. These readings are used to calculate the efficiency of the boiler in losses method.

TABLE 4.1 EFFICIENCY OF THE BOILER IN LOSSES METHOD

S.NO	PARTICULARS	UNIT – III	UNIT – IV
1.	a) Proximate Analysis		
	% Moisture	6.6	6.6
	% Ash	43.2	43.2
	% Volatile matter	23.9	23.9
	% Fixed carbon	28.4	28.4
	b) Gross calorific value (kcal/kg ^{0}k)	3529	3529
	c) Ultimate Analysis		
	% Carbon	37.9	37.9
	% Hydrogen	3.86	3.86
	% Nitrogen	0.85	0.85
	% Sulphur	0.33	0.33
	% Oxygen	6.99	6.99
2.	Fly Ash		
	% Combustibles	0.86	1.59
3.	Bottom Ash		
	% Combustibles	2.25	3.43

TABLE 4.2 READINGS USED TO CALCULATE THE EFFICIENCY OF THE BOILER IN LOSSES METHOD

S.NO	PARTICULARS	UNIT- III	UNIT- IV
1.	Main steam flow	193 tn/hr	229 tn/hr
2.	Main steam temperature	524.5^0 C	525^0 C
3.	Super heater steam pressure	90 kg/cm^2	98 kg/cm^2
4.	Feed water flow	188 tn/hr	234 tn/hr
5.	Feed water pressure	145 kg/cm^2	146 kg/cm^2
6.	Steam temperature before desuper heater	433^0 C	497^0 C
7.	Steam temperature after desuper heater	415^0 C	405.5^0 C
8.	Feed water temperature before economizer	149^0 C	157^0 C
9.	Flue gas temperature before economizer	493^0 C	511.5^0 C
10.	Flue gas temperature after economizer	330^0 C	327^0 C
11.	Flue gas temperature after air heater	128^0 C	130^0 C
12.	Ambient air temperature	27^0 C	27^0 C
13.	Air temperature after air heater	282.5^0 C	250^0 C

IN BOILER UNIT III & IV THE MAJOR CAUSES OF COMBUSTIBLE LOSS ARE:

1. EXCESS AIR.
2. LOW QUALITY FUEL.
3. BURNER DESIGN.

1. EXCESS AIR

Excess Air admission causes the combustible loss in Boiler. The excess air in the boiler is in the order of 40% and above against allowable limit of 20% i.e. Air supply for any load is same (40MW & 20MW the same air supply exist in Boiler). This causes the combustible loss.

2. LOW QUALITY FUEL

The Gross calorific Value is 3529 Kcal/kg. The low G.C.V coal also causes the combustible loss. This is due to high ash content of coal, which is 40% and above. It may be avoided by using good quality coal. But it has economic and availability problems.

B. BURNER DESIGN MODIFICATION (BMS)

It is designed to ensure the execution of safe orderly operating sequence in the startup and shutdown of fuel firing equipment and to prevent errors during commissioning and to adopt safe operating procedures

Loss due to Moisture in Air

High humidity of air causes the loss in the boiler. The arrangement required for heating the air in winter season is high when compared with summer season. The reading is taken for loss analysis, so the loss due to moisture content in air is considerable amount. But in summer season it may be reduced below 0.05%. So this is negligible in summer. It is an uncontrollable loss.

Loss due to Moisture in Fuel

Major cause of this loss Boiler unit III & IV are:

- *Excessive wetting down of coal.*
- *High moisture absorption by coal in yard storage.*

Loss due to Moisture in Ash

The boiler unit III & IV were designed for 30% of ash content in coal. But now, the coal contains early 50% ash. So this loss is nearly 2.3%.

TABLE 4.3 LOSSES IN BOILER UNIT-III

S.NO	LOSSES IN BOILER UNIT III	LOSS IN %
1	Dry gas loss	8.01
2	Loss due to % moisture in fuel	7.35
3	Loss due to combustible in ash	0.99
4	Loss due to sensible heat in ash	0.36
5	Loss due to air moisture	0.85
6	Loss due to radiation	0.41
	TOTAL	17.97

TABLE 4.4 LOSSES IN BOILER UNIT-IV

S.NO	LOSSES IN BOILER UNIT IV	LOSS IN
1	Dry gas loss	7.74
2	Loss due to % moisture in fuel	7.36
3	Loss due to combustible in ash	1.08
4	Loss due to sensible heat in ash	0.36
5	Loss due to air moisture	0.70
6	Loss due to radiation	0.41
	TOTAL	17.65

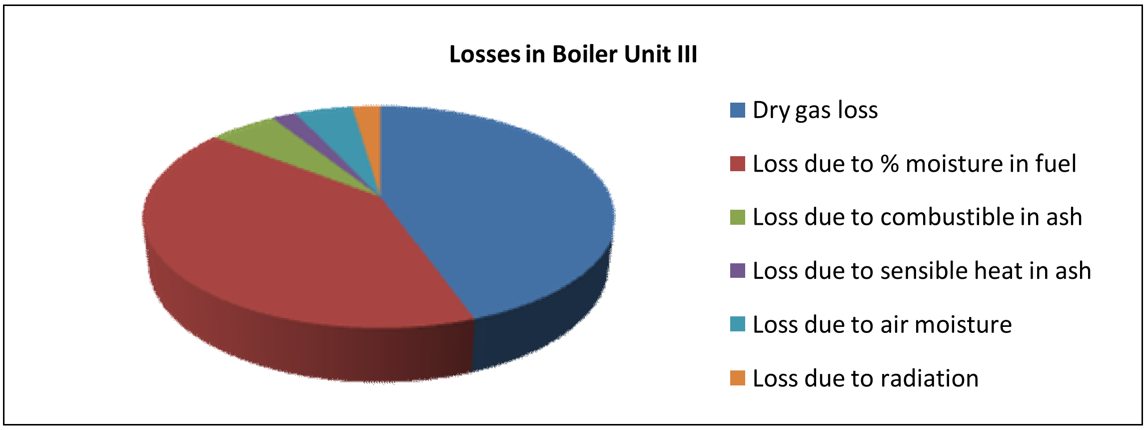

Figure 4.1 Pie chart showing percentage losses

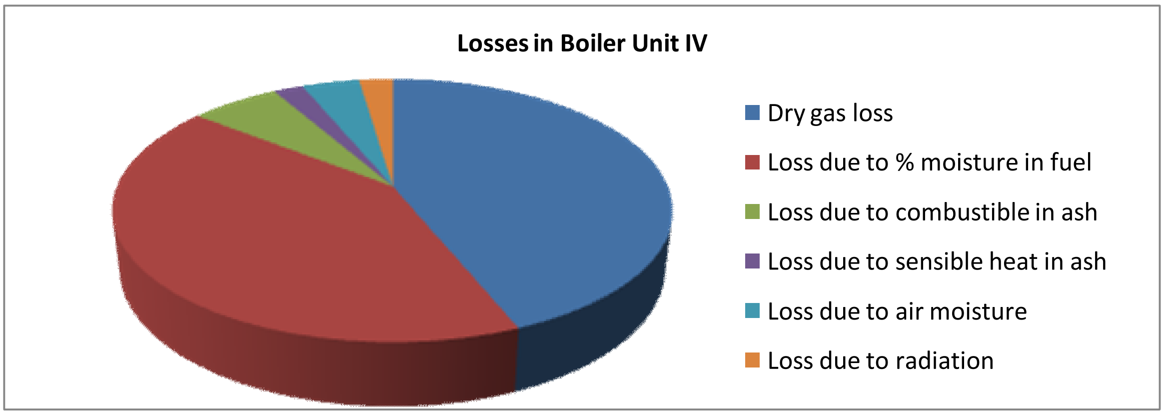

Figure 4.2 Pie chart showing percentage losses

Efficiency of the Boiler Unit-III = 100 – Total losses
= 100 – 17.97
= 82.03 %.

Efficiency of the Boiler Unit-IV = 100 – Total losses
= 100 – 17.65
= 82.35

IV. CONCLUSION

Thus, the efficiencies of the boiler units 3 and 4 have been calculated. They are found to be 82.03 and 82.35% respectively. The efficiency was calculated by the Indirect or Losses Method which has a significantly higher accuracy than the Direct Method employed at the power plant. Therefore, the boiler's efficiency as calculated by the plant can also be cross checked. The individual component efficiency losses were easily identified by the indirect method. The practical suggestions have been included as 'Rectification Measures', which on implementation are sure to check the losses and thereby, increase the efficiencies of the boiler units.

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