Efficiency Improvement Opportunity in Boiler Without Changing GCV of the Coal

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Abstract: ***Boiler is a most useful device for any industry for process and production. It is very necessary to calculate the efficiency. There are basically two methods to calculate the efficiency of boiler, direct method and indirect method. Both the methods give different values as direct method does not consider any loses whereas indirect method gives the result by calculating all the losses. Efficiency for different GCV has been shown in this paper for AFBC boiler and this paper also gives the description of calculation of efficiency for AFBC and CFBC boiler for 4000kcal/kg gross calorific value of fuel.***

Keywords: Boiler efficiency for AFBC and CFBC, efficiency difference, comparison, efficiency improvement opportunity.

Nomenclatures

Q_o = Heat output
Q_i = Heat input
Q = Quantity of steam generated per hour (kg/hr)
q = quantity of fuel per hour (kg/hr)
h_g = steam enthalpy (kcal/kg)
h_f = feed water enthalpy (kcal/kg)
GCV of fuel = gross calorific value of fuel (kcal/kg)
C_p = specific heat of flue gas
T_f = temperature of flue gas (^oC)
T_a = ambient temperature (^oC)
T_s = surface temperature (^oC)
m = mass of dry flue gas (kg/kg of fuel)
H_2 = percentage of H2 in fuel = kg of H2 in 1kg of fuel
C_p = specific heat of superheated steam
M= % of moisture present in fuel = kg of moisture in 1kg of fuel
AAR = actual air required (kg/kg of fuel)
M_{bw} = mass of blow down water (Kg/hr)
H_{bw} = enthalpy of blow down water at drum pressure (Kcal/kg)
H_{fw} = enthalpy of feed water (Kcal/kg)
Ma = mass of total ash generated/kg of fuel

1. Introduction

A boiler is defined as a closed vessel in which water or other liquid is heated, steam or vapor is generated, steam is superheated, or any combination therefore, under pressure or vacuum, for use external to itself, by the direct application of energy from the combustion of fuels, from electricity or nuclear energy. Basically coal is taken as the fuel in the industry for the steam production. Fuel having higher calorific value gives more heat per kg of fuel. Efficiency depends on the GCV of the fuel, higher the GCV higher is the efficiency. Efficiency of the boiler can be calculated by two methods, direct method and indirect method. Both methods give different results as indirect method considers all the losses whereas in direct method losses are not taken into consideration. These methods require various parameters to calculate the efficiency. These parameters are chemical analysis result of coal, feed waters analysis, coal feeding rate, steam pressure, steam generation per hour, flue gas analysis, humidity factor etc. Here the calculation has been done for 30TPH AFBC and CFBC boiler in INDIA GLYCOLS LIMITED with fuel having 4000KCal/Kg for coal.

2. Methods to Calculate Boiler Efficiency

There are two methods to calculate efficiency of boiler:
1. Direct Method
2. Indirect Method

1. Direct method: By this method efficiency can be calculated by heat input to the heat output.

Boiler efficiency $\eta = \frac{\text{Heat ouput}}{\text{Heat input}}$

Boiler efficiency $\eta = \frac{Q \times (h_g - h_f)}{q \times GCV\ of\ coal} \times 100$

2. Indirect method: Efficiency can be easily calculated by this method by calculating losses occurring in the boiler. Following losses were applicable to all the fuel used weather it is solid, liquid or gas fired boiler.
L1— Loss due to dry flue gas
L2— Loss due to hydrogen in the fuel
L3— Loss due to moisture in the fuel
L4— Loss due to moisture in air
L5— Loss due to un-burnt in fly ash
L6— Loss due to un-burnt in bottom ash
L7— Loss due to convection and radiation

i. Percentage heat loss due to dry flue gas

$$= \frac{m \times C_p \times (T_f - T_a)}{GCV\ of\ fuel} \times 100$$

m = mass of dry flue gas in kg/kg of fuel.

m = combustion products from fuel: CO_2 + SO_2 + Nitrogen in fuel + Nitrogen in the actual mass of air supplied + O_2 in flue gas. (H_2O/ water vapour in the flue gas should not be considered).

C_p = Specific heat of flue gas (0.23 kcal/kg^oC)

ii. Percentage of heat loss due to evaporation of water formed due to H_2 in fuel:

$$=\frac{9\times H_2\times[584+C_p(T_f-T_a)]}{GCV\ of\ fuel}\times 100$$

Where, H_2 – kg of H_2 in 1 kg of fuel

C_p – Specific heat of superheated steam (0.45kcal/kg°C)

iii. Percentage heat loss due to evaporation of moisture present in fuel

$$=\frac{M\times[584+C_p(T_f-T_a)]}{GCV\ of\ fuel}\times 100$$

Where, M – kg of moisture in 1kg of fuel

C_p– Specific heat of superheated steam (0.45 kcal/kg)°C

584 is the latent heat corresponding to the partial pressure of water vapour.

iv. Percentage heat loss due to moisture present in air

$$=\frac{AAS\times Humidity\times C_p\times(T_f-T_a)}{GCV\ of\ fuel}\times 100$$

C_p– Specific heat of superheated steam (0.45 kcal/kg°C)

v. Percentage heat loss due to un-burnt in flyash

$$=\frac{\frac{Total\ ash\ collected}{kg\ of\ fuel\ burnt}\times GCV\ of\ the\ fly\ ash}{GCV\ of\ the\ fuel}\times 100$$

vi. Percentage heat loss due to un-burnt in bottom ash

$$=\frac{\frac{Total\ ash\ collected}{kg\ of\ fuel\ burnt}\times GCV\ of\ the\ bottom\ ash}{GCV\ of\ the\ fuel}\times 100$$

vii. Percentage heat loss due to radiation and other uncounted loss.

Efficiency of the boiler (η) = 100 – (i + ii + iii + iv + v + vi + vii)

3. Results from Calculation

Results derived from the above formulas for different GCV has been shown in table 1 and 2 for AFBC boiler. By changing the GCV efficiency changes gradually, as we increase the GCV of coal efficiency increases and will be clear from below tables.

Table 1: Result of boiler efficiency calculation

GCV of coal	3000Kcal/kg	3300Kcal/kg	3600Kcal/kg	4000Kcal/kg	5000Kcal/kg	5800Kcal/kg
Steam generation rate	30000Kg/hr	30000Kg/hr	30000Kg/hr	30000Kg/hr	30000Kg/hr	30000Kg/hr
Operational hours	7200Hrs/year	7200Hrs/year	7200Hrs/year	7200Hrs/year	7200Hrs/year	7200Hrs/year
Steam pressure	45Kg/cm^2	45Kg/cm^2	45Kg/cm^2	45Kg/cm^2	45Kg/cm^2	45Kg/cm^2
Steam temperature	420°C	420°C	420°C	420°C	420°C	420°C
Coal firing rate	9009Kg/hr	8000Kg/hr	7211Kg/hr	6250Kg/hr	6110Kg/hr	4285Kg/hr
Ambient temperature	30°C	30°C	30°C	30°C	30°C	30°C
Humidity factor	0.018Kg/kg of dry air	0.018Kg/kg of dry air	0.018Kg/kg of dry air	0.018Kg/kg of dry air	0.018Kg/kg of dry air	0.018Kg/kg of dry air

Table 2: Efficiency calculated by Direct and Indirect Method

Boiler efficiency	3000Kcal/kg	3300Kcal/kg	3600Kcal/kg	4000Kcal/kg	5000Kcal/kg	5800Kcal/kg
Direct method	74.61%	76.30%	77.7%	80.5%	82.05%	83.69%
Indirect method	73.43%	75.03%	75.75%	78.67%	80.06	82.34

Figure 1: Efficiency vs. GCV of coal

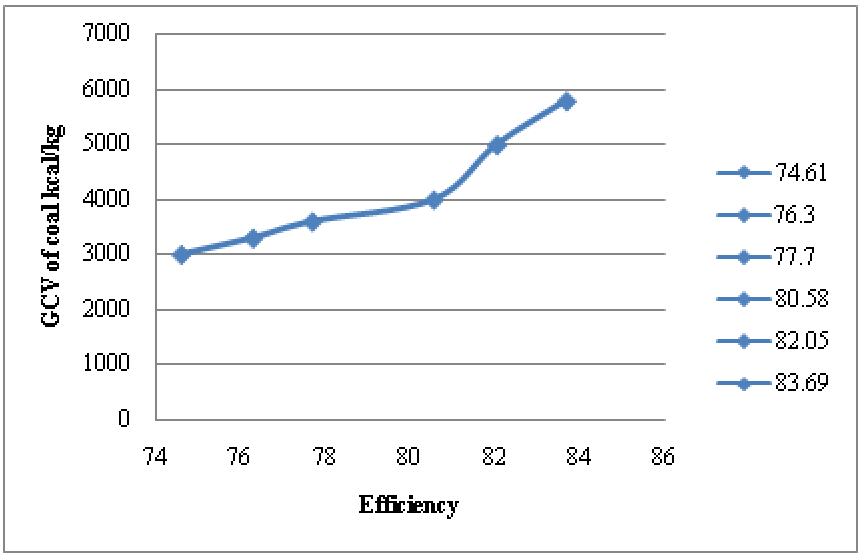

Figure 1: GCV of coal vs. Efficiency graph for AFBC Boiler

Figure 1 shows the relation between efficiency and GCV of the coal. Graph shows how the efficiency of boiler increases when the GCV of the coal is increased. Efficiency has been calculated for 3000, 3300, 3600, 5000 and 5800Kcal/kg GVC of coal and efficiencies are 74.61, 76.30, 77.7, 82.05 and 83.69% respectively. Efficiency for 5800Kcal/kg of the fuel is 83.69 for AFBC boiler whereas further in this paper it will be clear that for CFBC boiler 4000Kcal/kg of the fuel gives 83.9% efficiency.

4. Following Data Has Been Taken To Calculate Boiler Efficiency for AFBC and CFBC Boiler FOR 4000kcal/Kg GCV of Coal

BOILER TYPE	AFBC BOILER	CFBC BOILER
Steam generation rate	30000kg/hr	30000kg/hr
Operation hour's	7200 hrs/year	7200 hrs/year
Steam pressure	45kg/cm^2	45kg/cm^2
Steam temperature	420°C	420°C
Coal firing rate	6250kg/hr	6000kg/hr
GCV of fuel	4000kcal/kg	4000kcal/kg
Ambient temperature	30°C	30°C
Humidity factor	0.018kg/kg of dry air	0.018kg/kg of dry air

A. Feed water analysis

Feed water temperature	105°C
TDS (Total Suspended Solids)	1200ppm Max.
Total Alkanity	120ppm Max.
Caustic Alkanity	10ppm Max.
PH-value	7.1

B. Analysis of Coal

Carbon%	38
Hydrogen%	2.5
Nitrogen%	1
Oxygen%	12
Ash%	30
Moisture%	16
Sulphur%	0.5

C. Ash analysis

GCV of bottom ash	500kcal/kg
GCV of fly ash	200kcal/kg

5. Results from Calculation

Results derived from the above formulas for the Bituminous coal of D grade of GCV 4000kcal/kg for AFBC and CFBC boiler is shown in table 1 and 2.

Table 3: Result of boiler efficiency calculation

	AFBC boiler	*CFBC boiler*
Theoretical air requirement (kg/kg of coal)	4.77	4.77
Excess air requirement for complete combustion of coal	26.66%	26.66%
Actual air requirement (kg/kg of coal)	6.04	6.04
Heat loss in dry flue gas	8.20%	8.20%
Heat loss due to H_2 in fuel	3.57%	3.57%
Heat loss due to moisture in fuel	2.54%	2.54%
Heat loss due to moisture in air	0.1406%	0.1406%
Heat loss due to un-burnt fuel in fly ash	4.5%	1.5%
Heat loss due to un-burnt in bottom ash	1.25%	0.7%
Heat loss due to radiation and convection loss	2%	2%
Boiler efficiency	**77.8%**	**81.35%**

Table 4: Efficiency calculated by Direct and Indirect Method

Boiler efficiency	*AFBC (Atmospheric Fluidised Bed Combustion)*	*CFBC (Circulating Fluidised Bed Combustion)*
Direct Method	80.58%	83.94%
Indirect Method	77.8%	81.35%

6. Discussion

As GCV of the coal is increases efficiency increases. By increasing the GCV fuel to steam ratio increases increasing in efficiency of boiler. If CFBC is used instead of AFBC, un-burnt losses are reduced and efficiency of boiler increases. In CFBC a cyclone is used from where the un-burnt fuel particles are resend into the furnace for combustion whereas in AFBC boiler there is no such type of cyclone. Thus the un-burnt losses are reduced in CFBC boiler. 2-3% of efficiency is increased by using CFBC boiler.

7. Conclusion

The performance analysis performed, provides the difference in AFBC and CFBC boiler and by calculation of results following conclusion has been done:

- Efficiency for 5800Kcal/kg GCV of fuel for AFBC has 83.69% efficiency as for CFBC 4000Kcal/kg GCV of coal has 83.93% efficiency.
- With low grade fuel higher efficiency can be achieved by CFBC.
- Efficiency of CFBC boiler is greater than AFBC boiler for same GCV of the coal
- Un-burnt losses are less in CFBC as compared to AFBC boiler.
- Both the boiler has same working system but in CFBC the un-burnt coal is resend in the furnace for the burning process.
- By using CFBC coal burning rate per hour decreases as compared to AFBC boiler.
- If CFBC is used instead of AFBC boiler than 250 kg of coal can be saved per hour.

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