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Efficiency of Boiler for Coal and Bagasse as Fuel

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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 coal having GCV 3000Kcal/kg has been shown in this paper for AFBC boiler and has been compared with bagasse as fuel.

Keywords: Boiler efficiency for Coal, Boiler efficiency for bagasse, efficiency difference.

NOMENCLATURES
o = Heat output
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

I. 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 boiler with 3000Kcal/kg GCV of coal and then efficiency has been calculated for same boiler taking bagasse as fuel and changing its moisture % and shoeing effect of moisture on boiler efficiency.

II. METHODS TO CALCULATE BOILER EFFICIENCY

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°C)

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

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

Where, H – kg of H 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

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

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

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

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

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

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

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)

III. RESULTS FROM CALCULATION

a. ULTIMATE ANALYSIS OF THE COAL

a. Carbon% 38
b. Hydrogen% 2.5
c. Nitrogen% 1
d. Oxygen% 12
e. Ash% 30
f. Moisture% 16
g. Sulphur% 0.5

b. ASH ANALYSIS

h. GCV of bottom ash 500Kcal/kg
i. GCV of fly ash 200Kcal/kg

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 table.

Table 1: Result of boiler efficiency calculation.

	AFBC boiler
Theoretical air requirement (kg/kg of coal)	4.77
Excess air requirement for complete combustion of coal	26.66
Actual air requirement (kg/kg of coal)	6.04
Heat loss in dry flue gas	8.20%
Heat loss due to H_2 in fuel	3.57%
Heat loss due to moisture in fuel	2.54%
Heat loss due to moisture in air	0.1406%
Heat loss due to un-burnt fuel in fly ash	4.5%
Heat loss due to un-burnt in bottom ash	1.25%
Heat loss due to radiation and convection loss	2%
Total Losses	**22.20%**

Efficiency of the boiler (η) = 100 – Total losses

Boiler Efficiency by indirect method for 3000Kcal/kg GCV of fuel = 77.8%

IV. FOLLOWING DATA HAS BEEN TAKEN TO CALCULATE BOILER EFFICIENCY FOR BAGASSE AS FUEL

(a) Ultimate Analysis of Bagasse for Different Moisture

Table 2.

S.NO	COMPONENTS	%	%
1.	CARBON	22.16	22.16
2.	HYDROGEN	2.84	2.84
3.	OXYGEN	21	21
4.	NITROGEN	0	0
5.	SULPHUR	0	0
6.	ASH	4	4
7.	MOISTURE	50	46
8.	NCV	1800Kcal/kg	1900Kcal/kg

Results derived from the above formulas for different moisture with varying NCV of bagasse and have been shown in table 1 and 2 for AFBC boiler. By changing the moisture efficiency changes gradually, as NCV of bagasse increases and will be clear from below table 3.

Table 3.

	50% Moisture	**45% Moisture**
Theoretical air requirement (kg/kg of coal)	5.74	5.74
Actual air requirement (kg/kg of coal)	5.74	5.74
Heat loss in dry flue gas	3.64	3.45
Heat loss due to H_2 in fuel	8.47	8.02
Heat loss due to moisture in fuel	0.165	0.144
Heat loss due to moisture in air	0.072	0.068
Heat loss due to un-burnt fuel in fly ash	5	5
Heat loss due to un-burnt in bottom ash	3	2.5
Heat loss due to radiation and convection loss	2	2
TOTAL LOSS	**22.347%**	**21.182%**

Efficiency of the boiler (η) = 100 – Total losses

S.NO	METHOD	η for 50% Moisture	η for 45% Moisture
1.	**INDIRECT**	**77.653%**	**78.818%**

V. CONCLUSION

As moisture of bagasse is reduced efficiency of boiler increases. Other properties of fuel remain constant but by decreasing the moisture % in fuel NCV of bagasse increases which decrease losses in boiler.
Efficiency has been calculated for coal having GCV3000Kcal/kg of fuel and has been compared with efficiency calculated using bagasse as fuel.

- Efficiency for 3000 Kcal/kg of fuel was similar with bagasse having 50% moisture.
- As GCV of coal increases efficiency of boiler increases gradually but cost of fuel increases.
- By decreasing moisture % in bagasse efficiency of boiler increases.

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