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EFFICIENCY IMPROVEMENT IN INDUSTRIAL BOILER BY FLUE GAS DUCT INSULATION

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ABSTRACT

Now a days in industry major losses are find out so here we calculate these losses and find out efficiency of boiler. Boiler efficiency and energy losses from boiler are important parameter for any industry using boiler. In this work a detailed analysis was carried out for boiler at Anish Chemicals Bhavnagar. It is a combined water and fire tube boiler using biomass coal as fuel. Boiler efficiency calculated by direct method is in range of (78.5% to 81.6%). Major losses from boiler are heat loss due to radiation and convection from uninsulated surfaces (4.8% to 6.3%), heat loss due to flue gas (6.3% to 6.4%), heat loss due to blow down (0.263 to 0.398%), heat loss due to incomplete combustion (1.87% to 2.21%), heat loss due to unburnt coal in bottom ash(1.74 % to 1.86)and heat loss due to moisture present in fuel (1.3% to 1.6%).To reduce radiative and convective heat loss from flue gas duct surface, flexible glass mineral wool insulation was suggested.

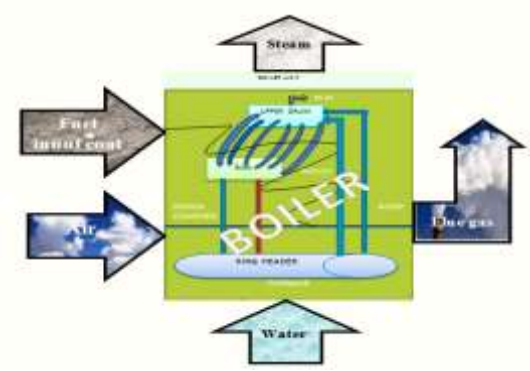
KEYWORDS: Boiler ,major losses, efficiency, insulation .

INTRODUCTION

In industrial boiler are generally packaged type so Boiler efficiency can be tested by the following two methods:

THEDIRECT METHOD:

This is also known as 'input-output method' dueto the fact that it needs only the useful output (steam) and the heat input (i.e. fuel) for evaluating the efficiency. Efficiency can be evaluated using the formula.



$$\text{Boiler Efficiency } (\eta) = \frac{Q \times (h_g - h_f)}{q \times GCV} \times 100$$

❖ **Parameters to be monitored for the calculation of boiler efficiency by direct method are :**

- Quantity of steam generated per hour (Q) in kg/hr.
- Quantity of fuel used per hour (q) in kg/hr.
- Enthalpy of steam at (h_g) at working pressure (kg/cm^2)and superheat temperature ,if any

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- Enthalpy of feed water (h_f)at The temperature of feed water
- Type of fuel and gross calorific value of the fuel (GCV) in kcal/kg of fuel

BOILER EFFICIENCY CALCILATION BY INDIRECT METHOD:

In order to calculate the boiler efficiency by indirect method, all the losses that occur in the boiler must be established. These losses are conveniently related to the amount of fuel burnt. In this way it is easy to compare the performance of various boilers with different ratings. The various losses associated with the operation of a boiler are discussed below with required formula.

1. HEAT LOSS DUE TO DRY FLUE GAS:([9] page 9)

This is the greatest boiler loss and can be calculated with the following formula:

$$L_1 = \frac{m \times cp \times (Tf - Ta)}{GCV\ of\ \ fuel} \times 100$$

2. HEAT LOSS DUE TO EVAPORATION OF WATER FORMED DUE TO H_2IN FUEL :([9] page 10)

The combustion of hydrogen causes a heat loss because the product of combustion is water. This water is converted to steam and this carries away heat in the form of its latent heat.

$$L_2 = \frac{9 \times H_2 \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ \ fuel} \times 100$$

3. HEAT LOSS DUE TO MOISTURE PRESENT IN FUEL:([9] page 10)

Moisture entering the boiler with the fuel as super heated vapour. This moisture
Loss is made up of the sensible heat to bring the moisture to boiling point, the latent heat of evaporation of the moisture, and the super heat required to bring this steam to the temperature of the exhaust gas. This loss can be calculated with the following formula

$$L_3 = \frac{M \times \{584 + C_p(T_f - T_a)\}}{GCV\ of\ \ fuel} \times 100$$

4. HEAT LOSS DUE TO MOISTURE PRESENT IN AIR:([9] page 11)

Vapour in the form of humidity in the incoming air, is super heated as it passes through the boiler. Since this heat passes up the stack, it must be included as a boiler loss. To relate this loss to the mass ofcoal burned, the moisture content of the combustion air and the amount of air supplied per unit mass of coal burned must be known. The mass of vapour that air contains can be obtained from psychometric charts .

$$L_4 = \frac{AAS \times humidity\ \ factor \times C_p \times (T_f - T_a)}{GCV\ of\ \ fuel} \times 100$$

5. HEAT LOSS DUE TO INCOMPLETE COMBUSTION:([9] page11)

Productsformedbyincompletecombustioncouldbemixedwithoxygenandburned again with a further release of energy. Such products include CO,H_2, and various hydrocarbons and are generally found in the flue gas of the boilers. Carbon monoxide is the only gas whose concentration can be determined conveniently in a boiler plant test.

$$L_5 = \frac{\%CO \times C}{\%CO + \%CO_2} \times \frac{5744}{GCV\ of\ \ fuel} \times 100$$

6. HEAT LOSS DUE TO RADIATION AND CONVECTION:([9] page 12)

Theotherheatlossesfromaboilerconsistofthelossofheatbyradiationandconvection

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fromthe boiler casting into the surrounding boiler house. Normallysurfacelossandotherunaccountedlossesisassumedbasedonthetype and size of the boiler as given below.Howeveritcanbecalculatedifthesurfaceareaofboileranditssurfacetemperatureare known as given below

$$L_6 = 0.548 \times \left[\left(\frac{T_s}{55.55} \right)^4 - \left(\frac{T_a}{55.55} \right)^4 \right] + 1.957 \times (T_s - T_a)^{1.25} \times \sqrt{\frac{(196.85\, V_m + 68.9)}{68.9}}$$

7. HEAT LOSS DUE TO UNBURNT IN FLY ASH :([9] page 13)

Smallamountsofcarbonwillbeleftintheashandthisconstitutesalossofpotentialheatinthefuel. Toassessttheseheatlosses,samplesofashmustbeanalyzedforcarbon content. The quantity of ash produced per unit of fuel must also be known.

$$L_7 = \frac{\text{Total ash collected / kg of fuel burnt} \times \text{GCVof fly ash}}{\text{GCV of fuel}} \times 100$$

8. HEAT LOSS DUE TO UNBURNT IN BOTTOM ASH :([9]page 13)

$$L_8 = \frac{\text{Total ash collected / kg of fuel burnt} \times \text{GCVof bottom ash}}{\text{GCV of fuel}} \times 100$$

By above methods are to be used for calculating boiler efficiency and major losses in boilers.So after calculate these losses we can improved boiler efficiency and reduce radiation and convective losses from flue gas duct line in boiler.By providing better insulation on flue gas duct line.Selection of material is mineral wool.
Following are calculation of boiler efficiency and different losses

CALCULATION TABLE

Sr. no	Parameters (%)	Week 1	Week 2	Week 3	Week 4
1	L1	6.3	5.9	5.19	4.8
2	L2	6.33	6.4	6.13	6.3
3	L3	0.263	0.351	0.367	0.398
4	L4	1.87	2.21	2.02	2.20
5	L5	1.8	1.86	1.74	1.84
6	L6	1.3	1.56	1.3	1.6
7	Boiler efficiency	81.6	78.5	80.2	79.6

Above analysis indicates the major areas of losses are find out so if we want to increase boiler efficiency these losses should be minimized by providing proper insulation on flue gas duct. For better insulation we have to choose proper insulating materials and calculate the amount which should be payback in proper time below the calculations are given for proper insulation of duct.

FLUE GAS DUCT INSULATION

Flue gas duct and furnace wall is not insulated. Bare wall temperature for flue gas duct is 73 °C and for furnace wall it is 45°C, So it is recommended to provide insulation on bare outside surface of flue gas duct.
Dimensions of flue gas duct : 0.4m × 0.3m cross section, 6.5 m length and 8 mm wall thickness.
Flexible glass mineral wool is suitable for temperature Range - 10 to 500°C (conductivity K =0.044 W/m° C)

Conductivity K =0.044 W/m° C)
Here T_s = 73°C and T_a = 31°C
Consider desired wall temperature after insulation = T_c = 51 °C
T_m= 52°C
Surface heat transfer co- efficient of hot bare surface
h = [0.85 + 0.005 (T_s – T_a)] × 10
= 10.6 W/m^2°C
Heat loss from bare flue gas duct surface
Q = h A' (Ts – Ta)

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Where A' = 9.1 m h =11.05 W/m^2 °C
T_s = 73 °C T_a = 31° C
Q = 4051.32 Watts
Surface heat transfer co-efficient after insulation
h' = [0.31 + 0.005 ($T_c - T_a$)] × 10
= 4.1 W/m$^{2\circ}$ C

Insulation thickness calculations :

R_{th} =
Putting values
R_{th} = 0.268 m$^{2\circ}$C/W
t = K × R_{th} = 0.0118m = 11.8 mm
We will select ½ " thickness insulation.
Heat loss from insulated surfaces :
Surface area after insulation
A" = (0.425 + 0.425 + 0.325 + 0.325)× 6.5 = 9.75 m^2
Heat loss from insulated surface
Q' = h' × A" × ($T_c - T_a$)
= 799.5 Watts
So yearly saving for12 hr / day working and 300 working days year
E = (Q – Q') × 300 × 12 ×3600
= 4.21 × 10^{10} J = 4.21 ×10^7 KJ = 11706 KW . hr
Cost of energy is 1.385 Rs / KW.hr
Annual monetary saving due to insulation = 11706 × 1.385
= 16212.8 Rs/ year

Cost of insulation :

Price of glass mineral wool is 25–40 Rs/Ft^2, let us consider it is 30 Rs/Ft^2
= 10.76 × 30 = 323 Rs/m^2
So cost of glass mineral wool = 323 × 9.75 = 3150 Rs.
Price of Al. cladding = 65 Rs /m^2
So cost of Al. cladding = 65 × 9.75 = 69 Rs.
Consider labor cost for insulation = 2000 Rs.
So total cost for insulation = 3150 + 69 + 2000 = 5784 Rs.

So payback time for insulation :

= × 365 = 130.21 days **= 4 months and 10 days**

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FOLLOWING CONCLUSIONS WERE MADE AFTER DETAILED ANALYSIS AND CALCULATIONS.

1. Boiler efficiency was calculated by direct method. In direct method efficiency is calculated as ratio of boiler output to boiler input, without calculating individual loss Boiler output is equal to enthalpy rise of feed water when it is converted to super heated steam. Boiler input is amount of energy supplied in the form of energy of fuel. Boiler efficiency calculated by this method is 78.5 to 81.6%.
2. Major energy losses in boiler are:
   a) Heat loss due to radiation and convection: Heat loss due to radiation and convection from insulated surface is 4.8% to 6.3% As a large area of flue gas duct and furnace is not insulated radiation and convective losses are high.
   b)Heat loss due to flue gas: Higher flue gas Discharge temperature is (153.9 ^{o} C to 155.8^{o}C) results in higher heat loss due to flue gas (6.3% to 6.4%).
   c) Heat loss due to moisture present in fuel: Heat loss due to moisture in fuel is (1.3% to 1.6%) .Fuel energy utilized to evaporate moisture present in fuel results in loss.
   d)Heat loss due to incomplete combustion: Heat loss due to incomplete combustion (1.87% to 2.21%). For effective conversion of chemical energy of fuel in to heat energy the combustion should be complete combustion. Combustion quality depends upon amount of air supplied, air velocity, air temperature, fuel size and fuel distribution etc. Higher CO% in flue gases indicated incomplete combustion.

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e)Heat loss due to unburnt coal in bottom ash: Heat loss due to unburnt coal in bottom ash(1.74% to 1.86%) . Some coal is left unburnt and discharged with ash, results in energy loss.

f)Heat loss due to blow down: Heat loss due to blow down(0.263% to 0.398%). blow down of hot boiler water is carried out to control concentration of dissolved solids and to remove sludge from water. Hot water discharged during blow down results in heat losses.

3. To recover heat loss due to flue gas it was suggested to use shell and tube type heat exchanger as economizer. It was designed using Kern method. Payback time for heat exchanger is 5 months.
4. It is suggested to use mineral glass wool insulation to reduce radiative and convective heat loss from flue gas duct. Payback time for insulation is 4 months and 10 days

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