ENERGY LOSS ESTIMATION IN COMBUSTION CHAMBER AND HEAT TRANSFER ZONES OF A COAL FIRED BOILER

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Abstract: *Boiler efficiency is an important in all industries. Using boiler higher efficiency results in reduced cost per unit production and reduced emission. Direct method can be used for calculation of boiler efficiency. In present work, experimental work was carried out on combined fire and water tube boiler. The boiler is designed to use coal/wood as fuel. Readings were taken for a-12 hour day. Compressed bio-mass waste was used as fuel. Boiler efficiency was calculated using direct method of efficiency calculation. As direct method does not focus on reasons of energy loss, important losses are calculated using standard methods. Flue gas loss, loss due to connection andradiation from an insulated surfaces, loss due to moisture in coal, blow down loss and loss due to incomplete combustion were calculated using methods and formulas recommended by bureau of energy efficiency. The major losses are loss due to connection and radiation from uninsulated surface (6.9%), heat loss due to moisture present in fuel (4.37%), and heat loss to time gas (4.28%). Energy recovery oppertiunities are indentified.*

1. INTRODUCTION

BOILER DESCRIPTION
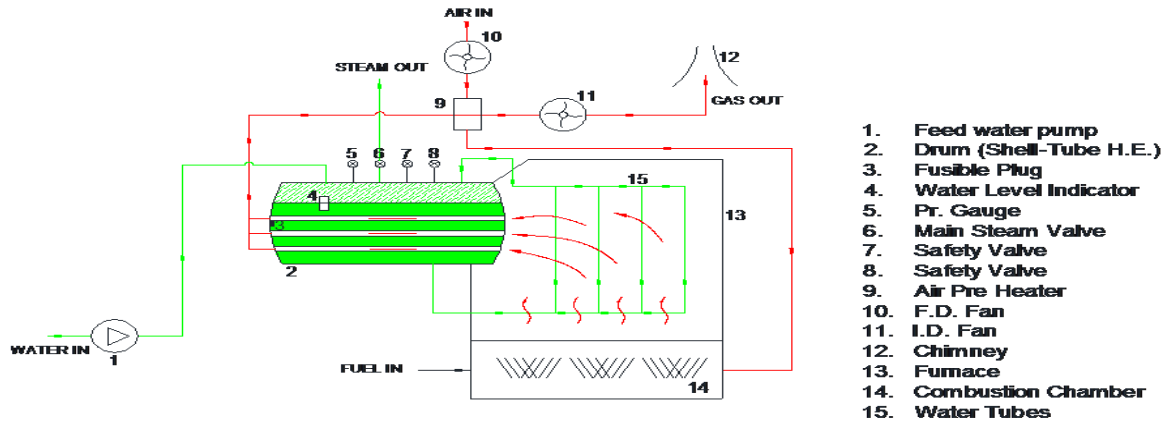
The boiler is a combined fire water tube boiler which can produce steam at 17.5 bar with maximum temperature 205 c

WATER CIRCUIT

feed water pump feeds water to boiler drum. The drum is a heat exchanger with hot gases at tube side and water at shell side. Hot water from bottom of drum is circulated to tube circuit inside the combustion zone of furnace. Thus within furnace water is at tube side and hot gases are at furnace wall side. Steam water mixture is transferred to drum. Steam is collect at top in the drum and it is drawn to main steam line by main steam valve.

GAS CIRCUIT

Atmosphere air is drawn by F.D fan, air is heated by energy of flue gases in air pre heater. Heated air enters the combustion chamber, combustion of coal take place in combustion chamber. Hot gases transfers heat to water inside the tube circuit. Gases passes through tubes of drum and transfers sensible heat to water which is at shell side. Flue gases coming out of drum passes through air preheater, I.D fan and chimney.

ARRANGEMENT OF BOILER CTM 25

1.	Feed water pump
2.	Drum (Shell-Tube H.E.)
3.	Fusible Plug
4.	Water Level Indicator
5.	Pr. Gauge
6.	Main Steam Valve
7.	Safety Valve
8.	Safety Valve
9.	Air Pre Heater
10.	F.D. Fan
11.	I.D. Fan
12.	Chimney
13.	Furnace
14.	Combustion Chamber
15.	Water Tubes

BOILER SPECIFICATION

1.Model CTM 25
2. Capacity : 2.5 tons/hr.
3. Design temperature : 205 oC
4. Type of fuel used : coal, wood
5. Working pressure : 17.5 kg/cm2
6. Hydraulic test pressure : 26.25 kg/cm2
7. Type of boiler : combined fire and water tube single pass

OBSERVATIONS

- Fuel firing rate   =   60.55kg/hr
- Steam generation rate   =   290 kg/hr
- Steam pressure   =   6 kg/cm2(g
- Steam temperature   =   185 oC
- Feed water temperature   =   65 oC
- %CO2 in Flue gas   =   11
- %CO in flue gas   =   0.41
- Average flue gas temperature =   145 oC
- Ambient temperature   =   31 oC
- Surface temperature of boiler
     Furnace wall   =   45 oC
- Wind velocity around the boiler   =   3.09 m/s
- Total surface area of
     boiler furnace   =   24.25 m2
- GCV of Bottom ash   =   822 kcal/kg

Fuel Analysis (in %)

- Amount of bottom ash in
     1 kg of coal   =   0.07767 kg
- Moisture in coal   =   24.11

- Carbon content   = 31.7
- GCV of Coal   =   3492 kcal/kg
- Surface area of flue gas duct   =   9.1 m2
- Surface area of boiler   =   24.25 m2
  furnace wall
- Surface temperature of   = 82 oC
  flue gas duct

EFFICIENCYCALCULATIONBY DIRECT METHOD:

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

$$\text{Boiler Efficiency(\%)} = \frac{Heat\ Output}{Heat\ Input}$$

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

Where

- Q   = Mass of steam generated =   290 kg/hr

- q   = Mass of fuel used = 60.55 kg/hr

- G.C.V. Of fuel = 3492 kcal/kg

- H   = Enthalpy of steam at pressure 6 kg/cm2 and temperature 185 oC
       = 2755.4 kJ/kg

- h   = Enthalpy of feed water at 65 C=272 kJ/kg

- Efficiency = 81%

THE PRINCIPLE LOSSES THAT OCCUR IN A BOILER ARE:

- Heat transfer losses (radiation and convective) from boiler Furnace wall and flue gas duct to the atmosphere
- Loss due to flue gas
- Loss due to blow down.
- Loss due to incomplete combustion of fuel.
- Loss due to unburnt coal in bottom ash
- Loss due to moisture present in fuel

ENERGY LOSS CALCULATION

🔳 1. Heat loss due to radiation and convection:

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

Where

- L $\quad=\quad$ Radiation loss in W/m^2
- V_m $\quad=\quad$ Wind velocity in m/s
- T_s $\quad=\quad$ Surface temperature (K)
- T_a $\quad=\quad$ Ambient temperature (K)

(A) HEAT LOSS FROM FURNACE WALL

$$Loss = \left[0.548 \times \left\{\left(\frac{T_s}{55.55}\right)^4 - \left(\frac{T_a}{55.55}\right)^4\right\} + 1.957 \times (T_s - T_a)^{1.25} \times \sqrt{\frac{196.85 V_m + 68.9}{68.9}}\right] W/m^2$$

Where

- Ts $\quad=\quad$ Surface temperature of furnace wall $= 318K$
- Ta $\quad=\quad$ Ambient temperature $= 304K$
- Vm $=\quad$ Wind velocity $= 3.09$ m/sec
- Surface area $= 24.25$ m^2

- **Loss = 10236.37 Watt**

(B) HEAT LOSS FROM FLUE GAS DUCT WALL

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

$= \qquad 730.89$ W/m^2

☐ Where

- Ts = Surface temperature of furnace wall = 355K
- Ta = Ambient temperature = 304K
- Vm = Wind velocity = 3.09 m/sec
- Surface area = 9.1 m^2

☐ **Loss = 6578.02Watt**

☐

% OF TOTAL LOSS IN RADIATION AND CONVECTION

$$Loss = \frac{Total\ loss}{G.C.V. * fuel\ consumption /sec} * 100$$

$= 0.06948 * 100$

TOTAL LOSS(L1) = 6.9%

2. HEAT LOSS DUE TO FLUE GAS

Where

- Loss = % heat loss due to flue gas
- mf = mass flow rate of flue gas =   345.135kg/hr
- Cp = Specific heat of flue gas = 0.23 kcal/kgk
- Tf = Flue gas temperature in c =145 oC
- Ta = Ambient temperature in c = 31 Oc
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  LOSS (L2)= 4.28 %

3. HEAT LOSS DUE TO BLOW DOWN

$$LOSS = mw * Cw(Two - Twi)$$

Where

- mw = Mass of water loss during blow down = 61.83 kg/hr
- Cw = Specific heat of water = 4.2 kJ/kgK
- Two = Temperature of water leaving boiler during blow down = 74 oC
- Twi = Temperature of water entering boiler = 65 oC

LOSS(L3) = 0.263 %

4.HEAT LOSS DUE TO INCOMPLETE COMBTION :

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

Where

- L = % heat loss due to partial conversion of C to CO
- CO2 = volume of CO2 in flue gas(%) = 11
- CO = actual volume of CO in flue gas(%) = 0.41
- C = carbon content kg/kg of fuel (%) = 31.74
- GCV of fuel = 3492 kcal/kg

Loss(L4) = 1.8 %

5.HEAT LOSS DUE TO UNBURNT COAL IN BOTTOM ASH

$$LOSS = \frac{Total\ ash\ collected/kg\ of\ fuel\ burnt * G.C.V.\ of\ bottom\ ash * 100.}{G.C.V.\ of\ fuel}$$

Where

- Amount of bottom ash collected in 1 kg of coal=0.07767 kg
- G.C.V. of bottom ash = 822 kcal/kg
- G.C.V. of fuel = 3492 kcal/kg
- LOSS(L5) = 1.8 %

6.HEAT LOSS DUE TO MOISTURE PRESENT IN FUEL

$$LOSS = \frac{M*[584 + CP(Tf - Ta)}{GCV \text{ of fuel}}*100$$

Where

- M = kg moisture in fuel on 1 kg basis
      = 0.2411
- Cp = Specific heat of super heated steam
       = 0.45 kcal/kg oC
- Tf = Flue gas temperature =145 oC
  Ta = Ambient tempertature = 31 oC
      LOSS (L6) = 4.3

2.   CONCLUTION

1. The major losses are loss due to connection and radiation from uninsulated surface (69%), heat loss due to moisture present in fuel(4.37%) and hrat loss due to flue gas (4.28%).
2. Energy recovery options are

- Modifying air preheater
- Insulating bare heat transfer surfaces
- Reducing coal size
- Increasing heat transfer surfaces area
- Drying the coal before combustion

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