Paper -2 Energy Efficiency in Thermal Utilities

Chapter -2 – Boilers

1. Boiler Efficiency (Direct Method) $(\eta) = \frac{\text{Heat Output}}{\text{Heat Input}} \times 100$

2. Boiler Efficiency (Direct Method) $(\eta) = \frac{Q \times (hg - hf)}{q \times GCV} \times 100$

Q = Quantity of Steam generated per hour (kg/hr)

q = Quantity of fuel used per hour (kg/hr)

hg = Enthalpy of Saturated Steam (kCal/kg)

hf = Enthalpy of feed water (kCal/kg)

GCV = Gross Calorific Value of Fuel (kCal/kg)

3. Evaporation ratio = $\frac{\text{Quantity of steam generated } \left(\frac{kg}{hr}\right)}{\text{Quantity of fuel consumed } \left(\frac{kg}{hr}\right)} \times 100$

4. Boiler Efficiency (Indirect Method)

1. Theoretical air required for combustion = $\frac{\{(11.6 \times C) + 34.8\left(H2 - \left(\frac{O2}{8}\right)\right) + (4.35 \times S)\}}{100}$ = kg/kg of fuel

C, H_2, O_2, S = Percentage of Carbon, Hydrogen, Oxygen & Sulphur present in the fuel

2. Percentage Excess Air supplied % = $\frac{\{O_2\%\}}{21 - O_2\%} \times 100$

3. Actual mass of Air Supplied /kg of fuel AAS = 1+(EA/100) ×Theoretical air

4. Actual mass of dry flue gas mass of dry flue gas = Mass of CO_2 in flue gas + Mass of N_2 content in the fuel+ Mass of N_2 in the combustion air supplied + Mass of oxygen in the flue gas + Mass of SO_2 in flue gas.

Boiler Efficiency by Indirect Method= 100 - (L1+L2+L3+L4+L5+L6+L7+L8)

1. Heat Loss due to dry flue gas L1 $= \dfrac{m \times Cp \times (Tf - Ta)}{\text{GCV of Fuel}} \times 100$

m = Mass of dry flue gas in (kg/kg of fuel)

Cp = Specific heat of flue gas in (kcal/kg)

Tf = Flue gas temperature in (^{o}C)

Ta = Ambient temperature in (^{o}C)

Mass of Dry flue gas = CO_2 in fuel + SO_2in fuel + N_2 in fuel + N_2 in Actual mass of air supplied + O_2 in flue gas

2. Heat Loss due to hydrogen in fuel L2 $= \dfrac{9H2 \times (584 + \{Cp \times (Tf - Ta)\})}{\text{GCV of Fuel}} \times 100$

H_2 = hydrogen present in fuel (kg/kg of fuel)

Cp = specific heat of super-heated steam in (Kcal/kg)

Tf = Flue gas temperature in (^{o}C)

Ta = Ambient temperature in (^{o}C)

584 = Latent heat of vaporization in (Kcal/kg)

3. Heat Loss due to Moisture present in fuel L3 $= \dfrac{M \times (584 + \{Cp \times (Tf - Ta)\})}{\text{GCV of Fuel}} \times 100$

M = Moisture in fuel (kg/kg of fuel)

Cp = specific heat of super-heated steam in (Kcal/kg)

Tf = Flue gas temperature in (^{o}C)

Ta = Ambient temperature in (^{o}C)

4. Heat Loss due to Moisture present in air L4 = $\frac{AAS \times \text{Humidity factor} \times \{Cp \times (Tf - Ta)\}}{\text{GCV of Fuel}} \times 100$

AAS = Actual mass of air supplied per kg of fuel

Humidity factor = Kg of water /kg of dry air

Cp = specific heat of super-heated steam in (Kcal/kg)

Tf = Flue gas temperature in (^{o}C)

Ta = Ambient temperature in (^{o}C)

5. Heat Loss due to incomplete combustion L5 = $\frac{\%CO \times C}{\%CO \times \%CO2} \times \frac{5654}{\text{GCV of fuel}} \times 100$

CO = Volume of CO in flue gas (%) (1% = 10000ppm)

CO_2 = Actual volume of CO_2 in flue gas (%)

C = Carbon content (kg/kg of fuel)

5654 = Heat loss due partial combustion of carbon (kcal/kg of carbon)

6. Heat Loss due to Radiation & Convection =

For Industrial Fire tube /Packaged boiler = 1.5% to 2.5%

For industrial Water tube boiler = 2 to 3%

For Power station boiler = 0.4% to 1%

Can be calculated using the equation also.

- Note: For Solid Fuels only L7 & L8 applicable

7. Heat Loss due to unburnt in fly ash L7 = $\frac{(\text{Total ashcollected /kg of fuelburnt}) \times \text{GCV of flyash}}{\text{GCV of fuel}} \times 100$

8. Heat Loss due to unburnt in bottom ash = $\frac{(\text{Total ashcollected /kg of fuelburnt}) \times \text{GCV of bottom ash}}{\text{GCV of fuel}} \times 100$

5. Blow Down (%) = $\frac{(\text{Feed water TDS} \times \% \text{ Make up water})}{(\text{Maximum Permissible TDS in Boiler Water} - \text{Feed water TDS})} \times 100$