M4-6: Boiler Performance Assessment

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Capacity Development Training Program on
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Boiler Capacity & Performance Parameters

Boiler Efficiency:

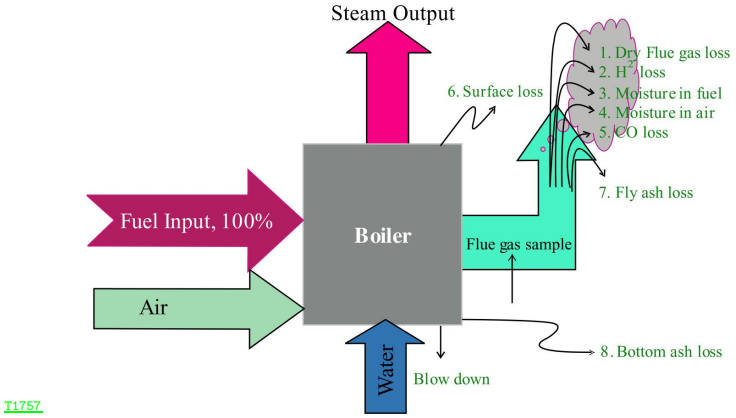
$$\eta_{boiler} \equiv 100\frac{Heat\ absorbed\ by\ feed\ water}{Energy\ released\ by\ fuel} = 100\frac{\dot{m}_w(h_g - h_w)}{\dot{m}_f\ GCV}$$

Evaporation Ratio:

$$Evaporation\ ratio = \frac{Quantity\ of\ steam\ generation}{Quantity\ of\ fuel\ consumption} = \frac{m_w}{m_f}$$

- Quantity of steam generated per hour (m_w) in kg/hr.
- Quantity of fuel used per hour (m_f) in kg/hr.
- Gross calorific value of the fuel (GCV) in kcal/kg of fuel
- h_g - Enthalpy of saturated steam in kcal/kg of steam
- h_w - Enthalpy of feed water in kcal/kg of water

Heat Losses in Boiler



$$Boiler\ efficiency = 100 - \sum L_i$$

The following losses are applicable to liquid, gas and solid fired boiler

- L_1 - Loss due to dry flue gas (sensible heat)
- L_2 - Loss due to hydrogen in fuel (H_2)
- L_3 - Loss due to moisture in fuel (H_2O)
- L_4 - Loss due to moisture in air (H_2O)
- L_5 - Loss due to carbon monoxide (CO)
- L_6 - Loss due to surface radiation, convection & other losses
- L_7 - Unburnt losses in fly ash (carbon)
- L_8 - Unburnt losses in bottom ash (carbon)

L_1 - Loss due to dry flue gas (sensible heat)

$$L_1 = \frac{m_{dg} C_{p,g} (T_f - T_a)}{GCV} \times 100$$

- m_{dg} = Mass of dry flue gas in kg/kg of fuel
- $C_{p,g}$ = Specific heat of flue gas kCal/kg°C
- T_f = Flue gas temperature in °C
- T_a = Ambient temperature in °C
- GCV = Gross calorific value of fuel in kCal/kg

$$m_{dg} = \left(\frac{A}{F}\right)_{A,G,D} + 1 - R - M - 9H_2$$

- R = Ash or residue content of fuel
- M = moisture content of fuel
- H_2 = H_2 content of fuel

L_2 - Loss due to hydrogen in fuel (H_2)

$$L_2 = 9H_2 \left[\frac{585 + C_{p,s}(T_f - T_a)}{GCV}\right] \times 100$$

L_3 - Loss due to moisture in fuel (H_2O))

$$L_3 = M \left[\frac{585 + C_{p,s}(T_f - T_a)}{GCV}\right] \times 100$$

L_4 - Loss due to moisture in air (H_2O))

$$L_4 = \omega \left(\frac{A}{F}\right)_{A,G,D} \left[\frac{C_{p,s}(T_f - T_a)}{GCV}\right] \times 100$$

- $C_{p,s}$ = Specific heat of steam kCal/kg°C
- ω = Humidity ratio of air kg-water/kg-dry-air

L_5 - Loss due to partial conversion of C to CO

$$L_5 = \frac{\%CO \times C}{\%CO + \%CO_2} \left[\frac{5654}{GCV}\right] \times 100$$

L_6 - Loss due to surface radiation, convection and other unaccounted losses

$$L_{loss} = 0.548 \left[\left(\frac{T_s}{55.55}\right)^4 - \left(\frac{T_a}{55.55}\right)^4\right] + 1.957 (T_s - T_a)^{1.25} \left[\frac{196.85 V_m + 68.9}{68.9}\right]^{0.5} \text{W/m}^2$$

$$L_s = \frac{L_{loss} \times A}{m_f \times GCV}$$

L_7 - Unburnt losses in fly ash (carbon)

$$L_7 = \frac{m_{fly\ ash} \times GCV_{fly\ ash}}{GCV} \times 100$$

L_8 - Unburnt losses in bottom ash (carbon)

$$L_8 = \frac{m_{bottom\ ash} \times GCV_{bottom\ ash}}{GCV} \times 100$$

Boiler Efficiency Calculation

Fuel Analysis (in %)		
Ash	=	48
Moisture	=	4.4
Carbon	=	36
Hydrogen	=	2.6
Nitrogen	=	1.1
Oxygen	=	7.3
Sulphur	=	0.6
GCV	=	3501 kcal/kg

Fuel firing rate	=	5600 kg/hr
Steam generation rate	=	21940 kg/hr
Steam pressure	=	43 kg/cm^2(g)
Steam temperature	=	377 °C
Feed water temperature	=	96 °C
%CO_2 in Flue gas	=	14
%CO in flue gas	=	0.55
Average flue gas temperature	=	190 °C
Ambient temperature	=	31 °C
Humidity in ambient air	=	0.0204 kg / kg dry air
Surface temperature of boiler	=	70 °C
Wind velocity around the boiler	=	3.5 m/s
Total surface area of boiler	=	90 m^2
GCV of Bottom ash	=	800 kcal/kg
GCV of fly ash	=	450 kcal/kg
Ratio of bottom ash to fly ash	=	90:10

[η = 100 - (7.1+4.37+0.82+0.25+2.2+0.37+0.62+9.98) = 74.4%]