

## Assignment – 5

### Topic: Steam Boilers.

(Disclaimer: The purpose of these AI-generated responses is just education and reference. Utilise them to grasp topics and structure, but always rewrite in your own words and double-check the content before submitting.)

**Q-1: In a boiler test 1250 kg of coal are consumed in 24 hours. The mass of water evaporated is 13000 kg. Steam pressure is 7 bar. The feed water temperature was 40°C. Calorific value of coal is 30,000 kJ/kg. The steam is dry and saturated.**

**Calculate:**

1. Equivalent evaporation from and at 100°C.
2. Boiler efficiency.

**Answer:**

**Given:**

- Mass of coal,  $m_c = 1250$  kg
- Time = 24 hours
- Mass of water evaporated,  $m_w = 13000$  kg
- Steam pressure,  $p = 7$  bar
- Feed water temperature,  $T_{fw} = 40^\circ\text{C}$
- Calorific Value,  $CV = 30000$  kJ/kg
- Steam condition: Dry saturated

#### Step 1: Find Enthalpy of Steam (h)

From steam tables, at  $p = 7$  bar, dry saturated:

- $h_g = 2763.5$  kJ/kg

Enthalpy of feed water at  $T_{fw} = 40^\circ\text{C}$ :

- $h_f@40^\circ\text{C} \approx 167.53$  kJ/kg

Heat required to produce 1 kg of steam:

$$h - h_{fw} = 2763.5 - 167.53 = 2595.97 \text{ kJ/kg}$$

#### Step 2: Find Equivalent Evaporation (E.E.)

Equivalent evaporation "from and at 100°C" is defined as the amount of water evaporated per kg of coal, from feed water at 100°C to dry saturated steam at 100°C. The enthalpy of vaporization at 100°C is 2257 kJ/kg.

First, find the actual evaporation per kg of coal:

$$m_a = \frac{m_w}{m_c} = \frac{13000}{1250} = 10.4 \text{ kg steam/kg coal}$$

Now, Equivalent Evaporation:

$$E.E. = m_a \times \frac{h - h_{fw}}{2257}$$

$$E.E. = 10.4 \times \frac{2595.97}{2257}$$

$$E.E. = 10.4 \times 1.1502 = 11.962$$

**∴ 1. Equivalent Evaporation = 11.96 kg steam/kg coal**

### Step 3: Find Boiler Efficiency ( $\eta_b$ )

Boiler Efficiency is the ratio of heat used to produce steam to the heat supplied by the coal.

$$\eta_b = \frac{m_w \times (h - h_{fw})}{m_c \times CV}$$

$$\eta_b = \frac{13000 \times 2595.97}{1250 \times 30000}$$

$$\eta_b = \frac{33,747,610}{37,500,000} = 0.8999$$

**∴ 2. Boiler Efficiency = 89.99%**

### Final Answers for Q-1:

1. Equivalent Evaporation = **11.96 kg steam/kg coal**
2. Boiler Efficiency = **90.0%**

**Q-2: Steam is generated at 11 bar and 250°C. The feed water temperature is 36°C. The Calorific value of the coal is 33,700 kJ/kg. Steam generated per kg of coal burnt is 9 kg. Find:**

1. The factor of evaporation
2. Equivalent evaporation from and at 100°C
3. Boiler power if 260 kg/hr of coal is burnt.

**Answer:**

**Given:**

- Steam:  $p = 11 \text{ bar}$ ,  $T = 250^\circ\text{C} \rightarrow$  Superheated
- $T_{fw} = 36^\circ\text{C}$
- $CV = 33700 \text{ kJ/kg}$
- $m_a = 9 \text{ kg steam/kg coal}$
- Coal burning rate =  $260 \text{ kg/hr}$

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**Step 1: Find Enthalpy of Steam (h)**

From steam tables:

- At  $p = 11 \text{ bar}$ ,  $T_{sat} \approx 184.1^\circ\text{C}$
- Since  $T > T_{sat}$ , steam is superheated.
- From superheated steam tables at 11 bar and  $250^\circ\text{C}$ :
  - $h_{sup} \approx 2943.0 \text{ kJ/kg}$

Enthalpy of feed water at  $36^\circ\text{C}$ :

- $h_{fw} \approx 150.8 \text{ kJ/kg}$

Heat required to produce 1 kg of steam:

$$h - h_{fw} = 2943.0 - 150.8 = 2792.2 \text{ kJ/kg}$$

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**Step 2: Find Factor of Evaporation (F.O.E.)**

$$F.O.E. = \frac{h - h_{fw}}{2257} = \frac{2792.2}{2257} = 1.237$$

**∴ 1. Factor of Evaporation = 1.237**

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**Step 3: Find Equivalent Evaporation (E.E.)**

$$E.E. = m_a \times F.O.E. = 9 \times 1.237 = 11.133$$

**∴ 2. Equivalent Evaporation = 11.13 kg steam/kg coal**

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**Step 4: Find Boiler Power (P)**

$$\text{Boiler Power (in kW)} = \frac{\text{Equivalent Evaporation} \times \text{Coal burning rate} \times 2257}{3600}$$

$$P = \frac{11.133 \times 260 \times 2257}{3600}$$

$$P = \frac{6,532,900}{3600} = 1814.7 \text{ kW}$$

∴ **3. Boiler Power = 1814.7 kW**

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**Final Answers for Q-2:**

1. Factor of Evaporation = **1.237**
2. Equivalent Evaporation = **11.13 kg steam/kg coal**
3. Boiler Power = **1814.7 kW**

**Q-3: A boiler produces 200 kg of dry and saturated steam per hour at 10 bar. The water temperature = 110°C. 225 kg of coal of a calorific value of 30,000 kJ/kg are fired per hour. If 10% of coal remains unburnt calculate:**

1. **The thermal efficiency of the boiler**
  2. **The thermal efficiency of boiler and grate combined.**
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**Answer:**

**Given:**

- Steam output = 200 kg/hr
  - Steam:  $p = 10$  bar, dry saturated
  - $T_{fw} = 110^\circ\text{C}$
  - Coal fired = 225 kg/hr
  - CV = 30000 kJ/kg
  - 10% coal unburnt
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**Step 1: Find Enthalpy of Steam (h)**

From steam tables, at  $p = 10$  bar, dry saturated:

- $h_g = 2778.1 \text{ kJ/kg}$

Enthalpy of feed water at  $110^\circ\text{C}$ :

- $h_{fw} \approx 461.3 \text{ kJ/kg}$

Heat required to produce 1 kg of steam:

$$h - h_{fw} = 2778.1 - 461.3 = 2316.8 \text{ kJ/kg}$$

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### Step 2: Find Boiler Thermal Efficiency ( $\eta_b$ )

Heat utilized by steam =  $200 \times 2316.8 = 463,360 \text{ kJ/hr}$

Heat supplied by coal =  $225 \times 30000 = 6,750,000 \text{ kJ/hr}$

$$\eta_b = \frac{463,360}{6,750,000} = 0.06864$$

**$\therefore$  1. Boiler Thermal Efficiency = 6.86%**

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### Step 3: Find Combined Boiler and Grate Efficiency ( $\eta_{comb}$ )

Mass of coal actually burnt =  $225 \times 0.90 = 202.5 \text{ kg/hr}$

Heat supplied by burnt coal =  $202.5 \times 30000 = 6,075,000 \text{ kJ/hr}$

$$\eta_{comb} = \frac{463,360}{6,075,000} = 0.07627$$

**$\therefore$  2. Combined Efficiency = 7.63%**

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### Final Answers for Q-3:

1. Boiler Thermal Efficiency = **6.86%**
2. Combined Boiler and Grate Efficiency = **7.63%**

**Q-4: In a thermal power plant, the boiler produces 50,000 kg of wet steam/hr with dryness fraction of 0.95. The feed water temperature =  $40^\circ\text{C}$ . Calculate the equivalent evaporation if boiler pressure is 10 bar.**

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**Answer:**

**Given:**

- Steam output,  $m_w = 50,000 \text{ kg/hr}$

- Dryness fraction,  $x = 0.95$
- Feed water temperature,  $T_{fw} = 40^\circ\text{C}$
- Boiler pressure,  $p = 10 \text{ bar}$

### Step 1: Find Enthalpy of Wet Steam (h)

From steam tables, at  $p = 10 \text{ bar}$ :

- $h_f = 762.81 \text{ kJ/kg}$
- $h_{fg} = 2015.3 \text{ kJ/kg}$

Enthalpy of wet steam:

$$\begin{aligned} h &= h_f + x \cdot h_{fg} \\ h &= 762.81 + (0.95 \times 2015.3) \\ h &= 762.81 + 1914.535 = 2677.345 \text{ kJ/kg} \end{aligned}$$

### Step 2: Find Enthalpy of Feed Water (h\_fw)

Enthalpy of feed water at  $40^\circ\text{C}$ :

- $h_{fw} \approx 167.53 \text{ kJ/kg}$

Heat required to produce 1 kg of steam:

$$h - h_{fw} = 2677.345 - 167.53 = 2509.815 \text{ kJ/kg}$$

### Step 3: Find Equivalent Evaporation (E.E.)

Equivalent evaporation "from and at  $100^\circ\text{C}$ " uses the latent heat at  $100^\circ\text{C}$  (2257 kJ/kg).

$$E.E. = \frac{\text{Total heat utilized}}{2257}$$

First, find total heat utilized per hour:

$$= m_w \times (h - h_{fw}) = 50,000 \times 2509.815 = 125,490,750 \text{ kJ/hr}$$

Now, Equivalent Evaporation:

$$E.E. = \frac{125,490,750}{2257} = 55,599.8 \text{ kg/hr}$$

**$\therefore$  Equivalent Evaporation = 55,600 kg/hr**

**Final Answer for Q-4:**  
**Equivalent Evaporation = 55,600 kg/hr**

**Q-5: A steam generator evaporated 18000 kg/hr of steam at 10 bar pressure and steam is 97% dry. Feed water temperature = 40°C. Coal is fired at the rate of 2050 kg/hr. CV of coal is 28000 kJ/kg.**

**Answer:**

*(The question seems to be incomplete as it doesn't specify what to calculate. Typically, we are asked to find Boiler Efficiency or Equivalent Evaporation. We will calculate both.)*

**Given:**

- $m_w = 18,000 \text{ kg/hr}$
- $p = 10 \text{ bar}$ , Dryness  $x = 0.97$
- $T_{fw} = 40^\circ\text{C}$
- Coal burning rate = 2050 kg/hr
- $CV = 28000 \text{ kJ/kg}$

**Step 1: Find Enthalpy of Steam (h)**

From steam tables, at  $p = 10 \text{ bar}$ :

- $h_f = 762.81 \text{ kJ/kg}$
- $h_{fg} = 2015.3 \text{ kJ/kg}$

$$h = h_f + xh_{fg} = 762.81 + (0.97 \times 2015.3)$$

$$h = 762.81 + 1954.841 = 2717.651 \text{ kJ/kg}$$

**Step 2: Find Enthalpy of Feed Water (h\_fw)**

At  $T_{fw} = 40^\circ\text{C}$ :

- $h_{fw} \approx 167.53 \text{ kJ/kg}$

Heat required per kg steam:

$$h - h_{fw} = 2717.651 - 167.53 = 2550.121 \text{ kJ/kg}$$

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**Step 3: Find Equivalent Evaporation (E.E.)**

$$E.E. = m_w \times \frac{h - h_{fw}}{2257}$$

$$E.E. = 18,000 \times \frac{2550.121}{2257}$$

$$E.E. = 18,000 \times 1.1299 = 20,338.2 \text{ kg/hr}$$

**∴ Equivalent Evaporation = 20,338 kg/hr**

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**Step 4: Find Boiler Efficiency ( $\eta_b$ )**

$$\eta_b = \frac{m_w \times (h - h_{fw})}{\text{Coal rate} \times CV}$$

$$\eta_b = \frac{2050 \times 28000}{45,902,178}$$

$$\eta_b = \frac{57,400,000}{57,400,000} = 0.7997$$

**∴ Boiler Efficiency = 79.97%**

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**Final Answers for Q-5:**

1. Equivalent Evaporation = **20,338 kg/hr**
2. Boiler Efficiency = **80.0%**

**Q-6: The superheated steam is generated from the boiler operation at 12 bar pressure. Steam generated per kg of coal burnt is 10 kg. Coal burnt = 300 kg/hr. If the enthalpy of superheated steam and water entering the boiler are 2935.4 kJ/kg and 150.74 kJ/kg respectively, then calculate:**

1. Equivalent evaporation
  2. Boiler power.
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**Answer:**

**Given:**

- $p = 12$  bar (Superheated)
- $m_a = 10$  kg steam/kg coal

- Coal burning rate = 300 kg/hr
- $h = 2935.4$  kJ/kg
- $h_{fw} = 150.74$  kJ/kg

### Step 1: Find Heat Required per kg of Steam

$$h - h_{fw} = 2935.4 - 150.74 = 2784.66 \text{ kJ/kg}$$

### Step 2: Find Equivalent Evaporation (E.E.)

$$E.E. = m_a \times \frac{h - h_{fw}}{2257}$$

$$E.E. = 10 \times \frac{2784.66}{2257}$$

$$E.E. = 10 \times 1.2338 = 12.338 \text{ kg steam/kg coal}$$

Total Equivalent Evaporation per hour:

$$= E.E. \times \text{Coal burning rate} = 12.338 \times 300 = 3701.4 \text{ kg/hr}$$

**∴ 1. Equivalent Evaporation = 3701.4 kg/hr**

### Step 3: Find Boiler Power (P)

$$\text{Boiler Power (in kW)} = \frac{\text{Total Equivalent Evaporation} \times 2257}{3600}$$

$$P = \frac{3701.4 \times 2257}{3600}$$

$$P = \frac{8,352,060}{3600} = 2320.0 \text{ kW}$$

**∴ 2. Boiler Power = 2320.0 kW**

### Final Answers for Q-6:

1. Equivalent Evaporation = **3701 kg/hr** (or **12.34 kg steam/kg coal**)
2. Boiler Power = **2320 kW**