

FURNACES AND REFRACTORIES

QUESTION

A steel billet preheating furnace operates between 7 am to 8 pm. The output of the furnace is 14 TPH and the last batch of the stock is removed from the furnace at 8 pm. In the first hour, 0.25 kL of furnace oil is fed to the furnace to raise the furnace temperature. It is assumed that the same amount of heat is also lost during the cooling of the furnace after 8 pm. Operating parameters after furnace stabilization following the first hour are given below.

▪ Average surface temperature of heating and soaking zone (area = 78 m ²):	120 °C
▪ Average surface temperature of areas other than heating And soaking zone (area = 12 m ²):	85 °C
▪ Furnace wall thickness on the billet extraction outlet side:	460 mm
▪ Opening on the billet extraction side:	1 m x 1m
▪ The outlet is opened:	12 times/d for 15 min
▪ Emissivity of furnace wall:	0.8
▪ Operating temperature of the soaking zone:	1340 °C
▪ Average flue gas temperature after air preheater:	750 °C
▪ Specific heat Cp of flue gas:	0.24 kCal/kg per oC
▪ Average O ₂ %:	10%
▪ Ambient temperature:	30 °C
▪ Theoretical air requirement of furnace oil:	14 kg air / kg fuel oil
▪ GCV of fuel oil:	10000 kCal/kg
▪ Average fuel oil consumption:	600 l/hr
▪ Specific gravity of furnace oil:	0.92
▪ H ₂ in furnace oil:	12%
▪ Moisture in furnace oil:	0.25%
▪ Radiation factor for D/X ratio of 2.17 (from graphs):	0.71
▪ Black body radiation at 1340 °C (from graphs):	36 kCal/kg/m ² /hr
▪ Heat loss at 120 °C through roofs and side walls:	1250 kCal/m ² /hr
▪ Heat loss at 85 °C through other areas:	777 kCal/m ² /hr

Calculate the operational efficiency of the furnace. The heat loss in the initial hour can be neglected

SOLUTION

Excess air

$$\begin{aligned} &= \% \text{ O}_2 / (21 - \% \text{ O}_2) \\ &= 10 / (21 - 10) \\ &= 90.9\% \end{aligned}$$

Mass of air supplied

$$\begin{aligned} &= (1 + \text{EA}/100) \times \text{Theoretical air} \\ &= (1 + 90.9) \times 14 \\ &= 26.6 \text{ kg/kg fuel oil} \end{aligned}$$

Operational efficiency of the furnace can be calculated by calculating the individual losses and then subtracting these from 100%. The chapter “Furnaces and Refractories” gives the formulas for each type of loss. The calculation of each loss is given below. The heat loss for the initial firing hour is neglected.

1. Dry flue gas loss

$$\begin{aligned} \text{Mass of dry flue gas} &= 26.6 + 1 = 27.6 \\ \text{Loss per kg fuel oil} &= (26.6 + 1) \times 0.24 \times (750 - 30) = 4748.5 \text{ kCal/kg fuel oil} \\ \text{Loss per day} &= 4748.5 \times 600 \times 0.92 \times 12 = 3.145 \times 10^7 \text{ Kcal} \end{aligned}$$

2. Loss due to evaporation of moisture

$$\begin{aligned} \text{Loss per kg fuel oil} &= 0.025 \{584 + 0.45 (750 - 30)\} = 3.2 \text{ kCal/kg} \\ \text{Loss per day} &= 3.2 \times 600 \times 0.92 \times 12 = 21197 \text{ kCal} \end{aligned}$$

3. Heat loss due to formation of water

$$\begin{aligned} \text{Loss per kg fuel oil} &= 9 \times 0.12 \{584 + 0.45 (750 - 30)\} = 980.64 \text{ kCal/kg} \\ \text{Loss per day} &= 980.64 \times 600 \times 0.92 \times 12 = 0.649 \times 10^7 \text{ kCal} \end{aligned}$$

4. Heat loss due to opening

The shape of opening is square
 $D/X = 1/0.46 = 2.17$
The factor of radiation = 0.71
Black body radiation at $1340^\circ\text{C} = 36 \text{ kCal/kg/m}^2/\text{hr}$
Emissivity = 0.8

$$\begin{aligned} \text{Loss per hour} &= 36 \times 14000 \times 0.71 \times 0.8 = 306720 \text{ kCal/hr} \\ \text{Total time of opening of the gate} &= 12 \times 15/60 = 3 \text{ hours} \\ \text{Loss per day} &= 306720 \times 3 = 920160 \text{ kCal} \end{aligned}$$

5. Heat loss through skin

a. Through roof & side wall

Heat loss at 120⁰C = 1250 kCal/m²/hr
Total area = 78 m²
Loss per hour = 1250 x 76 = 97500 kcal/hr
Loss per day = 97500 x 12 = 1170000 kCal

b. Through other areas

Heat loss at 85 ⁰C = 777 kCal/m²/hr
Total area = 12.0 m²
Loss per hour = 777 x 12 = 9324 kcal/hr
Loss per day = 111888 kCal

6. Heat loss due to cooling of furnace

Loss per day = 250 x 0.92 x 10000 = 0.23 x 10⁷ kCal

Total loss

= (3.145 x 10⁷ + 21197 + 0.649 x 10⁷ + 920160 + 1170000 + 111888 + 0.23 x 10³)
= 4.246x10³ kCal

Operational efficiency

Total fuel fired = (600 liters x 12 hrs + 250 liters) = 7450 liters

Heat input
= fuel use x specific gravity x GCV of fuel
= 7450 x 0.92 x 10000
= 6.85 x 10⁷ kCal

Efficiency
= 1 – (total losses) / heat input)
= 1- 4.246 x 10³ / 6.85 x 10⁷
= 0.38 = 38%