MADE EASY PUBLICATIONS

POSTAL BOOK PACKAGE 2026

MECHANICAL ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

POWER PLANT ENGINEERING

Steam Generators

Practice Questions : Level-I

Q.1 A boiler producing 2000 kg/hr of steam with enthalpy content of 2426 kJ/kg from feed water at temperature 40°C (liquid enthalpy = 168 kJ/kg). What is the equivalent evaporation in kg/hr? (enthalpy of vaporization of water at 100°C = 2258 kJ/kg)

Solution:

Given data: Rate of steam producing, m_s = 2000 kg/hr; Specific enthalpy of feed water, h_f = 168 kJ/kg; Specific enthalpy steam, h = 2426 kJ/kg; Enthalpy of vaporization of water, h_{fg} = 2258 kJ/kg

we know that,

Equivalent evaporation, $$m_e = \frac{\text{Total heat required to evaporated feed water}}{\text{Latent heat of steam at 100°C}}$$

$$= \frac{m_s(h - h_f)}{h_{fg}} = \frac{2000(2426 - 168)}{2258} = \textbf{2000 kg/hr}$$

Q.2 Economizer of a power boiler operating at 150 bar pressure receives 500 kg/s of water from boiler feed pump with specific enthalpy of 340 kJ/kg. Superheated steam leaves the boiler at 550°C with specific enthalpy of 3448.6 kJ/kg. Efficiency of the boiler is 90% and calorific value of the coal used is 10000 kJ/kg. Find the following :

(i) Heat added in economizer, evaporator and superheater in kJ/s

(ii) Percentage of heat added in economizer, evaporator and superheater out of total heat

(iii) Rate of coal consumption in kg/s

Also draw T-s plot showing the position of different components and heat added.

For 150 bar pressure, use the following table :

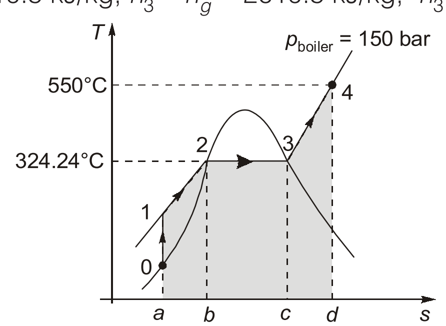
p_s(bar)	T_s(°C)	h_f(kJ/ kg)	h_{fg}(kJ/ kg)	h_g(kJ/ kg)
150	324.24	1610.5	1000	2610.5

Solution:

Given data: p_{boiler} = 150 bar; m = 500 kg/s; h_1 = 340 kJ/kg; h_4 = 3448.6 kJ/kg

η_{boiler} = 90%; CV = 10000 kJ/kg,

From steam table; $h_2 = h_f$ = 1610.5 kJ/kg, $h_3 = h_g$ = 2610.5 kJ/kg, $h_3 - h_2$ = 1000 kJ/kg



(i)

$$Q_{12} = Q_{economizer} = \dot{m}(h_2 - h_1) = 500\,(1610.5 - 340) = 635250 \text{ kJ/s}$$

$$Q_{23} = Q_{evaporator} = \dot{m}(h_3 - h_2) = 500\,(1000) \text{ kJ/s} = 500000 \text{ kJ/s}$$

$$Q_{34} = Q_{superheater} = \dot{m}(h_4 - h_3) = 500\,(3448.6 - 2610.5) \text{ kJ/s}$$

$$= 419050 \text{ kJ/s}$$

$$\text{Total heat added} = Q_{12} + Q_{23} + Q_{34} = 1554300 \text{ kJ/s}$$

(ii)

Component	Heat added (kJ/s)	Percentage %
Economizer	635250	40.87
Evaporator	500000	32.17
Superheater	419050	26.96

(iii) Rate of coal consumption,

$$\eta_{boiler} = \frac{Q_{total}}{\dot{m}_{coal} \times (CV)}$$

$$0.9 = \frac{1554300}{\dot{m}_{coal} \times 10000}$$

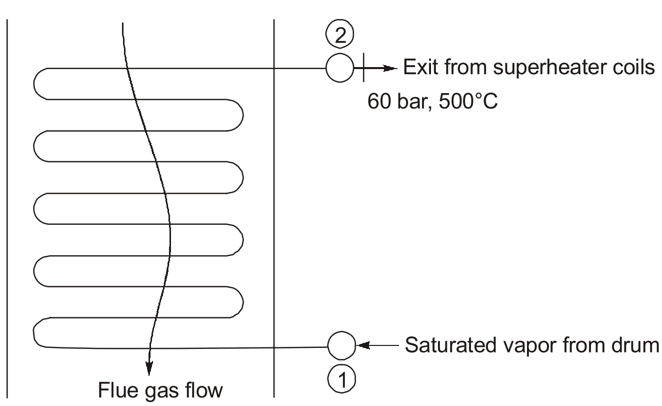
$$\dot{m}_{coal} = 172.7 \text{ kg/s}$$

Q.3 A superheater is to be designed using metallic coils (heat flux 150 kW/m^2) of inside diameter 50 mm and wall thickness 5 mm. The steam leaving the superheater coils is at 60 bars, 500°C and flows at a velocity of 10 m/s. If the steam mass flow rate is 90 kg/s, find the number and length of coils. For steam at 60 bars, take the following values – dry saturated steam h = 2784.3 kJ/kg, at 500°C superheated steam temperature h_{sup} = 3422.2 kJ/kg and specific volume v_{sup} = 0.05665 m^3/kg. The steam enters the superheater as dry and saturated.

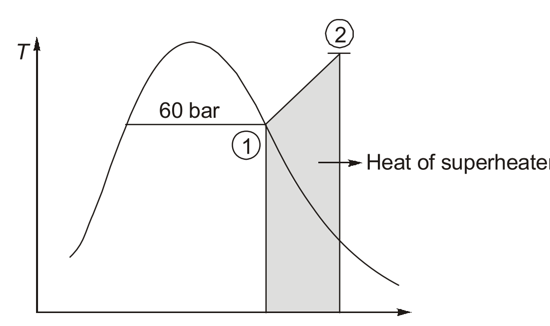
Solution:

Given data: Heat flux, $\dot{q}$ = 150 kW/m^2; d_i = 50 mm = 0.05 m,

Velocity, V = 10 m/s; $\dot{m}_s$ = 90 kg/s



Schematic of Superheater coils



Process on *T-s* coordinate

As given, $h_1 = h_g$ = 2784.3 kJ/kg, h_2 = 3422.2 kJ/kg and specific volume, v_2 = 0.05665 m^3/kg

Heat absorption rate in superheater coils,

$$\dot{Q} = \dot{m}_s(h_2 - h_1) = 90(3422.2 - 2784.3) = 57411 \text{ kW}$$

$$\text{Surface area required} = \frac{57411}{150} = 382.74 \text{ m}^2 \qquad [\text{As, } \dot{Q} = \dot{q} \times A]$$

From continuity equation, $\dot{m}_s = \rho_1 A_1 V_1 = \rho_2 A_2 V_2 = \left(n\frac{\pi}{4}d_i^2\right)\frac{V_2}{v_2} = 90$ kg/s

[where 'n' is the number of superheater coils]

$$n = \frac{4\times 90\times 0.05665}{\pi\times(0.05)^2\times 10} = 259.664 \simeq 260$$

Number of superheater coils, n = 260

As, Surface area, $A_0 = 382.74 = n\pi d_0 l$

d_0 = outer diameter = 50 + 2 × 5 = 60 mm [As thickness is 5 mm]

$$\text{Length of one coil} = \frac{382.74}{260\times\pi\times 0.06} = 7.8 \text{ m}$$

Practice Questions : Level-II

Q.4 A coal-based 660 MW capacity thermal power plant is having overall efficiency of 42%. It uses 600 kg/s of steam for running the turbine. Coal used in the power plant is having calorific value of 10000 kJ/kg. Fuel to air ratio is 1 : 10 for combustion in the boiler. Find the following :

(i) Specific steam consumption in kg/kWh
(ii) Mass flow rate of coal required in Tph (Tonnes per hour)
(iii) Mass flow rate of air required for combustion in kg/s
(iv) Heat required to be supplied to generate one unit of power (in kJ/kWh)
(v) Coal required to be supplied to generate one unit of power (in kg/kWh)

Solution:

Given data: Overall efficiency, $\eta_0 = 42\%$; Capacity of thermal power plant, $P = 660$ MW, Mass flow rate of steam, $\dot{m}_s = 600$ kg/s, Calorific value of coal, $(CV)_f = 10000$ kJ/kg, Air fuel ratio, $\dot{m}_a : \dot{m}_f = 10 : 1$

We know that,

$$\dot{m}_s \times W_{net}(\text{kJ/kg}) = 660\times 10^3 \text{ kW}$$

$$W_{net} = \frac{660\times 10^3}{600} = 1100 \text{ kJ/kg (of steam)}$$

(i) Specific steam consumption $= \frac{3600}{W_{net}} = \frac{3600}{1100} = 3.273$ kg/kWh

(ii) Total heat supplied $= \frac{660}{\eta_0}$ MW

$$\dot{m}_f \times (CV)_f = \frac{660\times 10^3}{0.42} \text{ kW}$$

$$\dot{m}_f = \frac{660\times 10^3}{0.42\times 10000} = 157.142 \text{ kg/s}$$

Mass flow rate of coal required, $\dot{m}_f$ = 565714.30 kg/hour = 565.714 tonne per hour

(iii) Mass flow rate of air required = (AFR) × $\dot{m}_f$ = 10 × 157.143 = 1571.43 kg/s

(iv) Heat required for unit power generation $= \frac{1\times 3600}{0.42}$ kJ/kWh = 8571.4286 kJ/kWh

(v) Coal required for unit power generation $= \frac{565.714\times 10^3}{(660)\times 10^3} = 0.857$ kg/kWh