MIN-106 - Tutorial 5

Shashank Aital
19114076
Batch-04
Branch-CSE

Q.1. $P = 500 kPa$, $T = 300°C$

$\Rightarrow h_1 = 3064.20$ kJ/kg ; $h_2 = 2747.7$ kJ/kg

$S_{water} = 4.187$ KJ/kg K

$$\Rightarrow \frac{dm_{steam}}{dt}(h_2 - h_1) = \frac{dm_{water}}{dt} S \Delta T$$

$$\Rightarrow \frac{dm_{steam}}{dm_{water}} = \frac{4.187 \times 60}{3064.20 - 2747.7} = \underline{0.795}$$

Q.2. $\frac{dm}{dt} = 0.1 m/s$

At $P = 1 MPa$, $T = 400°C$, $\Rightarrow h_1 = 3263.88$ kJ/kg

At $P = 500 kPa$, $T = 350°C$, $\Rightarrow h_2 = 3167.65$ kJ/kg

$$\Rightarrow \cancel{\frac{dm}{dt}}[h_1] = \cancel{\frac{dm}{dt}}\left[h_2 + \frac{v^2}{2}\right]$$

$$\Rightarrow v = \sqrt{2 \times 1000 \times (3263.88 - 3167.65)}$$

$$= 438.7 \ m/s$$

At $P = 500 kPa$, $T = 350°C \Rightarrow v = 0.57012 \ m^3/kg$

$$\Rightarrow \frac{dV}{dt} = vA = 0.57012 \times 0.1$$

$$\Rightarrow A = \frac{0.057012}{438.7} \times 10^4 \ cm^2 = \frac{570.12}{438.7} cm^2$$

$$= \underline{1.3 cm^2}$$

Q.3. $h_i = 632.81$ kJ/kg (At 1.5 MPa & 150°C)

$\cancel{h_f}$

At 200 kPa, $h_f = 504.7$ kJ/kg

$h_{fg} = 2201.7$ kJ/kg

$$\Rightarrow x = \frac{632.81 - 504.7}{2201.7} \quad (\because h = \text{constant})$$

$$\Rightarrow \boxed{x = 0.0579}$$

Now, $v_i = 1.0\overset{9}{\cancel{89}}\ m^3/kg$

$$v_{fin} = v_f + x v_{fg}$$

$$= 0.001061 + 0.0579 \times 0.883908$$

$$= 0.0522\ m^3/kg$$

Now $\cancel{\frac{v_i}{v} = \text{constant}}$

$$\Rightarrow \cancel{\frac{1.09}{5} = \frac{0.0522}{v}}$$

Now, sp. volume $\propto$ velocity

& At 1.2 MPa, 150°C, sp. volume = 0.001089

$$\Rightarrow \frac{0.001089}{0.0522} = \frac{5}{x}$$

$$\Rightarrow x = V_{final} = \underline{\underline{239.67\ m/s}}.$$

Q.4. $\frac{dm}{dt} = 2 kg/s$

$$h_{in} - h_{out} = \Delta(PV)$$
$$= (\Delta P) v$$
$$= (0.0010018)[2000 - 100]$$
$$= 1.90342 \text{ KJ/kg}$$

$$w = \Delta h + \frac{V^2}{2}$$
$$= 1.90342 + \frac{(15)^2}{2000}$$
$$= 1.90342 + 0.1125$$
$$= \underline{\underline{2.01592}} \text{ KJ/kg}$$

$$\Rightarrow \text{Power} = \dot{m} w$$
$$\approx \underline{\underline{4 \text{ KJ/kg}}}$$

Q.5. $\text{Power} = \frac{\dot{m}V^2}{2}$ $\qquad v = 0.001009$ ~~kg/~~ m^3/kg @ 100kPa/25°C

~~= 0.001 m³/kg~~

$$\Rightarrow 10^3 \times 2 = \dot{m} v^2$$

Also, $\dot{m} \times (\text{specific volume}) = A \times (\text{velocity})$

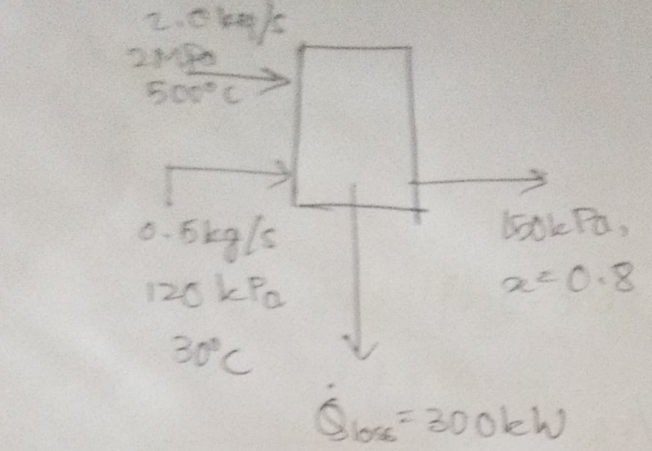
$$\Rightarrow \dot{m} = \frac{\pi (10^{-2})^2 \times (\text{velocity})}{4 \times 0.001009}$$

$$\Rightarrow 2 \times 10^3 = \frac{\pi \times 10^{-4} \times v^3}{4 \times 0.001009}$$

$$\Rightarrow \sqrt[3]{\frac{10090 \times 8}{\pi}} = v \Rightarrow \underline{\underline{v = 29.43}} \text{ m/s}$$

$$\Rightarrow \dot{m} = \frac{\pi \times 10^{-4} \times 29.43}{4 \times 0.001009} = \underline{\underline{2.311 \text{ kg/s}}}$$

Q-6.



$\dot{m}_3 = \dot{m}_1 + \dot{m}_2$
$= 2.5$ kg/s

(a) At 150 kPa, $v_f = 0.001053$ m³/kg

$v_g = 1.15695$ m³/kg

$\Rightarrow v = v_f + x v_{fg}$

$= 0.001053 + 0.8 \times 1.15695$

$= 0.926613$ m³/kg

Now, volume flow rate $= 0.926613 \times (2 + 0.5)$

$= 2.3165325$ m³/s

$\Rightarrow$ Exit velocity $= \dfrac{2.3165325}{\pi \times \left(\frac{0.15}{2}\right)^2}$

$= \underline{\underline{131.2 \text{ m/s}}}$

(b) $h_1 = 3467.55$ kJ/kg (steam table)

~~$h_2 = C_p T = 4.18 \times 303 = 126$~~

$h_2 = 125.66$ kJ/kg (steam table)

$h_3 = h_f + x h_{fg}$

$= 467.2 + 0.8 \times 2226.3$

$= 2248.24$ kJ/kg

$KE = \dfrac{V^2}{2}$

$= \dfrac{1}{1000} \times \frac{1}{2} \times (131.2)^2$

$= \underline{\underline{1056 \text{ kW}}}$

Now, $\dot{Q} = \dot{m}_1 h_1 + \dot{m}_2 h_2 - \dot{m}_3 h_3 - \dot{Q}_{loss}$

$$= 2 \times 3467.55 + 0.5 \times 125.66 - 2.5 \times (2248.24) - 300$$

$$= \cancel{1077.33\,kW} = 1056\,kW$$

Q-7. Now,

$$\left(\frac{dE}{dt}\right) = \frac{dQ}{dt} + \frac{dm_1}{dt}\left(u_1 + \frac{V_1^2}{2} + gz_1\right) - \frac{dm_2}{dt}\left(u_2 + \frac{V_2^2}{2} + gz_2\right)$$

$$- \left[\frac{dW_s}{dt} \underbrace{- P_1 v_1 \frac{dm_1}{dt} + P_2 v_2 \frac{dm_2}{dt}}_{\text{Flow works.}}\right]$$

Here, there is no heat transfer & work done

Also, final state has no flow $\Rightarrow P_2 V_2 \frac{dm_2}{dt} = 0$

$\Rightarrow E_{in} - E_{out} = \Delta E$

$\Rightarrow m(h_1) = m(u_2)$

$\Rightarrow \boxed{u_2 = h_1}$ $(= 3161.68$ kJ/kg$)$

Now at 8 bar, 500°C $\rightarrow u = 3125.95$ kJ/kg

600°C $\rightarrow u = 3297.91$ kJ/kg

$$\Rightarrow u_2 = 3161.68 = 3125.95 + \frac{T - 500}{100} \times (3297.91 - 3125.95)$$

$$\Rightarrow T - 500 = \frac{3573}{171.96}$$

$$\Rightarrow \boxed{T = 520°C}$$

At 8 bar, 500°C $\rightarrow v = 0.44331$ m³/kg

600°C $\rightarrow v = 0.50184$ m³/kg

$\Rightarrow v_{520} = 0.44331 + \frac{\cancel{20}}{\cancel{100}\ 5} \times (0.50184 - 0.44331)$

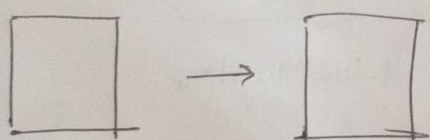
$= 0.44331 + 0.011706$

$= \underline{\underline{0.455016 \ m^3/kg}}$

$\Rightarrow V = 0.455016 \times 0.75$

$= \underline{\underline{0.342 \ m^3}}$

Q.8. Initial Final



100L, 1MPa, 200°C 100L, 50°C, 100kPa

State I → Superheated steam

State II → Compressed Liquid,

$m_1 = \frac{P_1 V_1}{RT_1} = \frac{1000 \times 0.1}{0.287 \times 473.15} = \underline{\underline{0.736 \ kg}}$

$m_2 = \frac{P_2 V_2}{RT_2} = \frac{100 \times 0.1}{0.287 \times 323.1} = \underline{\underline{0.1078 \ kg}}$

$\Rightarrow \boxed{m_1 - m_2 = 0.628 kg}$

Now, $m_1 u_1 - m_2 u_2 = m_{ex} h - Q$

$\Rightarrow h = \frac{h_1 + h_2}{2} = C_p \left(\frac{T_1 + T_2}{2}\right)$

$= 1.005 (273 + 125)$

$= 399.99 \ kJ/kg$

$\Rightarrow Q = (0.1078)(0.718)(323) - (0.736)(0.718)(473)$

$+ (0.736 - 0.1078)(399.99)$

$= \underline{\underline{25.7\ kJ}}$

Q.9. $m_1 = \frac{P_1 V}{RT_1} = \frac{500 \times 1}{0.287 \times 293.15} = \underline{\underline{5.94\ kg}}$

$m_2 = \frac{P_2 V}{RT_2} = \frac{1500 \times 1}{0.287 \times 308.15} = \underline{\underline{16.96\ kg}}$ ← Final mass of air

$\Delta m = m_2 - m_1$

$= 16.96 - 5.94 = \underline{\underline{11.02\ kg}}$

Now $Q = m_2 u_2 - m_1 u_1 + m_{steel} C_{steel} (\Delta T)_{steel}$

$- (\Delta m) h_{avg}$

$h_{avg} = \frac{C_p}{2}(T_1 + T_2) = \frac{1.005}{2} \times (273 + \frac{55}{2})$

$= 302.0025\ kJ/kg$

~~$\Rightarrow Q = 16.96 \times 0.718 \times 308.15 - 5.94 \times 0.718 \times 293.15$~~

~~$+ 40 \times 0.49 (35 - 20) - 11.02 \times 302.0025$~~

$Q = m_1(u_2 - u_1) + m_i(u_2 - u_i - RT_i) + m_{st} C_{st}(T_2 - T_1)$

$= 5.94 \times 0.717 (35 - 20) + 11.02(0.717(35 - 20) - 0.287 \times 293.2)$

$+ 40 \times 0.46 (35 - 20)$

$= 63.885 - 808.795 + 276$

$= \underline{\underline{-468.9\ kJ}}.$

Q.10. At 100 kPa, $v_f = 0.001043\ m^3/kg$

$$v_{fg} = 1.69296\ m^3/kg$$

$$\Rightarrow v = v_f + 0.01 v_{fg}$$
$$= 0.01797\ m^3/kg$$

$$\Rightarrow m_1 = \frac{0.2}{0.01797} = \underline{\underline{11.13 kg}}$$

At 2 MPa, $v_f = 0.001177\ m^3/kg$

$$v_{fg} = 0.09845\ m^3/kg$$

$$\Rightarrow v = v_f + 0.9 v_{fg}$$
$$= 0.8978\ m^3/kg$$

$$\Rightarrow m_2 = \frac{0.2}{0.8978} = \underline{\underline{2.23 kg}}$$

$$\Rightarrow \Delta m = 11.13 - 2.23 = \underline{\underline{8.9 kg}}$$

$$Q = m_2 u_2 - m_1 u_1 + m_e h_e$$

Now, At 100 kPa, $u_f = 417.33\ kJ/kg$

$$u_{fg} = 2088.72\ kJ/kg$$

$$\Rightarrow u_1 = u_f + 0.01 u_{fg}$$
$$= \underline{\underline{438.22}}\ kJ/kg$$

At 2 MPa, $v_f = 906.42$ kJ/kg

$v_{fg} = 1693.84$ kJ/kg

$\Rightarrow u_2 = v_f + 0.9 v_{fg}$

$= \underline{\underline{2430.88 \text{ kJ/kg}}}$

$m_e = \Delta m = 8.9 \text{kg}$ $\qquad h_e = h_g = 2799.51$ kJ/kg

~~$\Rightarrow Q = 2.33$~~

$\Rightarrow Q = 2.23 \times 2430.88 - 11.13 \times 438.22 + 8.9 \times 2799.51$

$= 25{,}459 \text{ kJ} = \underline{\underline{25.46 \text{ MJ}}}$