$\dot{m} = 10$ kg/min $= \frac{10}{60}$ kg/s

Given $p_1 = 1.5$ bar $p_2 = 5.5$ bar $\dot{Q} = -55$ kJ/s

$\rho_1 = 26$ kg/m³ $\rho_2 = 5.5$ kg/m³ $z_2 = 55$ m

$V_1 = 110$ m/s $V_2 = 190$ m/s

$u_1 = 910$ kJ/kg $u_2 = 710$ kJ/kg

(i) Change in enthalpy Δh

$$\Delta h = h_2 - h_1 = (u_2 + p_2 v_2) - (u_1 + p_1 v_1)$$

$$= \left(u_2 + \frac{p_2}{\rho_2}\right) - \left(u_1 + \frac{p_1}{\rho_1}\right)$$

$$= \left(710 \times 10^3 + \frac{5.5 \times 10^5}{5.5}\right) - \left(910 \times 10^3 + \frac{1.5 \times 10^5}{26}\right)$$

$$= -1,05,769.2 \text{ J/kg}$$

$$= -105.8 \text{ kJ/kg}$$

(ii) Work done during the process (W)

$$\dot{Q} - \dot{W} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2}{2} - \frac{V_1^2}{2} + g(z_2 - z_1)\right]$$

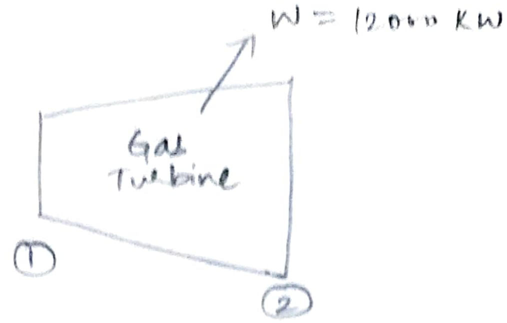
$$-55 \times 10^3 - \dot{W} = \frac{10}{60}\left[-105769.2 + \left(\frac{190^2}{2} - \frac{110^2}{2}\right) + 9.81 \times (55)\right]$$

$$\dot{W} = -39461.7 \text{ J/s}$$

$$= -39.46 \text{ kJ/s}$$

(2)

$\dot{m} = 15$ kg/s



Given

$h_1 = 1260$ KJ/Kg , $h_2 = 400$ KJ/Kg

$V_1 = 50$ m/s $\qquad V_2 = 110$ m/s

(i) $Q = ?$

$$\dot{Q} - \dot{W} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2}{2} - \frac{V_1^2}{2} + g\underbrace{\cancel{(z_2 - z_1)}}_{0}\right]$$

$$\dot{Q} - 12000 \times 10^3 = 15\left[(400 - 1260) \times 10^3 + \frac{110^2 - 50^2}{2}\right]$$

$$\Rightarrow \quad \dot{Q} = -828,000 \text{ W (or) J/s}$$

$$= -828 \text{ KW}$$

(ii) Given $v_1 = 0.45$ m³/kg $\Rightarrow \rho_1 = \frac{1}{v_1} = \frac{1}{0.45} = 2.22$ kg/m³

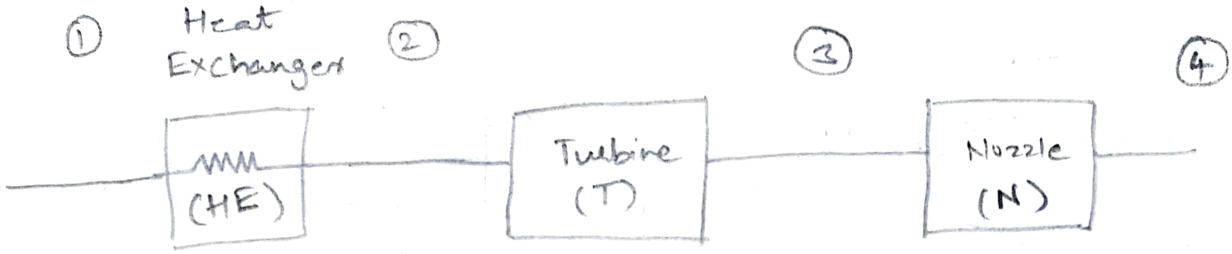
Inlet Area $A_1 = ?$

mass flow rate $\dot{m} = \rho_1 A_1 V_1$

$$15 = 2.22 \times A_1 \times 50$$

$$\Rightarrow \quad A_1 = 0.135 \text{ m}^2$$

③



Given,

$T_1 = 20^\circ C$ $\quad$ $T_2 = 820^\circ C$ $\quad$ $T_3 = 620^\circ C$ $\quad$ $T_4 = 510^\circ C$

$V_1 = 40\ m/s$ $\quad$ $V_2 = 40\ m/s$ $\quad$ $V_3 = 55\ m/s$

$\dot{m} = 2.5\ kg/s$

(i) $\dot{Q}_{HE} = ?$

$$\dot{Q}_{HE} - \cancel{\dot{W}_{HE}} = \dot{m}\left[(h_2 - h_1) + \left(\frac{V_2^2}{2} - \frac{V_1^2}{2}\right) + g(\cancel{z_2 - z_1})\right]$$

$\dot{W}_{HE} \to 0$, $\left(\frac{V_2^2}{2} - \frac{V_1^2}{2}\right) \to 0$ $\because (V_1 \simeq V_2)$, $g(z_2 - z_1) \to 0$

$$\dot{Q}_{HE} = \dot{m}(h_2 - h_1)$$
$$= \dot{m}\, C_p (T_2 - T_1)$$
$$= 2.5 \times 1005 \times (820 - 20)$$

$$\Rightarrow \quad \dot{Q}_{HE} = 20,10,000\ W \quad = 2010\ KW$$

(ii) $\dot{W}_T = ?$

$$\cancel{\dot{Q}_T} - \dot{W}_T = \dot{m}\left[(h_3 - h_2) + \left(\frac{V_3^2}{2} - \frac{V_2^2}{2}\right) + g(\cancel{z_3 - z_2})\right]$$

$\dot{Q}_T \to 0$, $g(z_3 - z_2) \to 0$

$$-\dot{W}_T = \dot{m}\, C_p (T_3 - T_2) + \left(\frac{V_3^2 - V_2^2}{2}\right)$$
$$= 2.5 \times 1005 \times (620 - 820) + \left(\frac{55^2 - 40^2}{2}\right)$$
$$= -5,01,787.5\ W$$

$$\Rightarrow \quad \dot{W}_T = 501.8\,KW$$

(iii) Nozzle exit velocity $V_4 = ?$

$$\underbrace{\cancel{\dot{Q}}_N}_{0} - \underbrace{\cancel{\dot{W}}_N}_{0} = \dot{m}\left[(h_4 - h_3) + \left(\frac{V_4^2 - V_3^2}{2}\right) + g\,\underbrace{(\cancel{z_4 - z_3})}_{0}\right]$$

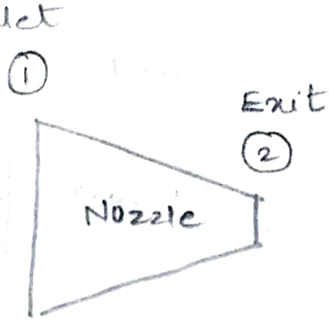
$$\dot{m}\,c_p(T_3 - T_4) = \dot{m}\,\frac{V_4^2 - V_3^2}{2}$$

$$\Rightarrow \quad 1005 \times (620 - 510) = \frac{V_4^2 - 55^2}{2}$$

$$\rightarrow \quad V_4 = 337\ m/s$$

4

Given,



$h_1 = 2800$ kJ/kg , $h_2 = 2600$ kJ/kg

$V_1 = 50$ m/s , $v_2 = 0.498$ m³/kg

$A_1 = 900$ cm²

$v_1 = 0.187$ m³/kg

(i) $V_2 = ?$

$$\underbrace{\cancel{\dot{Q}}}_{0} - \underbrace{\cancel{\dot{W}}}_{0} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} + \underbrace{g(\cancel{z_2} - z_1)}_{0}\right]$$

$$h_1 - h_2 = \frac{V_2^2 - V_1^2}{2}$$

$$(2800 - 2600) \times 10^3 = \frac{V_2^2 - 50^2}{2}$$

$$\Rightarrow V_2 = 634.4 \text{ m/s}$$

(ii) Mass flow rate $\dot{m} = ?$

$$\dot{m} = \rho_1 A_1 V_1 = \frac{1}{v_1} A_1 V_1$$

$$= \frac{1}{0.187} \times 900 \times 10^{-4} \times 50$$

$$\dot{m} = 24.06 \text{ kg/s}$$

(iii) $A_2 = ?$

$$\dot{m} = \rho_2 A_2 V_2 = \frac{1}{v_2} A_2 V_2$$

$$\Rightarrow 24.06 = \frac{1}{0.498} \times A_2 \times 634.4$$

$$\Rightarrow A_2 = 0.01889 \text{ m}^2$$

$$= 188.9 \text{ cm}^2$$

(5)

(1) $\dot{Q} = 60$ KJ/s (2)

$V_1 = 6$ m/s | Air Compressor | $V_2 = 5$ m/s

$p_1 = 1$ bar | | $p_2 = 7$ bar

$v_1 = 0.85$ m³/kg | | $v_2 = 0.16$ m³/kg

$u_2 = u_1 + 90$ KJ/kg

Given, $\dot{m} = 0.5$ kg/s

(i) $\dot{W} = ?$

$$\dot{Q} - \dot{W} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} + g\underbrace{(\cancel{z_2 - z_1})}_{0}\right]$$

$$-60 \times 10^3 - \dot{W} = 0.5\left[(u_2 + p_2 v_2) - (u_1 + p_1 v_1) + \frac{V_2^2 - V_1^2}{2}\right]$$

$$= 0.5\left[90 \times 10^3 + (7 \times 10^5 \times 0.16) - (1 \times 10^5 \times 0.85) + \frac{5^2 - 6^2}{2}\right]$$

$$\Rightarrow \dot{W} = -118497.25 \text{ W (or) J/s}$$

$$= -118.5 \text{ KW}$$

(ii) $A_1 = ?$, $A_2 = ?$

$$\dot{m} = \rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

$$\dot{m} = \frac{1}{v_1} A_1 V_1 = \frac{1}{v_2} A_2 V_2$$

$$0.5 = \frac{1}{0.85} \times A_1 \times 6 = \frac{1}{0.16} \times A_2 \times 5$$

$$\Rightarrow A_1 = 0.07083 \text{ m}^2 = 708.3 \text{ cm}^2$$

$$A_2 = 0.016 \text{ m}^2 = 160 \text{ cm}^2$$

(6) For a process,

$Q - W = \Delta E$

For a cycle,

$\Sigma Q = \Sigma W$

and $\Delta E = 0$

Process 1-2

$Q_{1-2} - W_{1-2} = \Delta E_{1-2}$

$\Rightarrow \Delta E_{1-2} = 0 - 4340$

$= -4340$ KJ/min

Process 2-3

$Q_{2-3} - W_{2-3} = \Delta E_{2-3}$

$\Delta E_{2-3} = 42000 - 0$

$= 42000$ KJ/min

Process 3-4

$Q_{3-4} - W_{3-4} = \Delta E_{3-4}$

$\Rightarrow W_{3-4} = Q_{3-4} - \Delta E_{3-4}$

$= -4200 + 73200$

$= 69000$ KJ/min

Process 4-1

$Q_{4-1} - W_{4-1} = \Delta E_{4-1}$

We can compute Q_{4-1} & ΔE_{4-1} from cycle

$\Sigma Q_{cycle} = Q_{1-2} + Q_{2-3} + Q_{3-4} + Q_{4-1}$

$-340 \times 200 = 0 + 42000 - 4200 + Q_{4-1}$

$\Rightarrow Q_{4-1} = -1,05,800$ KJ/min

$\Delta E_{cycle} = 0$

$\Rightarrow \quad \Delta E_{1-2} + \Delta E_{2-3} + \Delta E_{3-4} + \Delta E_{4-1} = 0$

$\Rightarrow \quad -4340 + 42000 - 73200 + \Delta E_{4-1} = 0$

$\Rightarrow \quad \Delta E_{4-1} = 35,540 \ \text{KJ/min}$

$\Delta W_{4-1} = Q_{4-1} - \Delta E_{4-1}$

$= -105800 - 35540$

$= -141,340 \ \text{KJ/min}$

Net rate of work output $\Sigma W = ?$

$\Sigma W = \Sigma Q$ (in a cycle)

$= -340 \times 200$

$= -68000 \ \text{KJ/min}$

$= -\dfrac{68000}{60} \ \text{KJ/s}$

$\Sigma W = -1133.3 \ \text{KW}$

7

gas was compressed from 1 to 2 at constant pressure

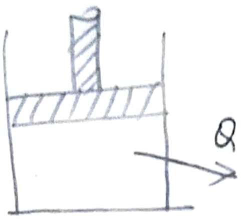
for a closed system undergoing constant pressure,

$$Q - W_{other} = \Delta H$$

$$Q - \underset{0}{W_{other}} = H_2 - H_1$$

$$Q = U_2 + P_2 V_2 - (U_1 + P_1 V_1)$$

$$-42.5 \times 10^3 = (U_2 - U_1) + 0.105 \times 10^6 \times (0.2 - 0.4)$$

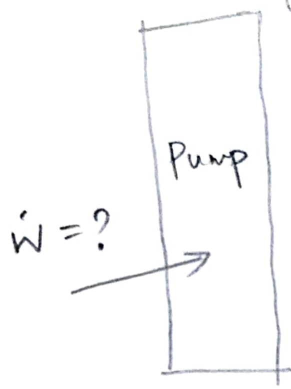


$$\Rightarrow U_2 - U_1 = -21,500 \text{ J}$$

$$U_2 - U_1 = -21.5 \text{ kJ}$$

Internal energy decreases by 21.5 kJ

(8)



(2) outlet $p_2 = 4.2$ bar
$z_2 = 8.5$ m
$d_2 = 10$ cm

$\dot{m} = 50$ kg/s

(1) Inlet $p_1 = 1$ bar
$z_1 = -2.2$ m
$d_1 = 20$ cm

$$\dot{Q} - \dot{W} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)\right]$$

$$\underbrace{\cancel{\dot{Q}}}_{0} - \dot{W} = \dot{m}\left[\underbrace{\cancel{(u_2 - u_1)}}_{0} + (p_2 v_2 - p_1 v_1) + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)\right]$$

For water, $\rho = 1000 \text{ kg/m}^3$

$$\Rightarrow v_1 = v_2 = \frac{1}{\rho} = \frac{1}{1000} = 10^{-3} \text{ m}^3/\text{kg}$$

$$\dot{m} = \rho A_1 V_1 = \rho A_2 V_2$$

$$\Rightarrow \dot{m} = \rho \times \frac{\pi}{4} \times d_1^2 \times V_1 = \rho \times \frac{\pi}{4} d_2^2 \times V_2$$

$$\Rightarrow 50 = 1000 \times \frac{\pi}{4} \times 0.2^2 \times V_1 = 1000 \times \frac{\pi}{4} \times 0.1^2 \times V_2$$

$$\Rightarrow V_1 = 1.59 \text{ m/s}$$

$$V_2 = 6.37 \text{ m/s}$$

on substituting

$$-\dot{W} = 50 \times \left[(4.2 \times 10^5 - 1 \times 10^5) \times 10^{-3} + \frac{6.37^2 - 1.59^2}{2} + 9.81 \times (8.5 + 2.2)\right]$$

$$\dot{W} = -22{,}199.6 \text{ W} = -22.2 \text{ kW}$$