1) Consider volume below piston as CV and here volume changes with respect to time.

Applying energy balance.

$$\rightarrow \frac{dE}{dt} = \dot{m}_i h_i + \cancel{\dot{Q}}^{0} - \cancel{\dot{m}_e}^{0} h_e - \dot{W}_{shaft}$$

(insulated) (no exit flow)

$$\rightarrow \boxed{\frac{dE}{dt} = \dot{m}_i h_i - \dot{W}_{shaft}}$$ ——— (2) marks

$$\int dE = \int \dot{m}_i h_i \, dt - \int \dot{W}_{shaft} \, dt$$

$$E_f - E_0 = h_i \int \dot{m}_i \, dt - \int \dot{W}_{shaft} \, dt$$

$$m_f u_f - \cancel{m_0}^{0} u_0 = h_i (m_f - m_0) - \int \dot{W}_{shaft}$$

$$\rightarrow \boxed{m_f u_f = h_i m_f - \int \dot{W}_{shaft} \, dt} \longrightarrow (a)$$ ——— (2) marks

work done by gas on spring = Energy stored in spring

$$\int \dot{W}_{shaft} \, dt = \frac{1}{2} k x_f^2$$ (x_f = final compression in spring)

$$= \frac{1}{2} (P_f A) x_f$$

$$\boxed{\therefore \int \dot{W}_{shaft} \, dt = \frac{1}{2} P_f V_f} \longrightarrow (b)$$ ——— (1) marks

from eqn's (a) and (b),

$$m_f u_f = h_i m_f - \frac{1}{2} P_f V_f$$

$$\boxed{\therefore m_f u_f = h_{supply} m_f - \frac{1}{2} P_f V_f}$$ $[\because h_i = h_{supply}]$ $\longrightarrow$ (1) marks

4 marks.

$$\Rightarrow u_f = h_{supply} - \frac{1}{2} P_f \left(\frac{V_f}{m_f} \right)$$

Multiplying by M_w (mol. wt)

$$u_f M_w = h_{supply} \cdot M_w - \frac{1}{2} P_f \left(\frac{V_f}{m_f} \cdot M_w \right)$$

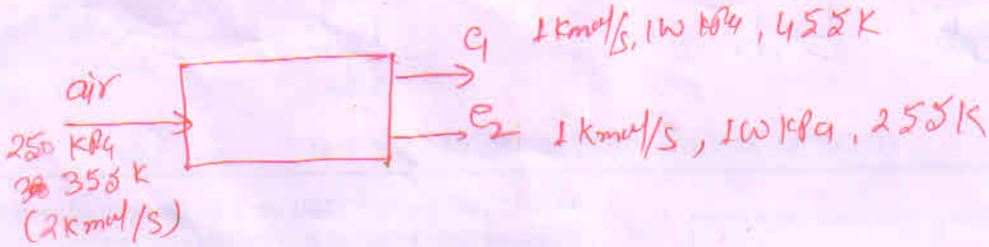
as $u_f M_w = c_v T_f$; $h_{supply} M_w = c_p T_{supply}$; $P_f \left(\frac{V_f}{m_f} \cdot M_w \right) = P_f v_f \cdot M_w = R T_f$

$\Rightarrow$ substituting c_v, T_{supply} values and calculating c_p from $c_p - c_v = R$

we get, $\frac{5R}{2} T_f = \frac{7R}{2} T_{supply} - \frac{1}{2} R T_f$

$$\Rightarrow T_f = \left(\frac{7}{6} \right) T_{supply} \Rightarrow \boxed{T_f = \frac{7 \times 600}{6} = 700 \text{ K}}$$

2)



1^{st} Law for flow process

$$\left.\dot{m}_i h_i = \dot{m}_{e_1} h_{e_1} + \dot{m}_{e_2} h_{e_2}\right] \longrightarrow 1 \text{ marks}$$

$$2 (C_p T_i) = (1) C_p T_{e_1} + (1) C_p T_{e_2}$$

$$2T_i = T_{e_1} + T_{e_2}$$

$$(2) \times 355 = 455 + 255$$

$$710 = 710 \Rightarrow \boxed{LHS = RHS} \longrightarrow 4 \text{ marks}$$

first Law is valid

$$\dot{S}_G = \dot{m}_{e_1} s_{e_1} + \dot{m}_{e_2} s_{e_2} - \dot{m}_i s_i$$

$$= \dot{m}_{e_1} s_{e_1} + \dot{m}_{e_2} s_{e_2} - (\dot{m}_{e_1} + \dot{m}_{e_2}) s_i$$

$$= \dot{m}_{e_1} (s_{e_1} - s_i) + \dot{m}_{e_2} (s_{e_2} - s_i)$$

$$= \dot{m}_{e_1} \left[C_p \ln\left(\frac{455}{355}\right) - R \ln\left(\frac{100}{250}\right)\right] + \dot{m}_{e_2} \left(C_p \ln \frac{255}{355} - R \ln \frac{100}{255}\right)$$

$$= C_p \ln \left(\frac{455 \times 255}{355 \times 355}\right) - R \ln \left(\frac{100 \times 100}{250 \times 255}\right)$$

$$= \frac{7 \times 8.314}{2} \ln \left(\frac{455 \times 255}{355 \times 355}\right) - 8.314 \ln \left(\frac{100 \times 100}{250 \times 255}\right)$$

$$= 12.8303 \text{ kJ/kg} > 0$$

Sumit dae.

3) At $25°C$, $P = 0.03166$ bar

$v_g = 43.4 \ m^3/kg$

$h_g = 2547.3$ KJ/kg

$s_g = 8.5592$ KJ/kg-K

At 3 bar and $200°C$ $v_2 = 0.7164 \ m^3/kg$

$h_2 = 2865.5$ KJ/kg

$s_2 = 7.3119$ KJ/kg.

$S_{Total} = S_{system} + S_{surroundings}$.

(so it is a quasi-static compression process by external agent)

Work done, $W = \left(\frac{P_1 + P_2}{2}\right)(v_2 - v_1)$

$= \left(\frac{3.0317}{2}\right)(0.7164 - 43.4) \times 100$

$= -6470.2$ KJ.

heat, $Q = \Delta U + W$

$= (U_f - U_i) + W$

$= \left[(h_f - P_f v_f) - (h_i - P_i v_i)\right] - 6470.2$

$= 2865.5 - [300(0.7164)] - 2547.3 + [0.03166 \times 100 \times 43.4] - 6470.2$

$= -6229.5156$ KJ

$S_{Total} = (S_2 - S_1) + \frac{|Q|}{T_{supply}}$.

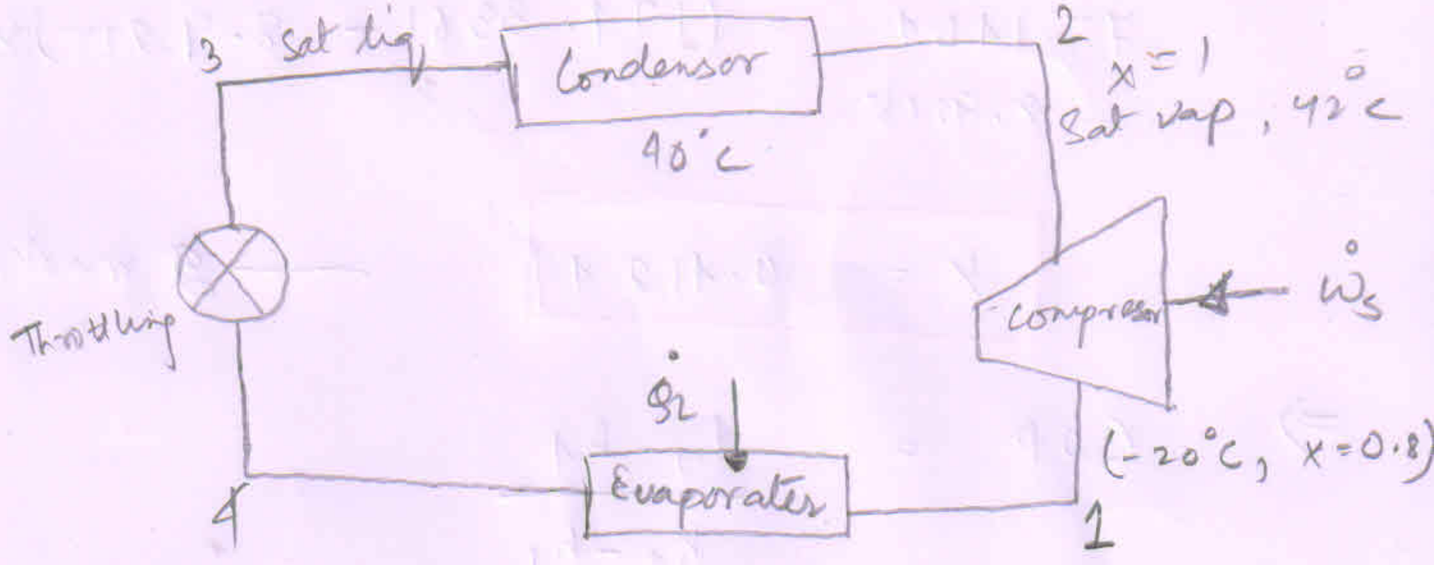
$= (7.3119 - 8.5592) + \frac{6229.5156}{523}$

$= -1.2473 + 11.91$

$=$ ~~13.158 KJ/kg-K~~.

$= 10.6627$ KJ/kg-K.

Q4



$\Rightarrow \quad h_2 = h_1 + \dfrac{\dot{W}_s}{\dot{m}}$

from saturated Frean table

$h_1 = (178.9017)(0.8) + (0.2)(17.9517)$

$h_2 = 203.7598 \times 1$

hence, $\quad \dot{W}_s = (h_2 - h_1)\,\dot{m}$

$\dot{W}_s = (203.7598 - \cancel{20}\ 146.7411)$

$\boxed{= 57.05 \text{ kw}}$ — 4 marks

$\Rightarrow \quad h_3 = h_f(42^\circ c) = 77.14\cancel{6}64 \text{ kJ/kg}$

$h_4 = h_3$

$\boxed{P = 100.341 \text{ kPa}}$
(& minimum)
2 marks

$h_4 = 77.1464$

at $-30^\circ C \quad h_g(-30^\circ c) = 174.3361$

$h_f(-30^\circ c) = 8.9215$

$h_4 = (174.3361)x + (8.9215)(1-x)$

$$77.1464 - 8.9215 = (174.3361 - 8.9215)x$$

$$\boxed{x = 0.4124}$$ — 2 marks

$$\Rightarrow \quad COP = \frac{h_1 - h_4}{h_2 - h_1}$$

$$= \frac{146.7117 - 77.1464}{203.7198 - 146.7117}$$

$$= \frac{69.5653}{57.0481}$$

$$\boxed{COP = 1.21}$$ — 4 marks

5

$n = 1$ mole

(a) $W_{\text{by paddle}} = -(W_{\text{by gas}}) = -(\cancel{Q}^{\,0} - \Delta U)$

$W_{\text{by paddle}} = \Delta U = n\,c_v\,\Delta T = \left(\frac{5R}{2}\right)(600-300)$

$= 750\,R = 6235.5\,J$

$= 6.2355\,kJ$

(b) $\Delta S_{total} = \Delta S_{gas} + \Delta S_{\text{surrounding}}$

(rigid tank, Q to surrounding $= 0$
hence $\Delta S_{\text{surroundy}} = 0$)

hence $\Delta S_{total} = \Delta S_{gas} + 0$

$= C_v \ln\frac{T_2}{T_1} + \cancel{R \ln\frac{V_2}{V_1}}^{\,0} \quad \Rightarrow V_2 = V_1$

$= \frac{5R}{2}\ln\left(\frac{600}{300}\right) = \frac{5R}{2}\ln 2 = 14.4\ J$

(c) $COP = \frac{Q_H}{W_{rev}}$

$\frac{1}{1-\frac{T_0}{T}} = \frac{\delta Q_H}{\delta W_{rev}} \Rightarrow \delta W_{rev} = \delta Q_H\left(1-\frac{T_0}{T}\right)$

$= (C_v\,dT)\left(1-\frac{T_0}{T}\right)$

$\Rightarrow W_{rev} = \int_{T_{1^\circ}}^{T_f} C_v\left(1-\frac{T_0}{T}\right)dT$

$= C_v(T_f - T_{1^\circ}) - T_0\,C_v \ln\frac{T_f}{T_{1^\circ}}$

$= \frac{5R}{2}(600-300) - (300)\frac{5R}{2}\ln 2$

$= 6235.5 - 4321.2015$

$= 1914.295\ J$

(d) $W_{rev} = \underbrace{C_v(T_f - T_{1^\circ})} - T_0\left(C_v \ln\frac{T_f}{T_{1^\circ}}\right)$

$\boxed{W_{rev} = W_{paddle} - T_0\,\Delta S_{total}}$ ($= \Delta S_{gas}$)

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