ME 24-221
THERMODYNAMICS I

Solution to Exam 2
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<u>Solution to Pb.1:</u>

Given: Refrigerator
$T_L = -5^oC = 268.15$ K
$T_H = 27^oC = 300.15$ K
$\beta_{claimed} = 10$

β_{carnot} is the maximum C.O.P one can get.

$$\beta_{carnot} = \frac{T_L}{T_H - T_L} = \frac{268.15}{32} = 8.38$$

$\beta_{claimed} > \beta_{carnot}$ which is not possible.

Hence the claim is **impossible**. --(a)

$\beta = \frac{Q_L}{W}$: Hence, $W = \frac{Q_L}{\beta}$ where $Q_L = 2$ kW

W is minimum when β is maximum i.e., $\beta_{carnot.}$

Hence $\mathbf{W_{min}} = \frac{Q_L}{\beta_{carnot}} = \frac{2}{8.38} = 0.238kW$ --(b)

<u>Solution to Pb 2:</u>

Given: Water
State 1: $T_1 = 1073.15$ K; $P_1 = 5000$ kPa; $\dot{m}_1 = 10$ kg/s
State 2: $T_2 = 773.15$ K; $P_2 = 100$ kPa; $\dot{m}_2 = 10$ kg/s
State 3: $P_3 = 30$ kPa; $x_3 = 0.9$ (Saturated; pressure entry; Table B.1.2)

States 1 and 2 are superheated. Hence from Table B.1.3, $h_1 = 4137.17$ kJ.kg and
$h_2 = 3478.44$ kJ/kg

Continuity: $\dot{m}_1 + \dot{m}_2 = \dot{m}_3 = 15$ kg/s

$$\dot{V}_3 = \frac{\dot{m}_3}{\rho_3} = v_3 \dot{m}_3$$

$$v_3 = v_{f,3} + x_3 v_{fg,3} = 0.001022 + (0.9)5.22816 = 4.706366 \, \text{m}^3/\text{s}$$

Therefore, $\dot{V}_3 = 15 * 4.706366 = 70.59 \, \text{m}^3$ ---(a)

First Law for CV, SSSF: $\dot{Q}_{CV} = 0$ (adiabatic; also neglecting KE and PE changes)

$$\dot{m}_3 h_3 - \dot{m}_1 h_1 - \dot{m}_2 h_2 = -\dot{W}_{CV}$$

And, $h_3 = h_{f,3} + x_3 h_{fg,3} = 289.21 + (0.9)2336.07 = 2391.673 \, \text{kJ/kg}$

Hence, $\dot{W}_{CV} = 10(4137.17) + 5(3478.44) - 15(239.673) = 22888.80 \, \text{kW}$ ----------(b)

<u>Solution to Pb. 3:</u>

Given: Air

State 1: $T_1 = 473.15$ K; $P_1 = 500$ kPa; $\dot{m}_1 = 2 \, \text{kg/s}$

State 2: $T_2 = 373.15$ K; $P_2 = 500$ kPa; $\dot{m}_2 = 5 \, \text{kg/s}$

State 3: $P_3 = 100$ kPa; $\forall_3 = 50 \, \text{m/s}$

$\dot{Q}_{CV} = 20 kW$; $\dot{W}_{CV} = 40 kW$

First Law for CV, SSSF: (Neglecting the inlet Velocities and PE change)

$$\dot{m}_3 (h_3 + \frac{\forall_3^2}{2}) - \dot{m}_1 h_1 - \dot{m}_2 h_2 = \dot{Q}_{CV} - \dot{W}_{CV}$$

T_{ref} as 0K, $h_3 = C_{po} T_3$; $h_1 = C_{po} T_1 = 1.004(473.15) = 475.04$ kJ/kg;
$h_2 = C_{po} T_2 = 1.004(373.15) = 374.64$ kJ/kg;

Also, for consistency of units: $\frac{\forall_3^2}{2} = \frac{50^2}{2 \times 1000} = 1.25 kJ / kg$

i.e., $7(C_{po} T_3 + 1.25) - 2(475.04) - 5(374.63) = 20 - 40$

$7 C_{po} T_3 + 8.75 - 2823.28 = -20$

$T_3 = 397.63$ K (or 124.48^oC) ---(a)

Diameter D = $\sqrt{\frac{4A}{\pi}}$

$$A_3 = \frac{\dot{V}_3}{\forall_3} = \frac{\dot{m}_3 v_3}{\forall_3}$$

Since for air, $P_3 v_3 = RT_3$ we get, $v_3 = RT_3/P_3$ = (0.287)(397.63)/100 = 1.1412 m^3/kg

$$A_3 = \frac{\dot{m}_3 v_3}{\forall_3} = \frac{7 \times 1.1412}{50} = 0.1597\,\text{m}^2$$

D_3 = 0.45 m ---(b)

$$\dot{m}_3 u_3 - \dot{m}_1 u_1 - \dot{m}_2 u_2 = 7C_{VO}T_3 - 2C_{VO}T_1 - 5C_{VO}T_2$$

= (7x0.717x397.63) – (2x0.717x473.15) – (5x0.717x373.15)

= -20.53 KW ---©