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Q1

$Q_{in} = 500 \frac{kJ}{kg}$ $T_2 = 500°C$ $r = 9.5$

$\frac{C_v}{R} = 2.5$

a.) $\eta_{\theta} = 1 - \left(\frac{V_2}{V_1}\right)^{R/C_v} = 1 - \left(\frac{1}{r}\right)^{1/2.5} = \boxed{0.59}$

b.) $\cancel{1 - \frac{T_1}{T_2} = 1 - \left(\frac{1}{r}\right)^{1/2.5}}$ closed $\therefore \Delta u = Q = C_v(T_3 - T_2)$

$\therefore 500 \frac{kJ}{kg} = 2.5R\,(T_3 - 773.15\,K) \rightarrow \cancel{T_3 = 797.21\,K} \cancel{\boxed{= 524.1\,°C}}$

c.) $\eta_{\theta} = \frac{-w_{s,net}}{Q_{in}}$ $\therefore w_{s,net} = \eta_{\theta} \cdot Q_{in} = 0.59 \cdot 500 \frac{kJ}{kg}$
$\boxed{= 296.8 \frac{kJ}{kg}}$

b $500 \frac{kJ}{kg} = 2.5 \left(8.314 \frac{kJ}{kmol\,K}\right)(T_3 - 773.15) \cdot \frac{1\,kmol}{\cancel{0.02896\,kg}\ 28.647\,kg}$

$\cancel{T_3 = 773.85\,K \boxed{= 500.7\,°C}}$

$T_3 = 1469.8\,K \boxed{= 1197\,°C}$

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Q2

$\dot{m} = 2.5 \ kg/s$ $\quad$ $P_1 = 15 \ MPa$ $\quad$ $T_1 = 550°C$

$P_2 = 0.015 \ MPa$

Pump: 5 → 6

a.) $W_s' = H_6 - H_5 = V(P_6 - P_5) = 0.001014 \ \frac{m^3}{kg} (15000 - 15) \ kPa$

$= 15.19 \ \frac{kJ}{kg} \cdot 2.5 \ \frac{kg}{s}$ $\boxed{= 37.99 \ kW}$

b.) $W_s = \frac{W_s'}{\eta} = \frac{37.99 \ kW}{0.9}$ $\boxed{= 42.21 \ kW}$

c.) turbine: 3→4' $\quad$ $S_3 = S_4' = 6.523 \ \frac{kJ}{kg K}$

$\cancel{@15 \ kPa: \ \text{sat mix} \ \therefore \ q = \frac{S - S^L}{S^V - S^L} = \frac{6.523 - 0.7549}{8.0071 - 0.7549} = 0.7954}$

$\cancel{H_4' = (1-q)H^L + qH^V = (1 - 0.7954) \cdot 225.94 + (0.7954) \cdot 2598.3}$

$\cancel{= 2112.8 \ \frac{kJ}{kg}}$

$\eta_a = \frac{-W_{s,net}}{Q_H} = \cancel{\frac{-(-1200)}{1200 \ kW}}$

$\eta_a = \frac{-(-600 \ kW + 37.99 \ kW)}{1200 \ kW}$ $\boxed{= 0.47}$

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Q3

$P_1 = 1.2 MPa$
$P_2 = 0.07 MPa$

a.) ~~Throttle: $H_1 = H_4 \rightarrow H_1 =$~~

2: Sat vap $\therefore$ $H_2 = 273.87 \frac{kJ}{kg}$

b.) $W_s' = H_3' - H_2$ $\qquad S_3' = S_2 = 0.91303$

S	H	T
0.9105	276.12	50.4
0.91303		
0.9389	285.47	60

$$H_3' = 276.12 + \frac{(285.47 - 276.12)}{(0.9389 - 0.9105)} \cdot (0.91303 - 0.9105) = 276.95$$

$\therefore W_s' = 276.95 - 273.87 = 3.08 \frac{kJ}{kg}$

c. Saturated mixture

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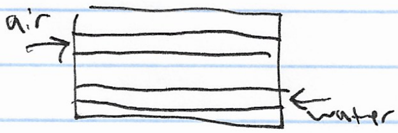
Q4

$\dot{m}_w = 5 \frac{kg}{s}$ $\quad T_{1w} = 22.5°C$ $\quad T_{2w} = ?$

$\dot{m}_A = 50 \frac{kg}{s}$ $\quad T_{1A} = 25°C$

$T_{2A} = 200°C$



$Q_w = \dot{m}\,\Delta H$ $\qquad Q_A = -Q_w = \dot{m}\,C_p(T_2 - T_1)$

$Q_A = -50 \frac{\cancel{kg}}{s} \cdot 3.5 \cdot 8.314 \frac{kJ}{\cancel{kmol}\,\cancel{K}} (175)\cancel{K} \cdot \frac{1\cancel{kmol}}{29\cancel{kg}}$

$= -8779.9\ kW \quad \therefore \quad Q_w = +8780\ kW$

$\cancel{\frac{kJ}{kg} \cdot \frac{kg\,K}{kJ} = K}$ $\quad \therefore \quad \frac{\cancel{kJ}}{\cancel{s}} \cdot \frac{\cancel{kg}\,K}{\cancel{kJ}} \cdot \frac{\cancel{s}}{\cancel{kg}} = K$

$\therefore\ 8780 \frac{\cancel{kJ}}{\cancel{s}} \cdot \frac{1\cancel{s}}{5\,kg} \cdot \frac{1\,kg\,K}{4.2\,kJ} = 418\ K \boxed{= 144.9°C}$

$Q = H_2 - H_1$

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Q5

$\dot{m} = 4\ kg/s$ $T_1 = 25°C$ $P_1 = 95\ kPa$

$Q = 0$ $\eta_c = 0.85$ $P_2 = 5000\ kPa$

$W_s' = \Delta H = C_p \Delta T = C_p (T_2 - T_1)$ $T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{R/C_P}$

$\therefore T_2 = 298.15 \left(\frac{5000\ kPa}{95\ kPa}\right)^{1/3.5} = 925.2\ K$

$\therefore W_s' = 3.5 \cdot 8.314 \frac{kJ}{kmol\,\cancel{K}} (-298.15 + 925.2)\cancel{K} = 18246 \frac{kJ}{kmol}$

$= 18246 \frac{kJ}{\cancel{kmol}} \cdot \frac{1\ \cancel{kmol}}{28\ \cancel{kg}} \cdot 4 \frac{\cancel{kg}}{s} \boxed{= 2607\ \cancel{kW}}$ ideal

$W_s = \frac{W_s'}{\eta_c} = \frac{2607\ kW}{0.85} \boxed{= 3066\ kW}$

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Q 6

$\chi_{CO_2} = 0.0004$ $V = 2.5\times10^9\ m^3$

$1\ m^3_{atm} = 42$ mol gas $atm = CO_2 + air$

$T_{atm} = 0°C$

$n_{tot} = 1.05\times10^{11}$ mol $\therefore n_{CO_2} = n_{tot} \cdot \chi_{CO_2} = 4.2\times10^7$ mol

$\therefore n_{air} = \cancel{1.05\times10} \ 1.049958\times10^{11}$ $\chi_{air} = 0.9996$

$W_s' = nT\Delta S_{mix}$ $\Delta S_{mix} = -R\sum x_i \ln x_i$

$\therefore \Delta S_{mix} = -R\left(0.0004 \ln(0.0004) + 0.9996 \cdot \ln(0.9996)\right)$

$= -R\cdot(-0.0035) = 0.029 \frac{kJ}{kmol\,K}$

$W_s' = 1.05\times10^{11}\ mol \cdot 273.15\ K \cdot 0.029 \frac{J}{mol\,K} = 8.416\times10^{11}\ J$

$= 8.416\times10^{11}\ J \cdot \frac{1\ MJ}{1000000\ J} = \cancel{8.42\ MJ}$

$\boxed{= 8.42\times10^5\ MJ}$