# Thermo HW 9

1.) $A = 100000 m^3$ $\quad Q_H = A \cdot Flux = 10^4 m^2 \cdot 275 \frac{W}{m^2} = 2.75 \times 10^7 W$

$Q_H = 2.75 \times 10^4$ kW

$W_{s,net\ claimed} = 1200 kW$

$Q_H = W_{s,net} + Q_C$ $\quad \eta_\theta = \frac{W_{s,net}}{Q_H} = \frac{1200 kW}{2.75 \times 10^4 kW} = 0.044$

$\eta_\theta = 1 - \frac{T_C}{T_H} = 0.06$

Since max $\boxed{\eta_\theta = 0.06}$ and the claimed $\boxed{\eta_\theta = 0.044,}$ This power output is possible

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2.) $V = 1 km^3$ $\quad \rho = 2600 \frac{kg}{m^3}$ $\quad C_p = 800 \frac{J}{kg K}$ $\quad T_H = 500K, T_C = 300K$

$Q_H = W_{s,net} + Q_C$ $\quad W_{out} = -\int_1^2 W_{s,net}\, dt$

$\eta_\theta = \frac{W_{s,net}}{Q_H}$ $\quad \therefore W_{out} = -\int_1^2 \eta_\theta Q_H\, dt$

$Q_H = \frac{dU}{dt} = \frac{mC\Delta T}{dt}$

$\therefore W_{out} = -\int_1^2 \eta_\theta \frac{mC dT}{\cancel{dt}} \cancel{dt}$

$= -mC\int_1^2 \left(1 - \frac{T_C}{T}\right) dT$

$= -mC\left[T - T_C \ln(T)\right]_1^2 = -mC\left[\Delta T - T_C \ln\left(\frac{T_f}{T_i}\right)\right]$

~~$\therefore W_{out} = \frac{2600\ kg}{1000000000}(800)\frac{J}{kgK}\left[200 - 300 \ln\left(\frac{3}{5}\right) K\right] = 0.735 J$~~

~~$\frac{W_{out}}{W_{s,net}} = \frac{0.735 J}{8000000 J/s} =$~~

$W_{out} = -2.6 \times 10^{12}\ kg\ (800) \frac{J}{kgK}\left[200 + 300 \ln\left(\frac{3}{5}\right)\right] = \cancel{7.348 \times 10^{17}}$

~~$\frac{W_{out}}{W_{s,net}} = \frac{7.35 \times 10^{17}}{8 \times 10^{+8}} =$~~ $\quad W_{out} = -9.724 \times 10^{16}$

$\frac{W_{out}}{-W_{s,net}} = \frac{-9.724 \times 10^{16}}{8 \times 10^8} = 1.22 \times 10^8 s$ $\boxed{= 4.2 \text{ Years}}$

3000000000

2 b.) ~~$1600 \times 10^{3}\ \cancel{kw} \cdot \frac{1\ kwhr}{3600\ \cancel{kw}} \cdot \frac{0.12}{\cancel{kwhr}} =$~~

$\frac{9.7 \times 10^{16}}{1 \times 10^{3}}\ \cancel{kJ} \cdot \frac{1\ kwhr}{3600\ \cancel{kw}} \cdot \frac{0.12}{\cancel{kwhr}}$ $\boxed{= \$3.24 \times 10^{9}}$

3.) $800\ kg/hr$ $\quad COP_R = 2.1 \quad$ \$0.14/kWhr

$COP_R = \frac{Q_c}{W_{s,net}}$ $\qquad$ Open: $0 = \dot{m}(H_{in} - H_{out}) - Q_c$

$H_{in} = 42.022 \frac{kJ}{kg}$ $\quad H_{out} = -337.63 \frac{kJ}{kg}$

$$Q_c = \frac{800\ kg}{hr}(42.022 + 337.63)\frac{kJ}{kg} = 303721.6\ \frac{kJ}{hr}$$

$$W_{s,net} = \frac{Q_c}{COP_R} = \frac{303721.6\ \frac{kJ}{hr}}{2.1} = 144629.3\ \frac{kJ}{hr} = 40.17\ kW$$

$$\frac{\$0.14}{1\ kWh} \cdot \frac{\cancel{\ }\ 1\ kWh}{3600\ kW} \cdot 40.17\ kW \cdot 3600 \cdot 24 \cdot 365 = \boxed{\$49{,}264/\text{year}}$$

4.) $T_1 = 550°C$ ~~[illegible]~~ $T_2 = ?$ $\dot{m} = 4.2 \frac{kg}{s}$

$P_1 = 10$ bar $P_2 = 0.5$ bar $w_{s,net} = 2.5$ MW

$0 = (H\dot{m})^{in} - (H\dot{m})^{out} + \cancel{Q} + w_s$

$S = S_2'$ if isentropic

$\eta_t = \frac{w}{w'} = \frac{\text{actual}}{\text{ideal}}$

$$S_1 = \frac{8.0311 + 7.7642}{2} = 7.898 \ \frac{kJ}{kg}$$

$$H_1 = \frac{3698.6 + 3479.1}{2} = 3588.85 \frac{kJ}{kg}$$

$S_2 = S_1$

$H_2$: $H_* = H_1 + \frac{(S - S_1)}{(S_2 - S_1)}(H_2 - H_1)$

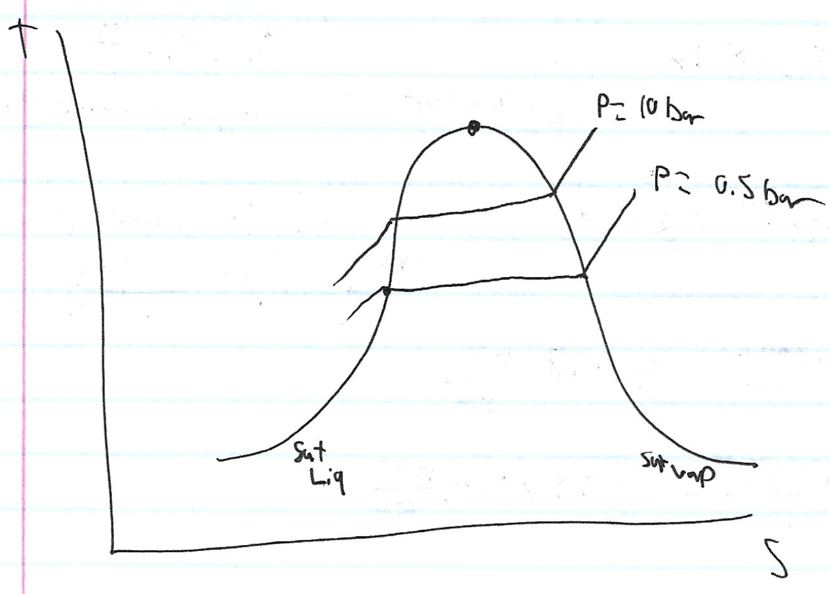
$$H_2 = 2682.4 + \frac{(7.898 - 7.6953)}{(7.9413 - 7.6953)}(2780.2 - 2682.4)$$

$$H_2 = 2762.99 \frac{kJ}{kg}$$

$$\therefore w' = H_2 - H_1 = (2762.99 - 3588.85) = \left(-825.864 \ \frac{kJ}{kg}\right) 4.2 \frac{kg}{s}$$

$w' = 3469$ kW

$$\eta_t = \frac{2500 \text{ kW}}{3469 \text{ kW}} \boxed{= 0.72 \therefore} \text{ Possible}$$


T
P = 10 bar
P = 0.5 bar
Sat
Liq
Sat vap
S

5) $T_1 = 298.15\,K$ $\quad P_2 = 4P_1$ $\quad Q = 0$ $\quad \frac{C_p}{R} = 2.5$

a.) $W_s = \Delta H + \cancel{Q}$ $\quad \Delta H = C_p \Delta T = C_p (T_2 - T_1) = C_p T_1 \left(\frac{T_2}{T_1} - 1\right)$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{R/C_p} \rightarrow \frac{T_2}{T_1} = 4^{1/2.5}$$

$$\therefore W_s = 2.5R \cdot 298.15\,K \left(4^{1/2.5} - 1\right)$$

$$= 2.5\left(8.314 \frac{kJ}{kmol\,\cancel{K}}\right) \cdot 298\,\cancel{K} \left(4^{(1/2.5)} - 1\right) = 4592.6 \frac{kJ}{kmol}$$

$M_{He} = 4 \frac{kg}{kmol}$ $\quad \therefore W_s' = \frac{4592.6 \frac{kJ}{\cancel{kmol}}}{4.0 \frac{kg}{\cancel{kmol}}} \boxed{= 1147.4 \frac{kJ}{kg}}$

B) $T_2 = \left(4^{1/2.5}\right) 298.15 = 519\,K \boxed{= 246°C}$

c) $W_s = \frac{W_s'}{\eta_o} = \frac{1147.4 \frac{kJ}{kg}}{0.7} \boxed{= 1639 \frac{kJ}{kg}}$