RETURN TO DR. THOMAS

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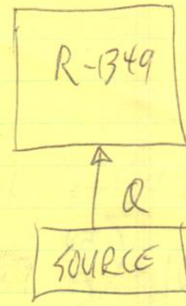
HOMEWORK #7 ~~6.34~~ 6.32, 6.39, ~~6.67~~ 6.73, 6.95, ~~6.99~~ 6-100, ~~6.100~~, ~~6.107~~ ~~6.110~~
6-102, 6-110

PROB. ~~6.34~~ 6.32



$V = 0.5\ m^3 \quad R\text{-}134a$

$P_1 = 200\ kPa, \quad X_1 = 0.4$

$P_2 = 400\ kPa \quad T_{HS} = 35°C$

FIND $\Delta S_R, \ \Delta S_{HS}, \ \Delta S_{TOTAL}$

$\Delta S_R = m(s_2 - s_1)$

$v = \frac{V}{m}, \quad m = \frac{V}{v}$

$v_1 = v_f + X_1 v_{fg} = (0.0007532) + (0.4)(0.0993 - 0.0007532)$

$v_1 = 0.04017\ \frac{m^3}{kg} = v_2$

$m = \frac{(0.5\ m^3)}{(0.04017\ \frac{m^3}{kg})} = 12.45\ kg$

$s_1 = s_f + X_1 s_{fg} = (0.1481) + (0.4)(0.9253 - 0.1481) = 0.459\ \frac{kJ}{kg\text{-}K}$

$U_1 = U_f + X_1 U_{fg} = (36.69) + (0.4)(221.43 - 36.69) = 110.59\ \frac{kJ}{kg}$

$X_2 = \frac{v_2 - v_f}{v_{fg}} = \frac{(0.04017) - (0.0007904)}{(0.0509) - (0.0007904)} = 0.7859$

$s_2 = s_f + X_2 s_{fg} = (0.2399) + (0.7859)(0.9145 - 0.2399) = 0.77\ \frac{kJ}{kg\text{-}K}$

$U_2 = U_f + X_2 U_{fg} = (61.69) + (0.7859)(231.97 - 61.69) = 195.5\ \frac{kJ}{kg}$

$$\Delta S_R = m(s_2 - s_1) = (12.45\ kg)(0.77 - 0.459\ \tfrac{kJ}{kg\text{-}K}) = \boxed{3.872\ \tfrac{kJ}{K}}$$

$$\Delta S_{HS} = \frac{Q}{T_S} \quad \underline{2^{ND}\ LAW}$$

$$Q - \overset{0}{W} = m(u_2 - u_1) \quad \text{FIRST LAW FOR R-134a}$$

$$Q = m(u_2 - u_1) = (12.45\ kg)(195.5 - 110.59\ \tfrac{kJ}{kg}) = 1057\ kJ$$

$$\Delta S_{HS} = \frac{-Q}{T_S} = \frac{-1057\ kJ}{35 + 273\ K} = \boxed{-3.432\ \tfrac{kJ}{K}}$$

$$\Delta S_{TOTAL} = \Delta S_R + \Delta S_{HS} = (3.872 - 3.432\ \tfrac{kJ}{K})$$

$$\boxed{\Delta S_{TOTAL} = 0.4398\ \tfrac{kJ}{K}}$$

PROB. 6.39

$Q = 0$ FIND T_2, W

$V_1 = \cancel{0.01}\ 0.05\ m^3$

$X_1 = 1$, $P_1 = 0.8\ MPa$

$P_2 = 0.4\ MPa$ $s_2 = s_1$ (REVERSIBLE, + ADIABATIC = ISENTROPIC)

PROB. 6-39 CONT.

$$m = \frac{V_1}{v_1}$$

$$v_1 = v_g \,(P_{sat} = 0.8 \text{ MPa}) = 0.0255 \ \frac{m^3}{kg}$$

$$u_1 = u_g = 243.78 \ \frac{kJ}{kg}$$

$$s_1 = s_g = 0.9066 \ \frac{kJ}{kg\text{-}K}$$

$$m = \frac{V_1}{v_1} = \frac{(\overset{0.05}{\cancel{0.01}} \ m^3)}{(0.0255 \ m^3/kg)} = \overset{1.961}{\cancel{0.392}} \ kg$$

$$s_2 = s_1 = 0.9066 \ \frac{kJ}{kg\text{-}K}$$

$$P_2 = 0.4 \text{ MPa} : \ s_f = 0.2399, \ s_g = 0.9145 \Rightarrow \text{SAT. MIX.}$$

$$T_2 = T_{sat}(0.4 \text{ MPa}) \boxed{= 8.93^\circ C}$$

FIRST LAW:

$$\overset{\nearrow 0}{Q} - W = m(u_2 - u_1)$$

$$W = -m(u_2 - u_1) = \cancel{-(0.392 \ kg)}$$

$$X_2 = \frac{s_2 - s_f}{s_{fg}} = \frac{(0.9066) - (0.2399)}{(0.9145) - (0.2399)} = 0.9883$$

$$u_2 = u_f + X_2 u_{fg} = (61.69) + (0.9883)(231.97 - 61.69) = 230 \ \frac{kJ}{kg}$$

$$W = -(\overset{1.961}{\cancel{0.392}} \ kg)(230 - 243.78 \ \frac{kJ}{kg})$$

$$\boxed{W = \cancel{5.41} \ kJ} \quad 27.02 \ kJ$$

PROB. ~~6.67~~ 6.73

$m_1 = 4\text{ kg Ar}$, $P_1 = 450\text{ kPa}$, $T_1 = 30°C$

$P_2 = 150\text{ kPa}$ ISENTROPIC PROCESS , FIND m_2

PERFECT GAS: $PV = mRT$

$\cancel{\frac{PV}{mT} = \text{CONST}}$ $\quad \frac{P}{mT} = \text{CONSTANT} = \frac{V}{R}$

$\cancel{\frac{P_1V_1}{m_1T_1} = \frac{P_2V}{}}$ $\quad \frac{P_1}{m_1T_1} = \frac{P_2}{m_2T_2}$

$$m_2 = m_1\left(\frac{T_1}{T_2}\right)\left(\frac{P_2}{P_1}\right)$$

ISENTROPIC RELATION:

$$\left(\frac{T_2}{T_1}\right)^{-1} = \left[\left(\frac{P_2}{P_1}\right)^{(k-1)/k}\right]^{-1}$$

$\cancel{\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{(k-1)/k}}$ $\quad \left(\frac{T_1}{T_2}\right) = \left(\frac{P_2}{P_1}\right)^{-(k-1)/k}$

$$m_2 = m_1\left(\frac{P_2}{P_1}\right)^{-(k-1)/k} \cdot \left(\frac{P_2}{P_1}\right)$$

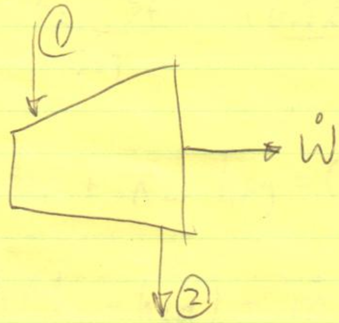
$$m_2 = m_1\left(\frac{P_2}{P_1}\right)^{[1-(k-1)/k]}$$

$$m_2 = m_1\left(\frac{P_2}{P_1}\right)^{1/k}$$

$$m_2 = (4\text{ kg})\left(\frac{150}{450}\right)^{1/1.667}$$

$$\boxed{m_2 = 2.069\text{ kg}}$$

PROB. 6.95



$\dot{Q} = 0$

$P_1 = 8 MPa, \; T_1 = 500°C$

$\dot{m} = 3 \frac{kg}{s}$

$P_2 = 30 \; kPa$

$\eta = 0.9$

FIND $T_2, \dot{W}$

$\dot{W} = -\dot{m}(h_{2a} - h_1) = \dot{m}(h_1 - h_{2a})$ 1ST LAW

$\eta = \frac{\dot{W}_a}{\dot{W}_s} \cong \frac{h_1 - h_{2a}}{h_1 - h_{2s}}$ NEGLECT ΔKE

$h_1 - h_{2a} = \eta(h_1 - h_{2s})$

NEED TO FIND h_1, h_{2s}

$h_1 = 3398.3 \frac{kJ}{kg}, \; s_1 = 6.724 \frac{kJ}{kg\text{-}K}$

ASSUME ISENTROPIC PROCESS TO FIND h_{2s} : $s_2 = s_1$

$s_2 = 6.724 \frac{kJ}{kg\text{-}K}, \; P_2 = 30 \; kPa$

AT $P_{sat} = 30 \; kPa, \; s_f = 0.9439, \; s_g = 7.7686 \Rightarrow$ SAT. MIX.

$T_2 = T_{sat} = 69.1°C$

PROB. 6.95 CONT.

$$X_{2s} = \frac{s_2 - s_f}{s_{fg}} = \frac{(6.724) - (0.9439)}{6.8247} = 0.8469$$

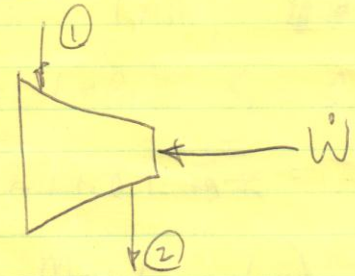
$$h_{2s} = h_f + X_{2s} h_{fg} = (289.23) + (0.8469)(2336.1) = 2268 \frac{KJ}{kg}$$

$$\dot{W} = \dot{m}(h_1 - h_{2a}) = \dot{m}\eta(h_1 - h_{2s})$$

$$\dot{W} = \left(3 \frac{kg}{s}\right)(0.9)\left(3398.3 - 2268 \frac{KJ}{kg}\right)$$

$$\boxed{\dot{W} = 3052 \text{ KW}}$$

PROB. ~~6.99~~ 6-100



$\dot{Q} = 0$

$X_1 = 1$, $P_1 = 120$ KPa, $\dot{V}_1 = 0.3 \frac{m^3}{MIN}$

$P_2 = 1$ MPa

$\eta = 0.8$

FIND T_2, $\dot{W}$, T-S DIAGRAM

$$\eta = \frac{W_s}{W_a} = \frac{h_{2s} - h_1}{h_{2a} - h_1}$$

$$\dot{W}_a = -\dot{m}(h_{2a} - h_1) = -\frac{\dot{m}}{\eta}(h_{2s} - h_1)$$

$$v = \frac{\dot{V}}{\dot{m}}, \quad \dot{m} = \frac{\dot{V}_1}{v_1}$$

$v_1 = v_g(P_{sat} = 120 \text{ KPa}) = 0.1614 \frac{m^3}{Kg}$, $T_1 = T_{sat}(120 \text{ KPa}) = -22.36$

$$\dot{m} = \frac{\left(0.3 \frac{m^3}{MIN}\right)}{\left(0.1614 \frac{m^3}{Kg}\right)} \cdot \left(\frac{MIN}{60 \text{ s}}\right) = 0.03098 \frac{Kg}{s}$$

$h_1 = h_g = 233.86 \frac{KJ}{Kg}$

$s_1 = s_g = 0.9354 \frac{KJ}{Kg\text{-}K}$

TO FIND h_{2s}, USE $s_2 = s_1 = 0.9354 \frac{KJ}{Kg\text{-}K}$

PROB. ~~6.99~~ 6-100 CONT.

AT $P_{sat} = 1\ MPa$, $s_g = 0.9043 \Rightarrow$ S.H.V.

AT $P_2 = 1\ MPa$, $s_2 = 0.9354\ \frac{kJ}{kg\text{-}K}$

$h_{2s} = 277.84\ \frac{kJ}{kg\text{-}K}$

$\dot{W}_a = -\frac{\dot{m}}{\eta}(h_{2s} - h_1)$

$\dot{W}_a = -\frac{(0.03098\ \frac{kg}{s})}{(0.8)} \cdot (277.84 - 233.86\ \frac{kJ}{kg})$

$\boxed{\dot{W}_a = -1.703\ kW}$

TO FIND THE ACTUAL EXIT TEMPERATURE, WE MUST FIND h_{2a}

$\dot{W}_a = -\dot{m}(h_{2a} - h_1)$

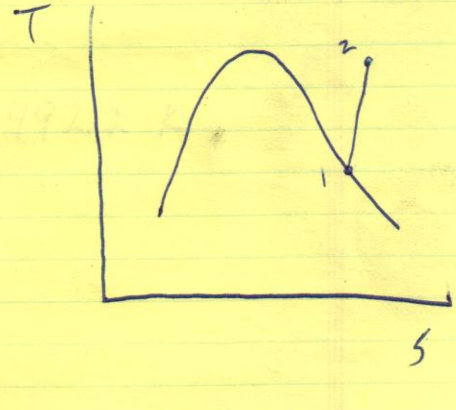
$h_{2a} = h_1 - \frac{\dot{W}_a}{\dot{m}}$

$h_{2a} = (233.86\ \frac{kJ}{kg}) - \frac{(-1.703\ kW)}{(0.03098\ \frac{kg}{s})}$

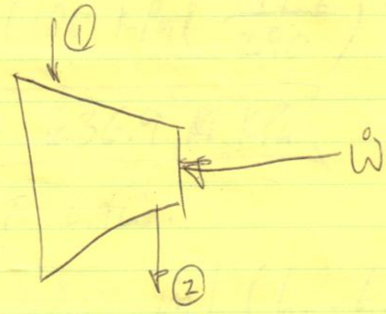
$\left.\begin{array}{l} h_{2a} = 288.8\ \frac{kJ}{kg} \\ P_2 = 1\ MPa \end{array}\right\}$

$\boxed{T_{2a} = 57.7\ °C}$

$s_{2a} \cong 0.96\ \frac{kJ}{kg\text{-}K}$



PROB. ~~6-100~~ 6-102



$\dot{Q} = 0$ AIR

$P_1 = 100$ kPa, $T_1 = 17°C$, $\dot{V}_1 = \cancel{1.2}\ 2.4\ \frac{m^3}{s}$

$T_2 = 257°C$

$\eta = 0.84$

FIND P_2, $\dot{W}_a$

ISENTROPIC EFFICIENCY:

$$\eta = \frac{W_s}{W_a} = \frac{h_{2s} - h_1}{h_{2a} - h_1}$$

$$h_{2s} = h_1 + \eta (h_{2a} - h_1)$$

$$h_{2s} = (290.16) + (0.84)(533.98 - 290.16)$$ TABLE A-17 p. 923

$$h_{2s} = 495 \ \frac{kJ}{kg}$$

FROM TABLE A-17, $T_{2s} = 492.2$ K

ISENTROPIC RELATION:

$$\left(\frac{T_2}{T_1}\right)_s = \left(\frac{P_2}{P_1}\right)^{(k-1)/k}$$

$$P_2 = P_1 \left(\frac{T_2}{T_1}\right)^{\frac{k}{k-1}}$$

PROB. ~~6.100~~ 6-102 CONT.

$$P_2 = (100\ kPa)\left(\frac{492.2}{290}\right)^{\frac{1.4}{0.4}}$$

$$\boxed{P_2 = 636.9\ kPa}$$

FIRST LAW:

$$\cancel{\dot{Q}}^{0} - \dot{W} = \dot{m}\left[(h_2 - h_1) + \cancel{\Delta KE}^{0} + \cancel{\Delta PE}^{0}\right]$$

$$\dot{W} = -\dot{m}(h_{2a} - h_1)$$

$$\dot{m} = \frac{\dot{V}_1}{v_1}$$

IDEAL GAS:

$$Pv = RT$$

$$v_1 = \frac{RT_1}{P_1}$$

$$\dot{m} = \frac{\dot{V}_1 P_1}{RT_1} = \frac{(\cancel{1.2}\ 2.4\ \frac{m^3}{s})(100\ kPa)}{(0.287\ \frac{kJ}{kg\text{-}K})(290\ K)} = \cancel{1.442}\ 2.883\ \frac{kg}{s}$$

$$\dot{W} = -(\cancel{1.442}\ 2.883\ \frac{kg}{s})(533.98 - 290.16\ \frac{kJ}{kg})$$

$$\boxed{\dot{W} = -\cancel{351}\ kW}$$

703.1 kW

PROB. ~~6.107~~ 6-110

~~FIRST~~ $T_{in,s} = 50°C$

~~$h_{fg} = 2305 \frac{kJ}{kg}$~~

~~$C_p = 4.2 \frac{kJ}{kg-K}$~~

$T_{in,cw} = 18°C$, $T_{OUT,cw} = 27°C$, $\dot{m}_{cw} = 101 \frac{kg}{s}$

FIND $\dot{m}_s$, $\dot{S}_{gen}$

FOR THE COOLING WATER,

$$\dot{Q} = \dot{m} C_p (T_2 - T_1) = \dot{m}(h_2 - h_1)$$

$$\cancel{\dot{m} = \frac{\dot{Q}}{C_p(T_2 - T_1)}} = \left(101 \frac{kg}{s}\right)\left(\overset{4.18}{\cancel{4.2}} \frac{kJ}{kg-K}\right)(27 - 18\ K)$$

$\dot{Q} =$ ~~3818 kW~~ 3800 kW

FOR THE STEAM,

$$\dot{Q} = \dot{m}(h_2 - h_1) = \dot{m} h_{fg}$$

$$\dot{m}_s = \frac{\dot{Q}}{h_{fg}} = \frac{(\overset{3800}{\cancel{3818}}\ kW)}{(\underset{\cancel{186}\ 2382.7}{\cancel{2305}}\ \frac{kJ}{kg})} = \overset{1.595}{\cancel{1.656}} \frac{kg}{s}$$

PROB. ~~6-107~~ 6-110 CONT.

2ND LAW FOR A STEADY FLOW PROCESS:

$$\dot{S}_{gen} = \sum \dot{m}_e s_e - \sum \dot{m}_i s_i - \cancel{\sum \frac{\dot{Q}_K}{T_K}}^{\,0}$$

$$\dot{S}_{gen} = \dot{m}_s s_{e,s} + \dot{m}_{cw} s_{e,cw} - \dot{m}_s s_{i,s} - \dot{m}_{cw} s_{i,cw}$$

$$\dot{S}_{gen} = \dot{m}_s (s_e - s_i)_s + \dot{m}_{cw}(s_e - s_i)_{cw}$$

$$\cancel{\dot{S}_{gen} = \dot{m}_s \left(C \ln \frac{T_2}{T_1}\right)}$$

$$\dot{S}_{gen} = \dot{m}_s (s_f - s_g) + \dot{m}_{cw} \cdot C \ln \frac{T_2}{T_1} \qquad s_{fg} = s_g - s_f$$

$$\dot{S}_{gen} = -\dot{m}_s s_{fg} + \dot{m}_{cw} C \ln \frac{T_2}{T_1}$$

$$\dot{S}_{gen} = -\left(\cancel{1.656}\ 1.595 \frac{kg}{s}\right)\left(7.3725 \frac{kJ}{kg-K}\right)$$

$$+ \left(101 \frac{kg}{s}\right)\left(\cancel{4.2}\ 4.18 \frac{kJ}{kg-K}\right) \ln\left(\frac{27+273}{18+273}\right)$$

$$\boxed{\dot{S}_{gen} = \cancel{0.7119}\ 0.1096 \frac{kW}{K}}$$

$1.102 \frac{kW}{K}$