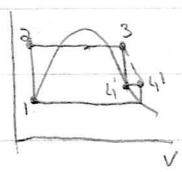
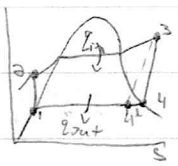
Jordan Whitaker

HW 2.2

18.





$h_1 = h_f = 94.02$ Btu/lbm

$V_1 = V_f = 0.016230$ ft³/lbm

$w_{p,in} = V_1 (P_2 - P_1)$

$= 0.016230 (1500 - 2)\left(\frac{1 \text{ Btu}}{5.404 \text{ psia} \cdot \text{ft}^3}\right)$

$= 4.550$ Btu/lbm

$h_2 = h_1 + w_{p,in}$

$= 94.02 + 4.550$

$= 98.572$ Btu/lbm

$s_3 = s_{4'} = 1.55$ Btu/lbm·R

$P_3 = 1500$ psia

$T_3 = 800$°F

$P_4 = 2$ psia

$s_f = 0.1750$ Btu/lbm·R

$s_{fg} = 1.7414$ Btu/lbm·R } saturated water-pressure table

$h_{fg} = 1025$ Btu/lbm

$h_3 = 1363.1$ Btu/lbm

$x_{4'} = \frac{s_{4'} - s_f}{s_{fg}}$

$= \frac{1.55 - 0.1750}{1.7414}$

$= 0.7965$

$h_{4'} = h_f + x_{4'} h_{fg}$

$= 94.02 + 0.7965 (1021.7)$

$= 873.86$ Btu/lbm

$\eta_T = \frac{h_3 - h_4}{h_3 - h_{4'}}$

$0.90 = \frac{1363.1 - h_4}{1363.1 - 873.86}$

$= 922.78$ Btu/lbm

$q_{out} = h_4 - h_1$

$= 922.78 - 94.02$

$= 830$ Btu/lbm

$q_{in} = h_3 - h_2$

$= 1363.1 - 98.572$

$= 1264.6$ Btu/lbm

$W_{net} = 1264.6 - 830$

$= 434.6$ Btu/lbm

$\dot{m} = \frac{\dot{W}_{net}}{w_{net}}$

$= \frac{2500\ kJ/s}{435.8\ Btu/lbm}\left(\frac{0.94782\ Btu}{1\ kJ}\right)$

$= 5.437\ lbm/s$

$\dot{W}_{T,out} = \dot{m}(h_3 - h_4)$

$= 5.437(1363.1 - 922.78)\left(\frac{1\ kJ}{0.94782\ Btu}\right)$

$= 2526.8\ kW$

$\dot{Q}_{in} = \dot{m} q_{in}$

$= (5.437)(1264.6)$

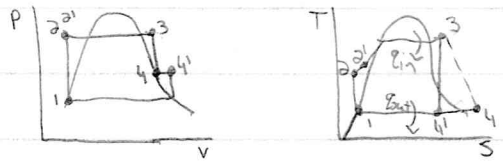
$= 6875.6\ Btu/s$

$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}}$

$= \frac{2500}{6875.6}\left(\frac{0.94782\ Btu}{1\ kJ}\right) \times 100$

$= 34.46\%$

(2c)



$T_3 = 147°C$

$P_3 = 3250\ kPa$

$h_3 = 761.54\ kJ/kg$

$s_3 = 2.5457\ kJ/kg \cdot K$

$T_4 = 179.5°C$

$P_4 = 410\ kPa$

$h_4 = 689.74\ kJ/kg$ (superheated, Isp. table)

$s_3 \Rightarrow s_4' = 2.5457\ kJ/kg \cdot K$

$h_4' = 670.4\ kJ/kg$

a) $\eta_T = \frac{h_3 - h_4}{h_3 - h_4'}$

$= \frac{761.54 - 689.74}{761.54 - 670.4} \times 100$

$= 78.77\%$

$P_1 = 410\ kPa$

$h_1 = 273.01\ kJ/kg$ (Sat. Isp. table)

$V_1 = 0.001842\ m^3/kg$ (Sat. Isp. table)

$h_2 = h_1 + w_{p,in}$

$= 273.01 + 5.81$

$h_2 = 278.82\ kJ/kg$

b) $w_{p,in} = \frac{V_1(P_2 - P_1)}{\eta_p}$

$= \frac{0.001842(3250 - 410)}{0.9}$

$= 5.81\ kJ/kg$

$\dot{W}_{T,out} = \dot{m}(h_3 - h_4)$

$= 305.6(761.54 - 689.74)$

$= 21942.08\ kW$

$\dot{W}_{p,in} = \dot{m} w_{p,in}$

$= 305.6(5.81)$

$= 1775.5\ kW$

$\dot{W}_{net} = \dot{W}_{T,out} - \dot{W}_{P,in}$

$= 21941.08 - 1775.5$

$\boxed{\dot{W}_{net} = 20166 \text{ kW}}$

c) $\dot{Q}_{in} = \dot{m}_{gas} C_{gas} (T_{in} - T_{out})$

$= 555.9 \times 1.118 (162 - 90)$

$\boxed{= 16765 \text{ kW}}$

$\eta_{th} = \dfrac{\dot{W}_{net}}{\dot{Q}_{in}}$

$= \dfrac{20166}{16765} \times 100$

$\boxed{\eta_{th} = 18.39\ \%}$

(3) 

$P_1 = 20 \text{ kPa}$

$h_1 = 251.42 \text{ kJ/kg}$ } Sat. Water Press. table

$V_1 = 0.001017 \text{ m}^3/\text{kg}$ }

$h_2 = h_1 + W_{P,in}$

$= 251.42 + 5.065$

$h_2 = 256.49 \text{ kJ/kg}$

$W_{P,in} = V_1 (P_2 - P_1)$

$= 0.001017 (5000 - 20) \left(\frac{1 \text{ kJ}}{1 \text{ kPa} \cdot \text{m}^3}\right)$

$\boxed{= 5.065 \text{ kJ/kg}}$

$P_4 = 1200 \text{ kPa}$

$h_f = 798.33 \text{ kJ/kg}$ } Sat. Water Press. table

$h_{fg} = 1985.4 \text{ kJ/kg}$ }

$h_4 = h_f + x_4 h_{fg}$

$= 798.33 + (0.96)(1985.4)$

$h_4 = 2724.3 \text{ kJ/kg}$

$s_f = 2.2159 \text{ kJ/kg·K}$

$s_{fg} = 4.3058 \text{ kJ/kg·K}$

$s_4 = s_f + x_4 s_{fg}$

$= 2.2159 + 0.96(4.3058)$

$s_4 = 6.3494 \text{ kJ/kg·K}$

$s_3 = s_4$

$h_3 = h_{s=6.21} + (h_{s=6.45} - h_{s=6.21})\left(\frac{s_3 - s_{6.21}}{s_{6.45} - s_{6.21}}\right)$

$= 2925.7 + (3069.3 - 2925.7)\left(\frac{6.3494 - 6.21}{6.3494 - 6.21}\right)$

$h_3 = 3068.27 \text{ kJ/kg}$

$P_6 = 20 \text{ kPa}$

$h_f = 251.42 \text{ kJ/kg}$ } sat. water press. table

$h_{fg} = 2357.5 \text{ kJ/kg}$ }

$h_6 = h_f + x_6 h_{fg}$

$= 251.42 + 0.96(2357.5)$

$h_6 = 2514.6 \text{ kJ/kg}$

$s_f = 2.8320 \text{ kJ/kg·K}$ } sat. water press. table

$s_{fg} = 7.0752 \text{ kJ/kg·K}$ }

$s_6 = s_f + x_6 s_{fg}$

$= 2.8320 + 0.96(7.0752)$

$s_6 = 7.6241 \text{ kJ/kg·K}$

$s_5 = s_6$

$h_5 = h_{s=7.38} + (h_{s=7.68} - h_{s=7.38})\left(\frac{s_5 - s_{7.38}}{s_{7.68} - s_{7.38}}\right)$

$= 3261.3 + (3477 - 3261.3)\left(\frac{7.6241 - 7.3793}{7.6779 - 7.3793}\right)$

$h_5 = 3438.2 \text{ kJ/kg}$

Same thing, solve w/ Temps.

$T_3 = 300 + (350 - 300)\left(\frac{6.3494 - 6.21}{6.3494 - 6.21}\right)$

$= 328.75°C$

$T_5 = 400 + (500 - 400)\left(\frac{7.6241 - 7.3793}{7.6779 - 7.3793}\right)$

$T_5 = 482.01°C$

$q_{in} = (h_3 - h_2) + (h_5 - h_4)$

$= (3068.27 - 2961.48) + (3438.2 - 2734.3)$

$= 3482.7 \text{ kJ/kg}$

$q_{out} = h_6 - h_1$

$= 2514.6 - 251.42$

$= 2263.2 \text{ kJ/kg}$

$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} \times 100$

$= 1 - \frac{2263.2}{3482.7} \times 100$

$\eta_{th} = 35.01\%$

$T_3 = 328.75°C$

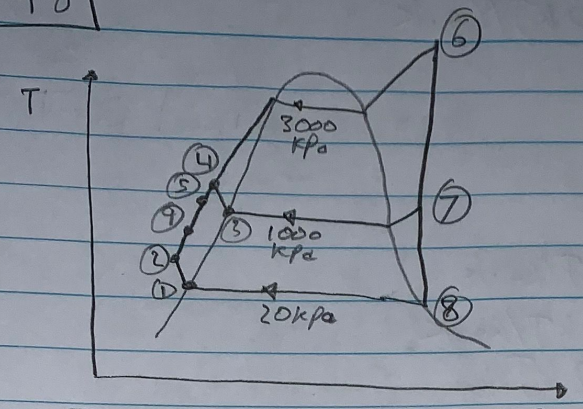
$T_5 = 482.01°C$

$\eta_{th} = 35.01\%$

MET 350

HW 2-1

10-48



T-s cycle Ideal Regen-Rankine cycle

$T_6 = 350^\circ C$

$P_6 = 3000 kPa$ from table A-6

$\Rightarrow h_6 = 3116.1 kJ/kg$

$\Rightarrow s_6 = s_7 = 6.7450 kJ/kg \cdot K$

$s_1 = 6.6956 kJ/kg \cdot k$ $\quad h_1 = 2828.3 kJ/kg$

$s_2 = 6.9265 kJ/kg \cdot k$ $\quad h_2 = 2943.1 kJ/kg$

$$\frac{s - s_1}{s_2 - s_1} = \frac{h_7 - h_1}{h_2 - h_1}$$

$\Rightarrow h_7 = 2852.86 kJ/kg$

$T_1 = 200^\circ C$

$T_2 = 250^\circ C$

$$\frac{T_7 - T_1}{T_2 - T_1} = \frac{s - s_1}{s_2 - s_1}$$

$\Rightarrow T_7 = 210.69^\circ C$

$s_8 = s_7 = 6.7450\ kJ/kg \cdot k$

$P_8 = 20\ kPa$
$\Rightarrow$ Table A-6
$\Rightarrow s_f = 0.832\ kJ/kg \cdot k$
$s_{fg} = 7.0752\ kJ/kg \cdot k$
$h_f = 251.42\ kJ/kg$
$h_{fg} = 2357.5\ kJ/kg$
$v_f = 0.00107\ m^3/kg$
$T_8 = 60.06^\circ C$

$s_8 = s_f + x_8 s_{fg}$
$\Rightarrow x_8 = 0.836$

$h_8 = h_f + x_8 h_{fg}$
$\Rightarrow h_8 = 2222.3\ kJ/kg$

$h_1 = h_f = 251.42\ kJ/kg$
$s_1 = s_f = s_2 = 0.832\ kJ/kg \cdot k$
$T_1 = 60.06^\circ C$

$h_2 - h_1 = v_1 (P_2 - P_1)$
$\Rightarrow h_2 = 254.45\ kJ/kg$

$s_4 = s_3 = 2.1381\ kJ/kg \cdot k$

$h_4 - h_3 = v_3 (P_2 - P_1)$

$\Rightarrow h_4 = 765 kJ/kg$

$s_4 = 2.1381 \; kJ/kg \cdot K$

$T_4 = 180.2°C$

$h_4 - h_{f@179.88} = v_3 (P_4 - P_3)$

$\Rightarrow h_4 = 764.76 \; kJ/kg$

$T_4 = 179.88°C$

$y(h_7 - h_5) = (1-y)(h_4 - h_2)$

$\Rightarrow y = 0.196$

$W_t = (h_6 - h_7) + (1-y)(h_7 - h_8)$

$\Rightarrow \boxed{W_t = 770 \; kJ/kg}$ — Work produced by turbine

$W_p = (1-y)(h_2 - h_1) + y(h_4 - h_2)$

$\Rightarrow \boxed{W_p = 3 \; kJ/kg}$ — work consumed by pump

$h_5 = y h_4 + (1-y) h_8$

$\Rightarrow h_5 = 764.8 kJ/kg$

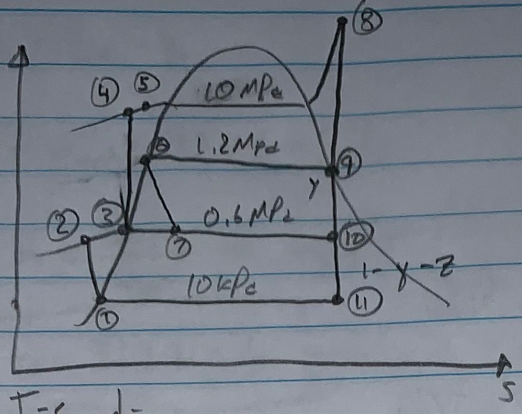
$Q_s = h_6 - h_5$

$\Rightarrow \boxed{2351.3 kJ/kg}$ — heat supplied to the boiler

MET 350

HW 2-1

10-53



T-s diagram

$h_1 = h_{f@10kPa} = 191.81\ kJ/kg$

$v_1 = v_{f@10kPa} = 0.00101\ m^3/kg$

$W_{PI,in} = v_1(P_2 - P_1)$

$= (0.00101 m^3/kg)(600 - 10 kPa)\left(\frac{1 kJ}{1 kPa \cdot m^3}\right)$

$= 0.5959\ kJ/kg$

$h_2 = h_1 + W_{PI,in} = 192.40\ kJ/kg$

$W_{PII,in} = (0.001101 m^3/kg)(10,000 - 600 kPa)$

$= 10.35\ kJ/kg$

$h_4 = h_3 + W_{PII,in}$

$h_4 = 680.73\ kJ/kg$

$s_8 = s_9 = s_{10} = s_{11} = 6.9045\ kJ/kg \cdot K$

$$x_{11} = \frac{s_{11} - s_{f11}}{s_{fg,11}}$$

$$x_{11} = 0.8341$$

$$h_{11} = h_{f11} + x_{11} h_{fg,11}$$

$$\Rightarrow h_{11} = 2187\ kJ/kg$$

$$y(h_9 - h_6) = 1(h_5 - h_4)$$

$$y = \frac{h_5 - h_4}{h_9 - h_6}$$

$$y = 0.05404$$

$$z = \frac{h_3 - h_2 - y(h_7 - h_2)}{h_{10} - h_2}$$

$$\Rightarrow z = 0.1694$$

$$q_{in} = h_8 - h_5$$

$$\Rightarrow q_{in} = 2827.5\ kJ/kg$$

$$q_{out} = (1 - y - z)(h_{11} - h_1)$$

$$\Rightarrow q_{out} = 1549.5\ kJ/kg$$

$$w_{net} = q_{in} - q_{out}$$

$$\Rightarrow w_{net} = 1278 \text{ kJ/kg}$$

$$\dot{m} = \frac{\dot{W}_{net}}{w_{net}} = \frac{400}{1278}\left(\frac{10^3 \text{ kJ/s}}{1 \text{ MW}}\right)$$

$$\boxed{\dot{m} = 313 \text{ kg/s}}$$ — mass flow rate

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}}$$

$$= 1 - 0.5480$$

$$\boxed{\eta_{th} = 45.2\%}$$ — thermal efficiency