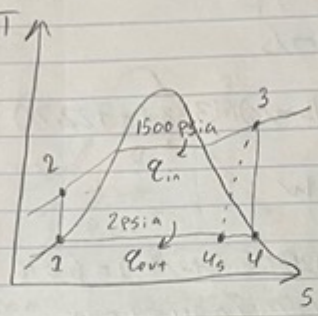
Colby Watts
350 HW 2.1
Professor Ayala
2/27/24

HW 2.1 Ch 10.: 18, 25, 34, 48, 53

10-18



$h_1 = h_f$ @ 2 psi = 94.02 Btu/lbm

$v_1 = v_f$ @ 2 psi = 0.016230 ft^3/lbm

$$w_{p,in} = v_1(P_2 - P_1)$$
$$= (0.016230\ ft^3/lbm)(1500-2)\ psia\left(\frac{1\ Btu}{5.404\ psia \cdot ft^3}\right)$$

$$= 4.50\ Btu/lbm$$

$$h_2 = h_1 + w_{p,in} = 94.02 + 4.50 = 98.52\ Btu/lbm$$

$P_3 = 1500$ psia, $T_3 = 800°F$ → $h_3 = 1363.1$ Btu/lbm, $s_3 = 1.5064$ Btu/lbm·R

$P_4 = 2$ psia, $s_4 = s_3$

$$x_{4s} = \frac{s_4 - s_f}{s_{fg}} = \frac{1.5064 - 0.1750}{1.7444} = 0.7633$$

$$h_{4s} = h_f + x_{4s} h_{fg} = 94.02 + (0.7633)(1021.7) = 873.86\ Btu/lbm$$

$$q_{in} = h_3 - h_2 = 1363.1 - 98.52 = 1264.6\ Btu/lbm$$
$$q_{out} = h_4 - h_1 = 922.79 - 94.02 = 828.8\ Btu/lbm$$
$$w_{net} = q_{in} - q_{out} = 1264.6 - 828.8 = 435.8\ Btu/lbm$$

$$\dot{W}_{net} = \dot{m} w_{net} \rightarrow \dot{m} = \frac{\dot{W}_{net}}{w_{net}} = \frac{2500\ kJ/s}{435.8\ Btu/lbm}\left(\frac{0.94782\ Btu}{1\ kJ}\right)$$

$$\dot{W}_{net} = 5.437\ lbm/s$$

$$\dot{W}_{T,out} = \dot{m}(h_3 - h_4) = (5.437\ lbm/s)(1363.1 - 922.79)\ Btu/lbm\left(\frac{1\ kJ}{0.94782\ Btu}\right)$$

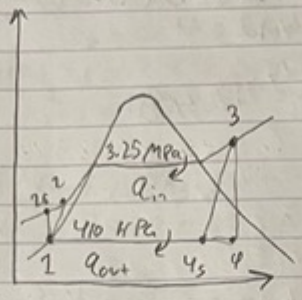
$$\dot{W}_{T,out} = 2526\ kW$$

$$Q_{in} = m q_{in} = (5.437\ lbm/s)(1264.6\ Btu/lbm) = 6876\ Btu/s$$

$$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = \frac{2500\ kJ/s}{6876\ Btu/s}\left(\frac{0.94782\ Btu}{1\ kJ}\right)$$

$$\eta_{th} = 34.5\%$$

10-25



Turbine:

$P_3 = 3250$ kPa, $T_3 = 147°C$ } $h_3 = 761.54$ kJ/kg, $S_3 = 2.5457$ kJ/kg·K

$P_4 = 410$ kPa, $S_4 = S_3$ } $h_{4s} = 670.40$ kJ/kg

$P_4 = 410$ kPa, $T_4 = 179.5°C$ } $h_4 = 689.74$ kJ/kg

$$\eta_T = \frac{h_3 - h_4}{h_3 - h_{4s}} = \frac{761.54 - 689.74}{761.54 - 670.40} = .788$$

Pump: $h_1 = h_f$ @ 410 kPa $= 273.01$ kJ/kg

$v_1 = v_f$ @ 410 kPa $= 0.001842$ m³/kg

$$w_{p,in} = v_1 (P_2 - P_1) / \eta_p$$
$$= (0.00182 \text{ m}^3/\text{kg})(3250 - 410)\text{kPa}\left(\frac{1\text{kJ}}{1\text{kPa}\cdot\text{m}^3}\right)/0.90$$
$$= 5.81 \text{ kJ/kg}$$
$$h_2 = h_1 + w_{p,in} = 273.01 + 5.81 = 278.82 \text{ kJ/kg}$$

$$\dot{W}_{T,out} = \dot{m}(h_3 - h_4) = (305.6 \text{ kJ/kg})(761.54 - 689.74)\text{ kJ/kg} = 21,941 \text{ kW}$$

$$\dot{W}_{p,in} = \dot{m}(h_2 - h_1) = \dot{m} w_{p,in} = (305.6)(5.81) = 1777 \text{ kW}$$

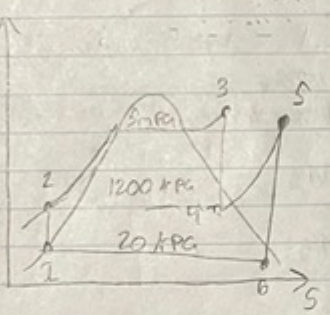
$$\dot{W}_{net} = \dot{W}_{T,out} - \dot{W}_{p,in} = 21,941 - 1777 = 20,165 \text{ kW}$$

$\dot{Q}_{in} = \dot{m}_{geo} C_{geo} (T_{in} - T_{out}) = (555.9)(4.18)(160-90)°C$

$\dot{Q}_{in} = 162,656$ kW

$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = \frac{20,165}{162,656} = 12.4\%$

10-34



$h_1 = h_f$ @ 20 kPa $= 251.42$ kJ/kg

$v_1 = v_f$ @ 20 kPa $= 0.0010172\ m^3/kg$

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

$= (0.0010172\ m^3/kg)(5000-20)$ kPa $\left(\frac{1\ kJ}{1\ kPa \cdot m^3}\right)$

$= 5.065$ kJ/kg

$h_2 = h_1 + W_{P,in} = 251.42 + 5.065 = 256.49$ kJ/kg

$P_4 = 1200$ kPa, $x_4 = 0.96$

$h_4 = h_f + x_4 h_{fg} = 798.33 + (0.96)(1965.4) = 2704.3$ kJ/kg

$s_4 = s_f + x_4 s_{fg} = 2.2159 + (0.96)(4.3058) = 6.3495$ kJ/kg·K

$P_3 = 5000$ kPa, $s_3 = s_4$

$h_3 = 3006.9$ kJ/kg

$T_3 = 372.2°C$

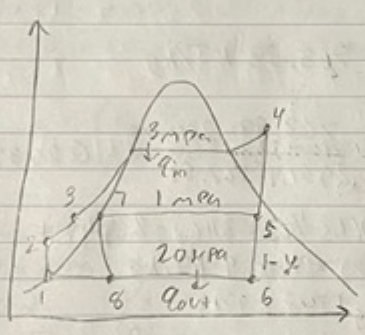
$P_6 = 20\ kPa$ $\left\{ h_6 = h_f + x_6 h_{fg} = 251.42 + (0.96)(2357.5) = 2514.6\ kJ/kg \right.$
$x_6 = 0.96$ $\left\{ s_6 = s_f + x_6 s_{fg} = 0.8320 + (0.96)(7.0752) = 7.6242\ kJ/kg \cdot K \right.$
$P_5 = 1200\ kPa$ $\left\{ h_5 = 3436.0\ kJ/kg \right.$
$s_5 = s_6$ $\left\{ T_5 = 461.1\ °C \right.$

$q_{in} = (h_3 - h_2) + (h_5 - h_4) = 3006.9 - 256.49 + 3436.0 - 2704.3$

$q_{in} = 3482.0\ kJ/kg$

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{2263.2}{3482.0} = 35\%$$

10-48



$h_1 = h_f @ 20\ kPa = 251.42\ kJ/kg$

$v_1 = v_f @ 20\ kPa = 0.001017\ m^3/kg$

$$w_{p,in} = v_1 (P_2 - P_1) = (0.001017\ m^3/kg)(3000 - 20)\ kPa \left(\frac{1\ kJ}{1\ kPa \cdot m^3} \right)$$

$h_2 = h_1 + w_{p,in} = 251.42 + 3.03 = 254.45\ kJ/kg$

$P_4 = 3000\ kPa$, $T_4 = 350°C$ $\Rightarrow$ $h_4 = 3116.1\ kJ/kg$, $s_4 = 6.7450\ kJ/kg \cdot K$

$P_5 = 1000\ kPa$, $s_5 = s_4$ $\Rightarrow$ $h_5 = 2851.9\ kJ/kg$

$P_6 = 20\ kPa$, $s_6 = s_4$

$$x_6 = \frac{s_6 - s_f}{s_{fg}} = \frac{6.7450 - 0.8320}{7.0752} = 0.8357$$

$$h_6 = h_f + x_6 h_{fg} = 251.42 + (0.8357)(2357.5)$$

$$h_6 = 2221.7\ kJ/kg$$

$P_7 = 1000\ kPa$, $x_7 = 0$ $\Rightarrow$ $h_7 = 762.51\ kJ/kg$, $T_7 = 179.9°C$

$s_8 = s_7 = 762.51\ kJ/kg$

$P_3 = 3000\ kPa$, $T_3 = T_7 = 209.9°C$ $\Rightarrow$ $h_3 = 763.53\ kJ/kg$

$$y = \frac{h_3 - h_8}{h_5 - h_7} = \frac{763.53 - 254.45}{2851.9 - 762.51} = 0.2437$$

$$W_{T,out} = h_4 - h_5 + (1-y)(h_5 - h_6) = 3116.1 - 2851.9 + (1 - 0.2437)(2851.9 - 2221.7) = 740.9\ kJ/kg$$

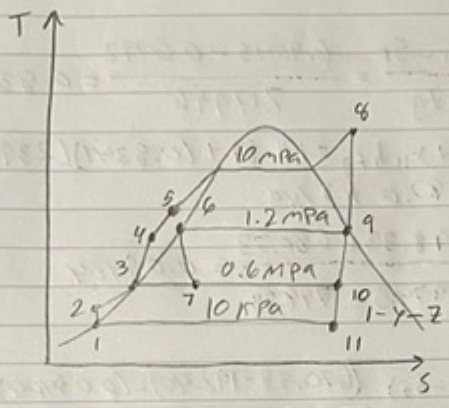
$$W_{P,in} = 3.03\ kJ/kg$$

$$q_{in} = h_4 - h_3 = 3116.1 - 763.53 = 2353\ kJ/kg$$

$$W_{net} = W_{T,out} - W_{P,in} = 740.9 - 3.03 = 737.8\ kJ/kg$$

$$\eta_{th} = \frac{W_{net}}{q_{in}} = \frac{737.8}{2353} = 0.3136$$

10-53



$h_1 = h_f$ @ 10 kPa = 191.81 kJ/kg

$v_1 = v_f$ @ 10 kPa = 0.00101 m^3/kg

$$W_{P1,in} = v_1(P_2 - P_1)$$
$$(0.00101\ m^3/kg)(600-10\ kPa)\left(\frac{1\ kJ}{1\ kPa \cdot m^3}\right)$$

$$h_2 = h_1 + W_{P1,in} = 191.81 + 0.60 = 192.40\ kJ/kg$$

$P_3 = 0.6$ MPa, Sat. liquid: $h_3 = h_f$ @ 0.3 MPa = 670.38 kJ/kg; $v_3 = v_f$ @ 0.3 MPa = 0.0010 m^3/kg

$$W_{PII,in} = v_3(P_4 - P_3)$$
$$= (0.00101\ m^3/kg)(10000 - 600\ kPa)\left(\frac{1\ kJ}{1\ kPa \cdot m^3}\right)$$
$$= 10.35\ kJ/kg$$

$$h_4 = h_3 + W_{PII,in} = 670.38 + 10.35 = 680.73\ kJ/kg$$

$P_6 = 1.2$ MPa, Sat. liquid: $h_6 = 3625.4$ kJ/kg; $s_6 = 6.9045$ kJ/kg·K

$P_8 = 1.2$ MPa, $s_8 = s_6$: $h_8 = 2974.5$ kJ/kg

$P_{10} = 0.6\ MPa$, $s_{10} = s_g$ $\Rightarrow h_{10} = 2620.9\ kJ/kg$

$P_{11} = 10\ kPa$, $s_{11} = s_g$

$$x_{11} = \frac{s_{11} - s_f}{s_{fg}} = \frac{6.9045 - 0.6492}{7.4996} = 0.8341$$

$$h_{11} = h_f + x_{11} h_{fg} = 191.81 + (0.8341)(2392.1)$$

$$h_{11} = 2187.0\ kJ/kg$$

$$y = \frac{h_3 - h_4}{h_9 - h_6} = \frac{798.33 - 680.73}{2974.5 - 798.33} = 0.05404$$

For open FWH

$$z = \frac{(h_3 - h_2) - y(h_7 - h_2)}{h_{10} - h_2} = \frac{(670.38 - 192.40) - (0.05404)(798.3 - 192.40)}{2820.9 - 192.40}$$

$$q_{in} = h_9 - h_5 = 3625.8 - 798.33 = 2827\ kJ/kg$$

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

$$q_{out} = (1 - 0.05404 - 0.1694)(2187.0 - 191.81)$$

$$q_{out} = 1549\ kJ/kg$$

$$\dot{m} = \frac{\dot{W}_{net}}{w_{net}} = \frac{400{,}000\ kJ/s}{1278\ kJ/kg} = 313.0\ kg/s$$

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{1549\ kJ/kg}{2827\ kJ/kg} = 45.2\ \%$$