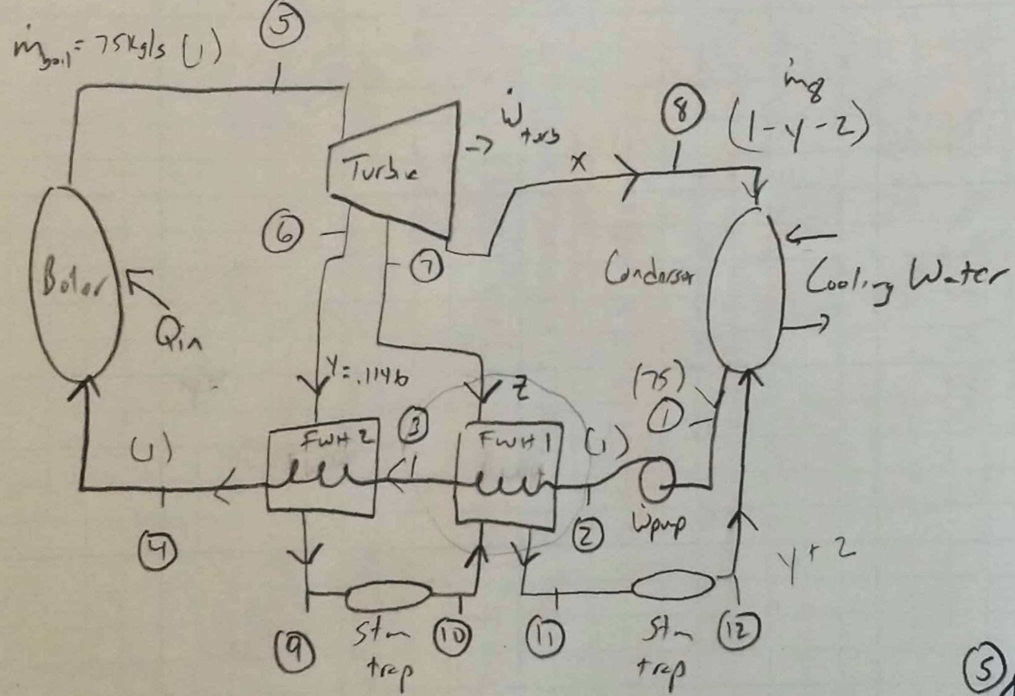
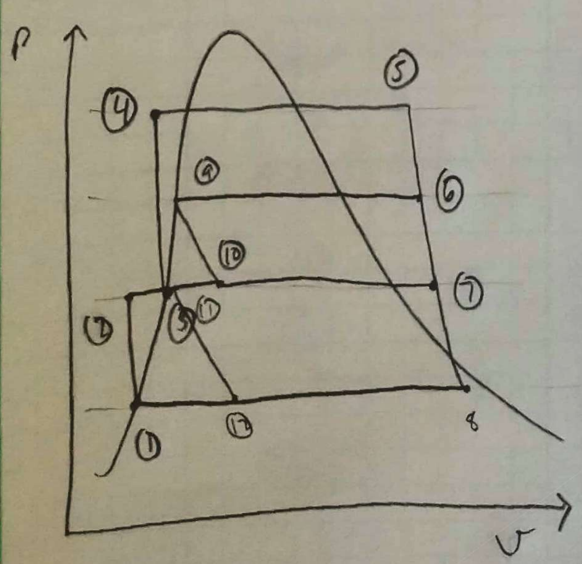
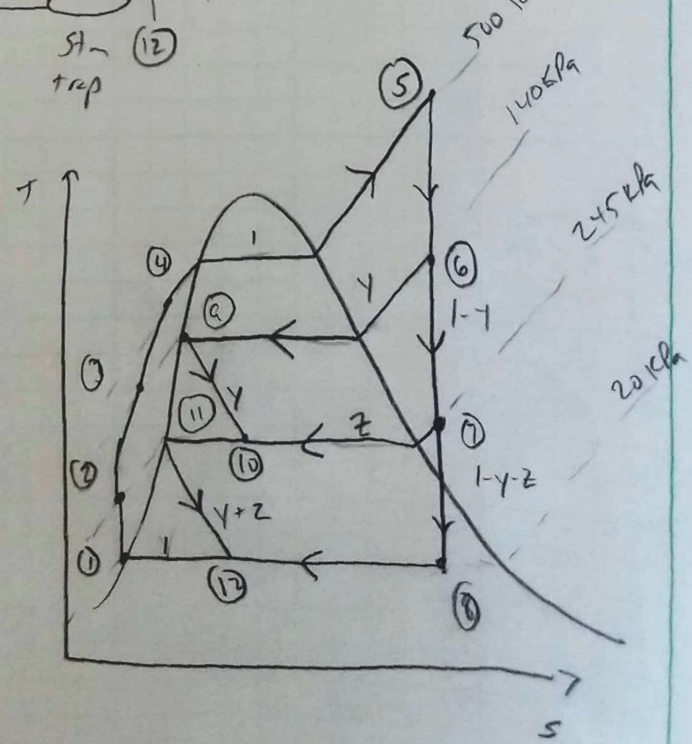
10-57

- Ideal Rankine w/ modifications
- 2 closed feedwater heaters
- $\dot{m}$ turbine inlet is 75 kg/s

- $c_p = 4.18$ kJ/kg-K for cooling water
- $\Delta T_{\text{cooling water}} = 10°C$







10-57

MET 350

HW 3.2

ML SUNDERLAND

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫
$P_1 = 20\,kPa$	$P_2 = 5000\,kPa$	$P_3 = 5000\,kPa$	$P_4 = 5000\,kPa$	$P_5 = 5000\,kPa$	$P_6 = 1400\,kPa$	$P_7 = 245\,kPa$	$P_8 = 20\,kPa$	$P_9 = 1400\,kPa$	$P_{10} = 245\,kPa$	$P_{11} = 245\,kPa$	$P_{12} = 20\,kPa$
$h_1 = 251.42$	$h_2 = 255.79$	$h_3 = 535.35$		$T_5 = 700°C$	$h_6 = 3406\,kJ/kg$	$h_7 = 2918\,kJ/kg$	$h_8 = 2477\,kJ/kg$	$x = 0$	$h_{10} = 829.96$	$x = 0$	$h_{12} = 535.35$
$v_1 = .00107$				$h_5 = 3900\,kJ/kg$	$s_6 = 7.512$	$s_7 = 7.512$	$s_8 = 7.512$	$h_9 = 829.96$		$h_{11} = 535.35$	
				$s_5 = 7.512$							

$$h_2 = h_1 + v_1(P_2 - P_1)$$

$$= 251.42 + .00107\left(4080\,\cancel{kPa}\,\frac{\cancel{1000\,Pa}}{1\,\cancel{kPa}}\,\frac{1\,N}{1\,Pa\,m^2}\,\frac{m^3}{\cancel{kg}}\,\frac{1\,kJ}{1000\,J}\right)$$

$$h_2 = 255.79\ kJ/kg$$

$$-h_4(75) + h_3(75) + h_6(\cancel{.1146}\ 10.845) - h_9(\cancel{.1146}\ 10.84) = 0$$

$$h_4 = \frac{535.35(75) + 3406(10.845) - 829.96(10.845)}{75}$$

$$h_4 = 908.28\ kJ/kg$$

Control Volume for FWH 1 to find z

$$h_2 + h_7(z) + h_{10}(y) - h_{11}(y+z) - h_3 = 0$$

$$h_2 + zh_7 + yh_{10} - yh_{11} - zh_{11} - h_3 = 0$$

$$z = \frac{h_3 + yh_{11} - yh_{10} - h_2}{h_7 - h_{11}}$$

$$z = \frac{535.35 + .1146(535.35) - .1146(829.96) - 255.79}{2918 - 535.35}$$

$$z = .1032 \Rightarrow \boxed{10.3\%}$$

Control Volume for Condenser for $\dot m_w$

$$\dot m_8 h_8 - \cancel{\dot m_1 h_1} - \left[\dot m_w h_{w,inlet} - \dot m_w h_{w,outlet}\right] + \dot m_{12} h_{12} = 0$$

$$\dot m_w (h_{w,inlet} - h_{w,out})$$

$$\dot m_w (c_p \Delta T)$$

$$\dot m_w = \frac{-\dot m_1 h_1 + \dot m_8 h_8 + \dot m_{12} h_{12}}{c_p \Delta T}$$

$$= \frac{75(251.42) + 75(1 - .1032 - .1146)2477 + 75(.1032 + .1146)(535.35)}{4.18(10)}$$

$$\boxed{\dot m_w = 3234.5\ kg/s}$$

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Find $\dot{W}_{net}$ and η_T

$\eta_T = \frac{W_{net}}{Q_{in}}$

$y = .1146$
$z = .1032$
$x = 1 - y - z = .7822$

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

$\dot{W} = w\,\dot{m}$

$w = \Delta h$

$Q_{in} = 75(h_5 - h_4)$
$= 75(3900 - 908.28)$
$\dot{Q}_{in} = 224{,}379 \text{ KW}$

$w_{t,out} = h_5 - y(h_6) - z(h_7) - x(h_8)$
$= 3900 - .1146(3400) - .1032(2918)$
$- .7822(2477)$

$\boxed{w_{t,out} = 1271.03 \text{ KJ/kg}}$

$w_{p\,in} = (h_2 - h_1)$
$= -(255.79 - 251.42)$
$w_{in} = 4.37 \text{ KJ/kg}$

$\eta_t = \frac{w_{net}}{Q_{in}} = \frac{95000 \text{ KW}}{224{,}379 \text{ KW}}$

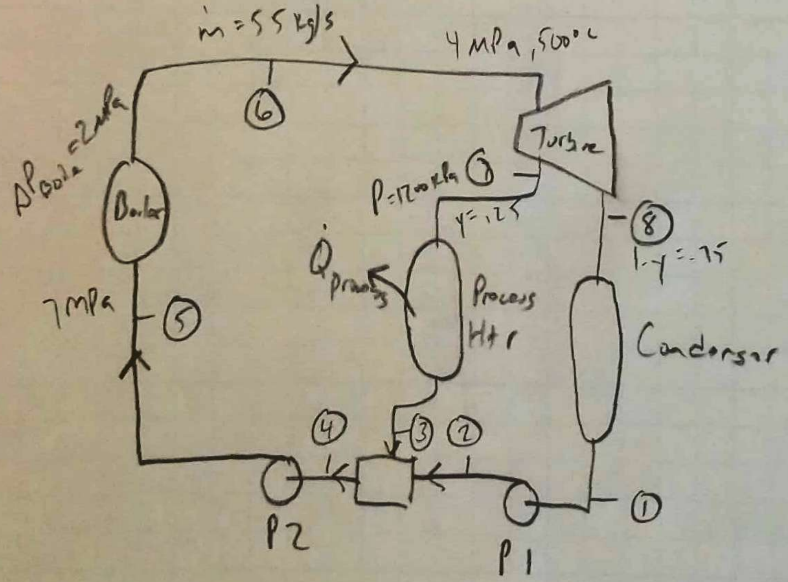
$\boxed{\eta_t = 47.3\%}$

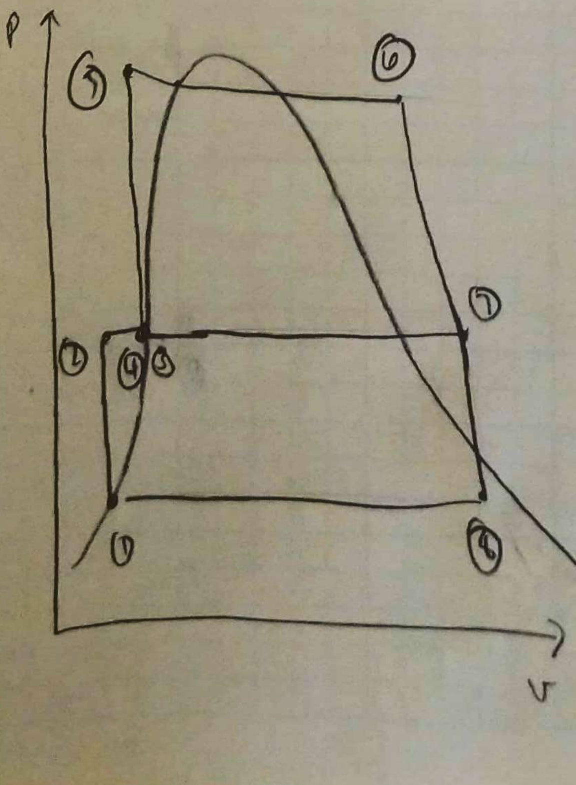
$w_{net} = w_{out} - w_{in} = 1271.03 - 4.37$
$w_{net} = 1266.7 \text{ KJ/kg}$

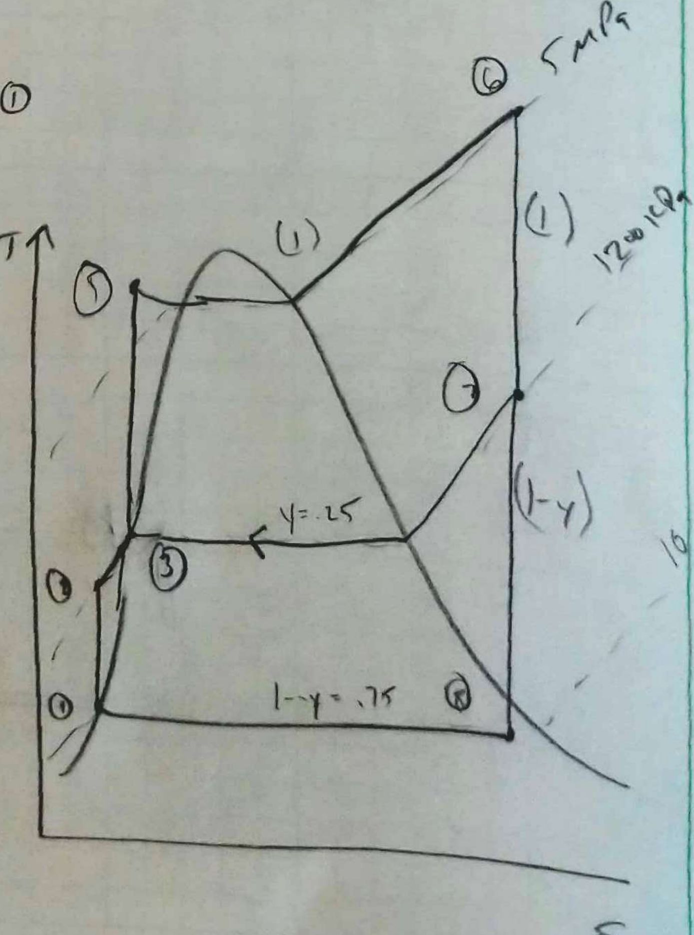
$\dot{W}_{net} = w_{net} \cdot 75$
$= 94{,}999 \text{ KW}$

10-69 Stm cogeneration plant

- Enters turbine @ 4 MPa, 500°C
- y = .25
- Process heating P = 1200 kPa
- Remainder expands to 10 kPa
- Boiler pressure is 7 MPa
- $\dot{m}_{boiler} = 55\ kg/s$







Pcont y = .25

Isent

Pcont

Isent

→ ① Pcont

① $\xrightarrow{\text{Isent}}$ ② ③ ④ ⟶ ⑤ $\xrightarrow{\text{P drop}}$ ⑥ $\xrightarrow{\text{Isent}}$ ⑦ ⑧

Pump

Pump

MET 350

HW 3.2

ML SUNDERLAND

① $P_1 = 10\,kPa$, $x = 0$, $h_1 = 191.81$, $v_1 = .00101$

② $P_2 = 1200\,kPa$, $h_2 = 193.01\,kJ/kg$

③ $P_3 = 1200\,kPa$, $h_3 = 798.33$

④ $v_4 = .001031$, $P_4 = 1200\,kPa$, $h_4 = 344.34\,kJ/kg$

⑤ $P_5 = 7\,MPa$, $h_5 = 350.33$

⑥ $P_6 = 4\,MPa$, $T = 500\,C$, $h_6 = 3446.0$, $s_6 = 7.0922$

⑦ $P_7 = 1200\,kPa$, $s_7 = 7.0922$, $h_7 = 3081.4$

⑧ $P_8 = 10\,kPa$, $s_8 = 7.0922$

$s_{f_8} = .6492$

$s_{fg_8} = 7.4996$

$h_f = 191.81$

$h_{fg} = 2392.1$

$h_8 = 2246.85$

$h_2 = h_1 + v(P_2 - P_1)$

$191.81 + .00101(1200 - 10)$

$h_2 = 193.01\,kJ/kg$

Control Volume on Mix for h_4

$\dot m_4 = 55\,kg/s$

$\dot m_3 = .25(55) = 13.75\,kg/s$

$\dot m_2 = 41.25\,kg/s$

$\cancel{\dot m_4} h_4 = \dfrac{\dot m_2 h_2 + \dot m_3 h_3}{\dot m_4}$

$h_4 = \dfrac{41.25(193.01) + 13.75(798.33)}{55}$

$h_4 = 344.35\,kJ/kg$

$h_5 = h_4 + v_4(P_5 - P_4)$

$344.35 - .001031($

$h_5 = 350.33$

W_{out}

$W_T = W_{67} + W_{78}$

$= \dot m(h_6 - h_7) + \dot m_8(h_7 - h_8)$

$= 55\,(3446 - 3081) + 41.25(3081 - 2246.85)$

$\dot W_{out} = 54.478.2\,KW$

Calculate x_8 ~10 kPa

$x_8 = \dfrac{s_8 - s_{f,8}}{s_{fg,8}} = \dfrac{7.0922 - .6492}{7.4996}$

$x_8 = .8591$

$h_8 = h_f + x_8(h_{fg})$

$= 191.81 + .8591(2392.1)$

$h_8 = 2246.85\,kJ/kg$

$\dot W_{net} = \dot W_{out} - \dot W_{in}$

$54{,}478.2 - 378.54$

$\dot W_{net} = 54099.5\,KW$

$\dot W_{in} = \dot W_{P1} + \dot W_{P2}$

$= \dot m_1(h_2 - h_1) + \dot m_4(h_5 - h_4)$

$= 41.25(193.01 - 191.81) + 55(350.33 - 344.34)$

$= 41.25\,\dfrac{kg}{s}\ 1.19\,\dfrac{kJ}{kg}$

$\dot W_{in} = 378.54\,KW$

$\dot Q_{process} = \dot m_7(h_7 - h_3)$

$= 13.75(3081.4 - 798.33)$

$\dot Q_{process} = 31392\,KW$

$\dot Q_{in} = \dot m_5(h_6 - h_5) =$

$= 55(3446 - 350.33)$

$\dot Q_{in} = 170262\,KW$

$\varepsilon = \dfrac{\dot W_{net} + \dot Q_{process}}{\dot Q_{in}}$

$= \dfrac{54099 + 31392}{170262}$

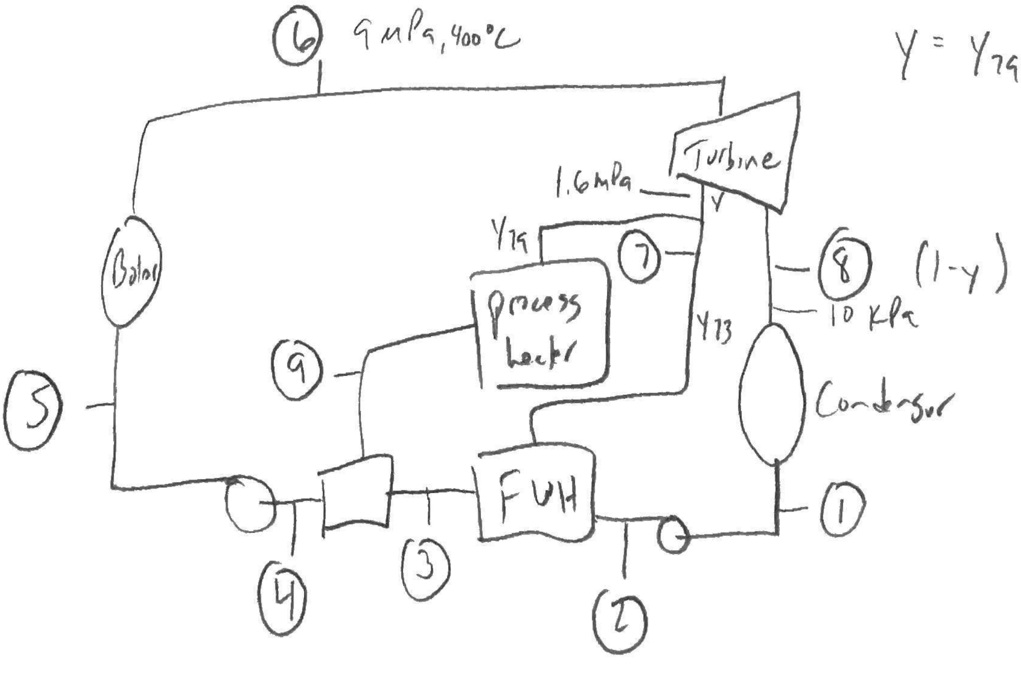
$\boxed{\varepsilon = 50.2\%}$

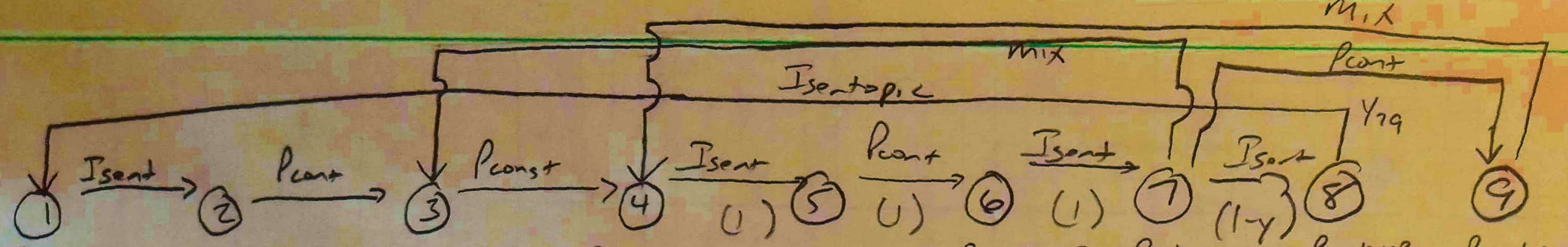
10-72

- Cogeneration power plant w/ regeneration
- Stm enters turbine @ 9 MPa and 400°C
- Expands to pressure 1.6 MPa
- 35% stm extracted from turbine and remainder expands to 10 KPa   35% = Y
- Part of extracted stm used in open feedwater heater
- Rest is used for process heating and leaves as saturated liquid @ 1.6 MPa
- Then, mixed w/ feedwater after OFH and then pumped to boiler
- Isentropic Pumps + Turbines
- Net Power output is 25 MW

☆ Find mass flow rate of stm through boiler

$Y = Y_{79} + Y_{73}$





$P_1 = 10$ kPa
$X_1 = 0$
$v_1 = 0.001010$
$h_1 = 191.81$
$s_1 = 0.6492$

$P_2 = 1.6$ MPa
$h_2 = h_1 + v_1(P_2 - P_1)$

$P_3 = 1.6$ MPa
$X_3 = 0$
$h_3 = 857.994$

$P_4 = 1.6$ MPa
$X_4 = 0$
$h_4 = 857.994$
$v_4 =$

$P_5 = 9$ MPa
$h_5 = 866.57$

$P_6 = 9$ MPa
$T_6 = 400°C$
$v_6 = .029940$
$h_6 = 3118.8$
$s_6 = 6.2876$

$P_7 = 1.6$ MPa
$s_7 = s_6 = 6.2876$
Find $x_7 \Rightarrow h_7$
Interpolate for
$s_{f,7} = 2.3423$
$s_{fg,7} = 4.0785$
$x_7 = \frac{6.2876 - 2.3423}{4.0785}$
$x_7 = 0.967314$

$P_8 = 10$ kPa
$s_8 = s_6$
$h_8 = 1990.25$

$P_9 = 1.6$ MPa
$x_9 = 0$
$T_9 = 201.26$ C
$h_9 = 857.994$ kJ/kg
$h_9 = h_3 = h_4$
$v_4 = .001159$

$$\frac{.001010\ \cancel{m^3}}{kg}\left|\frac{(1.6-.01)\ \cancel{MPa}}{}\right|\frac{1\ J}{1\ \cancel{Pa\,m^3}}\left|\frac{1000000\ \cancel{Pa}}{1\ \cancel{MPa}}\right|\frac{1\ kJ}{1000\ J}$$

$h_2 = 193.416$ kJ/kg

$h_5 = h_4 + v_4(P_5 - P_4)$

$$= 857.994 + \frac{.001159\ \cancel{m^3}}{kg}\left|\frac{(9-1.6)\ \cancel{MPa}}{}\right|\frac{1\ J}{1\ \cancel{Pa\,m^3}}\left|\frac{1000000\ \cancel{Pa}}{1\ \cancel{MPa}}\right|\frac{1\ kJ}{1000\ \cancel{J}}$$

$h_5 = 866.57$ kJ/kg

for h_8

$x_8 = \frac{s_8 - s_{f,8}}{s_{fg,8}}$

10 kPa
$s_8 = 6.2876$
$s_{f,8} = .6492$
$s_{fg,8} = 7.4996$
$h_{f,8} = 191.81$
$h_{fg,8} = 2392.1$

$x_8 = \frac{6.2876 - .6492}{7.4996} = .7518$

$h_8 = h_{f,8} + x_8(h_{fg,8})$

$= 191.81 + .7518(2392.1)$

$h_8 = 1990.25$

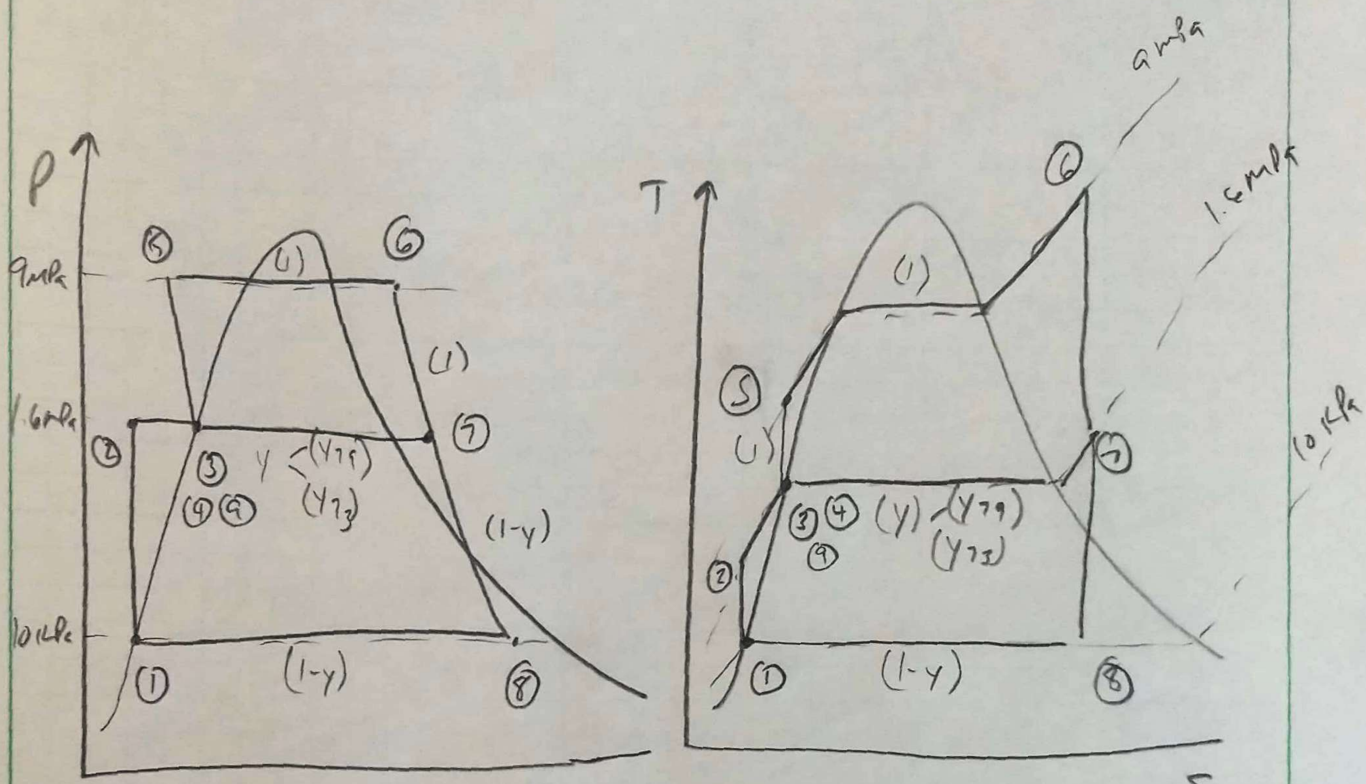
$h_7 = h_{f,7} + x_7(h_{fg,7})$

$h_{f,7} = 857.16$

$h_{fg,7} = 1934.68$

$h_7 = 857.16 + (.967314)(1934.68)$

$h_7 = 2728.6$ kJ/kg



States on Next Page

$\dot{W} = \dot{m}\, w_{net}$

$$\dot{W}_{net} = \overbrace{(\dot{W}^{(1)}_{6-7} + \dot{W}^{(1-y)}_{7-8})}^{W_{out}} - \overbrace{(\dot{W}_{1-2} - \dot{W}_{4-5})}^{W_{in}}$$

apply mass fraction

$$w_{net} \Rightarrow w_{6-7} + (1-y)w_{7-8} - (1-y)w_{1-2} - w_{4-5}$$

$$w_{net} = (h_6 - h_7) + .65(h_7 - h_8) - .65(h_2 - h_1) - (h_5 - h_4)$$

$$= (3118.8 - 2728.6) + .65(2728.6 - 1990.25) - .65(193.416 - 191.81) - (866.57 - 857.944)$$

$$w_{net} = 859.71\ kJ/kg$$

$$\frac{kg}{s} \quad \dot{m} = \frac{\dot{W}_{net}}{w_{net}} = \frac{25000\ \cancel{kW}}{859.71\ \cancel{kJ}}\bigg|\frac{1J}{1\ W\ s}\bigg|\frac{1kJ}{1000J}\bigg|\frac{\cancel{1000W}}{1\ \cancel{kW}}$$

$$\boxed{\dot{m} = 29.08\ kg/s}$$