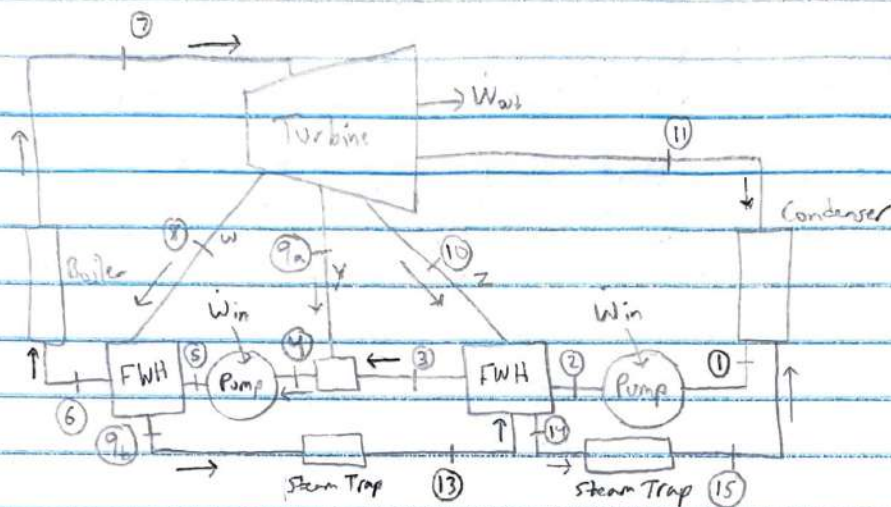


1.) Purpose: Determine fraction of extracted mass y and z for the open and closed FWH, cooling water temperature in the condenser, rate of heat rejected, net power and thermal efficiency of the plant.

Diagram:

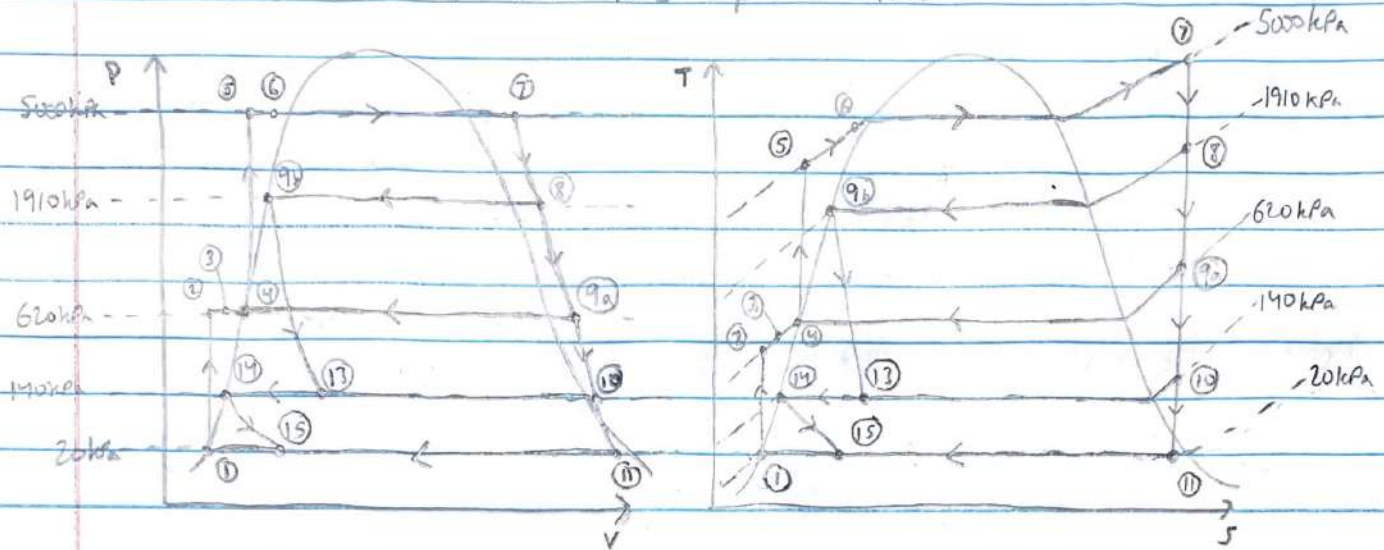


Process states and Selected Data

State	P, kPa	$T, ^\circ\text{C}$	$h, \text{kJ/kg}$	$s, \text{kJ/kg}\cdot\text{K}$
1	20			
2	620			
3	620			
4	620			
5	5000			
6	5000			
7	5000	700	3900	7.514
8	1910		3515	7.514
9	620		3154	7.514
10	140		2799	7.514
11	20		2478	7.514

Saturation data

Use Saturated water Table A-5 - pressure table



Source: Cengel, Boles, and Kanoglu. *Thermodynamics: An Engineering Approach*. 9th Edition. McGraw Hill. 2020

Design Considerations:

- Boiler feedwater and condensed steam assumed ideal states
- Assume no friction or heat losses
- Steady operating conditions

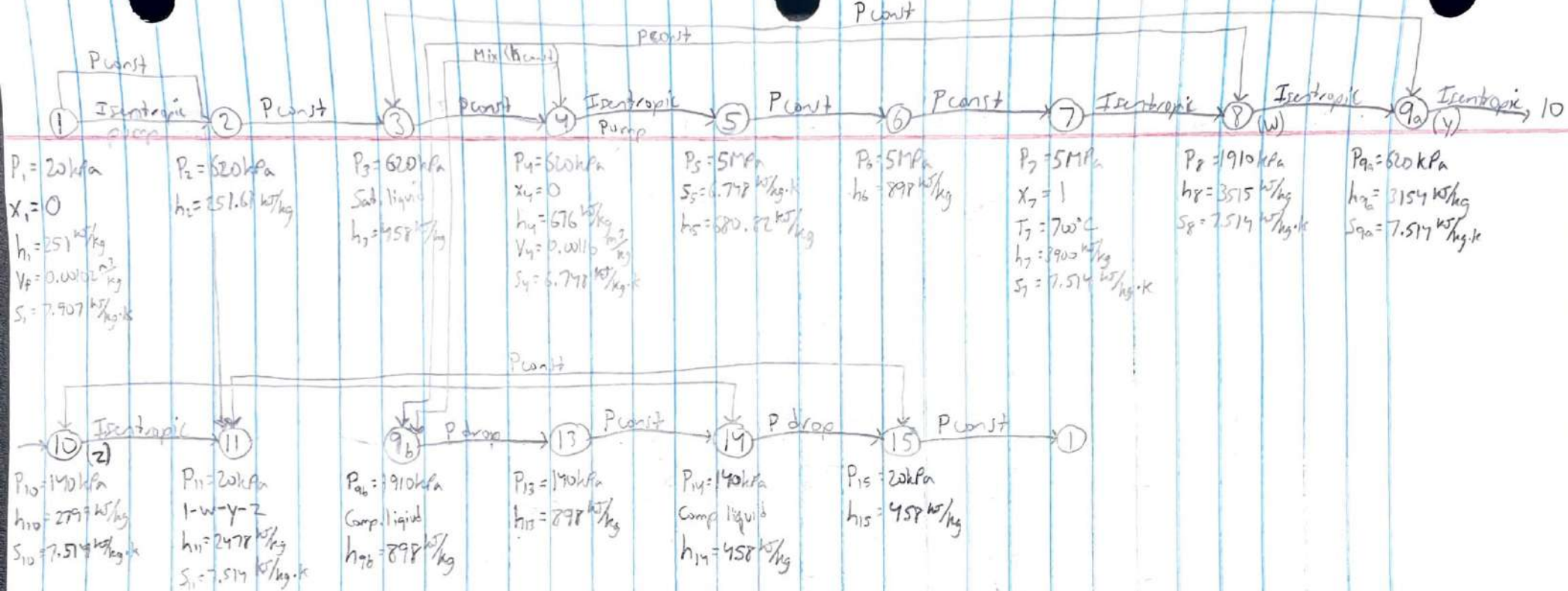
Data and Variables:

See table mentioned in previous section.

$$\dot{m}_{\text{inlet}} = 100 \text{ kg/s}$$

Materials: Water

Procedure: Find all states then solve each question.



Find h_2

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

$$h_2 = 0.00102(620 - 20) + 251$$

$$h_2 = 251.61$$

Find h_5

$$h_5 = V_4(P_5 - P_4) + h_4$$

$$h_5 = 0.0010(5 \text{ MPa} - 620) + 676$$

$$h_5 = 680.82$$

Find h_3

$$h_3 = h_f @ 1910 \text{ kPa} = 458 \text{ kJ/kg} = h_{14} = h_{15}$$

$$1) a) y(h_{g1}) + (1-y)(h_1) = h_4$$

$$3157y + 458 - 458y = 676$$

$$2696y = 218$$

$$y = 0.08$$

$$h_2 + zh_{10} = h_3 + (y+z)h_{11}$$

$$251.61 + 2799z = 458 + (0.08+z)458$$

$$2799z - 458z = 273.03$$

$$z = .104$$

$$b.) \text{ Given: } \dot{m}_w = 4200 \text{ kg/s}$$

$$C_p = 4.18 \text{ kJ/kg}\cdot\text{K}$$

$$\dot{m}_w C_p \Delta T_w = \dot{m}_{\text{inlet}} [(1-y-z)h_{11} + (y+z)h_{10} - h_1]$$

$$(4200 \text{ kg/s})(4.18) \Delta T = 100 [(1-0.08-.104)2799 + (0.08+.104)458 - 251]$$

$$17556 \Delta T = 100 [2022.048 + 84.272 - 251]$$

$$\Delta T = 10.57^\circ\text{C}$$

$$c.) \dot{Q}_{\text{out}} = \dot{m}_w C_p \Delta T$$

$$\dot{Q}_{\text{out}} = (4200)(4.18)(10.57)$$

$$\dot{Q}_{\text{out}} = 185566.92 \text{ kW}$$

$$W_{\text{net}} = W_{\text{tout}} - W_{\text{pin}}$$

$$= (h_7 - y h_{g7} - z h_{10} - (1-y-z)h_{11}) - (V_1(P_1 - P_2) + V_4(P_5 - P_4))$$

$$= (3900 - (0.08)(3157) - (.104)(2799) - (1-0.08-.104)(2478) - (.612 + 4.818))$$

$$= 1337.536 + 4.206$$

$$W_{\text{net}} = 1338.742 \text{ kJ/kg}$$

$$\dot{W}_{\text{net}} = \dot{m} W_{\text{net}}$$

$$= (100)(1338.742)$$

$$\dot{W}_{\text{net}} = 133874.2 \text{ kW}$$

$$\eta = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = \frac{133874.2}{300200} = .45 = \boxed{45\%}$$

$$\dot{Q}_{in} = \dot{m}(h_7 - h_6)$$

$$= 100(3900 - 898)$$

$$\dot{Q}_{in} = 300200 \text{ kW}$$

2.) a) $y(h_{9a}) = h_4$
 $y(3154) = 676$
 $y = 0.214$

b) $\dot{m}_w C_p \Delta T = \dot{m}_{inlet} [(1-y)h_{11} + yh_{15} - h_1]$
 $(4200)(4.18)\Delta T = 100[(1-0.214)(2478) + (0.214)(458) - 251]$
 $17556 \Delta T = 179472$
 $\Delta T = \boxed{10.22^\circ\text{C}}$

c) $\dot{Q}_{out} = \dot{m}_w C_p \Delta T$
 $\dot{Q}_{out} = (4200)(4.18)(10.22)$
 $\dot{Q}_{out} = \boxed{179472.32 \text{ kW}}$

$$\dot{W}_{net} = \dot{W}_{T_{out}} - \dot{W}_{P_{in}}$$

$$= (\dot{h}_7 - yh_{9a} - (1-y)h_{11}) - (V_1(P_2 - P_1) + V_4(P_5 - P_4))$$

$$= 3900 - (0.214)(3154) - (1-0.214)(2478) - (.612 + 4.818)$$

$$= 3900 - 674.956 - 1947.708 - 5.43$$

$$\dot{W}_{net} = 1271.91 \text{ kJ/kg}$$

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

$$= (100)(1271.91)$$

$$\dot{W}_{net} = \boxed{127190.6 \text{ kW}}$$

$$\eta = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = \frac{127190.6}{300200} = .42 = \boxed{42\%}$$

Summary: An ideal Rankine cycle was modified to include two closed feedwater heaters and one open feedwater heater. The purpose of FWHs are to preheat water delivered to the boiler and improve cycle efficiency.

Analysis: The steam trap from the closed FWH at 1910 kpa malfunctioned and got completely blocked. It was found that the "y" and "z" extracted mass was 0.08 and 0.104 for the cycle to operate properly and the thermal efficiency of the plant was 45%. Now, after the second steam trap got blocked, the "y" mass extracted was 0.214 and the plant's efficiency dropped to 42%.