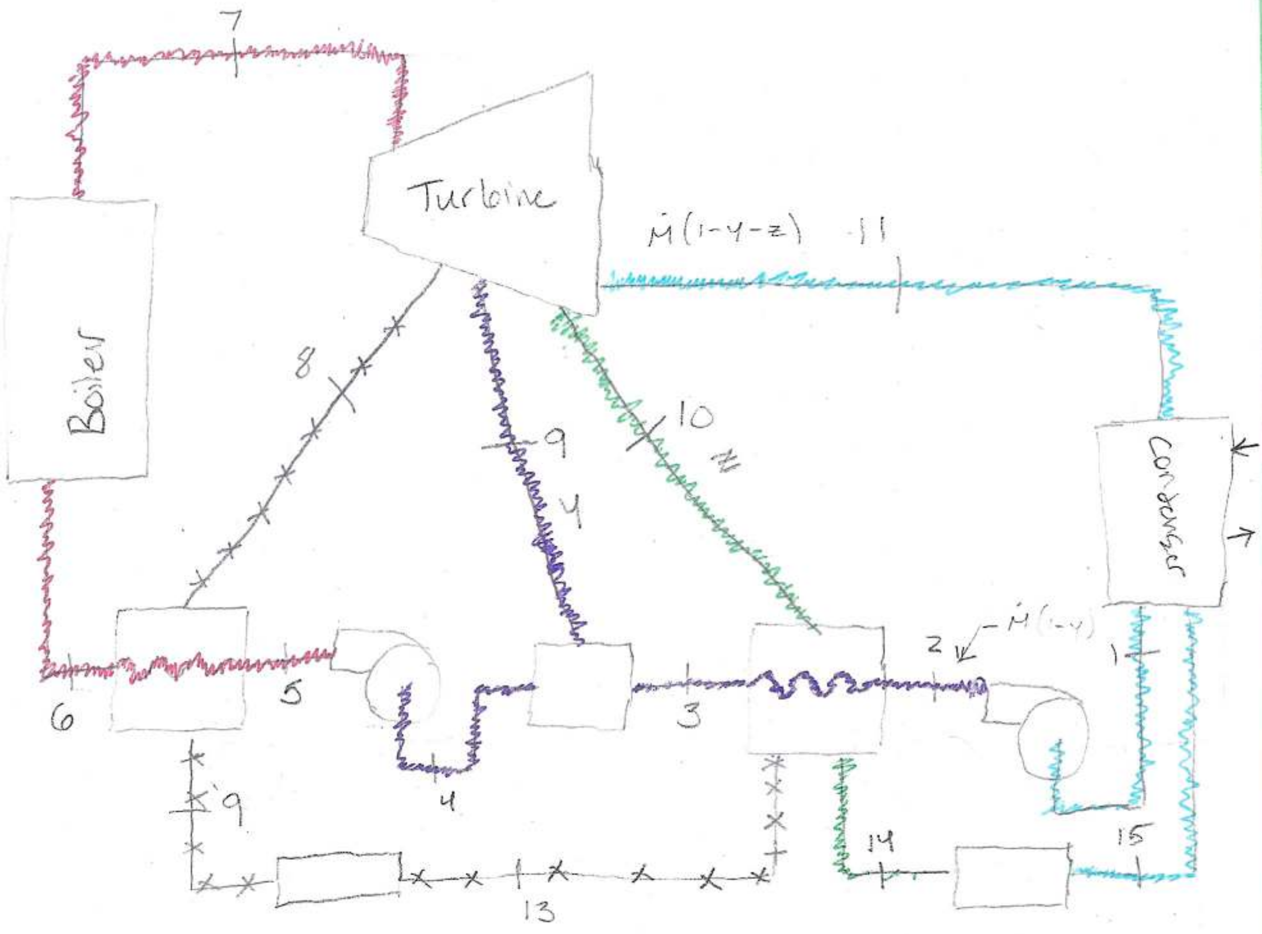
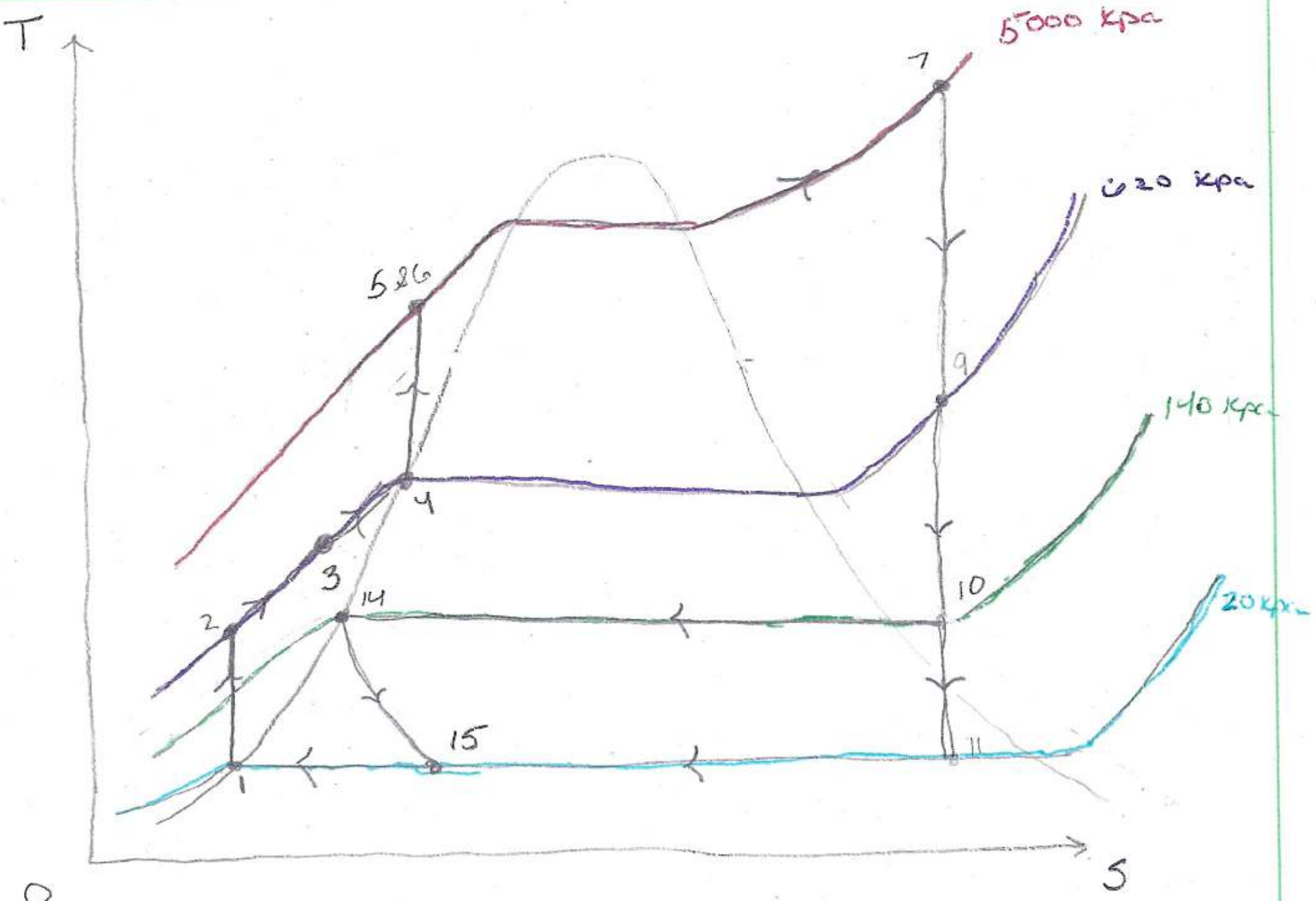
Rhiley Silvis | Test 2 | MET 350

Problem 1

Purpose: Given the Ideal Rankine steam cycle and under the circumstance of the closed water feeder getting clogged, Determine the mass extracted from "y" and "z" to guarantee proper operation of the cycle. Find the cooling water temperature rise in the condenser. And lastly I need to determine the rate of heat rejected in the condenser, the produced Net power, and the thermal efficiency.

Diagrams:

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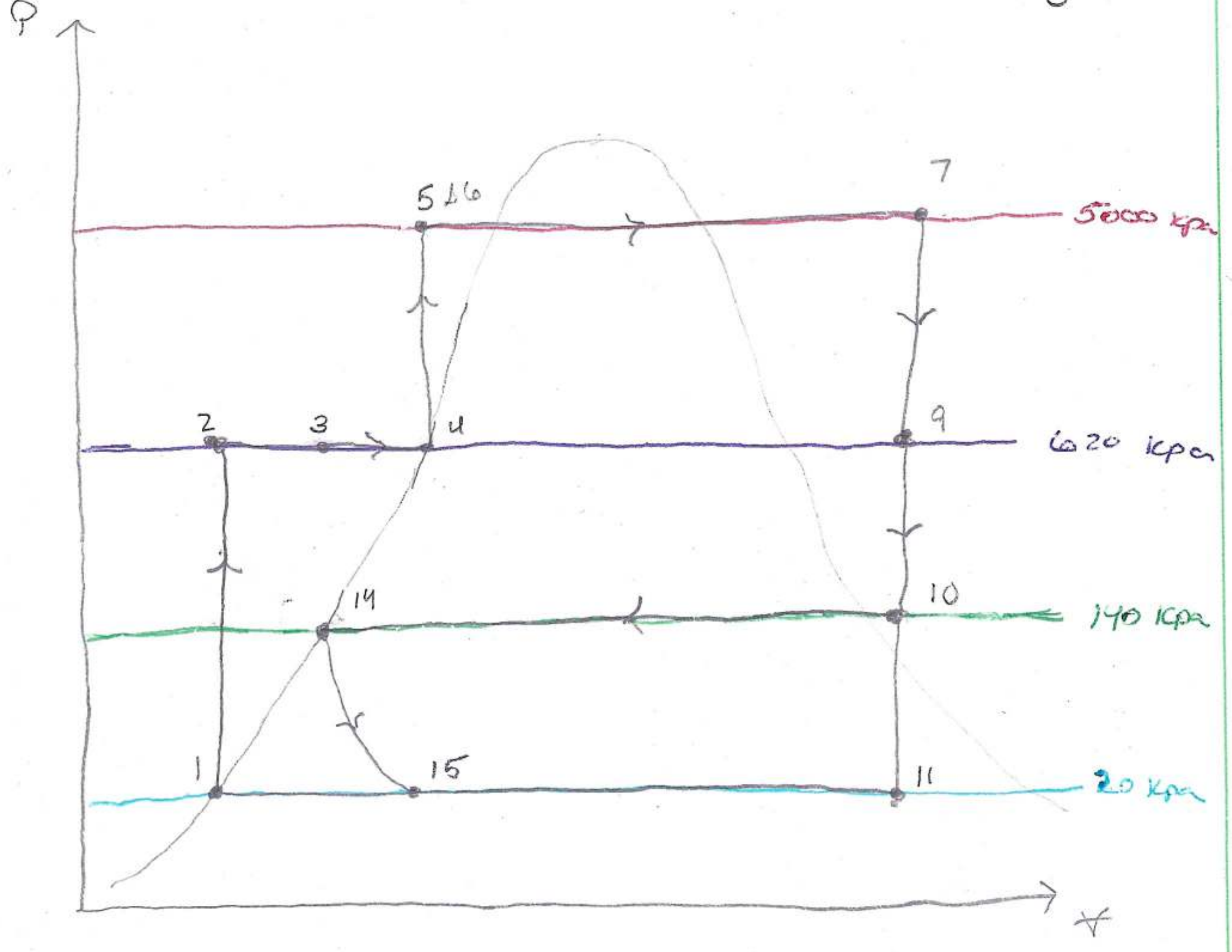
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Sources: Cengel & Boles & Kanoglu
Thermodynamics An engineering approach.
9th edition Mcraw Hill. 2019

Design Considerations:

I assume the following

1) Water is pure

2) pumps and turbines are Isentropic

3) No heat losses in connections, pipes, nor fluid friction.

4) at exit of shell for closed FWH fluid is saturated liquid

Data and Variables:

$\dot{M} = 100\ kg/s$

States 8, 9, 13 No longer apply

Process States Table

Saturation data Table

Materiales: Water

Procedure & Calculations:

→ Next page

— State 1) $P_1 = 20$ kpa, Sat liquid $\Bigg\}$ $T_1 = 60\ °C$, $v_1 = 0.001017\ m^3/kg$, $h_1 = 251.42\ kJ/kg$

— State 2) $P_2 = 620$ kpa, $s_1 = s_2$ $\Bigg\}$ $h_2 = 252.03\ kJ/kg$

$$h_2 = h_1 + v_1(P_2 - P_1) = 251.42 + 0.001017(620 - 20)$$

$$h_2 = 252.03$$

— State 4) $P_4 = 620$ kpa, Sat liquid $\Bigg\}$ $T_4 = 160.1\ °C$, $v_4 = 0.00110\ m^3/kg$, $h_4 = 676\ kJ/kg$, $s_4 = 6.7446\ kJ/kg \cdot K$

— State 5 & 6) $P_6 = 5000$ kpa, $s_6 = s_4$ $\Bigg\}$ $h_6 = 680.82\ kJ/kg$

$$h_6 = h_4 + v_4(P_6 - P_4) = 676 + 0.00110(5000 - 620)$$

$$h_6 = 680.82$$

— State 7) $h_7 = 3900\ kJ/kg$

— State 9) $h_9 = 3154\ kJ/kg$

— State 10) $h_{10} = 2799\ kJ/kg$

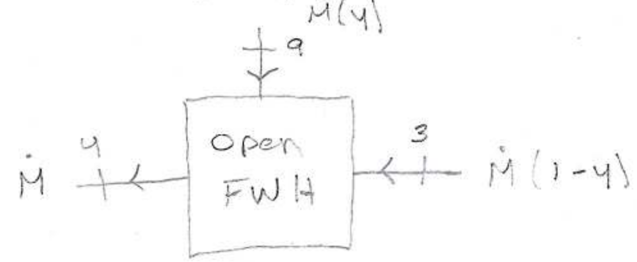
— State 11) $h_{11} = 2478\ kJ/kg$

— State 14) $P_{14} = 140$ kpa, Sat liquid $\Bigg\}$ $h_{14} = 458\ kJ/kg$

State 3) $h_3 = h_{14} = 458\ kJ/kg$

State 15) $h_{15} = h_{14} = 458\ kJ/kg$

a) Finding y & z

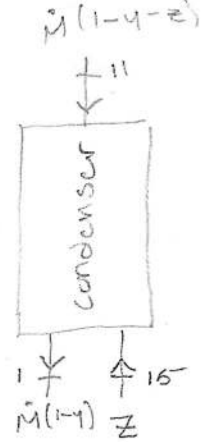


$$\dot{M} h_4 = \dot{M}(y) h_9 + \dot{M}(1-y) h_3$$

$$h_4 = y h_9 + h_3 - y h_3$$

$$y(h_9 - h_3) = h_4 - h_3$$

$$y = \frac{h_4 - h_3}{h_9 - h_3} = \frac{676 - 458}{3154 - 458} = \boxed{0.081}$$



$$\cancel{\dot{M}}(1-y-z) h_{11} = \cancel{\dot{M}}(1-y) h_1 + \cancel{\dot{M}}(z) h_{15}$$

$$h_{11} - y h_{11} - z h_{11} = h_1 - y h_1 + z h_{15}$$

$$z h_{15} + z h_{11} = h_{11} - y h_{11} + y h_1 - h_1$$

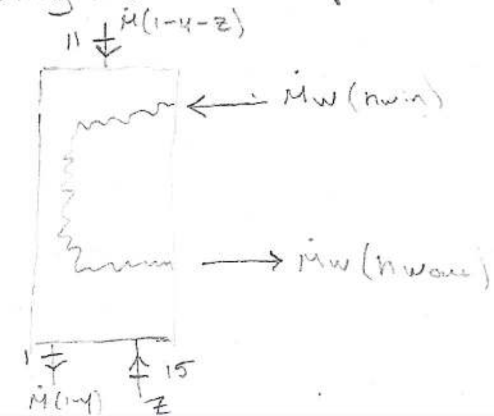
$$z(h_{15} + h_{11}) = h_{11} - y(h_{11} + h_1) - h_1$$

$$z = \frac{h_{11} - y(h_{11} + h_1) - h_1}{h_{15} + h_{11}}$$

$$z = \frac{2478 - 0.081(2478 + 251.42) - 251.42}{458 + 2478}$$

$$\boxed{z = 0.683}$$

b) Cooling water temp rise



$\dot{M}_w = 4200$ kg/s

$c_p = 4.18$ kJ/kg-K

$$\dot{M}_w(h_{w,in}) + \dot{M}(1-y-z)h_{11} + \dot{M}(z)h_{15}$$
$$= \dot{M}_w(h_{out}) + \dot{M}(1-y)h_1$$

$$\dot{M}_w(c_p \Delta T) = \dot{M}\left((1-y-z)h_{11} + (z)h_{15} - (1-y)h_1\right)$$

$$\Delta T = \frac{\dot{M}\left((1-y-z)h_{11} + (z)h_{15} - (1-y)h_1\right)}{\dot{M}_w \cdot c_p}$$

$$= \frac{100\ ^{kg}/_{s}\left((1-0.081-0.683)\,2478 + (0.683)\,458 - (1-0.081)\,251.03\right)}{4200\ ^{kg}/_{s} \cdot 4.18\ ^{kJ}/_{kg \cdot K}}$$

$$= \frac{100\ ^{kg}/_{s}\left(584.808 + 312.814 - 230.69\right)\ ^{kJ}/_{kg}}{4200\ ^{kg}/_{s} \cdot 4.18\ ^{kJ}/_{kg \cdot K}}$$

$$\boxed{\Delta T = 3.8\ K = 3.8\ ^{\circ}C}$$

c) Rate of heat rejected in condenser, W_{net}, η_{Th}

$$\dot{Q}_{out} = \dot{M}\,(h_{11} - h_1) = 100\ ^{kg}/_{s}\,(2478 - 251.42)\ ^{kJ}/_{kg}$$
$$= \boxed{222.67\ MW}$$

$$\dot{Q}_{in} = \dot{M}\,(h_7 - h_6) = 100\ ^{kg}/_{s}\,(3900 - 680.82)\ ^{kJ}/_{kg}$$
$$= 321.92\ MW$$

$$\dot{W}_{net} = \dot{W}_T - \dot{W}_P$$
$$\dot{W}_T = \dot{M}\,h_7 - \left[\dot{M}(y)h_9 + \dot{M}(z)h_{10} + \dot{M}(1-y-z)h_{11}\right]$$
$$100(3900) - 100\left[(0.081 \cdot 3154) + (0.683 \cdot 2799) + (0.236 \cdot 2478)\right]$$

$$= 114.8\ MW$$

$$\dot{W}_P = \dot{M}(1-y)(h_2 - h_1) + \dot{M}\,(h_5 - h_4)$$

$$= 100\,(0.919)(252.03 - 251.42) + 100\,(680.82 - 676)$$

$$= 0.538\ MW$$

$$\dot{W}_{net} = 114.8 - 0.538 = \boxed{114.26\ MW}$$

$$\eta_{Th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = \frac{114.26}{321.92} = \boxed{0.355}$$

Summary:

In total I was able to find how the fluid was divided after the last closed FWH became inoperable. I found that 2% of the fluid is sent to the Open FWH and 68% goes to the first Closed FWH. The temperature of the condenser cooling water increases to 3.8°c and the condenser rejects 222 MW. The Boiler system still produces a net work of 114 MW with the one Closed FWH down.

Analysis:

With one FWH inoperable, the system still had a thermal effiency of 35%. It is worse than it wouldve been fully fuctioning, but 35% still isnt bad for a boiler system.

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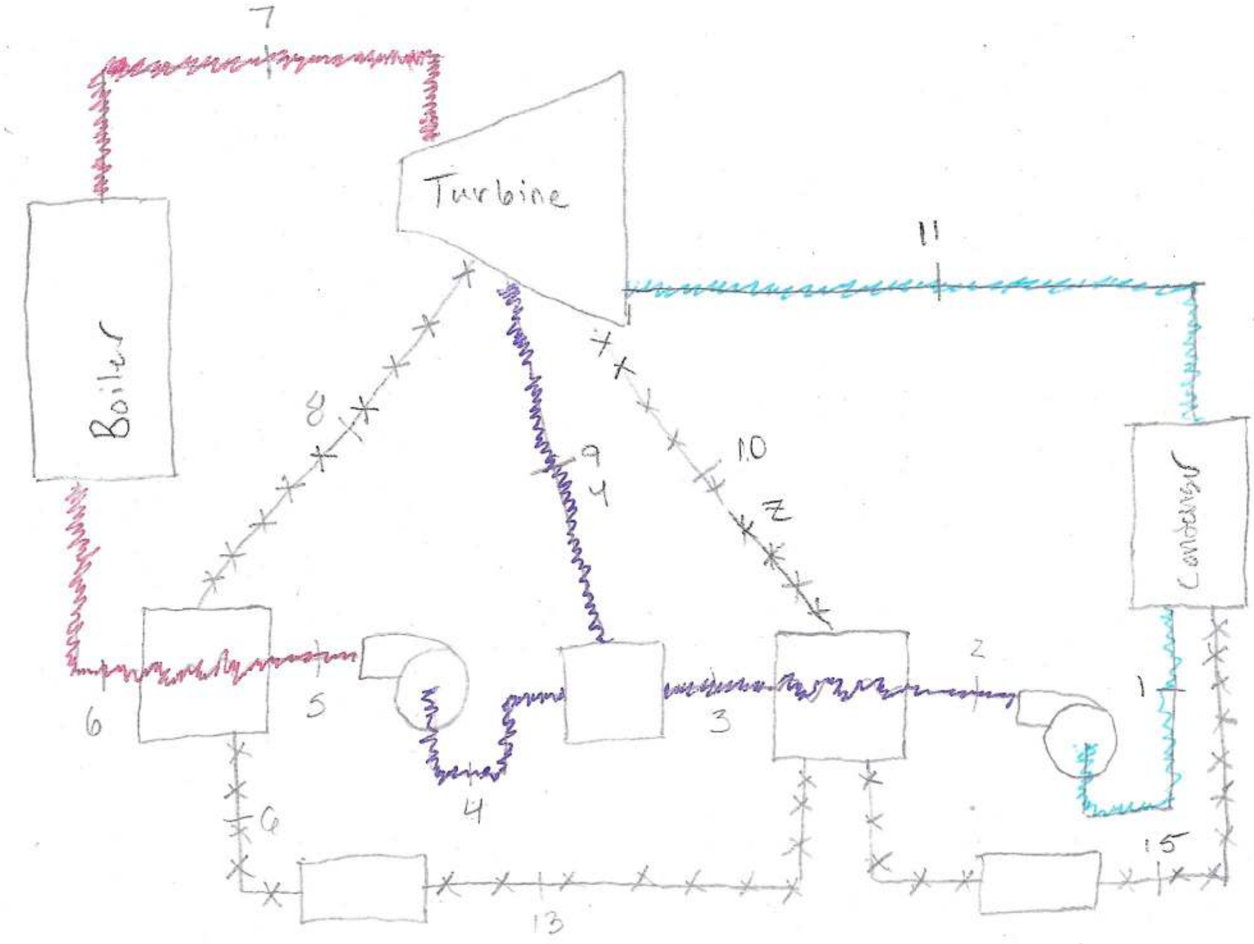
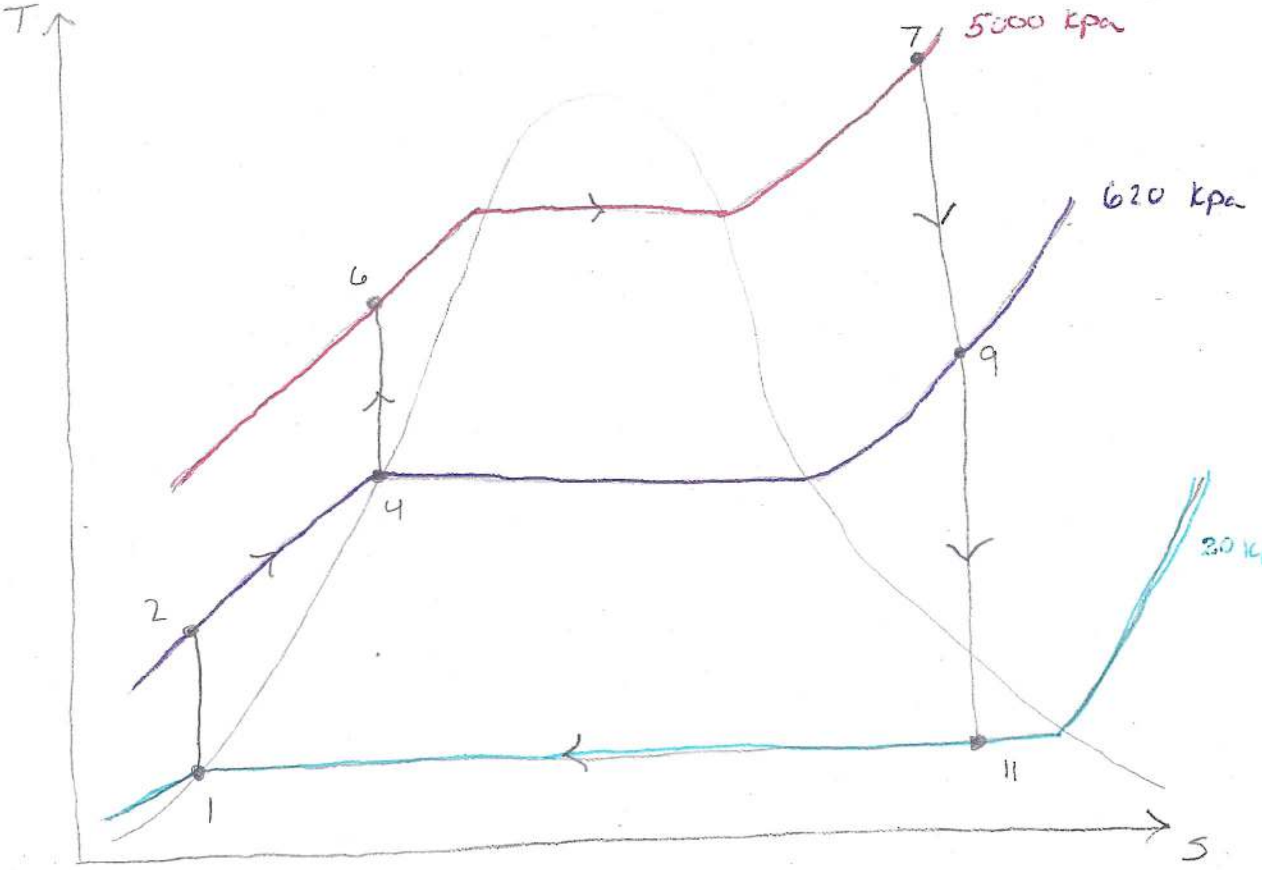
Problem 2

Purpose: I will take the system from Problem 1 but alter it to show the Other Closed FWH inoperable. I will then solve for how much mass is now going through line y to the Open FWH. I will then determine the new change in temp of the cooling water as well as the new rate of heat rejected, net work, and thermal efficiency.

Diagram:

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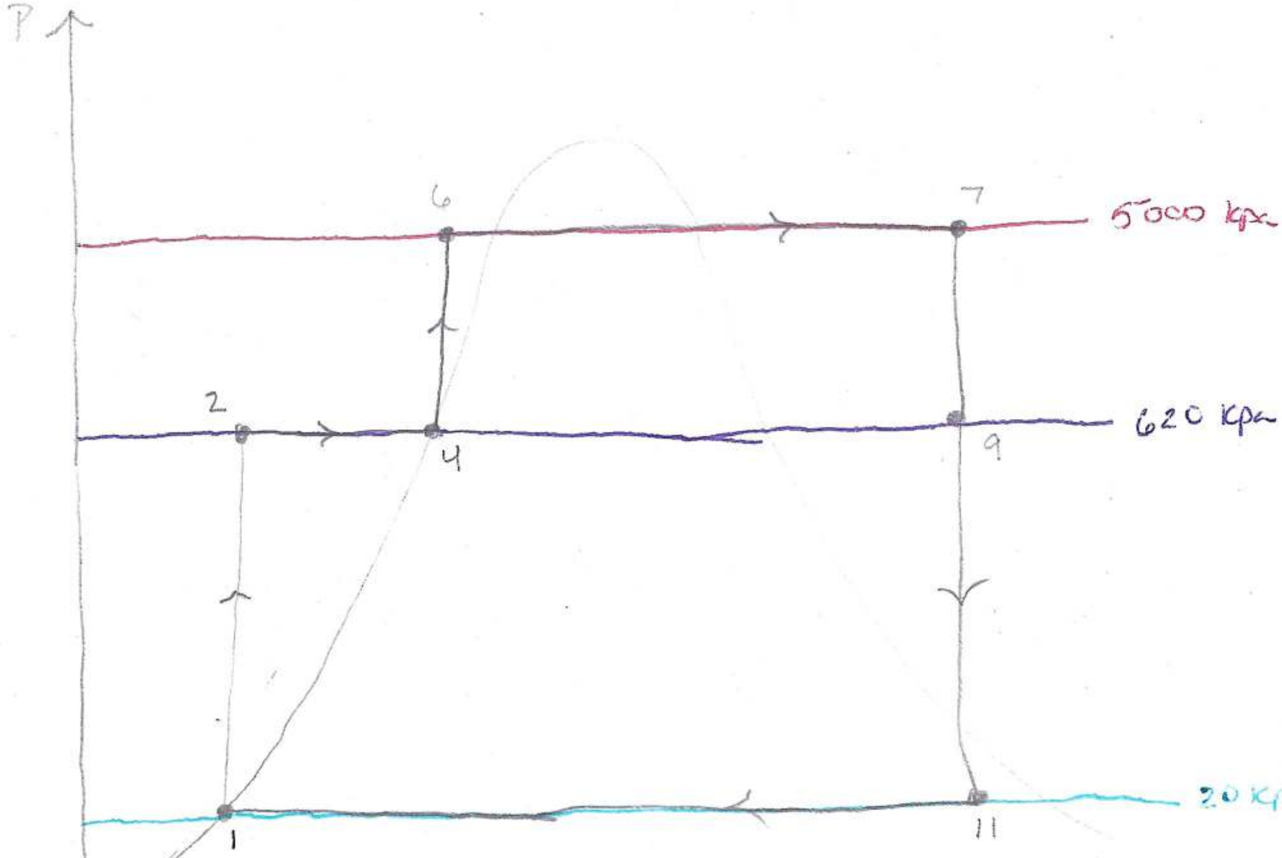
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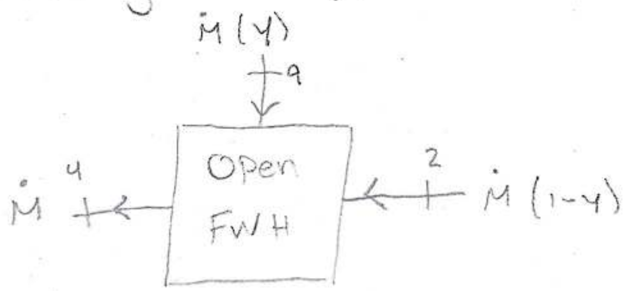
Procedure & Calculations:

- State 1) $h_1 = 251.42$ KJ/kg
- State 2) $h_2 = 252.03$ KJ/kg
- State 4) $h_4 = 676$ KJ/kg
- State 6) $h_6 = 680.82$ KJ/kg
- State 7) $h_7 = 3900$ KJ/kg
- State 9) $h_9 = 3154$ KJ/kg
- State 11) $h_{11} = 2478$ KJ/kg

- a) Solving for y)



$$\cancel{\dot{M}} h_4 = \cancel{\dot{M}}(y) h_9 + \cancel{\dot{M}}(1-y) h_2$$

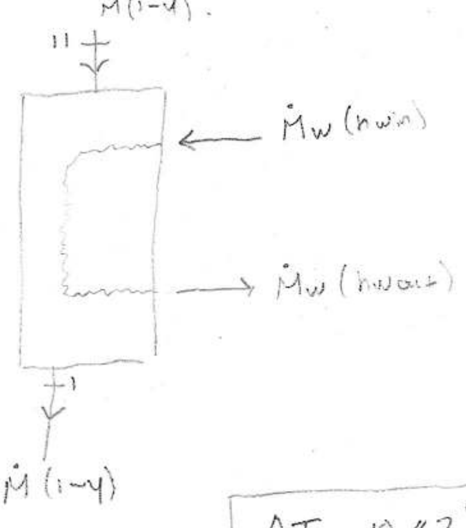
$$h_4 = y h_9 + h_2 - y h_2$$

$$y(h_9 - h_2) = h_4 - h_2$$

$$y = \frac{(676 - 252.03)}{(3154 - 252.03)}$$

$$\boxed{y = 0.146}$$

- b) Solving for ΔT of cooling water)



$$\dot{M}_w (h_{win}) + \dot{M}(1-y) h_{11} = \dot{M}_w (h_{wout}) + \dot{M}(1-y) h_1$$

$$\dot{M}_w (c_p \Delta T) = \dot{M}\left((1-y) h_{11} - (1-y) h_1\right)$$

$$\Delta T = \frac{\dot{M}\left((1-y)(h_{11} - h_1)\right)}{\dot{M}_w \cdot c_p}$$

$$= \frac{100 \text{ kg/s} \left((1-0.146)(2478 - 251.42) \text{ KJ/kg}\right)}{4200 \text{ kg/s} \cdot 4.18 \text{ KJ/kg}\cdot\text{K}}$$

$$= \frac{100 \cancel{\text{kg}} (1901.5) \cancel{\text{KJ}}/\cancel{\text{kg}}}{4200 \cancel{\text{kg}}/\cancel{\text{s}} \cdot 4.18 \cancel{\text{KJ}}/\cancel{\text{kg}}\cdot\text{K}}$$

$$\boxed{\Delta T = 10.83 \,^{\circ}C}$$

c) $\dot{Q}_{out}$, $\dot{W}_{net}$, η_{Th}

$\dot{Q}_{out} = \dot{M}(h_{11} - h_1) = 100\ kg/s\ (2478 - 251.42)\ kJ/kg$

$= \boxed{222.66\ MW}$

$\dot{Q}_{in} = \dot{M}(h_7 - h_6) = 100\ kg/s\ (3900 - 680.82)\ kJ/kg$

$= 321.92\ MW$

$\dot{W}_{net} = \dot{W}_T - \dot{W}_P$

$\dot{W}_T = \dot{M} h_7 - [\dot{M}(y) h_9 + \dot{M}(1-y) h_{11}]$

$= 100(3900) - 100[(0.146)3164 + (1-0.146)2478]$

$= 132.33\ MW$

$\dot{W}_P = \dot{M}(1-y)(h_2 - h_1) + \dot{M}(h_6 - h_4)$

$= 100(1-0.146)(252.03 - 251.42) + 100(680.82 - 676)$

$= 0.534\ MW$

$\dot{W}_{net} = 132.33 - 0.534 = \boxed{131.8\ MW}$

$\eta_{Th} = \dfrac{\dot{W}_{net}}{\dot{Q}_{in}} = \dfrac{131.8}{321.92} = \boxed{0.409}$

Summary:

Table comparison of 1 CFWH Vs None

	1 CFWH Down	2 CFWH Down
y	0.081	0.146
ΔT	3.8 °c	10.83 °c
$\dot{W}_T$	114.8 MW	132.33 MW
$\dot{W}_{net}$	114.26 MW	131.8 MW
η_{TH}	0.355	0.409

Analysis:

Comparing the two Scenarios the efficiency after loosing both closed feedwater Heaters increases. This is Suprising because I would've assumed there would be a decrease in efficiency. The system actually benefited by both CFWHs being down. The shift in mass going to the Open FWH increased the Turbine work produced which in turn increased the net work of the system. This is all under the assumption the p can handle the increased flow rate.