NOTE: Pages 4-7 I consider to be incorrect.
I was assuming state 3 was a compressed liquid because that is what I saw in the notes.
I then redid the work on the pages after that.
After I reread the question and noticed
STATE 3 is a saturated liquid.
PAGES are numbered.

Alex Gosborn

Thermal Applications

TEST 2

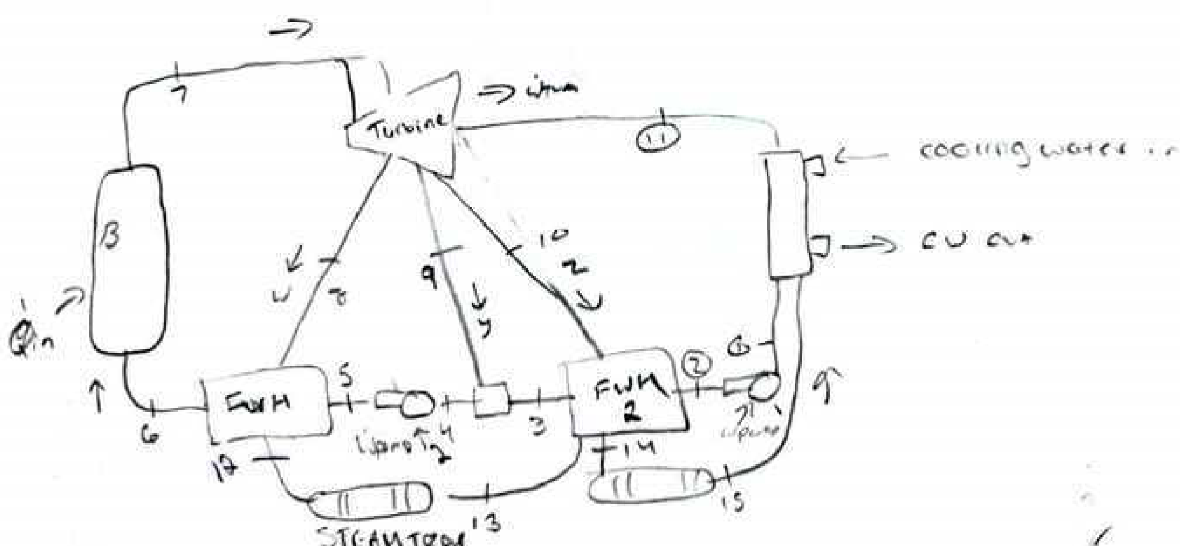
TEST 2

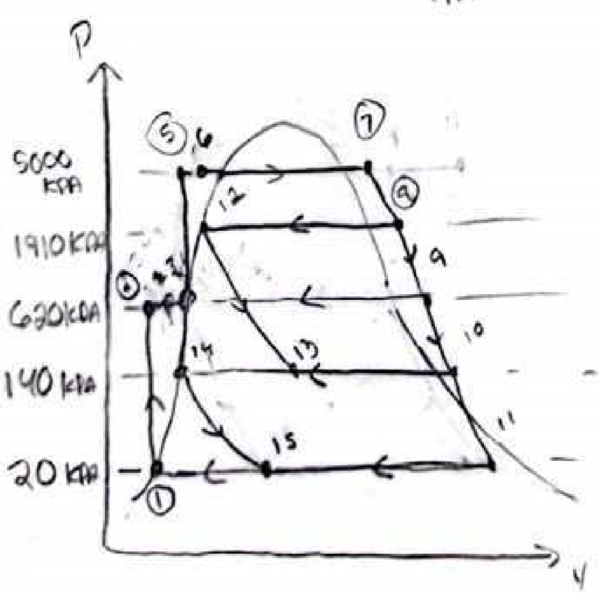
ALEX Goshorn

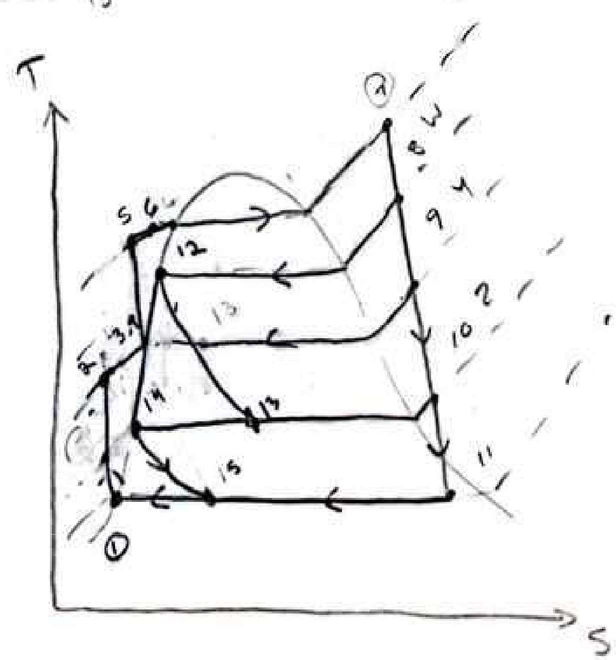
1) Purpose:

Determine the fraction of extracted mass "y and z". For the open and close feedwater heater that garuntees proper operation of cycle. Determine cooling water temperature rise in the condenser, in C° when flow rate is 4200 kg/s. Assume Cp = 4,18 kJ/kg·K. Also determine heat rejected in condenser, the produced net Power, and the thermal efficiency of the plant. Recieves 100 kg/s of steam

Drawings and Diagrams







Sources

- Cengal & Boles. Thermodynamics an engineering approach 8th edition. Mcgraw hill 2015.
- Class lecture NOTES
- Canvas slides and Problems 10-77,

Design Considerations

- I assume the following:
  1) The cycle recieves 100 kg/s of steam
  2) ~~Feed water heater~~ operating at 1910 KPA gets Blocked (The steam trap)*
  3) Condenser has cooling water flow rate of 4200 kg/s
  4) Assume cooling water has constant cp of 4,18 kg/kg·K
  5) NO heat loss in connecting pipes, neither fluid flow friction losses.

Data & Variables

- Condenser $\dot{m}$ = 4200 kg/s
- $\dot{m}_7$ = 100 kg/s

Materials : Water

PCONST

ISENT PUMP, PCONST, MIX, ISENT PUMP, PCONST, PCONST, ISENT, ISENT (PCONST), ISENT, ISENT (PCONST)

1 → 2 ✓ → 3 ✓ → 4 → 5 ✓ → 6 ✓ → 7 ✓ → ~~8~~ → 9 → 10 → 11 → ~~12~~ → ~~13~~ → 14 → 15

$P_1 = 20$ kPa | $P_2 = 620$ kPa | $P_3 = 620$ kPa | $P_4 = 620$ kPa | $P_5 = 5000$ kPa | $P_6 = 5000$ kPa | $P_7 = 5000$ kPa | $P_8 = 1416$ kPa | $P_9 = 620$ kPa | $P_{10} = 140$ kPa | $P_{11} = 20$ kPa | $P_{12} = 1910$ kPa | $P_{13} = 620$ kPa | $P_{14} = 140$ kPa | $P_{15} = 20$ kPa

$x_1 = 0$

$h_2 = 252.0302$

$h_3 = \cancel{588.32}$ 676

$h_4 = 676$

$h_6 = 688.16$

$T_1 = 60.06°C$

$h_1 = 251.42$

$s_1 = s_2 = 0.8320$

$s_1 = 0.8320$

$v_1 = 0.001017$

Table A-5

$h_c = h_{f@5000\,kPa} = 1154.5$

← TABLE →

$T_7 = 700°C$

$h_7 = 3900 \frac{kJ}{kg}$

$h_8 = 3515 \frac{kJ}{kg}$

$h_9 = 3154 \frac{kJ}{kg}$

$h_{10} = 2799 \frac{kJ}{kg}$

$h_{11} = 2970 \frac{kJ}{kg}$

$s_7 = s_8 = s_9 = s_{10} = s_{11} = 7.514 \frac{kJ}{kg \cdot K}$

$x = 0$

Find $h_{14} = h_{15}$

$h_{14} = 458$

$h_{15} = 458$

$x = \frac{h_{15} - h_{f,15}}{h_{fg,15}}$

$x = \frac{676\,\cancel{458} - 251.42}{2357.5}$

$\cancel{x = 0.18}$

USE PUMP EQUATION ⟷

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

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

$= (0.001017)(620 - 20) + 251.42$

$\boxed{h_2 = 252.0302}$

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

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

$= (0.001102)(5000 - 620) + 675.86$

$\boxed{h_5 = 680.68}$

Need to find h_6, h_3

1st Law Closed FWH

$\dot m_2 = z\dot m$

$\dot m_{2-z} = (1-z)\dot m$

$\dot m_{(z)} (h_{10} - h_{14}) = \dot m_{(1-z)} (h_3 - h_2)$

$z (h_{10} - h_{14}) = (1 - z)(h_3 - h_2)$

Two unknowns z and h_3

3 unknown 2 equations

Apply 1st Law to system that encloses FWH, OFWH, Pump 2

$\dot m_z (h_{10}) + (1-z)(h_2) + \dot W_p = \dot m h_6$

OPEN FWH ENERGY BALANCE

$y h_9 + (1-y) h_3 = h_4$

$h_4 = y h_9 + (1-y) h_3$

Need to find y

$y = \frac{h_4 - h_3}{h_9 - h_3}$

6 ← [ ] ← 10, ← 3

$\dot W_p = \dot m_{(y+z)} (h_5 - h_4)$

16-60

$z(h_{10}) + (1-z)(h_2) + (y+z)(h_5 - h_4) = h_6$

$y h_9 + (1-y) h_3 = h_4$

$z (h_{10} - h_{14}) = (1-z)(h_3 - h_2)$

3 unknown
3 equations
z, y, h_3

Scanned with CamScanner

I $z(h_{10}) + (1-z)(h_2) + (y+z)(h_5 - h_4) = h_6$ (4)

$y h_9 + (1-y) h_3 = h_4$

III $z(h_{10} - h_{14}) = (1-z)(h_3 - h_2)$

Rearrange II

$y h_9 + (1-y) h_3 = h_4$

$y = \dfrac{h_4 - h_3}{h_9 - h_3}$

$y h_9 + (1-y) h_3 = h_4$

$(1-y) h_3 = h_4 - y h_9$

$h_3 = \dfrac{h_4 - y h_9}{1-y}$ (11)

Substitute into III

$z(h_{10} - h_{14}) = (1-z)\left(\dfrac{h_4 - y(h_4)}{1-y} - h_2\right)$

Rearrange III

$z(h_{10} - h_{14}) = (1-z)(h_3 - h_2)$

$z h_{10} - z h_{14} = h_3 - h_2 - z h_3 + z h_2$

$z h_{10} - z h_{14} + z h_3 + z h_2 = h_3 - h_2$

$z(h_{10} - h_{14} + h_3 + h_2) = h_3 - h_2$

$z = \dfrac{h_3 - h_2}{h_{10} - h_{14} + h_3 + h_2}$

disregard

Put I into a single variable

$z(h_{10}) + (1-z)(h_2) + (y+z)(h_5 - h_4) = h_6$

$z(h_{10}) + (1-z) h_2 + y(h_5 - h_4) + z(h_5 - h_4) = h_6$

$z(h_{10} + h_5 - h_4) + y(h_5 - h_4) + 1 - z(h_2) = h_6$

$z(h_{10} - h_{14}) = (1-z)\left(\dfrac{h_4 - y(h_4)}{1-y} - h_2\right)$

$z(h_{10}) + (1-z)(h_2) + (y+z)(h_5 - h_4) = h_6$

$(y+z)(h_5 - h_4) = -z(h_{10}) - (1-z)(h_2) + h_6$

$y + z = \dfrac{-z(h_{10}) - (1-z)(h_2) + h_6}{(h_5 - h_4)}$

$y + z = \dfrac{-z(h_{10}) - (1-z)(h_2) + h_6}{(h_5 - h_4)}$

=

$3x$
$-2x$

$z(h_{10}) + (1-z)(h_2) + (y+z)(h_5 - h_4) = h_6$ Let $h_3 = x$ (5)

$yh_9 + (1-y)x_3 = h_4$

$z(h_{10} - h_{14}) = (1-z)(x - h_2)$

$z(h_{10}) + (1-z)(h_2) + (y+z)(h_5 - h_4) = h_6$

$- z(h_{10} - h_{14}) = (1-z)(x - h_2)$

$yh_9 + x - xy = h_4$

$h_2 = 252.0302$

$h_4 = 676$

$h_9 = 3154$

$h_{10} = 2799$

$h_{14} = 458$

$h_5 = 680.86$

$h_6 = 1154.5$

$$\begin{cases} zh_{10} + h_2 - zh_2 + yh_5 - yh_4 + zh_5 - zh_4 = h_6 \\ yh_9 + x - xy = h_4 \\ zh_{10} - zh_{14} = x - h_2 - xz + zh_2 \end{cases}$$

$$\begin{cases} z(h_{10} - h_2 + h_5 - h_4) + y(h_5 - h_4) + h_2 = h_6 \\ yh_9 + x - xy = h_4 \\ z(h_{10} - h_{14}) = zh_2 - xz - h_2 + x \end{cases}$$

TRYING TO FIGURE OUT SYSTEM OF EQUATIONS

$$\begin{cases} ① & z(2551.8298) + y(4.86) + 252.0302 = 1154.2 \\ ② & y(3154) + x - xy = 676 \\ ③ & z(2341) = z(252.0302) - xz - (252.0302) + x \end{cases}$$

$y(3154) - xy = 676 - x$

$y(3154 - x) = 676 - x$

$y = 676 - x$

PLUG INTO ①

$$\begin{cases} Ⓘ & z(2551.8298) + (676 - x)(4.86) + 252.0302 = 1154.2 \\ Ⓘ & z(2341) = z(252.0302) - xz - (252.0302) + x \end{cases}$$

$z(2551.8298) + 3534.3902 - 4.86x = 1154.2$

$z(2551.8298) = -2380.1902 - 4.86x$

$z = \dfrac{2380.1902 - 4.86x}{2551.8298}$

Plug into II

$$\frac{2580.1402 - 4.86x}{2551.8298} = \left(\frac{2330.1962 - 4.86x}{2551.8298}\right) - x($$

6

$$0.93 - (0.001x) = (0.93 - (0.001x)) - x(0.93 - (0.001x)) - 252.0302 + x$$

$$\cancel{0.93} - (0.001x) = (\cancel{0.93}) - x(0.001 - 1) - (0.93x) + x(1 + 0.001) - 252.0302 + x$$

$$252.0302 = 0.001x - x(-0.999) - 0.93x + x(1.001) + x$$

$$252.0302 = x(0.001 + 0.999 - 0.93 + 1.001)$$

$$252.0302 = x(1.071)$$

$$x = 235.32$$

$$\boxed{h_3 = 235.32}$$

$$y = 676 - x$$

$$\cancel{y = 676 - 235.32}$$

$$\cancel{\boxed{y = 440.68}}$$

$$y(3154) - (235.32)y = 676 - 235.32$$

$$y(3154 - 235.32) =$$

$$\boxed{y = 0.15}$$

$$z(2341) = z(252.0302) - (235.32)z - (252.0302) + 235.32$$

$$z(2341) = z(252.0302) + (252.0302 - 235.32)$$

← sign switch

$$z(2341) - z(252.0302) = 16.71$$

$$z(2341 - 252.0302) = 16.71$$

$$z(2088.9698) = 16.71$$

$$\boxed{z = 0.007}$$

I had Trouble with the system of eqations but eventually figured it out. The numbers seem reallistic and my h_3 seems reallistic aswell.

a) $\boxed{y = 0.15}$

$\boxed{z = 0.007}$

TB) Determine the cooling water temperature rise in the condenser, in C°, when cooling water flow rate is 4200 kg/s. Assume Cp= 4.18 kJ/kg·K (7)

Need to set up energy Balace for the condenser

$\dot{m}_T(1-y-z)h_{11}+(z)h_{15}-(1-y)h_1 = m_w C_p \Delta T$

$100(1-0.15-0.007)(2478)+(0.007)(458)-(1-0.15)(251.42) = 4200(4.18)\Delta T$

$\dfrac{208895.4+3.206-((0.85)(251.42))}{4200(4.18)} = \Delta T$

$\boxed{\Delta T = 11.88°C}$

c) Determine the rate of heat rejected in the condenser, the produced net Power, and the thermal efficiency

$\dot{Q}_{out} = \dot{m}_c \cdot C_p \cdot \Delta T$

$= 4200 \cdot 4.18 \cdot 11.88°C$

$\dot{Q}_{out} = 208565.28$

units?

$\dot{W}_{net} = \dot{W}_{out_{7-9}} + \dot{W}_{out_{9-10}} - \dot{W}_{in_{1-2}} - \dot{W}_{in_{4-5}}$

$\dot{W}_{net} = [\dot{m}(h_7-h_9)+\dot{m}(h_9-h_{10})-\dot{m}_{1-y-z}(h_2-h_1)-\dot{m}(h_5-h_4)$

$=\dot{m}[(h_7-h_9)+(h_9-h_{10})-(1-y-z)(h_2-h_1)-(y)(h_5-h_4)$

$\dot{W}_{net} = 100[(3900-3154)+(3154-2700)-(1-0.15-0.007)(252.0302-251.42)$

$-(0.15)(680.86-676)$

$= 100[746+454-0.514-0.729]$

$= 100 \cdot 1198.757$

$= 119,875.7$

$\dot{W}_{net} = 119875.7\ kW = \boxed{119.87\ MW}$

0.543

8

Now find Thermal Efficiency:

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

$$\dot{Q}_{in} = \dot{m}(h_5 - h_4)$$
$$= 100(680.86 - 676)$$
$$\dot{Q}_{in} = 486 \text{ MW}$$

$$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = \frac{119.87}{486} = \boxed{0.246}$$

For problem 1 I found the following answers

a) $y = 0.15$

$z = 0.007$

b) $\Delta T = 11.88°C$

c) $\dot{Q}_{out} = 208565.28$ kW

$W_{net} = 119.87$ MW

$\eta_{th} = 0.246$

I believe that my answers make sense. However, after rereading the question. If state 3 is on the curve then the $y = \frac{h_4 - h_3}{h_4 - h_3} = \frac{0}{h_4} = 0$

$$\dot{m}(z)(h_{10} - h_{14}) = \dot{m}(1-z)(h_3 - h_2)$$

$$z(2799 - 458) = h_3 + h_2 - z(h_3) - z h_2$$

$$z(h_{10} - h_{14}) - z(h_3 - h_2) = h_3 - h_2$$

$$z(h_{10} - h_{14} - h_3 + h_2) = h_3 - h_2$$

$$z = \frac{h_3 - h_2}{h_{10} - h_{14} - h_3 + h_2} \qquad \boxed{z = 0.22}$$

$$z = \frac{676 - 252.0302}{2799 - 458 - 676 + 252.0302}$$

Redoing 1B. with new y consideration

$$\dot{m}_T(1-y-z)h_{11} + (z)h_{13} - (1-y)h_1 = \dot{m}_w C_p \Delta T \quad \overset{\nwarrow}{\text{Water}}$$

$$\frac{100(1-z)h_{11} + z h_{13} - (1)h_1}{m_w C_p} = \Delta T$$

$$\frac{100(1-0.22)(2478) + (0.22)(458) - (251.42)}{4200(4.18)} = \Delta T$$

$$\boxed{\Delta T = 11^\circ C}$$

c) Redo 1C

$$\dot{Q}_{out} = \dot{m}_c \cdot C_p \cdot \Delta T$$
$$= 4200 \cdot 4.18 \cdot 11$$
$$= 193116 \text{ kW}$$

$$\dot{W}_{net} = \dot{W}_{out_{7-9}} + \dot{W}_{out_{9-10}} - \dot{W}_{in_{1-2}} - \dot{W}_{in_{4-5}} + \dot{W}_{out_{10-11}}$$

$$\dot{W}_{net} = (\dot{m}(h_7-h_9) + \dot{m}(h_9-h_{10}) - \dot{m}(h_2-h_1) - \dot{m}(h_5-h_4)$$

$$= \dot{m}[(h_7-h_9) + (h_9-h_{10}) - (1-y-z)(h_2-h_1) - (\cancel{h_5-h_4})^{0}$$
$$\quad 690-676$$

$$= 100[(3900-3154) + (3154-2700) - (1-0.22)(252.0302-251.42)$$
$$\quad (h_{10}-h_{11}) : (2799-2478)$$

$$= 100(746 + 454 - 0.514 + (321) - 4$$

$$= 100(1153.486 + 321 - 4$$

$$= \cancel{115348.6} \quad 1470.486$$

$$\dot{W}_{net} = \cancel{115348.6} \text{ kW} = \cancel{115.35 \text{ MW}}$$
$$147048.6 \text{ W}$$
$$= 147.048 \text{ MW}$$

Forget to account for

W_{out} 10-11

Redoing 1B. With new y consideration

$$\dot{m}_T (1-y-z) h_{11} + (z) h_{15} - (1-y) h_1 = m_w C_p \Delta T \quad \nwarrow_{\text{Netfir}}$$

$$\frac{100 (1-z) h_{11} + z h_{15} - (1) h_1}{m_w C_p} = \Delta T$$

$$\frac{100(1-0.22)(2478)+(0.22)(458)-(251.42)}{4200(4.18)} = \Delta T$$

$$\boxed{\Delta T = 11^\circ C}$$

c) Redo 1C

$$\dot{Q}_{out} = \dot{m}_C \cdot C_p \cdot \Delta T$$

$$= 4200 \cdot 4.18 \cdot 11$$

$$= 193116 \text{ kW}$$

$$\dot{W}_{net} = \dot{W}_{out_{7-9}} + \dot{W}_{out_{9-10}} - \dot{W}_{in_{1-2}} - \dot{W}_{in_{4-5}} + \dot{W}_{out_{10-11}}$$

$$\dot{W}_{net} = (\dot{m}(h_7 - h_9) + \dot{m}(h_9 - h_{10}) - \dot{m}(h_2 - h_1) - \dot{m}(h_5 - h_4)$$

$$= \dot{m}[(h_7 - h_9) + (h_9 - h_{10}) - (1-y-z)(h_2 - h_1) - (\underset{690-676}{\cancel{h_5 - h_4}})$$

$$= 100[(3960 - 3154) + (3154 - 2700) - (1-0.22)(252.0302 - 251.42$$

$$(h_{10} - h_{11}) : (2799 - 2478)$$

$$= 100(746 + 454 - 0.514 + (321) - 4$$

$$= 100(1153.486 + 321) - 4$$

$$= \cancel{115348.6} \quad 1490.486$$

$$\dot{W}_{net} = \cancel{115348.6} \text{ kW} = \cancel{115.35 \text{ MW}}$$

$$147048.6 \text{ kW}$$

$$= 147.048 \text{ MW}$$

Forgot to account for W_{out} 10-11

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

$\dot{Q}_{in} = \dot{m}(h_5 - h_4)$ CnETFS (14)

$= 100(680.818 - 676)$

Find h_5 $\dot{Q}_{in} = 481.8$

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

$0.00110(5000 - 620) + 676 = h_5$

$h_5 = 680.818$

$$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = \frac{147.048}{481.8} = \boxed{0.31}$$

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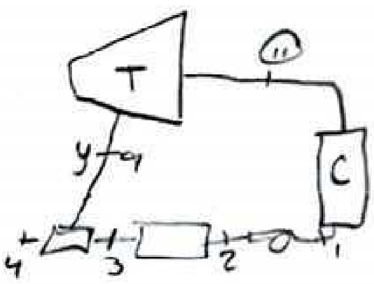
2) For the second question I can assume that the second steam trap is clogged and therefore

(A) $z = 0$. For the condenser I will use the same assumption of $C_p = 4.18 \frac{kJ}{kg \cdot K}$ and cooling water 4200 kg/s

OPEN FWH ENERGY BALANCE



$y h_9 + (1-y) h_3 = h_4$

$y h_9 + h_3 - y h_3 = h_4$

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

$$y = \frac{h_4 - h_3}{h_9 - h_3}$$

$$y = \frac{0}{h_9 - h_3} = \boxed{0}$$ y is still 0

(B) Redo Energy Balance w/ z closed

$\dot{m}_T(1 - \overset{0}{z}) h_{11} - (1 - \overset{0}{y}) h_1 = m_w C_p \Delta T$

$\dot{m}_T(h_{11}) - h_1 = m_w C_p \Delta T$

$$\frac{\dot{m}_T(h_{11}) - h_1}{m_w C_p} = \Delta T$$

$$\frac{100(2478) - 251.42}{4200(4.18)} = \Delta T$$

$$\boxed{\Delta T = 14.1}$$

(c)

11

$\dot{Q}_{out} = \dot{m}_c \cdot C_p \cdot \Delta T$ ← NOTES

$= 4200 \cdot 4.18 \cdot 14.1$

$\dot{Q}_{out}$ $\boxed{= 247539.6 \text{ kJ}}$

$\dot{W}_{net} = \dot{W}_{out_{7-11}} - \dot{W}_{in_{1-2}} - \dot{W}_{in_{4-5}}$

$= \dot{m}(h_7 - h_{11}) - \dot{m}_{(1-4)}(h_2 - h_1) - (h_5 - h_4)$

$= \dot{m}[(h_7 - h_{11}) - (h_2 - h_1) - (h_5 - h_4)$

$= 100[(3900 - 2478) - (252.0302 - 251.42) - (680 - 676)$

$\dot{W}_{net} = 141738.98 \text{ kW} = 141.738 \text{ MW}$

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

$\dot{Q}_{in} = \dot{m}(h_5 - h_4)$

$= 100(680.818 - 676)$

$\dot{Q}_{in} = 481.8$

NOTES

$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = \frac{141.738}{481.8} = \boxed{0.29}$

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1)

A: $y = 0$

$z = 0.22$

B: $\Delta T = 11°C$

C: $\dot{Q}_{out} = 193116 \text{ kW}$

$\dot{W}_{net} = 147.048 \text{ MW}$

$\eta_{th} = 0.31$

2)

A: $y = 0$

B = $\Delta T = 14.1 C$

C = $\dot{Q}_{out} = 247539.6 \text{ kW}$

$\dot{W}_{net} = 141.738 \text{ MW}$

$\eta_{th} = 0.29$