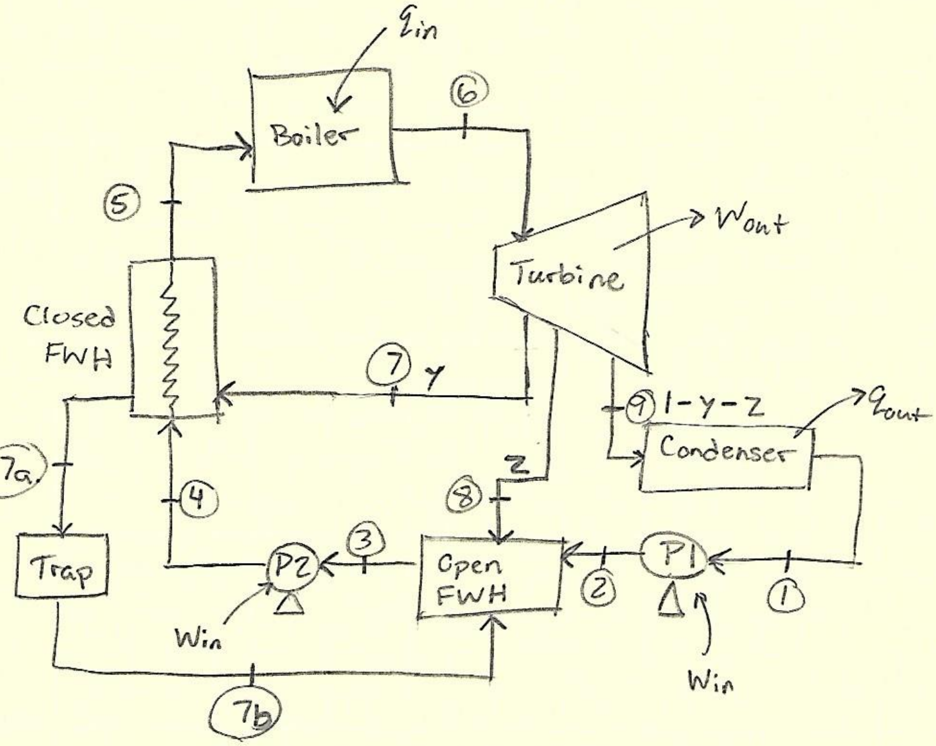
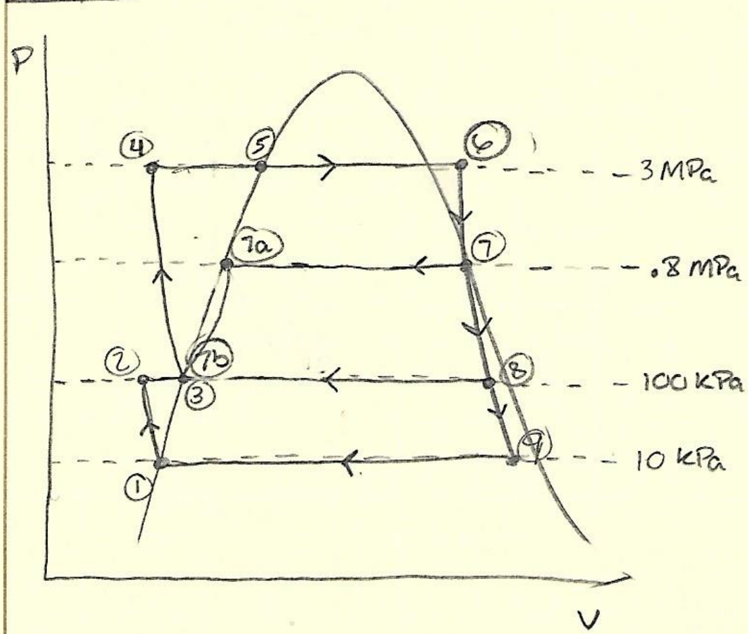
1. Purpose

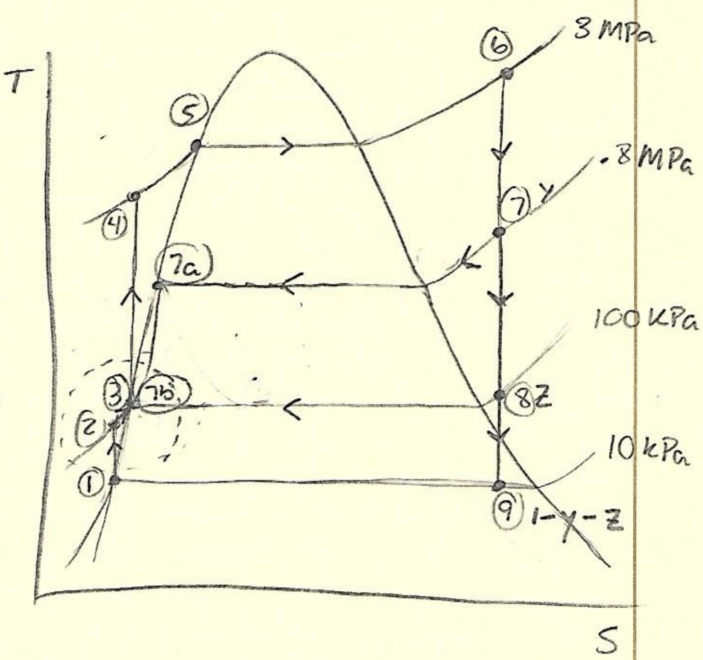
Determine the thermal effciency and specific net work for the full Power plant system as depicted below.

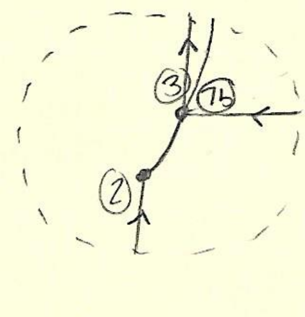
Diagrams



Graphs







1. ## Sources

Cengel & Boles. Thermodynamics - An Engineering Approach. 8th Edition. McGraw Hill, 2015

Design Considerations

1.) Water is pure

2.) Assume all pumps and turbines are isentropic and Ideal

3.) No heat Losses due to pipe lengths and joints

4.) All points before pumps must be sat. Liquid

Data and Variables

P = Pressure
T = Temperature
h = Enthalpy
S = Entropy
x = quality
V = Specific Volume

Y = Fraction of flow moving through ⑦
Z = Fraction of flow moving @ ⑧
$\dot{m}$ = mass flow rate
η_{TH} = Thermal Efficiency
$\dot{W}$ = Power   w = specific work

Materials

- Water

Procedure

1. Calculate individual states (find h, S, x)

- State 1:
  - $P_1 = 10\ kPa$
  - $x_1 = 0$
  - h_1 = Table A5 (Pg 906)
  - S_1 = Table A5
  - $V_1 = V_f$ = A5
- State 2:
  - $P_2 = 100\ kPa$
  - $S_2 = S_1$
  - $h_2 = v_1(P_2 - P_1) + h_1$
- State 3:
  - $P_3 = P_2$
  - $x = 0$
  - $V_3 = V_{f@P_3}$ = A5
  - $h_3 = h_{f@P_3}$ = A5
  - $S_3 = S_{f@P_3}$ = A5
- State 4:
  - $P_4 = 3\ MPa$
  - $S_4 = S_3$
  - $h_4 = h_3 + v_3(P_4 - P_3)$

1. Procedure Continued

- State 5:
  - $P_5 = P_4$
  - $T_5 =$
  - $h_5 =$ Table A5
- State 6:
  - $P_6 = P_4$ $\quad v_6 = A6$
  - $T_6 = 400\ °C$
  - $h_6 = A6\ (909)$
  - $s_6 = A6\ (909)$
- State 7: (y)
  - $P_7 = .8\ MPa$
  - $s_7 = s_6$
  - $h_7 = h_6 - v_6 (P_6 - P_7)$

$h_{7a} \overset{?}{=} h_{7b}$ ☆

- State 7a: (y)
  - $P_{7a} = .8\ MPa$
  - $x = 0$
  - $T_{7a} =$ Interpolate from A5
  - $h_{7a} =$ Interpolate from A5
- State 7b: (y)
  - $P_{7b} = 100\ kPa$
  - $x_{7b} = 0$
  - $h_{7b} = A5$
- State 8: (z)
  - $P_8 = 100\ kPa$ $\quad x_8 = \frac{s_8 - s_{f@100kPa}}{s_{fg@100kPa}} > 1$ = sat vapor
  - $s_8 = s_6$
  - $h_8 = h_6 - v_6 (P_6 - P_8)$
- State 9: (1 - y - z)
  - $P_9 = 10\ kPa$
  - $s_9 = s_6$
  - $x_9 = \frac{s_9 - s_{f@10kPa}}{s_{fg@10kPa}} < 1$ = mixture
  - $h_9 = h_{f@10kPa} + x_9 h_{fg@10kPa}$

2. Calculate y, z, 1 - y - z

$$y = \frac{h_5 - h_4}{h_7 - h_{7a}} = \dot{m}_{Frac} @\ 7, 7a, 7b$$

$$z = \frac{(h_3 - h_2) - y(h_{7b} - h_2)}{(h_8 - h_2)} = \dot{m}_{Frac} @\ 8$$

$$1 - y - z = \dot{m}_{Frac} @\ 2$$

1 Procedure cont.

3. Calculate W_{net} and η_{Th}

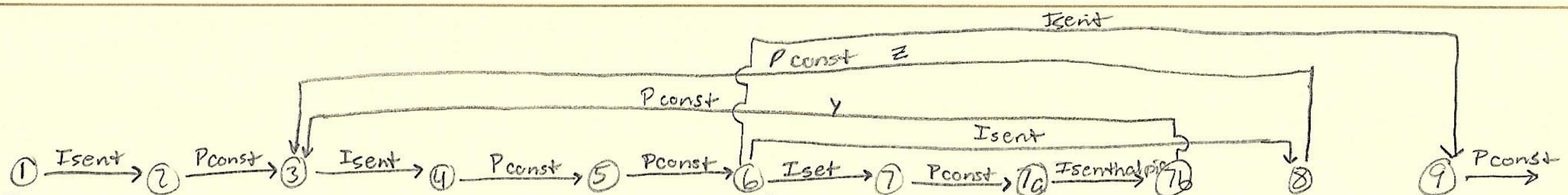
$$W_{net} = W_{out} - W_{in} = \left[(h_6 - h_7)y + (h_6 - h_8)z + (h_6 - h_9)(1-y-z)\right] - \left[(h_4 - h_3) + (h_2 - h_1)(1-y-z)\right]$$

$$q_{in} = h_6 - h_5$$

$$\eta_{TH} = \frac{W_{net}}{q_{in}}$$

Calculations

$h, s = kJ/kg$



1	2	3	4	5	6	7	7a	7b	8	9
$P_1 = 10 kPa$	$P_2 = 100 kPa$	$P_3 = P_2$	$P_4 = 3 MPa$	$P_5 = P_4$	$P_6 = P_4$	$P_7 = .8 MPa$	$P_{7a} = .8 MPa$	$P_{7b} = 100 kPa$	$P_8 = 100 kPa$	$P_9 = 10 kPa$
$x_1 = 0$	$s_2 = s_1$	$x_3 = 0$	$s_4 = s_3$	$x_5 = 0$	$T_6 = 400°C$	$s_7 = s_6$	$x_{7a} = 0$	$x_{7b} = 0$	$s_8 = s_6$	$s_9 = s_6$
$h_1 = 191.81$	$h_2 = 191.9009$	$v_3 = .001043$	$h_4 = 420.5$	$h_5 = 1008.3$	$v_6 = .09938$	$h_7 = 3231.48$	$h_{7a} = 720.87$	$h_{7b} = 417.51$	$h_8 = 2512.67$	$h_9 = 2193.08$
$s_1 = .6492$		$h_3 = 417.51$			$h_6 = 3231.7$				$x_8 = .93$	$x_9 = .837$
$v_1 = .001010$					$s_6 = 6.9235$					

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

$h_2 = (.001010)(100 - 10) + 191.81 = 191.9009$

$h_4 = v_3(P_4 - P_3) + h_3$

$h_4 = (.001043)(3000 - 100) + 417.51 = 420.5347$

$h_7 = -v_6(P_6 - P_7) + h_6$

$h_7 = -(.09938)(3 - .8) + 3231.7 = 3231.4814$

$x_8 = \frac{s_8 - s_{f@100 kPa}}{s_{fg@100 kPa}}$

$x_8 = \frac{6.9235 - 1.3028}{6.0562} = .928 < 1$

(mixture)

$h_8 = h_{f@100kPa} + x_8 h_{fg@10kPa}$

$h_8 = 417.51 + .93(2257.5) = 2512.67$

$x_9 = \frac{s_9 - s_{f@10kPa}}{s_{fg@10 kPa}}$

$x_9 = \frac{6.9235 - .6492}{7.4996} = .8366$

$h_9 = 191.81 + (.8366)(2392.1) = 2193.08$

mass Fractions:

$y = \frac{h_5 - h_4}{h_7 - h_{7a}} = \frac{1008.3 - 420.5}{3231.48 - 720.87} = .234$

$z = \frac{(h_3 - h_2) - y(h_{7b} - h_2)}{(h_8 - h_2)} = \frac{(417.51 - 191.9009) - (.234)(417.51 - 191.9009)}{(2512.67 - 191.9009)} = .0745$

$1 - y - z = .6915$

Calculations Continued

$$W_{net} = [(3231.7 - 3231.48)(.234) + (3231.7 - 2512.67)(.0745) + (3231.7 - 2193.08)(.6915)] - [(420.5 - 417.5) + (191.9009 - 191.81)(.6915)]$$

$$\boxed{W_{net} = 768.76 \ kJ/kg}$$

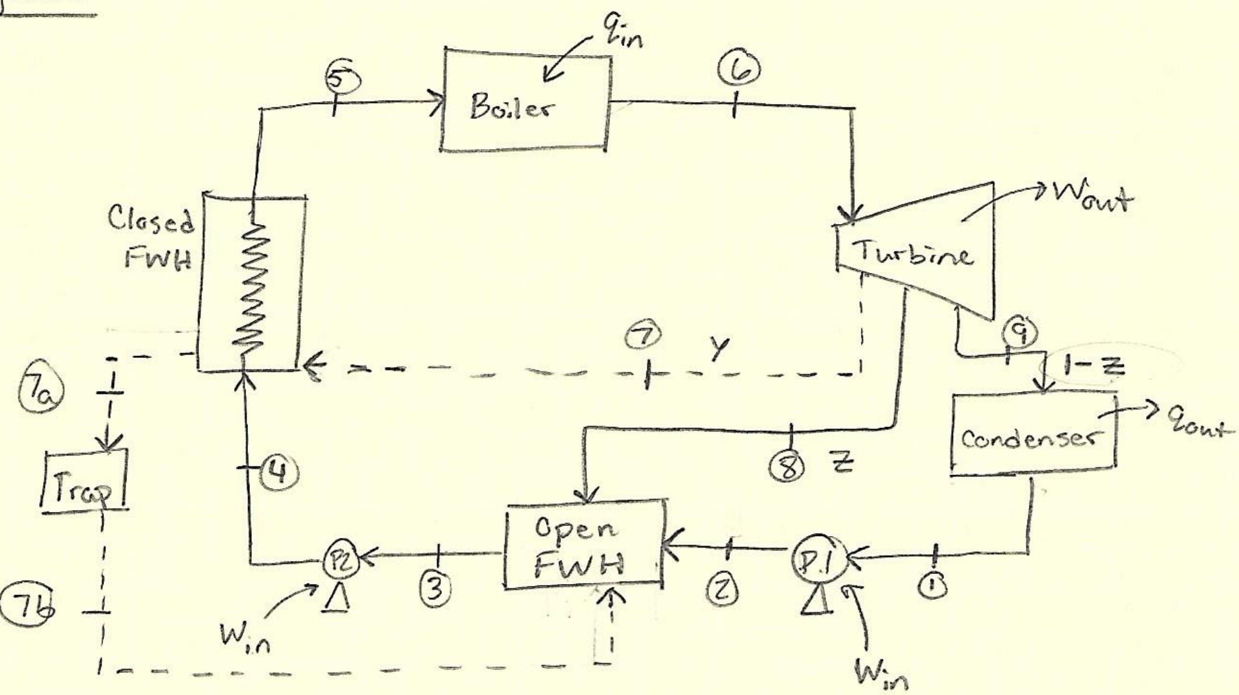
$$q_{in} = 3231.7 - 1008.3 = 2223.4 \ kJ/kg$$

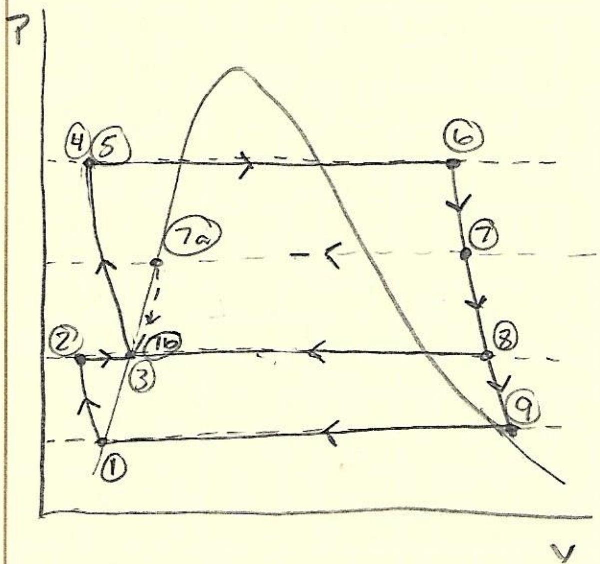
$$\boxed{\eta_{TH} = .346}$$

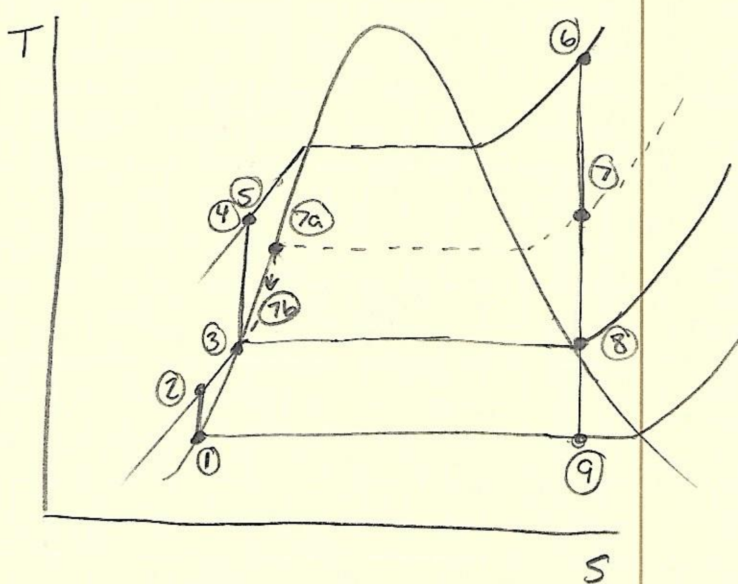
2. Purpose

To Determine the thermal efficiency, η_{TH}, and net work, w_{net}, for the steam power plant when the Extraction points 7, 7a, and 7b are not used due to maintenence.

Diagrams







------ = Not Included in thermal analysis

Source

Cengel & Boles. Thermodynamics - An Engineering Approach, 8th Edition. McGraw Hill, 2015.

Design Considerations

1.) Water is pure
2.) Assume all pumps and turbines are Isentropic and Ideal
3.) No heat loss due to imperfections
4.) All points before pumps must be sat. Liquid
5.) Points 7, 7a, 7b are not used Eliminating use of closed FWH

Data and Variables

P = Pressure
T = Temp
h = Enthalpy
S = Entropy
X = quality
V = specific volume

Z = Fraction of flow @ ⑧
$\dot{m}$ = mass flowrate
η_{TH} = Thermal Efficiency
W = specific Work

Materials

-Water

Procedure

1. Calculate individual States
   - follow same procedure for question 1
     - Do not use states 7, 7a, 7b
     - States 4 and 5 become equal
2. Calculate z and 1-z

☆ $$z = \frac{h_3 - h_2}{h_8 - h_2}$$

$$1 - z$$

3. Calculate W_{net} and η_{TH}

$$W_{net} = W_{out} - W_{in} = \left[(h_6 - h_8)z + (h_6 - h_9)(1 - z)\right] - \left[(h_4 - h_3) + (h_2 - h_1)(1 - z)\right]$$

Calculations

$h, s = kJ/kg$

① —Isent→ ② —P const→ ③ —Isent→ ④ —Equal→ ⑤ —Pconst→ ⑥ —Isent→ ⑧ ; ⑥ —Isent (1−y−z)→ ⑨ —Pconst→ ; ⑧ —Pconst (z)→ ③

①	②	③	④	⑤	⑥	⑧	⑨
$P_1 = 10$ kPa	$P_2 = 100$ kPa	$P_3 = P_2$	$P_4 = 3$ MPa	$P_5 = P_4$	$P_6 = P_4$	$P_8 = 100$ kPa	$P_9 = 10$ kPa
$x_1 = 0$	$s_2 = s_1$	$x_3 = 0$	$s_4 = s_3$	$s_5 = s_3$	$T_6 = 400°C$	$s_8 = s_6$	$s_9 = s_6$
$h_1 = 191.81$	$h_2 = 191.9009$	$v_3 = .001043$	$h_4 = 420.53$	$h_5 = h_4$	$v_6 = .09938$	$h_8 = 2512.67$	$h_9 = 2193.08$
$s_1 = .6492$		$h_3 = 417.51$			$h_6 = 3231.7$	$x_8 = .923$	$x_9 = .8366$
$v_1 = .001010$					$s_6 = 6.9235$		

$h_2 = (.001010)(100-10) + 191.81 = 191.9009$

$h_4 = (.001043)(3000-100) + 417.51 = 420.5347$

$x_8 = \frac{6.9235 - 1.3028}{6.0562} = .928$

$h_8 = 417.51 + .93(2257.5) = 2512.67$

$x_9 = \frac{6.9235 - .6492}{7.4496} = .8366$

$h_9 = 191.81 + (.8366)(2392.1) = 2193.08$

$y = 0$

$z = \frac{h_3 - h_2}{h_8 - h_2} = \frac{(417.51 - 191.9009)}{(2512.67 - 191.9009)} = .097$

$1 - z = .9028$

$W_{net} = [(3231.7 - 2512.67)(.097) + (3231.7 - 2193.08)(.9028)] - [(420.53 - 417.51) + (191.9009 - 191.81)(.9208)]$

$\boxed{W_{net} = 1003.8 \ kJ/kg}$

$q_{in} = h_6 - h_{4/5} = 3231.7 - 420.53 = \boxed{2811.17 \ kJ/kg}$

$\boxed{\eta_{TH} = .357}$

FOR BOTH CASES 1 AND 2

Summary

Case	W_{net} (kJ/kg)	η_{TH}
1	768.76	.346
2	1003.8	.357

Analysis

The big difference between the two cases of the steam power plant Was the net work produced by the cycle. Case 1 had a Lower net work because we had to considered the closed FWH, Which includes two additional states with different Enthalpies. When analized by the 2nd Law, The two different Enthalpies are what cause a lower net work. In Case 2 the Closed FWH is not used due to the maintanence being done on the system. Since the closed FWH was not used, States 4 and 5 became Identicle causing no difference in enthalpies. It was discovered thet the thermal efficiency was actually slightly higher when maintenance was being done and the closed FWH was not used.