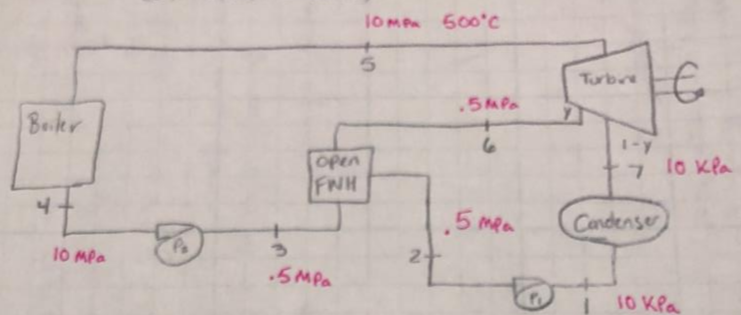
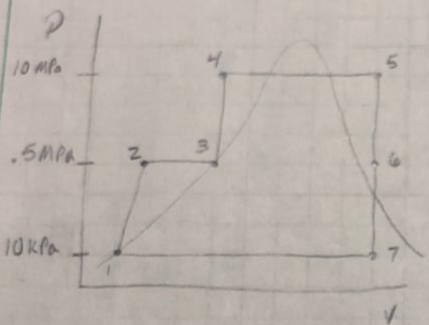
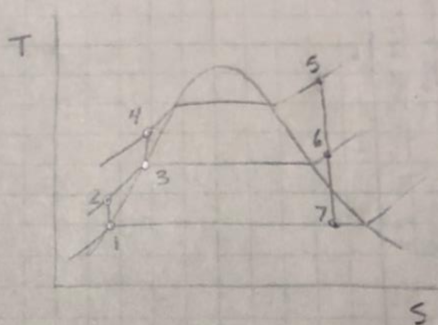
Problem 1 | Test 2 | Desmond Banks

Purpose: Determine (A) Mass flow rate
(B) Thermal efficiency

Drawings







Sources: Cengel & Boles. "Thermodynamics - An Engineering Approach". 4th edition, Mcgraw Hill 2002

Design Considerations:

- Turbine and pumps are isentropic processes
- Net output power 150 MW
- Source temp is 1300K
- Sink temp is 303K

Data and Variables

- $q_{in} = h_5 - h_4$
- $q_{out} = (1-y)(h_7 - h_1)$
- $W_{turb\,out} = (h_5 - h_6) + (1-y)(h_6 - h_7)$
- $W_{pump\,in} = (1-y)\, w_{pump\,1} + w_{pump\,2}$
- $\eta_{th} = 1 - \frac{q_{out}}{q_{in}}$

Calculations:

isent, Pconst, isent, Pconst, isent, isent

①
$P_1 = 10\,kPa$
$h_1 = 191.83\ kJ/kg$
$V_1 = .00101\ m^3/kg$
@Table A-5

②
$P_2 = .5\,MPa$
$h_2 = 192.32\ kJ/kg$

③
$P_3 = .5\,MPa$
$h_3 = 640.23\ kJ/kg$
$V_3 = .001093\ m^3/kg$

④
$P_4 = 10\,MPa$
$h_4 = 650.61\ kJ/kg$

⑤
$P_5 = 10\,MPa$
$T_5 = 600°C$
$h_5 = 3373.7\ kJ/kg$
$V_5 = .03279\ m^3/kg$
$S_5 = 6.5966\ kJ/kg\cdot K$
@Table A-6

⑥
$P_6 = .5\,MPa$
$S_6 = S_5 = 6.5966\,kJ/kg$
$X_6 = .955\ kJ/kg\cdot K$
$h_6 = 2653.85\,kJ/kg$

⑦
$P_7 = 10\,kPa$
$S_7 = S_5 = 6.5966\,kJ/kg$
$h_7 = 2089.32\ kJ/kg$

$$W_{pump\,1} = v_1(P_2 - P_1)$$
$$= (.00101)(500 - 10)\,kPa$$
$$W_{pump\,1} = .495\ kJ/kg$$

$$W_{pump\,2} = V_3(P_4 - P_3)$$
$$= (.001093)(10000 - 500)\,kPa$$
$$W_{pump\,2} = 10.384\ kJ/kg$$

$$X_6 = \frac{S_6 - S_f}{S_{fg}}$$
$$X_6 = \frac{(6.5966 - 1.8607)}{4.9606}$$
$$\underline{X_6 = .955\,kJ/kg\cdot K}$$

$$h_6 = h_f + X_6(h_{fg})$$
$$h_6 = 640.23 + (.955)(2108.5)$$
$$\underline{h_6 = 2653.85\ kJ/kg}$$

$$X_7 = \frac{(6.5966 - .6493)}{7.5009}$$
$$\underline{X_7 = .793\ kJ/kg\cdot K}$$

$$h_7 = h_f + X_7(h_{fg})$$
$$h_7 = 191.83 + (.793)(2392.8)$$
$$\underline{h_7 = 2089.32}$$

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Calculations:

$y = \frac{h_3 - h_2}{h_6 - h_2}$

$q_{in} = h_5 - h_4$

$q_{out} = (1-y)(h_7 - h_1)$

$y = \frac{(640.23 - 192.32)\ kJ/kg}{(2653.85 - 192.32)\ kJ/kg}$

$W_{net} = q_{in} - q_{out}$

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

$W_{net} = 150\ MW = 150000\ KW$

$y = \frac{447.91}{2461.53} = .182$

$\eta_{th} = 1 - \frac{q_{out}}{q_{in}}$

$y = .182$

$q_{in} = (3373.7 - 650.61)\ kJ/kg$

$q_{in} = 2723.09\ kJ/kg$

$q_{out} = (1 - .182)(2089.32 - 191.83)\ kJ/kg$

$(.818)(1897.49)\ kJ/kg$

$q_{out} = 1552.15\ kJ/kg$

$W_{net} = (2723.09 - 1552.15)\ kJ/kg$

$W_{net} = 1170.94\ kJ/kg$

$\dot{m} = \frac{150000\ KW}{1170.94\ kJ/kg}$

$\dot{m} = 128.1$

$\eta_{th} = 1 - \frac{1552.15\ kJ/kg}{2723.09\ kJ/kg}$

$\eta_{th} = 1 - .57$

$\eta_{th} = .43$ or 43%

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Procedure:

- Drew Pv and Ts diagrams
- Found states, their enthalpies, and volumes
- Calculated work of pumps
- Calculated "y" value
- Calculated q in and q out
- Calculated Wnet.
- Solved for $\dot{m}$
- Solved for Thermal efficiency

Summary:

The purpose of this problem was to test my Knowledge on regenerative Rankine cycles. My task for this problem was to calculate the mass flow rate of steam through the boiler and to calculate the thermal efficiency of the cycle.

Materials:

- Turbine
- Pumps(2)
- Boiler
- Condenser
- Open FWH
- water/steam

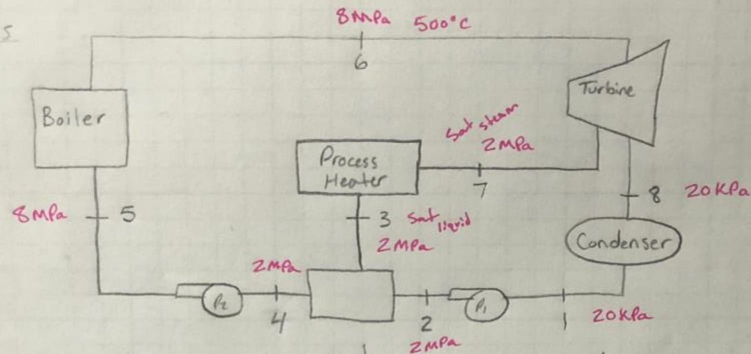
Analysis:

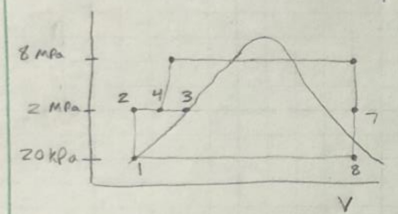
Analyzing the problem I realize that by creating a Pv and Ts diagram I was better able to find all of the states. After finding all of my states and their properties, I was able to calculate mass flow rate and the thermal efficiency of the cycle.

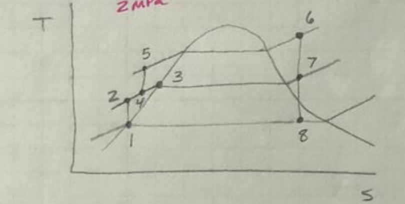
Problem 2 | Test 2 | Dezmond Banks

Purpose: Determine (A) the rate of process heat supply
(B) the net power output
(C) the utilization factor of the plant

Drawings







Sources: Cengel & Boles "Thermodynamics - An Engineering Approach" 4th edition, Mcgraw Hill 2002

Design Considerations:

- iscentropic efficiencies of turbines & pumps are 80%
- 25% saturated steam extracted from Turbine to process heater

Data & Variables:

- $\dot{Q}_{in} = \dot{m}_3 (h_4 - h_5)$
$\dot{Q}_{out} = \dot{m}_7 (h_7 - h_1)$
$\dot{Q}_P = \dot{m}_5 h_5 + \dot{m}_6 h_6 - \dot{m}_8 h_8$
$\dot{W}_{turb} = (\dot{m}_4 - \dot{m}_3)(h_4 - h_6) + \dot{m}_7 (h_6 - h_7)$
$\epsilon_u = 1 - \frac{Q_{out}}{Q_{in}}$
$W_{pump1} = \frac{v_1 (P_2 - P_1)}{\eta_{th}}$ $\quad W_{pump2} = \frac{v_4 (P_5 - P_4)}{\eta_{th}}$

Mixing chamber
Energy balance
$m_3 h_3 + m_2 h_2 = m_4 h_4$

Calculations:

① $P_1 = 20$ KPa, $h_1 = 251.40$ kJ/kg, $V_1 = .001017$ m³/kg

② $P_2 = 2$ MPa, $h_2 = 253.69$ kJ/kg

③ $P_3 = 2$ MPa, $h_3 = 908.79$ kJ/kg, $V_3 = .001177$ m³/kg

④ $P_4 = 2$ MPa, $h_4 = 417.47$ kJ/kg, $V_4 = .001043$

⑤ $P_5 = 8$ MPa, $h_5 = 425.29$ kJ/kg

⑥ $P_6 = 8$ MPa, $T_6 = 500°C$, $h_6 = 3398.3$ kJ/kg, $s_6 = 6.7240$ kJ/kg·K

⑦ $P_7 = 2$ MPa, $s_7 = 6.7240$ kJ/kg·K, $h_7 = 3079.88$ kJ/kg

⑧ $P_8 = 20$ kPa, $s_8 = 6.7240$ kJ/kg·K, $h_8 = 2451.6$ kJ/kg

$$h_{7s} = 2902.5 + (3023.5 - 2902.5)\left(\frac{6.7240 - 6.5453}{6.7664 - 6.5453}\right)$$

$$2902.5 + \underset{(97.77)}{121 * (.808)}$$

$$h_{7s} = 3000.27 \text{ kJ/kg}$$

$$h_7 = h_6 - \eta_{tur}(h_6 - h_{7s})$$

$$h_7 = 3398.3 - .80\underset{(398.03)}{(3398.3 - 3000.27)} \text{ kJ/kg}$$

$$h_7 = 3398.3 - 318.42$$

$$h_7 = 3079.88$$

$$W_{pump1} = \frac{V_1(P_2 - P_1)}{\eta_{pump} = .80}$$

$$\frac{(.001017)(2000 - 20)\text{kPa}}{.80}$$

$$W_{pump1} = 2.29 \text{ kJ/kg}$$

$$W_{pump2} = \frac{V_4(P_5 - P_4)}{\eta_{pump} = .80}$$

$$\frac{(.001043)(8000 - 2000)}{.80}$$

$$W_{pump2} = 7.82 \text{ kJ/kg}$$

$$h_5 = 417.47 + (7.82)$$

$$h_5 = 425.29 \text{ kJ/kg}$$

Mixing chamber

$$m_3 h_3 + m_2 h_2 = m_4 h_4$$

$$(2.5)(908.79) + (7.5)(253.69) = 10\, h_4$$

$$h_4 = 417.47$$

$$s_{8s} = s_f + x_8 s_{fg}$$

$$6.7240 = (.8320) + x_8(7.0766)$$

$$x_8 = .8326$$

$$m_3 = .25\, \dot{m}$$

$$m_3 = .25(10 \text{ kg/s})$$

$$m_3 = 2.5 \text{ kg/s}$$

efficiency: 80%

$\dot{m}_{turbine} = 10$ kg/s steam

$$\dot{Q}_{in} = \dot{m}_5(h_6 - h_5)$$

$$\dot{Q}_{out} = \dot{m}_8(h_8 - h_1)$$

$$\dot{Q}_P = \dot{m}_7(h_7 - h_3)$$

$$\dot{W}_{turb} = \dot{m}_6(h_6 - h_7) + m_8(h_7 - h_8)$$

$$h_{8s} = h_f + x_8 h_{fg}$$

$$= 251.40 + (.8326)(2358.3)$$

$$h_{8s} = 2214.92 \text{ kJ/kg}$$

$$h_8 = h_6 - \eta_{tur}(h_6 - h_{8s})$$

$$h_8 = (3398.3) - .80(3398.3 - 2214.92)$$

$$h_8 = 2451.6 \text{ kJ/kg}$$

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Calculations:

$Q_p = \dot{m}_7 (h_7 - h_3)$

$= (2.5)(3079.8 - 908.79)$

$Q_p = 5427.53$ kJ/s

$W_{pump} = m_1 (w_{pump1}) + m_4 (w_{pump2})$

$= 7.5(2.29) + 10(7.82)$

$W_{pump} = 95.38$ kJ/s

$\epsilon_u = \dfrac{W_{net} + Q_p}{Q_{in}}$

$\epsilon_u = \dfrac{(10189.87 + 5427.53)}{29730.1}$

$\epsilon_u = .525$ or 52.5%

$W_{turb} = \dot{m}_6 (h_6 - h_7) + m_8 (h_6 - h_8)$

$10(3398.3 - 3079.8) + 7.5(3398.3 - 2451.6)$

3185

$W_{turb} = 10285.25$ kJ/s

$W_{net} = W_{turb} - W_{pump}$

$= 10285.25 - 95.38$ kJ/s

$W_{net} = 10189.87$ kJ/s

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

$= 10(3398.3 - 425.29)$ kJ/kg

$Q_{in} = 29730.1$ kJ/s

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Procedure:

- Drew Pv and Ts diagrams
- Found states and their properties
- Calculated work of pumps
- Calculated Q_{in}
- Calculated $Q_{process}$
- Calculated W_{turb} & W_{pump}
- Solved for W_{net}
- Solved for ϵ_u

Summary:

The purpose of this problem was to test my knowledge on Cogenerative systems. My task for this problem was to create a Pv and Ts diagram and to determine the rate of process heat supply, net power output, and the utilization factor of the plant.

Materials:

- Turbine
- Condenser
- Pumps (2)
- Mixing chamber
- Feed water
- Boiler
- Process heater
- Steam

Analysis:

Analyzing the problem I realize that by creating a Pv and Ts diagram, I was better able to visualize what was happening and calculate my states. After finding all of my states and their properties, I was able to calculate rate of process heat supply, net power output, and the utilization factor of the plant.