Test 2

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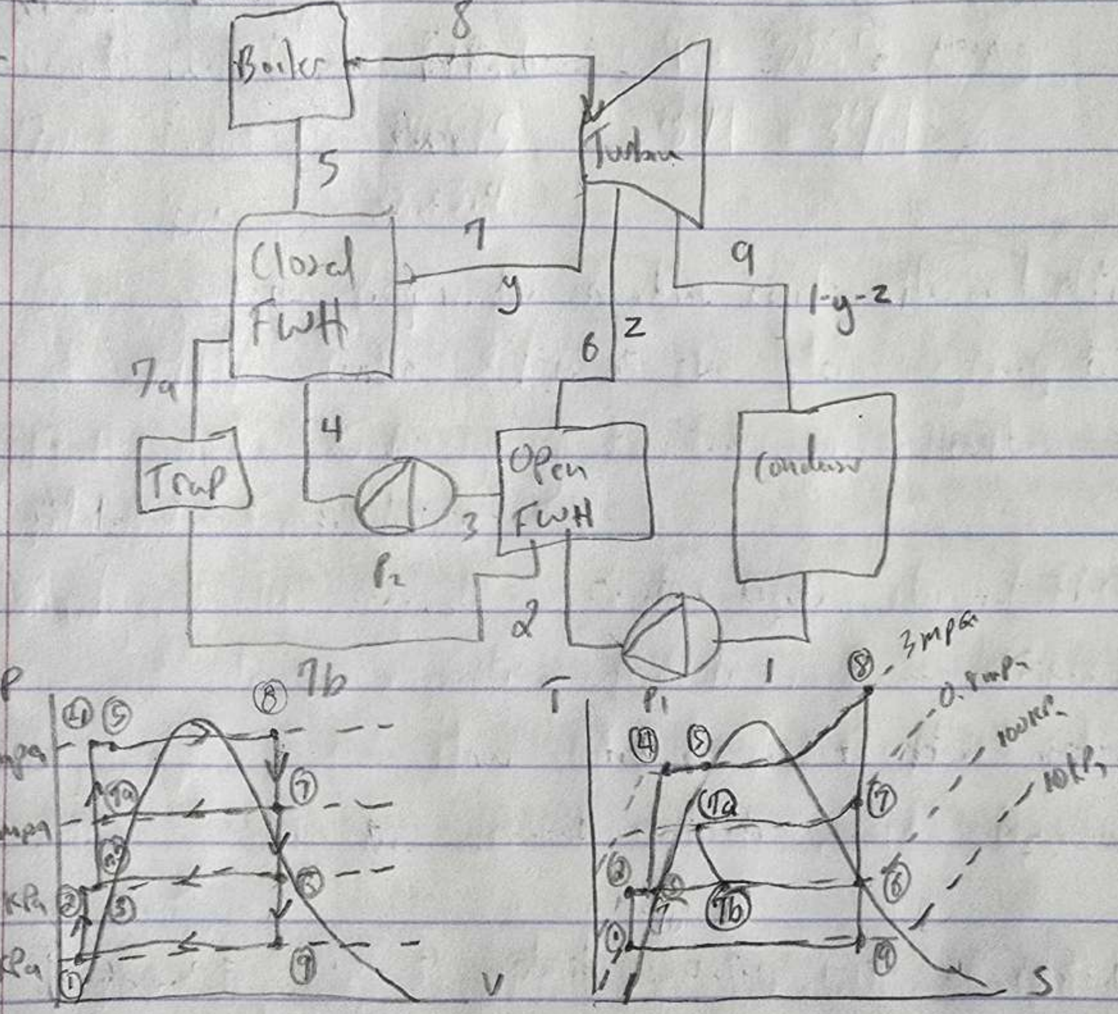
1.1 Purpose: To calculate the thermal efficiency of the cycle and specific net work with the fully operational Power Plant

1.2



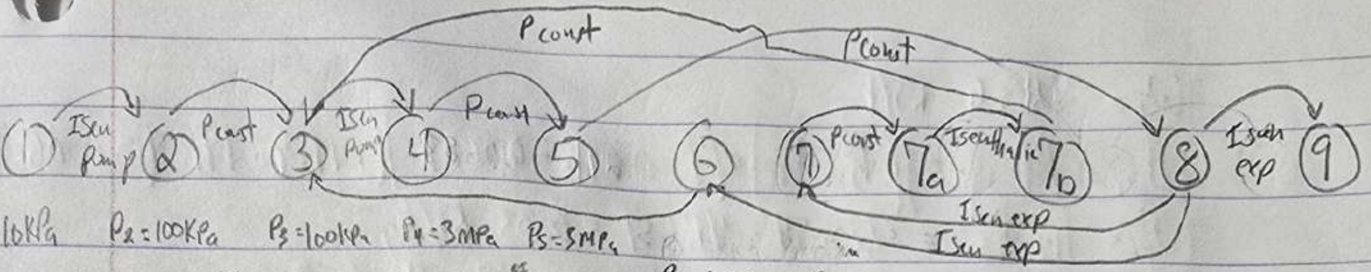
1.3 Source: Thermodynamics, an Engineering approach 9th edition McGraw Hill 2019

1.4 Design Considerations: Steady state and steady flow operation. The turbine and pumps are isentropic. The exit of the condensor, open FWH, and closed FWH are saturated liquids. Negiable kinetic and Potential energy changes.

1.5 Data and Variables

$P_1 = 10$ KPa $P_2 = 100$ kPa $P_3 = 0.8$ MPa $= 800$ kPa $P_4 = 3$ MPa $= 3000$ kPa

$T_4 = 400°C$



$P_1 = 10\,kPa$ $P_2 = 100\,kPa$ $P_3 = 100\,kPa$ $P_4 = 3\,MPa$ $P_5 = 3\,MPa$

$h_1 = 191.81\,kJ/kg$ $h_2 = 191.9\,kJ/kg$ $h_3 = 417.51\,kJ/kg$ $h_4 = 420.54\,kJ/kg$ $h_5 = 1008.3$ $x_5 = 0$

$V_1 = 0.00101\,m^3/kg$ $V_3 = 0.001043\,m^3/kg$ $x_3 = 0$ $S_5 = 1.3028$

$x_1 = 0$

$P_6 = 100\,kPa$ $x_6 = 0.92809$ $h_6 = 2512.67$

$P_7 = 0.8\,MPa$ $P_{7a} = 0.8\,MPa$ $P_{7b} = 100\,kPa$ $P_8 = 3\,MPa$ $P_9 = 10\,kPa$

$S_7 = S_8$ $S_3 = 7_a$ $h_{7b} = 417.51$ $T_8 = 400°C$ $S_8 = S_9$

$x_7 = 1.056$ $h_{7a} = 720.87\,kJ/kg$ $h_8 = 3231.7\,kJ/kg$ $h_9 = 2191.61$

$h_7 = 2892.4\,kJ/kg$ $S_8 = 6.9235$

$$h_2 = V_1(P_2 - P_1) + h_1 = 0.00101(100-10) + 191.81 = 191.9\ kJ/kg$$

$$h_4 = V_3(P_4 - P_3) + h_3 = 0.001043(3000-100) + 417.51 = 420.535$$

$$x_9 = \frac{S_9 - S_f}{S_{fg@10kPa}} = \frac{6.9235 - 0.6492}{7.4996} = 0.836$$

$$h_9 = x_9 \cdot h_{fg} + h_f = 0.836 \cdot 2392.1 + 191.81 = 2191.61\ kJ/kg$$

$$x_7 = \frac{S_7 - S_f}{S_{fg@0.8MPa}} = \frac{6.9235 - 2.0457}{4.6160} = 1.056$$

h_7 = Interpolated from steam tables

$$x_6 = \frac{S_6 - S_f}{S_{fg}} = \frac{6.9235 - 1.3028}{6.0562} = 0.92809$$

$$h_6 = x_6 \cdot h_{fg} + h_f = 0.92809 \cdot 2257.5 + 417.51 = 2512.67$$

$$q_{in} = h_8 - h_5 = 3231.7 - 1008.3 = 2223.4\ kJ/kg$$

$$y(h_7 - h_{7a}) = (h_5 - h_4) = y(2898.4 - 720.87) = (1008.5 - 420.54)\quad y = 0.271$$

$$(1-y-z)h_2 + zh_6 + yh_{7B} = h_3$$

$$(1 - 0.271 - z)(191.9) + z(2512.67) + 0.271(417.51) = 417.51$$

$$(0.729 - z)(191.9) + 2512.67z + 113 = 417.51$$

$$2520.77z = 164.61 \qquad z = 0.0653$$

$$W_T = (h_8 - h_7) + (1-y)(h_7 - h_6) + (1-y-z)(h_6 - h_9)$$

$$(3231.7 - 2892.4) + (1 - 0.271)(2892.4 - 2512.67) + (1 - 0.271 - 0.653)(2512.67 - 2191.61)$$

$W_T = 828.6$ kJ/kg

$W_{p1} = (1-y-z)(h_2-h_1) = (1-0.271-0.0653)(191.9-191.81) = 0.06$ kJ/kg

$W_{p2} = h_4 - h_3 = 420.54 - 417.51 = 3.03$ kJ/kg

$W_p = W_{p1} + W_{p2} = 0.06 + 3.03 = 3.09$ kJ/kg

$W_{net} = W_T - W_p = 828.6 - 3.09 = 825.5$ kJ/kg

$\eta_{th} = \frac{W_{net}}{q_{in}} = \frac{828.5}{2223.4} = 0.371 = 37.1\%$

1.8 Summary: The Regenerative Rankine cycle thermal efficiency was at 37.1% with 27% of the steam going to the closed FWH and 6.5% going to the open FWH.

1.9 Material: Fresh Water

1.10 Analysis: This regenative Rankine cycle showed the use of steam extraction used to improve efficiency by adjusting the flow rates to the FWH's net work and efficiency can be affected which could improve overall efficiency.

2.1 Purpose to keep the plant operating with a control valve to the closed FWH completely closed due to malfunction the flow to the open FWH may be adjusted to continue operations.

2.2
2.3
2.4
2.5 } Same as problem 1

$y = 0$

$(1-z)h_2 + z h_6 = h_3 = (1-z)(191.9) + z(2512.67) = 417.51$

$2320.77z = 225.61 \quad z = 0.0972$

$W_T = (h_8 - h_7) + (1-y)(h_7 - h_6) + (1-y-z)(h_6 - h_9)$

$W_T = (3231.7 - 2892.4) + (1-0)(2892.4 - 2512.67) + (1-0-0.0972)(2512.67 - 2191.61)$

$W_T = 1008.7$ kJ/kg

$W_{P1} = (1-y-z)(h_2 - h_1) = (1-0-0.0972)(191.9 - 191.81) = 0.072$ kJ/kg

$W_{P2} = h_4 - h_3 = 420.54 - 417.51 = 3.03$

$W_P = W_{P1} + W_{P2} = 0.072 + 3.03 = 3.1$ kJ/kg

$W_{net} = W_T - W_P = 1008.7 - 3.1 = 1005.6$ kJ/kg

$q_{in} = h_8 - h_5 = 3231.7 - 1008.3 = 2223.4$ kJ/kg

$\eta_{th} = \frac{W_{net}}{q_{in}} = \frac{1005.6}{2223.4} = 0.452 = 45.2\%$

2.8 Summary: efficiency increased from 37.1% to 45.2% with the valve to the closed FWH closed the valve to the open FWH was opened to 9.7% allowing for a higher net work and better efficiency.

2.9 Same as Problem 1

2.10 Analysis: The original design though not as thermally efficient as with the closed FWH valve, it may create excess stress to the open FWH and its components reducing the systems lifespan. Therefore the system should be fixed as soon as feasibly possible.