Problem #1 (Solution).

Answer to 3

Optimum degree of regeneration \( R = \frac{1}{2} \)

Thus,

\[
h_5 = \frac{h_6 + h_y}{2} \quad h_6 = 1317 \quad h_y = 174 \quad h_5 = 745
\]

The corresponding saturation pressure is \( p_s = p_2 = 0.9 \) MPa.

The closest data for superheated steam are for \( p = 1 \) MPa. Thus choose \( p_2 = p_5 = 1 \) MPa.

Answer to 4

Conditions at 1

\[
h_4 = 3348 \quad S_4 = 6.66
\]

Conditions at 2

\[
S_2 = 6.66 \quad p_2 = 1 \) MPa \quad h_2 = 2828
\]

Conditions at 3

\[
h_3 = h_e (1 - x_3) + h_v x_3 = 2072
\]

\[
S_3 = S_2 = 6.66 \quad x_3 = \frac{S_3 - S_e}{S_v - S_e} = \frac{6.66 - 0.59}{8.23 - 0.59} = 0.79
\]
Condintions at 4

\[ h_4 = 174 \]

Energy balance at the OFH

\[ \gamma \]

\[ \frac{h_5}{h_4} \]

\[ 1 \]

\[ h_5 = (1-\gamma)h_4 + \gamma h_2 = h_4 + \gamma (h_2-h_\text{u}) \implies \gamma = \frac{h_5-h_4}{h_2-h_4} \]

\[ \gamma = \frac{763-174}{2828-174} = 0.22 \]

Efficiency

\[ \eta = 1 - \frac{Q_\text{out}}{Q_\text{in}} = 1 - \frac{(1-\gamma)(h_5-h_\text{u})}{h_4-h_5} = 0.43 \]

Answer to 5. The efficiency can be improved by increasing the number of FHTs and the degree of regeneration R. R should be equal to \( \frac{Z}{Z+1} \) where Z is the number of FHTs. The efficiency can also be improved by reheating the steam and using a multiple stage turbine.
Problem #2

Problem 1

1. \[ P_1 = 120 \text{ bar}, \; T_1 = 520^\circ \text{C}, \; h_1 = 3401.8, \; S_1 = 6.55 \]

2. \[ P_2 = 10 \text{ bar}, \; S_2 = S_4 = 6.55, \; h_2 = 2783 \]

3. \[ X = \frac{S_2 - S_e}{S_v - S_e} = \frac{6.55 - 2.134}{6.586 - 2.134} = 0.99 \]

4. \[ h_{25} = 0.99 \times 2778.1 + 0.01 \times 763 = 2764 \]

5. \[ h_2 = h_4 + X \left( h_{25} - h_4 \right) = 2783 \]

6. \[ S_2 = 6.587 + \frac{2783 - 2778.1}{2827.9 - 2778.1} \times (6.694 - 6.586) = 6.597 \]

7. \[ P_3 = 0.08 \text{ bar}, \; S_3 = S_2 = 6.597 \]

8. \[ X = \frac{S_3 - S_e}{S_v - S_e} = \frac{6.597 - 0.59}{8.23 - 0.59} = 0.786 \]
\[ h_{36} = 2577 \times 0.786 + (1 - 0.786) \times 174 = 2062.8 \]

\[ h_3 = h_2 + \eta \left( h_{36} - h_2 \right) = 2084.4 \]

\[ h_6 = h_5 + \nu (p_6 - p_5) = 174 + 10^{-3} (2.16 \times 0.08 \cdot 10^5) / 10^{-3} \approx 186 \]

**C.F.H. Energy Balance**

\[ \eta (h_3 - h_9) = h_7 - h_6 \rightarrow \eta = \frac{h_7 - h_6}{h_3 - h_9} = \frac{730 - 186}{2283 - 763} = 0.27 \]

\[ h_7 = u (170^\circ C) + \nu (p_{refl} - h_{sat}(170^\circ C)) = 719 + \frac{\sqrt{10^{-3} (1210 - 7910^5)}}{1000} \approx 730 \]

\[ \eta = \frac{W_{max}}{\dot{Q}_{im}} = \frac{(h_1 - h_2) + (1 - \eta)(h_2 - h_3) - (h_6 - h_5)}{(h_7 - h_7)} = 0.418 \]

\[ \eta = 1 - \frac{\dot{Q}_{out}}{\dot{Q}_{im}} \rightarrow \dot{Q}_{out} = (-\eta) \dot{Q}_{im} = (-\eta) \frac{W_{net}}{2} = 557 \text{ MW} \]

\[ \dot{Q}_{out} = m_c \left[ h_{im} - h_{out} \right] = m_c \left[ (1 - \eta) h_3 + \eta \right] = 557 \times 10^3 \text{ KJ} \]

\[ m_c = \frac{557 \times 10^3}{(1 - 0.27) 2084.4 + 0.27 \times 763 - 174} = 3.58 \times 10^4 \text{ Kg/s} \]