Problem 10-53 as an example

\[
\begin{align*}
P_H &= 12500 \text{ kPa} \\
T_{\text{max}} &= 550 \text{ C} \\
P_{\text{cond}} &= 10 \text{ kPa} \\
P_{\text{CFWH}} &= 800 \text{ kPa} \\
P_{\text{OFWH}} &= 300 \text{ kPa} \\
W_{\text{dot\_net}} &= 250,000 \text{ kW}
\end{align*}
\]

State 1: SAT LIQ at \( P_{\text{cond}} \)

\[
\begin{align*}
P_{1} &= 10 \text{ kPa} = P_{\text{cond}} \\
h_{1} &= 191.81 \text{ kJ/kg} = h_{L\_p\_H2O}(P_{1}) \\
s_{1} &= 0.6492 \text{ kJ/kg-K} = s_{L\_p\_H2O}(P_{1})
\end{align*}
\]

State 2: isentropic from \( P_{\text{cond}} \) to \( P_{\text{OFWH}} \)

\[
\begin{align*}
P_{2} &= 300 \text{ kPa} = P_{\text{OFWH}} \\
h_{2} &= 192.09 \text{ kJ/kg} = h_{ps\_H2O}(P_{2}, s_{1})
\end{align*}
\]

State 3: SAT LIQ at \( P_{\text{OFWH}} \)

\[
\begin{align*}
P_{3} &= 300 \text{ kPa} \\
h_{3} &= 561.46 \text{ kJ/kg} = h_{L\_p\_H2O}(P_{3}) \\
s_{3} &= 1.6718 \text{ kJ/kg-K} = s_{L\_p\_H2O}(P_{3})
\end{align*}
\]

State 4: isentropic pumping to \( P_{H} \)

\[
\begin{align*}
P_{4} &= 12500 \text{ kJ/kg} = P_{H} \\
h_{4} &= 574.52 \text{ kJ/kg} = h_{ps\_H2O}(P_{4}, s_{3}) \\
T_{4} &= 134.68 \text{ C} = T_{ph\_H2O}(P_{4}, h_{4})
\end{align*}
\]

State 5: compressed liquid at known \( P \) and \( T \)

\[
\begin{align*}
T_{5} &= 170.41 \text{ C} = T_{sat\_p\_H2O}(P_{CFWH}) \\
P_{5} &= 12500 \text{ kPa} = P_{H} \\
h_{5} &= 727.51 \text{ kJ/kg} = h_{PT\_H2O}(P_{5}, T_{5})
\end{align*}
\]

State 6: SAT LIQ at \( P_{\text{CFWH}} \)

\[
\begin{align*}
P_{6} &= 800 \text{ kPa} = P_{\text{CFWH}} \\
h_{6} &= 721.02 \text{ kJ/kg} = h_{L\_p\_H2O}(P_{6})
\end{align*}
\]

State 7: throttled from \( P_{\text{CFWH}} \) to \( P_{\text{OFWH}} \) (\( h_{7} = h_{6} \))

\[
\begin{align*}
h_{7} &= 721.0178 \text{ kJ/kg} = h_{6}
\end{align*}
\]

State 8: entering turbine with given \( P \) and \( T \)

\[
\begin{align*}
P_{8} &= 12500 \text{ kPa} = P_{H} \\
T_{8} &= 550 \text{ C} = T_{\text{max}} \\
h_{8} &= 3476.55 \text{ kJ/kg} = h_{pT\_H2O}(P_{8}, T_{8}) \\
s_{8} &= 6.6317 \text{ kJ/kg-K} = s_{pT\_H2O}(P_{8}, T_{8})
\end{align*}
\]
state 9: isentropic expansion to $P_{\text{CFWH}}$

$P_9 = 800$ kPa = $P_{\text{CFWH}}$

$h_9 = 2755.05$ kJ/kg = $h_{ps\_H_2O}(P_9, s_8)$

state 10: isentropic expansion to $P_{\text{OFWH}}$

$P_{10} = 300$ kPa = $P_{\text{OFWH}}$

$h_{10} = 2578.53$ kJ/kg = $h_{ps\_H_2O}(P_{10}, s_8)$

state 11: isentropic expansion to $P_{\text{cond}}$

$P_{11} = 10$ kPa = $P_{\text{cond}}$

$h_{11} = 2099.96$ kJ/kg = $h_{ps\_H_2O}(P_{11}, s_8)$

from control volume on the CFWH, find the fraction 'y'

$yfrac = 7.52\% = (h_5-h_4)/(h_9-h_6)$

now use control volume on the OFWH to find the fraction 'z' in terms of 'y'

$zfrac = 13.8\% = \left( (h_3-h_2) + yfrac*(h_2 - h_7) \right) / \left( h_{10} - h_2 \right)$

put control volume around turbine:

$w_t = 1261.22$ kJ/kg = $h_8 - yfrac* h_9 - zfrac* h_{10} -(1 - yfrac - zfrac) * h_{11}$

Control volume around Pump1

$w_{p1} = -0.217$ kJ/kg = $(1 - yfrac - zfrac) * (h_1 - h_2)$

control volume around Pump2

$w_{p2} = -13.1$ kJ/kg = $(1)*(h_3-h_4)$

So $w_{\text{net}}$ per kg/s flowing in the boiler is

$w_{\text{net}} = 1247.95$ kJ/kg = $w_t+w_{p1}+w_{p2}$

And the mass flow rate to get $W_{\text{dot\_net}} = 250$MW is

$mdot = 200.33$ kg/s = $W_{\text{dot\_net}}/w_{\text{net}}$

$q_H = 2749.04$ kJ/kg = $h_8-h_5$

$\eta_{th} = 45.4\% = w_{\text{net}}/q_H$