Problem (5.2): A steam power plant operates on the reheat Rankine cycle. Steam enters the high-pressure turbine at 12.5 MPa and 550°C at a rate of 7.7 kg/s and leaves at 2 MPa. Steam is then reheated at constant pressure to 450°C before it expands in the low-pressure turbine. The isentropic efficiencies of the turbine and the pump are 85 percent and 90 percent, respectively. Steam leaves the condenser as a saturated liquid. If the moisture content of the steam at the exit of the turbine is not to exceed 5 percent, determine (a) the condenser pressure (b) the net power output (c) the thermal efficiency.

$P_c = 10\,kPa$

Ans. (9.73 kPa, 10.2 MW, 36.9%)

State 1 $P_1 = 10\,kPa \longrightarrow$ A-5

$h_1 = h_f = 191.81\ kJ/kg$

$v_1 = v_f = 0.00101\ m^3/kg$

State 2 $P_2 = 12.5\,MPa = 12500\,kPa$

$h_2 = h_1 + w_{pump} \Rightarrow h_2 = h_1 + v_1(P_2 - P_1)$

$h_2 = 191.81 + 0.00101(12500 - 10)$

$h_2 = 204.42\ kJ/kg$

State 3 $P_3 = 12.5\,MPa$, $T_3 = 550^\circ C$

A-6 $h_3 = 3476.5\ kJ/kg$, $s_3 = 6.6717\ kJ/kg.K$

State 4 $P_4 = 2\ MPa$ & $S_3 = S_4 = 6.6317$

$$h_4 = \frac{2903.3 + 3024.2}{2} = 2963.75\ kJ/kg$$

$$\eta_T = \frac{W_{T1}}{W_{T2}} = \frac{h_3 - h_4}{(h_3 - h_4')}$$

$$h_4' = h_3 - \eta_T (h_3 - h_4)$$

$$= 3476.5 - 0.85 (3476.5 - 2963.75)$$

$$h_4' = 3040.36\ kJ/kg$$

$$\eta_P = \frac{W_{P2}}{W_{P1}} = \frac{h_2 - h_1}{h_2' - h_1}$$

$$h_2' = \frac{h_2 - h_1}{\eta_P} + h_1$$

$$h_2' = \frac{204.42 - 191.81}{0.9} + 191.81$$

$h_2 = 205.8\ kJ/kg$

State 5 $\quad P_5 = 2\ MPa, \quad T_5 = 450^\circ C$

$$h_5 = \frac{3248.4 + 3468}{2} = 3358.35\ kJ/kg$$

$$S_5 = \frac{7.1292 + 7.4337}{2} = 7.2815\ kJ/kg$$

State-6 $\quad P_6 = 10\ kPa, \quad S_6 = S_5 = 7.2815$

$\rightarrow$ Table $\rightarrow h_f = 191.81$

$h_{fg} = 2392.105 f = 0.6492$

$S_{fg} = 7.4996$

$$x_6 = \frac{S_6 - S_f}{S_{fg}} \Rightarrow x_6 = \frac{7.2815 - 0.6492}{7.4996}$$

$x_6 = 0.884$

$$h_6 = h_f + x_6 h_{fg}$$

$$h_6 = 191.81 + 0.884\,(2392.1)$$

$$h_6 = 2356.4\ \text{KJ/Kg}$$

$$h_6' = h_5 - \eta_T (h_5 - h_6)$$

$$= 3358.35 - 0.95\,(3358.35 - 2356.4)$$

$$h_6' = 2464.2\ \text{KJ/Kg}$$

$$q_{in} = (h_3' - h_2') + (h_5' - h_4')$$

$$q_{in} =$$