10-38 A steam power plant that operates on a reheat Rankine cycle is considered. The condenser pressure, the net power output, and the thermal efficiency are to be determined.

Assumptions **1** Steady operating conditions exist. **2** Kinetic and potential energy changes are negligible.

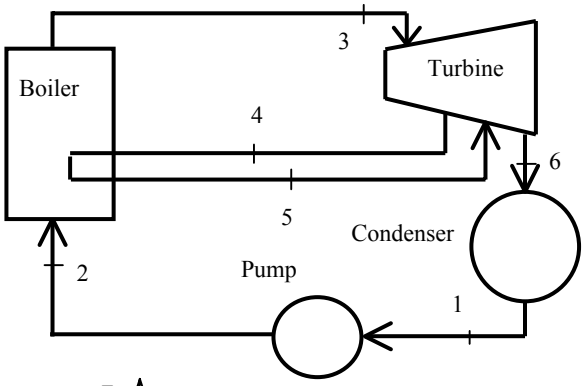
Analysis (*a*) From the steam tables (Tables A-4, A-5, and A-6),

$$\left.\begin{array}{l} P_3 = 12.5 \text{ MPa} \\ T_3 = 550°\text{C} \end{array}\right\} \begin{array}{l} h_3 = 3476.5 \text{ kJ/kg} \\ s_3 = 6.6317 \text{ kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_4 = 2 \text{ MPa} \\ s_{4s} = s_3 \end{array}\right\} h_{4s} = 2948.1 \text{ kJ/kg}$$

$$\eta_T = \frac{h_3 - h_4}{h_3 - h_{4s}}$$

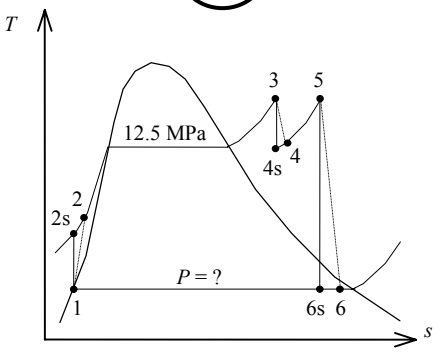
$$\rightarrow h_4 = h_3 - \eta_T (h_3 - h_{4s})$$
$$= 3476.5 - (0.85)(3476.5 - 2948.1)$$
$$= 3027.3 \text{ kJ/kg}$$



$$\left.\begin{array}{l} P_5 = 2 \text{ MPa} \\ T_5 = 450°\text{C} \end{array}\right\} \begin{array}{l} h_5 = 3358.2 \text{ kJ/kg} \\ s_5 = 7.2815 \text{ kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_6 = ? \\ x_6 = 0.95 \end{array}\right\} h_6 =$$

$$\left.\begin{array}{l} P_6 = ? \\ s_6 = s_5 \end{array}\right\} h_{6s} =$$



$$\eta_T = \frac{h_5 - h_6}{h_5 - h_{6s}} \longrightarrow h_6 = h_5 - \eta_T (h_5 - h_{6s})$$
$$= 3358.2 - (0.85)(3358.2 - 2948.1) = 3027.3 \text{ kJ/kg}$$

The pressure at state 6 may be determined by a trial-error approach from the steam tables or by using EES from the above equations:

$$P_6 = \mathbf{9.73 \text{ kPa}}, \quad h_6 = 2463.3 \text{ kJ/kg},$$

(*b*) Then,

$$h_1 = h_{f@\ 9.73 \text{ kPa}} = 189.57 \text{ kJ/kg}$$

$$\nu_1 = \nu_{f@\ 10 \text{ kPa}} = 0.001010 \text{ m}^3/\text{kg}$$

$$w_{p,\text{in}} = \nu_1 (P_2 - P_1)/\eta_p$$
$$= (0.00101 \text{ m}^3/\text{kg})(12{,}500 - 9.73 \text{ kPa})\left(\frac{1 \text{ kJ}}{1 \text{ kPa}\cdot\text{m}^3}\right)/(0.90)$$
$$= 14.02 \text{ kJ/kg}$$

$$h_2 = h_1 + w_{p,\text{in}} = 189.57 + 14.02 = 203.59 \text{ kJ/kg}$$

Cycle analysis:

$$q_{\text{in}} = (h_3 - h_2) + (h_5 - h_4) = 3476.5 - 3027.3 + 3358.2 - 2463.3 = 3603.8 \text{ kJ/kg}$$

$$q_{\text{out}} = h_6 - h_1 = 3027.3 - 189.57 = 2273.7 \text{ kJ/kg}$$

$$\dot{W}_{\text{net}} = \dot{m}(q_{\text{in}} - q_{\text{out}}) = (7.7 \text{ kg/s})(3603.8 - 2273.7)\text{kJ/kg} = \mathbf{10{,}242 \text{ kW}}$$

(*c*) The thermal efficiency is

$$\eta_{\text{th}} = 1 - \frac{q_{\text{out}}}{q_{\text{in}}} = 1 - \frac{2273.7 \text{ kJ/kg}}{3603.8 \text{ kJ/kg}} = 0.369 = \mathbf{36.9\%}$$