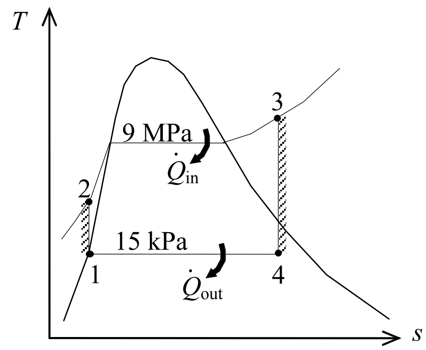
10-26 A 120-MW coal-fired steam power plant operates on a simple ideal Rankine cycle between the specified pressure limits. The overall plant efficiency and the required rate of the coal supply are to be determined.

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),

$$h_1 = h_{f@\,15\text{ kPa}} = 225.94 \text{ kJ/kg}$$
$$\boldsymbol{v}_1 = \boldsymbol{v}_{f@\,15\text{ kPa}} = 0.0010140 \text{ m}^3\text{/kg}$$

$$w_{p,\text{in}} = \boldsymbol{v}_1(P_2 - P_1) = (0.001014 \text{ m}^3\text{/kg})(9000 - 15 \text{ kPa})\left(\frac{1 \text{ kJ}}{1 \text{ kPa}\cdot\text{m}^3}\right) = 9.11 \text{ kJ/kg}$$
$$h_2 = h_1 + w_{p,\text{in}} = 225.94 + 9.11 = 235.05 \text{ kJ/kg}$$



$$\left.\begin{array}{l} P_3 = 9 \text{ MPa} \\ T_3 = 550°\text{C} \end{array}\right\} \begin{array}{l} h_3 = 3512.0 \text{ kJ/kg} \\ s_3 = 6.8164 \text{ kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_4 = 15 \text{ kPa} \\ s_4 = s_3 \end{array}\right\} x_4 = \frac{s_4 - s_f}{s_{fg}} = \frac{6.8164 - 0.7549}{7.2522} = 0.8358$$
$$h_4 = h_f + x_4 h_{fg} = 225.94 + (0.8358)(2372.4) = 2208.8 \text{ kJ/kg}$$

The thermal efficiency is determined from

$$q_{\text{in}} = h_3 - h_2 = 3512.0 - 235.05 = 3276.9 \text{ kJ/kg}$$
$$q_{\text{out}} = h_4 - h_1 = 2208.8 - 225.94 = 1982.9 \text{ kJ/kg}$$

and

$$\eta_{\text{th}} = 1 - \frac{q_{\text{out}}}{q_{\text{in}}} = 1 - \frac{1982.9}{3276.9} = 0.3949$$

Thus,

$$\eta_{\text{overall}} = \eta_{\text{th}} \times \eta_{\text{comb}} \times \eta_{\text{gen}} = (0.3949)(0.75)(0.96) = 0.2843 = \mathbf{28.4\%}$$

(*b*) Then the required rate of coal supply becomes

$$\dot{Q}_{\text{in}} = \frac{\dot{W}_{\text{net}}}{\eta_{\text{overall}}} = \frac{120{,}000 \text{ kJ/s}}{0.2843} = 422{,}050 \text{ kJ/s}$$

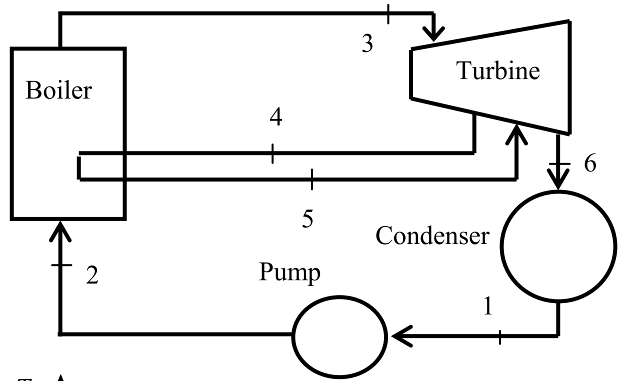
and

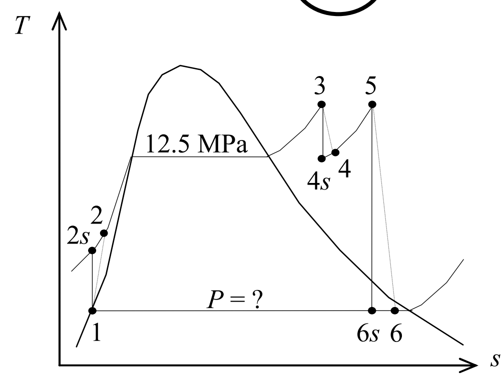
$$\dot{m}_{\text{coal}} = \frac{\dot{Q}_{\text{in}}}{C_{\text{coal}}} = \frac{422{,}050 \text{ kJ/s}}{29{,}300 \text{ kJ/kg}} = 14.404 \text{ kg/s} = \mathbf{51.9 \text{ tons/h}}$$

10-41 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),





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

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

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

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

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

$$\left.\begin{array}{l} P_6 = ? \\ x_6 = 0.95 \end{array}\right\} h_6 = \quad \text{(Eq. 1)}$$

$$\left.\begin{array}{l} P_6 = ? \\ s_6 = s_5 \end{array}\right\} h_{6s} = \quad \text{(Eq. 2)}$$

$$\eta_T = \frac{h_5 - h_6}{h_5 - h_{6s}} \longrightarrow h_6 = h_5 - \eta_T(h_5 - h_{6s}) = 3358.2 - (0.85)(3358.2 - h_{6s}) \quad \text{(Eq. 3)}$$

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

$P_6 =$ **9.73 kPa**, $h_6 = 2463.3$ kJ/kg,

(*b*) Then,

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

$$v_1 = v_{f@\,10\text{ kPa}} = 0.001010\text{ m}^3\text{/kg}$$

$$\begin{aligned} w_{p,\text{in}} &= v_1(P_2 - P_1)/\eta_p \\ &= (0.00101\text{ m}^3\text{/kg})(12{,}500 - 9.73\text{ kPa})\left(\frac{1\text{ kJ}}{1\text{ kPa}\cdot\text{m}^3}\right)/(0.90) \\ &= 14.02\text{ kJ/kg} \end{aligned}$$

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

Cycle analysis:

$$q_{\text{in}} = (h_3 - h_2) + (h_5 - h_4) = 3476.5 - 203.59 + 3358.2 - 2463.3 = 3603.8\text{ kJ/kg}$$

$$q_{\text{out}} = h_6 - h_1 = 2463.3 - 189.57 = 2273.7\text{ kJ/kg}$$

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

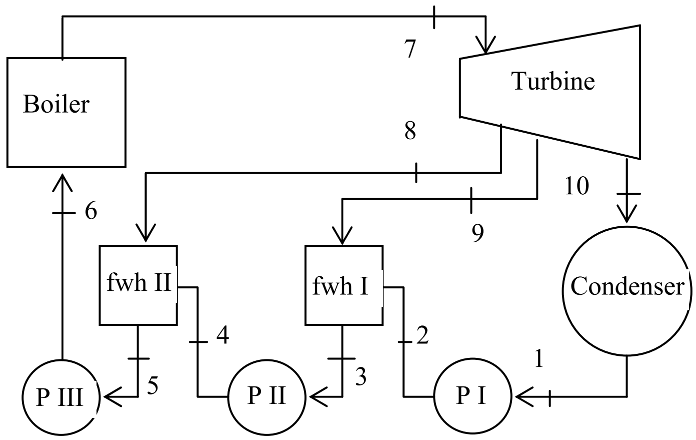
(*c*) The thermal efficiency is

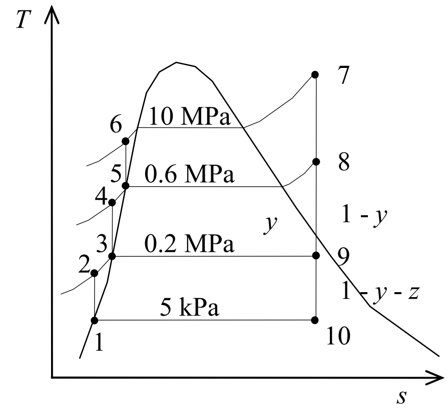
$$\eta_{\text{th}} = 1 - \frac{q_{\text{out}}}{q_{\text{in}}} = 1 - \frac{2273.7\text{ kJ/kg}}{3603.8\text{ kJ/kg}} = 0.369 = \mathbf{36.9\%}$$

10-52 A steam power plant operates on an ideal regenerative Rankine cycle with two open feedwater heaters. The net power output of the power plant and the thermal efficiency of the cycle 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),

$$h_1 = h_{f@\,5\text{ kPa}} = 137.75 \text{ kJ/kg}$$
$$\boldsymbol{v}_1 = \boldsymbol{v}_{f@\,5\text{ kPa}} = 0.001005 \text{ m}^3\text{/kg}$$
$$w_{pI,\text{in}} = \boldsymbol{v}_1(P_2 - P_1) = (0.001005 \text{ m}^3\text{/kg})(200-5 \text{ kPa})\left(\frac{1 \text{ kJ}}{1 \text{ kPa}\cdot\text{m}^3}\right) = 0.20 \text{ kJ/kg}$$
$$h_2 = h_1 + w_{pI,\text{in}} = 137.75 + 0.20 = 137.95 \text{ kJ/kg}$$

$$\left.\begin{array}{l} P_3 = 0.2 \text{ MPa} \\ \text{sat.liquid} \end{array}\right\} \begin{array}{l} h_3 = h_{f@\,0.2\text{ MPa}} = 504.71 \text{ kJ/kg} \\ \boldsymbol{v}_3 = \boldsymbol{v}_{f@\,0.2\text{ MPa}} = 0.001061 \text{ m}^3\text{/kg} \end{array}$$

$$w_{pII,\text{in}} = \boldsymbol{v}_3(P_4 - P_3) = (0.001061 \text{ m}^3\text{/kg})(600-200 \text{ kPa})\left(\frac{1 \text{ kJ}}{1 \text{ kPa}\cdot\text{m}^3}\right)$$
$$= 0.42 \text{ kJ/kg}$$
$$h_4 = h_3 + w_{pII,\text{in}} = 504.71 + 0.42 = 505.13 \text{ kJ/kg}$$

$$\left.\begin{array}{l} P_5 = 0.6 \text{ MPa} \\ \text{sat.liquid} \end{array}\right\} \begin{array}{l} h_5 = h_{f@\,0.6\text{ MPa}} = 670.38 \text{ kJ/kg} \\ \boldsymbol{v}_5 = \boldsymbol{v}_{f@\,0.6\text{ MPa}} = 0.001101 \text{ m}^3\text{/kg} \end{array}$$

$$w_{pIII,\text{in}} = \boldsymbol{v}_5(P_6 - P_5) = (0.001101 \text{ m}^3\text{/kg})(10{,}000-600 \text{ kPa})\left(\frac{1 \text{ kJ}}{1 \text{ kPa}\cdot\text{m}^3}\right)$$
$$= 10.35 \text{ kJ/kg}$$

$$h_6 = h_5 + w_{pIII,\text{in}} = 670.38 + 10.35 = 680.73 \text{ kJ/kg}$$

$$\left.\begin{array}{l} P_7 = 10 \text{ MPa} \\ T_7 = 600°\text{C} \end{array}\right\} \begin{array}{l} h_7 = 3625.8 \text{ kJ/kg} \\ s_7 = 6.9045 \text{ kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_8 = 0.6 \text{ MPa} \\ s_8 = s_7 \end{array}\right\} h_8 = 2821.8 \text{ kJ/kg}$$

$$\left.\begin{array}{l} P_9 = 0.2 \text{ MPa} \\ s_9 = s_7 \end{array}\right\} \begin{array}{l} x_9 = \dfrac{s_9 - s_f}{s_{fg}} = \dfrac{6.9045 - 1.5302}{5.5968} = 0.9602 \\ h_9 = h_f + x_9 h_{fg} = 504.71 + (0.9602)(2201.6) = 2618.7 \text{ kJ/kg} \end{array}$$

$$\left.\begin{array}{l} P_{10} = 5 \text{ kPa} \\ s_{10} = s_7 \end{array}\right\} \begin{array}{l} x_{10} = \dfrac{s_{10} - s_f}{s_{fg}} = \dfrac{6.9045 - 0.4762}{7.9176} = 0.8119 \\ h_{10} = h_f + x_{10} h_{fg} = 137.75 + (0.8119)(2423.0) = 2105.0 \text{ kJ/kg} \end{array}$$

The fraction of steam extracted is determined from the steady-flow energy balance equation applied to the feedwater heaters. Noting that $\dot{Q} \cong \dot{W} \cong \Delta\text{ke} \cong \Delta\text{pe} \cong 0$,

FWH-2:

$$\dot{E}_{\text{in}} - \dot{E}_{\text{out}} = \Delta\dot{E}_{system}^{\nearrow 0 \text{ (steady)}} = 0$$

$$\dot{E}_{\text{in}} = \dot{E}_{\text{out}}$$

$$\sum \dot{m}_i h_i = \sum \dot{m}_e h_e \longrightarrow \dot{m}_8 h_8 + \dot{m}_4 h_4 = \dot{m}_5 h_5 \longrightarrow y h_8 + (1-y) h_4 = 1(h_5)$$

where y is the fraction of steam extracted from the turbine ($= \dot{m}_8 / \dot{m}_5$). Solving for y,

$$y = \frac{h_5 - h_4}{h_8 - h_4} = \frac{670.38 - 505.13}{2821.8 - 505.13} = 0.07133$$

FWH-1:

$$\sum \dot{m}_i h_i = \sum \dot{m}_e h_e \longrightarrow \dot{m}_9 h_9 + \dot{m}_2 h_2 = \dot{m}_3 h_3 \longrightarrow z h_9 + (1-y-z) h_2 = (1-y) h_3$$

where z is the fraction of steam extracted from the turbine ($= \dot{m}_9 / \dot{m}_5$) at the second stage. Solving for z,

$$z = \frac{h_3 - h_2}{h_9 - h_2}(1-y) = \frac{504.71 - 137.95}{2618.7 - 137.95}(1 - 0.07136) = 0.1373$$

Then,

$$q_{\text{in}} = h_7 - h_6 = 3625.8 - 680.73 = 2945.0 \text{ kJ/kg}$$
$$q_{\text{out}} = (1-y-z)(h_{10} - h_1) = (1 - 0.07133 - 0.1373)(2105.0 - 137.75) = 1556.8 \text{ kJ/kg}$$
$$w_{\text{net}} = q_{\text{in}} - q_{\text{out}} = 2945.0 - 1556.8 = 1388.2 \text{ kJ/kg}$$

and

$$\dot{W}_{\text{net}} = \dot{m} w_{\text{net}} = (22 \text{ kg/s})(1388.2 \text{ kJ/kg}) = 30{,}540 \text{ kW} \cong \mathbf{30.5\ MW}$$

(*b*) The thermal efficiency is

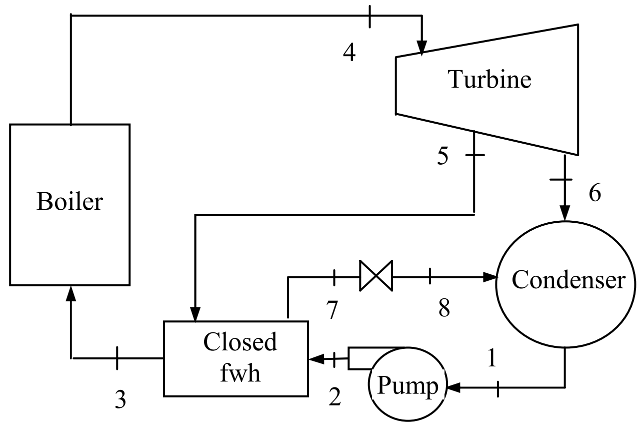
$$\eta_{\text{th}} = 1 - \frac{q_{\text{out}}}{q_{\text{in}}} = 1 - \frac{1556.8 \text{ kJ/kg}}{2945.0 \text{ kJ/kg}} = \mathbf{47.1\%}$$

10-53 An ideal regenerative Rankine cycle with a closed feedwater heater is considered. The work produced by the turbine, the work consumed by the pumps, and the heat added in the boiler are to be determined.

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

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

$$h_1 = h_{f\,@\,20\,\text{kPa}} = 251.42\ \text{kJ/kg}$$
$$\boldsymbol{v}_1 = \boldsymbol{v}_{f\,@\,20\,\text{kPa}} = 0.001017\ \text{m}^3/\text{kg}$$



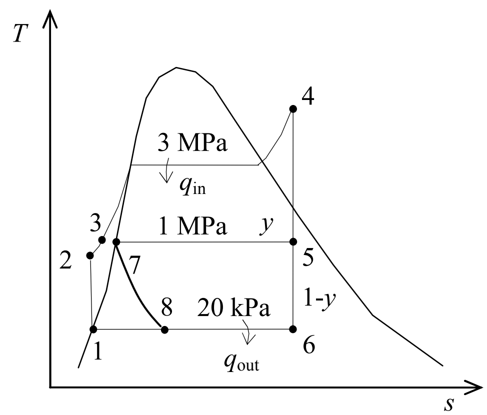
$$\begin{aligned} w_{\text{p,in}} &= \boldsymbol{v}_1(P_2 - P_1) \\ &= (0.001017\ \text{m}^3/\text{kg})(3000-20)\text{kPa}\left(\frac{1\ \text{kJ}}{1\ \text{kPa}\cdot\text{m}^3}\right) \\ &= 3.03\ \text{kJ/kg} \end{aligned}$$
$$h_2 = h_1 + w_{\text{p,in}} = 251.42 + 3.03 = 254.45\ \text{kJ/kg}$$

$$\left.\begin{aligned} P_4 &= 3000\ \text{kPa} \\ T_4 &= 350°\text{C} \end{aligned}\right\} \begin{aligned} h_4 &= 3116.1\ \text{kJ/kg} \\ s_4 &= 6.7450\ \text{kJ/kg}\cdot\text{K} \end{aligned}$$

$$\left.\begin{aligned} P_5 &= 1000\ \text{kPa} \\ s_5 &= s_4 \end{aligned}\right\} h_5 = 2851.9\ \text{kJ/kg}$$

$$\left.\begin{aligned} P_6 &= 20\ \text{kPa} \\ s_6 &= s_4 \end{aligned}\right\} \begin{aligned} x_6 &= \frac{s_6 - s_f}{s_{fg}} = \frac{6.7450 - 0.8320}{7.0752} = 0.8357 \\ h_6 &= h_f + x_6 h_{fg} = 251.42 + (0.8357)(2357.5) = 2221.7\ \text{kJ/kg} \end{aligned}$$

For an ideal closed feedwater heater, the feedwater is heated to the exit temperature of the extracted steam, which ideally leaves the heater as a saturated liquid at the extraction pressure.



$$\left.\begin{aligned} P_7 &= 1000\ \text{kPa} \\ x_7 &= 0 \end{aligned}\right\} \begin{aligned} h_7 &= 762.51\ \text{kJ/kg} \\ T_7 &= 179.9°\text{C} \end{aligned}$$
$$h_8 = h_7 = 762.51\ \text{kJ/kg}$$
$$\left.\begin{aligned} P_3 &= 3000\ \text{kPa} \\ T_3 &= T_7 = 209.9°\text{C} \end{aligned}\right\} h_3 = 763.53\ \text{kJ/kg}$$

An energy balance on the heat exchanger gives the fraction of steam extracted from the turbine ($= \dot{m}_5 / \dot{m}_4$) for closed feedwater heater:

$$\sum \dot{m}_i h_i = \sum \dot{m}_e h_e$$
$$\dot{m}_5 h_5 + \dot{m}_2 h_2 = \dot{m}_3 h_3 + \dot{m}_7 h_7$$
$$y h_5 + 1 h_2 = 1 h_3 + y h_7$$

Rearranging,

$$y = \frac{h_3 - h_2}{h_5 - h_7} = \frac{763.53 - 254.45}{2851.9 - 762.51} = 0.2437$$

Then,

$$w_{\text{T,out}} = h_4 - h_5 + (1-y)(h_5 - h_6) = 3116.1 - 2851.9 + (1 - 0.2437)(2851.9 - 2221.7) = \mathbf{740.9\ kJ/kg}$$
$$w_{\text{P,in}} = \mathbf{3.03\ kJ/kg}$$
$$q_{\text{in}} = h_4 - h_3 = 3116.1 - 763.53 = \mathbf{2353\ kJ/kg}$$

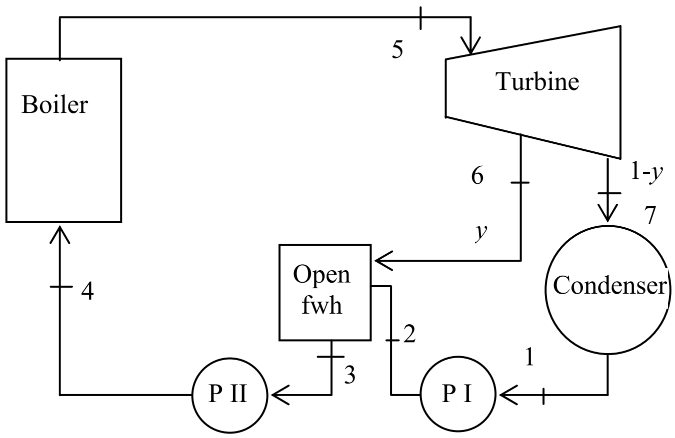
Also, $w_{\text{net}} = w_{\text{T,out}} - w_{\text{P,in}} = 740.9 - 3.03 = 737.8\ \text{kJ/kg}$

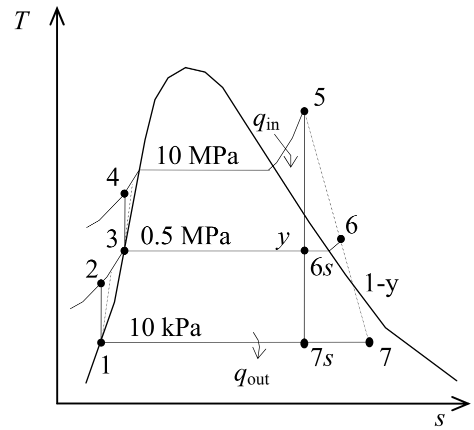
$$\eta_{\text{th}} = \frac{w_{\text{net}}}{q_{\text{in}}} = \frac{737.8}{2353} = 0.3136$$

10-100 An 150-MW steam power plant operating on a regenerative Rankine cycle with an open feedwater heater is considered. The mass flow rate of steam through the boiler, the thermal efficiency of the cycle, and the irreversibility associated with the regeneration process 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),

$$h_1 = h_{f\ @10\,\text{kPa}} = 191.81\ \text{kJ/kg}$$
$$\boldsymbol{v}_1 = \boldsymbol{v}_{f\ @10\,\text{kPa}} = 0.00101\ \text{m}^3/\text{kg}$$

$$\begin{aligned} w_{\text{pI,in}} &= \boldsymbol{v}_1(P_2 - P_1)/\eta_p \\ &= \left(0.00101\ \text{m}^3/\text{kg}\right)\left(500 - 10\ \text{kPa}\right)\left(\frac{1\ \text{kJ}}{1\ \text{kPa}\cdot\text{m}^3}\right)/(0.95) \\ &= 0.52\ \text{kJ/kg} \end{aligned}$$
$$h_2 = h_1 + w_{\text{pI,in}} = 191.81 + 0.52 = 192.33\ \text{kJ/kg}$$

$$\left.\begin{array}{l} P_3 = 0.5\ \text{MPa} \\ \text{sat liquid} \end{array}\right\} \begin{array}{l} h_3 = h_{f\ @0.5\,\text{MPa}} = 640.09\ \text{kJ/kg} \\ \boldsymbol{v}_3 = \boldsymbol{v}_{f\ @0.5\,\text{MPa}} = 0.001093\ \text{m}^3/\text{kg} \end{array}$$

$$\begin{aligned} w_{\text{pII,in}} &= \boldsymbol{v}_3(P_4 - P_3)/\eta_p \\ &= \left(0.001093\ \text{m}^3/\text{kg}\right)\left(10{,}000 - 500\ \text{kPa}\right)\left(\frac{1\ \text{kJ}}{1\ \text{kPa}\cdot\text{m}^3}\right)/(0.95) \\ &= 10.93\ \text{kJ/kg} \end{aligned}$$
$$h_4 = h_3 + w_{\text{pII,in}} = 640.09 + 10.93 = 651.02\ \text{kJ/kg}$$

$$\left.\begin{array}{l} P_5 = 10\ \text{MPa} \\ T_5 = 500^\circ\text{C} \end{array}\right\} \begin{array}{l} h_5 = 3375.1\ \text{kJ/kg} \\ s_5 = 6.5995\ \text{kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_{6s} = 0.5\ \text{MPa} \\ s_{6s} = s_5 \end{array}\right\} \begin{array}{l} x_{6s} = \dfrac{s_{6s} - s_f}{s_{fg}} = \dfrac{6.5995 - 1.8604}{4.9603} = 0.9554 \\ h_{6s} = h_f + x_{6s}h_{fg} = 640.09 + (0.9554)(2108.0) \\ \quad = 2654.1\ \text{kJ/kg} \end{array}$$

$$\eta_T = \frac{h_5 - h_6}{h_5 - h_{6s}} \longrightarrow \begin{aligned} h_6 &= h_5 - \eta_T\left(h_5 - h_{6s}\right) \\ &= 3375.1 - (0.80)(3375.1 - 2654.1) \\ &= 2798.3\ \text{kJ/kg} \end{aligned}$$

$$x_{7s} = \frac{s_{7s} - s_f}{s_{fg}} = \frac{6.5995 - 0.6492}{7.4996} = 0.7934$$

$$\left.\begin{array}{l} P_{7s} = 10 \text{ kPa} \\ s_{7s} = s_5 \end{array}\right\} \begin{array}{l} h_{7s} = h_f + x_{7s} h_{fg} = 191.81 + (0.7934)(2392.1) \\ \quad = 2089.7 \text{ kJ/kg} \end{array}$$

$$\eta_T = \frac{h_5 - h_7}{h_5 - h_{7s}} \longrightarrow h_7 = h_5 - \eta_T (h_5 - h_{7s}) = 3375.1 - (0.80)(3375.1 - 2089.7) = 2346.8 \text{ kJ/kg}$$

The fraction of steam extracted is determined from the steady-flow energy balance equation applied to the feedwater heaters. Noting that $\dot{Q} \cong \dot{W} \cong \Delta ke \cong \Delta pe \cong 0$,

$$\dot{E}_{\text{in}} - \dot{E}_{\text{out}} = \Delta \dot{E}_{\text{system}}^{\nearrow 0 \text{ (steady)}} = 0$$

$$\dot{E}_{\text{in}} = \dot{E}_{\text{out}}$$

$$\sum \dot{m}_i h_i = \sum \dot{m}_e h_e \longrightarrow \dot{m}_6 h_6 + \dot{m}_2 h_2 = \dot{m}_3 h_3 \longrightarrow y h_6 + (1-y) h_2 = 1(h_3)$$

where y is the fraction of steam extracted from the turbine ($= \dot{m}_6 / \dot{m}_3$). Solving for y,

$$y = \frac{h_3 - h_2}{h_6 - h_2} = \frac{640.09 - 192.33}{2798.3 - 192.33} = 0.1718$$

Then,

$$q_{\text{in}} = h_5 - h_4 = 3375.1 - 651.02 = 2724.1 \text{ kJ/kg}$$

$$q_{\text{out}} = (1-y)(h_7 - h_1) = (1 - 0.1718)(2346.8 - 191.81) = 1784.7 \text{ kJ/kg}$$

$$w_{\text{net}} = q_{\text{in}} - q_{\text{out}} = 2724.1 - 1784.7 = 939.4 \text{ kJ/kg}$$

and

$$\dot{m} = \frac{\dot{W}_{\text{net}}}{w_{\text{net}}} = \frac{150{,}000 \text{ kJ/s}}{939.4 \text{ kJ/kg}} = \mathbf{159.7 \text{ kg/s}}$$

(b) The thermal efficiency is determined from

$$\eta_{\text{th}} = 1 - \frac{q_{\text{out}}}{q_{\text{in}}} = 1 - \frac{1784.7 \text{ kJ/kg}}{2724.1 \text{ kJ/kg}} = \mathbf{34.5\%}$$

Also,

$$\left.\begin{array}{l} P_6 = 0.5 \text{ MPa} \\ h_6 = 2798.3 \text{ kJ/kg} \end{array}\right\} s_6 = 6.9453 \text{ kJ/kg} \cdot \text{K}$$

$$s_3 = s_{f \text{ @ } 0.5 \text{ MPa}} = 1.8604 \text{ kJ/kg} \cdot \text{K}$$

$$s_2 = s_1 = s_{f \text{ @ } 10 \text{ kPa}} = 0.6492 \text{ kJ/kg} \cdot \text{K}$$

Then the irreversibility (or exergy destruction) associated with this regeneration process is

$$i_{\text{regen}} = T_0 s_{\text{gen}} = T_0 \left(\sum m_e s_e - \sum m_i s_i + \frac{q_{\text{surr}}}{T_L}^{\nearrow 0} \right) = T_0 \left[s_3 - y s_6 - (1-y) s_2 \right]$$

$$= (303 \text{ K})[1.8604 - (0.1718)(6.9453) - (1 - 0.1718)(0.6492)]$$

$$= \mathbf{39.25 \text{ kJ/kg}}$$