

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),

$$h_1 = h_f @ 15 \text{ kPa} = 225.94 \text{ kJ/kg}$$

$$\nu_1 = \nu_f @ 15 \text{ kPa} = 0.0010140 \text{ m}^3/\text{kg}$$

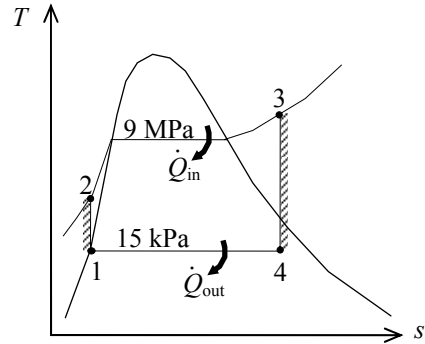
$$\begin{aligned} w_{p,\text{in}} &= \nu_1 (P_2 - P_1) \\ &= (0.001014 \text{ m}^3/\text{kg})(9000 - 15 \text{ kPa}) \left(\frac{1 \text{ kJ}}{1 \text{ kPa} \cdot \text{m}^3} \right) \\ &= 9.11 \text{ kJ/kg} \end{aligned}$$

$$h_2 = h_1 + w_{p,\text{in}} = 225.94 + 9.11 = 235.05 \text{ kJ/kg}$$

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

$$\left. \begin{array}{l} P_4 = 15 \text{ kPa} \\ s_4 = s_3 \end{array} \right\} x_4 = \frac{s_4 - s_f}{s_{fg}} = \frac{6.8164 - 0.7549}{7.2522} = 0.8358$$

$$h_4 = h_f + x_4 h_{fg} = 225.94 + (0.8358)(2372.4) = 2208.8 \text{ kJ/kg}$$



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

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