

**9-129** An ideal gas-turbine cycle with two stages of compression and two stages of expansion is considered. The back work ratio and the thermal efficiency of the cycle are to be determined for the cases of with and without a regenerator.

**Assumptions 1** The air standard assumptions are applicable. **2** Air is an ideal gas with variable specific heats. **3** Kinetic and potential energy changes are negligible.

**Properties** The properties of air are given in Table A-17.

**Analysis (a)** The work inputs to each stage of compressor are identical, so are the work outputs of each stage of the turbine since this is an ideal cycle. Then,

$$T_1 = 300 \text{ K} \longrightarrow \begin{aligned} h_1 &= 300.19 \text{ kJ/kg} \\ P_{r_1} &= 1.386 \end{aligned}$$

$$P_{r_2} = \frac{P_2}{P_1} P_{r_1} = (3)(1.386) = 4.158 \longrightarrow h_2 = h_4 = 411.26 \text{ kJ/kg}$$

$$T_5 = 1200 \text{ K} \longrightarrow \begin{aligned} h_5 &= h_7 = 1277.79 \text{ kJ/kg} \\ P_{r_5} &= 238 \end{aligned}$$

$$P_{r_6} = \frac{P_6}{P_5} P_{r_5} = \left(\frac{1}{3}\right)(238) = 79.33 \longrightarrow h_6 = h_8 = 946.36 \text{ kJ/kg}$$

$$w_{C,\text{in}} = 2(h_2 - h_1) = 2(411.26 - 300.19) = 222.14 \text{ kJ/kg}$$

$$w_{T,\text{out}} = 2(h_5 - h_6) = 2(1277.79 - 946.36) = 662.86 \text{ kJ/kg}$$

Thus,

$$r_{\text{bw}} = \frac{w_{C,\text{in}}}{w_{T,\text{out}}} = \frac{222.14 \text{ kJ/kg}}{662.86 \text{ kJ/kg}} = \mathbf{33.5\%}$$

$$q_{\text{in}} = (h_5 - h_4) + (h_7 - h_6) = (1277.79 - 411.26) + (1277.79 - 946.36) = 1197.96 \text{ kJ/kg}$$

$$w_{\text{net}} = w_{T,\text{out}} - w_{C,\text{in}} = 662.86 - 222.14 = 440.72 \text{ kJ/kg}$$

$$\eta_{\text{th}} = \frac{w_{\text{net}}}{q_{\text{in}}} = \frac{440.72 \text{ kJ/kg}}{1197.96 \text{ kJ/kg}} = \mathbf{36.8\%}$$

(b) When a regenerator is used,  $r_{\text{bw}}$  remains the same. The thermal efficiency in this case becomes

$$q_{\text{regen}} = \varepsilon(h_8 - h_4) = (0.75)(946.36 - 411.26) = 401.33 \text{ kJ/kg}$$

$$q_{\text{in}} = q_{\text{in,old}} - q_{\text{regen}} = 1197.96 - 401.33 = 796.63 \text{ kJ/kg}$$

$$\eta_{\text{th}} = \frac{w_{\text{net}}}{q_{\text{in}}} = \frac{440.72 \text{ kJ/kg}}{796.63 \text{ kJ/kg}} = \mathbf{55.3\%}$$

