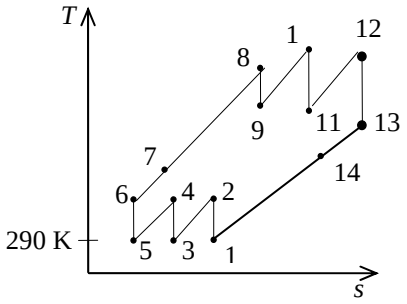
9-134 A regenerative gas-turbine cycle with three stages of compression and three stages of expansion is considered. The thermal efficiency of the cycle is to be determined.

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

Properties The properties of air at room temperature are c_p = 1.005 kJ/kg·K and k = 1.4 (Table A-2a).

Analysis The temperatures at various states are obtained as follows



$$T_2 = T_4 = T_6 = T_1 r_p^{(k-1)/k} = (290\text{ K})(4)^{0.4/1.4} = 430.9\text{ K}$$

$$T_7 = T_6 + 20 = 430.9 + 20 = 450.9\text{ K}$$

$$q_{\text{in}} = c_p(T_8 - T_7)$$

$$T_8 = T_7 + \frac{q_{\text{in}}}{c_p} = 450.9\text{ K} + \frac{300\text{ kJ/kg}}{1.005\text{ kJ/kg}\cdot\text{K}} = 749.4\text{ K}$$

$$T_9 = T_8\left(\frac{1}{r_p}\right)^{(k-1)/k} = (749.4\text{ K})\left(\frac{1}{4}\right)^{0.4/1.4} = 504.3\text{ K}$$

$$T_{10} = T_9 + \frac{q_{\text{in}}}{c_p} = 504.3\text{ K} + \frac{300\text{ kJ/kg}}{1.005\text{ kJ/kg}\cdot\text{K}} = 802.8\text{ K}$$

$$T_{11} = T_{10}\left(\frac{1}{r_p}\right)^{(k-1)/k} = (802.8\text{ K})\left(\frac{1}{4}\right)^{0.4/1.4} = 540.2\text{ K}$$

$$T_{12} = T_{11} + \frac{q_{\text{in}}}{c_p} = 540.2\text{ K} + \frac{300\text{ kJ/kg}}{1.005\text{ kJ/kg}\cdot\text{K}} = 838.7\text{ K}$$

$$T_{13} = T_{12}\left(\frac{1}{r_p}\right)^{(k-1)/k} = (838.7\text{ K})\left(\frac{1}{4}\right)^{0.4/1.4} = 564.4\text{ K}$$

$$T_{14} = T_{13} - 20 = 564.4 - 20 = 544.4\text{ K}$$

The heat input is

$$q_{\text{in}} = 300 + 300 + 300 = 900\text{ kJ/kg}$$

The heat rejected is

$$\begin{aligned} q_{\text{out}} &= c_p(T_{14} - T_1) + c_p(T_2 - T_3) + c_p(T_4 - T_5) \\ &= (1.005\text{ kJ/kg}\cdot\text{K})(544.4 - 290 + 430.9 - 290 + 430.9 - 290)\text{ R} \\ &= 538.9\text{ kJ/kg} \end{aligned}$$

The thermal efficiency of the cycle is then

$$\eta_{\text{th}} = 1 - \frac{q_{\text{out}}}{q_{\text{in}}} = 1 - \frac{538.9}{900} = 0.401 = \mathbf{40.1\%}$$