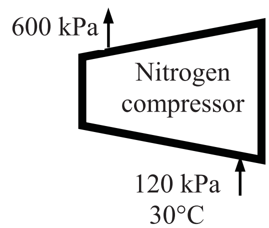
8-99 Nitrogen is compressed in an adiabatic compressor. The minimum work input is to be determined.

Assumptions **1** This is a steady-flow process since there is no change with time. **2** The process is adiabatic, and thus there is no heat transfer. **3** Nitrogen is an ideal gas with constant specific heats.

Properties The properties of nitrogen at an anticipated average temperature of 400 K are c_p = 1.044 kJ/kg·K and k = 1.397 (Table A-2*b*).

Analysis There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. We take the compressor as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as



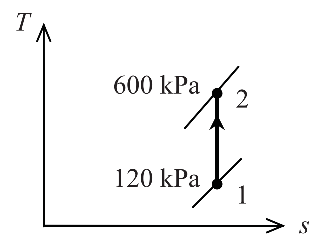
$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\substack{\text{Rate of net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta \dot{E}_{\text{system}}^{\nearrow 0 \text{ (steady)}}}_{\substack{\text{Rate of change in internal, kinetic,}\\ \text{potential, etc. energies}}} = 0$$

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

$$\dot{m}h_1 + \dot{W}_{\text{in}} = \dot{m}h_2$$

$$\dot{W}_{\text{in}} = \dot{m}(h_2 - h_1)$$

For the minimum work input to the compressor, the process must be reversible as well as adiabatic (i.e., isentropic). This being the case, the exit temperature will be



$$T_2 = T_1 \left(\frac{P_2}{P_1} \right)^{(k-1)/k} = (303 \text{ K}) \left(\frac{600 \text{ kPa}}{120 \text{ kPa}} \right)^{0.397/1.397} = 479 \text{ K}$$

Substituting into the energy balance equation gives

$$w_{\text{in}} = h_2 - h_1 = c_p (T_2 - T_1) = (1.044 \text{ kJ/kg} \cdot \text{K})(479 - 303)\text{K} = \mathbf{184\ kJ/kg}$$