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-2b).

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 steadyflow system can be expressed in the rate form as

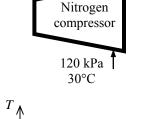
$$\frac{\dot{E}_{\rm in} - \dot{E}_{\rm out}}{\dot{E}_{\rm in} - \dot{E}_{\rm out}} = \underbrace{\Delta \dot{E}_{\rm system}}^{70 \text{ (steady)}} = 0$$
Rate of net energy transfer by heat, work, and mass
$$\dot{E}_{\rm in} = \dot{E}_{\rm out}$$

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

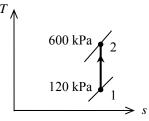
$$\dot{W}_{\rm in} = \dot{m}(h_2 - h_1)$$

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

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



600 kPa



Substituting into the energy balance equation gives

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