6-61 Air is compressed in an adiabatic compressor. The mass flow rate of the air and the power input are to be determined.

Assumptions **1** This is a steady-flow process since there is no change with time. **2** The compressor is adiabatic. **3** Air is an ideal gas with constant specific heats.

Properties The constant pressure specific heat of air at the average temperature of (20+400)/2=210°C=483 K is c_p = 1.026 kJ/kg·K (Table A-2*b*). The gas constant of air is R = 0.287 kPa·m^3/kg·K (Table A-1).

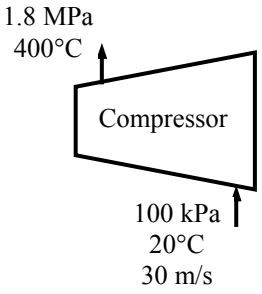
Analysis (*a*) There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. We take the compressor as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

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

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

$$\dot{m}\left(h_1 + \frac{V_1^2}{2}\right) + \dot{W}_{\text{in}} = \dot{m}\left(h_2 + \frac{V_2^2}{2}\right)$$

$$\dot{W}_{\text{in}} = \dot{m}\left(h_2 - h_1 + \frac{V_2^2 - V_1^2}{2}\right) = \dot{m}\left(c_p(T_2 - T_1) + \frac{V_2^2 - V_1^2}{2}\right)$$



The specific volume of air at the inlet and the mass flow rate are

$$\nu_1 = \frac{RT_1}{P_1} = \frac{(0.287\ \text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(20 + 273\ \text{K})}{100\ \text{kPa}} = 0.8409\ \text{m}^3/\text{kg}$$

$$\dot{m} = \frac{A_1 V_1}{\nu_1} = \frac{(0.15\ \text{m}^2)(30\ \text{m/s})}{0.8409\ \text{m}^3/\text{kg}} = \mathbf{5.351\ kg/s}$$

Similarly at the outlet,

$$\nu_2 = \frac{RT_2}{P_2} = \frac{(0.287\ \text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(400 + 273\ \text{K})}{1800\ \text{kPa}} = 0.1073\ \text{m}^3/\text{kg}$$

$$V_2 = \frac{\dot{m}\nu_2}{A_2} = \frac{(5.351\ \text{kg/s})(0.1073\ \text{m}^3/\text{kg})}{0.08\ \text{m}^2} = 7.177\ \text{m/s}$$

(*b*) Substituting into the energy balance equation gives

$$\dot{W}_{\text{in}} = \dot{m}\left(c_p(T_2 - T_1) + \frac{V_2^2 - V_1^2}{2}\right)$$

$$= (5.351\ \text{kg/s})\left[(1.026\ \text{kJ/kg}\cdot\text{K})(400 - 20)\text{K} + \frac{(7.177\ \text{m/s})^2 - (30\ \text{m/s})^2}{2}\left(\frac{1\ \text{kJ/kg}}{1000\ \text{m}^2/\text{s}^2}\right)\right]$$

$$= \mathbf{2084\ kW}$$

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