8-101 Air is expanded in an adiabatic nozzle by a polytropic process. The temperature and velocity at the exit are to be determined.

Assumptions **1** This is a steady-flow process since there is no change with time. **2** There is no heat transfer or shaft work associated with the process. **3** Air is an ideal gas with constant specific heats.

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

Analysis For the polytropic process of an ideal gas, $P\boldsymbol{v}^n = \text{Constant}$, and the exit temperature is given by

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{(n-1)/n} = (373\text{ K})\left(\frac{200\text{ kPa}}{700\text{ kPa}}\right)^{0.3/1.3} = \mathbf{279\ K}$$

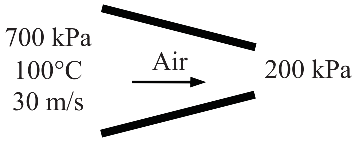
There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. We take nozzle as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

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

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

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

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}$$



Solving for the exit velocity,

$$\begin{aligned} V_2 &= \left[V_1^2 + 2(h_1 - h_2)\right]^{0.5} \\ &= \left[V_1^2 + 2c_p(T_1 - T_2)\right]^{0.5} \\ &= \left[(30\text{ m/s})^2 + 2(1.005\text{ kJ/kg}\cdot\text{K})(373-279)\text{K}\left(\frac{1000\text{ m}^2/\text{s}^2}{1\text{ kJ/kg}}\right)\right]^{0.5} \\ &= \mathbf{436\ m/s} \end{aligned}$$