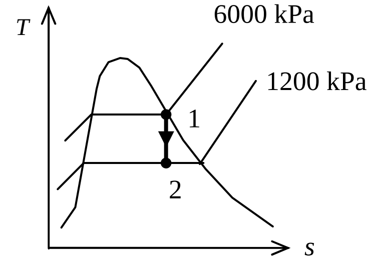
7-57 Steam enters a nozzle at a specified state and leaves at a specified pressure. The process is to be sketched on the *T-s* diagram and the maximum outlet velocity is to be determined.

Analysis (b) The inlet state properties are



$$\left.\begin{array}{l} P_1 = 6000 \text{ kPa} \\ x_1 = 1 \end{array}\right\} \begin{array}{l} h_1 = 2784.6 \text{ kJ/kg} \\ s_1 = 5.8902 \text{ kJ/kg} \cdot \text{K} \end{array} \quad \text{(Table A - 5)}$$

For the maximum velocity at the exit, the entropy will be constant during the process. The exit state enthalpy is (Table A-6)

$$\left.\begin{array}{l} P_2 = 1200 \text{ kPa} \\ s_2 = s_1 = 5.8902 \text{ kJ/kg} \cdot \text{K} \end{array}\right\} \begin{array}{l} x_2 = \dfrac{s_2 - s_f}{s_{fg}} = \dfrac{5.8902 - 2.2159}{4.3058} = 0.8533 \\ h_2 = h_f + x h_{fg} = 798.33 + 0.8533 \times 1985.4 = 2492.5 \text{ kJ/kg} \end{array}$$

We take the nozzle as the system, which is a control volume since mass crosses the boundary. Noting that one fluid stream enters and leaves the nozzle, the energy balance for this steady-flow system can be expressed in the rate form as

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

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

$$\dot{m}\left(h_1 + \frac{V_1^2}{2}\right) = \dot{m}\left(h_2 + \frac{V_2^2}{2}\right) \qquad (\text{since } \dot{W} \cong \dot{Q} \cong \Delta\text{pe} \cong 0)$$

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

Solving for the exit velocity and substituting,

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

$$V_2 = \left[V_1^2 + 2(h_1 - h_2)\right]^{0.5} = \left[(0 \text{ m/s})^2 + 2(2784.6 - 2492.5) \text{ kJ/kg}\left(\frac{1000 \text{ m}^2/\text{s}^2}{1 \text{ kJ/kg}}\right)\right]^{0.5}$$

$= \mathbf{764.3\ m/s}$