**8-60** Steam is expanded in an isentropic turbine. The work produced is to be determined.

***Assumptions*** **1** This is a steady-flow process since there is no change with time. **2** The process is isentropic (i.e., reversible-adiabatic).

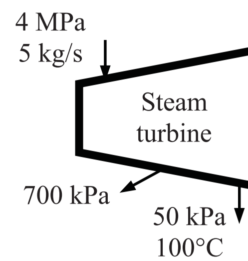
***Analysis*** There is one inlet and two exits. We take the turbine as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

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

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

$$\dot{m}_1 h_1 = \dot{m}_2 h_2 + \dot{m}_3 h_3 + \dot{W}_{out}$$

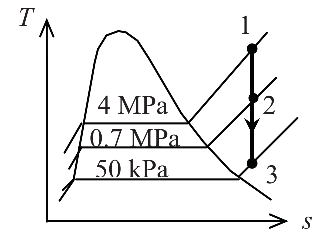
$$\dot{W}_{out} = \dot{m}_1 h_1 - \dot{m}_2 h_2 - \dot{m}_3 h_3$$




From a mass balance,

$$\dot{m}_2 = 0.05\dot{m}_1 = (0.05)(5 \text{ kg/s}) = 0.25 \text{ kg/s}$$

$$\dot{m}_3 = 0.95\dot{m}_1 = (0.95)(5 \text{ kg/s}) = 4.75 \text{ kg/s}$$




Noting that the expansion process is isentropic, the enthalpies at three states are determined as follows:

$$\left.\begin{array}{l} P_3 = 50 \text{ kPa} \\ T_3 = 100°\text{C} \end{array}\right\} \begin{array}{l} h_3 = 2682.4 \text{ kJ/kg} \\ s_3 = 7.6953 \text{ kJ/kg} \cdot \text{K} \end{array} \quad \text{(Table A-6)}$$

$$\left.\begin{array}{l} P_1 = 4 \text{ MPa} \\ s_1 = s_3 = 7.6953 \text{ kJ/kg} \cdot \text{K} \end{array}\right\} h_1 = 3979.3 \text{ kJ/kg} \quad \text{(Table A-6)}$$

$$\left.\begin{array}{l} P_2 = 700 \text{ kPa} \\ s_2 = s_3 = 7.6953 \text{ kJ/kg} \cdot \text{K} \end{array}\right\} h_2 = 3309.1 \text{ kJ/kg} \quad \text{(Table A-6)}$$

Substituting,

$$\begin{aligned} \dot{W}_{out} &= \dot{m}_1 h_1 - \dot{m}_2 h_2 - \dot{m}_3 h_3 \\ &= (5 \text{ kg/s})(3979.3 \text{ kJ/kg}) - (0.25 \text{ kg/s})(3309.1 \text{ kJ/kg}) - (4.75 \text{ kg/s})(2682.4 \text{ kJ/kg}) \\ &= \mathbf{6328 \text{ kW}} \end{aligned}$$