

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).

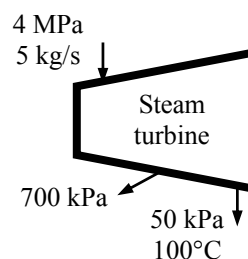
Analysis There is one inlet and two exits. We take the turbine as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\text{Rate of net energy transfer by heat, work, and mass}} = \underbrace{\Delta \dot{E}_{\text{system}}}_{\text{Rate of change in internal, kinetic, potential, etc. energies}} \stackrel{\text{no (steady)}}{=} 0$$

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

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

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



From a mass balance,

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

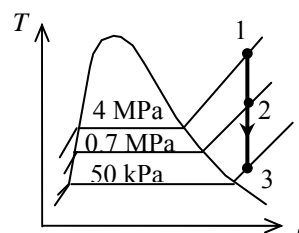
$$\dot{m}_3 = 0.95 \dot{m}_1 = (0.95)(5 \text{ kg/s}) = 4.75 \text{ kg/s}$$

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

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

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

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



Substituting,

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