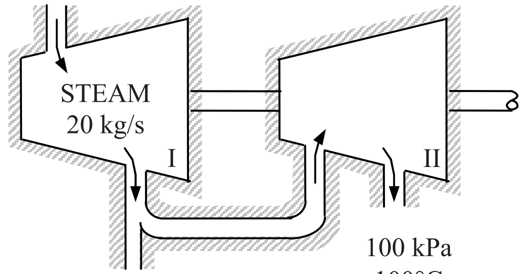
6-63 Steam expands in a two-stage adiabatic turbine from a specified state to another state. Some steam is extracted at the end of the first stage. The power output of the turbine is to be determined.

Assumptions **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** The turbine is adiabatic and thus heat transfer is negligible.



Properties From the steam tables (Table A-6)

$$\left.\begin{array}{l} P_1 = 12.5 \text{ MPa} \\ T_1 = 550°\text{C} \end{array}\right\} h_1 = 3476.5 \text{ kJ/kg}$$

$$\left.\begin{array}{l} P_2 = 1 \text{ MPa} \\ T_2 = 200°\text{C} \end{array}\right\} h_2 = 2828.3 \text{ kJ/kg}$$

$$\left.\begin{array}{l} P_3 = 100 \text{ kPa} \\ T_3 = 100°\text{C} \end{array}\right\} h_3 = 2675.8 \text{ kJ/kg}$$

Analysis The mass flow rate through the second stage is

$$\dot{m}_3 = \dot{m}_1 - \dot{m}_2 = 20 - 1 = 19 \text{ kg/s}$$

We take the entire turbine, including the connection part between the two stages, as the system, which is a control volume since mass crosses the boundary. Noting that one fluid stream enters the turbine and two fluid streams leave, the energy balance for this steady-flow system can be expressed in the rate form as

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

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

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

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

Substituting, the power output of the turbine is

$$\begin{aligned} \dot{W}_{\text{out}} &= (20 \text{ kg/s})(3476.5 \text{ kJ/kg}) - (1 \text{ kg/s})(2828.3 \text{ kJ/kg}) - (19 \text{ kg/s})(2675.8 \text{ kJ/kg}) \\ &= \mathbf{15{,}860 \text{ kW}} \end{aligned}$$