8-189 An insulated rigid tank is connected to a piston-cylinder device with zero clearance that is maintained at constant pressure. A valve is opened, and some steam in the tank is allowed to flow into the cylinder. The final temperatures in the tank and the cylinder are to be determined.

Assumptions **1** Both the tank and cylinder are well-insulated and thus heat transfer is negligible. **2** The water that remains in the tank underwent a reversible adiabatic process. **3** The thermal energy stored in the tank and cylinder themselves is negligible. **4** The system is stationary and thus kinetic and potential energy changes are negligible.

Analysis (a) The steam in tank A undergoes a reversible, adiabatic process, and thus $s_2 = s_1$. From the steam tables (Tables A-4 through A-6),

$$\left.\begin{array}{l} P_1 = 500 \text{ kPa} \\ sat.vapor \end{array}\right\} \begin{array}{l} \boldsymbol{v}_1 = v_{g@500 \text{ kPa}} = 0.37483 \text{ m}^3/\text{kg} \\ u_1 = u_{g@500 \text{ kPa}} = 2560.7 \text{ kJ/kg} \\ s_1 = s_{g@500 \text{ kPa}} = 6.8207 \text{ kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_2 = 150 \text{ kPa} \\ s_2 = s_1 \\ (sat.mixture) \end{array}\right\} \begin{array}{l} T_{2,A} = T_{sat@150 \text{ kPa}} = \mathbf{111.35^\circ C} \\ x_{2,A} = \dfrac{s_{2,A} - s_f}{s_{fg}} = \dfrac{6.8207 - 1.4337}{5.7894} = 0.9305 \\ \boldsymbol{v}_{2,A} = \boldsymbol{v}_f + x_{2,A}\boldsymbol{v}_{fg} = 0.001053 + (0.9305)(1.1594 - 0.001053) = 1.0789 \text{ m}^3/\text{kg} \\ u_{2,A} = u_f + x_{2,A}u_{fg} = 466.97 + (0.9305)(2052.3 \text{ kJ/kg}) = 2376.6 \text{ kJ/kg} \end{array}$$

The initial and the final masses in tank A are

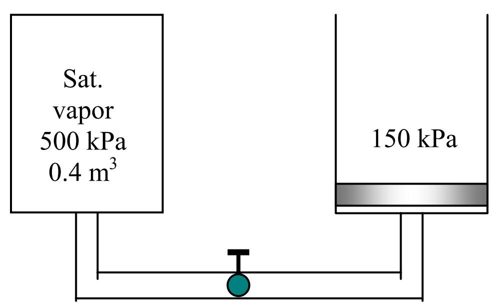
$$m_{1,A} = \frac{\boldsymbol{V}_A}{\boldsymbol{v}_{1,A}} = \frac{0.4 \text{ m}^3}{0.37483 \text{ m}^3/\text{kg}} = 1.067 \text{ kg} \quad \text{and} \quad m_{2,A} = \frac{\boldsymbol{V}_A}{\boldsymbol{v}_{2,A}} = \frac{0.4 \text{ m}^3}{1.0789 \text{ m}^3/\text{kg}} = 0.371 \text{ kg}$$

Thus,

$$m_{2,B} = m_{1,A} - m_{2,A} = 1.067 - 0.371 = 0.696 \text{ kg}$$

(*b*) The boundary work done during this process is

$$W_{b,out} = \int_1^2 Pd\boldsymbol{V} = P_B(\boldsymbol{V}_{2,B} - 0) = P_B m_{2,B}\boldsymbol{v}_{2,B}$$



Taking the contents of both the tank and the cylinder to be the system, the energy balance for this closed system can be expressed as

$$\underbrace{E_{in} - E_{out}}_{\substack{\text{Net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{system}}_{\substack{\text{Change in internal, kinetic,} \\ \text{potential, etc. energies}}}$$

$$-W_{b,out} = \Delta U = (\Delta U)_A + (\Delta U)_B$$

$$W_{b,out} + (\Delta U)_A + (\Delta U)_B = 0$$

or,

$$P_B m_{2,B}\boldsymbol{v}_{2,B} + (m_2u_2 - m_1u_1)_A + (m_2u_2)_B = 0$$

$$m_{2,B}h_{2,B} + (m_2u_2 - m_1u_1)_A = 0$$

Thus,

$$h_{2,B} = \frac{(m_1u_1 - m_2u_2)_A}{m_{2,B}} = \frac{(1.067)(2560.7) - (0.371)(2376.6)}{0.696} = 2658.8 \text{ kJ/kg}$$

At 150 kPa, $h_f = 467.13$ and $h_g = 2693.1$ kJ/kg. Thus at the final state, the cylinder will contain a saturated liquid-vapor mixture since $h_f < h_2 < h_g$. Therefore,

$$T_{2,B} = T_{sat@150 \text{ kPa}} = \mathbf{111.35^\circ C}$$