

Closed System Energy Analysis

5-29 Saturated water vapor is isothermally condensed to a saturated liquid in a piston-cylinder device. The heat transfer and the work done are to be determined.

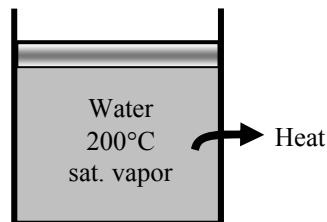
Assumptions **1** The cylinder is stationary and thus the kinetic and potential energy changes are zero. **2** There are no work interactions involved other than the boundary work. **3** The thermal energy stored in the cylinder itself is negligible. **4** The compression or expansion process is quasi-equilibrium.

Analysis We take the contents of the cylinder as the system. This is a closed system since no mass enters or leaves. The energy balance for this stationary closed system can be expressed as

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

$$W_{b,\text{in}} - Q_{\text{out}} = \Delta U = m(u_2 - u_1) \quad (\text{since KE} = \text{PE} = 0)$$

$$Q_{\text{out}} = W_{b,\text{in}} - m(u_2 - u_1)$$

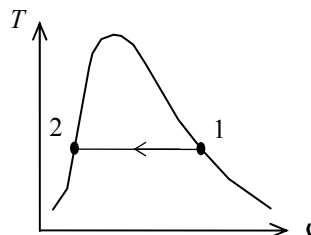


The properties at the initial and final states are (Table A-4)

$$\left. \begin{array}{l} T_1 = 200^\circ\text{C} \\ x_1 = 1 \end{array} \right\} \begin{array}{l} v_1 = v_g = 0.12721 \text{ m}^3/\text{kg} \\ u_1 = u_g = 2594.2 \text{ kJ/kg} \end{array}$$

$$P_1 = P_2 = 1554.9 \text{ kPa}$$

$$\left. \begin{array}{l} T_2 = 200^\circ\text{C} \\ x_2 = 0 \end{array} \right\} \begin{array}{l} v_2 = v_f = 0.001157 \text{ m}^3/\text{kg} \\ u_2 = u_f = 850.46 \text{ kJ/kg} \end{array}$$



The work done during this process is

$$w_{b,\text{out}} = \int_1^2 P dV = P(v_2 - v_1) = (1554.9 \text{ kPa})(0.001157 - 0.12721) \text{ m}^3/\text{kg} \left(\frac{1 \text{ kJ}}{1 \text{ kPa} \cdot \text{m}^3} \right) = -196.0 \text{ kJ/kg}$$

That is,

$$w_{b,\text{in}} = \mathbf{196.0 \text{ kJ/kg}}$$

Substituting the energy balance equation, we get

$$q_{\text{out}} = w_{b,\text{in}} - (u_2 - u_1) = w_{b,\text{in}} + u_{fg} = 196.0 + 1743.7 = \mathbf{1940 \text{ kJ/kg}}$$