4-37 Saturated vapor water is cooled at constant pressure to a saturated liquid. The heat transferred 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

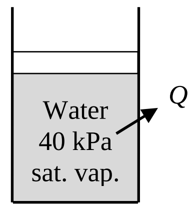
$$\underbrace{E_{in} - E_{out}}_{\substack{\text{Net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{system}}_{\substack{\text{Change in internal, kinetic,}\\ \text{potential, etc. energies}}}$$

$$-q_{out} - w_{b,out} = \Delta u = u_2 - u_1 \quad \text{(since KE = PE = 0)}$$

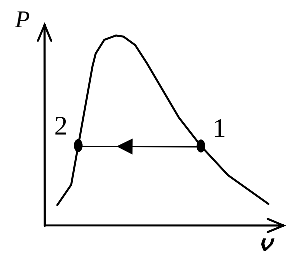
$$-q_{out} = w_{b,out} + (u_2 - u_1)$$

$$-q_{out} = h_2 - h_1$$

$$q_{out} = h_1 - h_2$$



since $\Delta u + w_b = \Delta h$ during a constant pressure quasi-equilibrium process. Since water changes from saturated liquid to saturated vapor, we have



$$q_{out} = h_g - h_f = h_{fg @ 40\text{ kPa}} = \mathbf{2318.4\ kJ/kg} \quad \text{(Table A-5)}$$

The specific volumes at the initial and final states are

$$\boldsymbol{v}_1 = \boldsymbol{v}_{g @ 40\text{ kPa}} = 3.993\text{ m}^3/\text{kg}$$

$$\boldsymbol{v}_2 = \boldsymbol{v}_{f @ 40\text{ kPa}} = 0.001026\text{ m}^3/\text{kg}$$

Then the work done is determined from

$$w_{b,out} = \int_1^2 P\,d\boldsymbol{V} = P(\boldsymbol{v}_2 - \boldsymbol{v}_1) = (40\text{ kPa})(0.001026 - 3.9933)\text{m}^3\left(\frac{1\text{ kJ}}{1\text{ kPa}\cdot\text{m}^3}\right) = \mathbf{159.7\ kJ/kg}$$