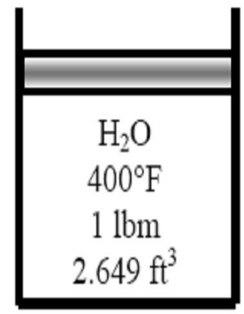
3-119E A piston-cylinder device that is filled with water is cooled. The final pressure and volume of the water are to be determined.

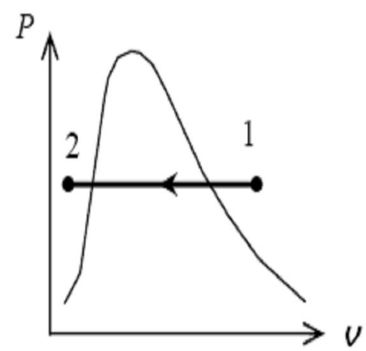


Analysis The initial specific volume is

$$v_1 = \frac{V_1}{m} = \frac{2.649\ \text{ft}^3}{1\ \text{lbm}} = 2.649\ \text{ft}^3/\text{lbm}$$

This is a constant-pressure process. The initial state is determined to be superheated vapor and thus the pressure is determined to be

$$\left.\begin{array}{l} T_1 = 400°\text{F} \\ v_1 = 2.649\ \text{ft}^3/\text{lbm} \end{array}\right\} P_1 = P_2 = \mathbf{180\ psia} \quad \text{(Table A-6E)}$$



The saturation temperature at 180 psia is 373.1°F. Since the final temperature is less than this temperature, the final state is compressed liquid. Using the incompressible liquid approximation,

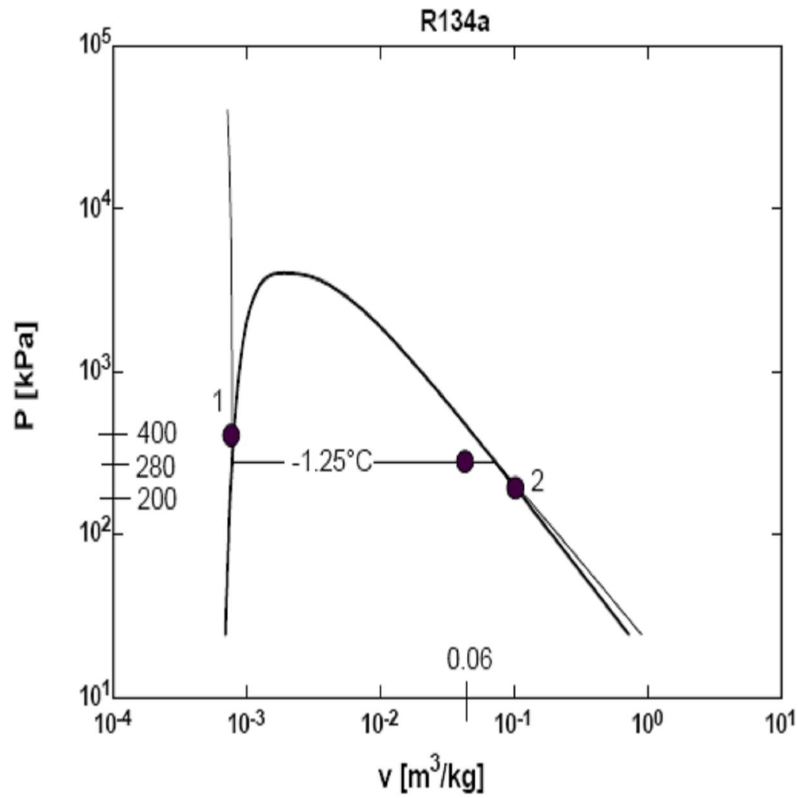
$$v_2 = v_{f\ @100°\text{F}} = 0.01613\ \text{ft}^3/\text{lbm} \quad \text{(Table A-4E)}$$

The final volume is then

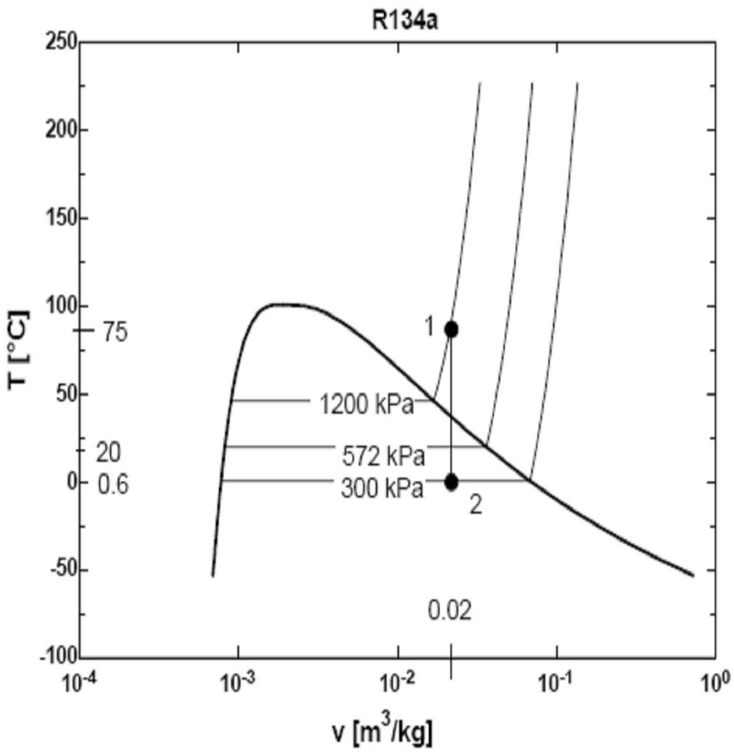
$$V_2 = m v_2 = (1\ \text{lbm})(0.01613\ \text{ft}^3/\text{lbm}) = \mathbf{0.01613\ ft^3}$$

3-141

(*a*) On the P-v diagram the constant temperature process through the state P = 280 kPa, v = 0.06 m^3/kg as pressure changes from P_1 = 400 kPa to P_2 = 200 kPa is to be sketched. The value of the temperature on the process curve on the P-v diagram is to be placed.



(b) On the T-v diagram the constant specific volume process through the state T = 20°C, v = 0.02 m^3/kg from P_1 = 1200 kPa to P_2 = 300 kPa is to be sketched. For this data set the temperature values at states 1 and 2 on its axis is to be placed. The value of the specific volume on its axis is also to be placed.



4-39 A cylinder is initially filled with saturated liquid water at a specified pressure. The water is heated electrically as it is stirred by a paddle-wheel at constant pressure. The voltage of the current source is to be determined, and the process is to be shown on a P-v diagram.

Assumptions **1** The cylinder is stationary and thus the kinetic and potential energy changes are zero. **2** The cylinder is well-insulated and thus heat transfer is negligible. **3** The thermal energy stored in the cylinder itself is negligible. **4** The compression or expansion process is quasi-equilibrium.

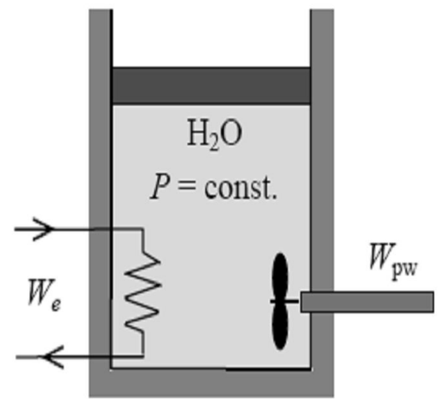
Analysis We take the contents of the cylinder as the system. This is a closed system since no mass enters or leaves. The energy balance for this stationary closed system can be expressed as

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

$$W_{\text{e,in}} + W_{\text{pw,in}} - W_{\text{b,out}} = \Delta U \quad (\text{since } Q = \text{KE} = \text{PE} = 0)$$

$$W_{\text{e,in}} + W_{\text{pw,in}} = m(h_2 - h_1)$$

$$(\mathbf{V} I \Delta t) + W_{\text{pw,in}} = m(h_2 - h_1)$$

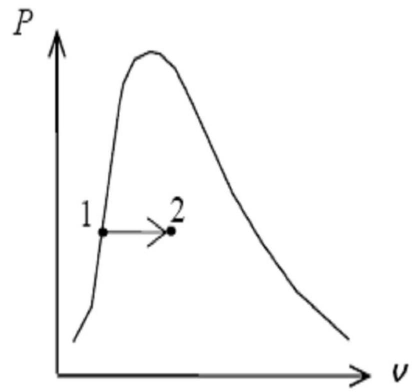


since $\Delta U + W_b = \Delta H$ during a constant pressure quasi-equilibrium process. The properties of water are (Tables A-4 through A-6)

$$\left.\begin{array}{l} P_1 = 175 \text{ kPa} \\ \text{sat.liquid} \end{array}\right\} \begin{array}{l} h_1 = h_{f@175 \text{ kPa}} = 487.01 \text{ kJ/kg} \\ v_1 = v_{f@175 \text{ kPa}} = 0.001057 \text{ m}^3/\text{kg} \end{array}$$

$$\left.\begin{array}{l} P_2 = 175 \text{ kPa} \\ x_2 = 0.5 \end{array}\right\} h_2 = h_f + x_2 h_{fg} = 487.01 + (0.5 \times 2213.1) = 1593.6 \text{ kJ/kg}$$

$$m = \frac{V_1}{v_1} = \frac{0.005 \text{ m}^3}{0.001057 \text{ m}^3/\text{kg}} = 4.731 \text{ kg}$$



Substituting,

$$\mathbf{V}I\Delta t + (400\text{kJ}) = (4.731 \text{ kg})(1593.6 - 487.01)\text{kJ/kg}$$

$$\mathbf{V}I\Delta t = 4835 \text{ kJ}$$

$$\mathbf{V} = \frac{4835 \text{ kJ}}{(8 \text{ A})(45 \times 60 \text{ s})}\left(\frac{1000 \text{ VA}}{1 \text{ kJ/s}}\right) = \mathbf{223.9 \text{ V}}$$

4-57 A spring-loaded piston-cylinder device is filled with nitrogen. Nitrogen is now heated until its volume increases by 10%. The changes in the internal energy and enthalpy of the nitrogen are to be determined.

Properties The gas constant of nitrogen is $R = 0.2968$ kPa·m^3/kg·K. The specific heats of nitrogen at room temperature are $c_v = 0.743$ kJ/kg·K and $c_p = 1.039$ kJ/kg·K (Table A-2a).

Analysis The initial volume of nitrogen is

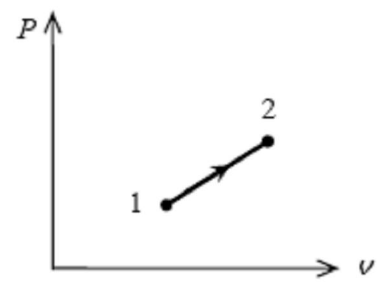
$$V_1 = \frac{mRT_1}{P_1} = \frac{(0.010\,\text{kg})(0.2968\,\text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(27+273\,\text{K})}{120\,\text{kPa}} = 0.00742\,\text{m}^3$$

The process experienced by this system is a linear P-v process. The equation for this line is

$$P - P_1 = c(V - V_1)$$

where P_1 is the system pressure when its specific volume is v_1. The spring equation may be written as

$$P - P_1 = \frac{F_s - F_{s,1}}{A} = k\frac{x - x_1}{A} = \frac{kA}{A^2}(x - x_1) = \frac{k}{A^2}(V - V_1)$$



Constant c is hence

$$c = \frac{k}{A^2} = \frac{4^2 k}{\pi^2 D^4} = \frac{(16)(1\,\text{kN/m})}{\pi^2 (0.1\,\text{m})^4} = 16{,}211\,\text{kN/m}^5$$

The final pressure is then

$$P_2 = P_1 + c(V_2 - V_1) = P_1 + c(1.1V_1 - V_1) = P_1 + 0.1cV_1$$

$$= 120\,\text{kPa} + 0.1(16{,}211\,\text{kN/m}^5)(0.00742\,\text{m}^3)$$

$$= 132.0\,\text{kPa}$$

The final temperature is

$$T_2 = \frac{P_2 V_2}{mR} = \frac{(132.0\,\text{kPa})(1.1 \times 0.00742\,\text{m}^3)}{(0.010\,\text{kg})(0.2968\,\text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})} = 363\,\text{K}$$

Using the specific heats,

$$\Delta u = c_v \Delta T = (0.743\,\text{kJ/kg}\cdot\text{K})(363 - 300)\text{K} = \mathbf{46.8\,kJ/kg}$$

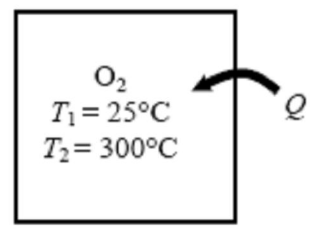
$$\Delta h = c_p \Delta T = (1.039\,\text{kJ/kg}\cdot\text{K})(363 - 300)\text{K} = \mathbf{65.5\,kJ/kg}$$

4-71 Oxygen is heated to experience a specified temperature change. The heat transfer is to be determined for two cases.

Assumptions **1** Oxygen is an ideal gas since it is at a high temperature and low pressure relative to its critical point values of 154.8 K and 5.08 MPa. **2** The kinetic and potential energy changes are negligible, $\Delta ke \cong \Delta pe \cong 0$. **3** Constant specific heats can be used for oxygen.

Properties The specific heats of oxygen at the average temperature of (25+300)/2=162.5°C=436 K are c_p = 0.952 kJ/kg·K and c_v = 0.692 kJ/kg·K (Table A-2*b*).

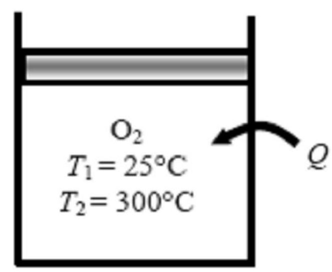
Analysis We take the oxygen as the system. This is a *closed system* since no mass crosses the boundaries of the system. The energy balance for a constant-volume process can be expressed as



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

$$Q_{\text{in}} = \Delta U = mc_v(T_2 - T_1)$$

The energy balance during a constant-pressure process (such as in a piston-cylinder device) can be expressed as



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

$$Q_{\text{in}} - W_{b,\text{out}} = \Delta U$$

$$Q_{\text{in}} = W_{b,\text{out}} + \Delta U$$

$$Q_{\text{in}} = \Delta H = mc_p(T_2 - T_1)$$

since $\Delta U + W_b = \Delta H$ during a constant pressure quasi-equilibrium process. Substituting for both cases,

$$Q_{\text{in},V=\text{const}} = mc_v(T_2 - T_1) = (1\,\text{kg})(0.692\,\text{kJ/kg}\cdot\text{K})(300-25)\text{K} = \mathbf{190.3\ kJ}$$

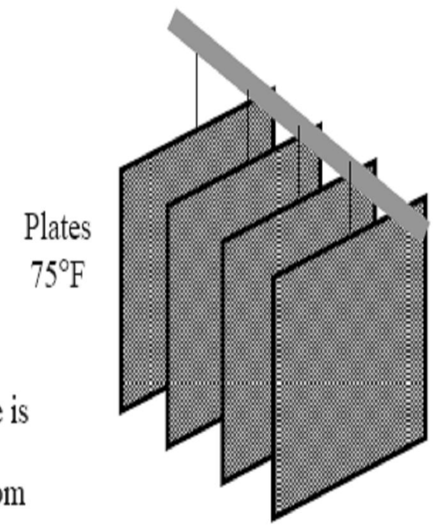
$$Q_{\text{in},P=\text{const}} = mc_p(T_2 - T_1) = (1\,\text{kg})(0.952\,\text{kJ/kg}\cdot\text{K})(300-25)\text{K} = \mathbf{261.8\ kJ}$$

4-95E Large brass plates are heated in an oven at a rate of 300/min. The rate of heat transfer to the plates in the oven is to be determined.

Assumptions **1** The thermal properties of the plates are constant. **2** The changes in kinetic and potential energies are negligible.

Properties The density and specific heat of the brass are given to be ρ = 532.5 lbm/ft³ and c_p = 0.091 Btu/lbm.°F.

Analysis We take the plate to be the system. The energy balance for this closed system can be expressed as



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

$$Q_{in} = \Delta U_{plate} = m(u_2 - u_1) = mc(T_2 - T_1)$$

The mass of each plate and the amount of heat transfer to each plate is

$$m = \rho V = \rho LA = (532.5\ \text{lbm/ft}^3)[(1.2/12\ \text{ft})(2\ \text{ft})(2\ \text{ft})] = 213\ \text{lbm}$$

$$Q_{in} = mc(T_2 - T_1) = (213\ \text{lbm/plate})(0.091\ \text{Btu/lbm.°F})(1000 - 75)\text{°F} = 17{,}930\ \text{Btu/plate}$$

Then the total rate of heat transfer to the plates becomes

$$\dot{Q}_{total} = \dot{n}_{plate} Q_{in,\ per\ plate} = (300\ \text{plates/min}) \times (17{,}930\ \text{Btu/plate}) = \mathbf{5{,}379{,}000\ Btu/min = 89{,}650\ Btu/s}$$