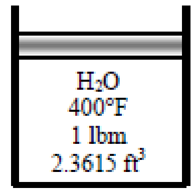
4-35E A piston-cylinder device that is filled with water is cooled. The final pressure and volume of the water are to be determined.

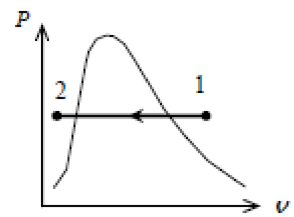


Analysis The initial specific volume is

$$v_1 = \frac{V_1}{m} = \frac{2.3615\ \text{ft}^3}{1\ \text{lbm}} = 2.3615\ \text{ft}^3/\text{lbm}$$

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

$$\left.\begin{array}{l} T_1 = 400°\text{F} \\ v_1 = 2.3615\ \text{ft}^3/\text{lbm} \end{array}\right\} P_1 = P_2 = \mathbf{200\ psia}\ \ (\text{Table A-6E})$$



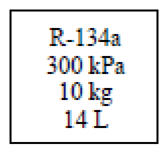
The saturation temperature at 200 psia is 381.8°F. Since the final temperature is less than this temperature, the final state is compressed liquid. Using the incompressible liquid approximation,

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

The final volume is then

$$V_2 = mv_2 = (1\ \text{lbm})(0.01613\ \text{ft}^3/\text{lbm}) = \mathbf{0.01613\ ft^3}$$

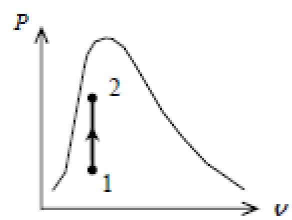
4-41 A rigid container that is filled with R-134a is heated. The temperature and total enthalpy are to be determined at the initial and final states.



Analysis This is a constant volume process. The specific volume is

$$v_1 = v_2 = \frac{V}{m} = \frac{0.014\ \text{m}^3}{10\ \text{kg}} = 0.0014\ \text{m}^3/\text{kg}$$

The initial state is determined to be a mixture, and thus the temperature is the saturation temperature at the given pressure. From Table A-12 by interpolation



$$T_1 = T_{\text{sat}\,@\,300\ \text{kPa}} = \mathbf{0.61°C}$$

and

$$x_1 = \frac{v_1 - v_f}{v_{fg}} = \frac{(0.0014 - 0.0007736)\ \text{m}^3/\text{kg}}{(0.067978 - 0.0007736)\ \text{m}^3/\text{kg}} = 0.009321$$

$$h_1 = h_f + x_1 h_{fg} = 52.67 + (0.009321)(198.13) = 54.52\ \text{kJ/kg}$$

The total enthalpy is then

$$H_1 = mh_1 = (10\ \text{kg})(54.52\ \text{kJ/kg}) = \mathbf{545.2\ kJ}$$

The final state is also saturated mixture. Repeating the calculations at this state,

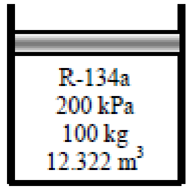
$$T_2 = T_{\text{sat}\,@\,600\ \text{kPa}} = \mathbf{21.55°C}$$

$$x_2 = \frac{v_2 - v_f}{v_{fg}} = \frac{(0.0014 - 0.0008199)\ \text{m}^3/\text{kg}}{(0.034295 - 0.0008199)\ \text{m}^3/\text{kg}} = 0.01733$$

$$h_2 = h_f + x_2 h_{fg} = 81.51 + (0.01733)(180.90) = 84.64\ \text{kJ/kg}$$

$$H_2 = mh_2 = (10\ \text{kg})(84.64\ \text{kJ/kg}) = \mathbf{846.4\ kJ}$$

4-42 A piston-cylinder device that is filled with R-134a is cooled at constant pressure. The final temperature and the change of total internal energy are to be determined.

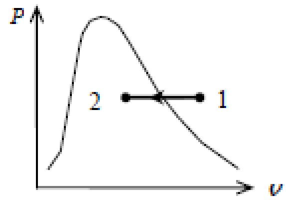


Analysis The initial specific volume is

$$v_1 = \frac{V}{m} = \frac{12.322 \text{ m}^3}{100 \text{ kg}} = 0.12322 \text{ m}^3/\text{kg}$$

The initial state is superheated and the internal energy at this state is

$$\left.\begin{array}{l} P_1 = 200 \text{ kPa} \\ v_1 = 0.12322 \text{ m}^3/\text{kg} \end{array}\right\} u_1 = 263.08 \text{ kJ/kg} \text{ (Table A-13)}$$



The final specific volume is

$$v_2 = \frac{v_1}{2} = \frac{0.12322 \text{ m}^3/kg}{2} = 0.06161 \text{ m}^3/\text{kg}$$

This is a constant pressure process. The final state is determined to be saturated mixture whose temperature is

$$T_2 = T_{\text{sat @ 200 kPa}} = \mathbf{-10.09°C} \text{ (Table A-12)}$$

The internal energy at the final state is (Table A-12)

$$x_2 = \frac{v_2 - v_f}{v_{fg}} = \frac{(0.06161 - 0.0007533) \text{ m}^3/\text{kg}}{(0.099867 - 0.0007533) \text{ m}^3/\text{kg}} = 0.6140$$

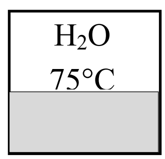
$$u_2 = u_f + x_2 u_{fg} = 38.28 + (0.6140)(186.21) = 152.61 \text{ kJ/kg}$$

Hence, the change in the internal energy is

$$\Delta u = u_2 - u_1 = 152.61 - 263.08 = \mathbf{-110.47 \text{ kJ/kg}}$$

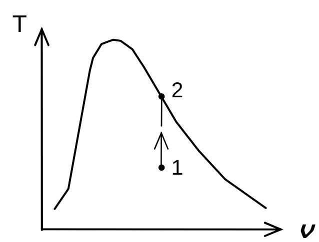
4-51 A rigid tank that is filled with saturated liquid-vapor mixture is heated. The temperature at which the liquid in the tank is completely vaporized is to be determined, and the T-v diagram is to be drawn.

Analysis This is a constant volume process ($v = V/m$ = constant), and the specific volume is determined to be



$$v = \frac{V}{m} = \frac{2.5 \text{ m}^3}{15 \text{ kg}} = 0.1667 \text{ m}^3/\text{kg}$$

When the liquid is completely vaporized the tank will contain saturated vapor only. Thus,



$$v_2 = v_g = 0.1667 \text{ m}^3/\text{kg}$$

The temperature at this point is the temperature that corresponds to this v_g value,

$$T = T_{\text{sat@}v_g = 0.1667 \text{ m}^3/\text{kg}} = \mathbf{187.0°C} \quad \text{(Table A-4)}$$

4-54 CD EES A piston-cylinder device contains a saturated liquid-vapor mixture of water at 800 kPa pressure. The mixture is heated at constant pressure until the temperature rises to 350°C. The initial temperature, the total mass of water, the final volume are to be determined, and the *P*-v diagram is to be drawn.

Analysis (a) Initially two phases coexist in equilibrium, thus we have a saturated liquid-vapor mixture. Then the temperature in the tank must be the saturation temperature at the specified pressure,

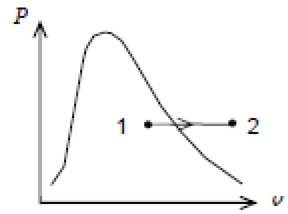
$$T = T_{\text{sat@800 kPa}} = \mathbf{170.41°C}$$

(b) The total mass in this case can easily be determined by adding the mass of each phase,

$$m_f = \frac{V_f}{v_f} = \frac{0.1\text{ m}^3}{0.001115\text{ m}^3/\text{kg}} = 89.704\text{ kg}$$

$$m_g = \frac{V_g}{v_g} = \frac{0.9\text{ m}^3}{0.24035\text{ m}^3/\text{kg}} = 3.745\text{ kg}$$

$$m_t = m_f + m_g = 89.704 + 3.745 = \mathbf{93.45\text{ kg}}$$



(c) At the final state water is superheated vapor, and its specific volume is

$$\left.\begin{array}{l} P_2 = 800\text{ kPa} \\ T_2 = 350^\circ\text{C} \end{array}\right\} v_2 = 0.35442\text{ m}^3/\text{kg} \qquad \text{(Table A-6)}$$

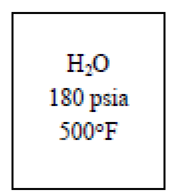
Then,

$$V_2 = m_t v_2 = (93.45\text{ kg})(0.35442\text{ m}^3/\text{kg}) = \mathbf{33.12\text{ m}^3}$$

4-56E Superheated water vapor cools at constant volume until the temperature drops to 250°F. At the final state, the pressure, the quality, and the enthalpy are to be determined.

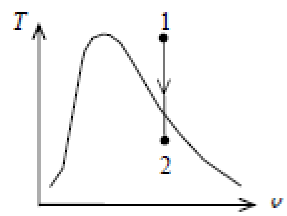
Analysis This is a constant volume process ($v = V/m$ = constant), and the initial specific volume is determined to be

$$\left.\begin{array}{l} P_1 = 180\text{ psia} \\ T_1 = 500^\circ\text{F} \end{array}\right\} v_1 = 3.0433\text{ ft}^3/\text{lbm} \qquad \text{(Table A-6E)}$$



At 250°F, v_f = 0.01700 ft^3/lbm and v_g = 13.816 ft^3/lbm. Thus at the final state, the tank will contain saturated liquid-vapor mixture since $v_f < v < v_g$, and the final pressure must be the saturation pressure at the final temperature,

$$P = P_{\text{sat@250°F}} = \mathbf{29.84\ psia}$$



(*b*) The quality at the final state is determined from

$$x_2 = \frac{v_2 - v_f}{v_{fg}} = \frac{3.0433 - 0.01700}{13.816 - 0.01700} = \mathbf{0.219}$$

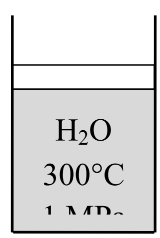
(*c*) The enthalpy at the final state is determined from

$$h = h_f + x h_{fg} = 218.63 + 0.219 \times 945.41 = \mathbf{426.0\ Btu/lbm}$$

4-61 Superheated steam in a piston-cylinder device is cooled at constant pressure until half of the mass condenses. The final temperature and the volume change are to be determined, and the process should be shown on a *T*-v diagram.

Analysis (*b*) At the final state the cylinder contains saturated liquid-vapor mixture, and thus the final temperature must be the saturation temperature at the final pressure,

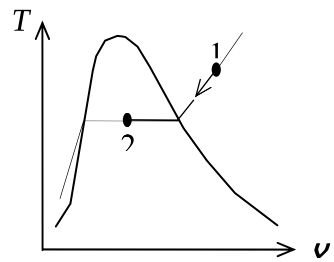
$$T = T_{\text{sat@1 MPa}} = \mathbf{179.88°C} \qquad \text{(Table A-5)}$$



(c) The quality at the final state is specified to be x_2 = 0.5. The specific volumes at the initial and the final states are

$$\left.\begin{array}{l} P_1 = 1.0 \text{ MPa} \\ T_1 = 300^\circ\text{C} \end{array}\right\} \boldsymbol{v}_1 = 0.25799 \text{ m}^3/\text{kg} \qquad \text{(Table A-6)}$$

$$\left.\begin{array}{l} P_2 = 1.0 \text{ MPa} \\ x_2 = 0.5 \end{array}\right\} \begin{aligned} \boldsymbol{v}_2 &= \boldsymbol{v}_f + x_2 \boldsymbol{v}_{fg} \\ &= 0.001127 + 0.5 \times (0.19436 - 0.001127) \\ &= 0.09775 \text{ m}^3/\text{kg} \end{aligned}$$



Thus,

$$\Delta \boldsymbol{V} = m(\boldsymbol{v}_2 - \boldsymbol{v}_1) = (0.8 \text{ kg})(0.09775 - 0.25799)\text{m}^3/\text{kg} = \mathbf{-0.1282 \ m^3}$$

4-63 Heat is supplied to a piston-cylinder device that contains water at a specified state. The volume of the tank, the final temperature and pressure, and the internal energy change of water are to be determined.

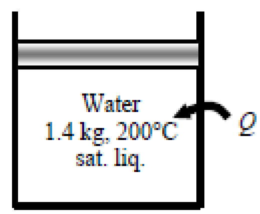
Properties The saturated liquid properties of water at 200°C are: v_f = 0.001157 m³/kg and u_f = 850.46 kJ/kg (Table A-4).

Analysis (a) The cylinder initially contains saturated liquid water. The volume of the cylinder at the initial state is

$$V_1 = m v_1 = (1.4 \text{ kg})(0.001157 \text{ m}^3/\text{kg}) = 0.001619 \text{ m}^3$$

The volume at the final state is

$$V = 4(0.001619) = \mathbf{0.006476 \ m^3}$$



(b) The final state properties are

$$v_2 = \frac{V}{m} = \frac{0.006476 \text{ m}^3}{1.4 \text{ kg}} = 0.004626 \text{ m}^3/\text{kg}$$

$$\left.\begin{array}{l} v_2 = 0.004626 \text{ m}^3/\text{kg} \\ x_2 = 1 \end{array}\right\} \begin{array}{l} T_2 = \mathbf{371.3^\circ C} \\ P_2 = \mathbf{21{,}367 \ kPa} \\ u_2 = 2201.5 \text{ kJ/kg} \end{array} \qquad \text{(Table A-4 or A-5 or EES)}$$

(c) The total internal energy change is determined from

$$\Delta U = m(u_2 - u_1) = (1.4 \text{ kg})(2201.5 - 850.46) \text{ kJ/kg} = \mathbf{1892 \ kJ}$$