3–129 Water initially at 300 kPa and 0.5 m^3/kg is contained in a piston–cylinder device fitted with stops so that the water supports the weight of the piston and the force of the atmosphere. The water is heated until it reaches the saturated vapor state and the piston rests against the stops. With the piston against the stops, the water is further heated until the pressure is 600 kPa. On the P-v and T-v diagrams, sketch, with respect to the saturation lines, the process curves passing through both the initial and final states of the water. Label the states on the process as 1, 2, and 3. On both the P-v and T-v diagrams,

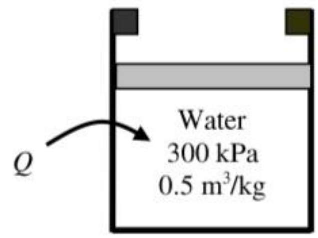
3-129 Water at a specified state is contained in a piston-cylinder device fitted with stops. Water is now heated until a final pressure. The process will be indicated on the P-υ and T- υ diagrams.

Analysis The properties at the three states are

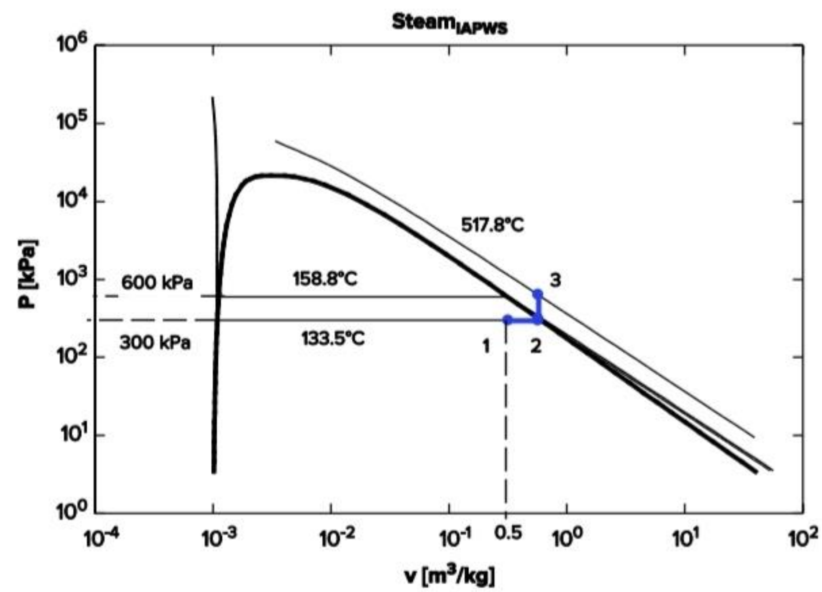
$$\left.\begin{array}{l} P_1 = 300 \text{ kPa} \\ \upsilon_1 = 0.5 \text{ m}^3/\text{kg} \end{array}\right\} T_1 = 133.5°\text{C} \quad \text{(Table A-5)}$$

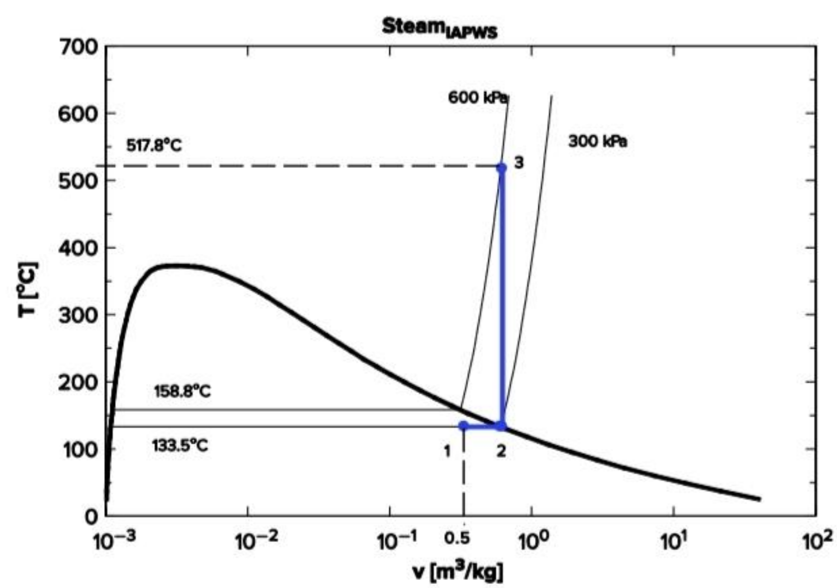
$$\left.\begin{array}{l} P_2 = 300 \text{ kPa} \\ x_2 = 1 \text{ (sat. vap.)} \end{array}\right\} \upsilon_2 = 0.6058 \text{ m}^3/\text{kg},\ T_2 = 133.5°\text{C} \quad \text{(Table A-5)}$$

$$\left.\begin{array}{l} P_2 = 600 \text{ kPa} \\ \upsilon_3 = 0.6058 \text{ m}^3/\text{kg} \end{array}\right\} T_2 = 517.8°\text{C} \quad \text{(Table A-6)}$$



Using Property Plot feature of EES, and by adding state points we obtain following diagrams.





3–123 A piston–cylinder device initially contains 0.2 kg of steam at 200 kPa and 300°C. Now, the steam is cooled at constant pressure until it is at 150°C. Determine the volume change of the cylinder during this process using the compressibility factor, and compare the result to the actual value.

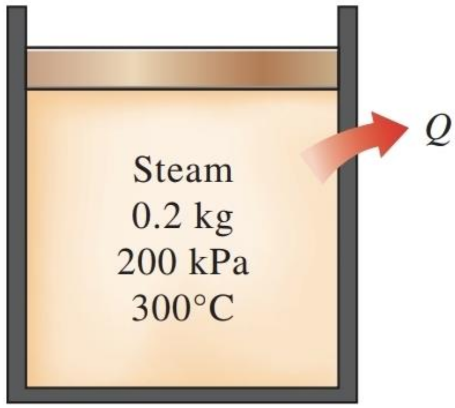


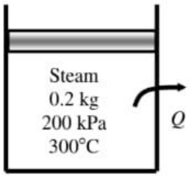
FIGURE P3–123

3-123 A piston-cylinder device contains steam at a specified state. Steam is cooled at constant pressure. The volume change is to be determined using compressibility factor.

Properties The gas constant, the critical pressure, and the critical temperature of steam are

$$R = 0.4615 \text{ kPa·m}^3\text{/kg·K}, \quad T_{cr} = 647.1 \text{ K}, \quad P_{cr} = 22.06 \text{ MPa}$$

Analysis The exact solution is given by the following:



$$\left.\begin{array}{l} P = 200 \text{ kPa} \\ T_1 = 300°\text{C} \end{array}\right\} v_1 = 1.31623 \text{ m}^3\text{/kg}$$

$$\left.\begin{array}{l} P = 200 \text{ kPa} \\ T_2 = 150°\text{C} \end{array}\right\} v_2 = 0.95986 \text{ m}^3\text{/kg} \quad \text{(Table A-6)}$$

$$\Delta V_{\text{exact}} = m(v_1 - v_2) = (0.2 \text{ kg})(1.31623 - 0.95986)\text{m}^3\text{/kg} = \mathbf{0.07128 \text{ m}^3}$$

Using compressibility chart (EES function for compressibility factor is used)

$$\left.\begin{array}{l} P_R = \dfrac{P_1}{P_{cr}} = \dfrac{0.2 \text{ MPa}}{22.06 \text{ MPa}} = 0.0091 \\ T_{R,1} = \dfrac{T_1}{T_{cr}} = \dfrac{300 + 273 \text{ K}}{647.1 \text{ K}} = 0.886 \end{array}\right\} Z_1 = 0.9956$$

$$\left.\begin{array}{l} P_R = \dfrac{P_2}{P_{cr}} = \dfrac{0.2 \text{ MPa}}{22.06 \text{ MPa}} = 0.0091 \\ T_{R,2} = \dfrac{T_2}{T_{cr}} = \dfrac{150 + 273 \text{ K}}{647.1 \text{ K}} = 0.65 \end{array}\right\} Z_2 = 0.9897$$

$$V_1 = \frac{Z_1 mRT_1}{P_1} = \frac{(0.9956)(0.2 \text{ kg})(0.4615 \text{ kPa}\cdot\text{m}^3\text{/kg}\cdot\text{K})(300 + 273 \text{ K})}{(200 \text{ kPa})} = 0.2633 \text{ m}^3$$

$$V_2 = \frac{Z_2 mRT_2}{P_2} = \frac{(0.9897)(0.2 \text{ kg})(0.4615 \text{ kPa}\cdot\text{m}^3\text{/kg}\cdot\text{K})(150 + 273 \text{ K})}{(200 \text{ kPa})} = 0.1932 \text{ m}^3$$

$$\Delta V_{\text{chart}} = V_1 - V_2 = 0.2633 - 0.1932 = \mathbf{0.07006 \text{ m}^3}, \quad \text{Error: } \mathbf{1.7\%}$$

3–124 A tank whose volume is unknown is divided into two parts by a partition. One side of the tank contains 0.03 m^3 of refrigerant-134a that is a saturated liquid at 0.9 MPa, while the other side is evacuated. The partition is now removed, and the refrigerant fills the entire tank. If the final state of the refrigerant is 20°C and 280 kPa, determine the volume of the tank.

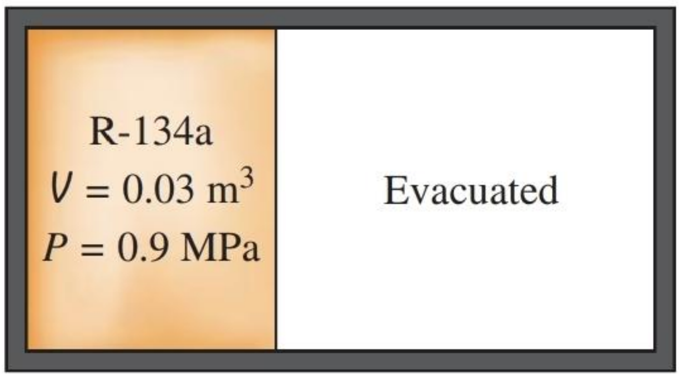
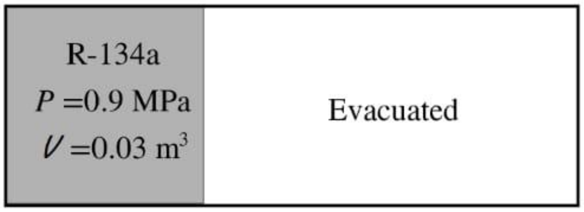


FIGURE P3–124

3-124 One section of a tank is filled with saturated liquid R-134a while the other side is evacuated. The partition removed, and the temperature and pressure in the tank are measured. The volume of the tank is to be determined.

Analysis The mass of the refrigerant contained in the tank is

$$m = \frac{V_1}{v_1} = \frac{0.03 \text{ m}^3}{0.0008580 \text{ m}^3/\text{kg}} = 34.96 \text{ kg}$$



since

$$v_1 = v_{f\ @0.9\ \text{MPa}} = 0.0008580 \text{ m}^3/\text{kg}$$

At the final state (Table A-13),

$$\left.\begin{array}{l} P_2 = 280 \text{ kPa} \\ T_2 = 20°\text{C} \end{array}\right\} v_2 = 0.07997 \text{ m}^3/\text{kg}$$

Thus,

$$V_{\text{tank}} = V_2 = m v_2 = (34.96 \text{ kg})(0.07997 \text{ m}^3/\text{kg}) = \mathbf{2.80\ m^3}$$

3–112 Carbon dioxide gas at 3 MPa and 500 K flows steadily in a pipe at a rate of 0.4 kmol/s. Determine (*a*) the volume and mass flow rates and the density of carbon dioxide at this state. If CO_2 is cooled at constant pressure as it flows in the pipe so that the temperature of CO_2 drops to 450 K at the exit of the pipe, determine (*b*) the volume flow rate at the exit of the pipe.

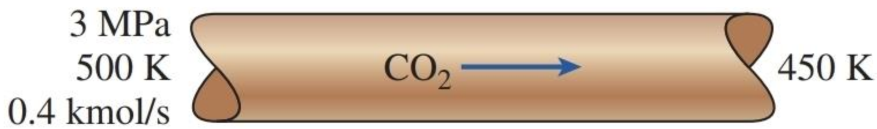
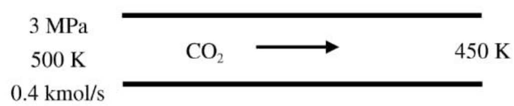


FIGURE P3–112

3-112 Carbon dioxide flows through a pipe at a given state. The volume and mass flow rates and the density of CO_2 at the given state and the volume flow rate at the exit of the pipe are to be determined.



Analysis (*a*) The volume and mass flow rates may be determined from ideal gas relation as

$$\dot{V}_1 = \frac{\dot{N}R_u T_1}{P} = \frac{(0.4 \text{ kmol/s})(8.314 \text{ kPa.m}^3\text{/kmol.K})(500 \text{ K})}{3000 \text{ kPa}} = \mathbf{0.5543\ m^3/s}$$

$$\dot{m}_1 = \frac{P_1 \dot{V}_1}{RT_1} = \frac{(3000 \text{ kPa})(0.5543 \text{ m}^3/s)}{(0.1889 \text{ kPa.m}^3\text{/kg.K})(500 \text{ K})} = \mathbf{17.60\ kg/s}$$

The density is

$$\rho_1 = \frac{\dot{m}_1}{\dot{V}_1} = \frac{(17.60 \text{ kg/s})}{(0.5543 \text{ m}^3\text{/s})} = \mathbf{31.76\ kg/m^3}$$

(b) The volume flow rate at the exit is

$$\dot{V}_2 = \frac{\dot{N}R_u T_2}{P} = \frac{(0.4 \text{ kmol/s})(8.314 \text{ kPa.m}^3\text{/kmol.K})(450 \text{ K})}{3000 \text{ kPa}} = \mathbf{0.4988\ m^3/s}$$

3–78 A rigid tank whose volume is unknown is divided into two parts by a partition. One side of the tank contains an ideal gas at 927°C. The other side is evacuated and has a volume twice the size of the part containing the gas. The partition is now removed and the gas expands to fill the entire tank. Heat is now transferred to the gas until the pressure equals the initial pressure. Determine the final temperature of the gas. *Answer:* 3327°C

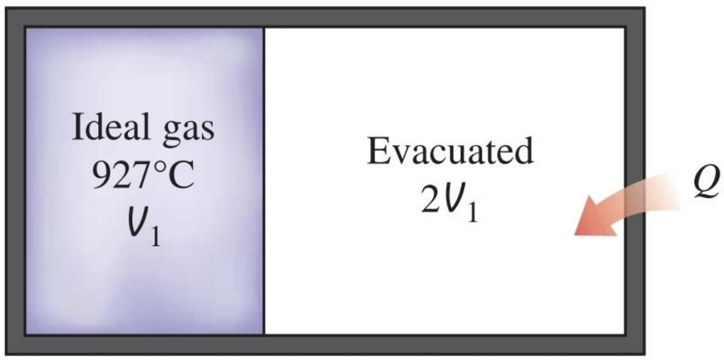


FIGURE P3–78

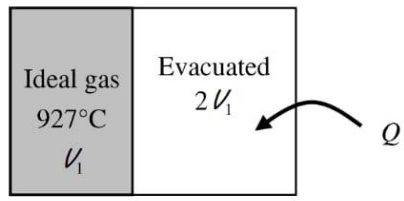
3-78 One side of a two-sided tank contains an ideal gas while the other side is evacuated. The partition is removed and the gas fills the entire tank. The gas is also heated to a final pressure. The final temperature is to be determined.

Assumptions The gas is specified as an ideal gas so that ideal gas relation can be used.

Analysis According to the ideal gas equation of state,

$$P_2 = P_1$$

$$V_2 = V_1 + 2V_1 = 3V_1$$



Applying these,

$$m_1 = m_1$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$T_2 = T_1 \frac{V_2}{V_1} = T_1 \frac{3V_1}{V_1} = 3T_1 = 3[(927 + 273)\text{ K}] = 3600\text{ K} = \mathbf{3327°C}$$

3–122 A 4-L rigid tank contains 2 kg of saturated liquid–vapor mixture of water at 50°C. The water is now slowly heated until it exists in a single phase. At the final state, will the water be in the liquid phase or the vapor phase? What would your answer be if the volume of the tank were 400 L instead of 4 L?

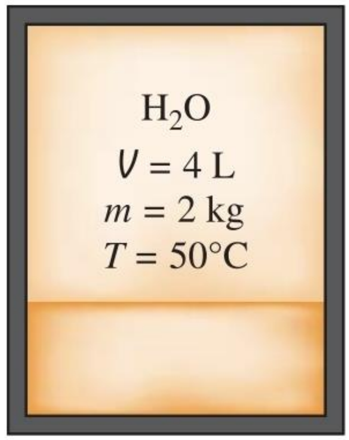
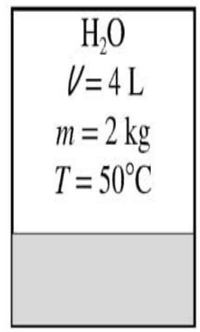


FIGURE P3–122

3-122 The rigid tank contains saturated liquid-vapor mixture of water. The mixture is heated until it exists in a single phase. For a given tank volume, it is to be determined if the final phase is a liquid or a vapor.

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

$$v_2 = v_1$$



The critical specific volume of water is 0.003106 m^3/kg. Thus if the final specific volume is smaller than this value, the water will exist as a liquid, otherwise as a vapor.

$$V = 4\ L \longrightarrow v = \frac{V}{m} = \frac{0.004 \text{ m}^3}{2 \text{ kg}} = 0.002 \text{ m}^3/\text{kg} < v_{cr} \text{ Thus, } \textbf{liquid}.$$

$$V = 400\ L \longrightarrow v = \frac{V}{m} = \frac{0.4 \text{ m}^3}{2 \text{ kg}} = 0.2 \text{ m}^3/\text{kg} > v_{cr}. \text{ Thus, } \textbf{vapor}.$$

3–63 The spring-loaded piston–cylinder device shown in Fig. P3–63 is filled with 0.5 kg of water vapor that is initially at 4 MPa and 400°C. Initially, the spring exerts no force against the piston. The spring constant in the spring force relation $F = kx$ is $k = 0.9$ kN/cm and the piston diameter is $D = 20$ cm. The water now undergoes a process until its volume is one-half of the original volume. Calculate the final temperature and the specific enthalpy of the water. *Answers:* 220°C, 1721 kJ/kg

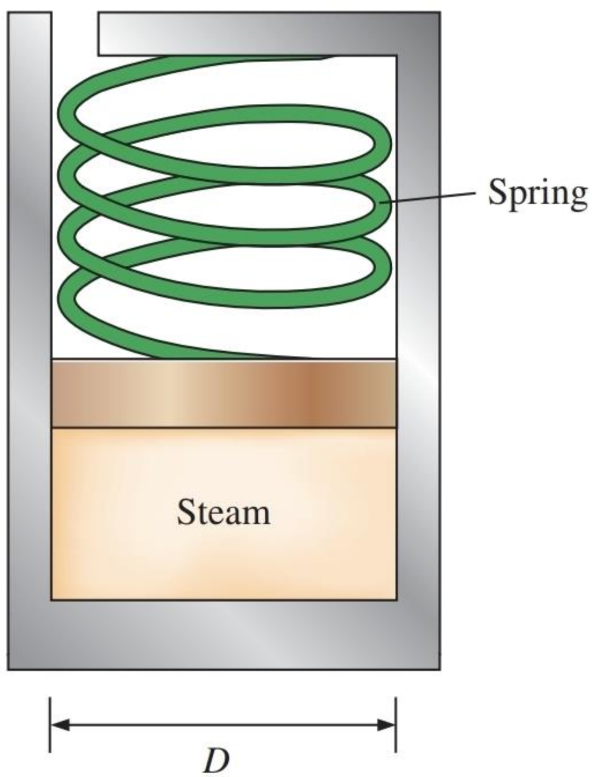


FIGURE P3–63

3-63 A spring-loaded piston-cylinder device is filled with water. The water now undergoes a process until its volume is one-half of the original volume. The final temperature and the enthalpy are to be determined.

Analysis From the steam tables,

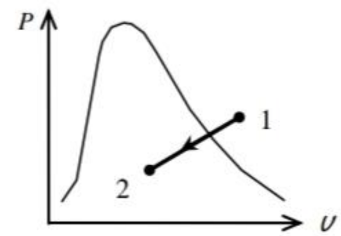
$$\left.\begin{array}{l} P_1 = 4 \text{ MPa} \\ T_1 = 400°\text{C} \end{array}\right\} \upsilon_1 = 0.07343 \text{ m}^3/\text{kg} \quad \text{(Table A-6)}$$

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

$$P - P_1 = c(\upsilon - \upsilon_1)$$

where P_1 is the system pressure when its specific volume is υ_1. The spring equation may be written as

$$P - P_1 = \frac{F_s - F_{s,1}}{A} = k\frac{x - x_1}{A} = \frac{kA}{A^2}(x - x_1) = \frac{k}{A^2}(V - V_1) = \frac{km}{A^2}(\upsilon - \upsilon_1)$$



Constant c is hence

$$c = \frac{km}{A^2} = \frac{4^2 km}{\pi^2 D^4} = \frac{(16)(90 \text{ kN/m})(0.5 \text{ kg})}{\pi^2 (0.2 \text{ m})^4} = 45{,}595 \text{ kN}\cdot\text{kg/m}^5$$

The final pressure is then

$$P_2 = P_1 + c(\upsilon_2 - \upsilon_1) = P_1 + c\left(\frac{\upsilon_1}{2} - \upsilon_1\right) = P_1 - \frac{c}{2}\upsilon_1$$
$$= 4000 \text{ kPa} - \frac{45{,}595 \text{ kN}\cdot\text{kg/m}^5}{2}(0.07343 \text{ m}^3/\text{kg}) = 2326 \text{ kPa}$$

and

$$\upsilon_2 = \frac{\upsilon_1}{2} = \frac{0.07343 \text{ m}^3/\text{kg}}{2} = 0.03672 \text{ m}^3/\text{kg}$$

The final state is a mixture and the temperature is

$$T_2 = T_{\text{sat @ 2326 kPa}} \cong \mathbf{220°C} \quad \text{(Table A-5)}$$

The quality and the enthalpy at the final state are

$$x_2 = \frac{\upsilon_2 - \upsilon_f}{\upsilon_{fg}} = \frac{(0.03672 - 0.001190) \text{ m}^3/\text{kg}}{(0.086094 - 0.001190) \text{ m}^3/\text{kg}} = 0.4185$$

$$h_2 = h_f + x_2 h_{fg} = 943.55 + (0.4185)(1857.4) = \mathbf{1721 \text{ kJ/kg}}$$

3–56 One kilogram of water fills a 150-L rigid container at an initial pressure of 2 MPa. The container is then cooled to 40°C. Determine the initial temperature and the final pressure of the water.

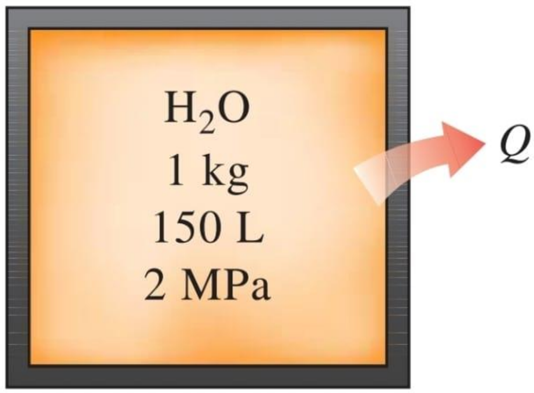
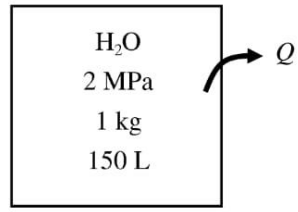


FIGURE P3–56

3-56 A rigid container that is filled with water is cooled. The initial temperature and the final pressure are to be determined.

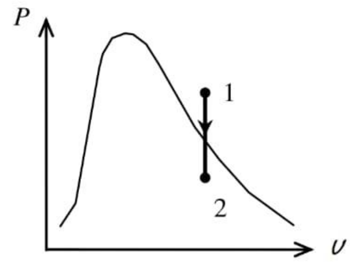
Analysis This is a constant volume process. The specific volume is



$$v_1 = v_2 = \frac{V}{m} = \frac{0.150 \text{ m}^3}{1 \text{ kg}} = 0.150 \text{ m}^3/\text{kg}$$

The initial state is superheated vapor. The temperature is determined to be

$$\left.\begin{array}{l} P_1 = 2 \text{ MPa} \\ v_1 = 0.150 \text{ m}^3/\text{kg} \end{array}\right\} T_1 = \mathbf{395^\circ C} \quad \text{(Table A-6)}$$



This is a constant volume cooling process ($v = V/m =$ constant). The final state is saturated mixture and thus the pressure is the saturation pressure at the final temperature:

$$\left.\begin{array}{l} T_2 = 40^\circ\text{C} \\ v_2 = v_1 = 0.150 \text{ m}^3/\text{kg} \end{array}\right\} P_2 = P_{\text{sat @ 40°C}} = \mathbf{7.385 \text{ kPa}} \text{ (Table A-4)}$$

3–64 A piston–cylinder device initially contains steam at 3.5 MPa, superheated by 5°C. Now, steam loses heat to the surroundings and the piston moves down, hitting a set of stops, at which point the cylinder contains saturated liquid water. The cooling continues until the cylinder contains water at 200°C. Determine (*a*) the initial temperature, (*b*) the enthalpy change per unit mass of the steam by the time the piston first hits the stops, and (*c*) the final pressure and the quality (if mixture).

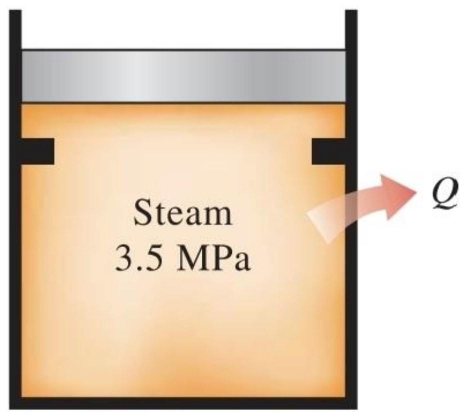
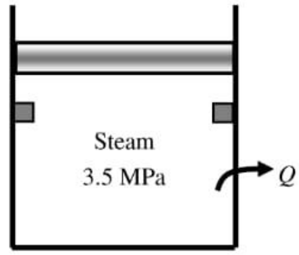


FIGURE P3–64

3-64 Heat is lost from a piston-cylinder device that contains steam at a specified state. The initial temperature, the enthalpy change, and the final pressure and quality are to be determined.



Analysis (*a*) The saturation temperature of steam at 3.5 MPa is

$$T_{\text{sat@3.5 MPa}} = 242.6°\text{C} \quad \text{(Table A-5)}$$

Then, the initial temperature becomes

$$T_1 = 242.6 + 5 = \mathbf{247.6°C}$$

Also,
$$\left.\begin{array}{l} P_1 = 3.5 \text{ MPa} \\ T_1 = 247.6°\text{C} \end{array}\right\} h_1 = 2821.1 \text{ kJ/kg} \quad \text{(Table A-6)}$$

(*b*) The properties of steam when the piston first hits the stops are

$$\left.\begin{array}{l} P_2 = P_1 = 3.5 \text{ MPa} \\ x_2 = 0 \end{array}\right\} \begin{array}{l} h_2 = 1049.7 \text{ kJ/kg} \\ v_2 = 0.001235 \text{ m}^3\text{/kg} \end{array} \quad \text{(Table A-5)}$$

Then, the enthalpy change of steam becomes

$$\Delta h = h_2 - h_1 = 1049.7 - 2821.1 = \mathbf{-1771 \ kJ/kg}$$

(*c*) At the final state

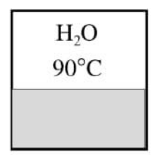
$$\left.\begin{array}{l} v_3 = v_2 = 0.001235 \text{ m}^3\text{/kg} \\ T_3 = 200°\text{C} \end{array}\right\} \begin{array}{l} P_3 = \mathbf{1555 \ kPa} \\ x_3 = \mathbf{0.0006} \end{array} \quad \text{(Table A-4 or EES)}$$

The cylinder contains saturated liquid-vapor mixture with a small mass of vapor at the final state.

3–50 A rigid tank with a volume of 1.8 m^3 contains 40 kg of saturated liquid–vapor mixture of water at 90°C. Now the w is slowly heated. Determine the temperature at which the liquid in the tank is completely vaporized. Also, show the process on a T-υ diagram with respect to saturation lines. *Answer: 256°C*

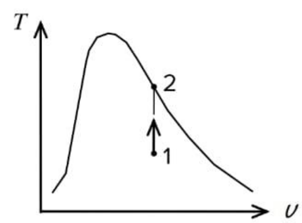
3-50 A rigid tank that is filled with saturated liquid-vapor mixture is heated. The temperature at which the liquid in the tank is completely vaporized is to be determined, and the T-υ diagram is to be drawn.

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



$$\upsilon = \frac{V}{m} = \frac{1.8 \text{ m}^3}{40 \text{ kg}} = 0.0450 \text{ m}^3/\text{kg}$$

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

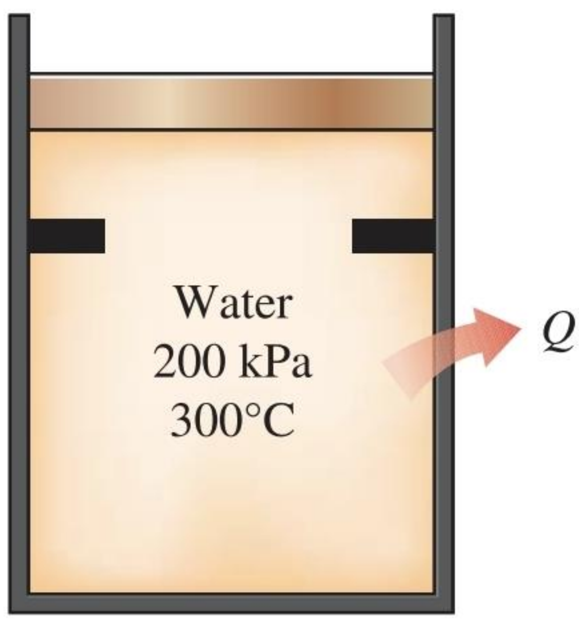


$$\upsilon_2 = \upsilon_g = 0.0450 \text{ m}^3/\text{kg}$$

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

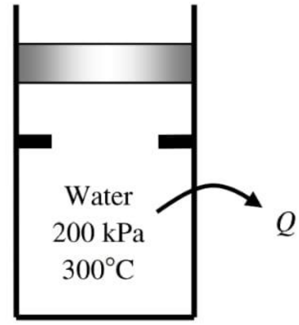
$$T = T_{\text{sat @ } \upsilon_g = 0.0450 \text{ m}^3/\text{kg}} = \mathbf{256°C} \qquad \text{(Table A-4)}$$

3–44 Water initially at 200 kPa and 300°C is contained in a piston–cylinder device fitted with stops. The water is allowed to cool at constant pressure until it exists as a saturated vapor and the piston rests on the stops. Then the water continues to cool until the pressure is 100 kPa. On the *T*-v diagram, sketch, with respect to the saturation lines, the process curves passing through the initial, intermediate, and final states of the water. Label the *T*, *P*, and v values for end states on the process curves. Find the overall change in internal energy between the initial and final states per unit mass of water.



3-44 A piston-cylinder device fitted with stops contains water at a specified state. Now the water is cooled until a final pressure. The process is to be indicated on the *T*-v diagram and the change in internal energy is to be determined.

Analysis The process is shown on *T*-v diagram. The internal energy at the initial state is

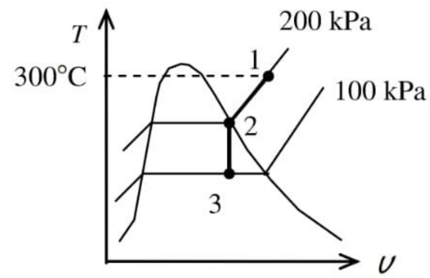


$$\left.\begin{array}{l} P_1 = 200 \text{ kPa} \\ T_1 = 300°\text{C} \end{array}\right\} u_1 = 2808.8 \text{ kJ/kg (Table A-6)}$$

State 2 is saturated vapor at the initial pressure. Then,

$$\left.\begin{array}{l} P_2 = 200 \text{ kPa} \\ x_2 = 1 \text{ (sat. vapor)} \end{array}\right\} v_2 = 0.8858 \text{ m}^3\text{/kg (Table A-5)}$$

Process 2-3 is a constant-volume process. Thus,



$$\left.\begin{array}{l} P_3 = 100 \text{ kPa} \\ v_3 = v_2 = 0.8858 \text{ m}^3\text{/kg} \end{array}\right\} u_3 = 1508.6 \text{ kJ/kg (Table A-5)}$$

The overall change in internal energy is

$$\Delta u = u_1 - u_3 = 2808.8 - 1508.6 = \mathbf{1300 \text{ kJ/kg}}$$

3–51 A piston–cylinder device contains 0.005 m^3 of liquid water and 0.9 m^3 of water vapor in equilibrium at 600 kPa. Heat is transferred at constant pressure until the temperature reaches 200°C.

(*a*) What is the initial temperature of the water?

(*b*) Determine the total mass of the water.

(*c*) Calculate the final volume.

(*d*) Show the process on a *P*-*v* diagram with respect to saturation lines.

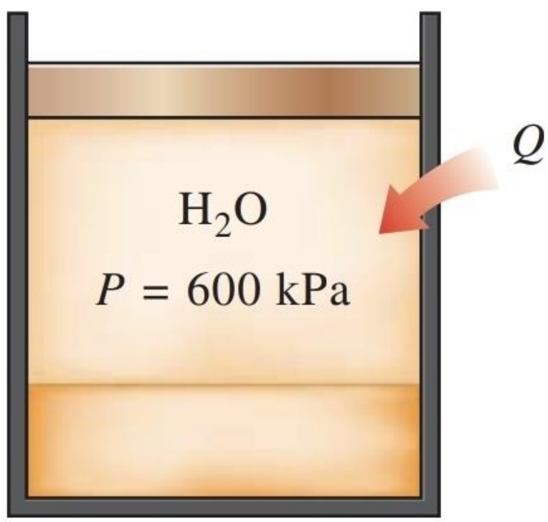


FIGURE P3–51

3-51 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 200°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,

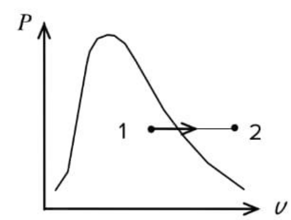
$$T = T_{\text{sat @ 600 kPa}} = \mathbf{158.8°C}$$

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

$$m_f = \frac{V_f}{v_f} = \frac{0.005\ \text{m}^3}{0.001101\ \text{m}^3/\text{kg}} = 4.543\ \text{kg}$$

$$m_g = \frac{V_g}{v_g} = \frac{0.9\ \text{m}^3}{0.3156\ \text{m}^3/\text{kg}} = 2.852\ \text{kg}$$

$$m_t = m_f + m_g = 4.543 + 2.852 = \mathbf{7.395\ kg}$$



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

$$\left.\begin{array}{l} P_2 = 600\ \text{kPa} \\ T_2 = 200°\text{C} \end{array}\right\} v_2 = 0.3521\ \text{m}^3/\text{kg} \quad \text{(Table A-6)}$$

Then,

$$V_2 = m_t v_2 = (7.395\ \text{kg})(0.3521\ \text{m}^3/\text{kg}) = \mathbf{2.604\ m^3}$$

3–37 One kilogram of water vapor at 200 kPa fills the 1.1989-m^3 left chamber of a partitioned system shown in Fig. P3–37. The right chamber has twice the volume of the left and is initially evacuated. Determine the pressure of the water after the partition has been removed and enough heat has been transferred so that the temperature of the water is 3°C.

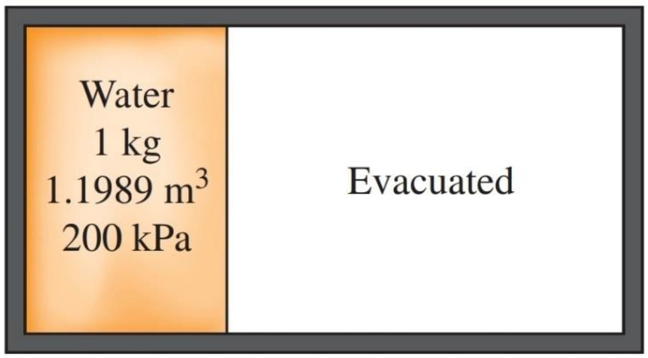
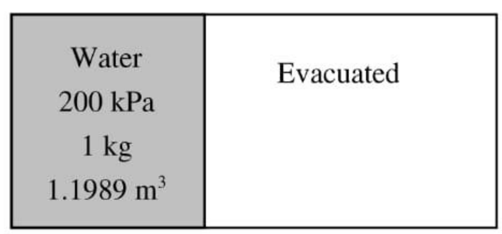


FIGURE P3–37

3-37 Left chamber of a partitioned system contains water at a specified state while the right chamber is evacuated. The partition is now ruptured and heat is transferred from the water. The pressure at the final state is to be determined.

Analysis The initial specific volume is



$$v_1 = \frac{V_1}{m} = \frac{1.1989 \text{ m}^3}{1 \text{ kg}} = 1.1989 \text{ m}^3/\text{kg}$$

At the final state, the water occupies three times the initial volume. Then,

$$v_2 = 3v_1 = 3(1.1989 \text{ m}^3/\text{kg}) = 3.5967 \text{ m}^3/\text{kg}$$

Based on this specific volume and the final temperature, the final state is a saturated mixture and the pressure is

$$P_2 = P_{\text{sat @ 3°C}} = \mathbf{0.768 \text{ kPa}} \quad \text{(Table A-4)}$$

3–42 10 kg of R-134a at 300 kPa fills a rigid container whose volume is 14 L. Determine the temperature and total enthalpy in the container. The container is now heated until the pressure is 600 kPa. Determine the temperature and total enthalpy when the heating is completed.

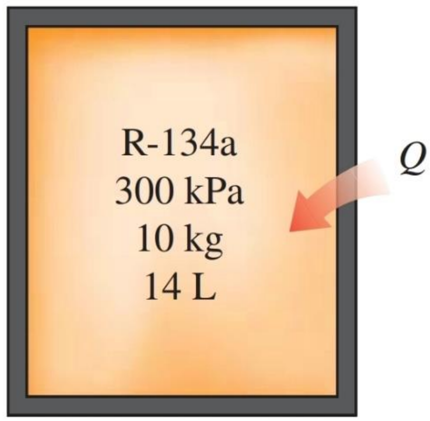


FIGURE P3–42

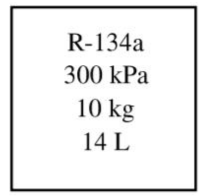
3-42 A rigid container that is filled with R-134a is heated. The temperature and total enthalpy are to be determined at the initial and final states.

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

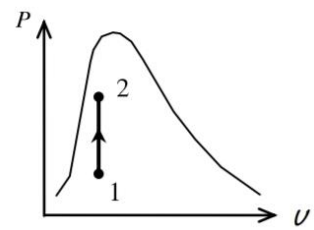
$$T_1 = T_{\text{sat @ 300 kPa}} = \mathbf{0.61°C}$$



Using EES, we would get 0.65°C. Then,

$$x_1 = \frac{v_1 - v_f}{v_{fg}} = \frac{(0.0014 - 0.0007735) \text{ m}^3/\text{kg}}{(0.067776 - 0.0007735) \text{ m}^3/\text{kg}} = 0.009351$$

$$h_1 = h_f + x_1 h_{fg} = 52.71 + (0.009351)(198.17) = 54.56 \text{ kJ/kg}$$



The total enthalpy is then

$$H_1 = mh_1 = (10 \text{ kg})(54.56 \text{ kJ/kg}) = \mathbf{545.6 \text{ kJ}}$$

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

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

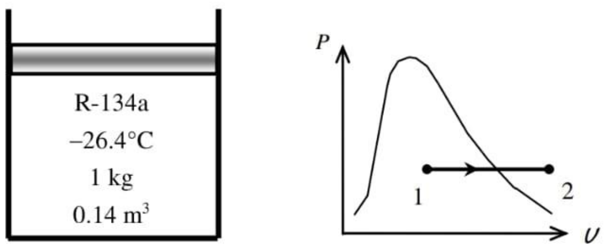
$$x_2 = \frac{v_2 - v_f}{v_{fg}} = \frac{(0.0014 - 0.0008198) \text{ m}^3/\text{kg}}{(0.034335 - 0.0008198) \text{ m}^3/\text{kg}} = 0.01731$$

$$h_2 = h_f + x_2 h_{fg} = 81.50 + (0.01731)(180.95) = 84.64 \text{ kJ/kg}$$

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

3–36 One kilogram of R-134a fills a 0.14-m^3 weighted piston–cylinder device at a temperature of –26.4°C. The container is now heated until the temperature is 100°C. Determine the final volume of the R-134a. *Answer:* 0.3014 m^3

3-36 A piston-cylinder device that is filled with R-134a is heated. The final volume is to be determined.



Analysis The initial specific volume is

$$v_1 = \frac{V_1}{m} = \frac{0.14 \text{ m}^3}{1 \text{ kg}} = 0.14 \text{ m}^3/\text{kg}$$

This is a constant-pressure process. The initial state is determined to be a mixture, and thus the pressure is the saturation pressure at the given temperature

$$P_1 = P_2 = P_{\text{sat @ -26.4°C}} = 100 \text{ kPa} \text{ (Table A-12)}$$

The final state is superheated vapor and the specific volume is

$$\left.\begin{array}{l} P_2 = 100 \text{ kPa} \\ T_2 = 100°\text{C} \end{array}\right\} v_2 = 0.30138 \text{ m}^3/\text{kg} \text{ (Table A-13)}$$

The final volume is then

$$V_2 = m v_2 = (1 \text{ kg})(0.30138 \text{ m}^3/\text{kg}) = \mathbf{0.30138 \text{ m}^3}$$

3–27 Complete this table for refrigerant-134a:

T, °C	*P*, kPa	*u*, kJ/kg	Phase description
20		95	
−12			Saturated liquid
	400	300	
8	600		

3-27 *Complete the following table for Refrigerant-134a*:

T, °C	*P*, kPa	*u*, kJ / kg	Phase description
20	***572.07***	95	***Saturated mixture***
-12	***185.37***	***35.76***	Saturated liquid
86.25	400	300	***Superheated vapor***
8	600	***62.37***	***Compressed liquid***

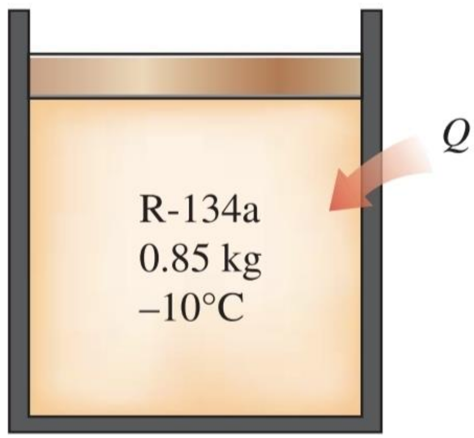
3–25 Complete this table for H_2O:

T, °C	*P*, kPa	*h*, kJ/kg	*x*	Phase description
	200		0.7	
140		1800		
	950		0.0	
80	500			
	800	3162.2		

3-25 *Complete the following table for* H_2O:

T, °C	*P*, kPa	*h*, kJ / kg	*x*	Phase description
120.21	200	***2045.8***	0.7	***Saturated mixture***
140	***361.53***	1800	***0.565***	***Saturated mixture***
177.66	950	***752.74***	0.0	***Saturated liquid***
80	500	***335.37***	- - -	***Compressed liquid***
350.0	800	3162.2	- - -	***Superheated vapor***

3–30 A piston–cylinder device contains 0.85 kg of refrigerant-134a at –10°C. The piston that is free to move has a mass of 12 kg and a diameter of 25 cm. The local atmospheric pressure is 88 kPa. Now, heat is transferred to refrigerant-134a until the temperature is 15°C. Determine (*a*) the final pressure, (*b*) the change in the volume of the cylinder, and (*c*) the change in the enthalpy of the refrigerant-134a.



3-30 A piston-cylinder device contains R-134a at a specified state. Heat is transferred to R-134a. The final pressure, the volume change of the cylinder, and the enthalpy change are to be determined.

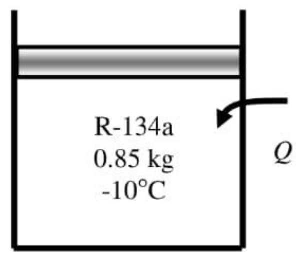
Analysis (a) The final pressure is equal to the initial pressure, which is determined from

$$P_2 = P_1 = P_{atm} + \frac{m_p g}{\pi D^2/4} = 88 \text{ kPa} + \frac{(12 \text{ kg})(9.81 \text{ m/s}^2)}{\pi (0.25 \text{ m})^2/4}\left(\frac{1 \text{ kN}}{1000 \text{ kg.m/s}^2}\right) = \mathbf{90.4 \text{ kPa}}$$

(b) The specific volume and enthalpy of R-134a at the initial state of 90.4 kPa and -10°C and at the final state of 90.4 kPa and 15°C are (from EES)

$v_1 = 0.2302 \text{ m}^3/\text{kg}$ $\quad h_1 = 247.77 \text{ kJ/kg}$

$v_2 = 0.2544 \text{ m}^3/\text{kg}$ $\quad h_2 = 268.18 \text{ kJ/kg}$



The initial and the final volumes and the volume change are

$$V_1 = m v_1 = (0.85 \text{ kg})(0.2302 \text{ m}^3/\text{kg}) = 0.1957 \text{ m}^3$$

$$V_2 = m v_2 = (0.85 \text{ kg})(0.2544 \text{ m}^3/\text{kg}) = 0.2162 \text{ m}^3$$

$$\Delta V = 0.2162 - 0.1957 = \mathbf{0.0205 \text{ m}^3}$$

(c) The total enthalpy change is determined from

$$\Delta H = m(h_2 - h_1) = (0.85 \text{ kg})(268.18 - 247.77) \text{ kJ/kg} = \mathbf{17.4 \text{ kJ/kg}}$$