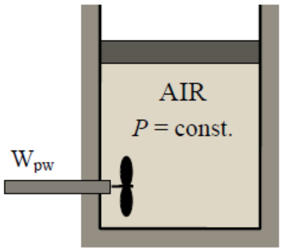
1. An insulated piston–cylinder device contains 100 L of air at 400 kPa and 25°C. A paddle wheel within the cylinder is rotated until 15 kJ of work is done on the air while the pressure is held constant. Determine the final temperature of the air.



Mass of air: P1*V1 = m*R*T   m = P1*V1/R*T m = 400*0.1/0.287*298   m = 0.468 kg

Q – W = u2 – u1   Q – ($W_{boundary}$ - $W_{mechanical}$) = u2 – u1   Wb = P*(V2 –V1)

Q – ((P*(V2 –V1)- $W_{mechanical}$) = u2 – u1 Q – (- $W_{mechanical}$) = (u2 + P*V2) – (u1 + P*V1)

Q – (-W_{mech}) = h2 – h1 or Q – (-W_{mech}) = m*(h2 – h1)

For ideal gases Q – (-W_{mech}) = m*cp*(T2 – T1)

Q = 0   0 – (-15) = 0.468*1.005*(T2 – 298)   T2= 330K or T2 = 57^{o}C

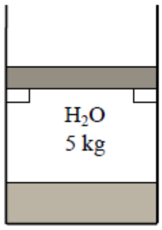
2. A mass of 5 kg of saturated liquid–vapor mixture of water is contained in a piston–cylinder device at 125 kPa. Initially, 2 kg of the water is in the liquid phase and the rest is in the vapor phase. Heat is now transferred to the water, and the piston, which is resting on a set of stops, starts moving when the pressure inside reaches 300 kPa. Heat transfer continues until the total volume increases by 20 percent. Determine (*a*) the initial and final temperatures, (*b*) the mass of liquid water when the piston first starts moving, and (*c*) the work done during this process. Also, show the process on a *P*-*v* diagram.

(*a*) Initially the system is a saturated mixture at 125 kPa pressure, and thus the initial temperature is

$$T_1 = T_{\text{sat@125 kPa}} = \mathbf{106.0°C}$$

The total initial volume is

$$V_1 = m_f v_f + m_g v_g = 2\times 0.001048 + 3\times 1.3750 = 4.127 \text{ m}^3$$



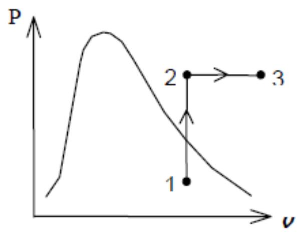
Then the total and specific volumes at the final state are

$$V_3 = 1.2V_1 = 1.2\times 4.127 = 4.953 \text{ m}^3$$

$$v_3 = \frac{V_3}{m} = \frac{4.953 \text{ m}^3}{5 \text{ kg}} = 0.9905 \text{ m}^3/\text{kg}$$

Thus,

$$\left.\begin{aligned} P_3 &= 300 \text{ kPa} \\ v_3 &= 0.9905 \text{ m}^3/\text{kg} \end{aligned}\right\} T_3 = \mathbf{373.6°C}$$



(*b*) When the piston first starts moving, P_2 = 300 kPa and V_2 = V_1 = 4.127 m^3. The specific volume at this state is

$$v_2 = \frac{V_2}{m} = \frac{4.127 \text{ m}^3}{5 \text{ kg}} = 0.8254 \text{ m}^3/\text{kg}$$

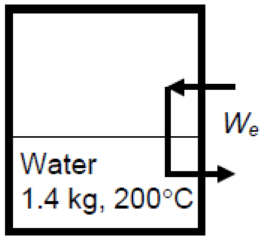
which is greater than v_g = 0.60582 m^3/kg at 300 kPa. Thus **no liquid** is left in the cylinder when the piston starts moving.

(*c*) No work is done during process 1-2 since V_1 = V_2. The pressure remains constant during process 2-3 and the work done during this process is

$$W_b = \int_2^3 P\,dV = P_2(V_3 - V_2) = (300 \text{ kPa})(4.953 - 4.127)\text{m}^3\left(\frac{1 \text{ kJ}}{1 \text{ kPa}\cdot\text{m}^3}\right) = \mathbf{247.6\ kJ}$$

3. An insulated rigid tank initially contains 1.4-kg saturated liquid water at 200°C. At this state, 25 percent of the volume is occupied by liquid water. Now an electric resistor placed in the tank is turned on, and the tank is observed to contain saturated water vapor after 20 min. Determine;
(*a*) the volume of the tank, (*b*) the final temperature, and (*c*) the electric power rating of the resistor.

The initial properties of steam
T1 = 200oC v1=vf1=0.001157 m3/kg and u1=uf1=851 kJ/kg



The initial water volume and the tank volume are

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

$$V_{\text{tank}} = \frac{0.001619\ \text{m}^3}{0.25} = \mathbf{0.006476\ m^3}$$

(*b*) Now, the final state can be fixed by calculating specific volume

$$v_2 = \frac{V_2}{m} = \frac{0.006476\ \text{m}^3}{1.4\ \text{kg}} = 0.004626\ \text{m}^3/\text{kg}$$

The final state properties are

$$\left.\begin{array}{l} v_2 = 0.004626\ \text{m}^3/\text{kg} \\ x_2 = 1 \end{array}\right\} \begin{array}{l} T_2 = \mathbf{371.3°C} \\ u_2 = 2201.5\ \text{kJ/kg} \end{array}$$

(*c*) Substituting,

$$W_{\text{e,in}} = (1.4\text{ kg})(2201.5 - 850.46)\text{kJ/kg} = 1892\text{ kJ}$$

Finally, the power rating of the resistor is

$$\dot{W}_{\text{e,in}} = \frac{W_{\text{e,in}}}{\Delta t} = \frac{1892\ \text{kJ}}{20 \times 60\ \text{s}} = \mathbf{1.576\ kW}$$