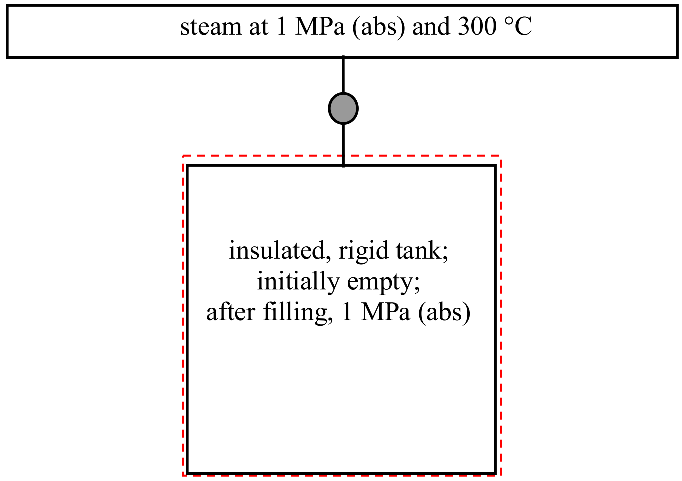
A rigid, insulated tank that is initially evacuated is connected through a valve to a supply line that carries steam at 1 MPa (abs) and 300 °C. The valve is opened and steam is allowed to flow slowly into the tank until the pressure reaches 1 MPa (abs) at which point the valve is closed. Determine the final temperature of the steam in the tank.



SOLUTION:

Apply the First Law (not as a rate equation but as a total change relation) to a CV surrounding the tank. Assume uniform and steady inlet properties.

$$\Delta E_{\text{CV}} + m_{\text{out}}\left(h + \tfrac{1}{2}V^2 + gz\right)_{\text{out}} - m_{\text{in}}\left(h + \tfrac{1}{2}V^2 + gz\right)_{\text{in}} = Q_{\substack{\text{added}\\ \text{to CV}}} + W_{\text{on CV}}$$

where E_{CV} is the total energy in the CV, m_{out} is the total mass of fluid that has left the CV (it's zero here since the tank has no outlets), and m_{in} is the total mass that has entered the CV. The heat added to the CV will be zero since the tank is insulated, and no other work is done on the CV besides pressure work (already included in the enthalpy terms).

The change in total energy of the CV is:

$$\Delta E_{\text{CV}} = m_{\text{in}} u_{\text{CV,f}}$$

where $u_{\text{CV,f}}$ is the final specific internal energy of the fluid within the CV. Note that since the tank is initially evacuated, the initial internal energy is zero. In addition, the kinetic and potential energies of the fluid contained within the tank will be negligible after filling.

The kinetic energy of the fluid entering the CV is also negligible since the tank fills slowly, and the potential energy contribution of the incoming stream is reasonably assumed to be negligible (changes in potential energy are typically significant for gases/vapor only for very large changes in elevation).

Simplifying the First Law relation gives:

$$m_{\text{in}} u_{\text{CV,f}} = m_{\text{in}} h_{\text{in}}$$

$$\boxed{\therefore u_{\text{CV,f}} = h_{\text{in}}}$$

For 300 °C steam at 1 MPa:

h = 3051.2 kJ/kg (steam tables from Moran and Shapiro)

$\Rightarrow u_{\text{CV,f}}$ = 3051.2 kJ/kg

At 1 MPa, $u_{\text{CV,f}}$ = 3051.2 kJ/kg corresponds to a temperature of $\boxed{T_{\text{CV,f}} = 456.2\ °\text{C}}$.