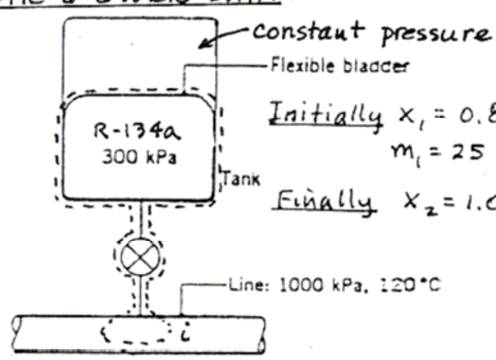
PROBLEM 4.118

KNOWN: A well-insulated tank containing R-134a is connected to a supply line. As refrigerant is allowed to flow into the tank, a flexible bladder in the tank expands to maintain the refrigerant in the tank at constant pressure.

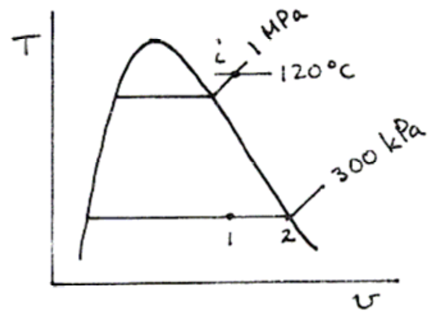
FIND: Determine the amount of mass admitted to the tank between the initial time and the instant when all the liquid in the tank is vaporized.

SCHEMATIC & GIVEN DATA:



Initially $x_1 = 0.8$
$m_1 = 25$ kg

Finally $x_2 = 1.0$



ENGR. MODEL: (1) The control volume is shown with $\dot{Q}_{cv} = 0$. (2) Conditions in the supply line remain constant. (3) The pressure remains constant in the tank. (4) Kinetic and potential energy effects are negligible.

ANALYSIS: The mass rate balance takes the form; $dm_{cv}/dt = \dot{m}_i$. With the assumptions listed, the energy rate balance is

$$\frac{dU_{cv}}{dt} = \cancel{\dot{Q}_{cv}}^{\,0} - \dot{W}_{cv} + \dot{m}_i h_i$$

The specific enthalpy h_i is constant by assumption (2). Thus, combining the mass and energy rate balances and integrating

$$\Delta U_{cv} = -W_{cv} + \int_{t_1}^{t_2} \dot{m}_i h_i \, dt$$

Since h_i is constant

$$\Delta U_{cv} = -W_{cv} + h_i \int_{t_1}^{t_2} \dot{m}_i \, dt = -W_{cv} + h_i (m_2 - m_1) \quad (1)$$

To evaluate the work, note that the pressure in the tank is constant. Thus

$$W_{cv} = \int p \, dV = p(V_2 - V_1) = p(m_2 v_2 - m_1 v_1) \quad (2)$$

Combining (1) and (2), and noting that $\Delta U_{cv} = m_2 u_2 - m_1 u_1$

$$m_2 u_2 - m_1 u_1 = -p(m_2 v_2 - m_1 v_1) + h_i (m_2 - m_1)$$

or

$$m_2 [(u_2 + p v_2) - h_i] = m_1 [(u_1 + p v_1) - h_i]$$

$$m_2 [h_2 - h_i] = m_1 [h_1 - h_i]$$

Continued on next slide

Problem 4-118 continued

Solving for m_2

$$m_2 = m_1\left(\frac{h_1 - h_i}{h_2 - h_i}\right)$$

Using data from Table A-11 at 3 bar: $h_f = 50.85$, $h_g = 247.59$ kJ/kg

$$h_1 = (50.85) + (0.8)[247.59 - 50.85] = 208.24 \text{ kJ/kg}$$
$$h_2 = 247.59 \text{ kJ/kg}$$

From Table A-12, $h_i = 356.52$ kJ/kg. Thus

$$m_2 = 25\text{ kg}\left(\frac{208.24 - 356.52}{247.59 - 356.52}\right) = 34.03 \text{ kg}$$

Finally,

$$\Delta m = m_2 - m_1$$
$$= 34.03 - 25 = 9.03 \text{ kg}$$