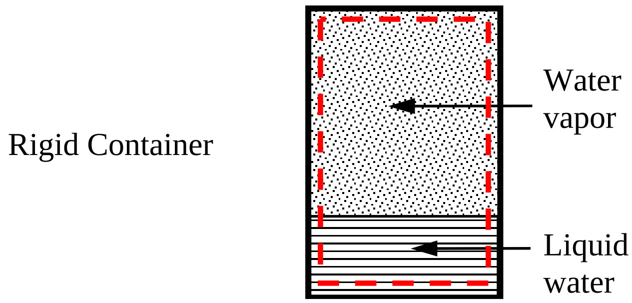
A 1.0 m^3 rigid container contains saturated mixture of water at 3000 kPa. 95% (by volume) of the container is occupied by saturated vapor and remaining 5% (by volume) is saturated liquid water. **Calculate the quality of the mixture**.



Solution:

From **TABLE A5** at 3000 kPa

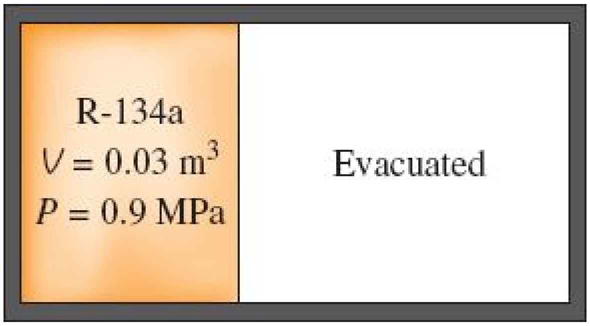
$$\upsilon_f = 0.001217\ m^3/kg$$

$$\upsilon_g = 0.066667\ m^3/kg$$

Quality of the mixture:

$$x = \frac{m_g}{m_f + m_g} = \frac{\dfrac{\forall_g}{\upsilon_g}}{\dfrac{\forall_f}{\upsilon_f} + \dfrac{\forall_g}{\upsilon_g}} = \frac{\dfrac{0.95\times\forall}{\upsilon_g}}{\dfrac{0.05\times\forall}{\upsilon_f} + \dfrac{0.95\times\forall}{\upsilon_g}} = \frac{\dfrac{0.95}{0.066667}}{\dfrac{0.05}{0.001217} + \dfrac{0.95}{0.066667}} = 0.26$$

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**.



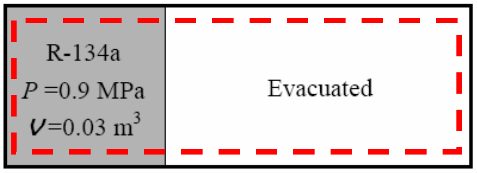
Solution

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),

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

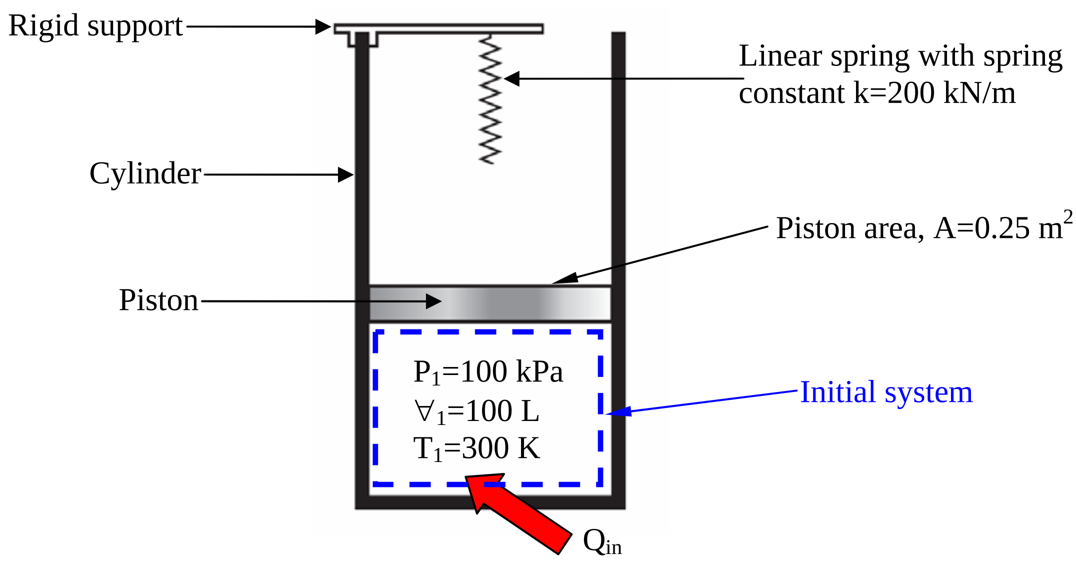
Thus,

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

A piston–cylinder device initially contains 100 L of Argon gas at 100 kPa and 300 K. Now heat is transferred to the gas causing the piston to rise until it touches the spring. The spring has a linear spring Constant of 200 kN/m. The volume inside the cylinder becomes 150 L when the piston just touches the spring. More heat is added to the cylinder so that the piston continues to rise and compresses the spring until the volume inside the cylinder becomes 200 L. The final temperature of the gas is recorded as 1560 K. The cross-sectional area of the piston is 0.25 m^2, determine

(a) **the final pressure (in kPa) inside the cylinder**, and
(b) **the total boundary work (in kJ) done by the piston**.

(Assume uncompressed spring force is zero)



Solution

Final pressure inside the cylinder:

Initial volume inside the cylinder: $\forall_1$ = 100 L = 0.1 m^3
Initial Pressure inside the cylinder: P_1 = 100 kPa

Volume inside the cylinder when piston just touches the spring: $\forall_2$ = 150 L = 0.15 m^3
Pressure inside the cylinder when piston just touches the spring: $P_2 = P_1$ = 100 kPa

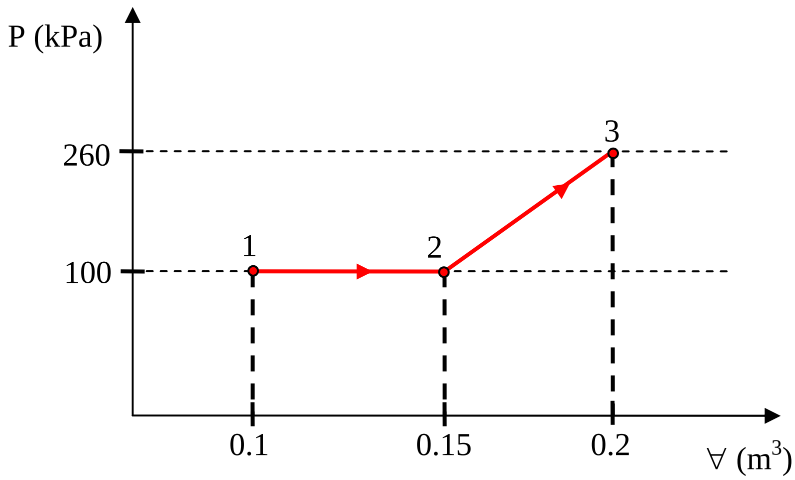
Final volume inside the cylinder: $\forall_3$ = 200 L= 0.2 m^3

Total displacement of the spring, $x = \dfrac{\forall_3 - \forall_2}{A} = \dfrac{(0.2 - 0.15)m^3}{0.25 m^2} = 0.2\ m$

Therefore, the final pressure, $P_3 = P_2 + \dfrac{kx}{A} = 100\,kPa + \dfrac{(200\ kN/m)\times(0.2\,m)}{0.25\ m^2} = 260\ kPa \Leftarrow Part(a)$

Boundary work:

Draw the P - ∀ (pressure – volume) diagram for the problem:

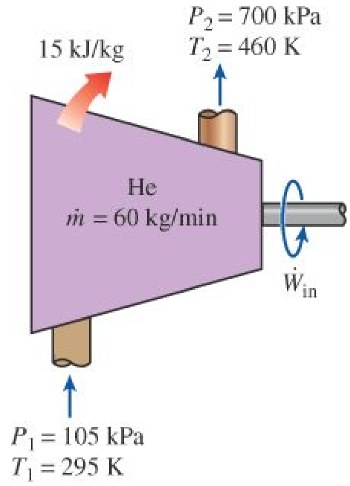


$$W_b = \int_1^3 P\, d\forall = \text{Area under the curve between 1 to 3 in P - } \forall \text{ diagram}$$

$$= (100\,kPa) \times (0.2 - 0.1)\, m^3 + \frac{1}{2} \times (260 - 100) kPa \times (0.2 - 0.15)\, m^3$$

$$= 14\, kJ \quad \Leftarrow \quad Part(b)$$

Helium is to be compressed from 105 kPa and 295 K to 700 kPa and 460 K. A heat loss of 15 kJ/kg occurs during the compression process. Neglecting kinetic energy changes, **determine the power input required for a mass flow rate of 60 kg/min**.

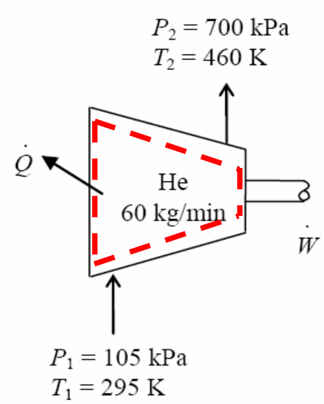


Solution:

Assumptions **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** Helium is an ideal gas with constant specific heats.

Properties The constant pressure specific heat of helium is $c_p = 5.1926$ kJ/kg·K (Table A-2a).

Analysis There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. We take the compressor as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as



$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\text{Rate of net energy transfer by heat, work, and mass}} = \underbrace{\Delta \dot{E}_{system}^{\nearrow 0 \text{ (steady)}}}_{\text{Rate of change in internal, kinetic, potential, etc. energies}} = 0$$

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{W}_{in} + \dot{m}h_1 = \dot{Q}_{out} + \dot{m}h_2 \quad (\text{since } \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

$$\dot{W}_{in} - \dot{Q}_{out} = \dot{m}(h_2 - h_1) = \dot{m}c_p(T_2 - T_1)$$

Thus,

$$\dot{W}_{in} = \dot{Q}_{out} + \dot{m}c_p(T_2 - T_1)$$
$$= (60/60 \text{ kg/s})(15 \text{ kJ/kg}) + (60/60 \text{ kg/s})(5.1926 \text{ kJ/kg}\cdot\text{K})(460 - 295)\text{K}$$
$$= \mathbf{872\,kW}$$