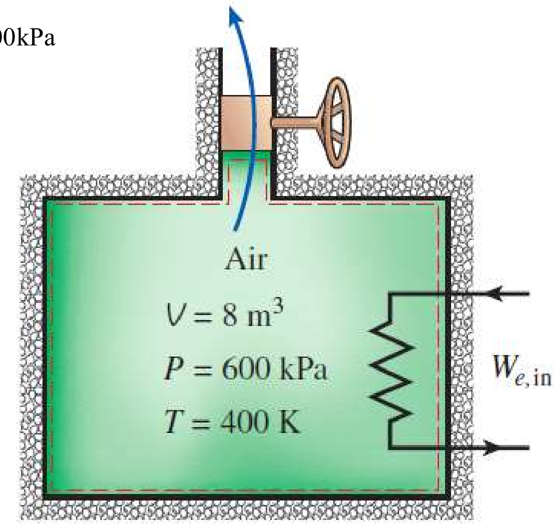
Given: $kJ := 1000J$

An insulated 8 m^3 rigid tank contains air at 600 kPa and 400 K. A valve connected to the tank is now opened, and air is allowed to escape until the pressure inside drops to 200 kPa. The air temperature during the process is maintained constant by an electric resistance heater placed in the tank.

$V := 8m^3 \quad P_1 := 600kPa \quad T := 400K \quad P_2 := 200kPa$



Required:

Determine the electrical energy supplied to the air during this process.

Solution:

Mass Conservation

$$\frac{d}{dt}m_{sys} = \Sigma m'_{in} - \Sigma m'_{out}$$

$$\frac{d}{dt}m_{sys} = -m'_{out}$$

1st Law (for adiabatic, rigid w/ no ΔKE and ΔPE)

$$\frac{d}{dt}E_{sys} = \Sigma E'_{in} - \Sigma E'_{out}$$

$$\frac{d}{dt}U_{sys} = W'_{elec,in} - m'_{out} \cdot h_{out}$$

Substituting mass conservation into the 1st law yields

$$\frac{d}{dt}U_{sys} = W'_{elec,in} + h_{out} \cdot \frac{d}{dt}m_{sys}$$

Integrating yields

$$\Delta U_{sys} = W_{elec,in} + h_{out} \cdot \Delta m_{sys}$$

$$m_2 \cdot u_2 - m_1 \cdot u_1 = W_{elect,in} + h_{out} \cdot (m_2 - m_1)$$

Solving for the electrical work done shows

$$W_{elect,in} = (m_2 \cdot u_2 - m_1 \cdot u_1) - h_{out} \cdot (m_2 - m_1)$$

Going to Table A-17 @ $T = 400K$ shows

$$h_{out} := 400.98 \frac{kJ}{kg} \qquad u_1 := 286.16 \frac{kJ}{kg} \qquad u_2 := 286.16 \frac{kJ}{kg}$$

Assuming the air behaves as an ideal gas, the initial and final masses may be found by

$$m = \frac{P \cdot V}{R \cdot T}$$

Going to Table A-1 @ air shows

$$R := 0.287 \frac{kJ}{kg \cdot K}$$

Solution (contd.):

The initial and final masses are then

$$m_1 := \frac{P_1 \cdot V}{R \cdot T} = 41.812\,\text{kg} \qquad m_2 := \frac{P_2 \cdot V}{R \cdot T} = 13.937\,\text{kg}$$

The electrical work done is then

$$\boxed{W_{elec,in} := \left(m_2 \cdot u_2 - m_1 \cdot u_1\right) - h_{out} \cdot \left(m_2 - m_1\right) = 3201 \cdot \text{kJ}}$$