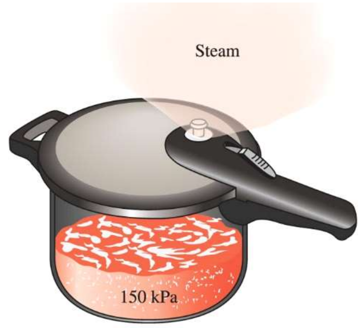
Given: $kJ := 1000J$

Steam is leaving a 4 L pressure cooker whose operating pressure is 150 kPa. It is observed that the amount of liquid in the cooker has decreased by 0.6 L in 40 minutes during the steady operating conditions. The cross-sectional area of the exit opening is 8 mm^2.

$$V_{tot} := 4L \qquad P := 150kPa \qquad \Delta V := 0.6L \qquad \Delta t := 40min \qquad A_e := 8mm^2$$

Required:



Pressure cooker

Determine

(a) the mass flow rate of the steam and the exit velocity,

(b) the flow and total energies of the steam (per unit mass), and

(c) the rate at which energy leaves the cooker by steam.

Solution:

There are a few different ways that the system may be drawn. The first is to include both the liquid and the steam. The second is to include just the liquid portion of the water. The third is to include just the steam portion of the water.

The volumetric flow rate of the liquid water (system 2) is given by

$$V' := \frac{\Delta V}{\Delta t} = 2.5 \times 10^{-7} \frac{m^3}{s}$$

The mass flow rate of the liquid water (system 2) is then given by

$$m'_L = \frac{V'}{\nu_f}$$

Going to Table A-5 @ $P = 150 \cdot kPa$ shows

$$\nu_f := 0.001053 \frac{m^3}{kg}$$

The mass flow rate of the liquid water (system 2) is then

$$m'_L := \frac{V'}{\nu_f} = 2.374 \times 10^{-4} \frac{kg}{s}$$

If the mass flow rate of the liquid water is leaving system 2, it must be entering system 3 (just the steam portion). Assuming system 3's control volume remains constant (i.e. Δm_{cv} for system 3 is approximately zero), then the mass entering system 3 must be mass leaving system 3. Thus, the mass flow rate leaving the cooker is

$$\boxed{m'_s := m'_L = 2.374 \times 10^{-4} \frac{kg}{s}} \text{ (a)}$$

The volumetric flow rate at the exit is given by

$$V'_e = m'_s \cdot \nu_g$$

Solution (cont.):

Going to Table A-5 @ $P = 150 \cdot kPa$ shows

$$\nu_g := 1.1594 \frac{m^3}{kg}$$

The volumetric flow rate at the exit is then

$$V'_e := m'_s \cdot \nu_g = 2.753 \times 10^{-4} \frac{m^3}{s}$$

The exit velocity is then given by

$$\boxed{V_e := \frac{V'_e}{A_e} = 34.41 \frac{m}{s}} \qquad \text{(a)}$$

The energy that the steam has is from two different sources, internal energy (i.e., it's temperature), and its flow. Using the definition of enthalpy, the flow energy may be identified as

$$h = u + P \cdot \nu$$

$$e_{flow} = P \cdot \nu = h - u$$

Since at the exit the flow is all steam, the flow energy is

$$e_{flow} = h_g - u_g$$

Going to Table A-5 @ $P = 150 \cdot kPa$ shows

$$u_g := 2519.2 \frac{kJ}{kg} \qquad h_g := 2693.1 \frac{kJ}{kg}$$

Thus the flow energy is

$$\boxed{e_{flow} := h_g - u_g = 173.9 \cdot \frac{kJ}{kg}} \qquad \text{(b)} \qquad P \cdot \nu_g = 173.9 \cdot \frac{kJ}{kg}$$

The total energy of the steam is simply

$$\boxed{e_{tot} := h_g + \frac{V_e^2}{2} = 2693.7 \cdot \frac{kJ}{kg}} \qquad \text{(b)}$$

The rate at which energy leaves the cooker by steam is given by

$$\boxed{E'_{out} := m'_s \cdot e_{tot} = 639.5\,W} \qquad \text{(c)}$$