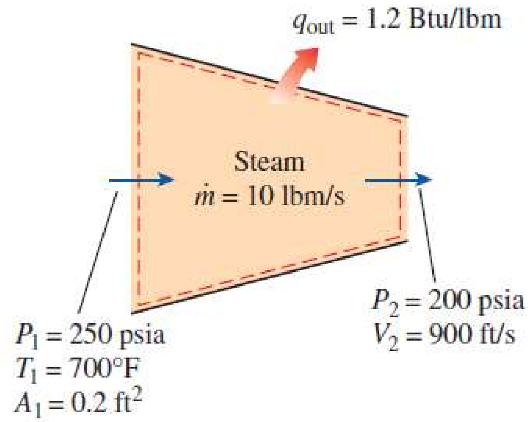
Given:

Steam at 250 psia and 700°F steadily enters a nozzle whose inlet area is $0.2\ \mathrm{ft}^2$. The mass flow rate of steam through the nozzle is 10 lbm/s. Steam leaves the nozzle at 200 psia with a velocity of 900 ft/s. Heat losses from the nozzle are estimated to be 1.2 Btu/lbm.

$P_1 := 250\ \mathrm{psi}$ $\quad T_1 := 700\ \mathrm{°F}$ $\quad A_1 := 0.2\ \mathrm{ft}^2$

$P_2 := 200\ \mathrm{psi}$ $\quad V_2 := 900\ \dfrac{\mathrm{ft}}{\mathrm{s}}$

$m' := 10\ \dfrac{\mathrm{lbm}}{\mathrm{s}}$ $\quad q_{out} := 1.2\ \dfrac{\mathrm{BTU}}{\mathrm{lbm}}$



Required:
Determine the inlet velocity and the exit temperature of the steam.

Solution:
Going to Table A-5E @ $P := P_1 = 250\ \mathrm{psi}$ shows

$$T_{sat} := 400.98\ \mathrm{°F}$$

Since $T_1 > T_{sat}$, state 1 is in the superheated region. Going to Table A-6E @ $P := P_1 = 250\ \mathrm{psi}$ and $T := T_1 = 700\ \mathrm{°F}$ shows

$$\nu_1 := 2.6883\ \frac{\mathrm{ft}^3}{\mathrm{lbm}} \qquad h_1 := 1371.4\ \frac{\mathrm{BTU}}{\mathrm{lbm}}$$

The density at the inlet condition is found by

$$\rho_1 := \frac{1}{\nu_1} = 5.959\ \frac{\mathrm{kg}}{\mathrm{m}^3}$$

The velocity at the inlet condition is found by

$$m' = \rho \cdot A \cdot V \qquad \text{rearranging} \qquad \boxed{V_1 := \frac{m'}{\rho_1 \cdot A_1} = 134.4\ \frac{\mathrm{ft}}{\mathrm{s}}}$$

<u>1st Law</u> in rate form for a nozzle with negligible changes in potential energy is

$$\frac{\mathrm{d}}{\mathrm{d}\,t} E_{sys} = \Sigma E'_{in} - \Sigma E'_{out}$$

$$0 = m'_{in} \cdot \left(h_{in} + \frac{V_{in}^2}{2} + g_e \cdot z_{in}\right) - m'_{out} \cdot \left(h_{out} + \frac{V_{out}^2}{2} + g_e \cdot z_{out}\right) - Q'_{out}$$

$$0 = m' \cdot \left(h_{in} + \frac{V_{in}^2}{2}\right) - m' \cdot \left(h_{out} + \frac{V_{out}^2}{2}\right) - m' \cdot q_{out}$$

$$h_{out} = h_{in} + \frac{V_{in}^2 - V_{out}^2}{2} - q_{out}$$

Thus the enthalpy at the exit is

$$h_2 := h_1 + \frac{V_1^2 - V_2^2}{2} - q_{out} = 1354\ \frac{\mathrm{BTU}}{\mathrm{lbm}}$$

Solution (cont.):
Going to Table A-5E @ $P := P_2 = 200\ \text{psi}$ shows

$$h_g := 1198.8\ \frac{\text{BTU}}{\text{lbm}}$$

Since $h_2 > h_g$, the outlet condition is in the superheated region. Going to Table A-6E @ $P := P_2 = 200\ \text{psi}$ and $h := h_2 = 1354\ \frac{\text{BTU}}{\text{lbm}}$ shows that interpolation is needed. This is done below.

$$h_a := 1322.3\ \frac{\text{BTU}}{\text{lbm}} \qquad h_b := 1374.1\ \frac{\text{BTU}}{\text{lbm}}$$

$$T_a := 600\ °\text{F} \qquad T_b := 700\ °\text{F}$$

$$\boxed{T_2 := \frac{h_2 - h_a}{h_b - h_a} \cdot \left(T_b - T_a\right) + T_a = 661.9\ °\text{F}} \qquad \boxed{T_2 = 1122\ °\text{Ra}}$$