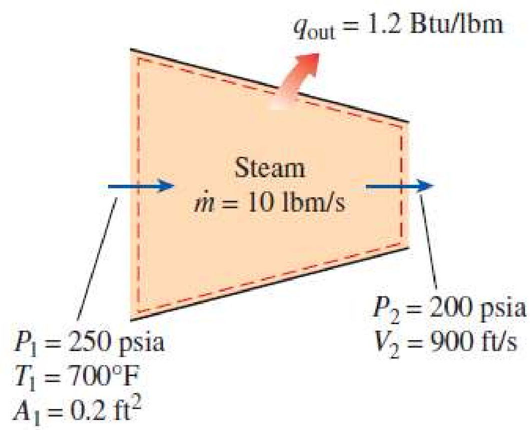
Given:

Steam at 250 psia and 700°F steadily enters a nozzle whose inlet area is 0.2 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.

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

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

$m' := 10\,\dfrac{\text{lbm}}{\text{s}}$ $\quad q_{out} := 1.2\,\dfrac{\text{Btu}}{\text{lbm}}$



Required:

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

Solution:

Going to Table A-5E @ $P_1 = 250\cdot\text{psi}$ shows

$$T_{sat} := 400.98\,°F$$

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

$$\nu_1 := 2.6883\,\frac{\text{ft}^3}{\text{lbm}} \qquad h_1 := 1371.4\,\frac{\text{Btu}}{\text{lbm}}$$

The density at the inlet condition is found by

$$\rho_1 := \frac{1}{\nu_1} = 0.372\cdot\frac{\text{lbm}}{\text{ft}^3}$$

The velocity at the inlet condition is found by

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

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

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

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

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

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

Solution (cont.):

Thus the enthalpy at the exit is

$$h_2 := h_1 + \frac{V_1^{\,2} - V_2^{\,2}}{2} - q_{out} = 1354.4 \cdot \frac{\mathrm{Btu}}{\mathrm{lbm}}$$

Going to Table A-5E @ $P_2 = 200 \cdot \mathrm{psi}$ shows

$$h_g := 1198.8 \frac{\mathrm{Btu}}{\mathrm{lbm}}$$

Since $h_2 > h_g$, the outlet condition is in the superheated region. Going to Table A-6E $P_2 = 200 \cdot \mathrm{psi}$ and $h_2 = 1354.4 \frac{\mathrm{Btu}}{\mathrm{lbm}}$ shows that interpolation is needed. This is done below.

$$h_a := 1322.3 \frac{\mathrm{Btu}}{\mathrm{lbm}} \qquad h_b := 1374.1 \frac{\mathrm{Btu}}{\mathrm{lbm}}$$

$$T_a := 600\ {}^\circ\mathrm{F} \qquad T_b := 700\ {}^\circ\mathrm{F}$$

$$\boxed{T_2 := \frac{h_2 - h_a}{h_b - h_a} \cdot \left(T_b - T_a\right) + T_a = 661.9 \cdot {}^\circ\mathrm{F}}$$