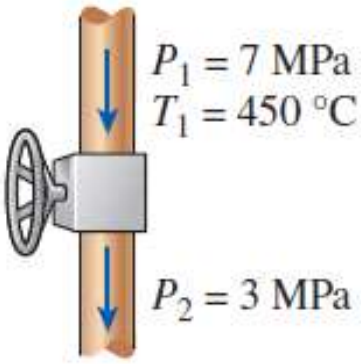
Given: $kJ := 1000J$

Steam at 7 MPa and 450°C is throttled in a valve to a pressure of 3 MPa during a steady-flow process.

$P_1 := 7MPa \qquad T_1 := 450\,°C \qquad P_2 := 3MPa$



Required:

Determine the entropy generated during this process and whether it satisfies the Second Law of Thermodynamics.

Solution:

Starting with an entropy balance for a steady flow device shows

$$\frac{d}{dt}S_{sys} = \Sigma S'_{in} - \Sigma S'_{out} + S'_{gen}$$

$$0 = \Sigma S'_{in} - \Sigma S'_{out} + S'_{gen}$$

$$S'_{gen} = \Sigma S'_{out} - \Sigma S'_{in} = m'\cdot\left(s_2 - s_1\right)$$

The entropy generation on a specific basis is found by

$$s_{gen} = \frac{S'_{gen}}{m'} = \frac{m'\cdot\left(s_2 - s_1\right)}{m'} = s_2 - s_1$$

Going to Table A-5 @ $P_1 = 7000\,kPa$ shows

$T_{sat} := 285.83\,°C$

Since $T_1 > T_{sat}$ the state is superheated. Going to Table A-6 @ $P_1 = 7\cdot MPa$ & $T_1 = 450\cdot °C$ shows

$$s_1 := 6.6353\,\frac{kJ}{kg\cdot K} \qquad h_1 := 3288.3\,\frac{kJ}{kg}$$

It's known for a throttling value the enthalpy remains constant so

$$h_2 := h_1 = 3288.3\,K\cdot\frac{kJ}{kg\cdot K}$$

Going to Table A-5 @ $P_2 = 3000\,kPa$ shows

$$h_g := 2803.2\,\frac{kJ}{kg}$$

Since $h_2 > h_g$ the state is superheated. Going to Table A-6 @ $P_2 = 3\cdot MPa$ & $h_2 = 3288.3\frac{kJ}{kg}$ shows that interpolation is needed.

$$h_a := 3231.7\,\frac{kJ}{kg} \qquad h_b := 3344.9\,\frac{kJ}{kg}$$

$$s_a := 6.9235\cdot\frac{kJ}{kg\cdot K} \qquad s_b := 7.0856\cdot\frac{kJ}{kg\cdot K}$$

$$s_2 := \frac{h_2 - h_a}{h_b - h_a}\cdot\left(s_b - s_a\right) + s_a = 7.005\cdot\frac{kJ}{kg\cdot K}$$

Solution (contd.):

The specific entropy generation is then

$$s_{gen} := s_2 - s_1 = 0.3693 \cdot \frac{kJ}{kg \cdot K}$$

The Second Law of Thermodynamics is satisfied because s_{gen} is not negative.

It should be noted that the increase in entropy is a result of unrestrained expansion.