Given:

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

$$P_1 := 7 \text{ MPa}$$
 $T_1 := 450 \text{ °C}$ $P_2 := 3 \text{ MPa}$

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

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

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

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

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 @ $P_1 = 7000 \text{ kPa}$ shows

$$T_{sat} := 285.83 \, ^{\circ}C$$

Since $T_1 > T_{sat}$ the state is superheated. Going to Table A-6 @ $P_1 = 7.000$ MPa and $T_1 = 450.0$ °C shows

$$s_1 := 6.6353 \frac{\text{kJ}}{\text{kg K}}$$
 $h_1 := 3288.3 \frac{\text{kJ}}{\text{kg}}$

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

$$h_2 := h_1 = 3288 \frac{\text{kJ}}{\text{kg}}$$

Going to Table A-5 @ $P_2 = 3000 \text{ kPa}$ shows

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

Since $h_2 > h_g$ the state is superheated. Going to Table A-6 @ $P_2 = 3.000$ MPa and $h_2 = 3288$ $\frac{\text{kJ}}{\text{kg}}$ shows that interpolation is needed.

$$\begin{aligned} h_a &:= 3231.7 \ \frac{\text{kJ}}{\text{kg}} & h_b &:= 3344.9 \ \frac{\text{kJ}}{\text{kg}} \\ s_a &:= 6.9235 \ \frac{\text{kJ}}{\text{kg K}} & s_b &:= 7.0856 \ \frac{\text{kJ}}{\text{kg K}} \\ s_2 &:= \frac{h_2 - h_a}{h_b - h_a} \cdot \left(s_b - s_a\right) + s_a = 7.005 \ \frac{\text{kJ}}{\text{kg K}} \end{aligned}$$

The specific entropy generation is then

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

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

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

