47.20 A refrigeration cycle using R-123 operates between $75 psia$ and $220 psia$ with no sub-cooling. During isenthalpic expansion, what is the change in entropy of the refrigerant?

A. $0.001 \frac{Btu}{lb \cdot {}^\circ F}$

B. $0.003 \frac{Btu}{lb \cdot {}^\circ F}$

C. $0.01 \frac{Btu}{lb \cdot {}^\circ F}$

D. $0.04 \frac{Btu}{lb \cdot {}^\circ F}$

Sketch the process line from State 3 to State 4 representing the expansion process within a typical refrigeration cycle. Use the table for Refrigerant 123 to obtain the enthalpy and entropy at State 3. Since there is no sub-cooling, the refrigerant is a saturated liquid at State 3.

$$P_3 = 220 psia$$

$$h_3 = h_f = 78.66 \frac{Btu}{lb}$$

$$s_3 = s_f = 0.138 \frac{Btu}{lb ^\circ R}$$

The expansion from $3 \rightarrow 4$ is isenthalpic, therefore the enthalpy at State 4 is the same as the enthalpy at State 3.

$$h_4 = h_3 = 78.66 \frac{Btu}{lb}$$

Since the expansion process line from $3 \rightarrow 4$ is vertically down on the Pressure-Enthalpy diagram, State 4 is observed to be a saturated mixture, as it is within the vapor dome. Use the Refrigerant 123 table again to obtain the enthalpy values h_f and h_{fg} at the lower pressure of State 4. Calculate the quality at State 4. Refer to Properties for Two-Phase (Vapor-Liquid) Systems for a reminder of the formulas involving quality.

$$P_4 = 75 psia$$

$$h_f = 53.58 \frac{Btu}{lb}$$

$$h_{fg} = 115.68 \frac{Btu}{lb}$$

$$h_4 = h_f + \chi_4 h_{fg}$$

$$\chi_4 = \frac{h_4 - h_f}{h_{fg}} = \frac{78.66 \frac{Btu}{lb} - 53.58 \frac{Btu}{lb}}{115.68 \frac{Btu}{lb}} = 0.404$$

Use the same line in the table to obtain the entropy values s_f and s_{fg}. Calculate the entropy at State 4 using the quality, χ_4.

$$s_f = 0.102 \frac{Btu}{lb^\circ R}$$

$$s_{fg} = 0.199 \frac{Btu}{lb^\circ R}$$

$$s_4 = s_f + \chi_4 s_{fg} = \left(0.102 \frac{Btu}{lb^\circ R}\right) + (0.404)\left(0.199 \frac{Btu}{lb^\circ R}\right) = 0.182 \frac{Btu}{lb^\circ R}$$

Finally, calculate the change in entropy during the expansion process.

$$\Delta s = s_4 - s_3 = 0.182 \frac{Btu}{lb^\circ R} - 0.138 \frac{Btu}{lb^\circ R} = 0.044 \frac{Btu}{lb^\circ R}$$

Answer D

47.21 A flash distilation vessel boils seawater to make potable water. The pressure in the vessel is held at $10\ in\ Hg$ vacuum. What temperasure does the seawater boil at?

A. $162^\circ F$

B. $192^\circ F$

C. $212^\circ F$

D. $228^\circ F$

Convert the pressure in the vessel to absolute terms of $psia$, using conversions from the Measurement Relationships table as needed. Recall that vacuum pressure reads negative on a gauge, but pressure is always positive in absolute terms.

$$P_g = (-10 in\,Hg)\left(\frac{1 psi}{2.036 in\,Hg}\right) = -4.91 psig$$

$$P_a = P_g + 14.7 psi = -4.91 psig + 14.7 psi = 9.8 psia$$

Use the Properties of Saturated Water and Steam table to look up the saturation temperature at $9.8 psia$. The saturation temperature is the boiling point of water at a given pressure. As a sense check, the boiling point should be *lower* than at standard conditions since there is less pressure holding the molecules from escaping.

$$T_{sat@9.8psia} \approx 192^\circ F$$

Ignore boiling point elevation; salinity accounts for only about $+1^\circ F$ and is outside the intended scope of the problem.

Answer B