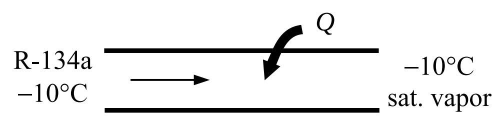
8-152 In an ice-making plant, water is frozen by evaporating saturated R-134a liquid. The rate of entropy generation is to be determined.

Assumptions **1** Steady operating conditions exist. **2** Kinetic and potential energy changes are negligible.

Analysis We take the control volume formed by the R-134a evaporator with a single inlet and single exit as the system. The rate of entropy generation within this evaporator during this process can be determined by applying the rate form of the entropy balance on the system. The entropy balance for this steady-flow system can be expressed as

$$\underbrace{\dot{S}_{in} - \dot{S}_{out}}_{\text{Rate of net entropy transfer by heat and mass}} + \underbrace{\dot{S}_{gen}}_{\text{Rate of entropy generation}} = \underbrace{\Delta \dot{S}_{system}}_{\text{Rate of change of entropy}}^{\nearrow 0 \text{ (steady)}}$$

$$\dot{m}_1 s_1 - \dot{m}_2 s_2 + \frac{\dot{Q}_{in}}{T_w} + \dot{S}_{gen} = 0$$



$$\dot{S}_{gen} = \dot{m}_R (s_2 - s_1) - \frac{\dot{Q}_{in}}{T_w}$$

$$\dot{S}_{gen} = \dot{m}_R s_{fg} - \frac{\dot{Q}_{in}}{T_w}$$

The properties of the refrigerant are (Table A-11)

$$h_{fg\,@\,-10°C} = 205.96 \text{ kJ/kg}$$
$$s_{fg\,@\,-10°C} = 0.78263 \text{ kJ/kg} \cdot \text{K}$$

The rate of that must be removed from the water in order to freeze it at a rate of 4000 kg/h is

$$\dot{Q}_{in} = \dot{m}_w h_{if} = (4000/3600 \text{ kg/s})(333.7 \text{ kJ/kg}) = 370.8 \text{ kW}$$

where the heat of fusion of water at 1 atm is 333.7 kJ/kg. The mass flow rate of R-134a is

$$\dot{m}_R = \frac{\dot{Q}_{in}}{h_{fg}} = \frac{370.8 \text{ kJ/s}}{205.96 \text{ kJ/kg}} = 1.800 \text{ kg/s}$$

Substituting,

$$\dot{S}_{gen} = \dot{m}_R s_{fg} - \frac{\dot{Q}_{in}}{T_w} = (1.800 \text{ kg/s})(0.78263 \text{ kJ/kg} \cdot \text{K}) - \frac{370.8 \text{ kW}}{273 \text{ K}} = \mathbf{0.0505\ kW/K}$$