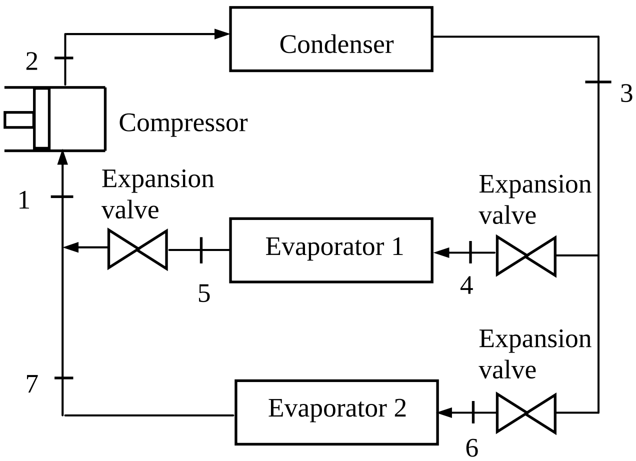
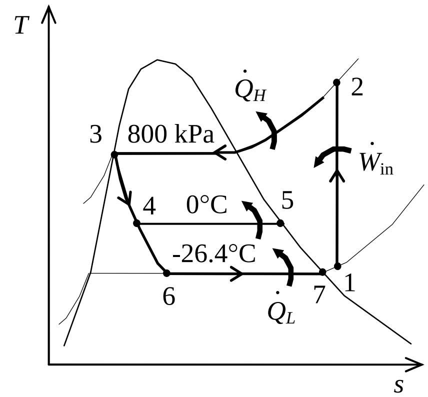
11-61 A two-evaporator compression refrigeration cycle with refrigerant-134a as the working fluid is considered. The cooling rate of the high-temperature evaporator, the power required by the compressor, and the COP of the system are to be determined.

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





Analysis From the refrigerant tables (Tables A-11, A-12, and A-13),

$$\left.\begin{array}{l} P_3 = 800 \text{ kPa} \\ \text{sat. liquid} \end{array}\right\} h_3 = h_{f\,@\,800\text{ kPa}} = 95.47 \text{ kJ/kg}$$

$$h_4 = h_6 \cong h_3 = 95.47 \text{ kJ/kg} \quad \text{(throttling)}$$

$$\left.\begin{array}{l} T_5 = 0°\text{C} \\ \text{sat. vapor} \end{array}\right\} h_5 = h_{g\,@\,0°\text{C}} = 250.45 \text{ kJ/kg}$$

$$\left.\begin{array}{l} T_7 = -26.4°\text{C} \\ \text{sat. vapor} \end{array}\right\} h_7 = h_{g\,@\,-26.4°\text{C}} = 234.44 \text{ kJ/kg}$$

The mass flow rate through the low-temperature evaporator is found by

$$\dot{Q}_L = \dot{m}_2(h_7 - h_6) \longrightarrow \dot{m}_2 = \frac{\dot{Q}_L}{h_7 - h_6} = \frac{8 \text{ kJ/s}}{(234.44 - 95.47) \text{ kJ/kg}} = 0.05757 \text{ kg/s}$$

The mass flow rate through the warmer evaporator is then

$$\dot{m}_1 = \dot{m} - \dot{m}_2 = 0.1 - 0.05757 = 0.04243 \text{ kg/s}$$

Applying an energy balance to the point in the system where the two evaporator streams are recombined gives

$$\dot{m}_1 h_5 + \dot{m}_2 h_7 = \dot{m} h_1 \longrightarrow h_1 = \frac{\dot{m}_1 h_5 + \dot{m}_2 h_7}{\dot{m}} = \frac{(0.04243)(250.45) + (0.05757)(234.44)}{0.1} = 241.23 \text{ kJ/kg}$$

Then,

$$\left.\begin{array}{l} P_1 = P_{\text{sat}\,@\,-26.4°\text{C}} \cong 100 \text{ kPa} \\ h_1 = 241.23 \text{ kJ/kg} \end{array}\right\} s_1 = 0.9789 \text{ kJ/kg} \cdot \text{K}$$

$$\left.\begin{array}{l} P_2 = 800 \text{ kPa} \\ s_2 = s_1 \end{array}\right\} h_2 = 286.26 \text{ kJ/kg}$$

The cooling rate of the high-temperature evaporator is

$$\dot{Q}_L = \dot{m}_1(h_5 - h_4) = (0.04243 \text{ kg/s})(250.45 - 95.47) \text{ kJ/kg} = \mathbf{6.58 \text{ kW}}$$

The power input to the compressor is

$$\dot{W}_{in} = \dot{m}(h_2 - h_1) = (0.1 \text{ kg/s})(286.26 - 241.23) \text{ kJ/kg} = \mathbf{4.50 \text{ kW}}$$

The COP of this refrigeration system is determined from its definition,

$$\text{COP}_\text{R} = \frac{\dot{Q}_L}{\dot{W}_{in}} = \frac{(8 + 6.58) \text{ kW}}{4.50 \text{ kW}} = \mathbf{3.24}$$