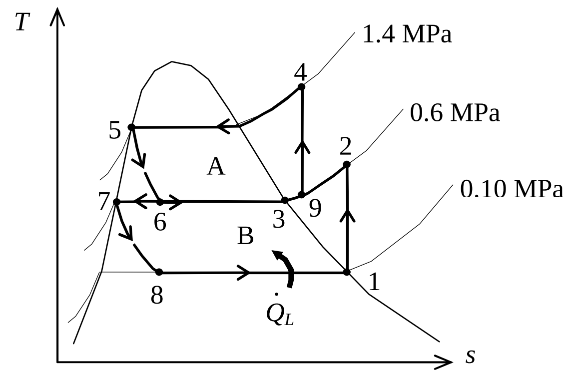
11-58 A two-stage compression refrigeration system with refrigerant-134a as the working fluid is considered. The fraction of the refrigerant that evaporates as it is throttled to the flash chamber, the rate of heat removed from the refrigerated space, and the COP are to be determined.

Assumptions **1** Steady operating conditions exist. **2** Kinetic and potential energy changes are negligible. **3** The flash chamber is adiabatic.

Analysis (*a*) The enthalpies of the refrigerant at several states are determined from the refrigerant tables (Tables A-11, A-12, and A-13) to be

$$h_1 = 234.44 \text{ kJ/kg}, \quad h_2 = 271.40 \text{ kJ/kg}$$
$$h_3 = 262.40 \text{ kJ/kg},$$
$$h_5 = 127.22 \text{ kJ/kg}, \quad h_6 = 127.22 \text{ kJ/kg}$$
$$h_7 = 81.51 \text{ kJ/kg}, \quad h_8 = 81.51 \text{ kJ/kg}$$



The fraction of the refrigerant that evaporates as it is throttled to the flash chamber is simply the quality at state 6,

$$x_6 = \frac{h_6 - h_f}{h_{fg}} = \frac{127.22 - 81.51}{180.90} = \mathbf{0.2527}$$

(*b*) The enthalpy at state 9 is determined from an energy balance on the mixing chamber:

$$\dot{E}_{\text{in}} - \dot{E}_{\text{out}} = \Delta\dot{E}_{\text{system}}^{\nearrow 0 \text{ (steady)}} = 0$$
$$\dot{E}_{\text{in}} = \dot{E}_{\text{out}}$$
$$\sum \dot{m}_e h_e = \sum \dot{m}_i h_i$$
$$(1)h_9 = x_6 h_3 + (1 - x_6)h_2$$
$$h_9 = (0.2527)(262.40) + (1 - 0.2527)(271.40) = 269.13 \text{ kJ/kg}$$

$$\left.\begin{array}{l} P_9 = 0.6 \text{ MPa} \\ h_9 = 269.13 \text{ kJ/kg} \end{array}\right\} s_9 = 0.9443 \text{ kJ/kg} \cdot \text{K}$$

also,

$$\left.\begin{array}{l} P_4 = 1.4 \text{ MPa} \\ s_4 = s_9 = 0.9443 \text{ kJ/kg} \cdot \text{K} \end{array}\right\} h_4 = 287.28 \text{ kJ/kg}$$

Then the rate of heat removed from the refrigerated space and the compressor work input per unit mass of refrigerant flowing through the condenser are

$$\dot{m}_B = (1 - x_6)\dot{m}_A = (1 - 0.2527)(0.25 \text{ kg/s}) = 0.1868 \text{ kg/s}$$

$$\dot{Q}_L = \dot{m}_B(h_1 - h_8) = (0.1868 \text{ kg/s})(234.44 - 81.51) \text{ kJ/kg} = \mathbf{28.57 \text{ kW}}$$

$$\begin{aligned} \dot{W}_{\text{in}} &= \dot{W}_{\text{compI,in}} + \dot{W}_{\text{compII,in}} = \dot{m}_A(h_4 - h_9) + \dot{m}_B(h_2 - h_1) \\ &= (0.25 \text{ kg/s})(287.28 - 269.13) \text{ kJ/kg} + (0.1868 \text{ kg/s})(271.40 - 234.44) \text{ kJ/kg} \\ &= 11.44 \text{ kW} \end{aligned}$$

(*c*) The coefficient of performance is determined from

$$\text{COP}_\text{R} = \frac{\dot{Q}_L}{\dot{W}_{\text{net,in}}} = \frac{28.57 \text{ kW}}{11.44 \text{ kW}} = \mathbf{2.50}$$

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