11-20 A commercial refrigerator with refrigerant-134a as the working fluid is considered. The quality of the refrigerant at the evaporator inlet, the refrigeration load, the COP of the refrigerator, and the theoretical maximum refrigeration load for the same power input to the compressor are to be determined.

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

Analysis (*a*) From refrigerant-134a tables (Tables A-11 through A-13)

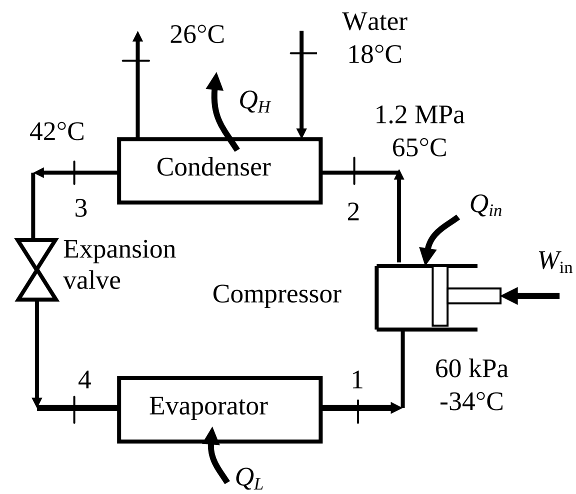
$$\left.\begin{array}{l} P_1 = 60\text{ kPa} \\ T_1 = -34°\text{C} \end{array}\right\} h_1 = 230.03\text{ kJ/kg}$$

$$\left.\begin{array}{l} P_2 = 1200\text{ kPa} \\ T_2 = 65°\text{C} \end{array}\right\} h_2 = 295.16\text{ kJ/kg}$$

$$\left.\begin{array}{l} P_3 = 1200\text{ kPa} \\ T_3 = 42°\text{C} \end{array}\right\} h_3 = 111.23\text{ kJ/kg}$$

$$h_4 = h_3 = 111.23\text{ kJ/kg}$$

$$\left.\begin{array}{l} P_4 = 60\text{ kPa} \\ h_4 = 111.23\text{ kJ/kg} \end{array}\right\} x_4 = \mathbf{0.4795}$$



Using saturated liquid enthalpy at the given temperature, for water we have (Table A-4)

$$h_{w1} = h_{f@18°\text{C}} = 75.47\text{ kJ/kg}$$

$$h_{w2} = h_{f@26°\text{C}} = 108.94\text{ kJ/kg}$$

(*b*) The mass flow rate of the refrigerant may be determined from an energy balance on the compressor

$$\dot{m}_R(h_2 - h_3) = \dot{m}_w(h_{w2} - h_{w1})$$

$$\dot{m}_R(295.16 - 111.23)\text{kJ/kg} = (0.25\text{ kg/s})(108.94 - 75.47)\text{kJ/kg}$$

$$\longrightarrow \dot{m}_R = 0.0455\text{ kg/s}$$

The waste heat transferred from the refrigerant, the compressor power input, and the refrigeration load are

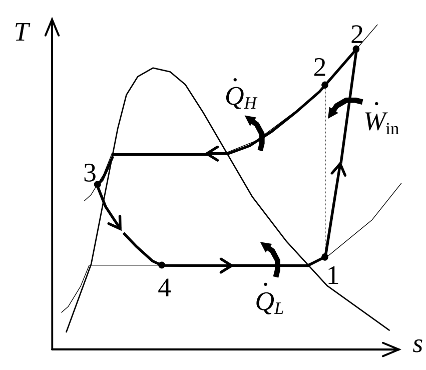
$$\dot{Q}_H = \dot{m}_R(h_2 - h_3) = (0.0455\text{ kg/s})(295.16 - 111.23)\text{kJ/kg} = 8.367\text{ kW}$$

$$\dot{W}_{\text{in}} = \dot{m}_R(h_2 - h_1) - \dot{Q}_{\text{in}} = (0.0455\text{ kg/s})(295.16 - 230.03)\text{kJ/kg} - 0.450\text{ kW} = 2.513\text{ kW}$$

$$\dot{Q}_L = \dot{Q}_H - \dot{W}_{\text{in}} - \dot{Q}_{\text{in}} = 8.367 - 2.513 - 0.450 = \mathbf{5.404\text{ kW}}$$

(*c*) The COP of the refrigerator is determined from its definition

$$\text{COP} = \frac{\dot{Q}_L}{\dot{W}_{\text{in}}} = \frac{5.404}{2.513} = \mathbf{2.15}$$



(*d*) The reversible COP of the refrigerator for the same temperature limits is

$$\text{COP}_{\max} = \frac{1}{T_H / T_L - 1} = \frac{1}{(18 + 273)/(-30 + 273) - 1} = 5.063$$

Then, the maximum refrigeration load becomes

$$\dot{Q}_{\text{L,max}} = COP_{\max}\dot{W}_{\text{in}} = (5.063)(2.513\text{ kW}) = \mathbf{12.72\text{ kW}}$$