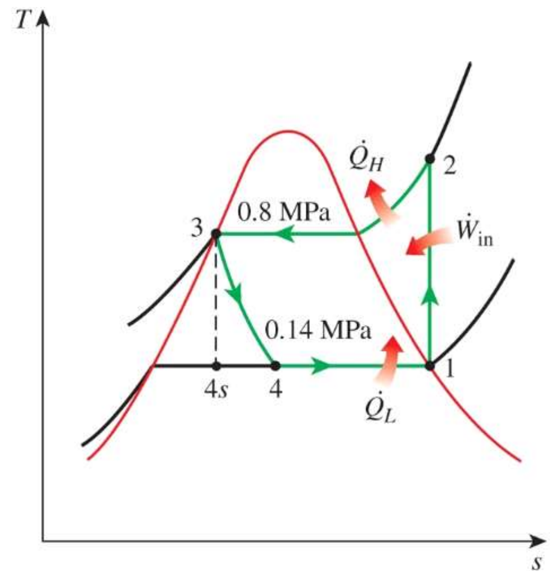
Given: $kJ := 1000J$

A refrigerator uses R-134a as the working fluid and operates on an ideal vapor-compression refrigeration cycle between 0.14 and 0.8 MPa.

$P_L := 0.14MPa \quad P_H := 0.8MPa$



Required:

If the mass flow rate of the refrigerant is 0.05 kg/s, determine the rate of heat removal from the refrigerated space and the power input to the compressor, the rate of heat rejection to the environment, and the COP of the refrigerator.

Solution:

The mass flow rate is defined as

$$m' := 0.05 \frac{kg}{s}$$

Going to Table A-12 @ $P_L = 140 \cdot kPa$ & $x_1 := 1$ shows

$$h_1 := 239.16 \frac{kJ}{kg} \qquad s_1 := 0.94456 \frac{kJ}{kg \cdot K}$$

Going to Table A-12 @ $P_H = 800 \cdot kPa$ & $s_2 := s_1 = 0.94456 \frac{kJ}{kg \cdot K}$ shows that the state is superheated.

Going to Table A-13 @ $P_H = 0.8 \cdot MPa$ & $s_2 = 0.94456 \frac{kJ}{kg \cdot K}$ shows that interpolation is needed.

$$s_a := 0.9480 \frac{kJ}{kg \cdot K} \qquad s_b := 0.9802 \frac{kJ}{kg \cdot K}$$

$$h_a := 276.45 \frac{kJ}{kg} \qquad h_b := 286.69 \frac{kJ}{kg}$$

$$h_2 := \frac{s_2 - s_a}{s_b - s_a} \cdot \left(h_b - h_a\right) + h_a = 275.356 \cdot \frac{kJ}{kg}$$

Going to Table A-12 @ $P_H = 800 \cdot kPa$ & $x_3 := 0$ shows

$$h_3 := 95.47 \frac{kJ}{kg} \qquad s_3 := 0.35404 \frac{kJ}{kg \cdot K}$$

Since the process from state 3 to state 4 is a throttling valve, the enthalpy remains constant.

$$h_4 := h_3 = 95.47 \cdot \frac{kJ}{kg}$$

The heat removed by the refrigerator is then found by

$$\boxed{Q'_L := m' \cdot \left(h_1 - h_4\right) = 7.184 \cdot kW}$$

Solution (contd.):

The power input to the compressor is then found by

$$\boxed{W'_{in} := m' \cdot \left(h_2 - h_1\right) = 1.81 \cdot kW}$$

The rate of heat rejection is then found by

$$\boxed{Q'_H := m' \cdot \left(h_2 - h_3\right) = 8.994 \cdot kW}$$

Alternatively, the rate of heat rejection could be found by

$$Q'_H := Q'_L + W'_{in} = 8.994 \cdot kW$$

The COP of the refrigerator is then found by

$$\boxed{COP_R := \frac{Q'_L}{W'_{in}} = 3.97}$$

If an isentropic turbine was used instead of a throttling value, state 4s could be found by

$$s_{4s} := s_3 = 0.354 \cdot \frac{kJ}{kg \cdot K}$$

Going to Table A-12 @ $P_L = 140 \cdot kPa$ & $s_{4s} = 0.354 \cdot \frac{kJ}{kg \cdot K}$ shows

$$s_f := 0.11087 \frac{kJ}{kg \cdot K} \qquad s_g := 0.94456 \frac{kJ}{kg \cdot K} \qquad h_f := 27.08 \frac{kJ}{kg} \qquad h_g := 239.16 \frac{kJ}{kg}$$

$$x_{4s} := \frac{s_{4s} - s_f}{s_g - s_f} = 0.292$$

$$h_{4s} := h_f + x_{4s} \cdot \left(h_g - h_f\right) = 88.939 \cdot \frac{kJ}{kg}$$

The work produced by the turbine is then found by

$$W'_{out} := m' \cdot \left(h_3 - h_{4s}\right) = 0.327 \cdot kW$$

The heat removed by the cycle is then given by

$$Q'_L := m' \cdot \left(h_1 - h_{4s}\right) = 7.511 \cdot kW$$

The COP of the cycle is then given by

$$COP_R = \frac{Q'_L}{W'_{net}} = \frac{Q'_L}{W'_{in} - W'_{out}}$$

or

$$COP_R := \frac{Q'_L}{W'_{in} - W'_{out}} = 5.064$$