

Given:

R-134a enters the condenser of a residential heat pump at 800 kPa and 35°C at a rate of 0.018 kg/s and leaves at 800 kPa as a saturated liquid.

Required:

If the compressor consumes 1.2 kW of power, determine the COP of the heat pump and the rate of heat absorption from the outside air.

Solution:

The inlet conditions, flow rate, and outlet conditions of the R-134a are defined as

$$P_1 := 800 \text{ kPa} \quad T_1 := 35 \text{ }^{\circ}\text{C} \quad \dot{m}' := 0.018 \frac{\text{kg}}{\text{s}} \quad P_2 := 800 \text{ kPa} \quad x_2 := 0$$

The net work required of the compressor is defined as

$$\dot{W}'_{net,in} := 1.2 \text{ kW}$$

1st Law for just the condenser (assuming steady state, rigid, and no ΔKE and ΔPE)

$$\frac{d}{dt} E_{sys} = \Sigma \dot{E}'_{in} - \Sigma \dot{E}'_{out}$$

$$0 = \dot{m}' \cdot h_1 - \dot{m}' \cdot h_2 - \dot{Q}'_H$$

Solving for the heat rejected by the condenser yields

$$\dot{Q}'_H = \dot{m}' \cdot (h_1 - h_2)$$

Going to Table A-11 @ $T_1 = 35 \text{ }^{\circ}\text{C}$ & $P_1 = 800 \text{ kPa}$ shows that the state is super heated.

Going to Table A-13 @ $T_1 = 35 \text{ }^{\circ}\text{C}$ & $P_1 = 800 \text{ kPa}$ shows that interpolation is needed.

$$T_a := 31.31 \text{ }^{\circ}\text{C} \quad T_b := 40 \text{ }^{\circ}\text{C} \quad h_a := 267.29 \frac{\text{kJ}}{\text{kg}} \quad h_b := 276.45 \frac{\text{kJ}}{\text{kg}}$$

$$h_1 := \frac{T_1 - T_a}{T_b - T_a} \cdot (h_b - h_a) + h_a = 271.2 \frac{\text{kJ}}{\text{kg}}$$

Going to Table A-12 @ $P_1 = 800 \text{ kPa}$ & $x_2 = 0$ shows

$$h_2 := 95.47 \frac{\text{kJ}}{\text{kg}}$$

The heat rejected by the condenser is then

$$\dot{Q}'_H := \dot{m}' \cdot (h_1 - h_2) = 3163 \text{ W}$$

The COP of the heat pump is then given by

$$\text{COP}_{HP} := \frac{\dot{Q}'_H}{\dot{W}'_{net,in}} = 2.636$$

The heat rejected by the heat pump is then given by

$$\dot{Q}'_L := \dot{Q}'_H - \dot{W}'_{net,in} = 1.963 \text{ kW}$$