Given:

R-134a is to be cooled by water in a condenser. R-134a enters the condenser with a mass flow rate of 6 kg/min at 1 MPa and 70°C and leaves at 35°C. The cooling water enters at 300 kPa and 15°C and leaves at 25°C.

$$m'_R := 6 \, \frac{kg}{min} \qquad P_{R,in} := 1 \text{ MPa} \qquad T_{R,in} := 70 \text{ °C} \qquad T_{R,out} := 35 \text{ °C}$$

$$P_{w,in} := 300 \text{ kPa} \qquad T_{w,in} := 15 \text{ °C} \qquad T_{w,out} := 25 \text{ °C}$$

Required:

Assuming the pressure drop is negligible, determine the mass flow rate of the cooling water and the rate of heat transfer from R-134a to the water.

Solution:

1st Law (for adiabatic, rigid, stead flow device with no changes in kinetic and potential energy)

$$\frac{d}{dt} E_{sys} = \Sigma E'_{in} - \Sigma E'_{out}$$ **Note:** The system encompasses the entire condenser.

$$0 = \Sigma E'_{in} - \Sigma E'_{out}$$

$$0 = m'_w \cdot h_{w,in} + m'_R \cdot h_{R,in} - m'_w \cdot h_{w,out} - m'_R \cdot h_{R,out}$$

Solving for m'_w yields

$$m'_w = m'_R \cdot \frac{h_{R,out} - h_{R,in}}{h_{w,in} - h_{w,out}}$$

Going to Table A-4 @ $T := T_{w,in} = 15 \text{ °C}$ and $P := P_{w,in} = 300 \text{ kPa}$ shows that the state is a compressed liquid. However, the compress liquid table (A-7) does not have the necessary pressure values so the state will be approximated by the saturated liquid value of Table A-4. This is shown below.

$$h_{w,in} := 62.982 \, \frac{kJ}{kg}$$

Going to Table A-4 @ $T := T_{w,out} = 25 \text{ °C}$ and $P := P_{w,in} = 300 \text{ kPa}$ shows that the state is a compressed liquid. However, the compress liquid table (A-7) does not have the necessary pressure values so the state will be approximated by the saturated liquid value of Table A-4. This is shown below.

$$h_{w,out} := 104.83 \, \frac{kJ}{kg}$$

Going to Table A-11 @ $T := T_{R,in} = 70 \text{ °C}$ and $P := P_{R,in} = 1 \text{ MPa}$ shows that the state is superheated.

Going to Table A-13 @ $T := T_{R,in} = 70 \text{ °C}$ and $P := P_{R,in} = 1 \text{ MPa}$ shows

$$h_{R,in} := 303.87 \, \frac{kJ}{kg}$$

Going to Table A-11 @ $T := T_{R,out} = 35 \text{ °C}$ and $P := P_{R,in} = 1 \text{ MPa}$ shows that the state is a compressed liquid. However, there are no compressed liquid tables for R-134a so the state will be approximated by the saturated liquid value of Table A-11. Interpolation must be performed. This is shown below.

$$T_a := 34 \text{ °C} \qquad\qquad T_b := 36 \text{ °C}$$

$$h_a := 99.41 \, \frac{kJ}{kg} \qquad h_b := 102.34 \, \frac{kJ}{kg}$$

$$h_{R,out} := \frac{T_{R,out} - T_a}{T_b - T_a} \cdot \left(h_b - h_a \right) + h_a = 100.9 \, \frac{kJ}{kg}$$

Solution (cont.):

The mass flow rate of the water is then given by

$$m'_w := m'_R \cdot \frac{h_{R,out} - h_{R,in}}{h_{w,in} - h_{w,out}} = 0.4851 \; \frac{kg}{s}$$

$$m'_w = 29.10 \; \frac{kg}{min}$$

The rate of heat transfer from the R-134a to the water may be found by redefining the system boundary to include just the water. This is done below.

<u>1st Law</u> (for rigid, stead flow device with no changes in kinetic and potential energy)

$$\frac{d}{dt} E_{sys} = \Sigma E'_{in} - \Sigma E'_{out}$$ **Note:** The system encompasses just the water side of the condenser.

$$0 = \Sigma E'_{in} - \Sigma E'_{out}$$

$$0 = m'_w \cdot h_{w,in} + Q'_{in} - m'_w \cdot h_{w,out}$$

Solving for the rate of heat transfer shows

$$Q'_{in} := m'_w \cdot \left(h_{w,out} - h_{w,in} \right) = 20.3 \; kW$$

Finding the rate of heat transfer from the R-134a to the water could have also been found by redefining the system boundy to include just the R-134a. This is done below.

<u>1st Law</u> (for rigid, stead flow device with no changes in kinetic and potential energy)

$$\frac{d}{dt} E_{sys} = \Sigma E'_{in} - \Sigma E'_{out}$$ **Note:** The system encompasses just the water side of the condenser.

$$0 = \Sigma E'_{in} - \Sigma E'_{out}$$

$$0 = m'_R \cdot h_{Rin} - m'_R \cdot h_{Rout} - Q'_{out}$$

Solving for the rate of heat transfer shows

$$Q'_{out} := m'_R \cdot \left(h_{R,in} - h_{R,out} \right) = 20.3 \; kW$$

This can be seen to be the same as the other method's solution.