Given: $kJ := 1000J$

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.

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

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

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 @ $T_{w,in} = 15 \cdot °C$ & $P_{w,in} = 300 \cdot kPa$ 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 @ $T_{w,out} = 25 \cdot °C$ & $P_{w,in} = 300 \cdot kPa$ 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 @ $T_{R,in} = 70 \cdot °C$ & $P_{R,in} = 1 \cdot MPa$ shows that the state is superheated.

Going to Table A-13 @ $T_{R,in} = 70 \cdot °C$ & $P_{R,in} = 1 \cdot MPa$ shows

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

Solution (cont.):

Going to Table A-11 @ $T_{R,out} = 35\cdot°C$ & $P_{R,in} = 1\cdot MPa$ 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.

$$T_a := 34\,°C \qquad T_b := 36\,°C$$

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

$$h_{R,out} := \frac{T_{R,out} - T_a}{T_b - T_a}\cdot\left(h_b - h_a\right) + h_a = 100.875\cdot\frac{kJ}{kg}$$

The mass flow rate of the water is then given by

$$\boxed{m'_w := m'_R\cdot\frac{h_{R,out} - h_{R,in}}{h_{w,in} - h_{w,out}} = 0.4851\cdot\frac{kg}{s}} \qquad \boxed{m'_w = 29.1\cdot\frac{kg}{min}}$$

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

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

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.

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

$$0 = m'_R\cdot h_{R,in} - m'_R\cdot h_{R,out} - Q'_{out}$$

Solving for the rate of heat transfer shows

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

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