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.

$$m'_R := 6 \frac{\text{kg}}{\text{min}}$$
 $P_{R,in} := 1 \text{ MPa}$ $T_{R,in} := 70 \text{ °C}$ $T_{R,out} := 35 \text{ °C}$ $P_{W,in} := 300 \text{ kPa}$ $T_{W,in} := 15 \text{ °C}$ $T_{W,out} := 25 \text{ °C}$

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)

$$\frac{\mathrm{d}}{\mathrm{d} t} E_{sys} = \Sigma E'_{in} - \Sigma E'_{out}$$
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' yields

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

Going to Table A-4 @ $T := T_{w,in} = 15$ °C and $P := P_{w,in} = 300$ 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 @ $T := T_{w,out} = 25$ °C and $P := P_{w,in} = 300$ 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 @ $T := T_{R,in} = 70$ °C and $P := P_{R,in} = 1$ MPa shows that the state is superheated.

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

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

Going to Table A-11 @ $T := T_{R,out} = 35$ °C and $P := P_{R,in} = 1$ 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.

$$\begin{split} T_a &:= 34 \text{ °C} & T_b := 36 \text{ °C} \\ h_a &:= 99.41 \text{ } \frac{\text{kJ}}{\text{kg}} & h_b := 102.34 \text{ } \frac{\text{kJ}}{\text{kg}} \\ h_{R,\text{out}} &:= \frac{T_{R,\text{out}} - T_a}{T_b - T_a} \cdot \left(h_b - h_a\right) + h_a = 100.9 \text{ } \frac{\text{kJ}}{\text{kg}} \end{split}$$

Solution (cont.):

The mass flow rate of the water is then given by

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

$$m'_{w} = 29.10 \frac{\text{kg}}{\text{min}}$$

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.

1st Law (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

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

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.

1st Law (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

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

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