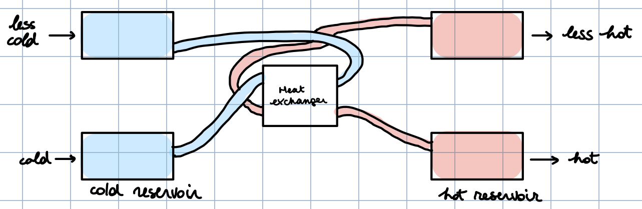
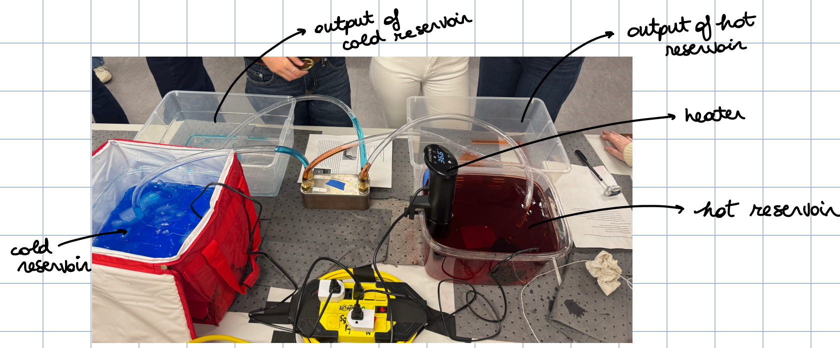
photo + shematic of the device

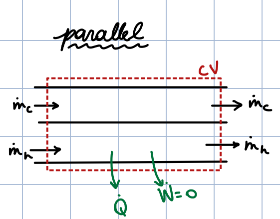


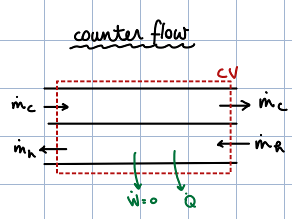


Qualitative description of the device

The device we analyzed is a hot to cold water heat exchanger. We attached a tube with a pump from a cold reservoir and a tube with a pump from a hot reservoir to a heat exchanger and then attached tubes from the Heat exchanger to empty reservoirs. When turning on both pumps the liquid flowed from each reservoir, through the heat exchanger into an empty reservoir each. When flowing through the heat exchanger the hot water and cold water never mixed. Instead heat was transferred from the hot water to the cold water through conduction through the metal heat exchanger walls separating the two flows. The heat exchanger felt cold to the touch where the cold liquid flowed into it and warm to the touch where the hot liquid flowed into it. After passing through the heat exchanger, the temperature of the hot liquid decreased and the temperature of the cold liquid increased.

system diagram of the device operating at control volume





quantitative + qualitative data collected during the experiment

General observations:
The 2/4 side of the metal pump gets hotter in parallel, compared to the 1/3

Parallel flow
Hot 43.1 —27.3
Cold 4.0–23.6

Counter flow
Hot 43.1 — 23.0
Cold 6.3– 28.1
The hot becomes colder than the cold The cold becomes hotter than the hot, Can only happen with counter flow

Parallel flow, hotter
Hot: 50.0 — 30.0
Cold 4.0 — 23.0

Pinched hot tube
Hot 42.4–26.5
Cold 9.6–24.9
A lot less hot liquid in tub than cold liquid in other tub

mass balance:

$$\dot{m}_{h,in} = \dot{m}_{h,out} = \dot{m}_h$$

$$\dot{m}_{c,in} = \dot{m}_{c,out} = \dot{m}_c$$

(assume $\dot{m}_h = \dot{m}_c$ because the same pump was used for the hot and the cold reservoir)

assume air & He pump is used (link cited below), with flowrate 450L/h = 0.125 kg/s

energy balance:

$$\dot{E} = \dot{Q} - \dot{W} + \Sigma \dot{m}_i (h_i + \frac{V_i^2}{2} + gz_i) - \Sigma \dot{m}_o (h_o + \frac{V_o^2}{2} + gz_o)$$

assume $\Delta PE = \Delta KE = 0$, assume steady state, assume $\dot{W} = 0$ and, c_p for water 4184 J/kg·K

assume water is an incompressible fluid

$$0 = \dot{m}_c h_{c,i} + \dot{m}_h h_{h,i} - \dot{m}_c h_{c,o} - \dot{m}_h h_{h,o} + \dot{Q}$$

$$\dot{Q} + \dot{m}_c c_p (T_{c,i} - T_{c,o}) = \dot{m}_h c_p (T_{h,o} - T_{h,i})$$

$$\dot{Q} = \dot{m}_h c_p (T_{h,o} - T_{h,i}) + \dot{m}_c c_p (T_{c,o} - T_{c,i})$$

entropy balance:

$$\dot{S} = \Sigma \frac{\dot{Q}}{T_b} + \Sigma \dot{m}_i s_i - \Sigma \dot{m}_o s_o + \dot{\sigma} \qquad (\dot{\sigma} \geq 0)$$

assume water is an incompressible fluid, assume steady state, c_p for water 4184 J/kg·K

assume $T_b = 25°C = 298$ K

$$0 = \dot{m}_c c \ln\left(\frac{T_{c,i}}{T_{c,o}}\right) + \dot{m}_h c \ln\left(\frac{T_{h,i}}{T_{h,o}}\right) + \dot{\sigma} + \Sigma \frac{\dot{Q}}{T_b}$$

$$\dot{\sigma} = \dot{m}_c c \ln\left(\frac{T_{c,o}}{T_{c,i}}\right) + \dot{m}_h c \ln\left(\frac{T_{h,o}}{T_{h,i}}\right) - \Sigma \frac{\dot{Q}}{T_b}$$

using these formulas for

parallel flow:

$\dot{Q} = 1.99$ kJ/s

$\dot{\sigma} = 2.26$ J/kg·K·s

counter flow:

$\dot{Q} = 889.1$ J/s

$\dot{\sigma} = 1.96$ J/kg·K·s

A change made in the set-up of the heat exchanger was setting the flow up in parallel flow first and then in counter flow.

The heat exchanger in counter flow has a higher efficiency as a higher temperature difference is maintained between the hot and the cold flow throughout the process. This higher efficiency of the counter flow is also proven by the fact that both the heat lost to the surroundings and the entropy generated are less for counter flow than for parallel flow. (These values were found through plugging in the temperatures measured in the experiment into the derived energy and entropy equations). Lower entropy generation in counter flow signals that in counter flow there are less irreversibilities (through for example heat lost to surroundings) and thus that less useful energy is lost. Lower entropy generation also means that the process is closer to a reversible process, which has ideal thermodynamic performance.

Reference for mass flow rate of the heat pump used in the experiment

https://www.amazon.com.be/-/en/Air-Pump-Up-Lift-Dehumidifiers/dp/B07D8DQMYT/ref=asc_df_B07D8DQMYT?

mcid=8ea932042a543d118359cca2029b55b1&tag=begogshpadde-21&linkCode=df0&hvadid=712581418278&hvpos=&hvnetw=g&hvrand=10419331664042526324&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&h

vlocint=&hvlocphy=9219354&hvtargid=pla-519965981437&psc=1&language=en_GB&gad_source=1