Heat Exchanger Lab

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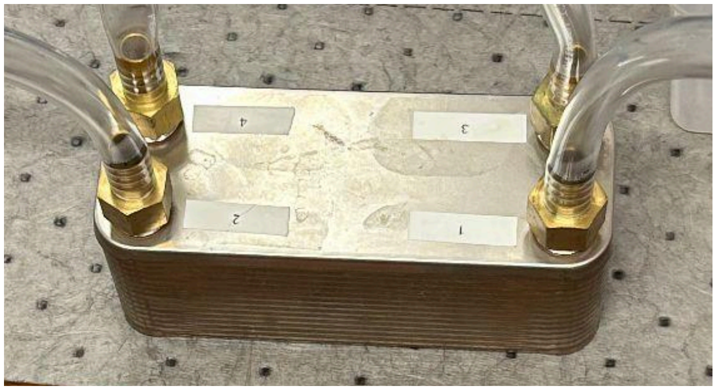


Summary:

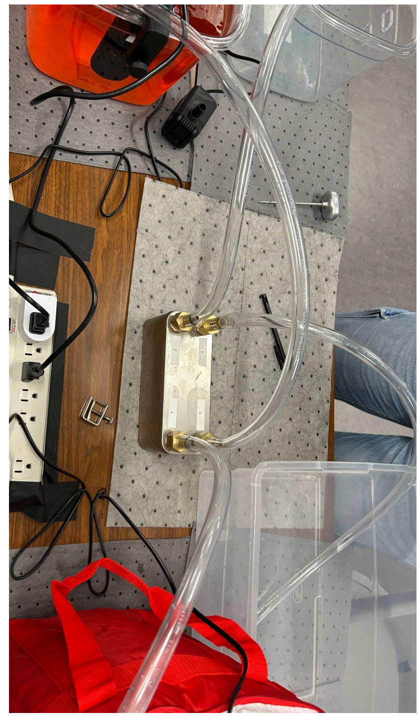
- Ran a heat exchanger 2 separate way (Counter and parallel flow) to see the difference in initial cold and hot temperatures
- Ran the heat exchangers twice per counter and parallel flow. Once with slow mass flow rate and once with fast mass flow rate
- Total trials conducted: 4
    - Trial 1:
        - Parallel Flow: Fast
    - Trial 2:
        - Parallel Flow: Slow
    - Trail 3:
        - Counter Flow: Fast
    - Trial 4:
        - Counter Flow: Slow
- For each trial the initial and final temperatures of both the hot and cold reservoirs were taken
- Each trial had different initial temperatures to make data more diverse
- Analysis consists of:
    - Discussion of data
    - Heat exchangers in the real world
    - Adiabatic?
    - Steady state operation?
    - Kinetic and potential energy changes?

Lab Set Up:

Counter Flow:

- Hot and cold traveling in opposite directions

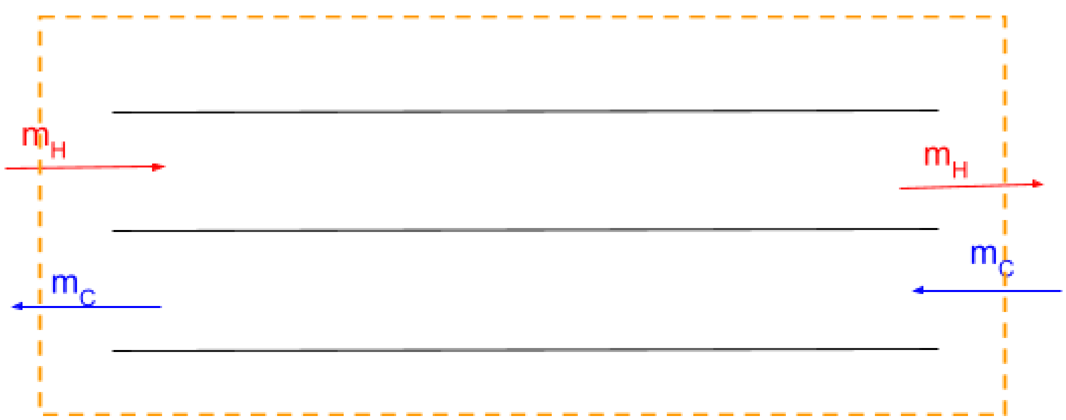
Parallel Flow:



- Hot and cold traveling in the same direction

Schematic:

(Counter flow)



Data:

Parallel Flow:

Fast:

T_{Hi} = 43 ℃

T_{HF} = 31.8 ℃

ΔT = -11.2

T_{Ci} = 17.5 ℃

T_{CF} 29.3 ℃

ΔT = 11.8

Slow:

T_{Hi} = 42.8 ℃

T_{HF} = 30.5 ℃

ΔT = -12.3

T_{Ci} = 21.6 ℃

T_{CF} 28.9 ℃

ΔT = 7.3

Counter Flow:

Fast:

T_{Hi} = 44.8 ℃

T_{HF} = 28.2 ℃

ΔT = -16.6

T_{Ci} = 18 ℃

T_{CF} = 31.8 ℃

ΔT = 13.8

Slow:

T_{Hi} = 45.6 ℃

T_{HF} = 25.3 ℃

ΔT = -20.3

T_{Ci} = 13.8 ℃

T_{CF} 33.4 ℃

ΔT = 19.6

Equations:

Mass Balance: *Assuming steady-state*

$$\dot{m}_{in} = \dot{m}_{out}$$

$$\dot{m}_{Hi} + \dot{m}_{Ci} = \dot{m}_{Ho} + \dot{m}_{Co}$$

$$\dot{m}_h \neq \dot{m}_c$$

Energy Balance: *Assuming steady-state and rigid*

$$\cancel{\frac{dE}{dt}} = \dot{Q}_{cv} - \cancel{\dot{W}}_{cv} + \dot{m}_{Hin}(h_{Hi}) + \dot{m}_{Cin}(h_{ci}) - \dot{m}_{HO}(h_{HO}) - \dot{m}_{co}(h_{co})$$

$$\dot{Q}_{cv} = \dot{m}_H(h_{Ho} - h_{Hi}) + \dot{m}_c(h_{co} - h_{ci})$$

$$\dot{Q}_{cv} = \dot{m}_H c_{p_H}(T_{Ho} - T_{Hi}) + \dot{m}_c c_{p_c}(T_{co} - T_{ci})$$

Analysis:

- **Parallel vs Counter:**
  - Counter flow has larger ΔT for every trial
- **Changing hot reservoir:**
  - Higher T_{Hi} means larger ΔT so larger Q between hot and cold
- **Changing absolute and relative flow rates (slow vs fast):**
  - Slow has generally has larger ΔT
- **Pinching the tube:**
  - Adds flow restriction
  - Increases ΔT on that side by reducing flow on that loop

Real World Uses:

- Car radiator:
  - Transfers thermal energy from a hot fluid like an engine coolant to a cold one like air
- Power plants:
  - Steam from a turbine is condensed by cooling water

Adiabatic Assumption:

- Our exchanger is not perfectly adiabatic as some heat is lost to the surroundings and gained from the pumps. This can be seen because T_{CF} does not exactly match T_{Hi}, so some heat must be lost to the environment. This reduces the effective heat transfer between the hot and cold streams compared to an ideal adiabatic exchanger and introduces error when we estimate effectiveness or U using the ideal energy balance.

Steady State:

- No, right now this experiment is not operating in a steady state as that would mean temperatures at each port and in each reservoir are not changing with time (or changing very slowly). However, we saw that the temperatures were constantly changing at each port, so we can't say this is steady-state.

How to get closer to steady state:

- Start with full buckets (large thermal mass)
- Moderate flow rates so the exchanger doesn’t change the bucket temperature too fast.
- If possible, keep the heater on at a level that roughly balances the heat you’re removing from the hot reservoir, so its temperature is nearly constant for a short period.
- Limit the duration of each “run” so reservoir temperatures don’t drift much during your measurements.

Kinetic energy changes:

- Kinetic and potential energy changes between inlet and outlet on each line are negligible compared to the enthalpy change from temperature differences, so we ignore them in our energy balance.