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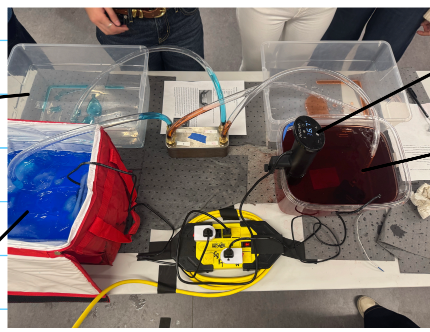
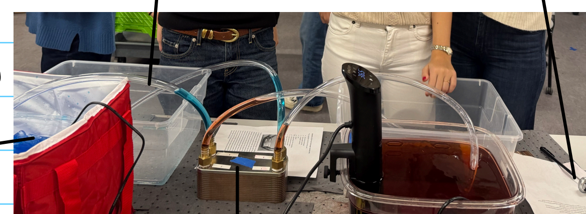
3) [45] Complete your portfolio assignment. Please select a real-world instance of a device or system that we have learned about in this course, explain how it works in detail, and then discuss how its performance would change under a change in design or operating conditions. Logistical information can be found with the portfolio assignment and document also marked as due 11/24/25. Your report should include:

- photos and schematics of the device or system
- a qualitative description of the device or system
- a system diagram of the device or system operating (either CV or CM), showing work and heat transfer interactions as well as any relevant mass flows
- mass balance, energy balance, and entropy balance equations (as relevant) capturing the physics more central to the device or system operation
- describe a change to device or system design or operating conditions and then how that change influences device performance

Photos of Set-Up:

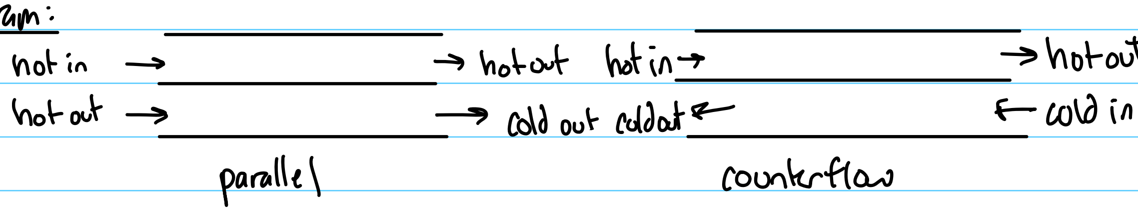




Explination of Set-Up:

The device is a small, water-to water heat exchanger. One loop carries hot water from a heated resevior, the other loop carries cold water from a chilled resevoir. The two streams never mix, instead, heat is transfered by conduction through metal seperating the cannels and convection between each fluid and metal surface. We ran several operating conditions: parallel flow, counter flow, parallel flow with hotter hot inlet, pinched hot tube/reduced hot flow (all data seen on other page). We also noticed that one side of the metal block got hotter than the other during parallel flow. This suggests that the block is not perfectly insulated and that some heat is leaking to the surrounding and/or not being conducted evenly around the block.

System Diagram:



Data during Experimentation:

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 temp of the hot anova increased to like 44.5 rapidly after the flow started

The hot becomes colder than the cold
The cold becomes hotter than the hot
Can only happen with counter flow
Do CV to analyse and show its possible

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

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:

$$\dot m_{hin} = \dot m_{hout} = \dot m_h$$

$$\dot m_{cin} = \dot m_{cout} = \dot m_c$$

Enthropy Balance:

$$\sum \dot m s_{in} + \frac{\dot Q_{ev}}{T_b} = \sum \dot m s_{out} + \dot S_{gen} \qquad \dot S_{gen} \geq 0$$

$$\dot m_h C_{ph} \ln\left(\frac{T_{hout}}{T_{hin}}\right) + \dot m_c C_{pc} \ln\left(\frac{T_{cout}}{T_{c\,in}}\right) - \frac{\dot Q_{enc}}{T_b} = \dot S_{gen} \geq 0$$

$$T_{c,out} > T_{h,out}$$

Energy Balance:

$$\sum \dot m \left(h + \frac{V^2}{2} + gz\right)_{in} + \dot Q - \dot W = \sum \dot m \left(h + \frac{V^2}{2} + gz\right)_{out}$$

$$\Delta KE = 0 \qquad \Delta PE = 0$$

$$\dot m_h h_{hin} + \dot m_c h_{cin} + \dot Q_{ev} = \dot m_h h_{hout} + \dot m_c h_{cout}$$

$$\dot m_h C_{ph} (T_{hin} - T_{hout}) = \dot m_c C_{pc} (T_{cout} - T_{cin}) + \dot Q_{enc}$$

$$\dot m_h (T_{hin} - T_{hout}) = \dot m_c (T_{cout} - T_{cin})$$

Effect of Design/Operating Changes:

↳ Pinched Hot Tube (Reduced Hot Mass Flow Rate)

The pinched hot tube reduces $\dot m_h$ while keeping $\dot m_c$ about the same. Here:

hot: 42.4°C → 26.5°C (large drop: 16°C)

cold: 9.6°C → 24.9°C (increase: 15.3°C)

From the energy balance: $\dot m_h (T_{hin} - T_{hout}) \approx \dot m_c (T_{cout} - T_{cin})$. Thus reducing $\dot m_h$ forces a larger temperature drop on the hot side to supply the same heat to the cold stream. There will be a lot less hot liquid in the tub than cold liquid in the other tub. This makes the hot side leave at a lower temp, but if $\dot m_h$ becomes too low, you quickly cool the hot reservoir and the device reaches a new steady state.

Specific Analysis

Alfa Laval T2 Plate Heat Exchanger

This is a compact plate heat exchanger used in HVAC and industrial cooling. The T2 uses a stack of corrugated metal plates to increase heat transfer.

Specifications:

- Model: Alfa Laval T2
- Heat Transfer Area: 0.04 - 0.06 m^2
- Typical Plate Count: 10 - 50
- Max Operating Temperature: 180°C
- Max Operating Pressure: 1.6 MPa
- Common Fluids: water, glycol mixtures, oils

(parallel flow example)

How the Alfa Laval T2 Works:

Flow Path:

i) Hot and Cold fluids enter alternating plate channels

ii) Each plate is gasketed, forcing the fluids into zig-zag pathways

iii) High turbulence enhances convection coefficients by 2-5x compared to smooth channels

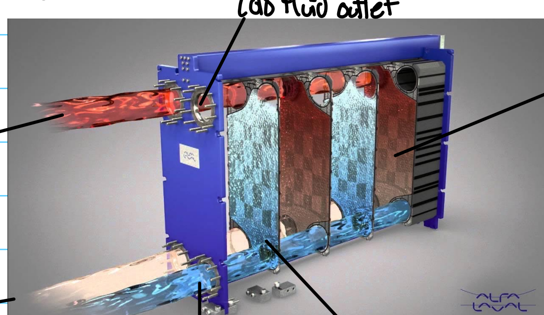
Heat Transfer Mechanism:

i) Hot fluid convects heat to the stainless-steel plate surface

ii) Heat conducts through the corrugated metal plate

iii) Cold fluid convects heat away from the opposite side

System Diagram:



→ This is a standard T2

Thermo Analysis Using Real Device Numbers:

Assume:

Hot side: 75°C in → 50°C out

Cold side: 25°C in → 45°C out

Fluids: water

Hot side flow rate: 0.25 kg/s

Cold side flow rate: 0.30 kg/s

$C_p = 4180$ J/kgK

Energy Balance:

Hot side heat loss:

$$\dot{Q}_h = \dot{m}_h C_p (T_{h,in} - T_{h,out}) = (0.25)(4180)(75-50) = 26.1 \text{ kW}$$

Cold side heat gain:

$$\dot{Q}_c = \dot{m}_c C_p (T_{c,out} - T_{c,in}) = (0.30)(4180)(45-25) = 25.1 \text{ kW}$$

Difference = 4% → expected due to heat loss to enviornment (real-world)

Entropy Generation:

$$\dot{S}_{gen} = \dot{m}_h C_p \ln\left(\frac{T_{h,out}}{T_{h,in}}\right) + \dot{m}_c C_p \ln\left(\frac{T_{c,out}}{T_{c,in}}\right)$$

$$\dot{S}_{gen} = (0.25)(4180)\ln(323/348) + (0.30)(4180)\ln(318/298)$$

$$\dot{S}_{gen} = 3.1 \text{ W/K}$$

This shows real irreversible heat exchange

Comparison to Experimental Lab Exchanger:

- The small lab exchanger showed uneven heating of the block which means it has imperfect insulation
- The T2 has high insulation and high-area plates, reducing heat loss
- The lab heat exchanger shows "parallel vs counterflow" which matches the known differences for plate heat exchangers like the T2
- The lab heat exchanger mimics how mass flow increases ΔT per kg which is also true for plate exchangers like the T2

Design Change Analysis:

Proposed Change: Reduce hot-side mass flow from 0.25 kg/s to 0.12 kg/s

Predicted Effects:

i) Larger hot-side temprature drop:

$\Delta T_h \uparrow$, hot outlet temp could drop from 50°C to 38°C

ii) Reduced total heat transfer:

$\dot{Q} \propto \dot{m}_h \times \Delta T_h$ so the increased ΔT cannot fully compensate for halved $\dot{m}_h$

Realistic recalculated heat load would be $\dot{Q}_{new} = 19\,kW$ which is a drop from 26kW

iii) Higher Entropy Generation:

Larger temp difference across plates → more irreversibility

iv) Approach to LMTD limit:

At extremly low flows, the exchanger behaves more like a batch cooler, reducing efficiency

Overall: The device becomes more effective but less efficient.

Sources

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