Majicom - active water cooling

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Majicom overview

- Majicom are already in place in rural areas of Tanzania
- They provide energy efficient filtered drinking water
- They want to also provide users with the option of chilled water
- However due to the limited power supply, the solutions to this problem are not simple

Active cooling deliverables

We have identified several options for cooling:

- Cooling on demand
- Cooling the whole tank with either peltier cells or refrigerant cycles
- Cooling by exchanging heat with cold mains water
- Cooling a second, smaller tank

To achieve that we have determined the following aims to be determined:

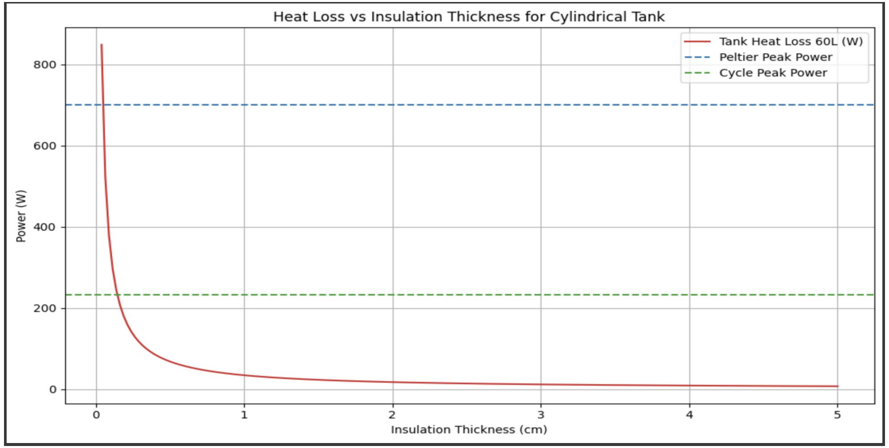
- Heat losses from the cold tank
- Efficiency and feasibility of Peltier and refrigerant cooling systems

These values will be then used to give a recommendation as to what cooling system should be used.

Tank losses

Initial back of the page calculations showed that thermal tank losses should be small, but these calculations involved many simplifications.

CFD modelling seemed appropriate to understand the full story of thermal losses in a climate like Tanzania's



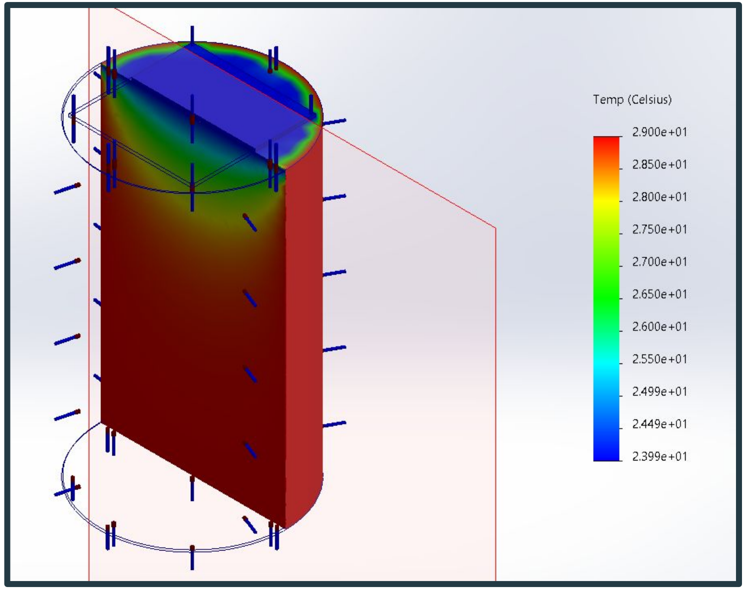
CFD Validation of tank thermal losses

Provide detailed analysis of heat losses

In various conditions

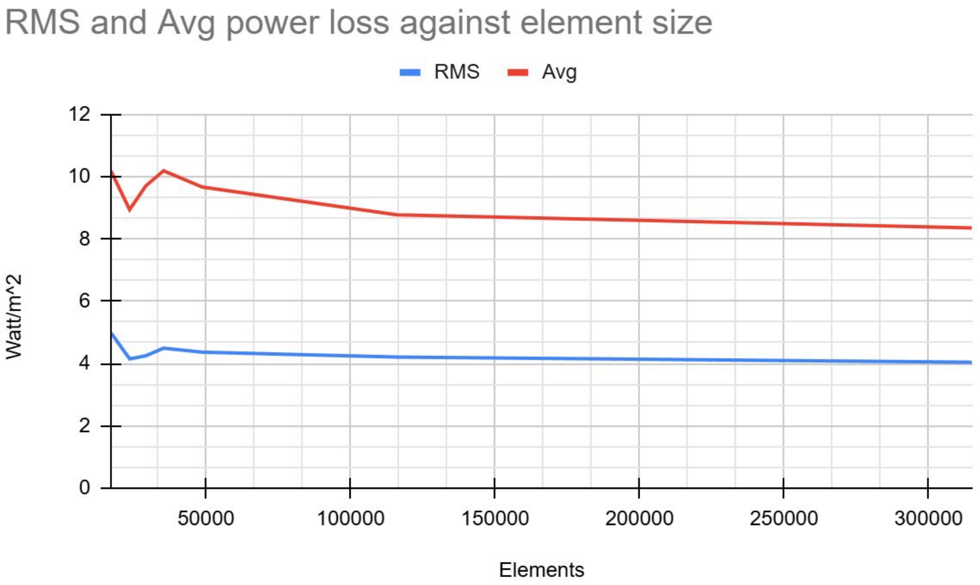
Method:

- Mesh convergence study
- Static Model
- Convective Model
- Analysis of results
- Conclusion of CFD Analysis



Static Mesh Convergence Study

- Mesh size of 130,000 chosen
- Accurate to within 2% of higher end results
- Compromise of simulation time and accuracy



Results - Static Model

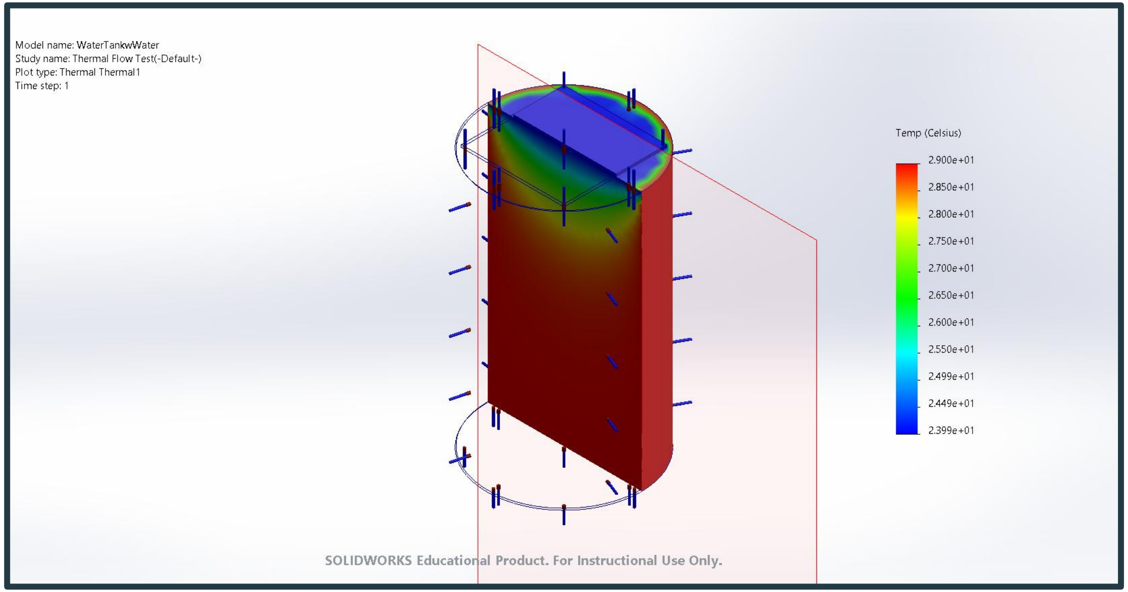
Heat losses - 8.7W overall

Peltier power:

18-80W

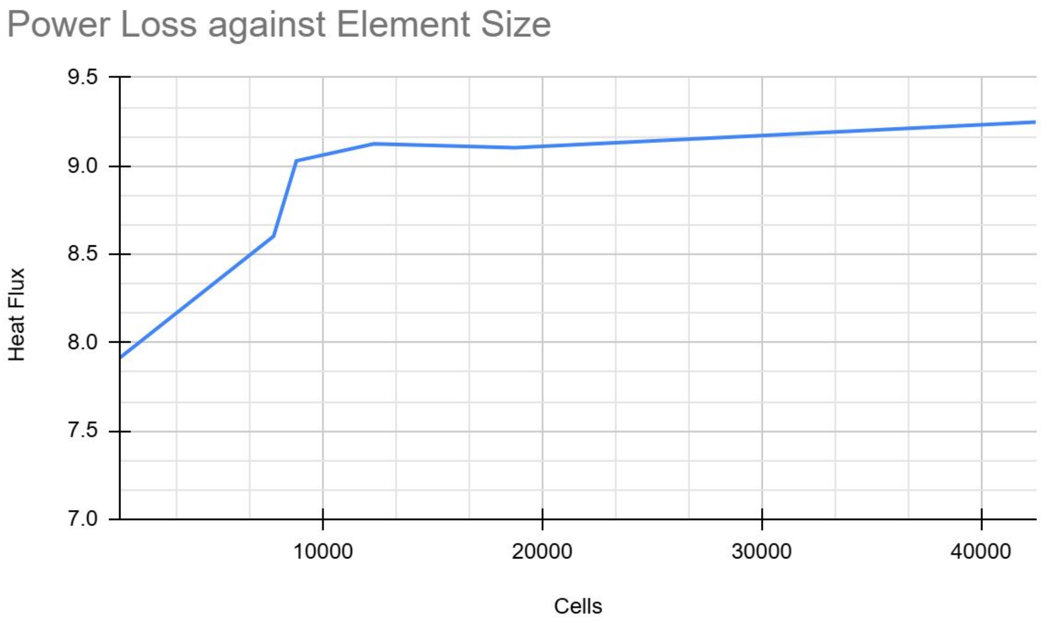
Traditional cooling pipe power:

~5.8W



Convective Mesh Convergence Study

- Element size of 40000 chosen.
- Most accurate but still quick to run



Results - Convective Model

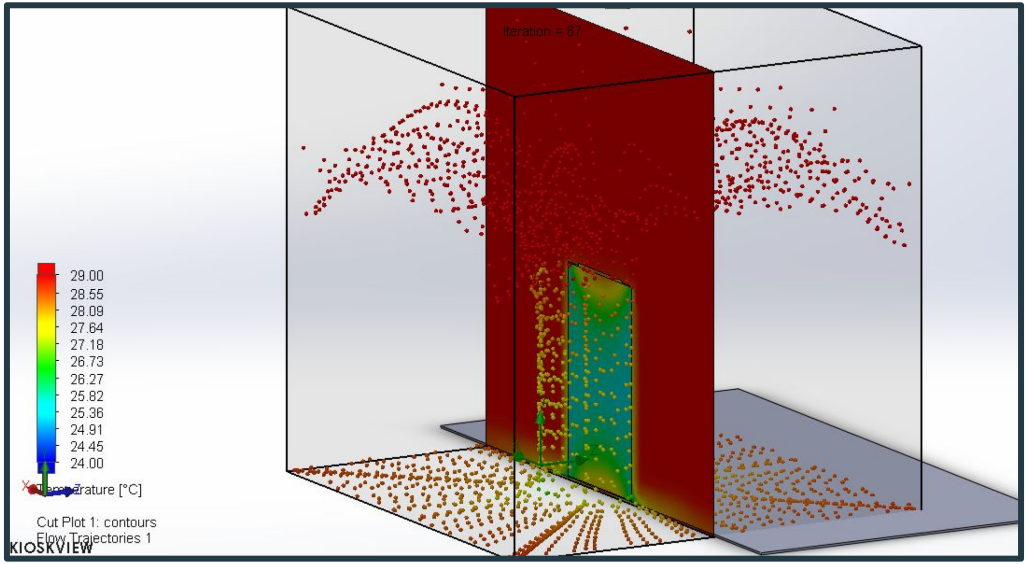
Heat losses - 9.24W overall

Peltier power:

20-90W

Traditional cooling pipe power:

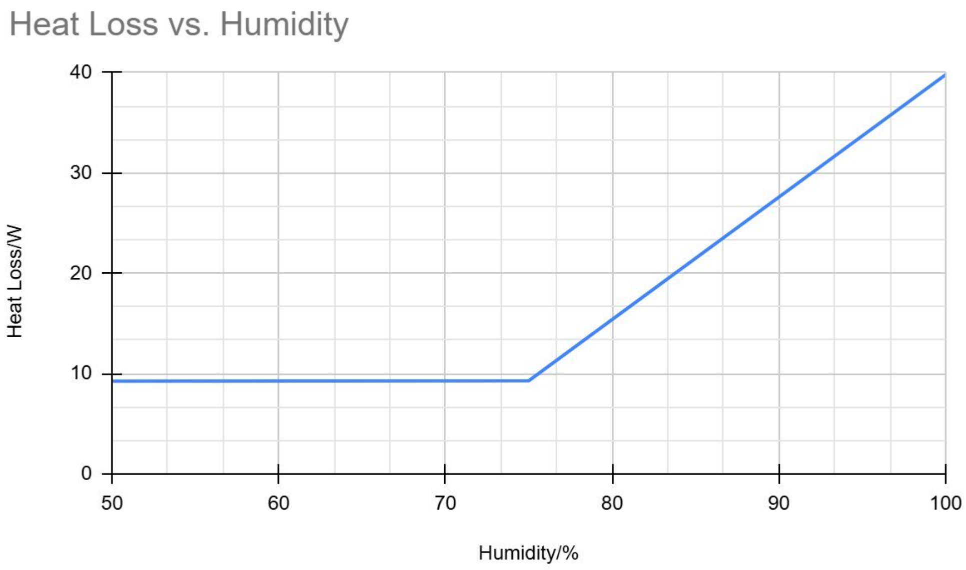
~6.2W



Humidity?

Humidity levels varied

- 50% - 9W
  - Average minimum humidity
- 75% - 9W
  - Average maximum humidity
- 100% - 40W
  - (theoretical maximum during specific hours of the wet season)



Analysis

- Static agreed with convective analysis
- Humidity poses temporary “power surge” risk, within electronic limits for refrigerant cooling.
- Expected power consumption shows refrigerant cooling is more desirable

Mains Water - Free Cooling

<u>Objective:</u>

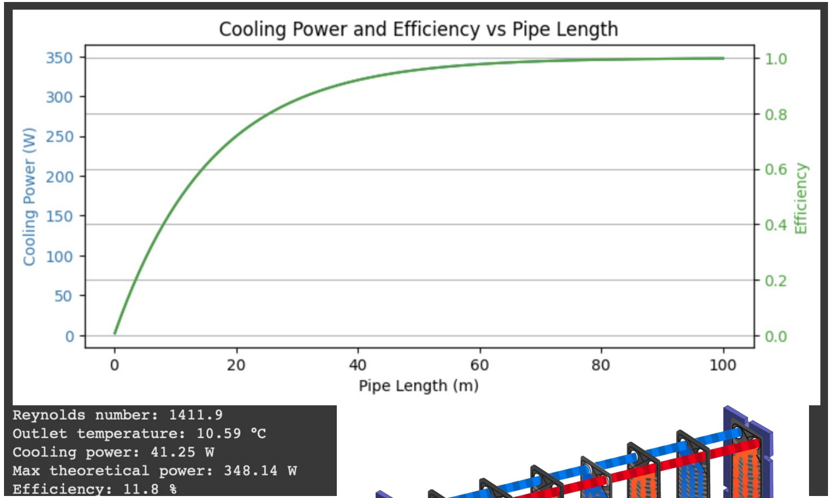
Understand whether the cooling power available from incoming cold tap water could be harnessed to aid tank cooling.

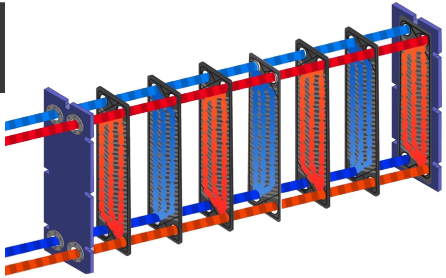
<u>Work Done:</u>

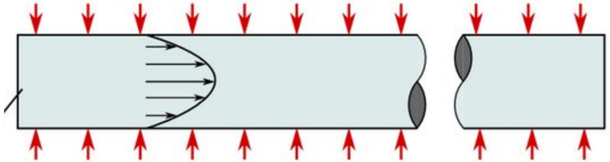
- Research - Mains water in Tanzania up to 15 degrees below ambient
- Aspired tank cooling is significantly less than this - how do we exchange heat
- Could running copper pipes through the tank be a feasible solution?
- What about operation outside of peak times?
- What can be changed with refill strategy?

<u>Conclusions:</u>

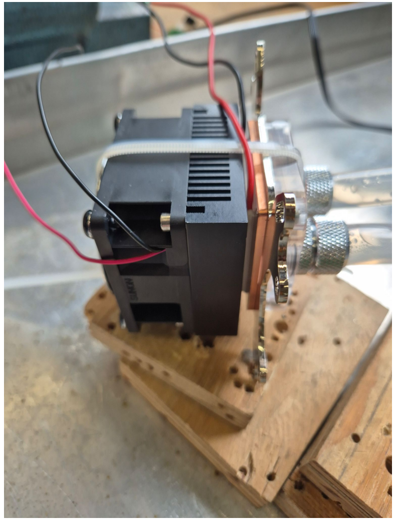
A mains water cooling solution would introduce higher complexity and cost, but if these kiosk are being implemented in the long term then it could be an energy efficient cooling source.

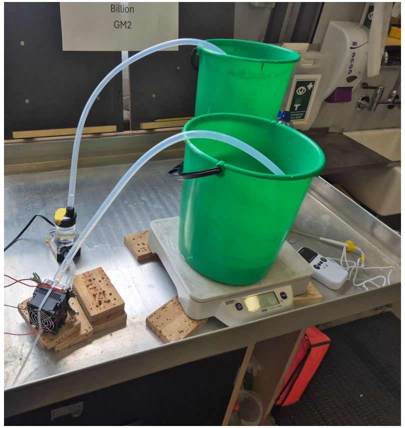






Experimental Setup





OBJECTIVE

Test the feasibility of cooling the water by a significant amount as it is being dispensed, as opposed to cycling water in and out a tank

PC Cooling Components

- Fan
- Heat Exchanger
- Pump
- Pipes

Other Components

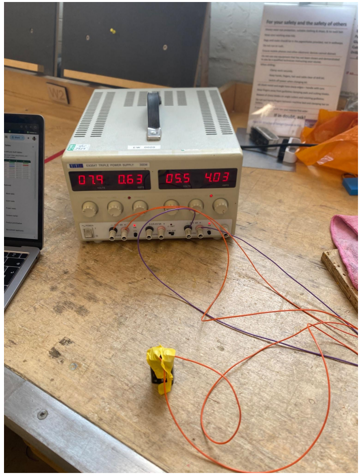
- CUED Power supply (limitations)
- Peltier Cell (limitations)
- Digital Thermometer

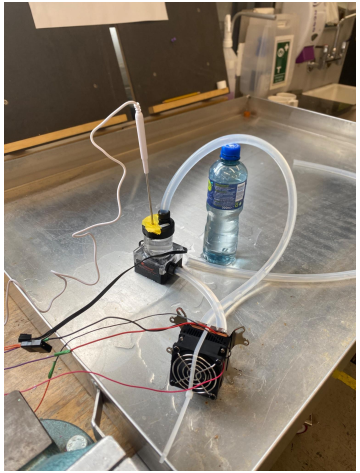
SETUP A

Water was pumped from one bucket to another at rates similar to dispensal, measuring the temperature drop

SETUP B

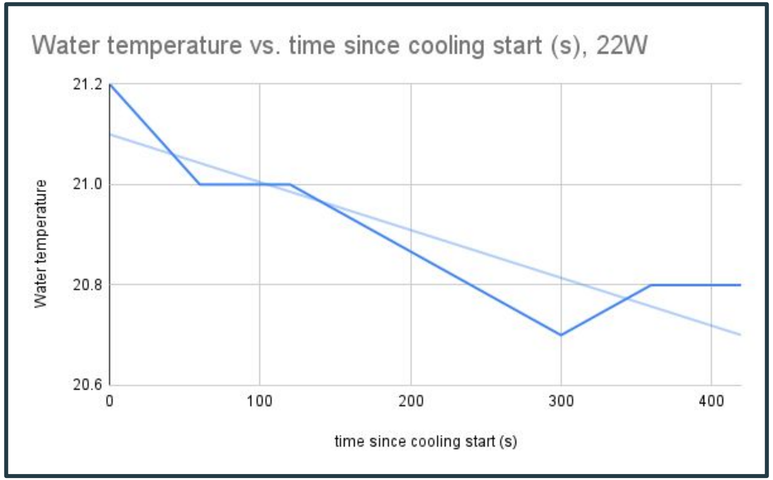
A small volume of water was pumped continuously around the circuit, meaning the same heat exchanger mechanics but a higher change in temperature





Experimental Results

- For Setup A, the maximum cooling we could hope for given we had a floor on pumping speed, and a ceiling on input power, was within the experimental error.
- For Setup B, we now had cooling that was significant enough to measure, however the cooling rate was a fraction of the theoretical maximum cooling power



Temperature results for a 22W run on setup B

Experiment conclusions

The experimental results led to a few conclusions:

- Peltier cells require a lot of current and that is more than conventional power systems usually work with. This suggests that the electrical side of the setup will be harder to build and more costly
- Peltier cells require a large amount of cooling. It was noted that even at this low power, the cell heated up considerably which reduced the cooling efficiency. For such a setup to work a large fan and cooling system would be needed.
- At the flow rates expected in the kiosk the rate of heat transfer was not high enough. This may be partially due to the low power available, but could be at least partially due to not enough heat transfer in the water cooled plate.

Together this leads us to the result that Peltier cells are not suitable

Power calculations

Detailed calculations can be found on the github page:

Cooling the whole tank with cyclic cooler - 250 Watts

Cooling a smaller tank - 70 Watts

Energy Transferred:

$$Q = m \cdot c_p \cdot \Delta T$$

Thermal Power:

$$\dot{Q} = \frac{Q}{t_{\text{avg}}}$$

Required Electrical Power for Cooling Cycle:

$$P_{\text{elec}} = \frac{\dot{Q}}{\text{COP}_{\text{cycle}}} \cdot R_{\text{cold}}$$

- R_{cold} — Ratio of cold water to total water processed (dimensionless)

Other considerations

- Refrigerant cycles are expensive

A short market survey has determined that the cost of such a system is on the order of magnitude of £100

- Cyclic coolers have a limited lifespan, so care must be taken to specify a long-lasting set-up
- An interesting solution would be to develop a process for recycling old cooling systems in situ in Africa which would reduce waste and cost at the same time

Next steps and final conclusions

We believe our investigation was useful in determining the paths for future research on cooling systems for Majicom kiosk.

We determined that adding a refrigerant cooling system is feasible.

Adding a smaller, secondary tank for cold water would allow to reduce the power consumption to achievable levels.

We advise to purchase a commercial cold water dispenser to reverse-engineer a working solution and implement a similar set up in the kiosk