GM2 - Assistive Passive Water Cooling for Majicom T2

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Background

Working with Majicom, who are building water dispensers in Africa to address the problem of the lack of clean and affordable drinking water due to the lack of water resources.

The water dispensers have integrated water filter to provide clean drinking water while being cheaper than bottled water.

The dispensers are currently in use on a campus at Kenya but will be extended to other areas in the future, with Tanzania being the next .

Overview

Problem:

- Chilled water desired from user poll
- Hot and humid climate at Tanzania

Proposed solution:

- To achieve a temperature drop of 3-5 degrees
- Utilizing evaporative, radiative or other assisted passive cooling means
- Minimisation of energy usage

Current situation:

- No cooling devices incorporated currently
- Aiming to integrate cooling features in upcoming major redesign
- Expected to be launched for service next year

Design considerations

<u>Robust</u>

- Protection against monkeys, insects or other small animals
- Suitability at required operating temperatures and humidity
- Adaptability across wet and dry seasons
- Dust/ sand-proof
- Protection against vandalism

Key: Withstanding the operating environment

<u>Complexity</u>

- Minimise maintenance requirements
- Cost control to allow for affordably priced end-products
- Considerations on possibility of being assembled locally

Key: Aiming for the most simplistic solution

Evaluation of approach

Safety

- Is it safe to use? Does it contaminate the water?
- Does it affect the functionalities of the device?

Effectiveness

- Performance of water cooling approach for given environment
- Additional costs
- Degree of complexity

In addition, there are no constraints on interoperability and infrastructure as it will be a brand new design of a standalone device. Power will come from a solar panel but will not be a major concern as our approach is based on a limited energy consumption.

Evaporative Cooling + Fans

Concept:

- **Porous, damp fabric jacket** wrapped around the water tank to enable evaporative cooling.
- The fabric can be kept moist using a **simple wicking system or gravity-fed drip** from a small water reservoir.
- A **low-power fan (USB or solar-powered)** included to increase airflow and maximise evaporation.
- Optional additions like **terracotta tiles** beneath the fabric can extend moisture retention.

Mechanism:

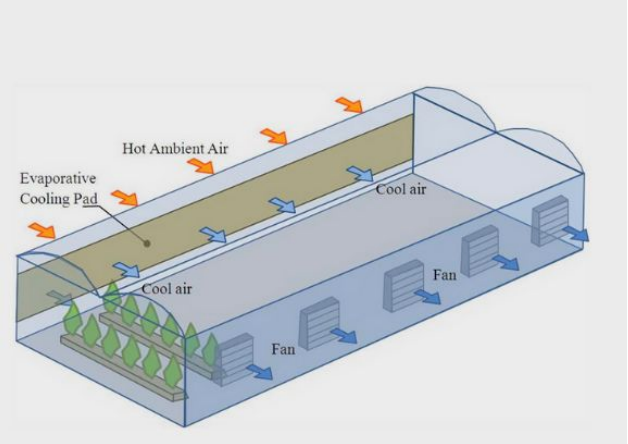
- Evaporation draws **latent heat** from the tank surface, lowering its temperature. Airflow significantly boosts evaporation rates, even in humid climates like Tanzania.
- Using a fan ensures a **steady air current** over the wet surface, preventing stagnation and enabling sustained cooling
- Clay components provide passive water storage and a prolonged evaporative effect.

Evaporative Cooling + Fans

Suggested Testing:

Evaporative cooling has two main components to test:

The air flow over the vessel and the net cooling due to design, material or humidity modifiers. For different vessel designs airflow will be tested by simulation or scale modelling (of vessel and kiosk) to optimise design and fan placement. With material effects it will be vital to measure both internal temperature and also any deviation of external humidity to the ambient humidity.



PCM Cooling Sleeves with Heat Bars

Concept:

- Phase change materials (PCMs) can absorb large amounts of heat as they melt and maintain a stable surrounding temperature
- Pouches with a certain melting temperature can be attached around the tank with metal strips, acting as heat spreaders.
- Suitable for hotter/ humid environment in Tanzania

Mechanism:

- Ambient heat flowing into the tank is redirected into the PCM via the metal spreaders for faster and more even energy absorption
- PCM undergoes a phase transition from solid to liquid to buffer the temperature increases during the hottest part of the day
- PCM re-solidifies at lower temperatures during the night

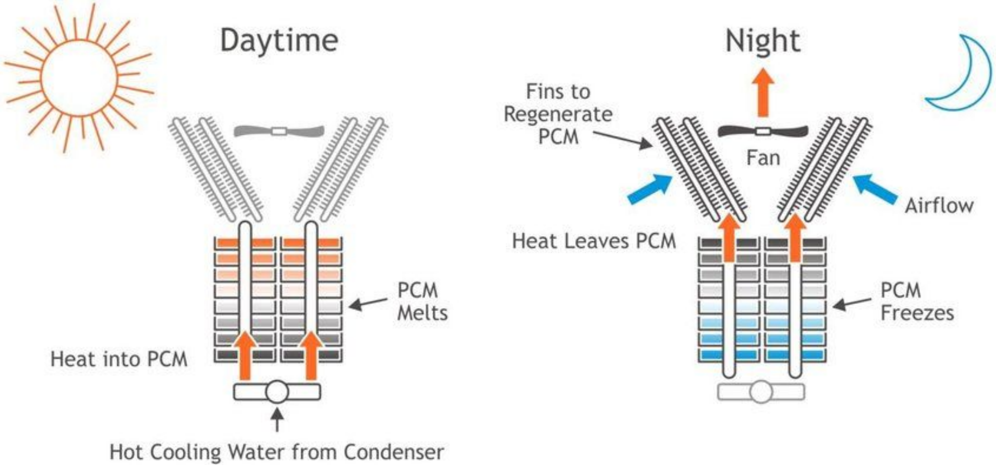
Concerns:

- Volume of water cooled by PCM before its depletion during the day

PCM Cooling Sleeves with Heat Bars

Suggested Testing:

Testing will involve determining the maximum volume of water that a fixed mass of PCM can cool for a given reduction in temperature, as well as determining the effects of mounting geometry and variations in water temperature throughout the day.



PCM Cooling Sleeves with Heat Bars (Backup, pls dont delete yet)

Concept: Phase change materials (PCMs) are ideal for environments like Tanzania as they can absorb large amounts of heat during their melting process and maintain a stable surrounding temperature. Pouches that melt at a certain temp, can be attached around the tank with metal strips to act as heat spreaders.

Mechanism: As ambient heat flows into the tank, it is redirected into the PCM via the metal spreaders, allowing faster and more even energy absorption. The PCM undergoes a phase transition from solid to liquid, buffering temperature increases during the hottest part of the day. At night, when ambient temperatures drop, the PCM re-solidifies and becomes ready for the next day.

Suggested Testing:

The main concern for a PCM approach is how much water will the PCM be able to cool before being full depleted for the day. Testing would involve determining the maximum volume of water that a fixed mass of PCM can cool by a predetermined amount. Additionally testing will need to be done into how mounting geometry will impact cooling rate. PCM will deliver all cooling effects as soon as it is warm enough outside. It is, as such, also important to considering how the temperature of the water will vary across the day and whether it remains sufficiently cool.

Radiative Cooling with insulation

Concept:

- Thermal buffer by 2-3 cm air gap between shell and water container
- Reflective foil or white paint along outer shell to deflect solar radiation
- Thermal mass elements including ceramic tiles or stones to be added to the base and sides of the tank to absorb and dampen incoming heat

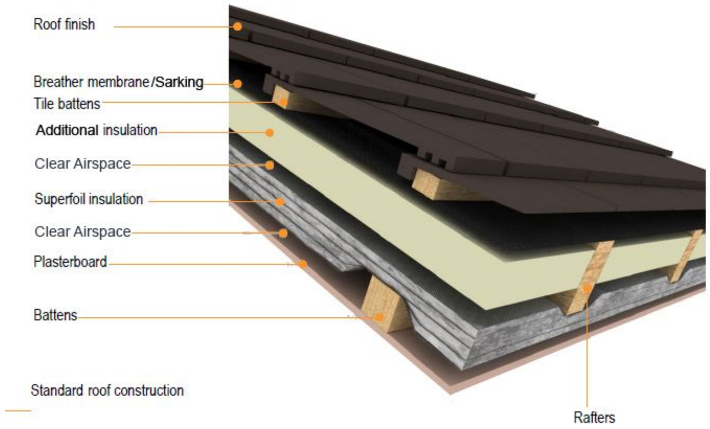
Mechanism:

- The air gap limits conductive heat transfer
- The reflective surface reduces the solar radiation absorbed
- The thermal mass materials limit the temperature rise with their high specific heat capacity and reduces temperature spikes
- Similar to the thermal insulation principles of vacuum flasks or passive solar homes, such that no electricity is required and could be done by using only common or recycled materials

Radiative Cooling with insulation

Suggested Testing:

Testing will involve determining the effects of coating material and tank aspect ratio on the net reduction in temperature.



Radiative Cooling with insulation (Backup, pls dont delete yet)

Concept: This design places the water container inside a larger shell to create a 2–3 cm air gap, which acts as a thermal buffer. The outer shell is lined with reflective foil or coated in white paint to deflect solar radiation. At the base and sides of the tank, thermal mass elements like ceramic tiles or stones can be added to absorb and dampen incoming heat.

Mechanism: The air gap limits conductive heat transfer, while the reflective surface prevents the tank from absorbing solar radiation. Thermal mass materials absorb heat slowly due to their high heat capacity, reducing temperature spikes and delaying heat transmission to the water. This setup mimics the thermal insulation principles of vacuum flasks or passive solar homes, requiring no electricity and using only common or recycled materials.

Suggested Testing:

Testing will involve determining the effects of coating material and tank aspect ratio on the net reduction in temperature.

Deliverables

Evaporative Cooling:

- A scale model or simulation that demonstrates how the design facilitates airflow whilst keeping the kiosk safe from damage and clean
- Ideal fan size and power consumption
- Vessel Material Choice

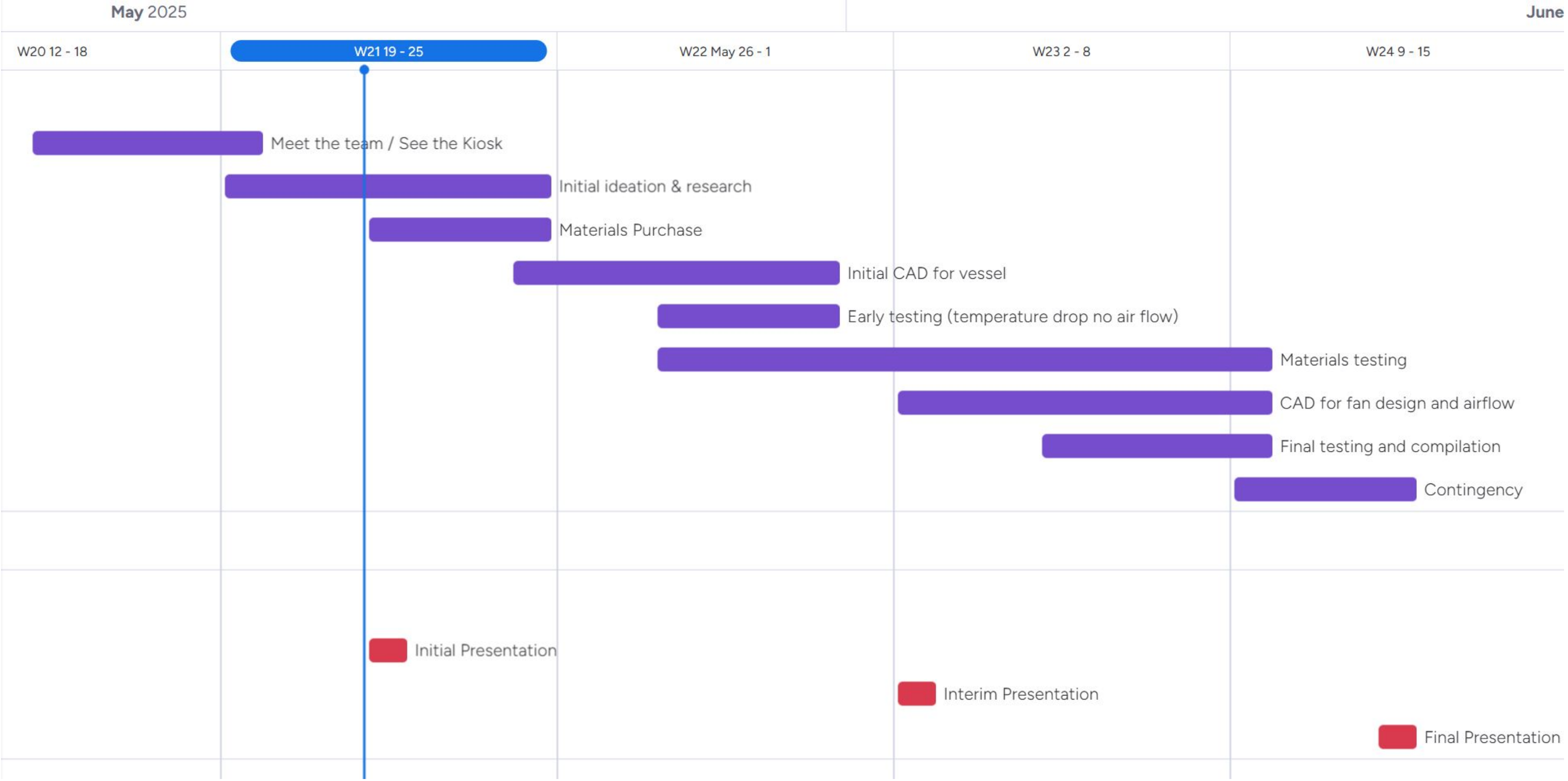
PCM:

- Deliverable mass of cool water per day
- Estimates for water temperature variation across the day
- Design of vessel that can house PCM

Radiative / Insulation:

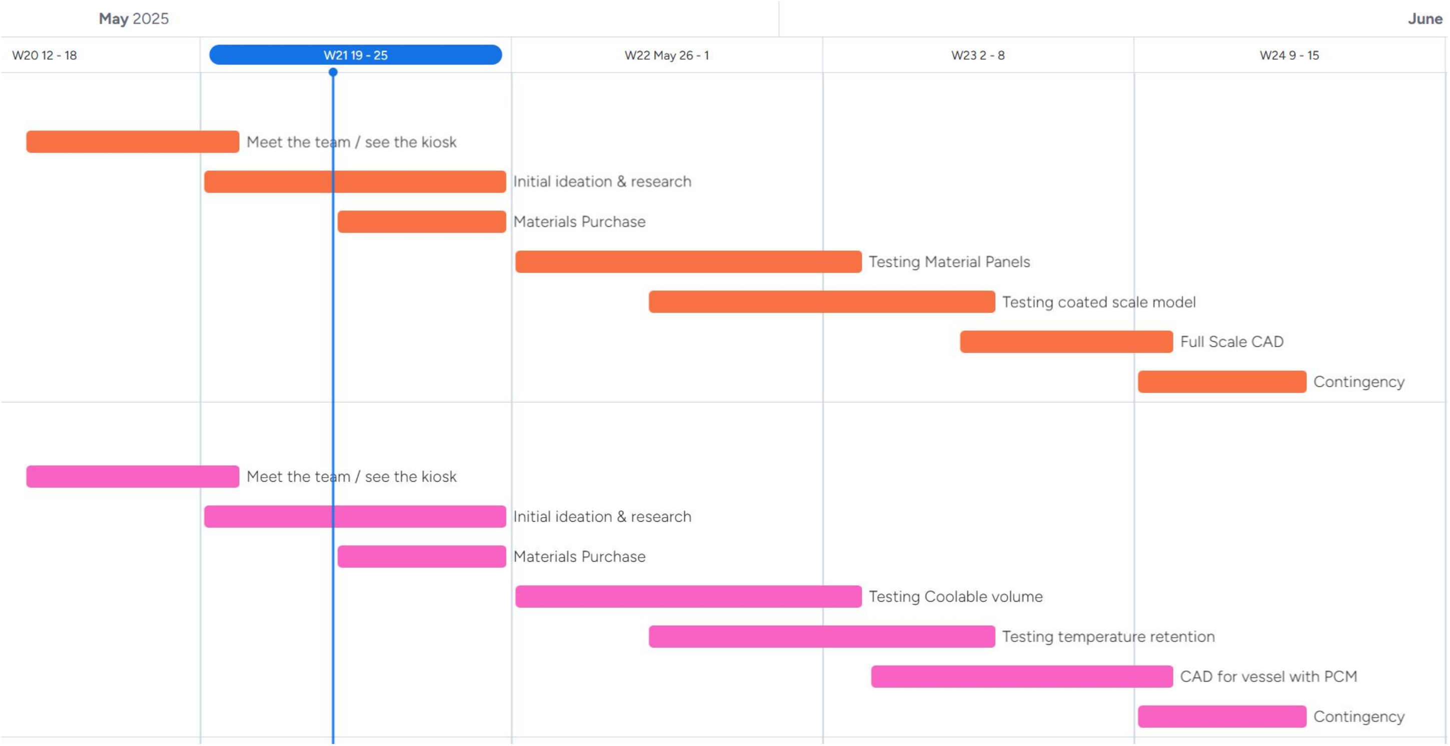
- Material selection with demonstration of temperature drop for a coated vessel

Timeline



Purple - Evaporative cooling

Timeline Continued



Orange - Radiative Cooling, Pink - PCM

The team

Oishi (Bio & Mech) - Strengths: CAD, Design, Time management. Weaknesses: Coding, Github. 3D printing and Laser cutter trained. -

Timothy (Mech & Aero) - Strengths: Report writing, Planning, Fluids. Weakness: Github, Design. Additional Training Required: 3D printing and laser cutting

Alex (Mech & Aero) - Strengths: CAD, Mechanics & Materials, Design. Weaknesses: Git, Coding, Structures. Additional Training Required: OpenSCAD, Air flow testing or simulation

Materials

A broad range of materials and testing apparatus will be required to verify and validate our design concepts. Below is an initial list of equipment that we may need to acquire externally

Electronics & Instrumentation

Digital Thermometers

Humidity Sensors

Handheld Anemometer

Electric USB Fan

Heating apparatus (heating lamps)

Materials

PCM Thermal Pad

Ceramic / Terracotta Sheets, Reflective Foil

1-2 Litre bucket (PE?)

Costing

Working with a £150 budget, most of budget is expected to be spent on the purchase of equipment for building a prototype. A rough estimate of the prices are listed below:

<u>Electronics & Instrumentation</u>

Water Temperature Sensor - £5-10

Ambient Temperature and Humidity Sensors - £2-7

Handheld Anemometer - £10-20 (note: may be possible to borrow from CUED)

Electric Cooling Fan - £3-8

Heating apparatus (heating lamps/ Fan Heaters) - ~ no more than £20 (estimated)

<u>Materials</u>

PCM Thermal Pad (100mmx100mm) - £3-6 per pad

Ceramic / Terracotta Sheets, Reflective Foil - ~£10 (estimated)

1-2 Litre bucket (PE?) - ~£5

It is unlikely that the total cost of our proposed approach will exceed £100, giving us some buffer in case of additional equipment needed or if alternative approaches are required

Materials & Costing

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<u>Materials</u>

PCM Thermal Pad - £3-6 per $0.01m^2$

Ceramic / Terracotta Sheets, Reflective Foil - ~£10 (estimated)

1-2 Litre bucket (PE?) - ~£5

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Risk Assessment

Activity	Potential Risk	How We're Handling It
Handling PCM materials	Leakage, skin contact, irritation (if not sealed properly)	Using sealed pouches + wearing gloves just in case
Cutting/assembling insulation/frames	Cuts from scissors or sharp edges (e.g. metal strips, foil)	Using safety scissors, cutting on mats, and sanding any sharp edges
Using fans or small electrical parts	Short-circuit, minor shock, overheating	Only using low-voltage (USB/battery) components, testing everything beforehand
Working with reflective/foil materials	Eye strain, heat absorption if misused	Avoiding direct sunlight glare; keeping surfaces outside-facing or shaded
Heating setups (e.g. sun or lamp tests)	Overheating, burns if using lamps	Not leaving setups unattended, using lamps in safe, ventilated spots
General material handling	Minor splinters, rough edges, falling objects	Sanding surfaces, keeping workspace organised, wearing gloves where needed

Contingency

Evaporative Cooling

- If the system dries out too quickly, we'll increase the water reservoir or wick thickness, or integrate clay tiles beneath to retain moisture.

PCM Cooling

- If PCMs don't reduce the temperature enough, we'll increase PCM mass, improve thermal contact with aluminium fins, or switch to a more suitable melting point.
- If packs leak or aren't available, we'll use DIY paraffin pouches or temporary gel pack substitutes while maintaining reflective insulation.

Radiative Cooling

- If insulation performance is weak, we'll add more layers (foam, bubble wrap), adjust the air gap size, or combine with PCM or evaporative methods.

General Contingencies

- If materials are delayed, we'll prototype with recycled or easy-to-source items (cardboard, bottles, foil, stones).
- If we run out of time, we'll prioritise qualitative results and visible observations — just enough to prove concept and direction.