Water Evaporation Cooler

Sustainable Refrigeration in the Developing World

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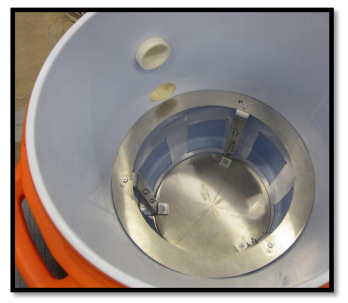
Problem Statement & Objectives

- Create low cost, easy maintenance, off-the-grid refrigerator
- Use a low pressure evaporative cooling cycle
- Maintain ~ 10°C steady-state temperature
- Condense and reuse water
- Powered by batteries charged from solar panels

Preliminary Capillary Action of Sand Test

Fine grain sand in a vertical container easily saturates from a shallow pool of water within a few seconds

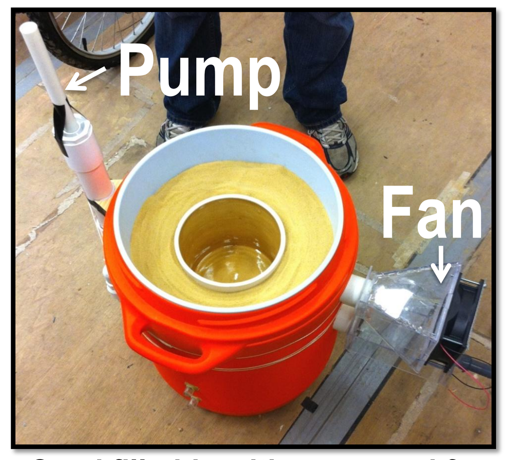
Device Construction & Components



Empty water reservoir at bottom of container

Wire & cloth permeable airflow tubes

Food storage pot & airflow tubes above water reservoir

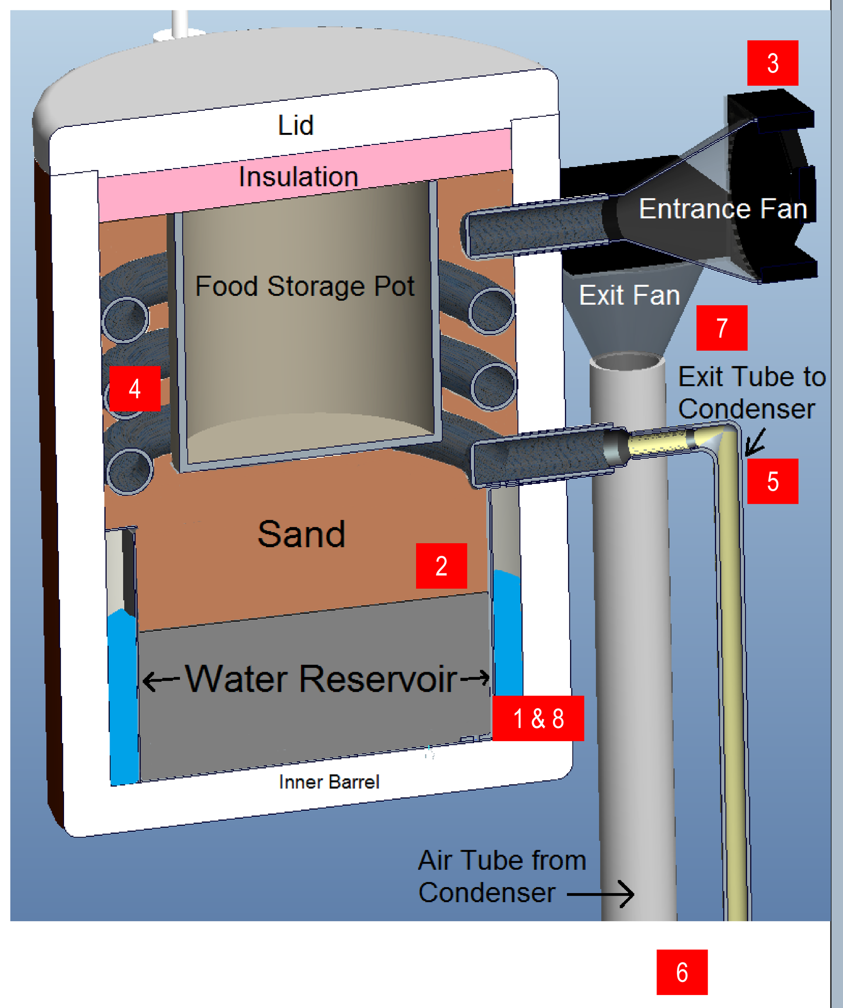


Sand filled-in with pump and fan attached to cooler

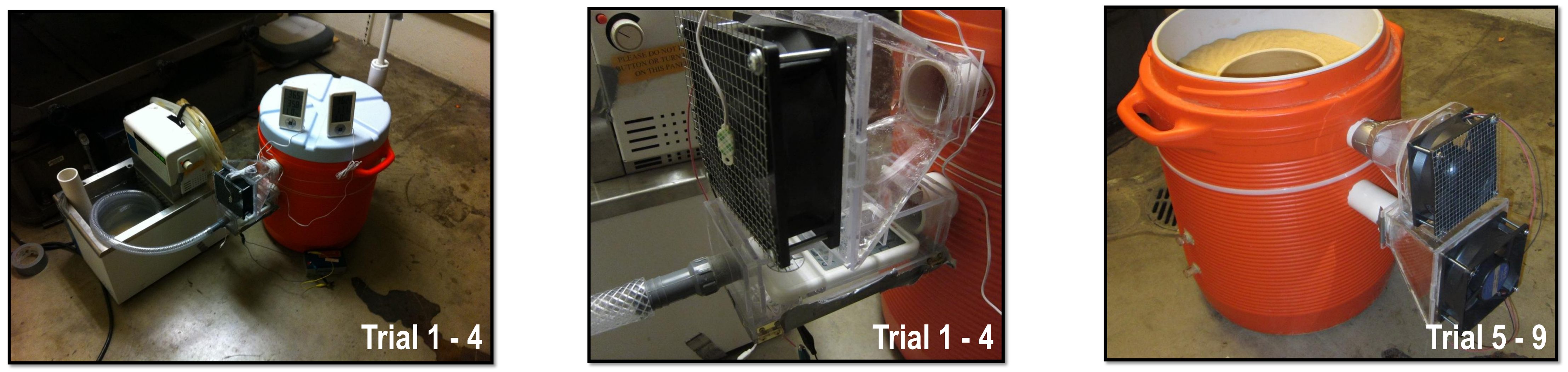
Insulation above food storage pot

Device Operation

1. Water is pumped into reservoir
2. Sand absorbs water
3. Entrance fan pushes air in
4. Air evaporates water through tube walls
5. Saturated air travels to condenser
6. Water condenses in tubes underground
7. Exit fan pulls air out
8. Water is pumped from condenser to reservoir



Testing Procedures and Operating Conditions

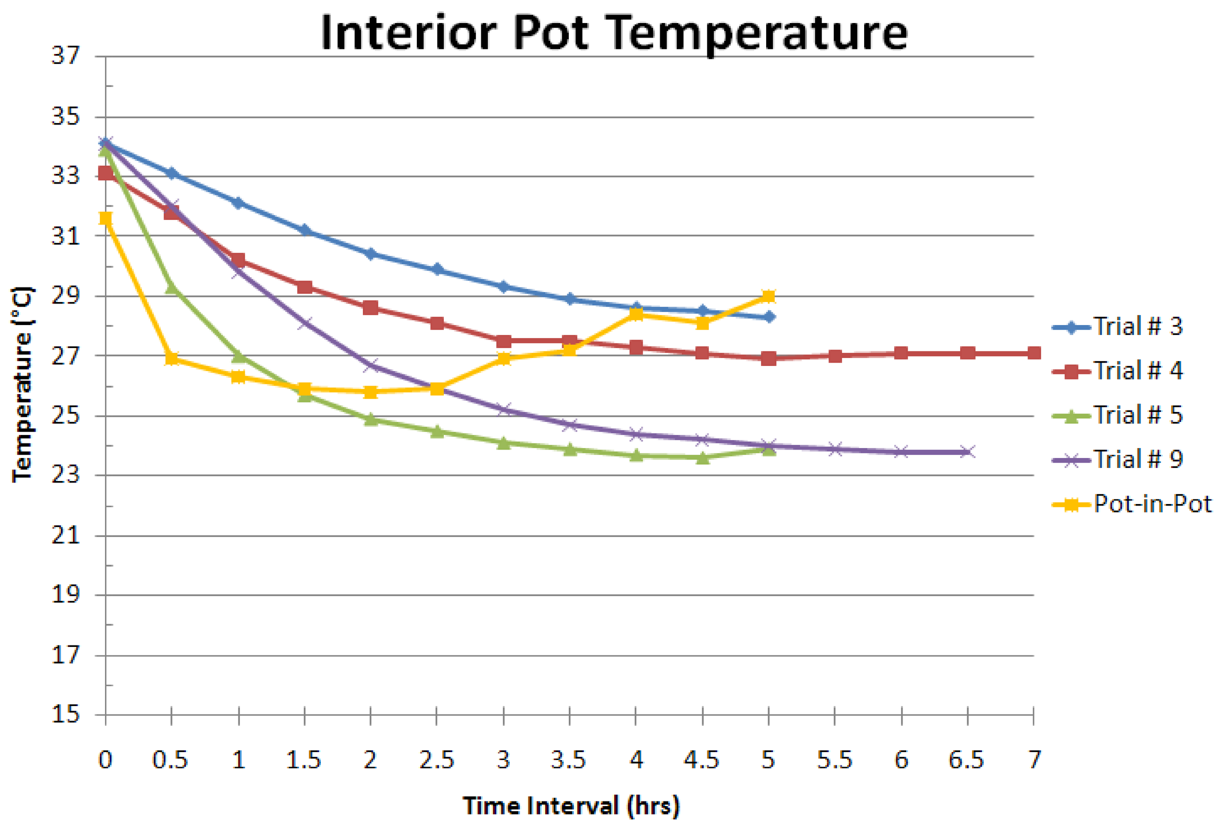


Testing was completed in a large incubator set to approximately 38°C with a relative humidity of under 20%. Nighttime was simulated in a room set to approximately 21°C with a relative humidity of 55%. A total of 56 hours was spent conducting tests.

Tests Conducted

Trial	Entrance Fan	Exit Fan	Larger Fan at Entrance	Condenser Run	3 Coils of Airflow Tube	5 Coils of Airflow Tube	Ambient Temp. 38°C (Daytime)	Ambient Temp. 21°C (Nighttime)	Steady State Temperature (°C)
1	X			X	X		X		N/A
2	X			X	X		X		23.6
3	X			X	X		X		28.3
4	X			X	X		X		27.1
5	X	X			X		X		23.8
6	X	X			X			X	19.9
7	X	X				X		X	18.2
8	X	X				X	X		22.3
9	X	X				X	X		23.8
10			X			X	X		24.2

Results



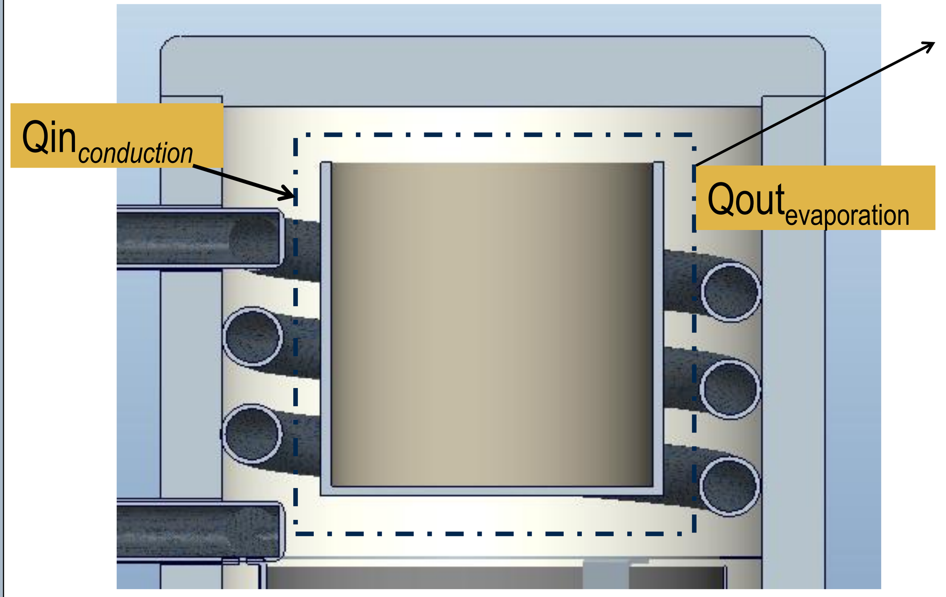
The device consistently outperformed the traditional pot-in-pot cooler used extensively in Third World Countries.

The device **always** achieved a steady state temperature.

Increasing the tubing length by 50%, Trial 9, had no effect on the final temperature.

Trial 5 & 9 both arrive at similar temperatures after the same operation time.

Analysis



Heat conduction into system

$$Qcond = \frac{2\pi Lk(T_{s1} - T_{s2})A}{\ln(r_2 / r_1)}$$

Heat loss through evaporation

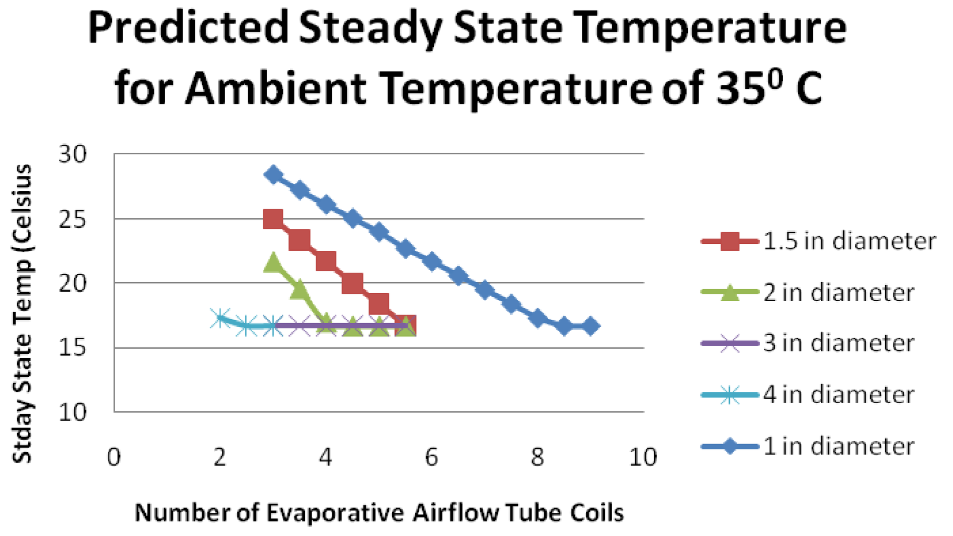
$$Qevap = \dot{m}\, Hfg_{water}$$

Langmuir Equation

$$\dot{m} = \frac{P * SurfaceArea}{\sqrt{\frac{T}{m}}\, k}$$

$k = 2\pi R$

R= gas constant



- Model assumes ideal conditions
- At 35˚C all configurations converge at 16.7˚C
- If ambient humidity remains low, lower inner temperatures can be achieved in cooler climates

Improvements Over Existing Devices

- Condenses and reuses water
  - Pot-in-Pot requires two liters a day
- Is not contingent upon natural air flow
- Insulated from surroundings including radiant ground heat
- Does not require constant support during operation
- Reaches a steady state temperature
  - Pot-in-Pot has no stable temperature

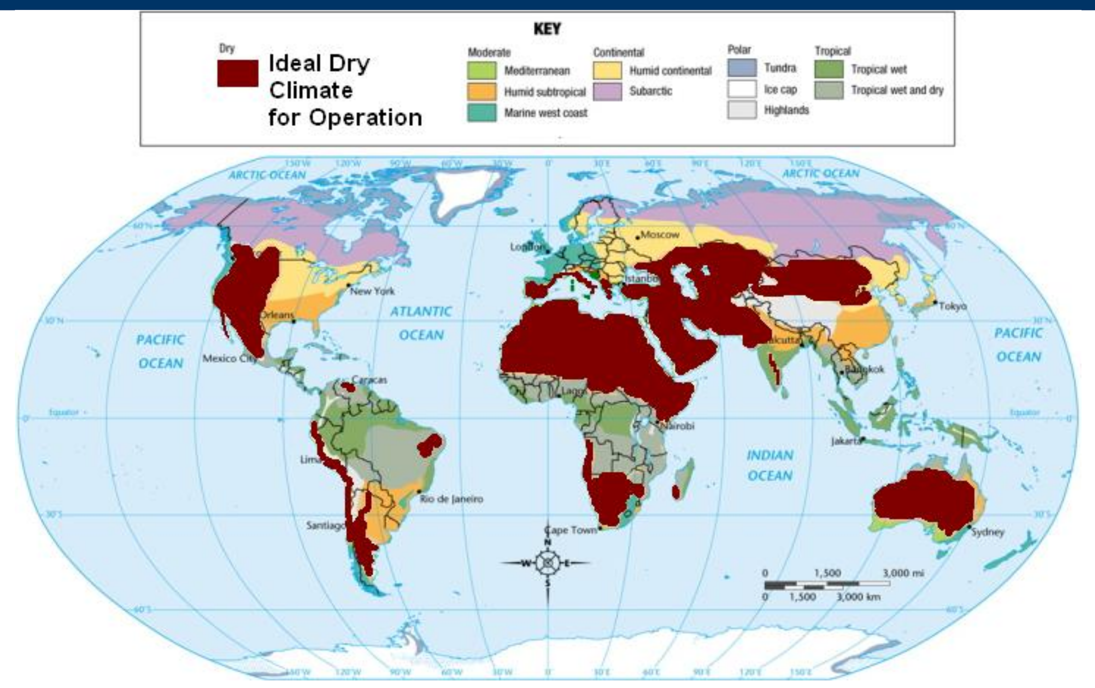
Traditional Pot-in-Pot

Future Design Configuration

To reach the lowest possible temperatures:

- Place fans at entrance and exit of airflow tube
- Use more robust fans to increase cooling capacity
- Increase outer diameter of container to allow for 4 in. diameter airflow tube, which will reduce head loss and increase surface area
- Use 2-3 coils of airflow tube
- Reduce height of reservoir in order to reduce excess volume that must be cooled
- Add silica gel dehumidifier packets to entrance
- Power device with solar panels

Conclusion



Evaporative Cooling is effective in climates that have consistently hot temperatures and low ambient humidity. Grasslands, Deserts, Savannah and Steppe Regions of the globe all provide ideal environments for using this evaporative refrigeration.

Acknowledgments

Special thanks to the Biology department for allowing testing in their facilities, to the AFL for materials and fabrication services, and Dan Velez in the Pao Ceramics lab for making the clay pot.