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El Domo Open Source

Powerless Fridge

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Introduction

Currently 30% of the food cultivated to be consumed is wasted. We thrive in an agronomic system, where nature is the factor that we are the most dependent on. That is why it is important to find a way to preserve food for as long as possible.

In this system, the way food is grown and the means by which it reaches it's final costumer is vary but if the food is wasted, all effort and resources are wasted aswell.

There are many factors by which this food can be damaged; pests are the greatest threat, but once they survive they face new challenges such as storage, transportation or refrigeration.

Many ancient civilizations evidenced this problem and despite not having electricity they developed systems that prolonged the duration of food.

That is why during this investigation the examples of our predecessors and how they responded to the problematic emerged as a result, since a high percentage of our users do not have access to an electrical refrigerant or even electricity.

The following proposal is a concept based of a cold room with the main idea that had to be powerless and with accessible materials. Our propoposal is based on a physical-chemical phenomenon known as “evaporative cooling” allowing it to generate through the evaporation of water to decrease the high temperatures and make the food last for longer time.

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BACKGROUND

Evaporative cooling ancient techniques.

Ancient Persian Storage Systems
The Yakhchāl

According to POCHEE, H.(2017) The Yakhchāl Is an ancient type of ice house hat functions as an evaporative cooler. Above ground, the structure had a domed shape, but had a subterranean storage space. It was often used to store ice, but sometimes was used to store food as well.

Persian engineers were building yakhchāls in the desert to capture and store ice. A yakhchāl takes advantage of the low humidity in desert climates which promotes the evaporation of water.

The yakhchāl is built of a unique water-resistant mortar called sarooj, composed of sand, clay, egg whites, lime, goat hair, and ash in specific proportions, that is resistant to heat transfer and is thought to be completely water-impenetrable. This material acts as an effective insulation all year round.(POCHEE, H.,2017)

Fig.1 Adopted from The Yakhchāl, POCHEE, H.(2017). Recovered From https://www.maxfordham.com

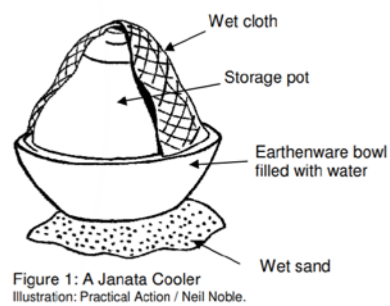
Examples

Some examples of evaporative cooling designs by technology-challenging poverty (2012).

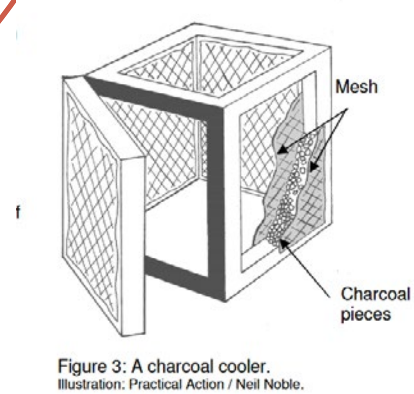
Pot designs: The basic design consists of a storage pot placed inside a bigger pot that holds water.

Bamboo Cooler: It needs a bamboo frame wrapped with hessian cloth ensuring that the cloth is dipping into the water to allow water to be drawn up. Keeping the storage space cool.

Charcoal Cooler: made from an open timber frame. The wooden frame is covered in mesh, inside and out, leaving a 25mm (1") cavity which is filled with pieces of charcoal. The charcoal is sprayed with water, and when wet provides evaporative cooling. The framework is mounted outside the house on a pole with a metal cone to deter rats and a good coating of grease to prevent ants getting to the food.



Janata Cooler (Pot design). Illustration by Neil Noble



Charcoal Cooler.
Illustration by Neil Noble

Static Cooling Chambers

The Indian Agricultural Research Institute has developed a cooling system. The basic structure can be built from bricks and river sand, with a cover made from cane or other plant material and sacks or cloth and There must also be a nearby source of water.

Construction is fairly simple. First the floor is built from a single layer of bricks, then a cavity wall is constructed of brick around the outer edge of the floor with a gap of about 75mm (3”) between the inner wall and outer wall. This cavity is then filled with sand. After construction the walls, floor, sand in the cavity and cover are thoroughly saturated with water.

Main features of the evaporative cooling phenomenon

Basic principles of evaporative cooling by technology-challenging poverty (2012).

Evaporative cooling occurs when the air has a low humidity level.
Very dry air can absorb a lot of moisture so greater cooling occurs.

The cooling may not occur if the air is saturated with water.

An evaporative cooler is made of a porous material that is fed with water.

PROPOSAL

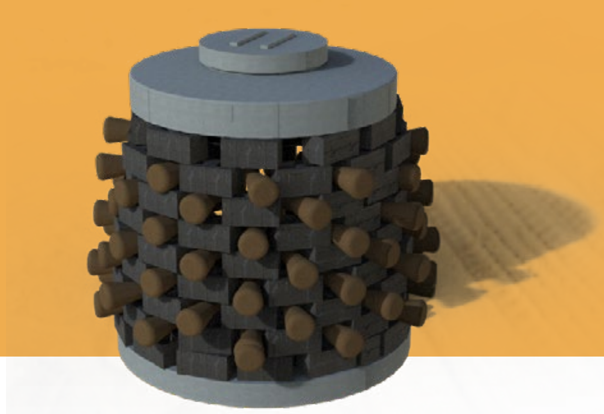
Proposal

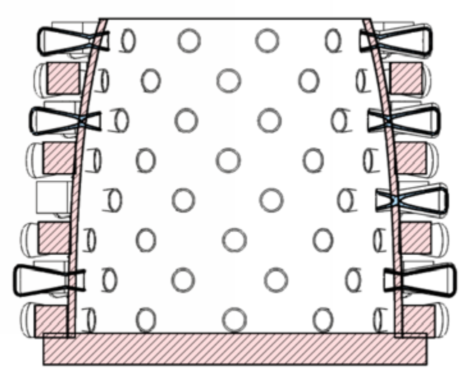
Powerless Fridge

With the background research findings, it was decided to propose a solution for the powerless fridge applying the evaporative cooling methodology at a larger scale. This proposal is thought to be for communal use across villages in the rural areas of Ecuador but it can easily be applied to other areas with a similar climate.

Cold rooms are more common than what they seem, specially in the Middle East. It's very common to find these rooms in households, specifically in areas where electricity is a luxury or the access to it is very limited. Cold rooms are a great way to keep food from going bad as quickly as if they were stored in regular/warm weather.

The proposed structure for this powerless fridge is an under or partially underground structure, formed by metallic rods, encompassed by bricks, concrete, dirt and for the food storage raw clay jars will be used. The jars will be placed in between the bricks inside the structure. The jars will be partially inside the structure because for the evaporative cooling method the jars need to be in constant contact with dirt so when the indirect sunlight evaporates the water stored underground the temperature inside the jars will decrease.





Experimentation

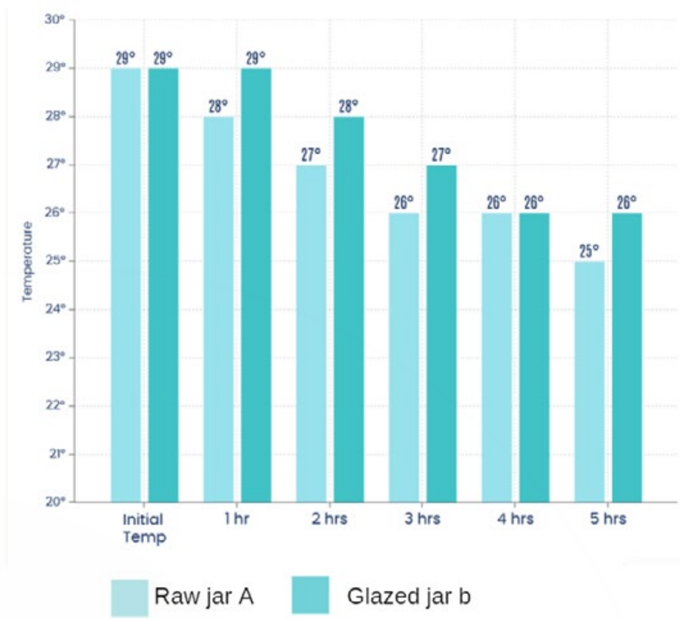
To fully understand how the evaporative cooling phenomenon works, 3 samples were taken. These samples were also taken as proof that the evaporation by cooling phenomenon was the right fit for this project.

Materials:

- Multimeter with temperature sensor.
- 2 clay jars with lids (1 raw and 1 glazed)
- Something to take notes
- Measuring tool

Scenario 1

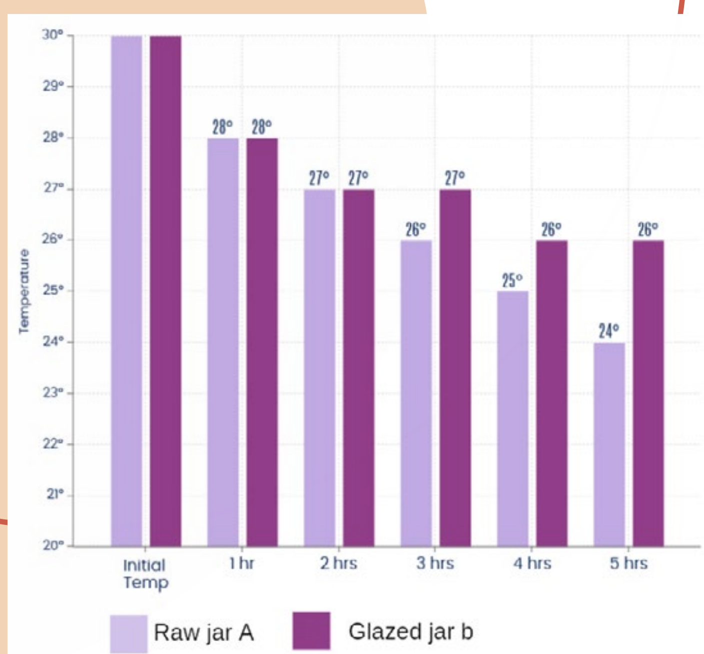
Jar A & B were closed with a lid and covered in dry soil.
The temperature was measured every hour.
They were put in the shade.



Jar A: The final temperature was 5 degrees lower to the initial one.
Jar B: The glazed jar does not allow water filtration. So the evaporation process was slower.

Scenario 2

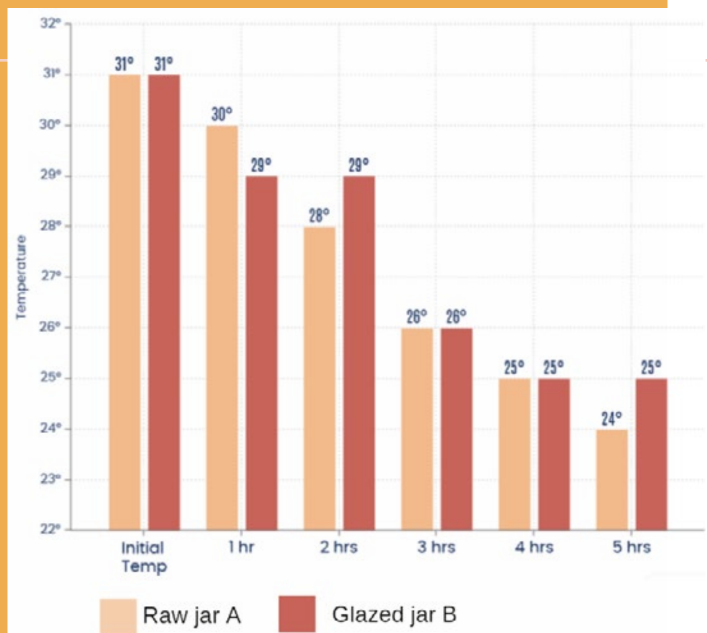
Jar A & B were closed, covered with soil and wet every hour.
The temperature was measured every hour. They were put in the shade.



Jar A: The final temperature was 6 degrees to the initial one.
Jar B: did not get wet at all because of the varnish.

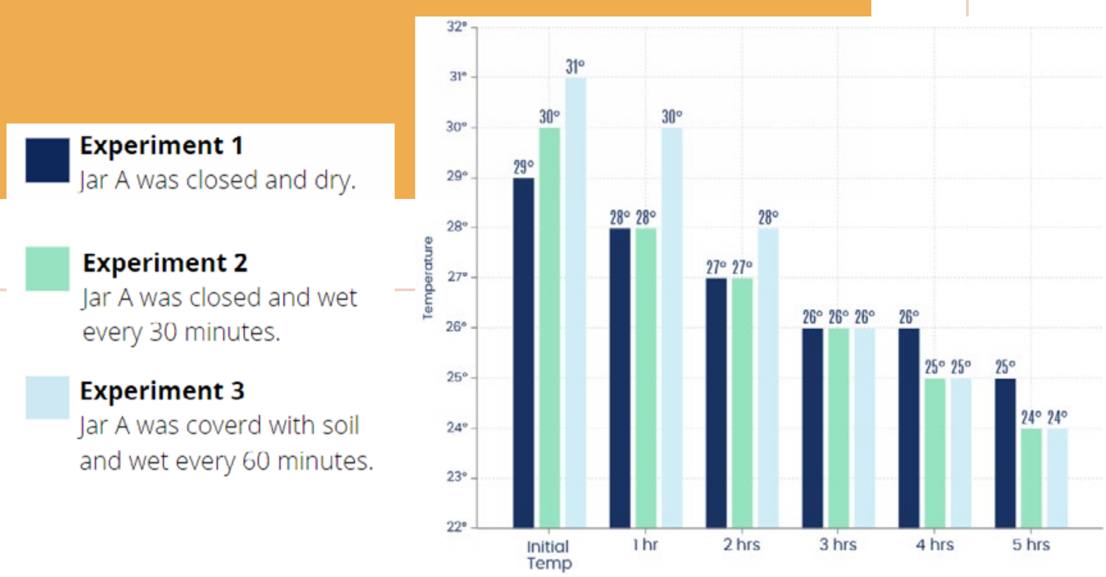
Scenario 3

Jar A & B were closed and wet every 30 mins.
The temperature was measured every hour.
They were put in the shade.|



Jar A: The final temperature was 7 degrees lower to the initial one with the raw jar.
Jar B: After 3 hours it started to rain and the temperature dropped exponentially.

Scenario 1, 2 & 3 | Jar A



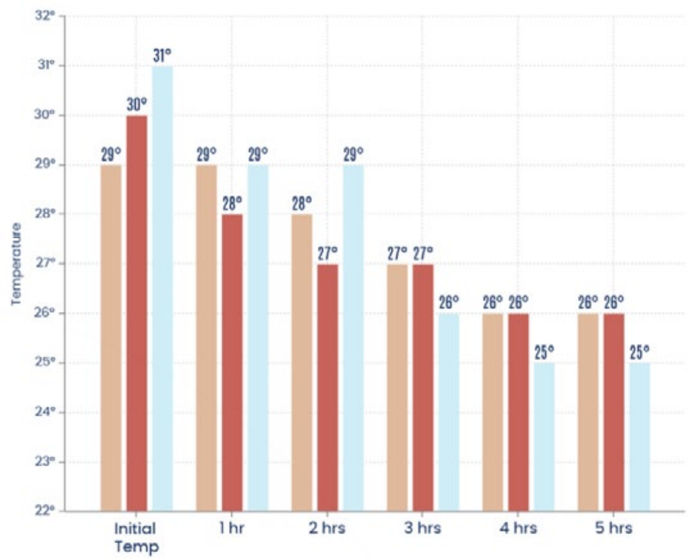
Wetting the jars increases the evaporation process and makes the temperature drop faster.

Scenario 1, 2 & 3 | Jar A

Experiment 1
Jar A was closed and dry.

Experiment 2
Jar A was closed and wet every 30 minutes.

Experiment 3
Jar A was coverd with soil and wet every 60 minutes.

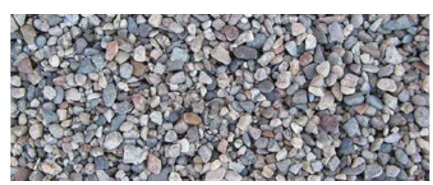


Although the jar was varnished, the temperature decreased.

HOW TO BUILD IT

MATERIALS

This list of materials is needed to build the exact proposal. Feel free to adapt this system as it best fits your necessities as well as the quantity of materials.

MATERIAL	Requirements & Quantity	REFERENCE
Bricks/Cinder Block	Made with fine concrete or cement mortars, used in the construction of walls and walls The block sizes: 40cm x 15cm x 20cm Qty: 81	
Iron Rods	It is hard, malleable and easy to form alloys with other metals. Note: we suggest 2 options considering that it would be necessary to consult or measure the strength of the entire structure and validate the land on which it will be built. -From 4 to 6 Rods No,3 with stirrups every 15	
Clay Jars	Evey jar should fit between the bricks. The measures of every jar will depend on the market and place, but it has to be long to pass the foundation mix and get contact with the dirt. Size: 50cm tall x 20cm wide Qty: 80	
Cement	Cement is a binder formed from a mixture of calcined and subsequently ground limestone and clay, which has the property of hardening after being in contact with water.	
Crushed stone or Gravel	The rocks formed by clasts of size between 2 and 64 millimeters are called gravel. Of all the different types that exist, make sure this is for making concrete mix.	
Sand	This sand is clean and free from salt encrustations.Make sure using the right for the mix. It must have no organic impurities. This sand is commonly used for construction work.	

STEPS

Step 1: Build the Metallic Structure

Separate the metallic rods into two groups: one is to use horizontally and the other is to use vertically to create the net.

Group A (vertical): You will need 15 metal rods that measure 2.7m. each

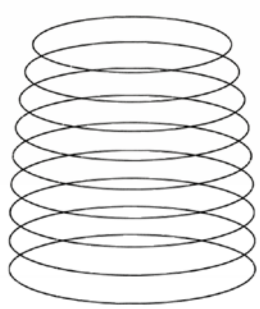
Group B (horizontal): You will need 9 circles made out of metal rods of these measurements:

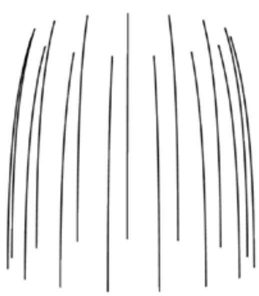
1: D = 1.7m.	2. D = 1.8m.	3.D = 1.9m.
4. D = 2.0m.	5. D = 2.03m.	6. D = 2.06m.
7. D = 2.08m.	8. D = 2.09m.	9. D = 2.1m.

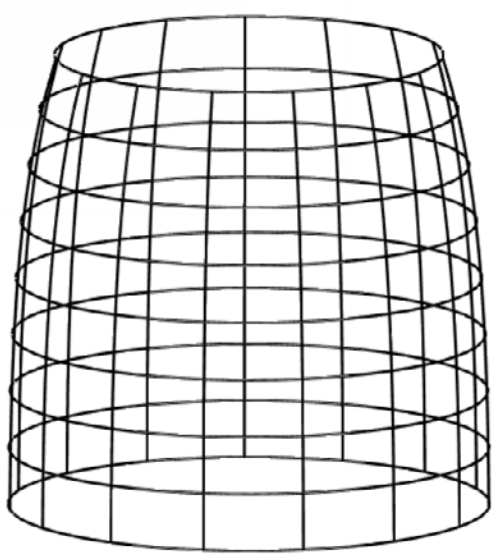
First, create the circles. The previous list shows the exact order (top to bottom) these circles should be placed in the construction. Each circle should have a distance of 25cm. between the next/previous circle.

Once you have placed the 9th. Circle on the ground as a base is time to distribute the vertical rods. Each vertical rod should have 40cm. In between the next/previous rod. The vertical rods should be all hugging the different diameters of the circles in order to create a 'dome' shape.

Create the grid as evenly as possible and secure them while you are placing the other parts. Once you are happy with the grid, weld the connecting points together.





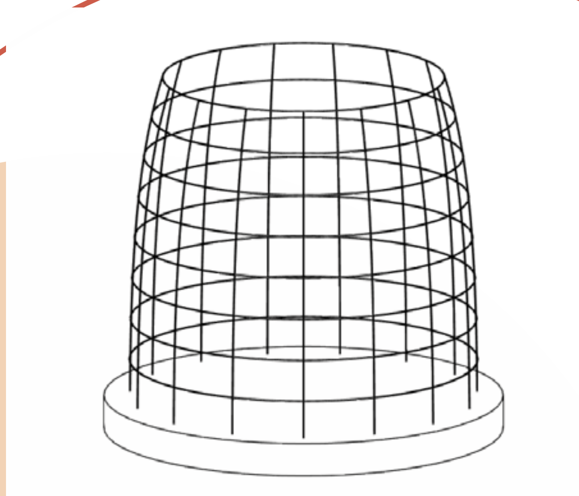


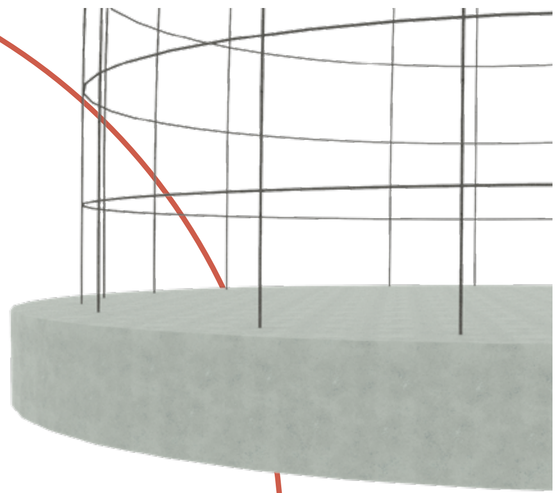
Step 2: Create the base

Dig a circular hole in the ground: 2.5m wide and the depth will vary depending on if the cold room is to be ¾ underground or completely surrounded by soil.

For this proposal, the cold room is to be built completely underground, so the hole needs to be at least 2.5m deep.

Now you need to build a 30-40cm thick concrete base where the metal rods will be kept secure. All you will need to do is scrape off the soil, top soil, and add gravel fill if needed. After that, surround the circular shape with any material you have at hand like wood so that the concrete won't spill all over the dirt.

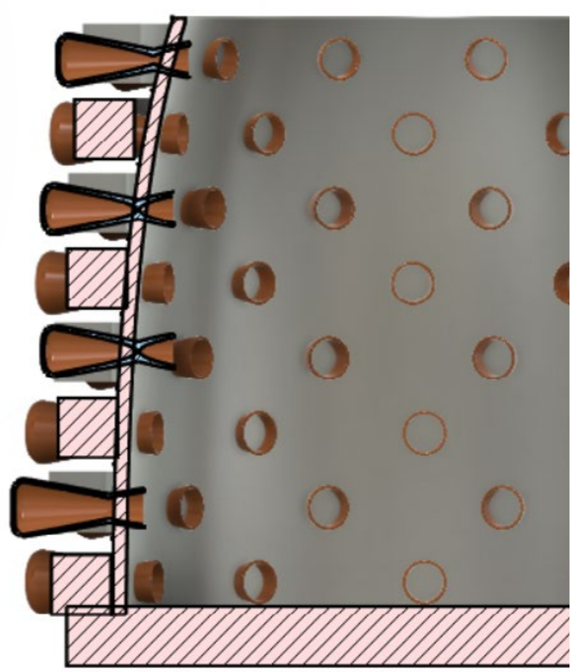




Step 3: Build the grid

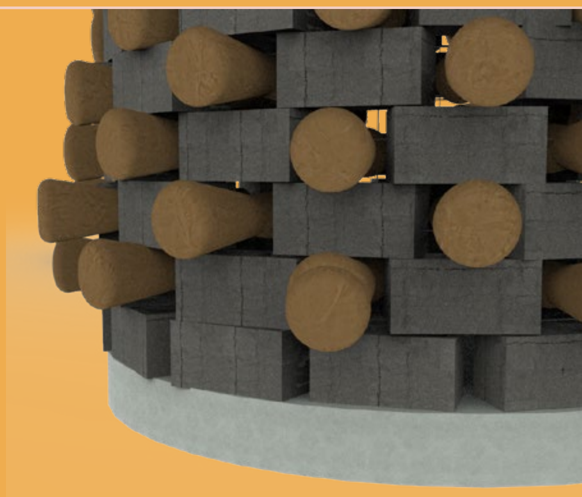
For this step, you will need the cinder blocks, the raw clay jars and concrete. With the help of the previous grid created with the metal rods you will build a pattern alternating in between cinder block and clay jar by levels. In total, there would be 9 levels of the cider-jar pattern to reach the top of the dome.

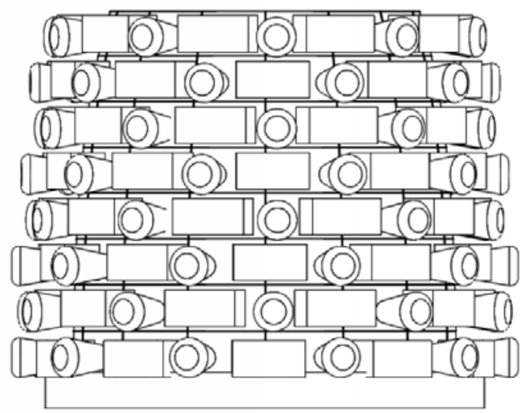
The spaces in the metal rod grid, is where the clay jars should fit while creating each level. Following the shape of the metal rod structure, the building pattern by level goes like this:
cinder block, clay jar, cinder block, clay jar and so on until the circle for the first level is completed. The jars and cider blocks should be secured in place with the help of concrete.



Important: remember that the jars should be in contact AT ALL TIME with the dirt so that the "cooling by evaporation" phenomenon happens. The hole in the jars should be facing front and only exceeding the cinder by a couple centimeters on the inside yet on the outside the jar's body should be aligned with the inside wall created by the cinder blocks.

And if necessary, build a mold with wood or bamboo to keep the concret mix away from the bottom of the jar.





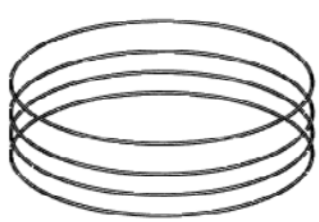
Step 4: Build the top

Now we need to build the top of the dome. For this, we will build another metal structure first (see below 1.1) to create the base for the concrete.

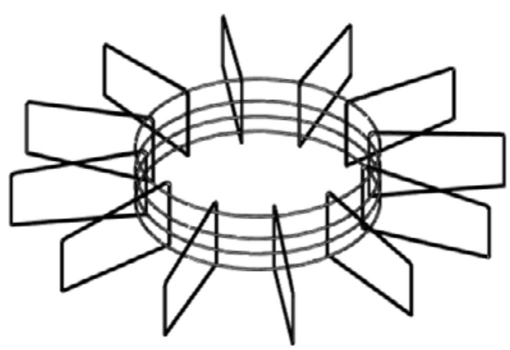
For this structure we will need:

- 3 circles made out of No.3 metal rods (10m). Each circle has a diameter of 1m. (1.0)
- 12 rectangles made out of No.3 metal rods (21m). Each rectangle measures 56cm. by 32cm. (1.1)

The rectangles need to surround the circles, distributed as evenly as possible.



Reference 1.0

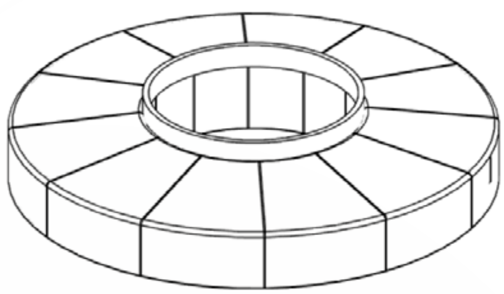


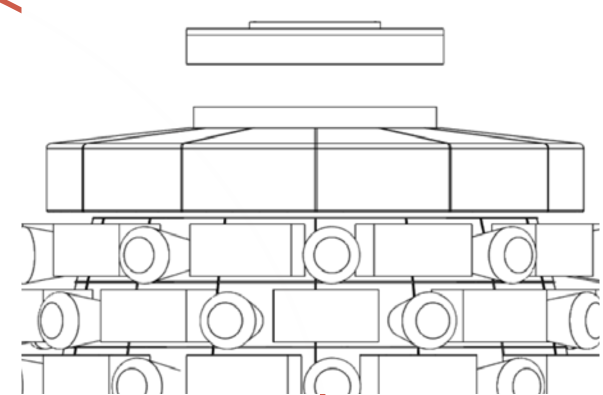
Reference 1.1

Now what is left to do is too place the metal structure on top of the dome, this metal structure should be at floor level since it will be the entrance to the dome.

Once you have placed it, pour concrete to give shape to it. You can use wood, or any material you have in hand to help shape the cement.

After the base is dry, with cement add a 10cm. tall wall surrounding the entrance, this will be the tongue so that the groove (which will be the door) will go on top of it and help keep away insects and water from entering the cold room, as well help to keep the heat away from the inside.

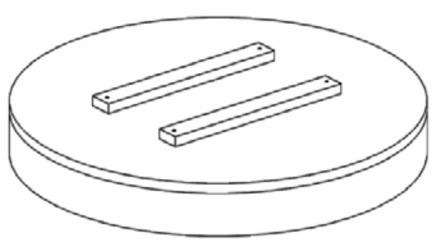


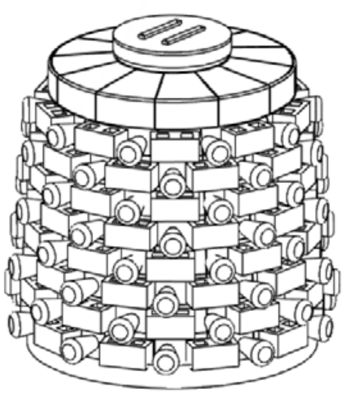


Step 5: Build the cover

It is important that the lid covers a minimum of 10 centimeters of the hole, this will prevent rainwater from entering.

You can place pallets in a row or simply add a board that covers it. And you can also use wood or metal, whichever is the most accessible.





EXPERIMENTATION

Prototype

To prove the system integrated into the cold room, a prototype was made. The temperature was monitored every hour (1) for 6 hours and after every temperature check, the soil surrounding the prototype was wet in order to check how effective the "evaporative cooling" phenomenon would be in the real proposal.

Materials:
- 1 clay pot with a lid (15cm wide by 20cm deep)
- multimeter
- soil
- water

Procedure

Time	Temperature (outside)	Temperature (inside)
7:00	19C°	19C°
8:00	19C°	19C°
9:00	20C°	18C°
10:00	21C°	18C°
11:30	23C°	17C°
1:00	23C°	17C°

The lowest temperature was reached when the sun was at it's highest point. The pot was under the shadow receiving direct sunlight for instances.

ADAPTATIONS

The principle underlying evaporative cooling is the fact that water must have heat applied to it for it to change from a liquid to a gas state (evaporate). When evaporation occurs, this heat is taken from the water that remains in the liquid state, resulting in a cooler liquid.

Evaporative cooling systems use the same principle as perspiration to provide cooling for machinery and buildings. A cooling tower is a heat-rejection device, which discharges warm air from the cooling tower to the atmosphere through the cooling of water. In the HVAC industry, the term "cooling tower" is used to describe both open- and closed-circuit heat-rejection equipment.

If you need to do any variation or adapt it according to your/the community needs, just keep in mind the principles on which the evaporative cooling method works and make sure they are present in any variation/modification you do and the cold room will be effective.

Mandatory Aspects:

- The dirt must have contact with the exterior part of the jar all the time.
- Check the type of soil and prepare the base of the dome according to its needs. Consult an expert if necessary.
- Plant small plants or grass on top of the dirt that covers the dome, this way the dirt will be more stable and the roots of the plants will hold water that will be released later on helping to keep the cold room cool.
- The metallic skeleton structure is a MUST so that the dome won't collapse because of the weight of the dirt, plants, etc. that lays on top of it.

¿What happens if the size of the jar changes?

Nothing, just make sure the jars are tall enough that when put in the middle of the cinder blocks, at least half if not more is showing so that it will be in direct contact with dirt and the evaporative cooling phenomenon will take place.

¿How to adapt the big structure to a smaller one?

Just keep in mind the layers this cold room has and the principles of the evaporative cooling phenomenon: breathable yet solid material for the jar (it should be able to absorb water), at least half of the jar should be in contact with dirt 100% of the time, indirect sunlight, make sure to wet the dirt often, depending on the climate conditions: if it is too sunny and hot, you should be watering the dirt at least once a day, twice would be better (in the morning and at mid-day). If it's cooler, not much water is needed.

¿What other materials can I use to cover the structure?

Dirt and plants or a mixture of dirt and sand. We want to have these type of materials or elements on top of the dome so the water can pass through them easily, reach the jars and after that, the evaporation can happen with ease again while the water in its other form (gas) can go through them as well.

CONCLUSIONS

1. The model developed using the system is only an exemplification of what can be done to take advantage of the evaporative cooling phenomenon in areas where electricity is not available/limited.

2. This model is a concept. The system can be easily adaptable based on the requirements/necessities of each individual case.

3. The key for the evaporative cooling phenomenon to work is to have the containers where the food is to be stored be of a breathable material and for them to be in direct contact with the soil, which needs to be wet in order to cool off the contents inside the containers.

4. If the fridge is to be completely underground, small to medium plants and grass on top of it is a great idea because it will make the soil more stable which means it will always be covering the fridge and the roots are excellent water collectors so the soil will be wet for longer which will lead to not having to wet the soil as often as if there was only dirt.

5. If the fridge is to be 2/3rds. underground, it's best to build a cabin. This will help by creating a barrier from direct sunlight to the jars/containers with the food and when open, not as much heat will enter the fridge as if it was fully exposed to the sun.

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ANNEXES

TECHNICAL SHEETS

Material	Metal Rods
Description	These are used to create the metallic grid which will give more strength to the structure of the cold room. Also to create the structure for the entrance for the dome
Measurements	Group A: 41m of ¼” metal rods (No.3) Group B: 56m. of ¼” metal rods (No.3) Entrance: 30m of ¼” metal rods (No.3)
Use	Separate the rods into two groups: one is to use horizontally and the other is to use vertically to create the net. Group A (vertical): You will need 15 metal rods that measure 2.7m. each Group B (horizonal): You will need 9 circles made out of metal rods of these measurements: 1: D = 1.7m. 2. D = 1.8m. 3. D = 1.9m. 4. D = 2.0m. 5. D = 2.03m. 6. D = 2.06m. 7. D = 2.08m. 8. D = 2.09m. 9. D = 2.1m. Entrance: you need to build 3 circles with a diameter of 1m each. (9.5m of metal rods) & build the structure to give shape to the top of the entrance. For this, you will build 12 rectangles that measure 56cm x 32cm. Each. (20.5m of metal rods).

	
Material	Cinder blocks
Description	These are used to create a grind to put the clay jars in between.
Measurements	81 blocks of 40x20x20cm.
Use	The blocks will be piled up in 9 levels, alternating between jar and cinder blocks.

	
Material	Clay (Raw: oven-cooked but with no varnish. We need the clay to be able to absorb water and let go of gas/vapor)
Description	These are put in between the cinder blocks. The measurements don't need to be exact, the closer the better but just keep in mind the jars should fit in the cinder block grid, if the jars are thicker then a thicker layer of concrete should be used on top of the blocks to reach the top of the jars.
Measurements	80 clay jars of 50cm. Tall x 20cm width.
Use	The blocks will be piled up in 9 levels, alternating between jar and cinder blocks. The opening should be facing the inside of the chamber, the body should be at least showing 50% out of the cinder blocks, and be in direct contact with dirt 100% of the time.

Material	Concrete
Description	To secure the cinder blocks/jar in place. To separate the inside of the chamber from the outside. To create the foundation of the dome and secure the metal rods in place. To create the entrance of the dome.
Measurements	As needed
Use	The concrete is to secure the jars and cinder blocks in place. In case the jars exceed the height of the block, concrete layers should be added until they are on level again. The concrete is used to creator the inside layer of the chamber that seals the inside with no contact with dirt, limiting animals, insects, etc. to enter the chamber and eat/disrupting the food kept in it.

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