Postharvest Fruit and Vegetable Storage

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Refrigerated cold rooms

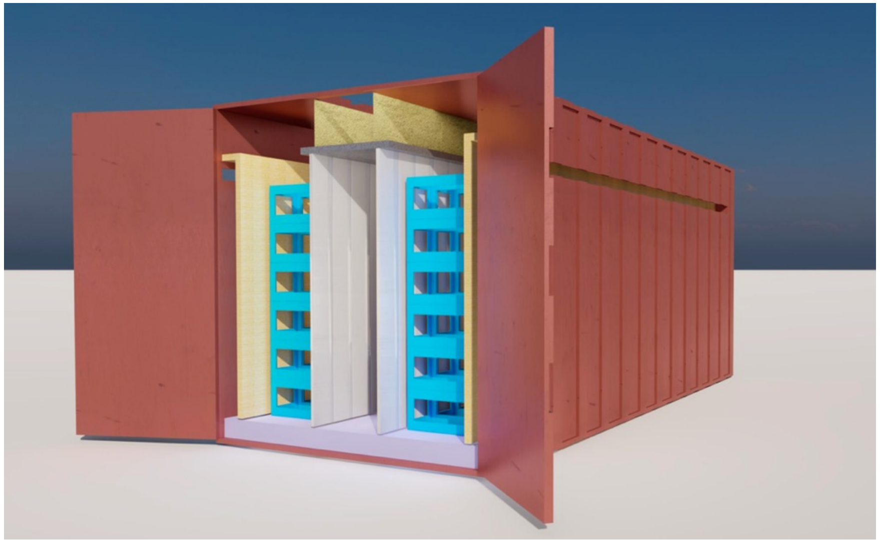
Charcoal evaporative cooling chambers

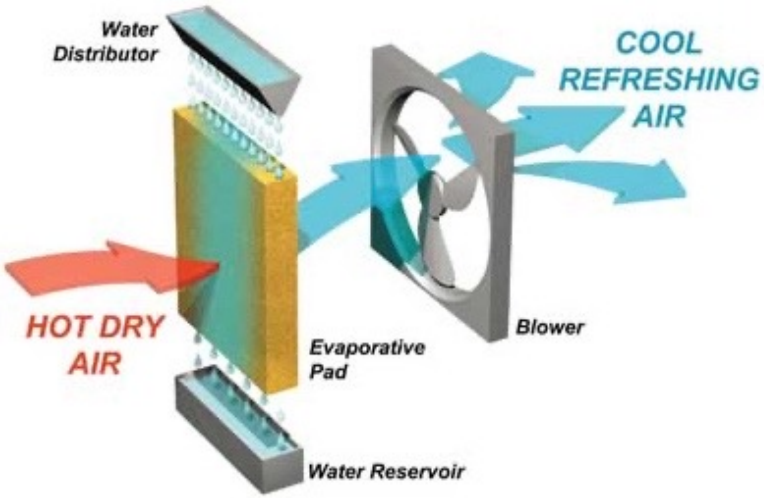
- Farmers have a need for improved postharvest fruit and vegetable storage
  - Food spoilage, lower prices at market, time spent transporting produce
- Areas for improvement for refrigerated cold rooms:
  - Cost of construction, energy consumption, low humidity
- Areas for improvement for charcoal cooling chambers:
  - Temperature decrease, water consumption, cost

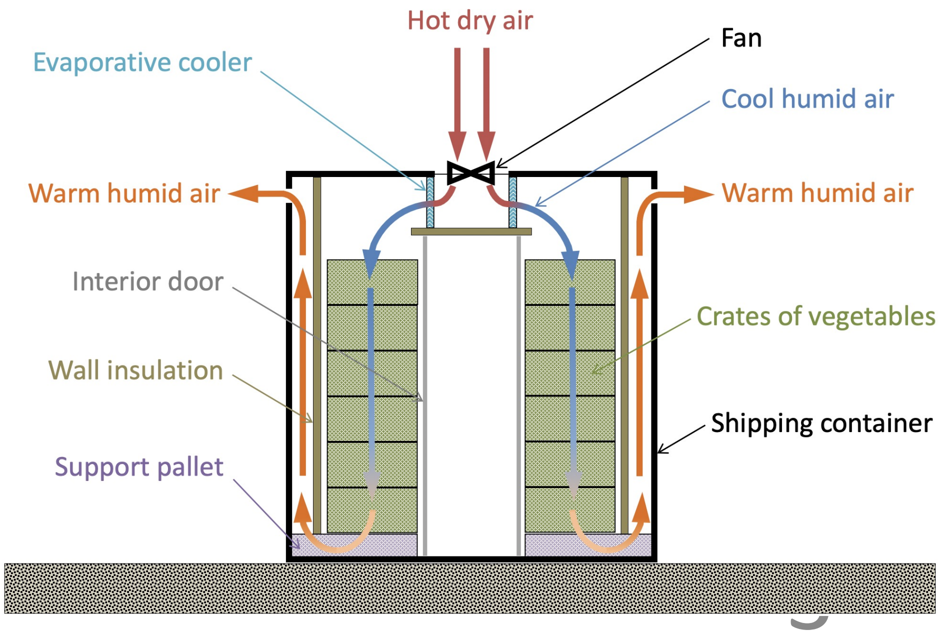
Shipping Container Based Design

Idea:

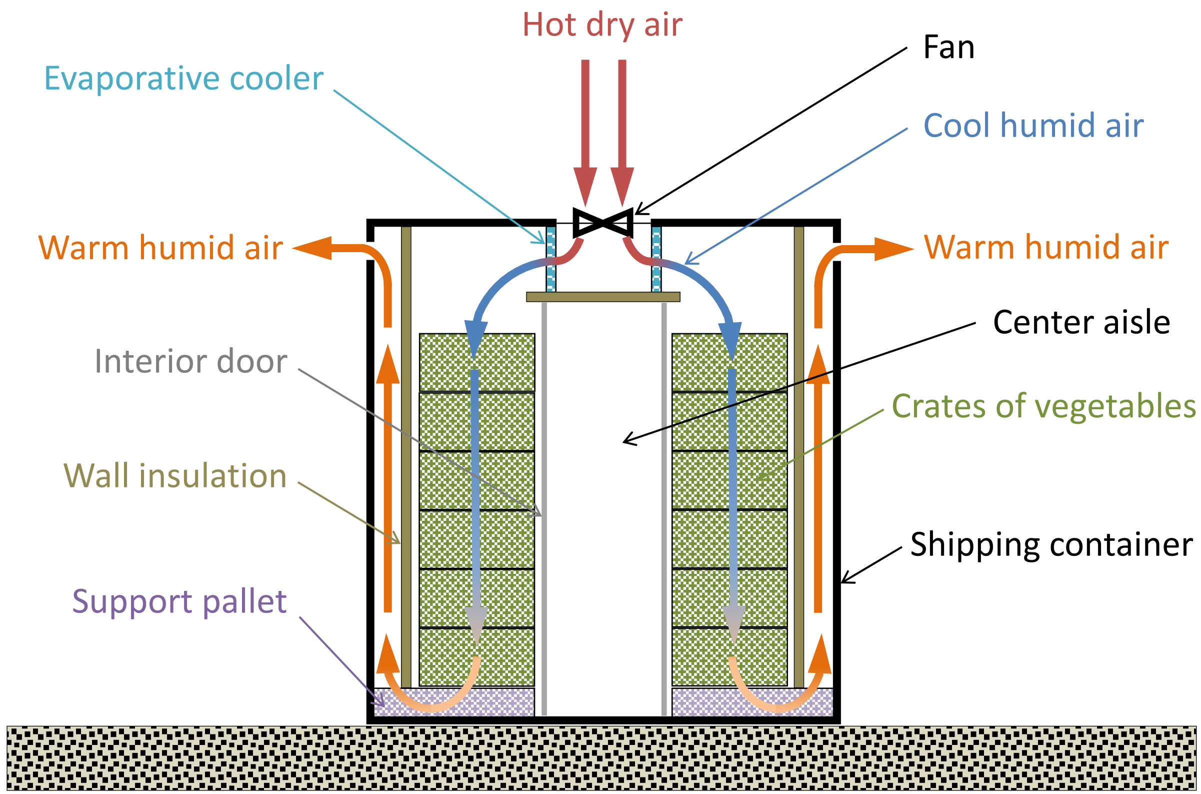
- A used shipping container can be the primary structure
- "Swamp cooler" blows cool air directly through crates







Evaporative cooling
pad materials:



Cross section of shipping container showing airflow pathways (view from the front with doors removed)

Shipping Container Based Chamber at MIT

Interior of the shipping container located on MIT's campus (prior to the installation of the electronic control system and insulation on the left wall and the ceiling). The team is modifying this 10' x 8' x 8' container to function as an evaporative cooling chamber. Visible is insulation (blue) on both open doors, insulation on the back wall (pink), an insulating wall (pink) spaced 3" from the exterior steel wall of the container, and the evaporative cooling unit hanging from the center of the ceiling. The stacks of plastic vegetable crates filled with water bottles are on the back-right corner of the container but are not visible.

Shipping Container Based Chamber at MIT

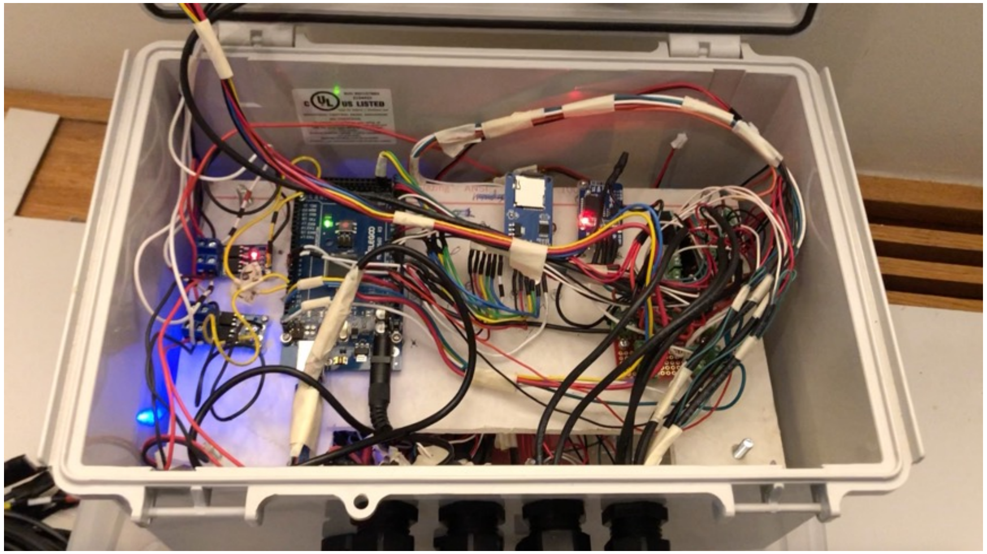
Left: Crates (black) in the experimental storage area are visible prior to the installation of the front wall. The experimental storage area contains 3 stacks, each stack is 6 crates tall, and each crate contains eighty 8-ounce water bottles. The door to the left of the crates is mounted on an overhead track

Center: The experimental storage area after the installation of the front wall to isolate the three stacks of crates. The door is in the closed position.

Right: The experimental storage area with the door slid open to expose the crates for removal and placement.

In practice the full length of the container would be used with multiple sliding doors to allow enclosure and access to all of the storage area. For our current testing we are using ¼ of the available storage area to avoid purchasing an additional 4,000+ water bottles.

Electronic Control System



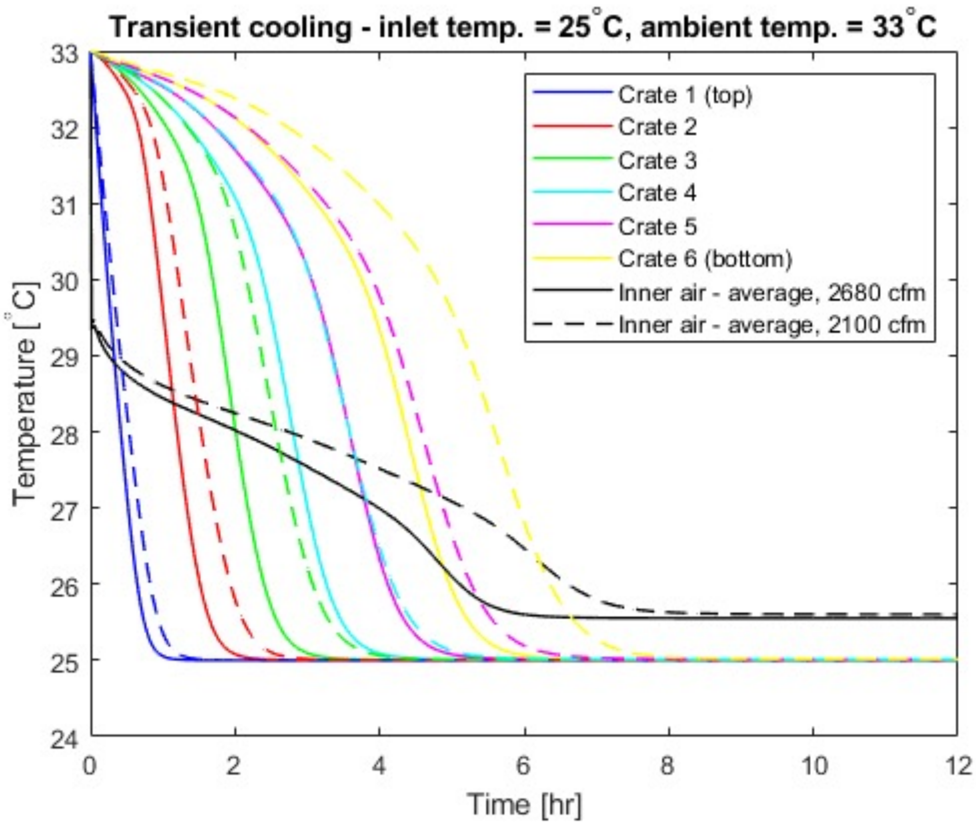
Measures and records

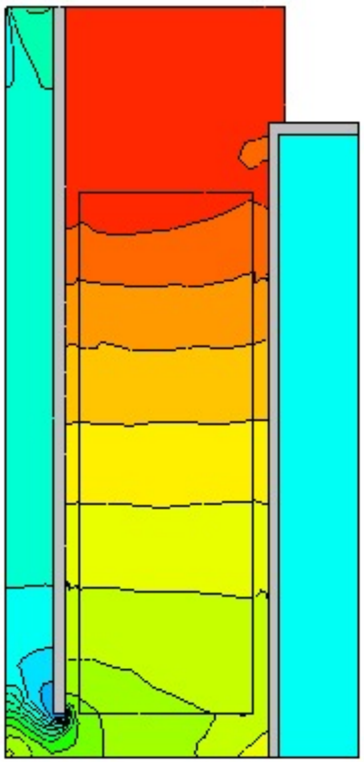
- Temperature
- Humidity
- Pressure
- Air speed
- Moisture
- Water levels

Controls:

- Water pump
- Fan speed

Heat and Mass Transfer Modeling





- Expected that we can cool vegetables by 8 °C in 6 hours
- Requires ~1.6 kW of solar panels and ~12 kWh of battery backup

MIT D-Lab designing for a more equitable world

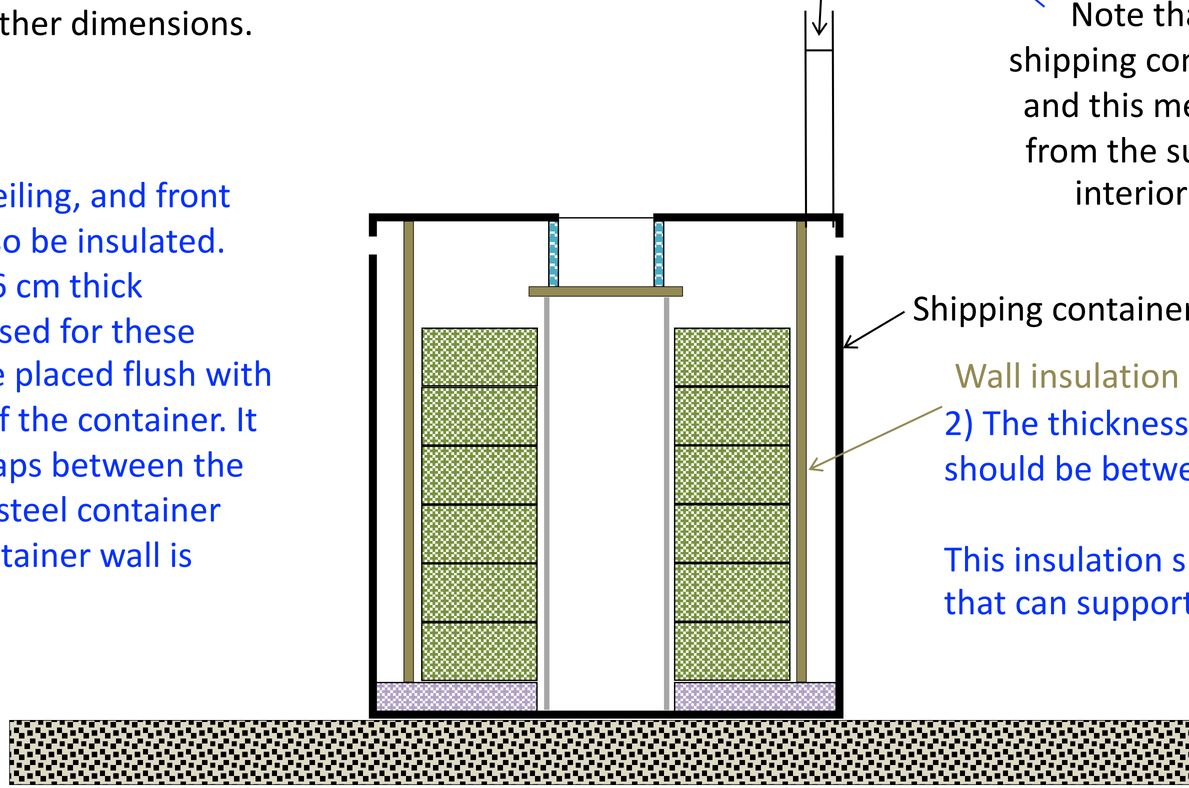
This gap width will be determined in part by the crate dimensions, wall insulation thickness and available materials

We can make a final decision once we have the other dimensions.

1) On the sides of the chamber, the gap between the interior of the shipping container wall and the wall insulation should be between 4 cm and 7 cm

Note that the wall of the shipping container is corrugated, and this measurement is made from the surface closest to the interior of the container

3) The back wall, ceiling, and front wall (doors) will also be insulated. The same 4 cm to 6 cm thick insulation can be used for these surfaces but can be placed flush with the inner surface of the container. It is OK to leave air gaps between the insulation and the steel container wall where the container wall is corrugated



Shipping container

Wall insulation

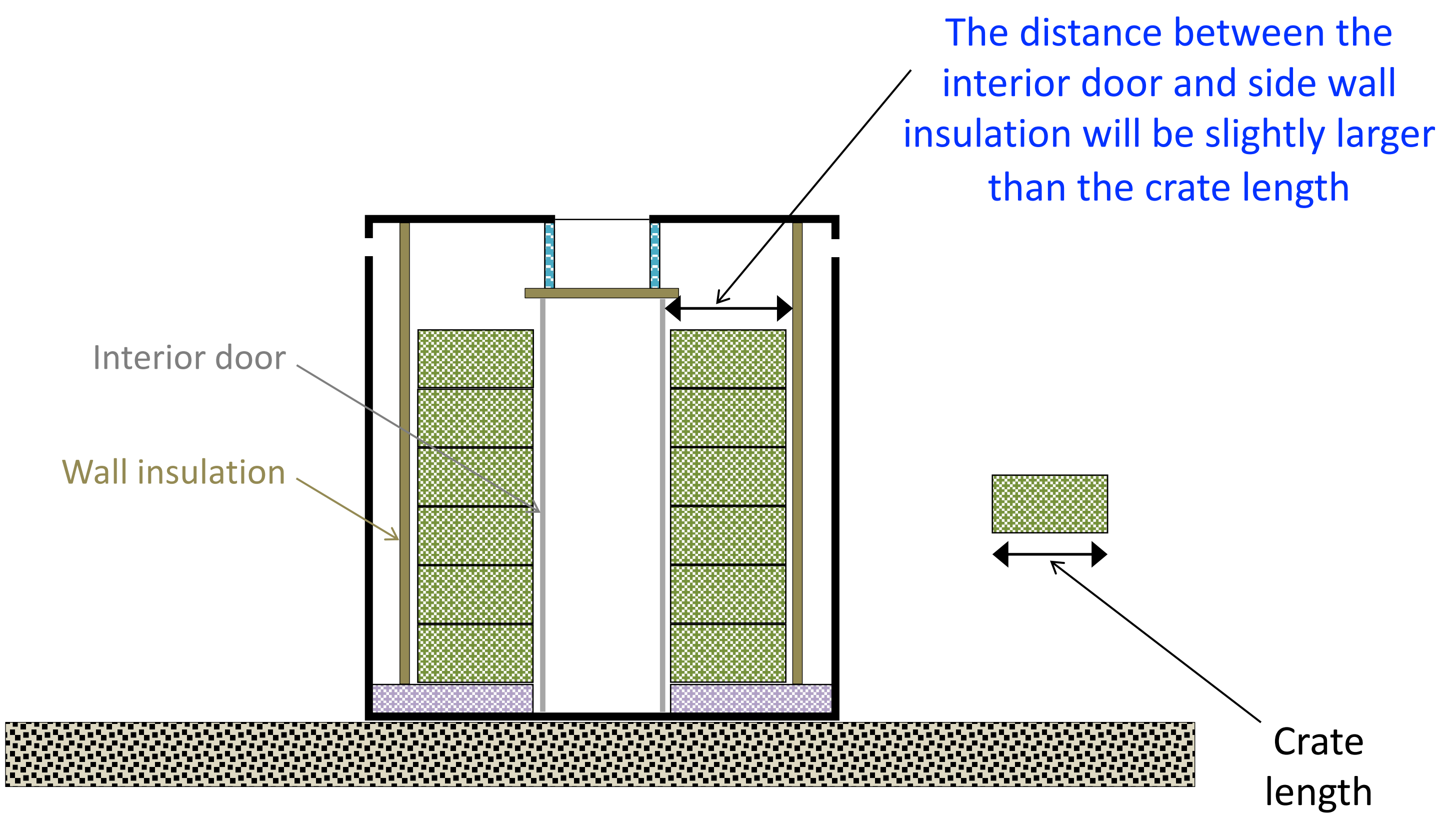
2) The thickness of the wall insulation should be between 4 cm and 6 cm

This insulation should be a rigid board that can support it’s own weight

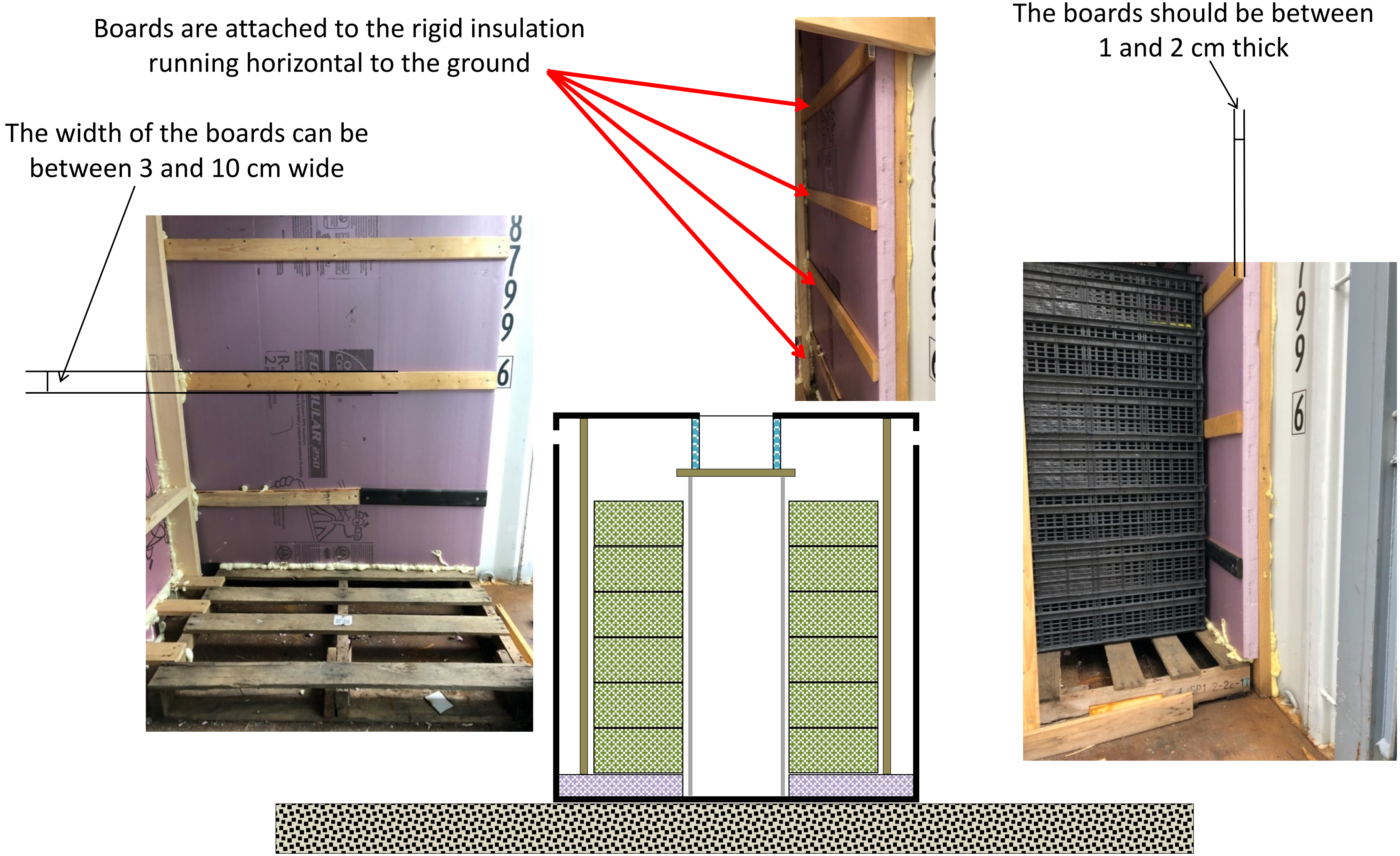
Gap between the side container wall and the wall insulation

We have found that there are fairly consistent sizes for vegetable crates around the world. Our chamber design is intended to be tailored for the most common crate sizes in a specific region. The size of the crates will impact the location of the interior doors

Can you send the dimensions of any common crate sizes? (length, width, and height)



Distance between the side wall insulation and the interior door



Air flow optimization (inducing turbulence)

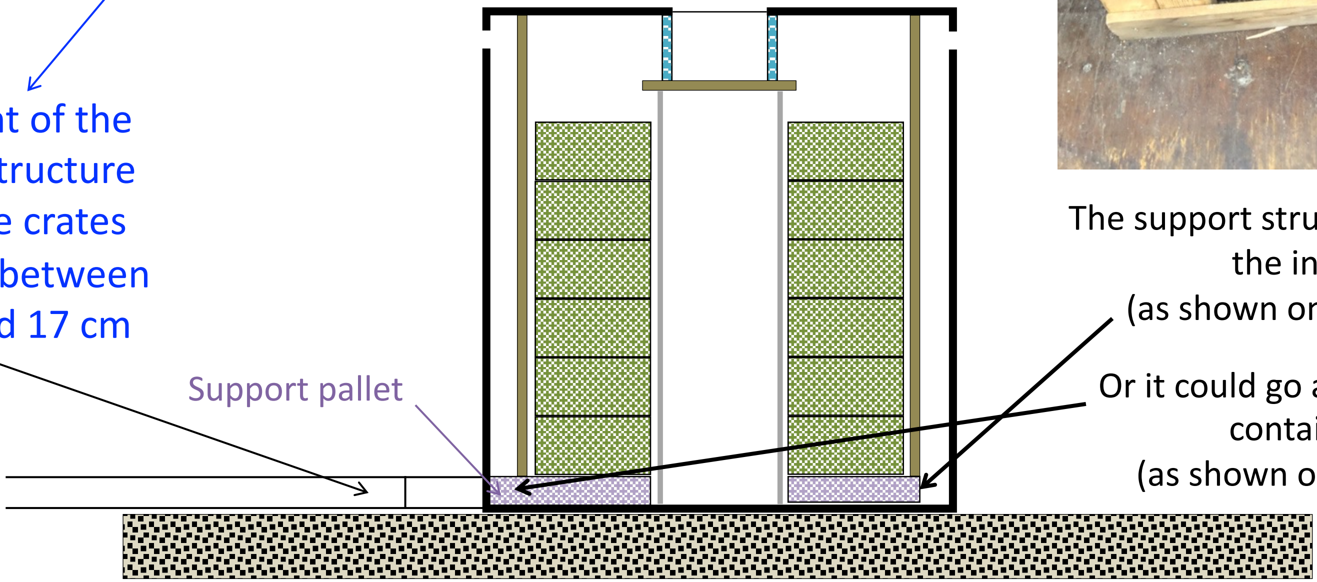
There needs to be gaps in the support structure to allow air to flow down into the structure from the crates above, and then into the channel that is the gap between the wall insulation and the container wall

The total height of the support structure will depend on the thickness of the structure itself, the **minimum** height of the **air gap** inside the support structure is 10 cm, but can be larger

Air can flow through the bottom of the crates through these openings

The height of the support structure under the crates should be between 12 cm and 17 cm

Support pallet



The support structure could stop at the insulation (as shown on the right side)

Or it could go all the way to the container wall (as shown on the left side)

Support structure and airflow under the crates

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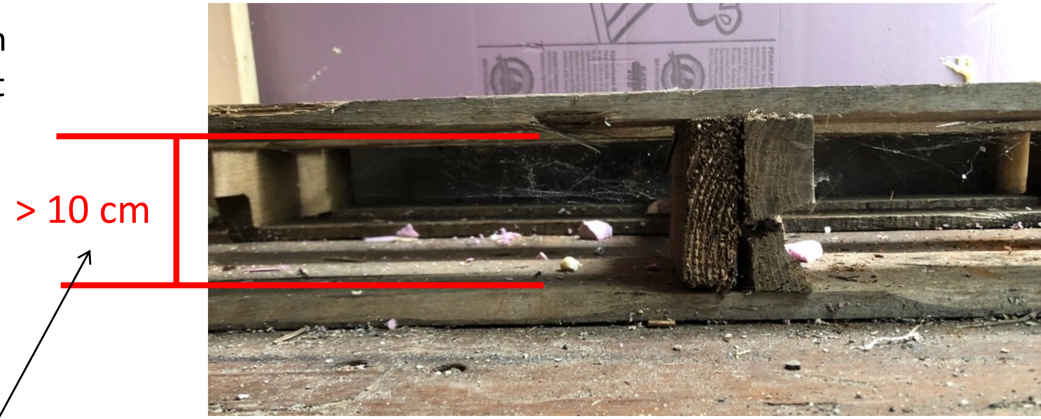

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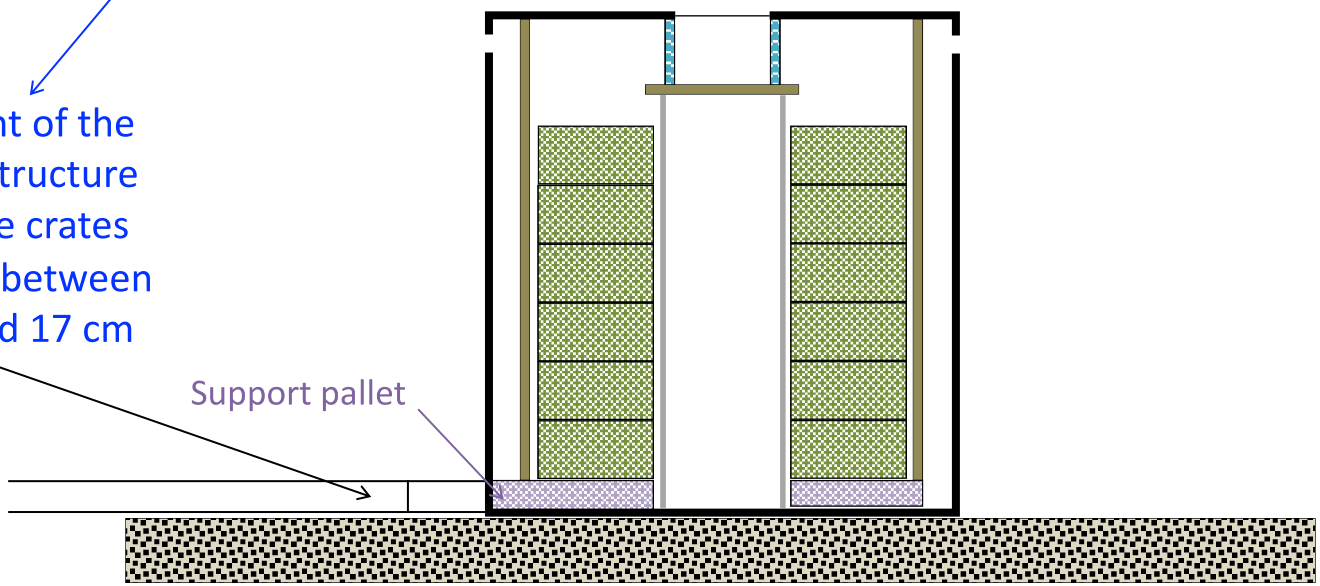
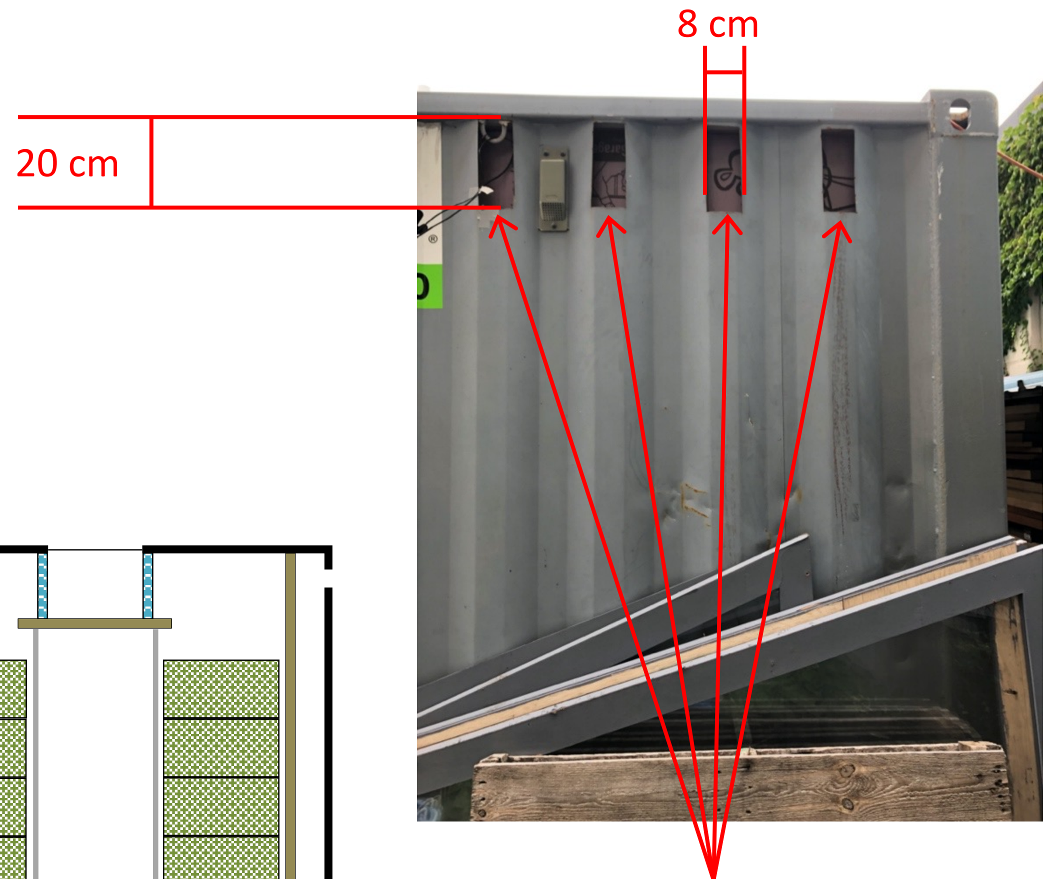
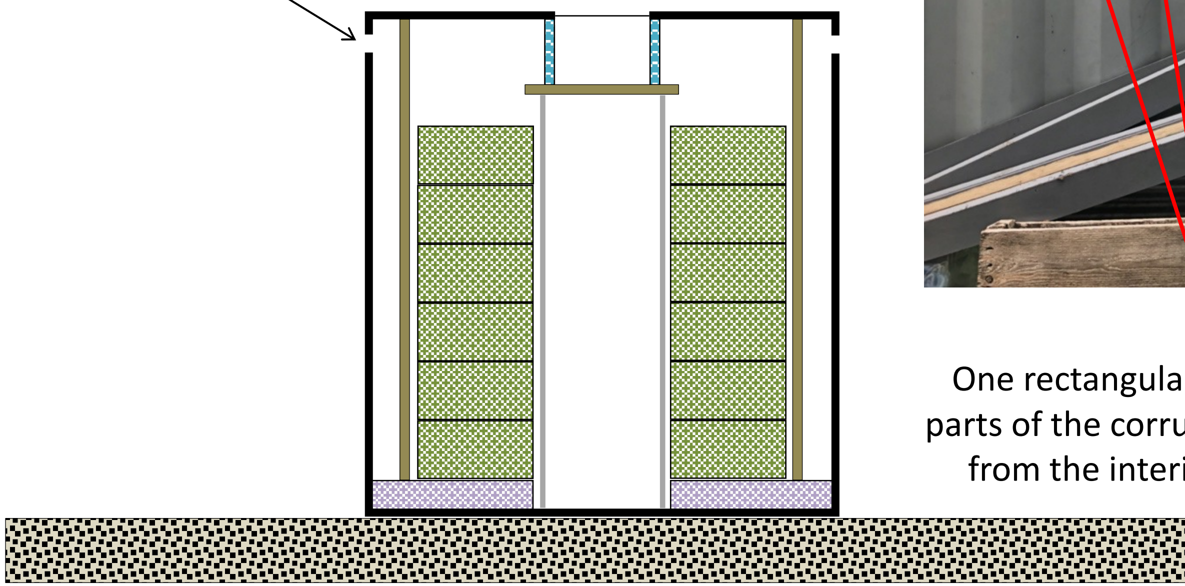


Support structure and airflow under the crates

Holes will need to be cut in the exterior wall of the shipping container for air to exit

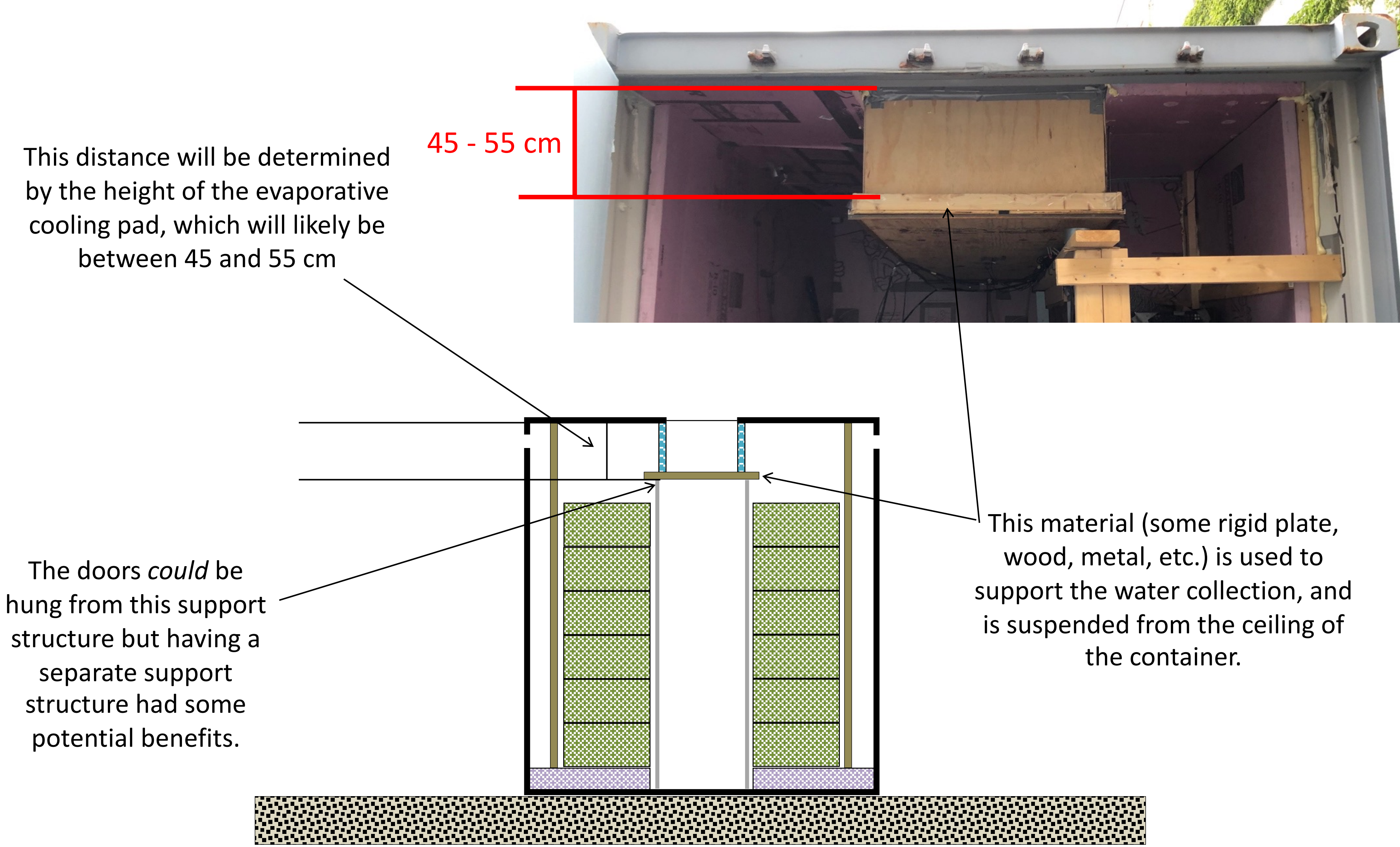
We cut holes 8 cm wide and 20 cm tall near the top of the container wall at each of the parts of the exterior wall that is farthest from the interior of the container



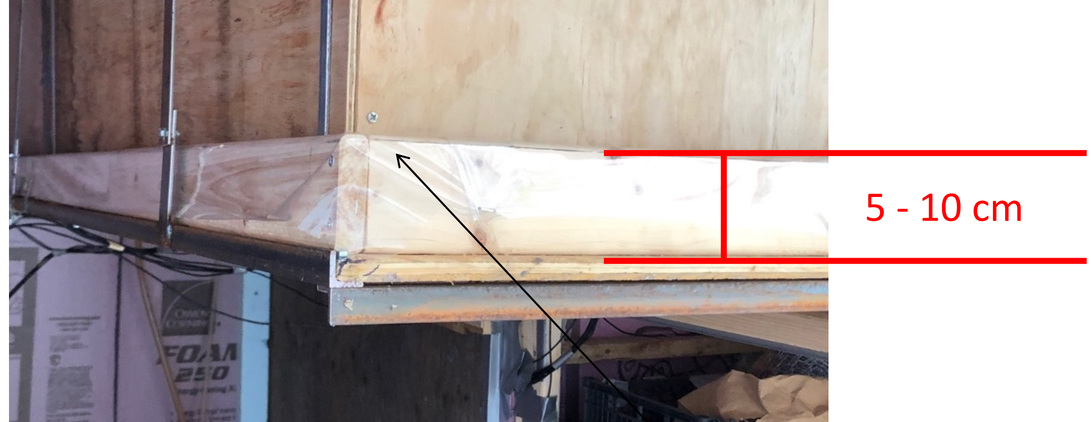


One rectangular hole at each of the parts of the corrugation that is farthest from the interior of the container

Holes for airflow exit



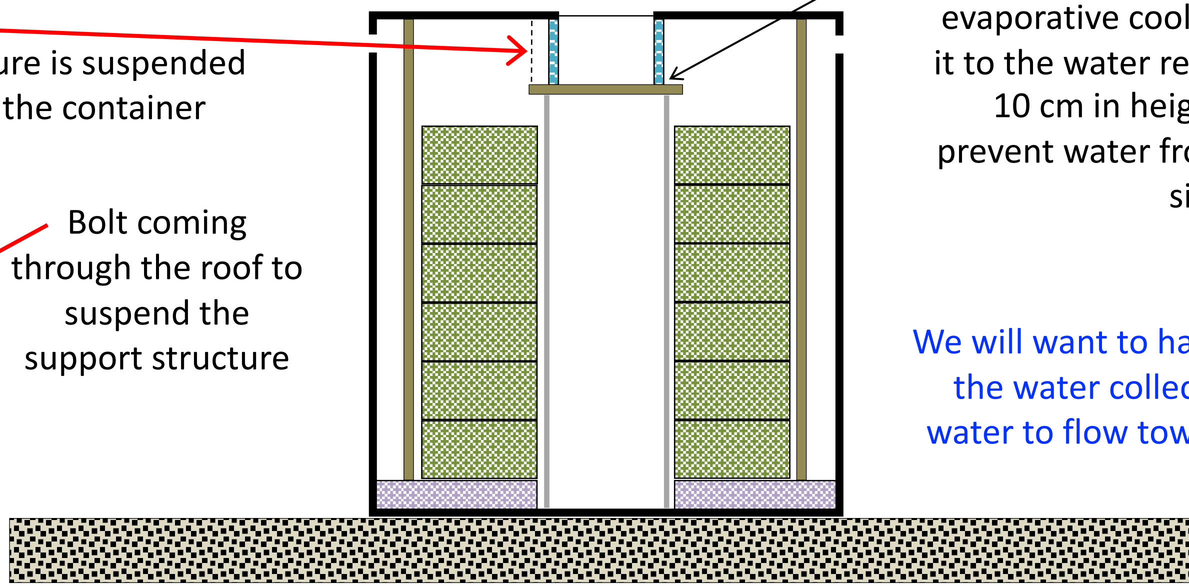
Support structure for evaporative cooling pads and water collection



A plastic sheet covers the plate and collects excess water coming off the evaporative cooling pad and return it to the water reservoir. A lip of ~ 5-10 cm in height is needed to prevent water from exiting over the sides

The support structure is suspended from the roof of the container

Bolt coming through the roof to suspend the support structure



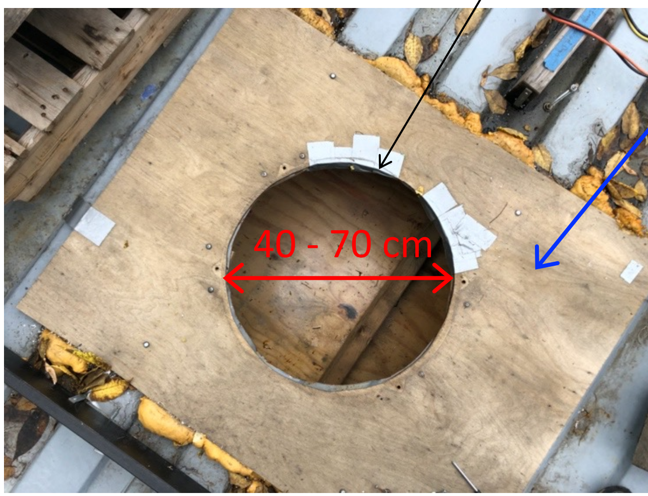
We will want to have a slight tilt inside the water collection tray to allow water to flow towards the drain hole

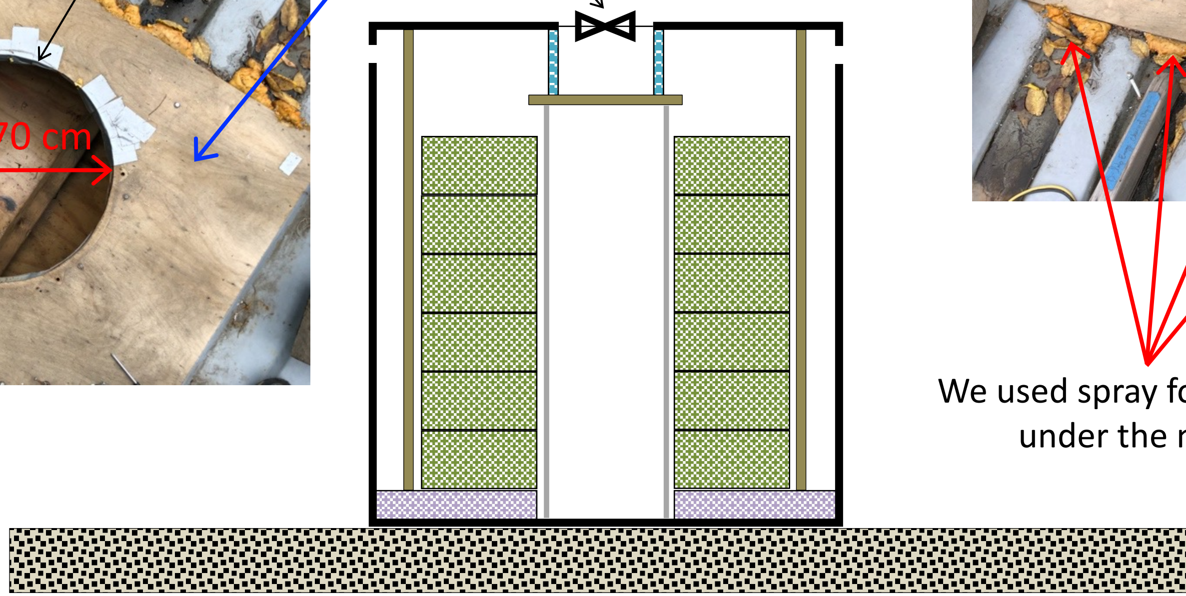
Support structure for evaporative cooling pads and water collection

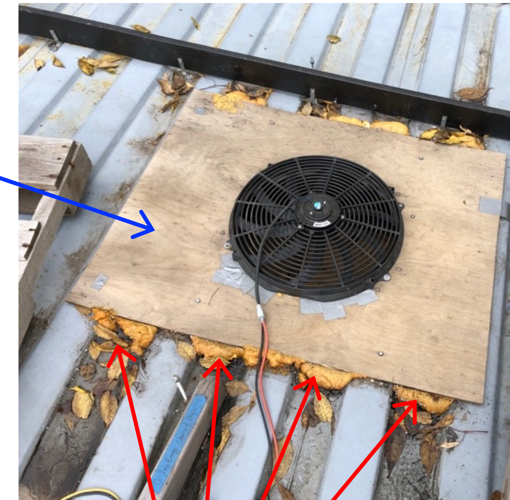
The holes in the ceiling will be determines by the size and number of the fans. The fans will need to be less than 70 cm in diameter

Because the roof is corrugated extra care will need to be taken to prevent water from running into the hole beneath the fan or fan mounting plate

A mounting plate is used to attach the fan to the roof of the container







We used spray foam to seal the gaps under the mounting plate

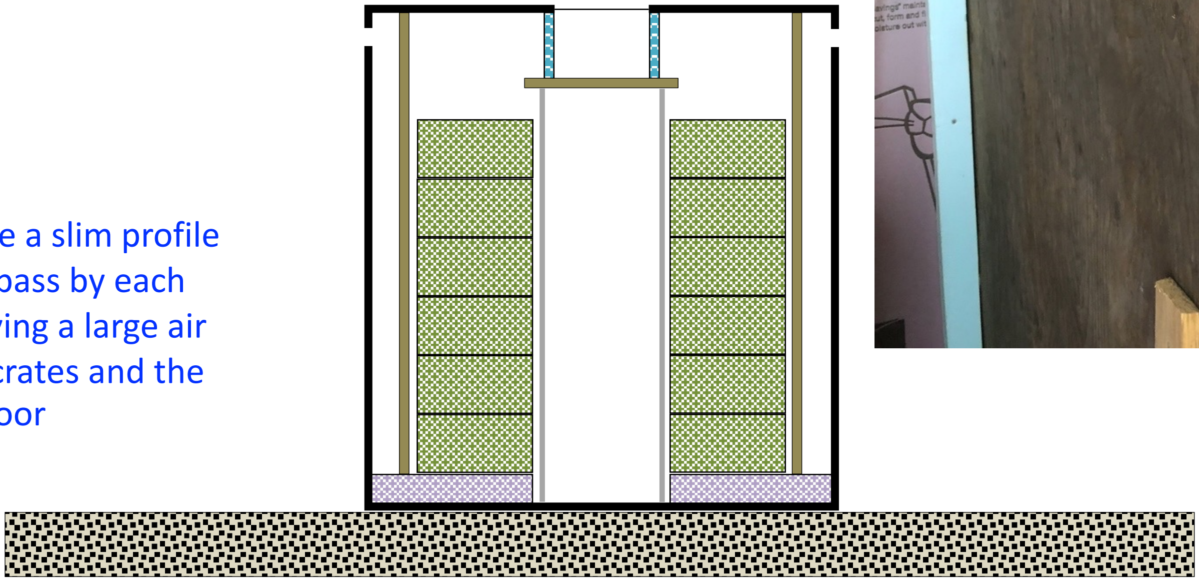
For the system in India where we will not be using solar panels, we will need some type of tilted rain and shade cover over the holes for the fans

Mounting of the fans

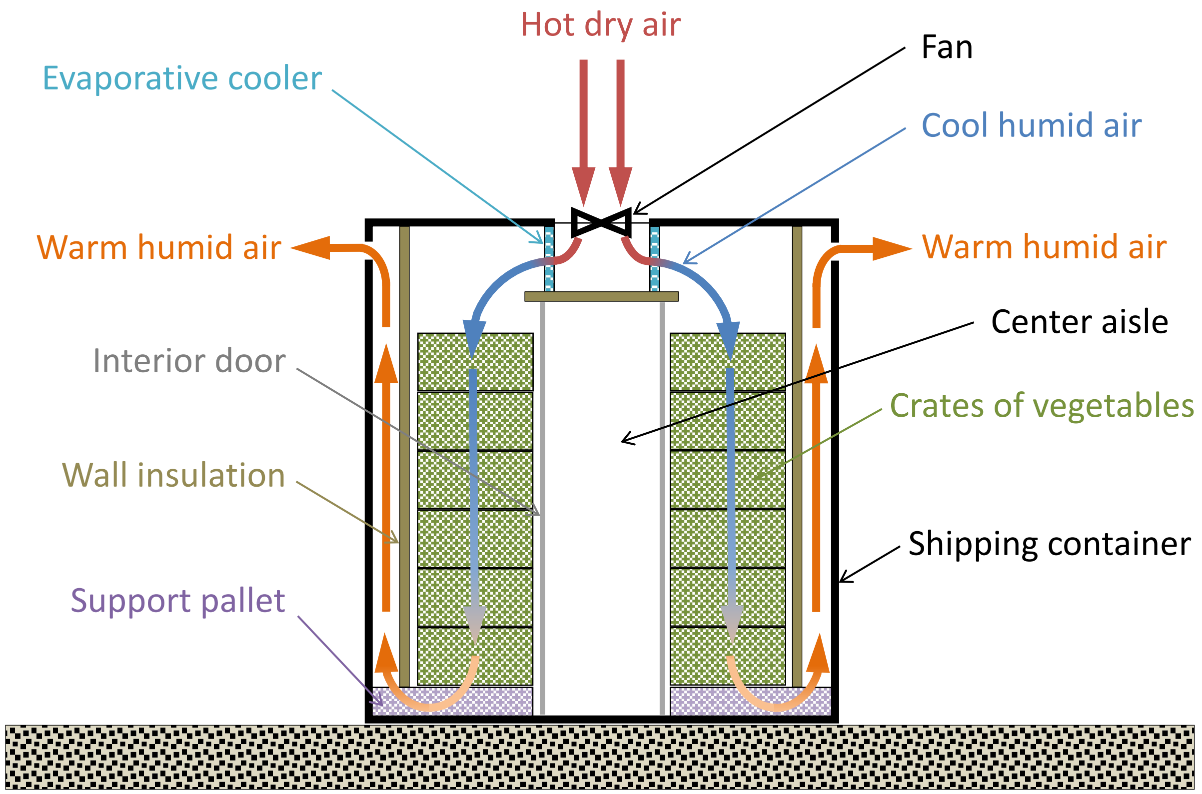
The doors are suspended from track that is either mounted on:
1) A header (shown here)
or
2) Directly onto the support structure for the evaporative cooling unit

This extra plate was added to prevent airflow between the top of the door and and the track

The doors should be a slim profile so that they can pass by each other without leaving a large air gap between the crates and the outer door



Sliding doors


Hot dry air
Fan
Evaporative cooler
Cool humid air
Warm humid air
Warm humid air
Center aisle
Interior door
Crates of vegetables
Wall insulation
Shipping container
Support pallet