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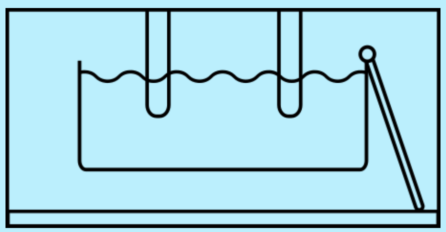
Portable Ice Maker

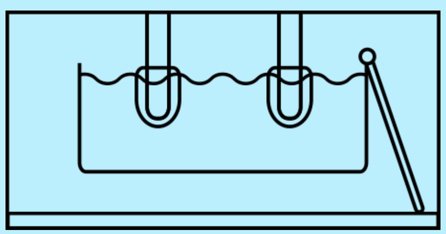
Component Role and Function

Rob Borrett

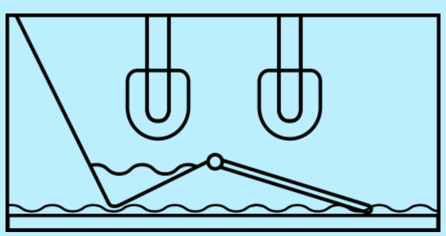
How does it work?



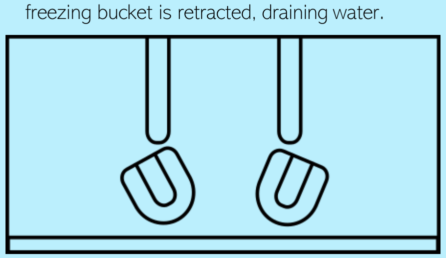
Step 1: Freezing bucket filled with water, submerging Ice probes.



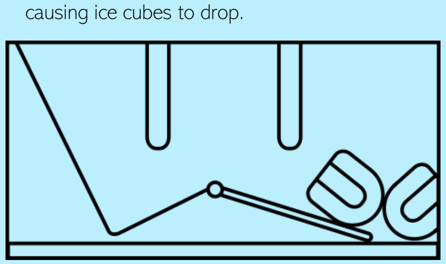
Step 2: Water around probes freezes. Ice cubes begin to form.



Step 3: Once ice cubes are fully formed, freezing bucket is retracted, draining water.



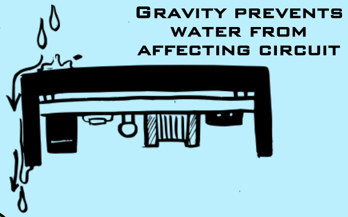
Step 4: Probes are suddenly heated, causing ice cubes to drop.



Step 5: Freezing bucket is returned to starting position, shovelling ice cubes into collection basket.

1 Main PCB & Micro-controller

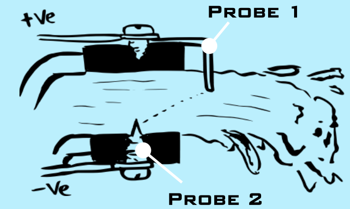
The brains of the device. Receives signals from all the sensors and makes decisions based on these inputs to then control the device's functionality. The PCB receives mains power supply (230V 50Hz AC) and converts it to 12V DC for some of the components. Clever housing means no waterproofing is required.



2 Thermistor

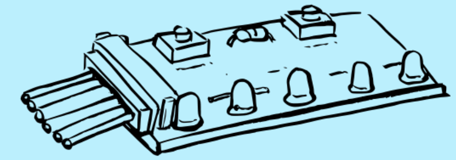
Measures the temperature of the environment and adjusts the length of time that ice is produced for. Positioned on opposite side of device to the cooling fan, away from moving air to give a more representative measurement of ambient temperature

3 Water Sensor



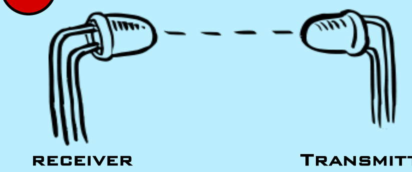
Positioned on the outlet of the pump tubing, it consists of two electrical probes that aren't connected. When the pump is on, a potential difference of 1V is applied between the two probes. If there is water present, the two probes are electrically connected so current can flow through the water between the two probes. If there is no water, the pump is just pumping air, so there is no medium for the current to flow across.

4 User Interface



The user interface consists of a sheet of plastic glued onto the top panel of the caseworks. The caseworks is designed to have flexures beneath the buttons, that allow the buttons on the through hole mounted PCB below to be actuated.

5 IR sensors

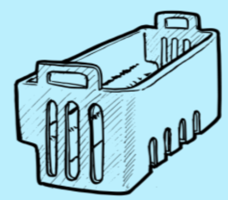


IR LED emitter and IR receiver. Detects the when the ice cube basket is full because the light connection between the emitter and receiver is broken. The sensors are only active for a short period, after the ice cubes have been dropped and shovelled into the ice basket. They are covered in hot glue as a waterproofing measure.

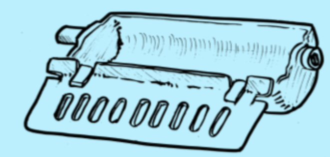
6 Insulation

Keeps the temperature of the water low by reducing heat dissipation through walls of product. Outer casing and water tank provide the shell for the insulation to sit in. It is filled via an insulative foam that solidifies, through a hole on the bottom of the product, covered by a black sticker.

7 Ice Basket

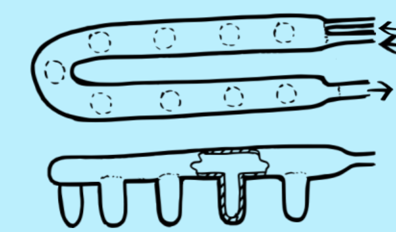


8 Freezing bucket & shovel



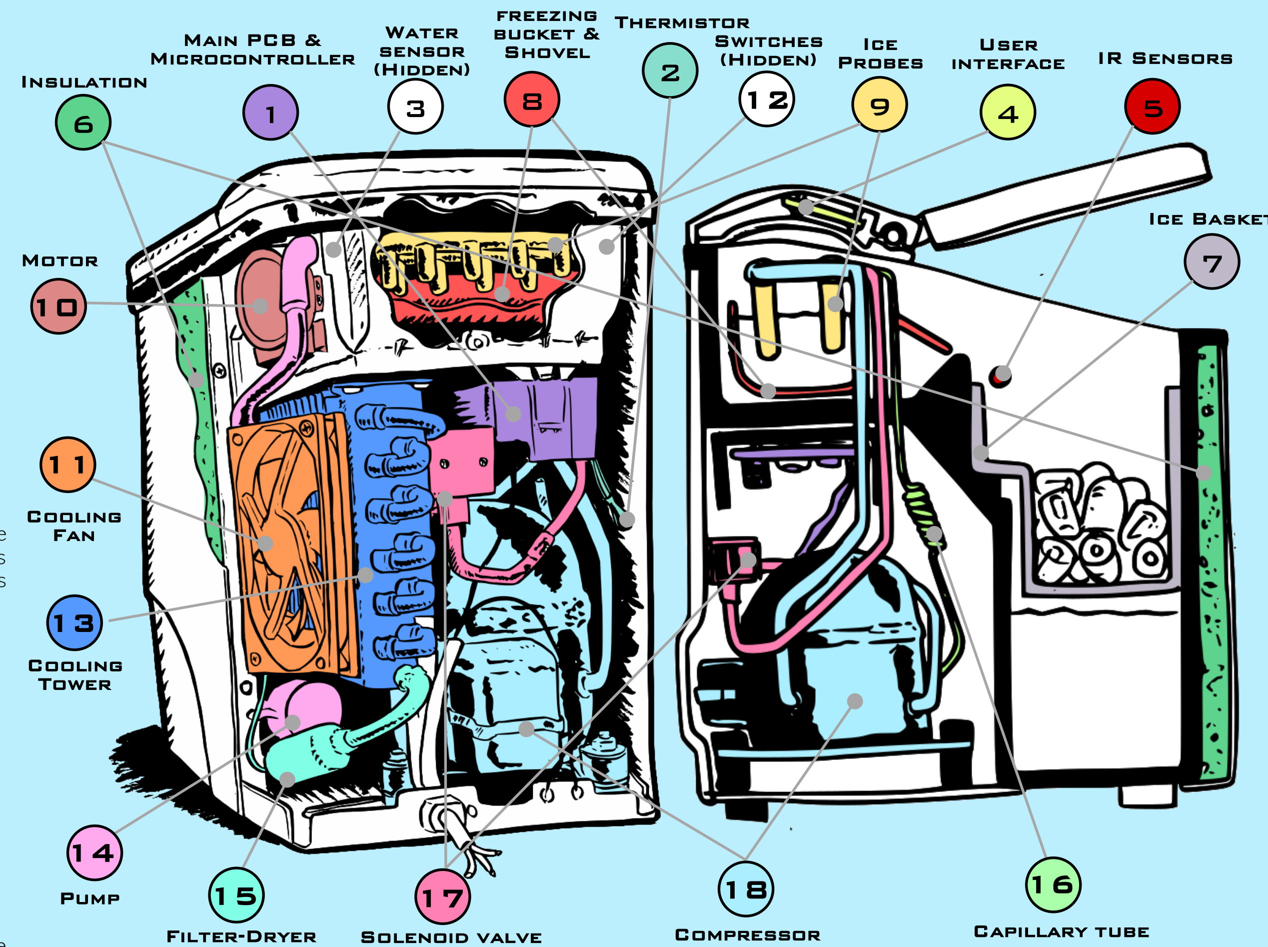
9 Ice Probes/ Evaporator

This is where the coolant absorbs heat from the environment, causing rapid freezing. The coolant goes from being a low-pressure liquid to a gas, and this change in state quickly removes large quantities of heat from the surrounding environment. There are two inlets; the thin capillary tube and the thick pipe which carries hot coolant for dropping the cubes at the end of each batch. It takes a while for hot coolant to be flushed out at the start of a cycle, meaning the ice cubes nearest the inlet are always significantly larger than those near the outlet.



10 Synchronous Motor

Controls the freezing bucket's position as instructed by the microcontroller. Simple half-moon profile of motor shaft allows the ice bucket to easily slide on and be locked in place.

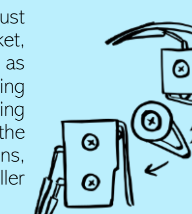


11 Cooling Fan

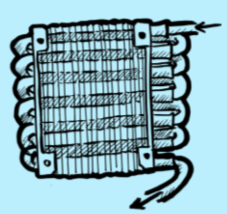
This large diameter fan performs the crucial role of pushing air through the heat sink. This means more heat is dissipated through the heat sink as the warmed air is quickly replaced by cool air.

12 Switches & Lever arm

The lever arm acts as a thrust baring for the freezing bucket, preventing axial movement, as well as indicating the freezing bucket's position by actuating the microswitches when in the lowered and raised positions, telling the microcontroller when to stop the motor.



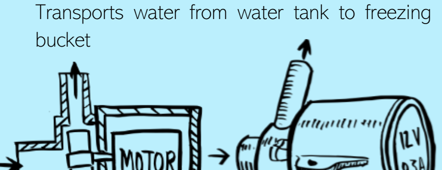
13 Cooling tower/ Condenser



Receives warm high-pressure vapor from the compressor and cools it via the heat sink as the loops of piping pass through the grilled area. The heat sink is designed to have a large surface area, using thin aluminum foils with a high thermal conductivity. The output is a condensed cooled liquid coolant.

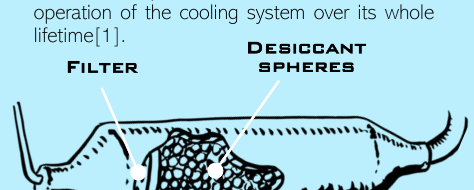
14 Water Pump

Transports water from water tank to freezing bucket

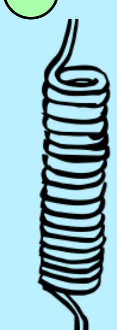


15 Filter-Dryer

Absorbs system contaminants such as water and filters out any debris that may have entered the system, such as rust flakes or wear debris from the compressor. This ensures economical operation of the cooling system over its whole lifetime[1].

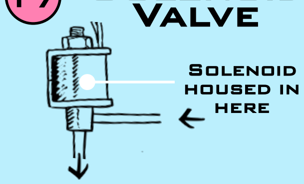


16 Capillary Tube



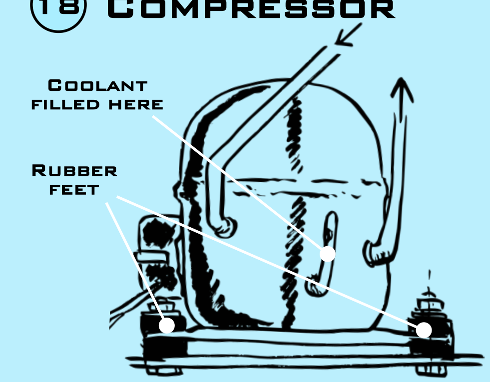
Coiled to increase its length. The small diameter of capillary tube has a throttling effect, causing a pressure drop across it, meaning low pressure coolant enters the evaporator[2].

17 Solenoid Valve



Used to direct hot high-pressure coolant vapor into the ice probes after the ice cubes have formed, so that the ice cubes fall from the probes, allowing them to be shoveled into the ice basket. Most of the time this valve remains closed, preventing the hot coolant from entering the evaporator. A stock component.

18 Compressor



The heart of the product. Compresses the low temperature vaporized coolant, heating it up, outputting a warm high-pressure vapour. Its rubber feet are intended to dampen the vibrations caused by the oscillating pump in the compressor, and spring washers are used to prevent the bolts from coming undone. The whole cooling system is filled through compressor through a crimped off pipe.

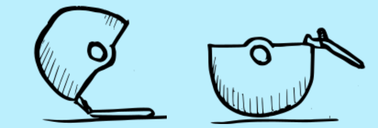
References: **[1]** Goodson, M.P. & Bullard, C.W.. (2020). Refrigerator/Freezer System Modeling. **[2]** Bright Hub PM. 2020. *Capillary Tube Refrigeration. Capillary Tube in Refrigeration, Air Conditioning* Accessed from: https://www.brighthubengineering.com

Freezing Bucket & Ice Shovel

Deep-Dive

Sub-Assembly Role

The freezing bucket provides a container for the small amount of water that gets frozen into the ice cubes. It has two positions that it can be in; lowered for ice production, and raised to allow the ice cubes to fall off the ice probes. The action of lowering the freezing bucket causes the shovel to push the freshly dropped ice cubes into the ice basket.

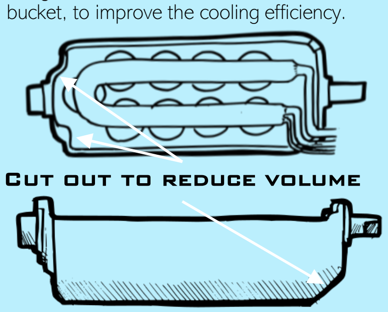


Reducing Ice Clumping

Front grills drain any water that accumulates around the ice cubes as they are shovelled into the ice basket. Without these grills, this water would be tipped into the ice basket, over the ice cubes, and would freeze, causing the ice cubes to stick together.

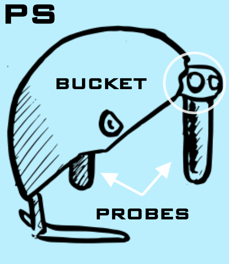
Increased Efficiency

The cooler the water around the ice probes is, the faster the ice can be produced.. Therefore by reducing the volume of water that the bucket can hold, the larger your ice cubes will be in a given time and the less energy is wasted cooling un-frozen water. These two cut-out features shows how the designers have reduced the volume of the bucket, to improve the cooling efficiency.

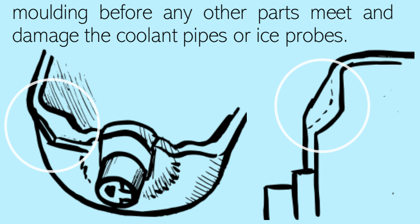


Cut-outs and Stops

This stepped feature ensures that the freezing bucket does not contact the coolant pipes that fill/ empty the ice probes when in the raised position, as this could damage them.

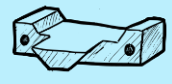


This flat extended feature also acts as a backup. If the switches fail for whatever reason, this flat face will come into contact with a feature on the main water tank moulding before any other parts meet and damage the coolant pipes or ice probes.



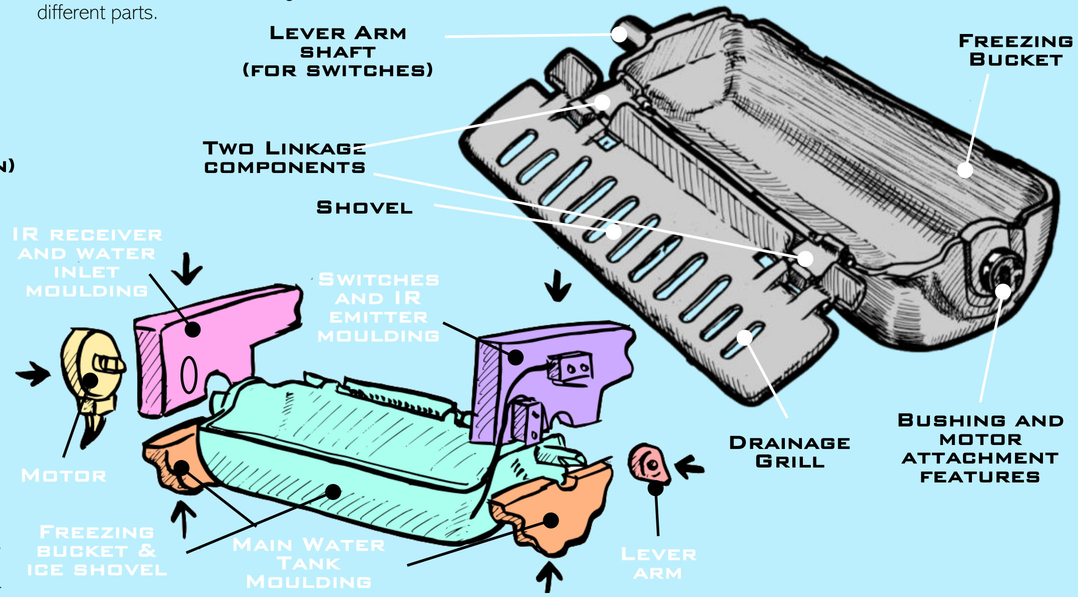
Useful Symmetry

The linkage component is symmetrical, even though the (excluding the pin holes). This done to reduce the part count of the device. The reflected set of features allows the same part to be twice used on the opposite side of the shovel, instead of creating two different parts.



Small But Mighty

The Linkage component is designed to lock the shovel in place, creating a sturdy platform to push the ice cubes from as the bucket is lowered, whilst folding back on itself as the bucket is raised. It is also designed to prevent the shovel from jack knifing when returning from its raised position.

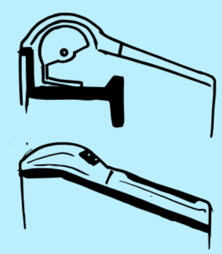


Poorly Finished & Rightly So

All the plastic parts in the freezing bucket and shovel sub-assembly are poorly finished, there are areas of flash that isn't removed, and some ugly gate scars where no effort has been made to clean them up, and rightly so. These imperfections don't effect the mechanical performance of the part and the sub-assembly isn't in full view of the user- they certainly wont be touching it. Finishing these parts to a high standard adds unnecessary costs to the product.

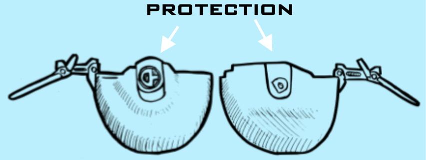
Industrial Design

The ice bucket has to swing up into the roof of the housing to properly function. The product's industrial design deals with the challenges that this poses by turning it into a styling feature, making the product look less boxy, and more visually interesting.



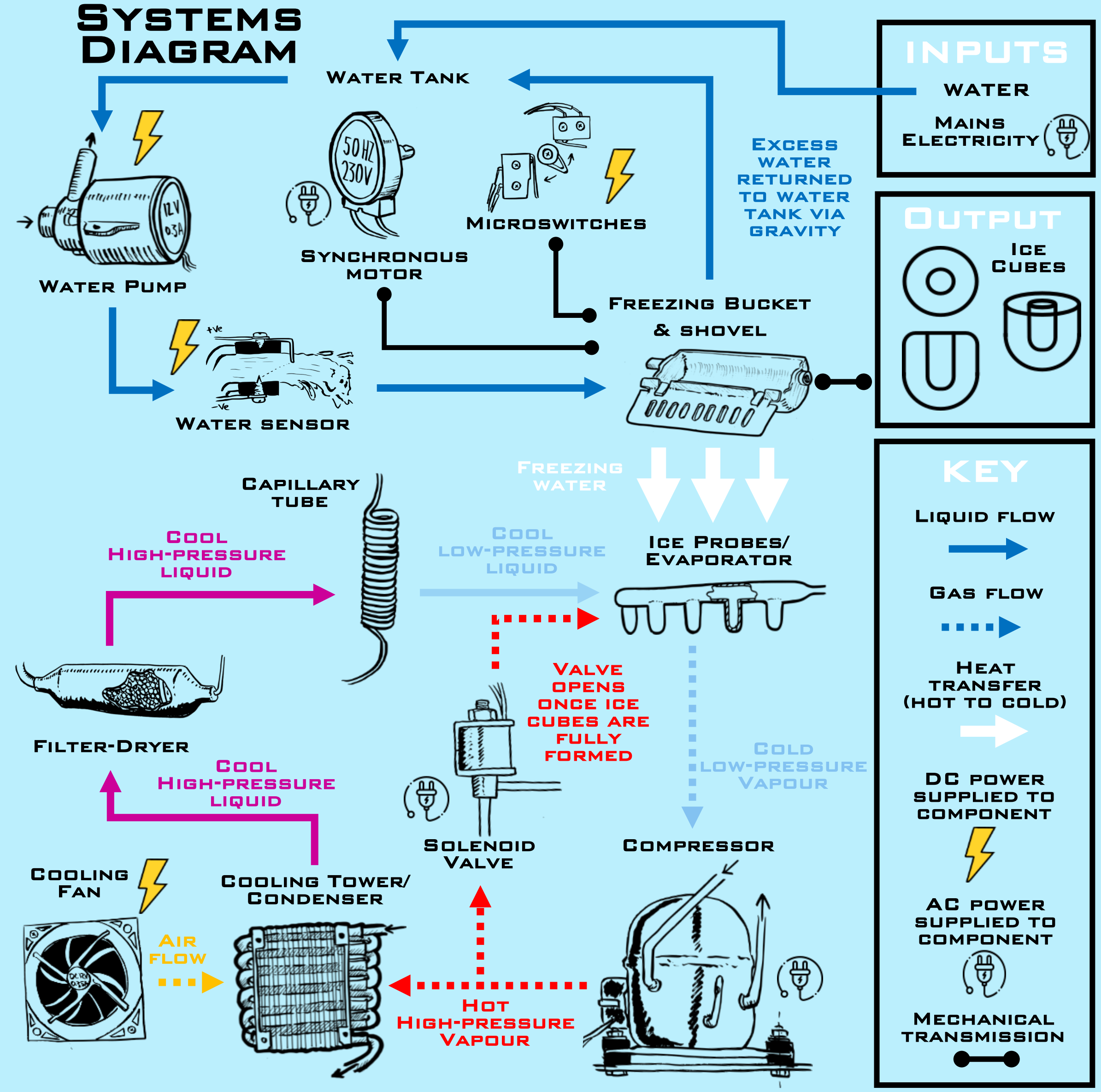
Directed Water Flow

There is no sensor for telling the microcontroller when the bucket is fully filled, so the bucket is always over filled. The bucket is angled slightly forward In its lowered position so that the water flows over the front edge and no where else. By doing this, it keeps the water away from vulnerable areas that water could leak through.



Further water proofing measures have been taken on the ice bucket. These raised sections prevent water from traveling through and along the baring holes and shafts which are not sealed in any way. In the right diagram the raised edge is extended further as the join between the part that houses the switches and IR emitter, and the main water tank moulding, has no lip or seal. This raised edge prevents water from spilling onto and seeping through the join.

Systems Diagram

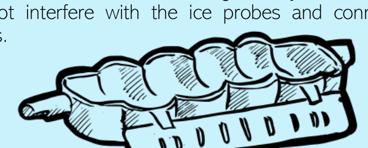


Improvements

Optimising Freezing Bucket

More optimisation on the freezing bucket geometry could be done to further reduce the volume of water it can contain. Using CAD and swept volumes I think you could quite easily create the optimised geometry. Which would look something like the sketch below.

Several constraints make this hard to do. The rotation of the bucket means the minimum volume of water that can be held is the swept volume of the nine ice cubes as they are rotated through 90 degrees. There are also further constraints in that the geometry of the bucket cannot interfere with the ice probes and connecting pipes.



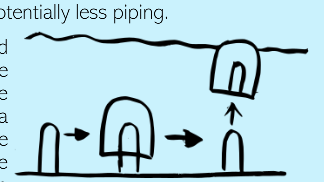
Cost Cutting

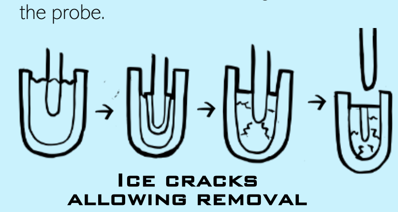
There are a some of components that seem a bit overkill, and after removing them and testing the device, I think that they could be permanently removed. For example, the cooling tower is connected to the main water tank moulding via four screws. There is also a strip of steel that acts as a support connecting the cooling tower to the base plate of the product. It is clear that the steel is there for structural reasons however

Improving Efficiency

The process seems inefficient, repeatedly replacing hot coolant with cold coolant in the ice probes. Is there a way that the need for hot coolant could be removed? This would also mean no solenoid valve is needed and potentially less piping.

For example could a system be designed whereby ice cubes are formed around the probes that are submerged under water. Ice forms around the probes until it gets to a critical size when it floats to the surface of the water. The buoyancy of the ice cube overcomes the forces sticking the ice cube to the probe.





Another method could be to make the freezing bucket the exact volume and shape of the ice cubes. Water expands as it freezes, so once all of the water has frozen is will be pushing on the sides of the freezing bucket. If the bucket is strong enough it could encourage the ice cubes to crack slightly, freeing themselves from the ice probes, allowing them to be pulled away.

Two Thermistors

The addition of a thermistor in the water tank could would have very little cost implications, and with the correct integration in the control system, it would mean the ice machine could still effectively produce ice when the water is very warm. It could also then produce ice more quickly when very cold water is added to the tank instead of producing overly large ice cubes like it currently does.

Resizing Thermistor

The thermistor seems ill-sized for this system. I was surprised to find a thermistor in the product after its inactive response towards temperature changes in my user experience studies. I tested the thermistor by heating it to different temperatures and timing the batch length for ice cubes on the small setting. There proved to be very little change until high temperatures were reached. It seems bizarre to have a system that doesn't significantly change between room temperature (20°C) and a very hot day (35°C). In user reviews on Amazon, there were a small number of complaints related to this subject, with customers saying how their machine just couldn't handle being outside on warm days. I would resize the thermistor or adjust the control system to produce a time response to temperature similar to that shown in orange.