ikich

Portable Ice Maker

Manufacture, Assembly and Costing

Rob Borrett

Bill of Materials

	Part	Material	Mass/Kg	Cost/£
Lid Subassembly	User Interface Panel	ABS	0.004	£0.0054
	Top Bodywork	Painted ABS	0.075	£0.2000
	Top Lid Casing	Painted ABS	0.050	£0.1200
	Window	Clear ABS	0.043	£0.0589
	Bottom Lid Casing	Black ABS	0.024	£0.0328
	Internal Roof	White ABS	0.026	£0.0356
	Control Panel PCB	PCB	0.012	£0.3800
Sensing & Freezing Bucket Subassembly	Left IR Sensor Mount	Black ABS	0.015	£0.0164
	Right IR Sensor Mount	Black ABS	0.020	£0.0274
	IR Emitter + Receiver	Mixed	0.002	£0.1000
	2x Lever Microswitches	Mixed	0.003	2x £0.1800
	Water Sensor	Aluminium Wire	0.002	£0.0100
	Lever Arm	Grey ABS	0.001	£0.0014
	Freezing Bucket	Grey ABS	0.042	£0.0575
	Ice Shovel	Grey ABS	0.024	£0.0328
	2x Linkage Component	Grey ABS	0.003	2x £0.0041
	4x Hinge Pins	Mild Steel	0.001	4x £0.0010
	12mm Bushing	Aluminium	<0.001	£0.0350
	Synchronous Motor	Mixed	0.088	£0.5000
Internal Housing Subassembly	Water Tank	Black ABS	0.450	£0.6165
	Insulation Housing	Black ABS	0.164	£0.2246
	PCB Box	Black ABS	0.029	£0.0397
	PCB Box Lid	Black ABS	0.016	£0.0219
	Main PCB	PCB	0.053	£2.2190
	Fused UK Mains Plug + Wires	Mixed	0.206	£0.6400
	Pump	Mixed	0.042	£0.5365
	Ø6x 300mm Water Pipe	Silicone Rubber	0.006	£0.0500
	Tube Connector	Silicone Rubber	0.002	£0.0100
	Pump Connecter	Silicone Rubber	0.003	£0.0100
	Water Tank Plug	Silicone	<0.001	£0.0100
	Plug Attachment	White ABS	0.002	£0.0074
Cooling System Subassembly	Solenoid Valve	Mixed	Combined Mass: 4.393	£1.5200
	Cooling Tower	Mixed		£5.0000
	Filter Dryer	Mixed		£1.2400
	Compressor	Mixed		£13.3800
	Coolant	Cyclopentane		£0.2100
	2x Ø6x150mm Pipe	Copper		2x £0.0769
	3 way Tee Fitting	Copper		£0.2560
	Evaporator	Nickel Plated Copper		£5.000
	Cooling Fan	Mixed	0.126	£1.8700
	Fan Guard	Stainless Steel	0.031	£0.1218
	Tall Support	Galvanised Sheet Steel	0.044	£0.0126
	Short Support	Galvanised Sheet Steel	0.013	£0.0130
	Chassis	Galvanised Sheet Steel	0.38	£0.1090
	2x Back Foot	White TPR	0.007	2x £0.1800
Final Touches	Front Bodyworks	Painted ABS	0.227	£0.6219
	Back Bodyworks	Painted ABS	0.285	£0.7809
	Insulative Foam	Polyurethane	0.120	£0.1728
	Ice Basket	Grey ABS	0.080	£0.1096
	Ice Scoop	Grey ABS	0.021	£0.0288
Fasteners	4x M6x30 Bolts	Zinc Plated 4.8 Grade Steel	0.008	4x <£0.0190
	4x M6 Hex Nuts	Zinc Plated Steel	0.003	4x <£0.0054
	4x M6 Spring Washers	Spring Steel	0.001	4x <£0.0021
	4x M6 Plain Washers	Zinc Plated Steel	0.003	4x <£0.0082
	19x M4x10 Round Head Philips Screw	Zinc Plated Steel	<0.001	19x <£0.0126
	14x M4x12 Round Head Philips Screw	Zinc Plated Steel	0.002	14x <£0.0133
	12x M4x8 Round Head Philips Screw	Zinc Plated Steel	0.001	12x <£ 0.0090
	2x M3x6 Screw	Brass	<0.001	2x <£0.0100

As a general rule, prices of parts manufactured in-house have been calculated by the cost of the raw material. The cost of brought-in components are estimated as being 40% of the retail price from a Chinese supplier (without delivery charges) and some are directly quoted from wholesale suppliers.

Online wholesale price per kg of ABS: £1.3700
Online wholesale price per kg of Steel: £0.2781

100,000 22x88mm single sided, through hole PCB quoted at £0.18 per unit + £0.20 for the electrical components.

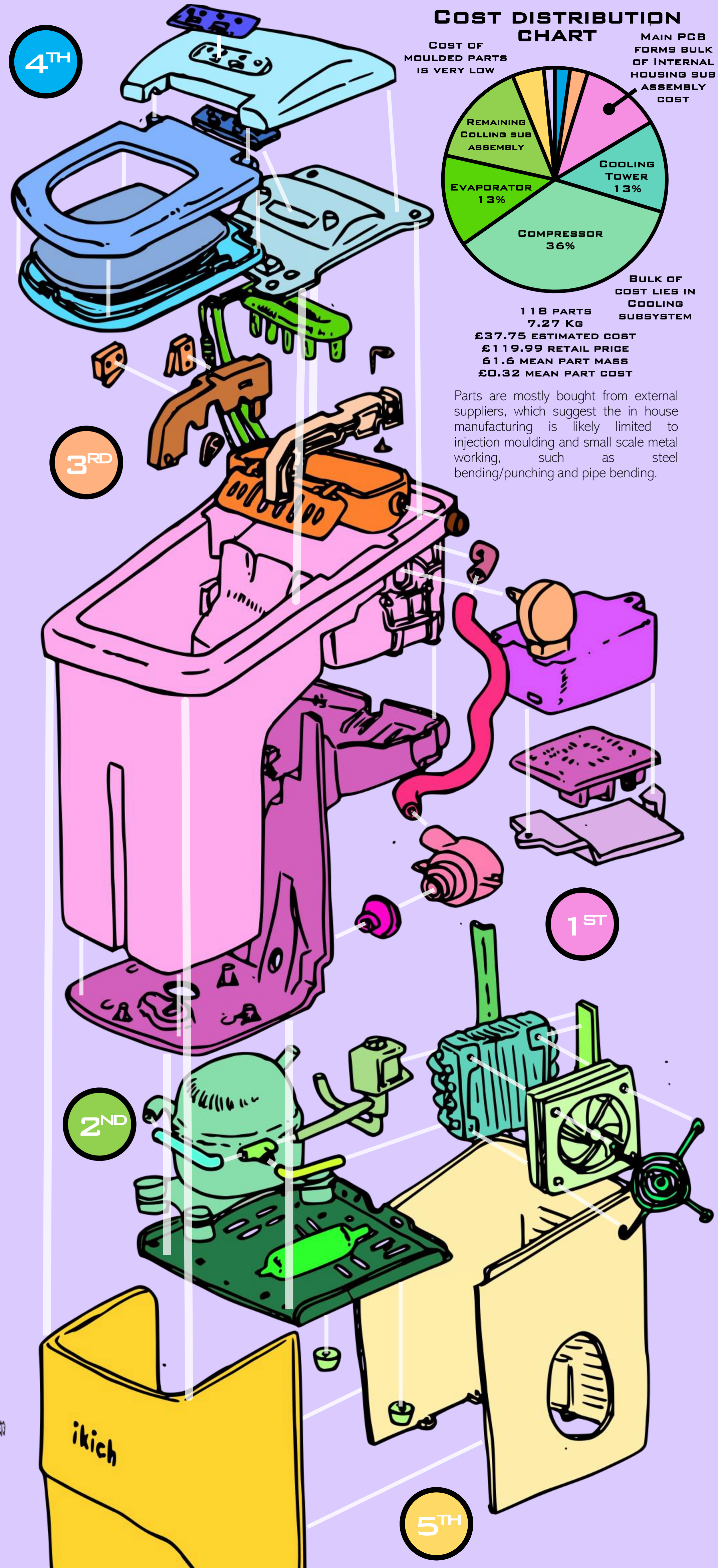
Replacement cooling towers can be found online however the typical price is upwards of £25. I estimate that Ikich can obtain them for around £5 as the raw material cost of the component is low, however a complex assembly process is required to fix the pipes inside the structure of aluminium fins. A similar rational is applied for the Evaporator

The cooling system cannot be disassembled without melting the brazed joins. The bulk of the mass comes from the compressor, which is the largest part volume-wise and also the most expensive.

The compressor manufacturer was contacted and a quote was obtained for bulk a purchase. It is likely to be cheaper in reality due to deals brokered between the companies, however it gives a ball park figure.

Painted ABS parts are more expensive. Due to the faux metallic paint. The manufacturers invest a lot of effort into making the product look nice, so that customers will be willing to buy the product. Estimating two 20ml coats of paint for each bodyworks part, with silver polyurethane paint sourced online at around £5 per litre. It effectively doubles the price of the part.

Estimated Cost £30-£40



118 parts
7.27 Kg
£37.75 estimated cost
£119.99 retail price
61.6 mean part mass
£0.32 mean part cost

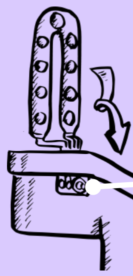
Parts are mostly bought from external suppliers, which suggest the in house manufacturing is likely limited to injection moulding and small scale metal working, such as steel bending/punching and pipe bending.

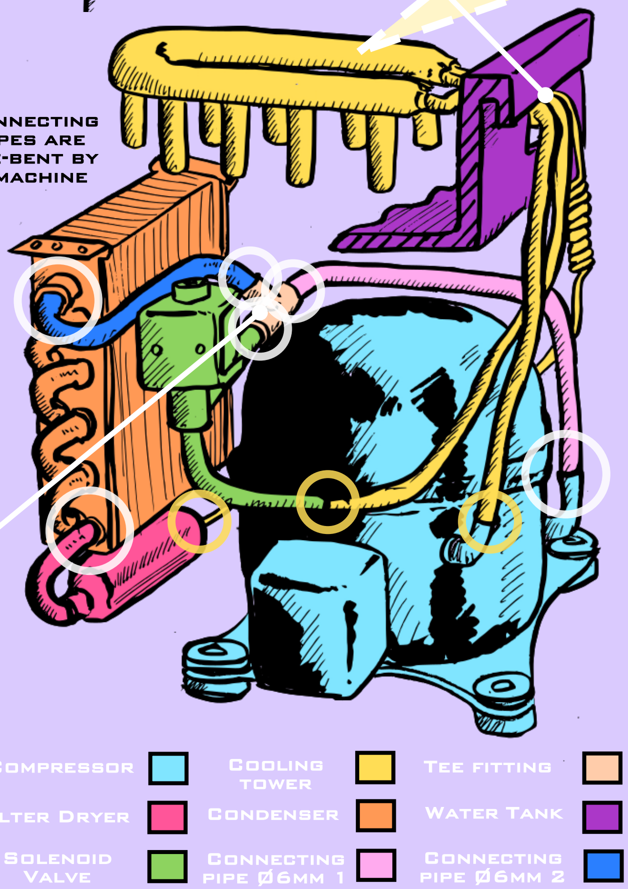
Colour Shades Key

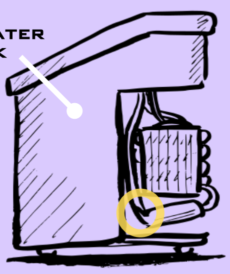
Lid subassembly
Sensing & Freezing Bucket Subassembly
Internal Housing Subassembly
Cooling System Subassembly
Final touches
Number indicates assembly sequence

Cooling System Sub-Assembly And Manufacture

The evaporator is the last part to be attached to the cooling system subassembly. The input/output pipes have to be threaded through a hole in the water tank moulding and then connected to onto the correct pipes in the compressor, filter dryer and solenoid valve. This means when the evaporator's pipes are brazed to the rest of the sub-assembly, at temperatures upwards of 700°C [1], it has to be done in very close proximity to these thermoplastic parts that can melt from 190°C [2]. It must be assumed that some sort of heat shield is placed between the pipes being brazed and the injection moulded parts, as there are no signs of heat damage on the ABS mouldings.

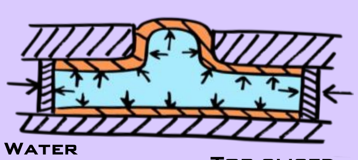






Tee fitting: Hydraulic Bulge

A water filled copper tube is compressed at both ends [3]



Complex Evaporator manufacture

Starting with the raw materials shown below, the Evaporator is manufactured through the following processes

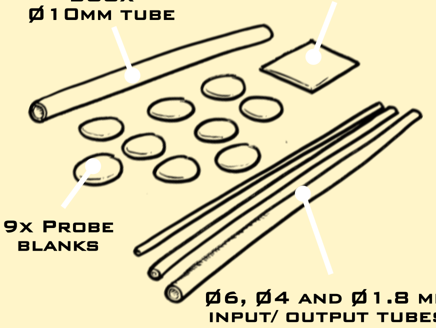
Necking process applied to a 10 mm copper tube, to form the necessary shapes to mate with the input and output pipes. Conventionally the necking process would be done by spinning the copper tubes but the asymmetric shape of the input tube makes this extremely difficult. It is more likely that is was done using a multi-stage drawing process, with a necking die to turn the copper into the required shape.

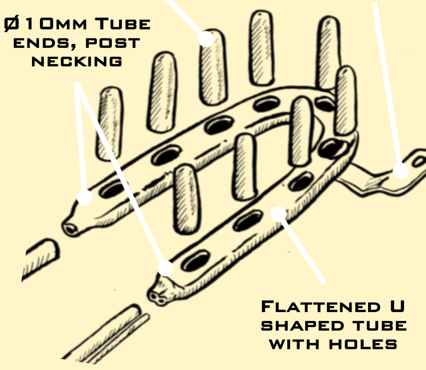
The tube is then bent into the U shape using a pipe bending machine. One half of the pipe is flattened using a press, and 9 holes are drilled into the newly formed flat edge, for the probes to be joined to.

The probes are likely to have been deep drawn from disks of copper. This would been done in multiple stages, forming the metal around various intermediate dies, to turn the blanks into the cylindrical shape with the correct dimensions needed for the assembly.

The joins between the different parts are very clean, however there is a clear ribbon of metal around each join, suggesting they were brazed together. The brazed joins are very neat, and likely to have been done in an automated process, with a robotic arm or a mechanical jig to aid humans. Capillary action causes the filler metal to flow into the thin gaps between the fittings, securing the two copper parts together and leaving a tidy looking join.

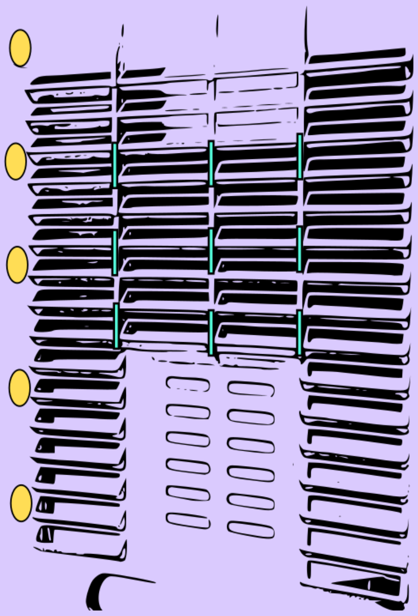
On this part, Brazing has to be done simultaneously or in a single heating event. Copper is extremely conductive, so heating up each node individually would cause the already brazed parts to fall off as the filler metal melts again. It is likely that the whole part would have been heated up to do this, rather than simultaneously heating each node.

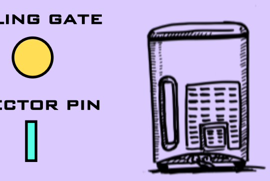




A nickel coating covers the copper pipes. This is to improve the Evaporator's resistance to corrosion. It is likely that this is done through electroplating. The finish is very smooth and even, but also very thin. There is a tide line at the same position on each of the input/output tubes indicating the part was submerged in a liquid, a further clue that backs the suggestion that electroplating was used.

Well Placed Gates and Ejector Pins





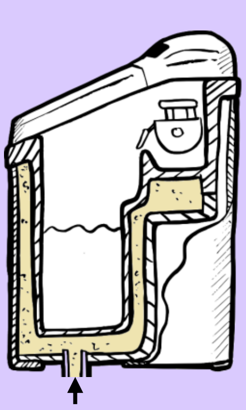
Injection moulding grills can be difficult. A manufacturer has to ensure the gates are correctly positioned to reduce the amount of weld lines. Weld lines are imperfections in the plastic that form when two flow fronts of plastic meet and the polymer chains fail to intermingle properly. They are a nuisance because they create visible imperfections as well as weakening the parts.[4]

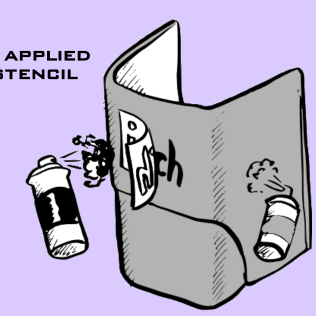
By placing all of the gates in close proximity to the grill, it means the molten plastic will flow continually through the grills features into the rest of the part, as the mould is filled. Any weld lines are quickly overcome by the movement of the plastic, through the region.

The shapes made by the grill in the tool makes them liable to stick, which could cause them to break as the rest of the part is puled away. Ejector pins are located in the middle of the grill to ensure the grill is supported as it is removed from the mould.

Additional Processes

An expanding insulation foam is filled through a hole in the bottom of the product, occupying the cavity formed between the water tank, front bodywork and insulation housing. It provides structural support for the front of the product, gluing the front bodywork panel in place, as well as thermally insulating the water reservoir.





A metallic finish is applied to the bodyworks via spray painting. Small areas of paint on the inside give this away, showing that the finish is not dipped or applied during the molding process. Painting will have either be done by hand with an industrial paint sprayer, or through and automated process.

Improvements

Better Feet Material Choice

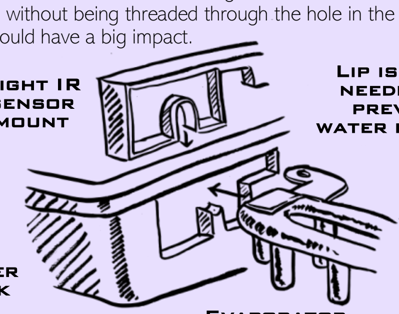
The device wobbles because there are 4 feet that aren't properly levelled. If the two back feet were made from a softer grade of rubber, this problem could be solved. If the weight is more on one side, the corresponding foot will be squashed more, bringing the other foot down and onto the ground.

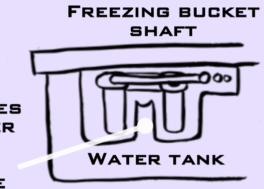
Unnecessary Metallic Finish Adds Cost

Painting mouldings with the metallic finish is an unnecessary expense. Many of the higher end products in the market don't have this finish, adopting a shiny black or white look that would equally fit into a kitchen environment. Adopting this look would save Ikich around 80p per product, by current estimates.

Re-design the water tank to suit the Evaporator

The water tank should be redesigned to allow the evaporator to be assembled into the rest of the cooling system without being threaded through the hole in the water tank first. The proposed change is only a small one but it could have a big impact.





This could be done without any additional parts and it would make the cooling system subassembly quicker and easier to assemble. All the brazing can then be done away from the any thermoplastic parts, removing the risk of melting.

Make It Recyclable

The foam insulation sticks to the front bodyworks panel, making the panel almost impossible to remove without cutting it free from the insulation. Similarly the evaporator and water tank can't be separated without cutting through the water tank or un-brazing the evaporator from the rest of the parts. The user manual instructs you not to dispose of the product with general waste, but to contact the retailer who sold it to you, who will dispose of it correctly The person disposing of the product is not going to go to the effort of properly separating and cleaning the parts, as it is currently so difficult. An easily removable sacrificial film could be placed around the walls of the insulation cavity so that the insulation foam sticks to the film instead of the bodyworks, allowing the bodyworks easy removal for recycling.

Peltier Cooling System

It may prove more cost effective to employ a Peltier cooling system instead of the current compressor based, cooling system. Particularly in the future when the Peltier technology becomes more efficient and cheaper than the current system. This would remove the need for a compressor (the most expensive part), and the solenoid valve. The copper pipes and coolant could be replaced by water filled silicone tubes to carry heat away from a heatsink on the hot side of of the Peltier module, making the assembly much simpler, with less mechanical dependency.

References: [1] https://princeizant.com/copper-brazing-filler-metals,
[2] https://www.plastikcity.co.uk/useful-stuff/material-melt-mould-temperatures,
[3] https://cnkpipefitting.com/pipe-fittings-manufacturing-process/,
[4] https://www.covestro.com/en/media/newsletters/healthcare-polymers/2018_10_understanding-and-optimizing-weld-lines-in-thermoplastic-molding