Appendices

Adapting a mosquito trap for future deployment in African communities

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Contents

Appendix A. Further background information

DEBATE ABOUT NUMBER OF MALARIA DEATHS

While the WHO estimated a number of 450,000 malaria deaths, the IHME estimated that in 2010, malaria caused 1.2 million deaths[7]. The IHME included the deaths that have been contributed to malaria using the method of verbal autopsy: it entails talking to family of the deceased to establish the cause of death. A study by Lozano et al[9] shows that where malaria is not a common cause of death, physicians are more likely to assign malaria as the cause of death on the basis of the symptoms recorded. In areas where malaria is a common cause of death, physicians tend to underestimate it[8]. In Ifakara, Tanzania it is commonly said that people with little spending power often self-diagnose with malaria due to the high cost of an official diagnosis.

Richens, J., Imrie, J., & Copas, A. (2000). Condoms and seat belts: the parallels and the lessons. The Lancet, 355(9201), 400-403.

RISK COMPENSATION

As shown by Oria et al (2015), people tended to stop using ITN's when they have a SMoT system installed because they felt protected. This psychological phenomenon is called risk compensation: it is seen when people overestimate the level of security that a measure delivers, and then ignore other safety measures or push the limits of dangerous behaviour.

Richens, Imrie, & Copas (2000) argue that with seatbelt-wearing and condom use alike, no law can guarantee full coverage, and more importantly, can prevent risk compensation. Rather, Richens argues, that increasing the perceived risk is a more effective way to decrease accidents or spread of STDs. Punishment, as a means of pushing the right behaviour, might help as long as the punishment is not too harsh; but incentives to continue good behaviour have been proven to be far more effective; in a study performed among Californian drivers who were offered a free 12-month extension of their drivers licence after an accident free year, the accident rate was 22% lower than the control group. The year after that, they performed 33% better despite the absence of an incentive!

In ground traffic design, the idea of Shared Space (for example, the dutch system of Fiets Straten, figure 1) increases the perceived risk (a car would be forced to drive more careful) to minimise risk compensation. A similar product feature could be implemented to

Figure 1. Fietsstraat in Almere, the Netherlands. Image by Dura Vermeer.

prevent users from stopping to use other intervention methods. How exactly is

A textual warning on the product might be one way of achieving this goal, as might a combination of warnings, education and check-ups.

Ownership

STIMULATING OWNERSHIP

Tubben (2017) mentioned that one of the reasons SMoTs were not properly maintained was lack of ownership among end users.
If ownership was stimulated by the trap design, users will feel more responsible as well. People feel ownership over something or someone for a number of reasons. Apart from true ownership (legal ownership) people develop feelings of ownership over something for a number of reasons:

- Control
- Deep Knowledge
- Investment

Control
If people have direct control to manipulate a product of system, they feel ownership. For example the operator of a crane might feel ownership because of the daily interaction of control. Translating this idea to the trap would result in experiences that include for example handles and buttons to give the user control over the product functionality.

Deep knowledge
If people know the ins and outs of a system or product, they are invested in something and more likely to have feelings of ownership. For example a museum curator might feel ownership over 'his' collection he has extensive knowledge in. This is difficult to translate to a trap design, but a 'hidden' feature that is discovered over time might be a way to achieve this.

Investment
After spending a lot of time, money or energy into something, people are more likely to become attached to that item, creating feelings of ownership. For example, someone helping out in a soup kitchen over many years might feel a level of ownership over the charities' kitchen. As people will spend time cleaning the trap, this might be achieved automatically. It should however, be clear to the user what actions have to be performed at what time.

Micro-solar companies

In figure 2, a number of Micro-solar system manufacturers are compared. Some advertise their retail locations, others don't.

NUMBER OF SOLAR SYSTEMS SOLD

Data is extrapolated from a report by GOGLA, the industry foundation that reports on a half-yearly basis, in partnership with the world bank.

In the first half of 2018, 395,000 SHS were sold, that are capable of supporting a mosquito trap (>20Wp solar panel). The rise of PAYG (pay-as-you-go) systems makes a larger system increasingly accessible to poorer households. The eastern-African market in particular is growing fast.

Of the 180,000 D30 systems that were leased out by M-Kopa in a PAYG system between October 2016 and March 2018, the majority was sold in Kenya.

Figure 2. Sales figures of several MSC brands. Note that installed base figures include smaller systems, that only provide a few bulbs to a household and are unable to power a mosquito trap. They also are worldwide sales, including the Indian market.

Name (founding year)	Installed base in households (2018)	Project-based future installed base (year)	Retail locations	Sales system
Mobisol (2011)	500.000			Pay-as-you-go
BBOXX (2010)	150.000	2.500.000 (Congo, 2020) 500.000 (Togo, 2022)	-	Pay-as-you-go
M-Kopa (2011)	600.000		650	Deposit + pay-as-you-go
Sun King (Green light Planet, 2009)	5.300.000		2400	Deposit + pay-as-you-go
d.light (2008)	20.000.000		25000	Pay-as-you-go, deposit in terms
Off-grid electric (2012)	50.000			Pay-as-you-go
TOTAL	**26.600.000**	**3.000.000**	**28050**	

Appendix B. User Insights

User insights from 'scenario'

FIRST IMPRESSIONS

"In one case, a local electrician walked by and stared at the trap for a long time. He was invited to come closer and participate in a user test, but he refused. He stayed where he was, all the while, he kept staring at the trap, eyes wide open. After a while, I invited him again to come closer and offered to explain the trap. Eventually he did come closer, but it felt like he could accuse me of witchcraft any second. After explaining, I could ask some questions about his experiences with mosquitoes and mosquito traps, which he answered. Since he was an electrician, he only asked me if the trap could run on DC."

-Cedric

Most participants remained strongly neutral upon seeing the trap for the first time. Some did know what it was because they knew about my project, most did not. After a brief explanation, most users touched the tarpaulin, watched inside through the mesh on the canopy, and touched the inlet module. Upon explaining what the device is and how it functions, most users remained neutral. There were a few users, like the electrician and several females, who were very nervous (see local participants).

PLACING THE TRAP

A beam near the IHI offices was selected for convenient hanging of the trap. Some of the participants were involved in hanging the trap, others preferred to let me handle it. The question in the interview concerning trap placement was answered in different ways. Some answered inside, in the living area, outside, or right outside the sleeping area. The reason for placement was based on education or perception (I am inside, I don't want mosquitoes inside, therefore place the trap inside). While education is an important factor in every IVM project, the product can be designed in a way that it will naturally be used outside or inside.

One of the woman saw the trap hanging and noticed that hanging is the best way of placing the trap, because her children (aged 5/7) might otherwise play with it.

"If I place the trap on the table, my children will play with it, it won't work"

Two of the men remarked it as well. They, as well as another male and another female, also suggested different ways of making the hanging more convenient or safe.

"I would build a wooden frame, like a 7, to hold it. Also higher, so the children can't reach it."

"I suggest a strong and stiff steel cable. For the thieves, to cut it, this (holds rope) with their knife, is easy. Also put a sign, for information, what it is."

"Maybe put it on a stick? To prevent the wind from blowing against the house?"

"I would fix it against the house, to prevent mechanical movement. And higher, because that is where the mosquitoes often are: higher near the roof."

At a hanging position outside the house, children are able to play with the trap if placed at 50 cm without fencing. The line between a mosquito trap and a piñata is thin indeed. Cattle might destroy it or eat parts of it. Cattle was seen wandering around many of the houses on the countryside, most noticeable chickens (>25), goats (3), cows (3), geese (2), pheasants (2) and rabbits (1) (between brackets the amount of households).

REMOVING THE INLET MODULE

When the trap is turned on, the nichrome wire starts heating. After a while, it reaches considerable temperature (around 50°). Because the wire, located at the top of the inlet pipe, is very exposed the user, this can cause potentially dangerous situations. When the inlet module is removed by the user, the top of the inlet module is a very natural grabbing point, and it is possible that at the moment of taking out the inlet module, the nichrome wire is still hot. All but one users grabbed the inlet pipe in a way that might cause them to get hurt, even after being explained to that the inlet pipe might have been hot. One user tried to get between the inlet pipe and canopy with her fingers, and fiddled around for a while, ultimately succeeding in removing the inlet pipe but with significantly more effort.

Before removing the inlet module, most users slightly tilted the whole trap towards them. This was done to prevent the inlet module being blocked by the wire holding the trap.

PLACING MB5

The strips of the MB5 odour blend are difficult to apply inside the trap. No hook or other attachment system was build yet, so the odour blends were stuck between the overhanging edge of the inlet pipe and broad upper canopy ring. In one occasion the strips fell in the water container, which was fortunately empty at that time. The average user does not have gloves available to them, so handling the odour stripes might prove difficult without contaminating the trap, themselves and other objects. The MB5 strips were not involved in the regular user tests, only with technicians in the semi-field setup.

FILLING THE WATER CONTAINER

Many users were insecure about the necessary amount of water to pour into the water container. Questions like ‘is this enough?’ or ‘more?’ were asked regularly, despite the 0.2 liters noted on the instructions form and the, partly filled, 1 liter bottle provided. This insecurity might be due to the user test environment, but it is also a possible source of stress in a real use scenario. Since there is no way of telling how full the container currently is, there is no feedback system, and the foldable container is rather large, it can be difficult to determine how much more a user should pour in. In one case, the user put the entire bottle into the container. Nonetheless, the filling of the container with water was a pleasurable experience for most, once the insecurity about the amount was taken away.

Many users reacted on the question regarding continued use and upkeep. Some argued that when properly instructed, it would not be a problem. Others said they didn’t know, which might be a way of telling that it is actually too much effort. One user argued that the rain might fill the water container.

“The rain will fill the trap, but only in the wet season”

It was found that in the semi-field environment, many pieces of dirt, dead insects and straw accumulated in the water in the container. This was in a scenario where the trap is used and moved daily, but nonetheless regular cleaning of the container and changing of the water container is recommended. Mosquitoes may lay their eggs in the water, which makes the problem larger rather than smaller.

(DIS)ASSEMBLY OF THE INLET MODULE

As mentioned under technical insights; the catch pot, fan and inlet pipe connect in opposite directions, which is both handy (in case of loosening the catch pot) and difficult (assembling the catch pot again). Users seemed confused when they loosened the fan, but not the catch pot. One user spotted the bayonet fixing while another user was struggling with it (against the test protocol) and became overly excited for having spotted it. The disassembly was difficult due to still swollen parts.

SECURING AND EMPTYING THE CATCH POT

The slot used for closing the catch pot was not used during the semi-field trials because the assembly was locked together tightly and loosening the catch pot could prove difficult without escapes. Instead, the inlet pipe was blocked by stretching a mesh over it and securing it with a rubber band.

Figure 4. Closing off the catch container by sliding a piece of plastic between the fan and the catch container.

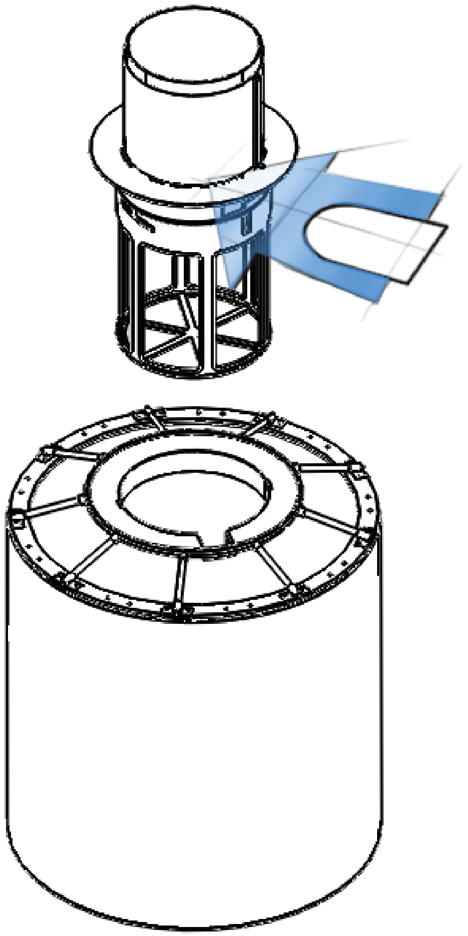


Figure 3. A user puts the entire water bottle into the trap.

Users had a difficult time locating the slot for closing the catch pot (figure 4); none of the participants indicated they would use it to close the catch pot. After pointing out the feature in the post-interview, only one user said he would find it a useful feature. Other users would prefer to close off the inlet module by stretching flexible gauze over it, or covering it in another way. When asked what people would do when there were still live mosquitoes inside the catch pot, opinions differed. The participants with a scientific background were keen to suck out the live mosquitoes using a siphon, while others would wait until they are dead, or shake the catch pot until all mosquitoes are immobilised.

Seeing the dead mosquitoes inside the catch pot did not cause a vivid response from the users initially, when asked about it, they remarked they did see them, but apparently gave them no further attention. Some users remarked that if the trap captured more than a certain amount of mosquitoes (20 or 25 per night) they would be satisfied with its performance.

Emptying the catch pot turned out to be a quite easy task for the participants, as all just shook the catch pot until all mosquitoes were expelled. Several wings, legs and torsos were still found in the edges and mesh after the participants were done with the user test. This implies that over a prolonged period of use, the catch pots might not stay clean.

“Just shake it. Easy”

OTHER USER INSIGHTS

Scientific use

A significant percentage of mosquitoes caught by the trap are shredded by the fast-spinning fan. While this is good in a user scenario where the user prefers to not bother, it makes cleaning the catch pot more difficult, as mosquito body parts get stuck in the edges of the catch pot, and in the mesh. Also, for research purposes and differentiating between mosquito species, it would be better to keep mosquitoes intact.

Local participants

One participant, a local woman with no scientific background, answered slightly panicked to the question about placement: "I don't know, I don't work here (IHI), I don't know anything about mosquitoes, ask one of the scientists!" Of course, it was explained before and after this statement that every answer and action is correct. When asked why they were nervous, they named fear of breaking something and lack of knowledge; therefore lack of self-confidence played a role. This nervous attitude was found to be the case with more of the local women, the men (especially those working at IHI) seemed more confident in their dealings with the trap.

Pleasant experiences

Filling the trap with water was experienced by at least two users as a pleasant experience. Also the heating of the nichrome wire was seen as a nice experience, but only once the user knew what is was for (attracting mosquitoes). One user stood next to the trap for a brief moment, warming his hands to the trap as to a campfire, clearly glad to see, feel and hear the trap working. The seeing of the trap in good working order in general was perceived as a happy moment for most users. The sound of the fan was not considered a problem for any of the participants, even considering that it might be placed outside the bedroom. In fact, the multi-sensory experience of seeing, feeling and hearing the trap perform made this part the most enjoyable of the user evaluation.

Final remarks

Often, the user would play around with the miniatures, say they liked them a lot, thanked me and got up. Several researchers mentioned they were happy with the project and foresee a promising future of the project. Users rarely left looking unhappy, some were neutral, and most were looking excited or happy.

Appendix C. Semi-field details

INTRODUCTION

A semi-field experiment was set up using the 3x32 method. This is a solid scientific method for determining trap preference, since all variables, like the screenhouse and odour blends, are randomised. The experiment was done 15 times, of which 6 are fully usable results and another 6 are useful in part. One replicate was considered as loss, due to two failed trap batteries. Finally two more replicates were done to determine the effect of CO_2 on trapping.

SCREENHOUSES

The Ifakara Health Institute has build the so-called mosquito city (GPS coordinates) on a piece of land several kilometers from the city. There, screenhouses are constructed in which semi-field experiments can be performed. The IHI was selected because of availability of these facilities, as well as close ties to the WUR, and location in the countryside of western Tanzania.

The screenhouses measured 7x9 meters each and were build on a concrete foundation, with a small moat to prevent ants from entering. Three screenhouses were used, each equipped with a slightly scaled down house inside. The houses were modelled after common architectural styles present in the Tanzanian countryside. They were build from local materials such as bricks, corrugated sheet metal, straw and mud, and each had two rooms, a door, two windows, and several other air inlets. The screenhouses were void of vegetation, but did contain some elements to make it look like a real environment; some rocks, a defect water pump, etc. Each screenhouse was cleaned of spider webs before and during the experiments.

SETUP

The M-Tego traps were hanged using a combination of locally sourced red rope and imported fishing wire. They were hanged with the inlet pipe at a height of 65 cm. The Suna trap was placed in a metal wireframe, which in turn was placed on a few bricks. The inlet was at a height of 65 cm. The traps were cleaned before use (70% ethanol) and handled with gloves afterwards.

Inside each house, the following setup was placed (figure X). By placing a source of CO_2 and odour blend inside, a human presence is simulated. Each fan was placed to create an airflow directing the odour and CO_2 towards the nearest window.
The release pots were placed in the corner of each screenhouse and the mosquitoes were released manually, around 18:00 (6 pm).
The experiment ends at approximately 06:20 (6:20 am) the following morning. These times were chosen to permit travelling time between Ifakara and mosquito city, during daylight. The mean runtime of the experiments was 12 hours and 23 minutes. (s=22 minutes)

Only small variations were measured in temperature during the experiments, with only one day were a slight wind was recorded (NE wind). Mean starting temperature (recorded at mean 17:58 s=20 min) was 32.4º C (s=1.4). At the end of the experiment (6:21, s=8 min) the mean temperature was 22.9º C (s=0.8). Mean humidity varied between 38.1% (s=4.7) in the evening and 78.0% in the morning (s=6.0). The temperature and humidity were recorded with a Brannan type 38/660/0 thermometer and the weather station in the IHI.

CO2

The yeast was sourced from the company Pasha (produced in Turkey), the molasses from the Kilombero sugar company. The water was local tap water. A mixture of 500 grams of Molasses, 2 liters of water and 17,5 grams of yeast was used (as described by (...). The mixture was poured into jerrycans (capacity 5,5 liters) and mixed thoroughly. One container was placed next to each trap, in a way that the outlet was placed right next to the trap.

Repair protocol

Repairs to the traps were made by using the following protocol:

1. The copper elements were stripped (they came loose anyway) and wires were connected at that spot by tying the copper wires together and covering the connection with duct tape to prevent short-circuiting
2. The Nichrome wire was turned on, causing it to expand. Then, it was turned off, and after cooling down, rewired. The space between nichrome wire was guaranteed by taping the wires to the inlet pipe on 4-6 locations with duct tape, depending on further needs
3. The catch pot, fan module and inlet pipe were fixed together with duct tape, essentially making them one part. This prevented them from falling apart during removal from the canopy.
4. The plastic part of the canopy, expanded by sunlight and heat, was heated with a hairdryer and consequently expanded again in the right direction.
5. After further exposure to heat outside, the same problem of deformation happened. As a quick solution, the narrowest 'bridge' in the canopy ring was cut through using a knife, so it could open in case of removal of the inlet module.

WATER CONTAINER TEMPERATURE

The temperature of the water in the water container was measured twice at the end of the day (figure 5), around 17:00, before changing of the water. Also the temperature of the water that was going into the trap was measured. The water container was hanging in the shadow of the house during the whole day, while the water bottle was standing in direct sunlight for several hours. Before an experiment, the water container was emptied and filled with 0.7L of water from the water bottle.

	Mean air temperature	Mean water temperature	Δ
Water inside container of M-Tego 1	35.1° C	34.0° C	-0.9° C
Water inside water bottle left in sunlight at the beginning of the day	35.1° C	39.7 ° C	+4.6° C

Figure 5. Results of measurements of water and air temperatures.

Thus, it can be concluded that for passive heating to work, the trap has to be hanged in full sunlight. Due to this condition, it is deemed unlikely that a large number of traps placed near houses will heat up enough during the day to attract mosquitoes in the evening and night time. Adding the water container also adds user effort, and when upkeep is not done enough the water container is a potential site for mosquito breeding, which makes the problem larger.

HEATED INLET TEMPERATURE

The temperature at a distance of 2 cm from the inlet pipe was measured at two occasions (figure 6).

	Air temperature	Ambient air temperature	Δ
1	34.1° C	34.8° C	+0.7° C
2	36.2° C	37.0 ° C	+0.8° C

Figure 6. Results of measurements of general air and near the heated inlet pipe temperature.

In a post-experiment trial, the duration of heated wire on a battery charge was measured and found to last between 10 and 11 hours at a room temperature of 28.2º C, which is 0,5º C warmer than the average night temperature of the screenhouses.

OVERALL TEMPERATURE

Only small variations were measured in temperature during the experiments, with only one day were a slight wind was recorded (NE wind). Mean starting temperature (recorded at mean 17:58 s=20 min) was 32.4º C (s=1.4). At the end of the experiment (6:21, s=8 min) the mean temperature was 22.9º C (s=0.8). Mean humidity varied between 38.1% (s=4.7) in the evening and 78.0% in the morning (s=6.0). The temperature and humidity were recorded with a Brannan type 38/660/0 thermometer and the weather station in the IHI.

CO2

During the Rusinga field experiment, CO_2 was provided to the users through a network of women providing the households with fermenting molasses on a daily basis. A mixture of yeast, molasses and water, as used in the experiments, only produces CO_2 for a few hours, for a maximum of one night. It should therefore be replaced on a daily basis. In the case of Rusinga Island, the combination of logistical challenges and the need for intensive training to households made the researchers decide to remove CO_2 from the 'blend'. From the semi-field testing it turned out that making the yeast and molasses blend every day was a task that quickly became a habit. It was however, labour-intensive and time-consuming, so an alternative is preferred.

Appendix D. Heat mapping

Figure 6. Measurements setup in the climate room of the Wageningen University Research.

Figure 7. Comparison between placement of heating elements under the fan (left) and heating elements on top of the canopy (right). As can be seen, heating elements on the canopy better distribute heat around the inlet pipe.

Temperature increases in ºC. The temperature increases as measured by this probe were not significant.

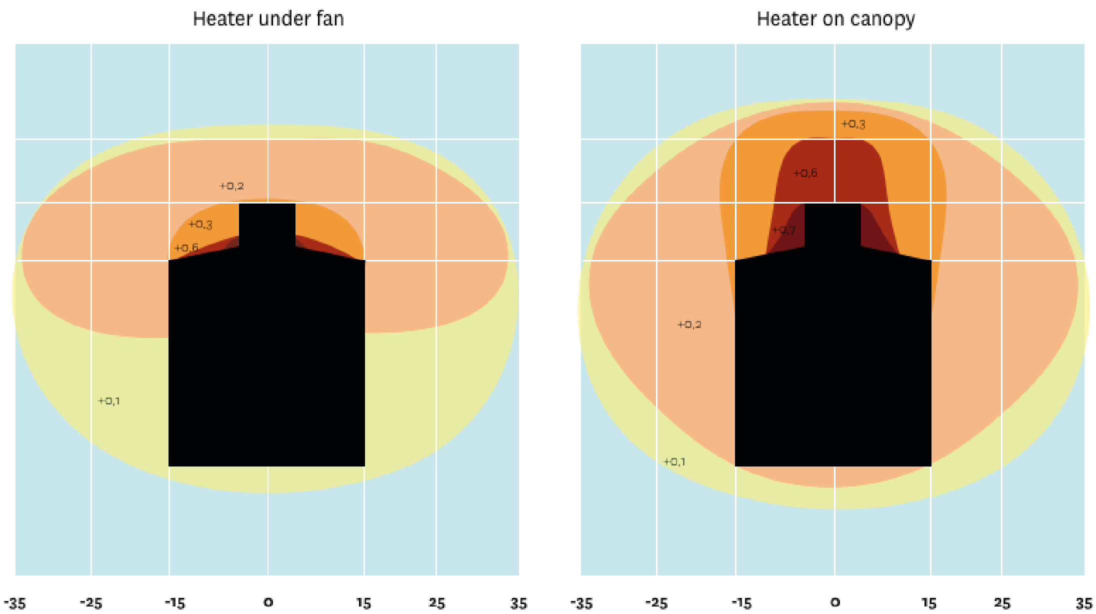


Figure 8. Measurements of temperature at 0, 10, 20 and 50 mm away from human skin.

It is hypothesised that since mosquitoes can sense these small temperature differences, a heating element should produce at least these temperature differences.

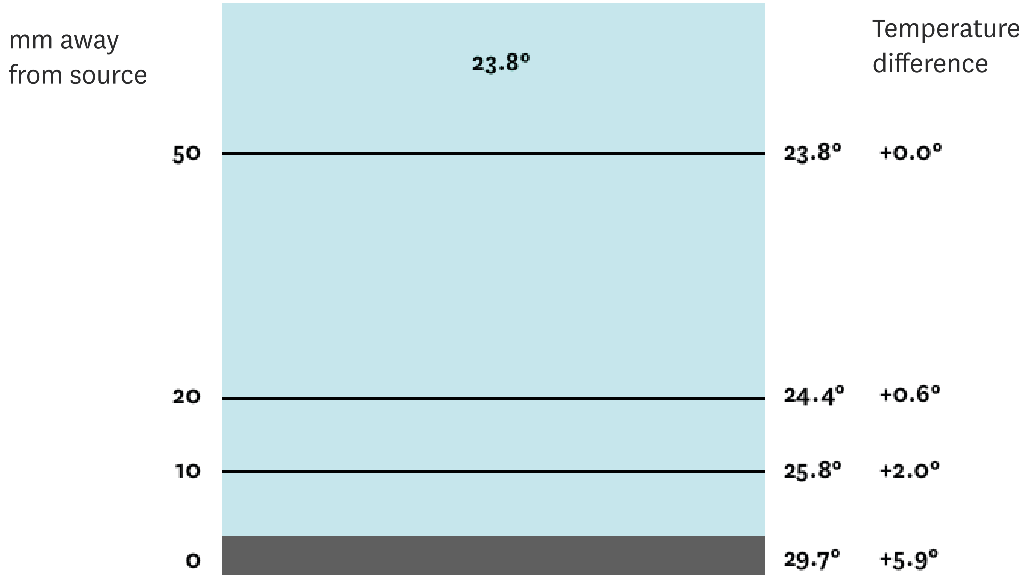
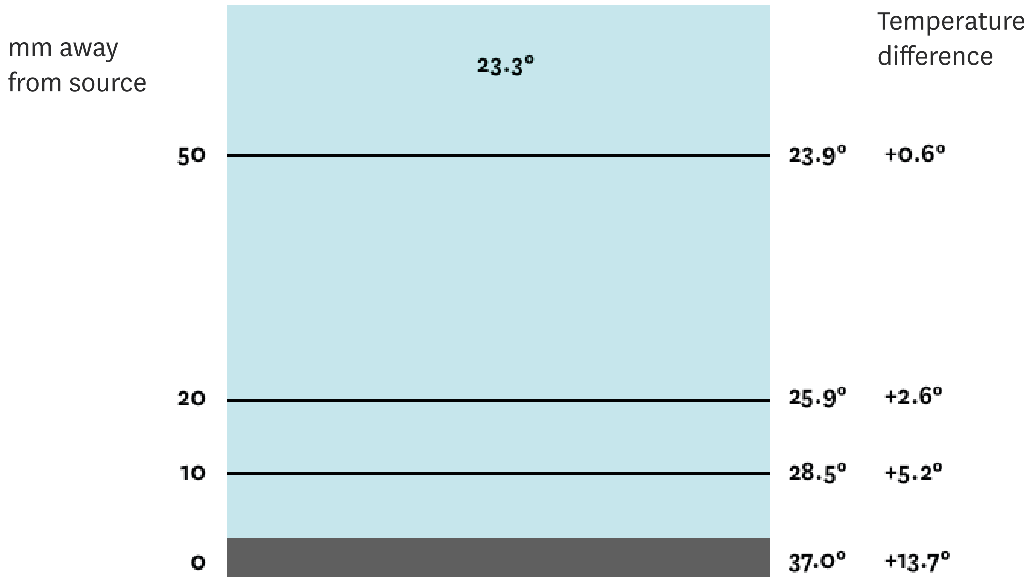


Figure 9. Measurements Polyamide heating elements. It produces far more heat that human skin in similar conditions.



Appendix E. Technical data package

This appendix consists of two parts:

A. Part list
B. Technical drawings

A. PART/DRAWING LIST

Total assembly

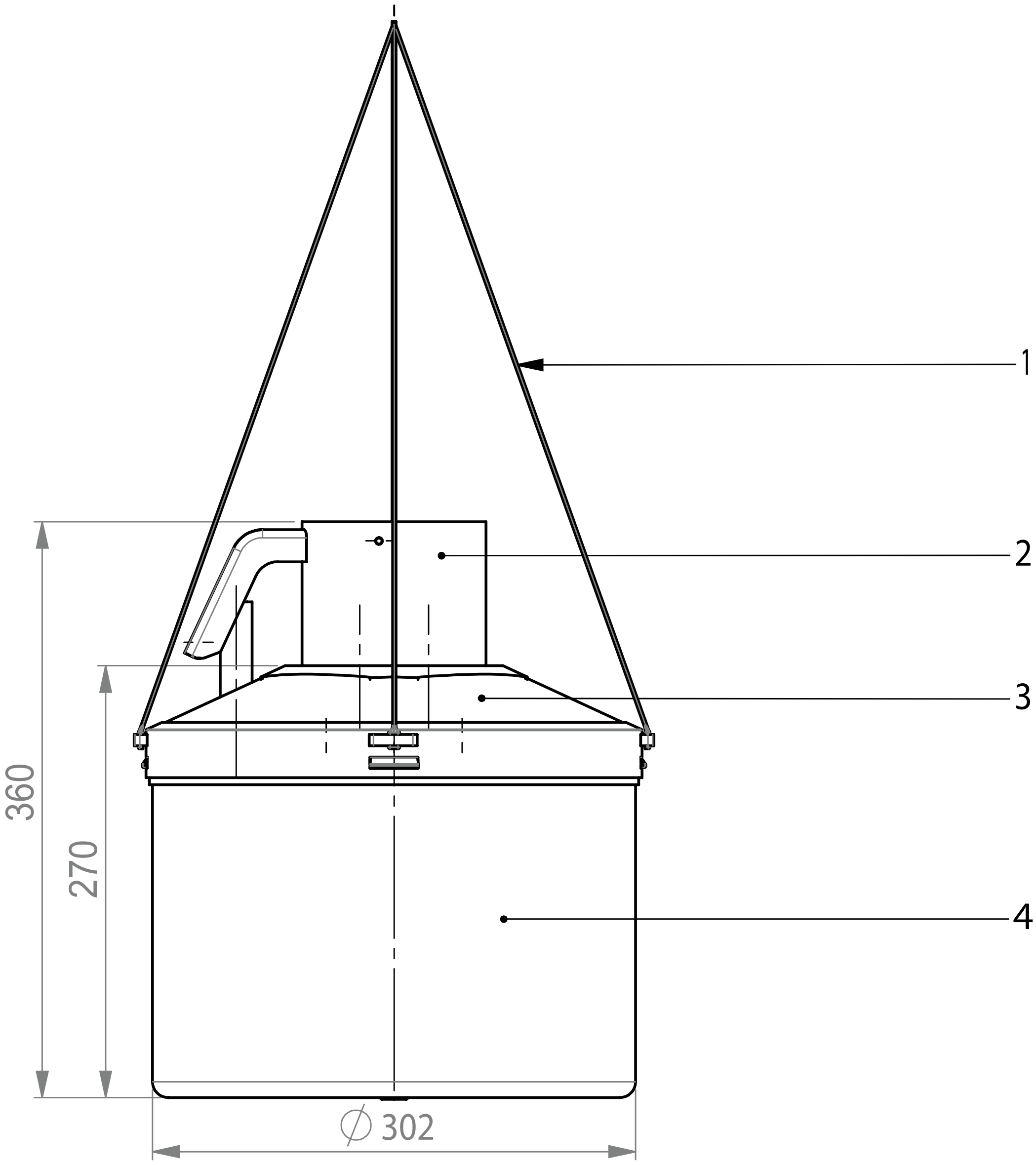
C. Catch Container
- C1 Container
- C2 Hatch
- C3 Slider

T. Canopy
- T1 Canopy frame
- T2 Heating element
- T3 Fan
- T4 Odour tray
- T5 Co2 tube

B. Bottom
- B1 Band
- B2 Bag
- B3 Eyelet

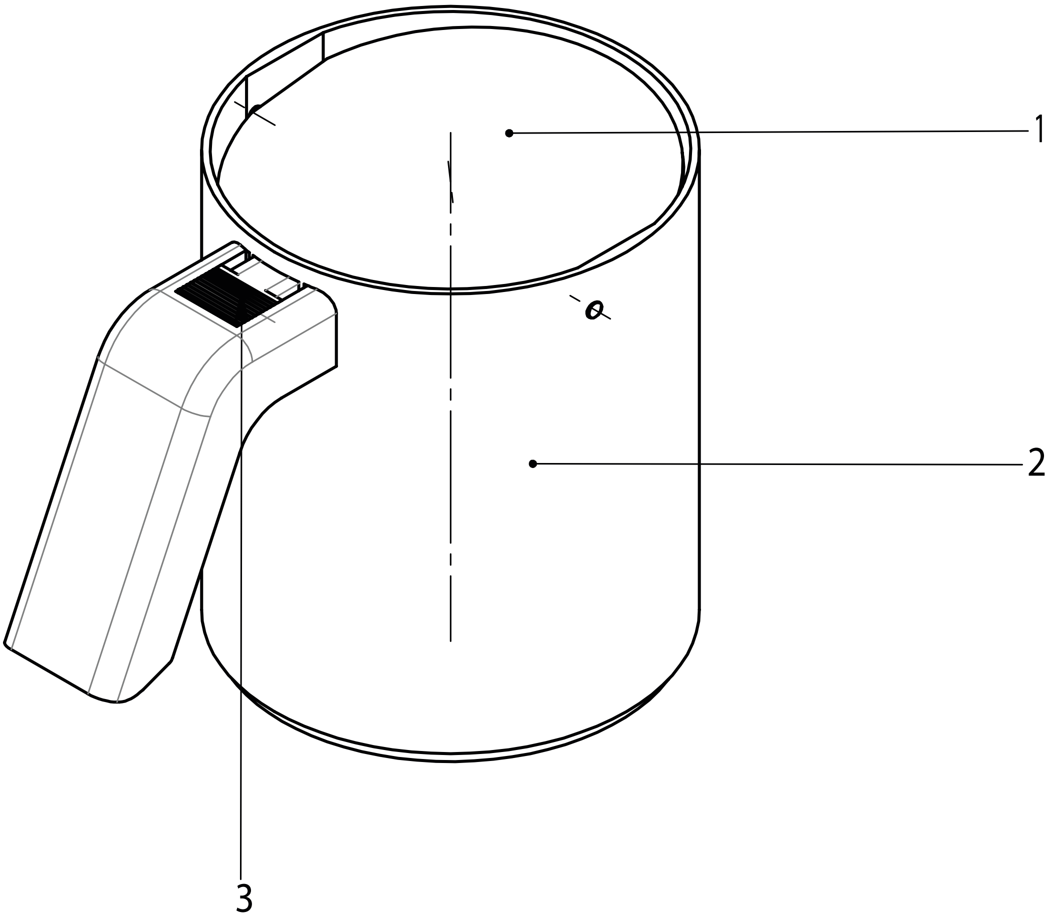
Other (no Tech. drawings)
- O1 Rope
- O2 Power cable
- O3 Mesh canopy
- O4 Mesh catch container
- O5 Screw terminal

Complete Assembly



ITEM NO.	PART NUMBER	QTY.	Drawing No.
1	O1 rope	4	
2	C assembly	1	
3	T Assembly	1	
4	B Assembly	1	

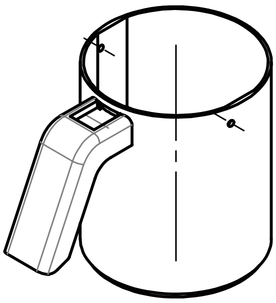
C Assembly

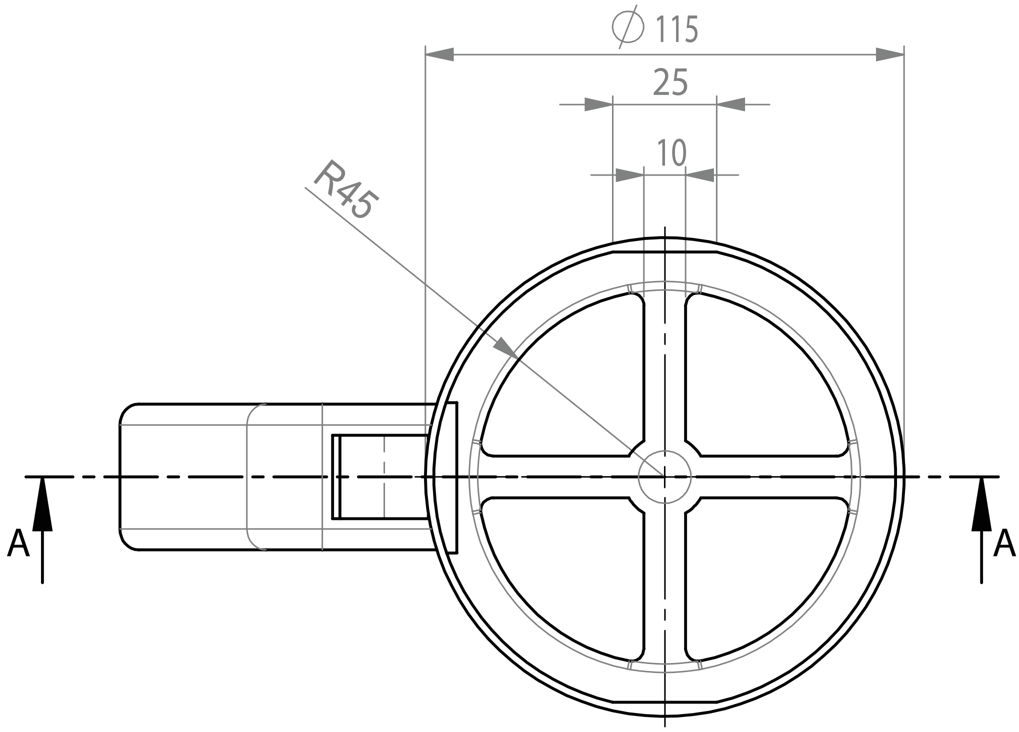


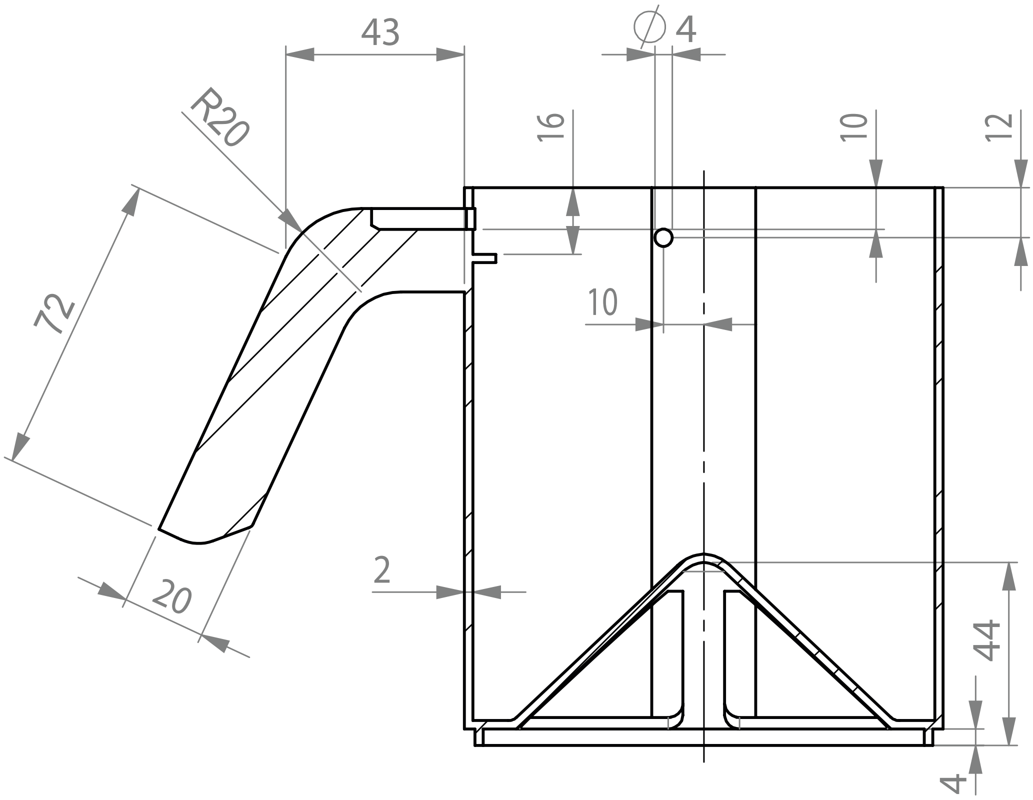
ITEM NO.	PART NUMBER	QTY.
1	C2 hatch	1
2	C1 container	1
3	C3 slider	1

C1 CONTAINER

Material: Polypropylene, UV protective coated
Production: injection moulding
Weight: 122 grams



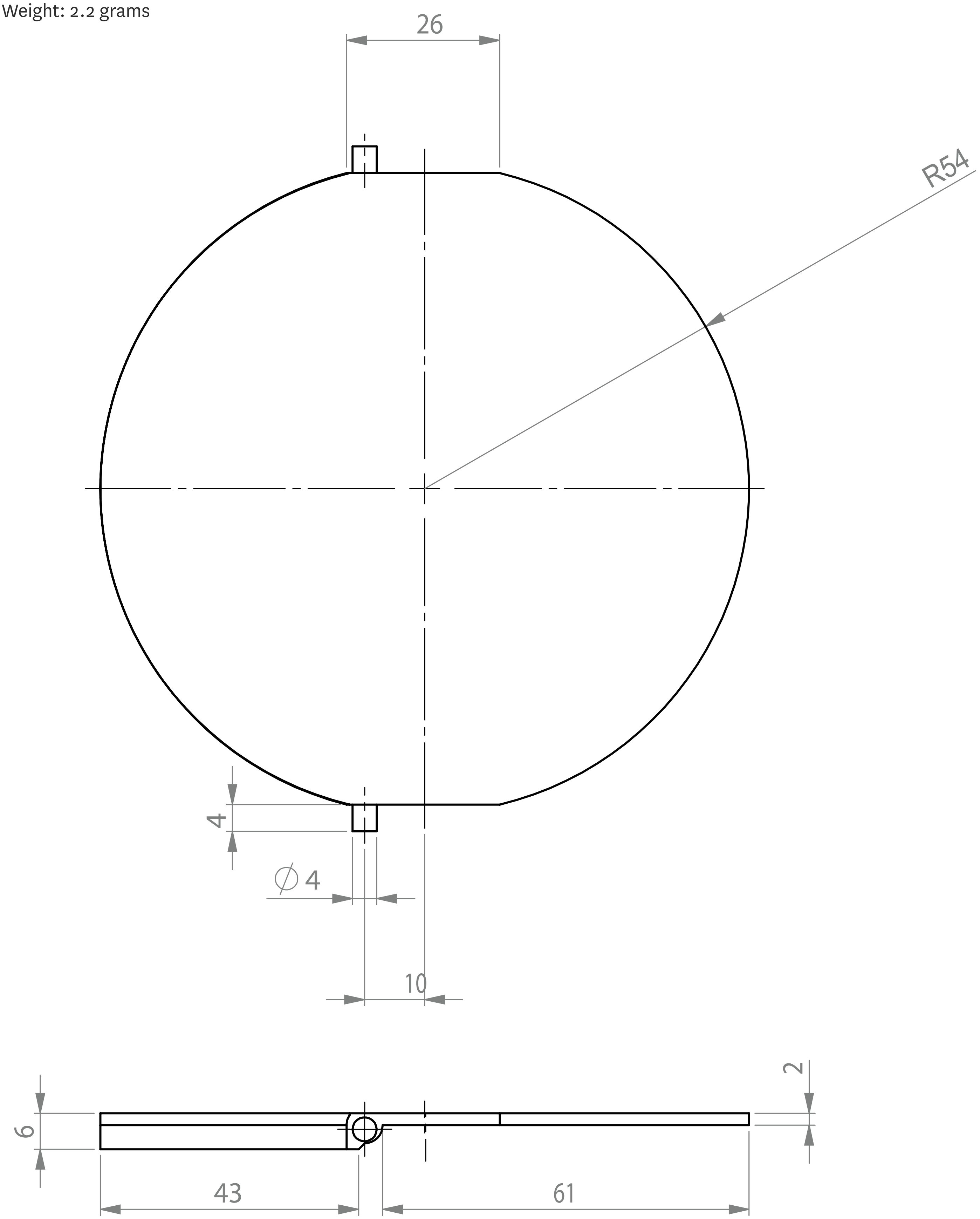




A-A

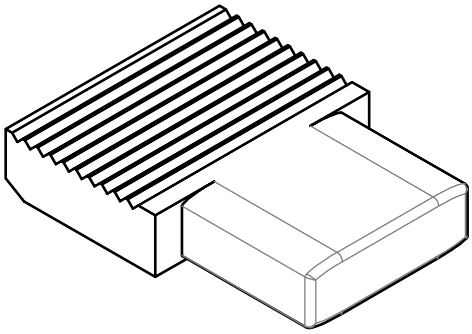
C2 HATCH

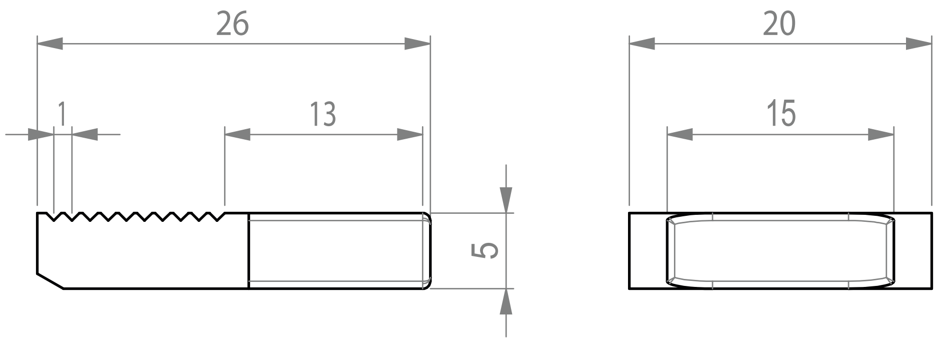
Material: Polypropylene
Production: injection moulding
Weight: 2.2 grams



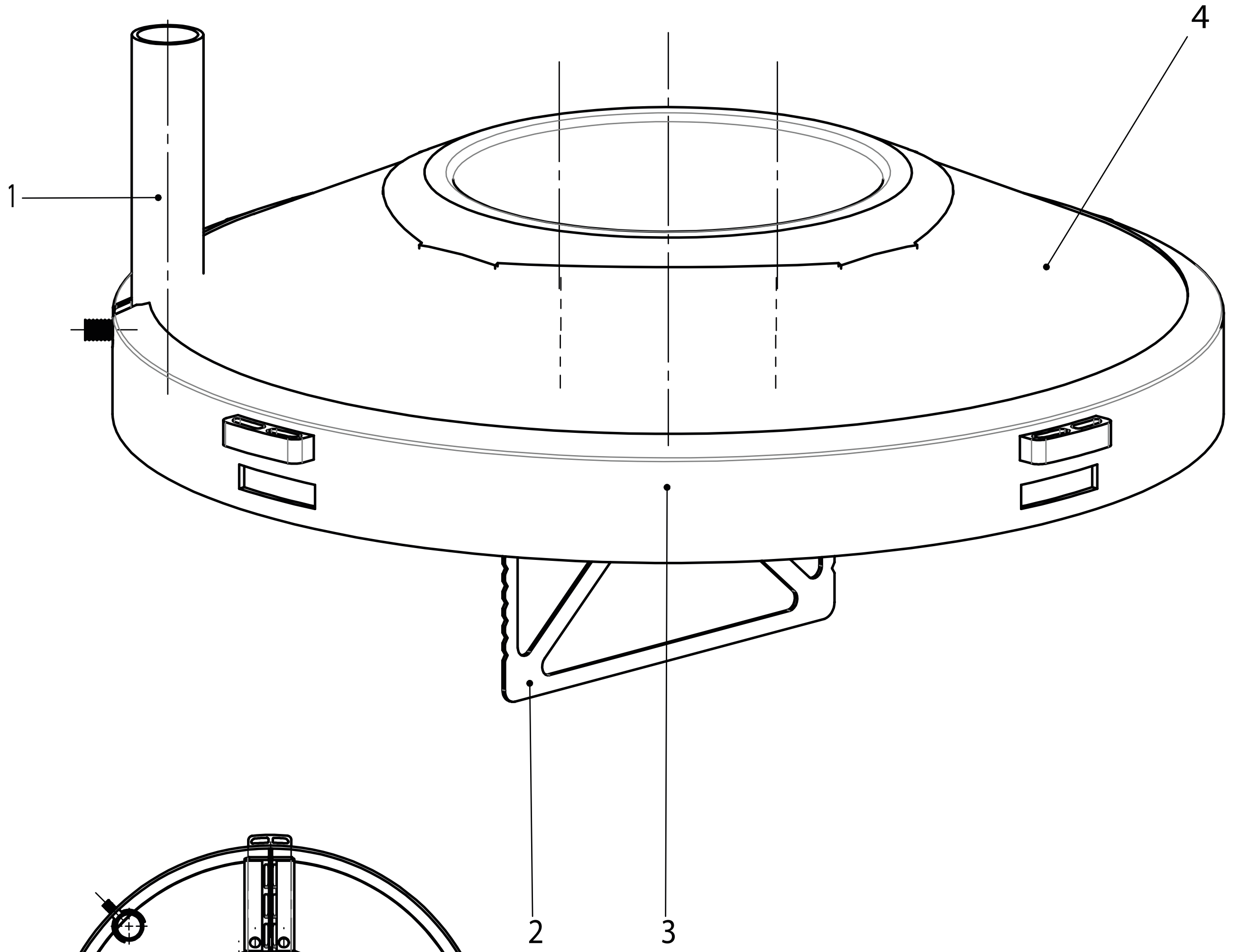
C3 SLIDER

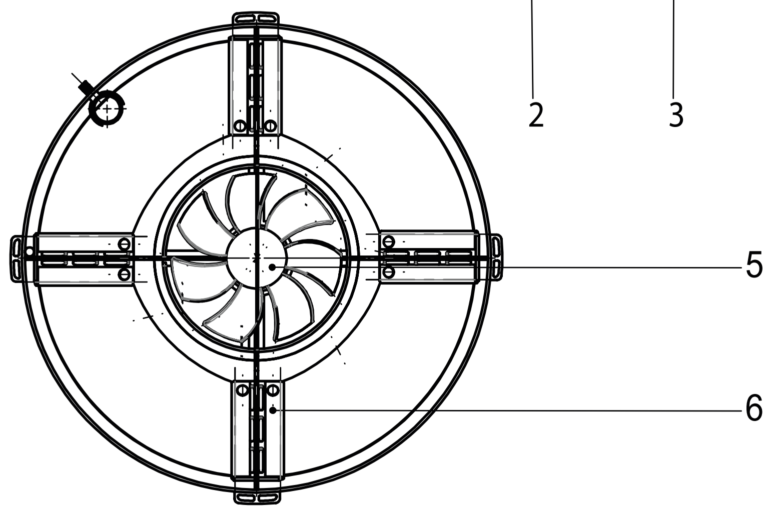
Material: Polypropylene
Production: injection moulding
Weight: 5 grams





T Assembly

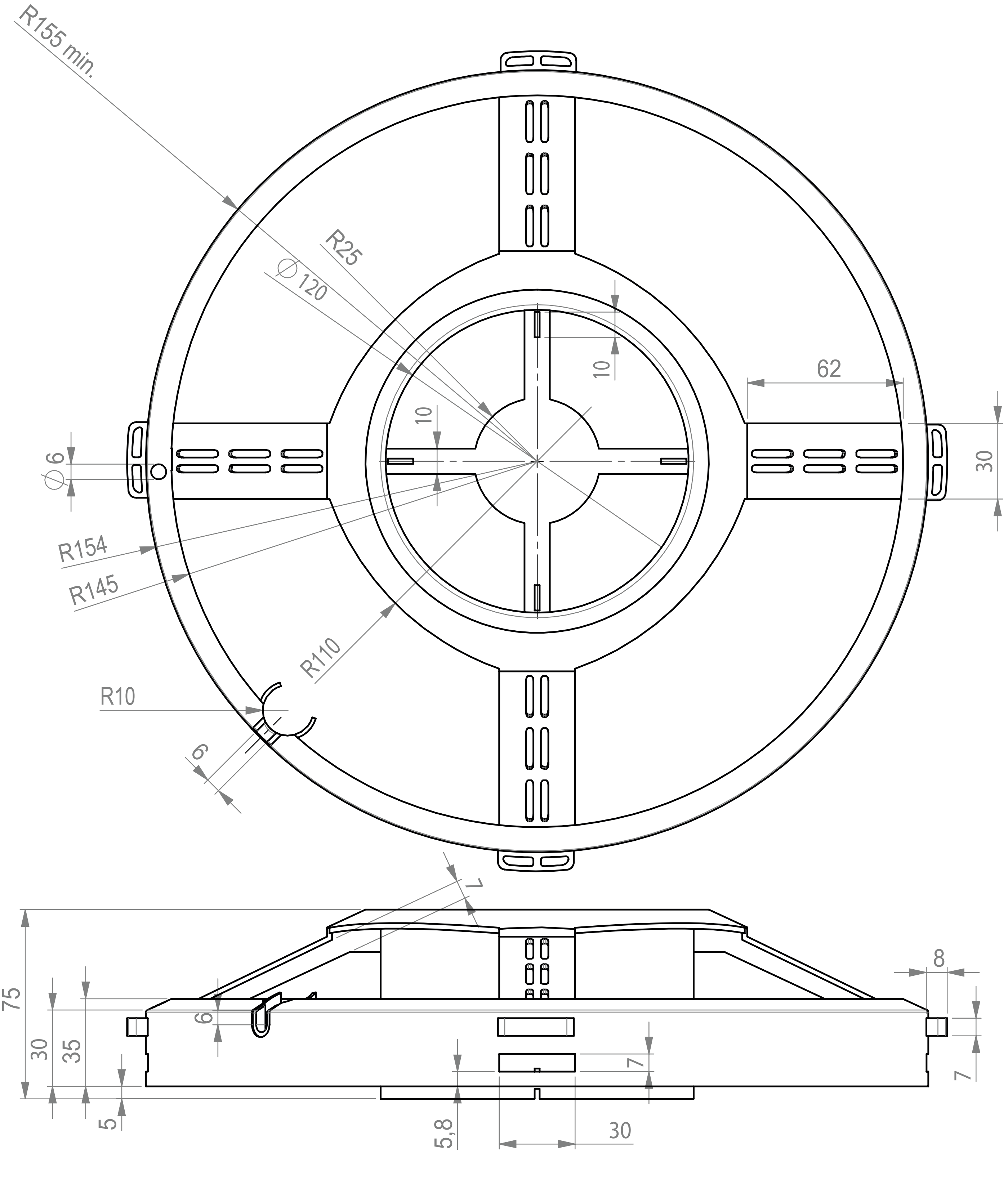




ITEM NO.	PART NUMBER	QTY.
1	T5 Co2 tube	1
2	T4 odour tray	1
3	T1 Canopy frame	1
4	O3 mesh canopy	1
5	T3 fan	1
6	T2 heating element	4

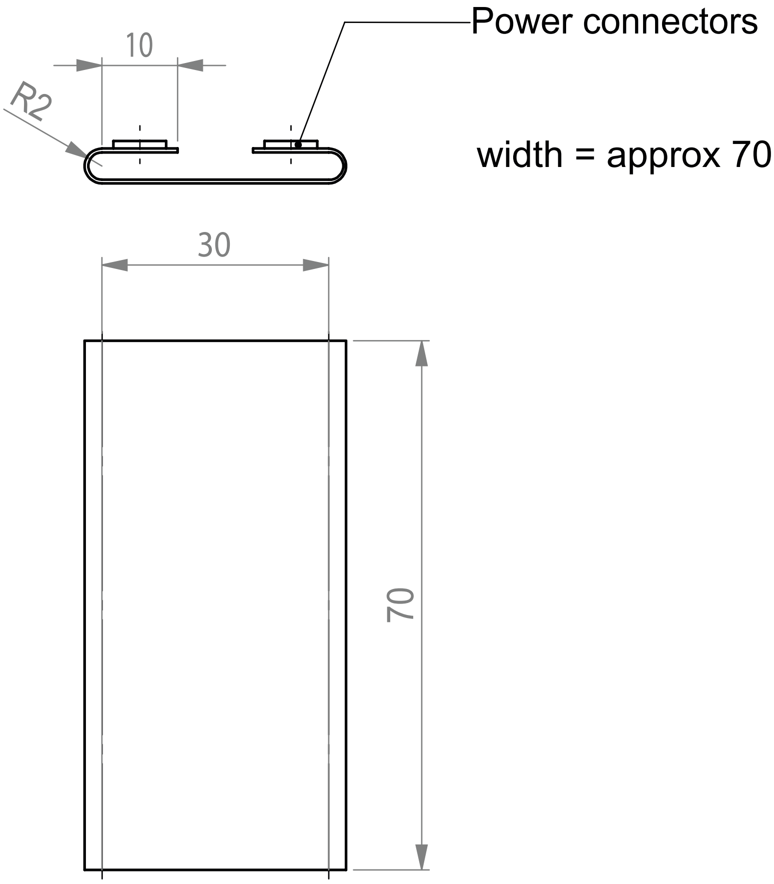
T1 CANOPY FRAME

Material: Polypropylene, UV protective coated
Production: injection moulding
Weight: 176 grams



T2 HEATING ELEMENT

Custom Polyamide heating element
2W, 12V DC

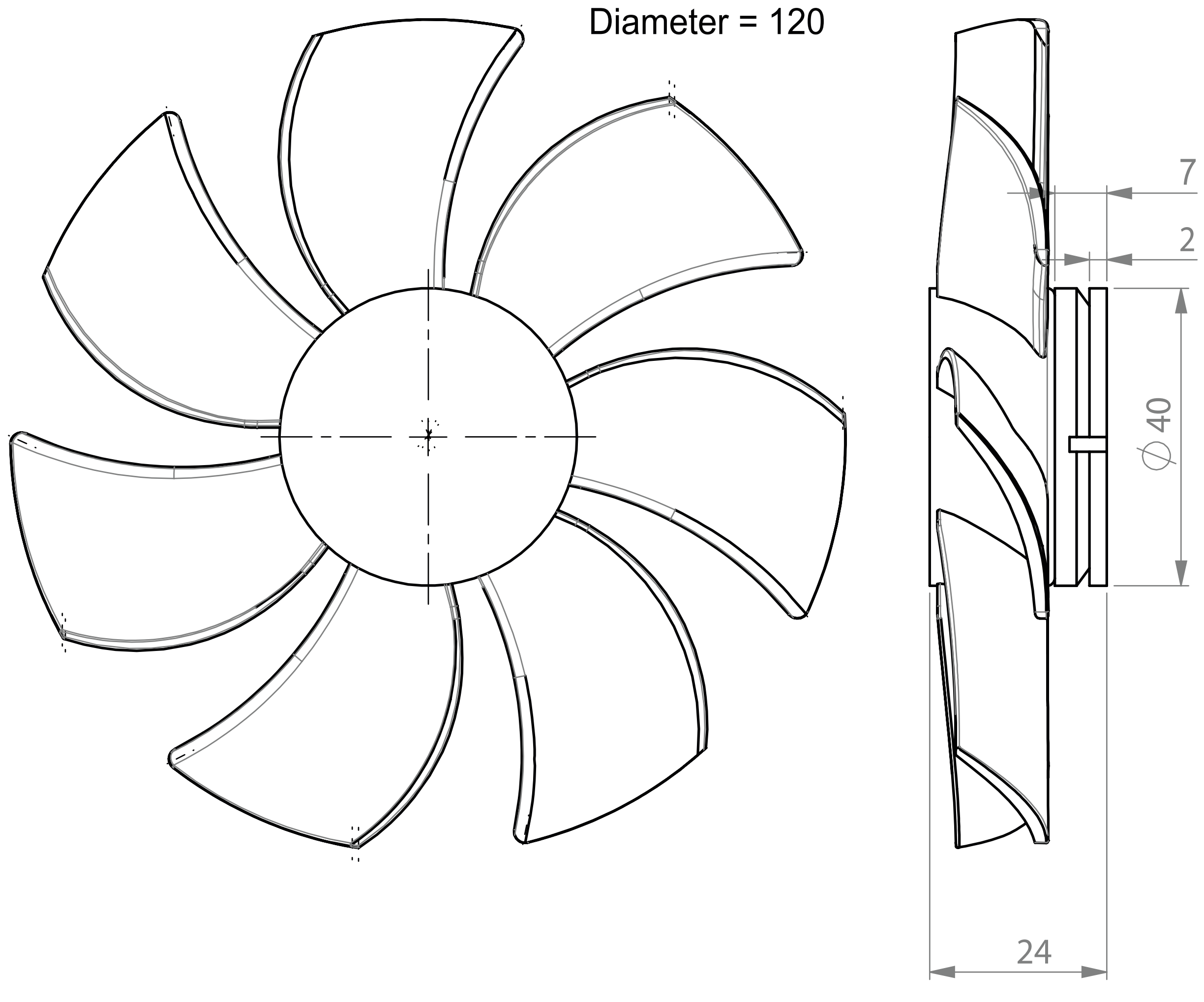


T3 FAN

Custom adaptation of JD-12025C1H2 fan
3.36W, 12V
Grade IP55 water/dust protection

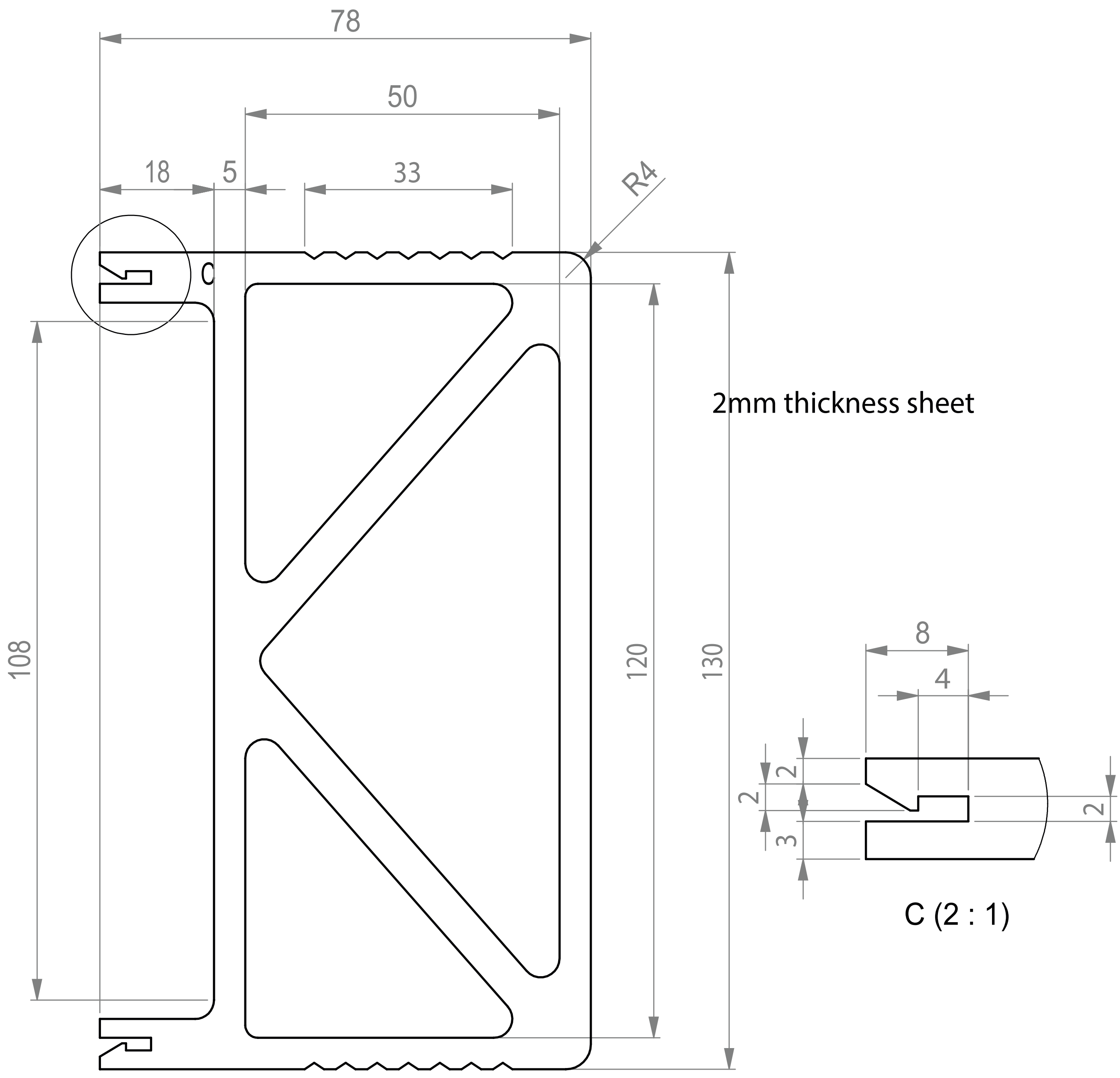
Weight: 100 grams

JD 120-25C1H2 brushless fan without casing



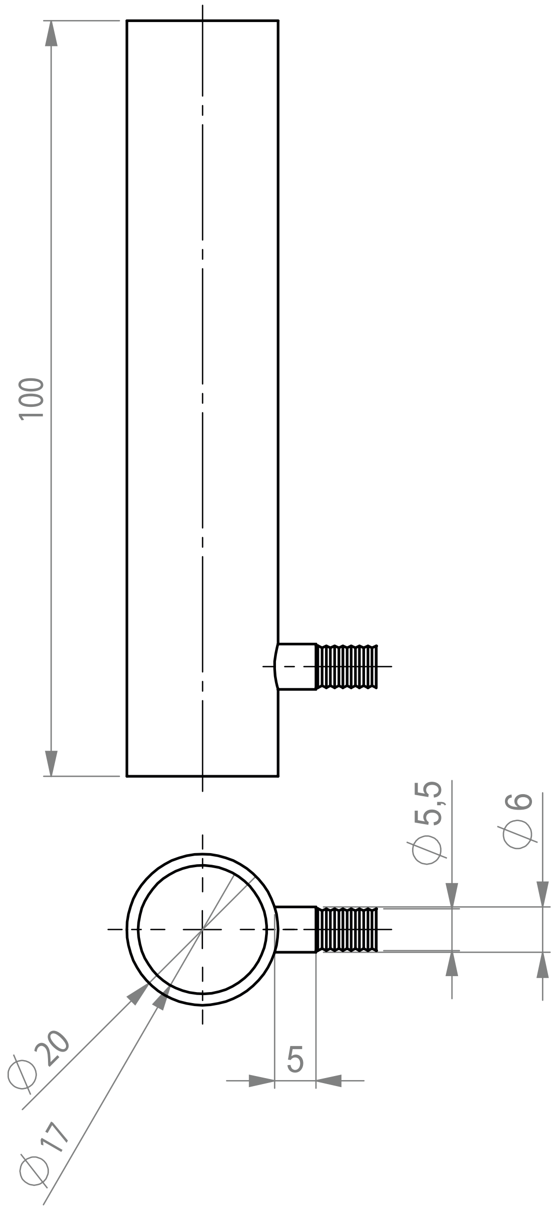
T4 ODOUR HOLDER

Material: Polypropylene sheet
Production: Lasercut
Weight: 20 grams



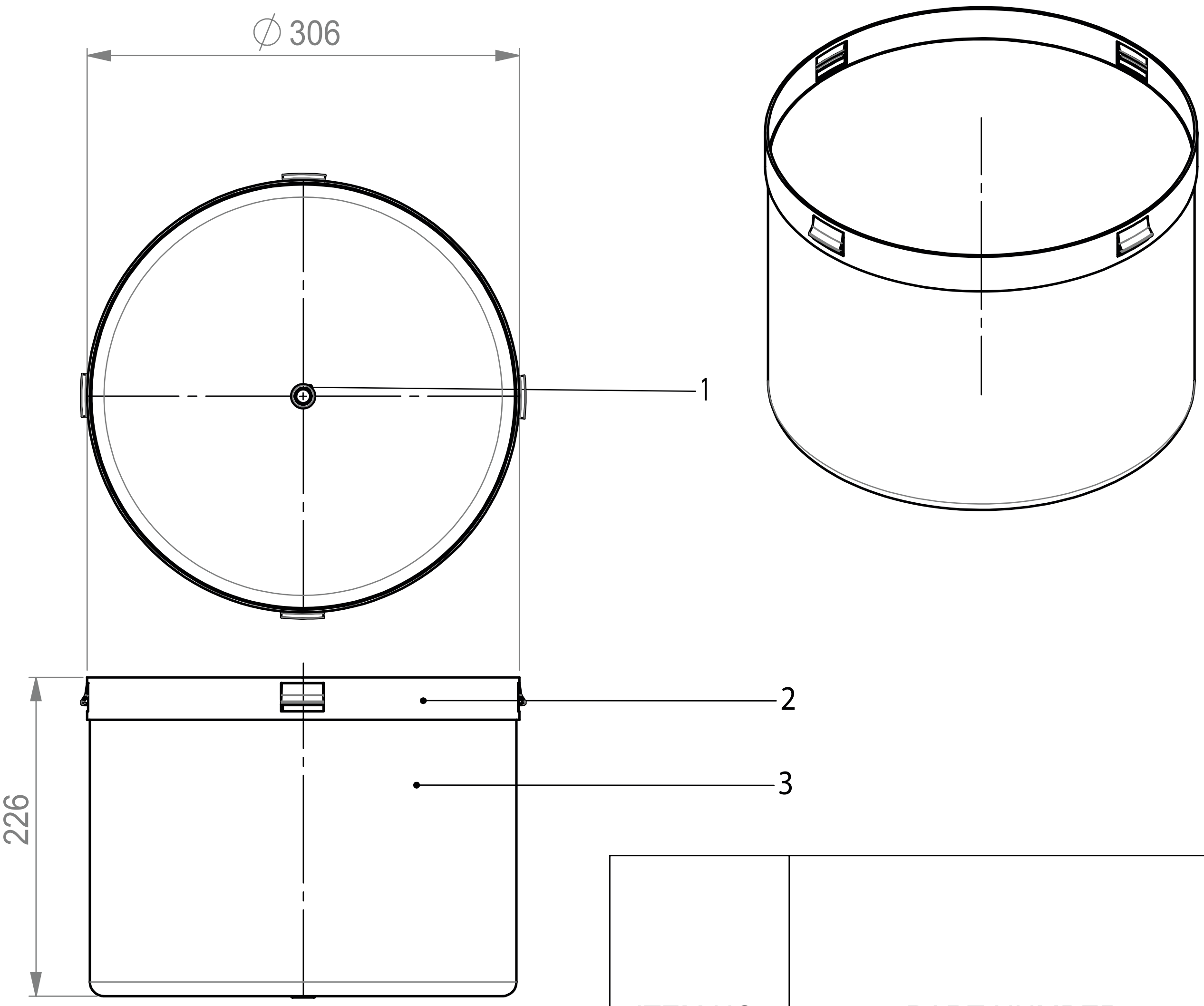
T5 CO2 TUBE

Material: Polypropylene
Production: Injection moulded
Weight: 40 grams



B Assembly

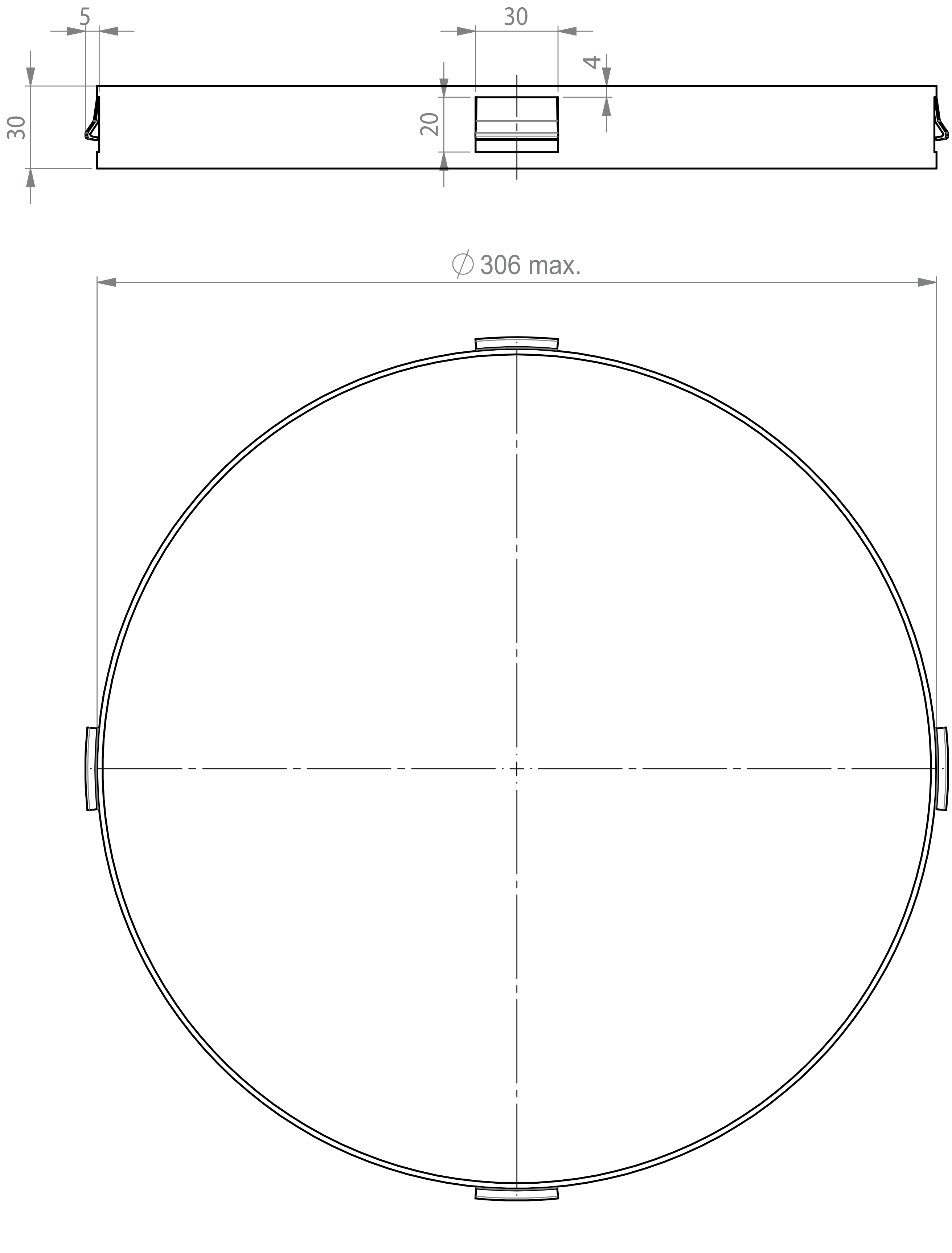
Assembly:
1. Pressing the eyelet into designated hole of bag.
2. Glue the bag to the band



ITEM NO.	PART NUMBER	QTY.
1	B3 Eyelet	1
2	B1 Band	1
3	B2 Bag	1

B1 BAND

Material: Polypropylene sheet
Production: Lasercut, thermoformed
Weight: 50 grams

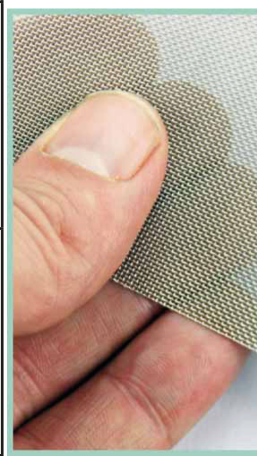


B2 BAG

Material: Woven Polyethylene (PE) (a.k.a Tarpaulin)
Production: cut and sewn
Weight: 40 grams

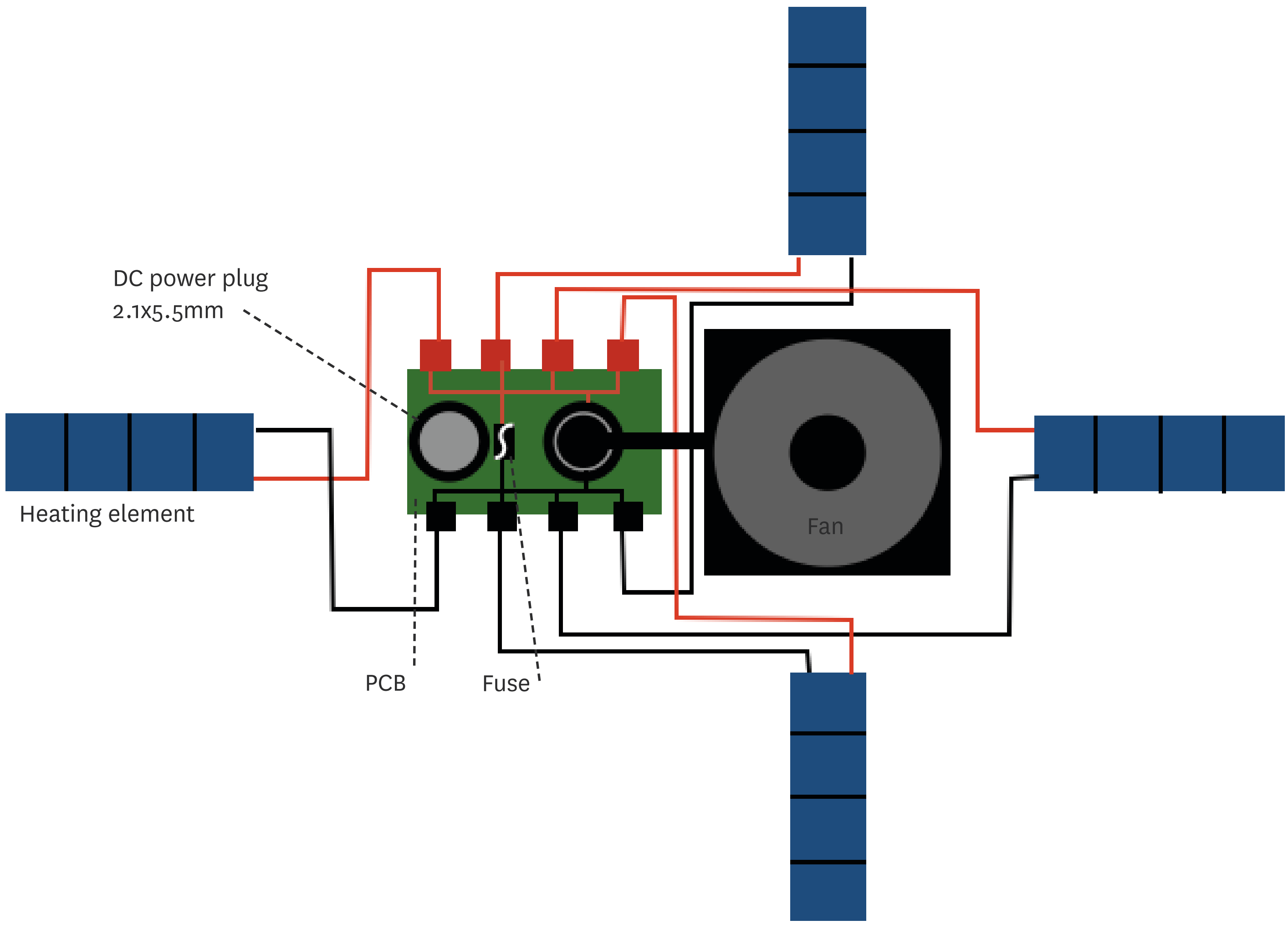
O1-O5

Other parts not yet described.

Item	Material	Properties	Picture
O1 rope	Nylon	Neutral colour	
O2 Power cable		DC plug 5.5x2.1 male to male	
O3 Mesh canopy	Aluminium, polyester, depending on further research and costs.	Nominal hole size 0.2-0.5mm. To be optimised by further research.	
O4 Mesh catch container	Stainless steel	Nominal hole size 0.5-1mm. To be optimised by further research.	
O5 PCB		Connects the heating elements and fan to the power cable. (see next page)	See page 32

05 PCB IN SYSTEM

Parallel switching the heating elements and fan to DC connector.



Appendix F. System parts

In this appendix, a few things are discussed concerning the power system. The power system was an integral part of the 'SolarMal' trial and will likely be used a blueprint for future malaria intervention (research) projects.

WHY A POWER SYSTEM?
As explained in the 'background' chapter, the power system is necessary because often, there is no reliable grid available in the African regions where the systems are installed. For research projects, there is the benefit that people without electricity are far more likely to participate in a research study. In the Rusinga island project, for example, the entire island participated. There generally is some sepsis against scientific research based on previous experience and lore.

PARTS OF THE SYSTEM
The system consists of a solar panel, a battery, and a controller of sorts to a) distribute the power over electronic devices and b) switch the trap on and off automatically.

The solar panel should have a power of at least 20Wp. This panel generates between 0.09 and 0.2 kWh per day.

The trap has a power consumption of at most 83Wh per day. The lights use around 36Wh per day. These needs translate into a battery capacity of 9.9Ah. For security, the battery should have a capacity of at least 12Ah.

Cost indications from alibaba if bought in bulk (>10,000)

COSTS OF THE SYSTEM

A 12Ah lead-acid battery can be bought in bulk for around $10.
For solar panels, $0,50 per Watt is common.
A 20W solar panel costs around $10.
A controller can be bought for $15, and other electronic parts required for another $10.

A total sum is therefore $45. This is significantly lower than the prices in the Solarmal project. These prices are partly lower because the cost of solar panels has dropped significantly since 2013.

Appendix G. Micro emotion scan and user testing

Method

- Create a space where users can interact with the product.
- Make sure all the necessities are present; the trap, water, a place to suitably hang the trap.
- Invite users to the place by asking if they would like to participate
- Obtain written consent to have photos taken and quotes recorded
- Explain what the goal of the research is
- Explain what the product is
- Carry out the protocol

PROTOCOL

1. Look at the trap: what do you think?
2. Take the trap, touch it, explore! What do you think or feel now?
3. Find a suitable place to hang the trap
4. Unfold the tarpaulin bag. How did it go?
5. Fill the trap with 0.5L of water
6. Plug in the trap. How does it work? How do you feel?
7. Now unplug the trap
8. Take out the inlet module.
9. How would you take out the mosquitoes inside? How would you prevent them from escaping?
10. Loosen the catch container. How did it go?
11. Empty the catch container. How do you feel?
12. Put the trap back together

INTERVIEW GUIDELINE QUESTIONS

- How do you think it went?
- What could be improved about the user interactions?
- What was easy, what went well?

- Where would you place the trap?
- How do people feel about vector trapping just outside their houses?
- What would make you feel safe?
- Is there a need for user safety from the user perspective?
- What is the user need?
- Do they see user need in vector trapping/killing? Or do they see other needs?

- Ask about functionality. What do users need, what are features that are necessary, what is unnecessary/too much?

Phases	First Look		Setup				Use	Upkeep					
	First look	First touch	hanging	unfolding	filling water	plug in	Looking at it work	unplug	take out tube	loosen mosquito container	Store mosquito container	refill water	re-assemble
Experience													
Insights													
Quotes													

Appendix H. Decision tree

1 TOPOLOGICAL CHANGE

1.1 Changing electronic connections
The current electronic connections seem prone to obstruction by dust, sand or water, and therefore short-circuiting

2.1 Making the catch container more accessible
Currently, the catch container is not very accessible to the user. Therefore, a new configuration is needed.

Result: catch container on top of the design.

2 KEEPING THE TARPAULIN BAG

2.1 Visual clue
The bag is a great visual clue for mosquitoes. Especially when dark, it forms a stark contrast with the wall or sky behind.

2.2 expenses of other materials/options
Other types of materials, such as stiff plastics, quickly become expensive and particularly require large mould investments

2.3 volume for airflow
The bag creates a lot of volume for the airflow to circulate in

3 ONE PIECE CANOPY

3.1 Manufacturing cost of current solution
The multi-piece canopy in M-Tego I is expensive because of multiple moulds required and assembly costs.

3.2 Options for easier connections to other parts
In one part-injection moulded canopy, it is easy to add the features for, e.g. a CO_2 pipe, wire for hanging, odour placement, etc.

4 HANDLE ON CATCH CONTAINER

4.1 Current handling is dangerous
With the heated parts in the position they're in now, it is dangerous to not have a clear use clue for the user where to grab the inlet.

4.2 Ease of use
Simply making the product easier to use is a good reason to add a handle

5 MOVING THE HEATING ELEMENTS

5.1 Exposed position
In their current position, they can easily be touched unintended (dangerous when hot) and damaged.

5.2 wiring
By being on the catch container, they have an extra wire dangling around (or the 'touch' connectors that might cause trouble). This is undesirable.

6 ADDING A PCB

6.1 Timer
Because a timer is thought to not be present in all types of controllers, adding one on an internal pcb is removing the need for a special type of controller.

6.2 Ease of replacement
Adding a PCB with a terminal for wiring from the heating elements and fan will make replacement of these parts easier.

6.3 Fuse
A fuse is added for prevention of over-current that might occur with unstable controllers.

7 MESH MATERIAL

7.1 fragility of material
While somewhat strong, a polymer mesh is not very impact-resistant, bending on impact. An aluminium or steel mesh stays in form on impact.

7.2 Durability of polymer mesh
During testing, it became clear that small holes form in the polymer mesh easily. This makes the trap accessible for the smaller and aggressive *Aedes* mosquitoes.

7.3 Formability of material during manufacturing and assembly
A polymer mesh has to be manually placed

on the canopy because it lacks stiffness, an aluminium or steel mesh can be pre-formed.

7.4 Price of steel mesh
Steel mesh was found to be significantly more expensive than aluminium mesh ($9/m^2 compared to $1.5/m^2).

7.5 Theft
While aluminium and steel are desirable materials, the lack of object weight makes the mesh unattractive to thieves.

8 SUSPENDING THE TRAP

8.1 Suspending the trap is un-sustainable
Children and animals will see the trap as a piñata, play with it.

8.2 Suspending the trap is sustainable
The trap will be protected from flooding, ants and smaller animals entering the trap.

8.3 Suspending the trap is flexible
The hanging of the trap makes that the trap can be placed in many different places, both urban and in nature.

8.4 Hanging the trap is cheap
Hanging is far more affordable than designing a custom frame or stools for holding.

9 REMOVING WATER FROM THE TRAP

9.1 Sun height
The sun around the equator rises much higher in the sky, leading to less sunlight on the water container

9.2 trees
Houses are build around trees, which provide shade

9.3 user upkeep
Water adds significant (bi-daily) user upkeep, because the water evaporates quickly.

9.4 architecture
Houses often have overhanging roofs, which also provide shade to the suspended trap

10 HEATING ELEMENTS INSTEAD OF NICHROME WIRE

10.1 Fragility
Nichrome wire does not rust, but is rather fragile due to the nature of wire; one cut stops the entire system.

10.2 Need for concentration
The Nichrome wire likely used too much power to be feasible in prototype I phases. The change of location to on the canopy thus required power concentration in order to produce enough heat locally, which means separate smaller systems.

10.3 Desire to keep costs of system down
Since electricity is very valuable to the rural African, it is desired to save as much battery capacity for household use. Therefore, the trap needs to use as little electricity as possible- while increasing performance at least 3X.

11 LOCATION OF HEAT ELEMENTS

see 5 also.

11.1 the experiments with heating elements
Beneath the fan were less successful than those with the heating elements on top of the fan. (less heat spread around the trap) See Appendix D, heat mapping.

11.2 exposure of heating elements
The heating elements should as much as possible face outwards, and be as close to the outer layer (mesh) of the trap. Also should be as 'high' in the product as possible.

12 FAN TYPE

12.1 performance
The current fan type provides enough air flow to capture mosquitoes, so the current fan specifications are good.

12.2 cost
The new fan will be produced in large volumes, making a new design feasible.

13 ODOUR POSITION

13.1 Odour above fan
Odour above the fan obstructed the airflow too much

13.2 Odour spreading
By stretching the material, the scent can be spread as much as possible.

13.3 Accessibility
The odour should be accessible when replacement is needed, but not easily damaged or removed

14 PLASTIC PARTS MATERIALS

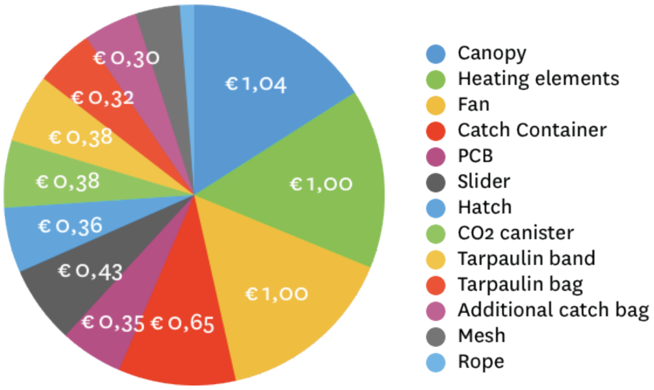
http://www.grantadesign.com/products/ces/

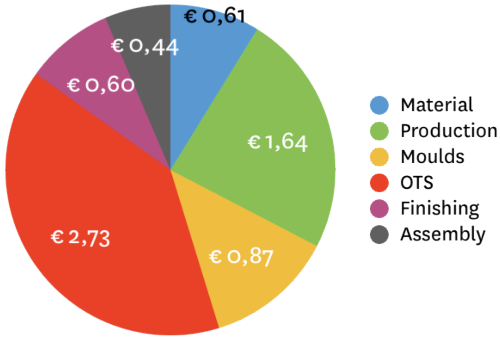
14.1 CES
The Cambridge Engineering Selector was used to select materials that were affordable (under €2,50 per Kg) and have a high glass-transition temperature (over at least 100º C). Materials were ranked by tensile strength.
PP fulfilled both demands and offers good performance strength-wise.

https://polymer-additives.specialchem.com/selection-guide/uv-stabilizers-for-polypropylene/uv-stabilizers-for-pp-fibers

14.2 UV stabilisation
Several types of UV-resistance stabilisers are available for polymers. This makes the plastic parts (and particularly PP) better resistant in the outdoor sun for prolonged periods of time. The stabilisers are added to the grains of PP before the injection moulding. Hindered amines light stabilizers (HALS) is a set of chemicals that slows the degrading process caused by UV radiation.

Appendix I: Cost calculation



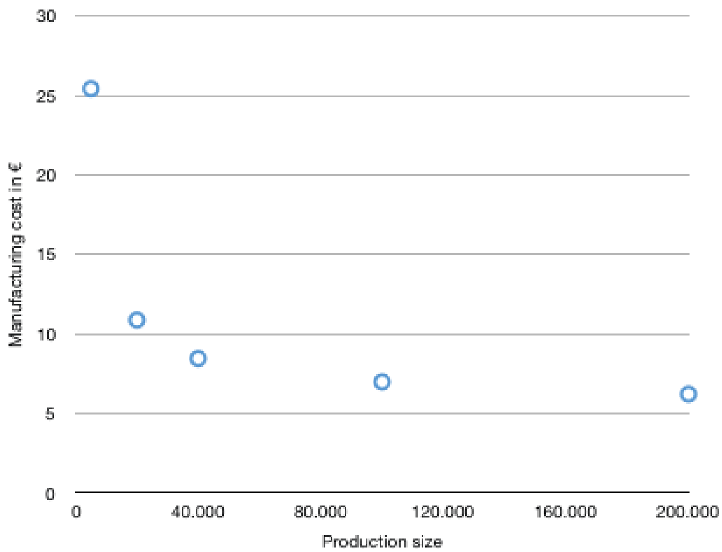


		Material				Process	
			Weight	Cost/Kg	Material Cost	Name	Notes
Catch container	**Hatch**	Polypropelene	0,01	€ 1,25	€ 0,01	Injection Moulding	included in container mould
	Container	Polypropelene	0,122	€ 1,25	€ 0,15	Injection Moulding	
	Slider	Polypropelene	0,005	€ 1,25	€ 0,01	Injection Moulding	included in canopy mould
Canopy	**Canopy**	Polypropelene	0,175	€ 1,25	€ 0,22	Injection Moulding	
	CO2 canister	Polypropelene	0,06	€ 1,25	€ 0,08	Injection Moulding	included in container mould
Tarp bag	**Tarpaulin bag**	Tarpaulin 75 g/m2	0,08	€ 0,30	€ 0,02	Cutting	
	bag band	Polypropelene	0,05	€ 1,25	€ 0,06	Die cutting and bending	
Mesh		Aluminium mesh	0,2	€ 0,28	€ 0,06	Laser cutting	10 sec/unit
OTS							
Fan							
Heating elements							
Rope							
Additional catch bag							
PCB							
Production amount	100000						
	Totals		0,702		€ 0,61		

Right: influence of batch size on production costs

left: manufacturing cost by part (utter left) and production step.

Below: full table of costs and prices



					Finishing		Assembly		Total
Mould	Mould cost/ startup cost	Mould/part	Production costs/part	Total production	Name	Price	Name	Time (s)	
1	€ 10000	€ 0,10	€ 0,10	€ 0,20	UV protection coating	€ 0,15	Pressing in	10	€ 0,36
1	€ 10000	€ 0,10	€ 0,25	€ 0,35	UV protection coating	€ 0,15			€ 0,65
2	€ 32500	€ 0,33	€ 0,10	€ 0,43					€ 0,43
2	€ 32500	€ 0,33	€ 0,35	€ 0,68	UV protection coating	€ 0,15	Screwing in fan, connecting bag	20	€ 1,04
1	€ 10000	€ 0,10	€ 0,20	€ 0,30					€ 0,38
		€ 0,00	€ 0,30	€ 0,30			Glueing	10	€ 0,32
	€ 2000	€ 0,02	€ 0,30	€ 0,32					€ 0,38
			€12/uur	€ 0,04	Applying edge	€ 0,15	Glueing	20	€ 0,25
							Fitting box	20	
							Total assembly time	80	
							Total assembly cost	€ 0,44	€ 0,44
							Price each	Amount	
					Fan	/piece	€ 1,00	1	€ 1,00
					Heating elements	/piece	€ 0,25	4	€ 1,00
					Rope	/meter	€ 0,02	4	€ 0,08
					Additional catch bag	/piece	€ 0,30	1	€ 0,30
					PCB	/piece	€ 0,35	1	€ 0,35
								Performance edition	€ 6,32
	€ 87000	€ 0,87	€ 1,64			€ 0,60		Science edition	€ 6,99

Right page: an overview of sales prices, system part costs, performance estimations and overhead estimations, and their influences on efficiency per €.

System sales prices breakdown

		M-Tego sans wire		Suna (2015)		Suna 2019		M-Tego super hot wire (high power)		M-Tego optimised power		Science edition (trap only)	
Full system selling price		**€ 80,44**		**€ 156,50**		**€ 97,00**		**€ 103,62**		**€ 76,37**		**€ 31,80**	
	Solar panel	€ 15,00	20 Watts	€ 22,50	20 Watts	€ 15,00	20 Watts	€ 25,00	40 Watts	€ 15,00	20 Watts		
	Battery	€ 10,00	12 AH	€ 29,00	12 AH	€ 10,00	12 AH	€ 20,00	20 AH	€ 10,00	12 AH		
	Other (cables etc)	€ 30,00		€ 35,00		€ 30,00		€ 30,00		€ 30,00			
Trap selling price (ex VAT)		€ 24,00		€ 70,00		€ 42,00		€ 27,00		€ 20,16		€ 30,00	
INC VAT		€ 25,44		€ 70,00		€ 42,00		€ 28,62		€ 21,37		€ 31,80	
	Manufacturing costs	€ 8,00		€ 23,33		€ 14,00		€ 9,00		€ 6,72		€ 10,00	
	Overhead	€ 16,00		€ 46,67		€ 28,00		€ 18,00		€ 13,44		€ 20,00	
	Profit												
	Subsidy												
Performance		290		100		100		450		450		450	
		2,9	Better than Suna					4,5	Better than Suna	4,5	Better than Suna	4,5	Better than Suna
Performance/€		3,6		0,6		1,0		4,3		5,9		14,2	
		5,6	Better than old suna			1,6	Better than old Suna	6,8	Better than old Suna	9,2	Better than old Suna	9,9	Better than old Suna (trap only)
		3,5	Better than new suna					4,2	Better than new Suna	5,7	Better than new Suna	5,9	Better than new Suna (trap only)

“Indifference towards people and the reality in which they live is actually the one and only cardinal sin in design.”

Dieter Rams