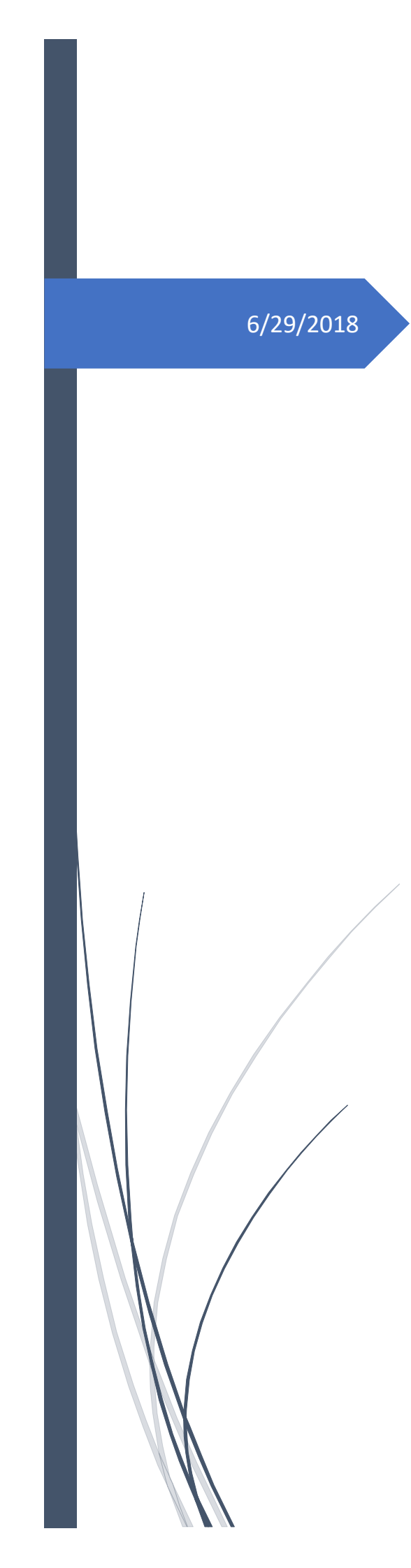




6/29/2018

Precious Plastic

William May-White

[William May-White \(P101973\)](#)

Abstract

In this report the compression moulding machine from the Precious Plastic project was critiqued and safety flaws have been highlighted. By using product design tools such as QFD, Pugh Matrix and FMEA analysis key elements of the compression machine have been modified to adhere to health and safety regulations in the UK. Large emphasis of the safety of the users has been included so that the compression machine can be used with other machines in educating the public in the importance of recycling/repurposing plastic. While all the safety factors had to be included it was as important that the cost was kept as low as possible, with recycling and repurposing components when possible.

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Precious Plastics

Mission Statement

“Precious Plastic is a global community of hundreds of people working towards a solution to plastic pollution. Knowledge, tools and techniques are shared online, for free. So, everyone can start (yes, you too!).

We are independent, poor but free :)

Hundreds of people all over the world contribute to the project with their skills & knowledge, single or monthly donations.” (Precious Plastics, 2018)

Precious plastics are attempting to fix one of the biggest human-related ecological disasters in history. Precious plastic has identified that instead of recycling waste plastic via community councils it is able to offer the knowledge to create a pop recycling plant for all to use. It is tackling the worlds waste plastic on a local scale.

Precious plastic does not sell any machinery or spaces but offer an ethos for everyone to embrace, use and share adding their own little touch to it. The more people who are on board on this project the faster it might grow leading to further innovation and adoption in places around the world.

The United Kingdom puts the 14th least amount of plastic in landfill in Europe (Plastics Europe, 2018). The UK government has set targets to get landfill plastics down to under 10% by 2035 (Carrington, 2018) which even today would not put the UK in the top 5 in Europe. The growing need for bigger change is greatly needed. Precious plastics will not single handily help the UK meet its target by 2035 but it may change people attitude and help people gain awareness of the problem the world faces.

What Precious Plastics Offer

Precious plastics have designed and created a pop up recycling plant. It allows people to bring waste plastic along and create something different with out of it. What they create is really to the imagination of the local designers. First the plastic needs to be processed where the plastics is broken into small pellets. Once the plastics have been broken down then they are heated and to melting point and formed into a desired object using moulds or die. Once that is complete the person now has something that can be used or sold. Typically, the objects are simple and decreative but never the less the chances are the plastic used would be going to landfill.

The Machinery

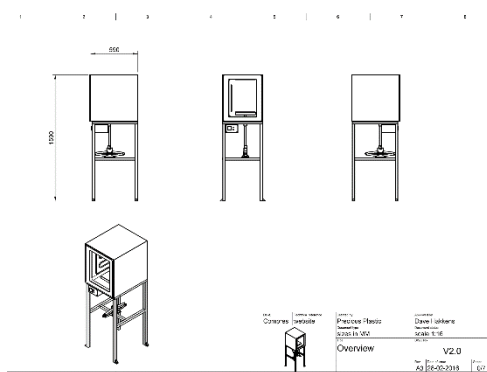
The machinery in this report which will be analysed and developed is the low-pressure injection moulding oven. As seen in Fig.1 the oven is very basic and is comprised of many recyclable parts which can be found at scrap yards and recycling plants. The main components are an oven, base, jack, mould and power source.

Precious Plastic's ethos of recycling is carried through in the designs of the machinery. The design is based closely on the industrial version of the machinery but on a small scale. This allows the cost to be kept low and does not need industrial knowledge.

Precious Plastic design are all open source and free to download from there website. The kit comprises of blueprints, posters, labels information, CAD files, manual, wiring diagrams and videos. The kit almost covers all aspect of the machine and what is needed, a forum is also available for the Precious Plastic community to share ideas, innovations and designs. It can also be used for help if people may have queries or problems.



Fig.1. (Precious Plastic, 2018)



Each machine is designed on a modular basis, so each component is independent of each other meaning that it can be easily replaced, improved, changed, repaired and maintained without effecting the overall machine (Precious Plastic, 2018).

The plastic pellets are placed in the mould and placed in the oven. The oven will be set to 200 degrees centigrade until plastic is melted. Pressure will be applied with the use of the car jack until mould is filled, the pressure should then be released and then it will be left to cool.

For producing plastics products, the Precious Plastic compression oven does exactly as intend but in very simple way. The main objective was to get a piece of machinery which could do such task at the lowest possible price while reusing as much as possible. In this case Precious Plastic have achieved just that. The design is simple and even if a part may break it can be easily replaced. A machine like this can be produced for around €120.00 that is with paying for components from a scrapyard.

All the machinery that Precious Plastics offer is an exercise of gaining industrial knowledge, allowing for people to use their imagination to innovate the machinery. For example, the fundamentals of the compression machine will not change, plastic will be heated, compressed and ejected. The one big change that will be done is the moulds used. The machine can produce simple shapes and blocks such as bowls and tiles. This machine could produce the plastic containers for the sorting process instead of buying containers. This could possibly be a good addition to the starter pack and possibly a mould design could be given.

The oven is completely capable of producing simple shapes but when compared to an industrial version there are some huge flaws. An industrial version heats the plastic in a separate container then injects the melt into a warm mould. The part is left to cool then the part is ejected, this process can be sped up by using cooling journals in the mould to dissipate the heat more efficiently. A cycle time for an industrial moulding machine is would be sub one minute, while the Precious Plastic compression machine has a cycle time of over two hours. This is because the mould is the same temperature as the oven and the oven needs to cool down before anything can be taken out. The oven will cool down slightly quicker than most ovens due to there being a hole at the bottom for the mould to be moved by the car jack. While this might help the oven cool down quicker it does not help the oven reach it optimised temperature. This is a big design flaw, heat is escaping from the oven thus using more energy, exerting heating into the surrounding area and increasing heat up time.

Another flaw in the capabilities of this machine is the restriction of what moulds can be created. Only two moulds can be used at a time in the oven and weld line must be horizontal to the base otherwise molten plastic may seep out. By having two parts to the mould it greatly reduces the complexity achievable. In an industrial equivalent the mould mates perfectly, the exact amount of plastics is injected and the correct amount of clamping pressure is used.

The main problem is that the Precious Plastic machine heats and compresses all in one, while an industrial version the heat and compression are two separate parts. To produce a precious plastic machine similar would be very difficult and unnecessary.

The Precious Plastic oven does not need to reproduce the same part repeatedly in the quickest possible time. Yes, the biggest flaw of the machine is the cycle time but the diversity of what it can produce far outweighs the cycle time. If the mould is made from two pieces and fits within the dimensions of the oven then many simple designs can be produced.

Costing

In Fig.2 is an approximated price break down of the machinery supplied by precious plastics.

Bill of materials compression

Description	Material	Details	Quantity	Where to get it	Remarks	Price
Machine parts						
• Round bar	Steel	25MM	45 cm	Scrapyard		3
□ Square tube	Steel	30x30x3MM	1500 cm	Scrapyard		45
L Angle profile	Steel	30x30x3mm	260 cm	Scrapyard		2
Sheet metal	Steel	1mm		scrapyard	can be rough, just for coverage	25
Sheet metal	Steel	25x25x3 mm		scrapyard		5
Oven	-	45x45x55	1	scrapyard		10
Electronics						
PID Controller	-	0-400 Degree	1	Ebay		10
SSR	-	2-24 V	1	Ebay		4
Thermocouple	-	Type K	1	Ebay		8
Power switch	-	220V	1x	Scrapyard/Hardware store		3
Led indicator	-	220V	1x	Hardware store		3
Powercord	-		5 M	Scrapyard/Hardware store		2
Fig.2 (Precious Plastic, 2018)				Total		€120
						Price varies depending on where you live

The total cost of €120.00 could be considered reasonably cheap. Also, parts of the machine could be recycled thus not costing anything. It is the cost of the daily running of the machine which would be the most expensive part. An estimated running cost can be calculated a kWh of electricity cost average £0.13 in the UK (Bulb, 2018). The average oven is 2400 Watts and the oven will be used for five hours of a day. The daily cost will be £1.56, £31.20 a month and \$405.60 a year based upon five day working weeks. This is an estimation so there are many variables which could come into consideration. Such as insulation of the oven, efficiency, stop/starting and the contents of the oven. The £1.56 does not seem a great deal of money, but this is one of five machines also there are other energy consuming systems in the recycling plant. This could be taken as a flaw of the machine as well. It would be very hard to recoup the money to run this plant by selling products if this machine can only produce four items a day. A far more self-sustainable energy source is required if this is going to last. To use a 3kW solar panel system with battery source for just this machine

would cost approximately £4500.00 (SolarPanelGuide, 2018). If the precious plastic program was going to be permanent, then the investment in solar panel system could be warranted.

An energy recuperation system could also be a viable option.

Another option is to start selling the products made, this could be done locally or on an internet market place. This could start to recuperate some of the running cost. The Precious Plastics recycling should not be driven by money to be self-sufficient but to educate the local community of how to recycle and how easily it is to make a difference.

Safety

With regards to safety of the machine the compression oven is relatively safe if the correct working practice are followed. The heat is contained inside an insulated oven so the outside of the oven will be relatively warm but not hot. Oven manufactures would have taken precautions to stop such health and safety issues. Where the biggest concern to health and safety would be the base and jack arm. The jack arm goes directly into the oven thus meaning it is exposed to the temperatures and will be at 200 degrees centigrade. Due to it having a steel structure it will conduct the heat well and could possibly be hot enough to burn. This is a big issue if the oven is going to be used by the public. The lower section of the oven should be enclosed so even if the arm becomes hot it is not accessible by anybody.

Another possible issue of health and safety is removing the mould early. The oven will be at 200 degrees centigrade as well as the mould and melt if not solidified. There are many possible scenarios where people may get injured. The machine is only as safe as the person using it, so good working practise are needed with clear instructions on how and when to open the oven and remove the mould.

Extraction of fumes is a critical issue when it comes to melting plastic, while at 200 degrees centigrade here should be very minimal fumes it still should be risk assessed and precautions put in place such as extraction and ventilation.

The HSE's "The Controlling Fume During Plastics Processing" states that

"Ventilation

- *Ensure processes are well ventilated in all cases.*
- *Provide local exhaust ventilation (LEV) wherever material manufacturers recommend it and your own assessment confirms it is required.*

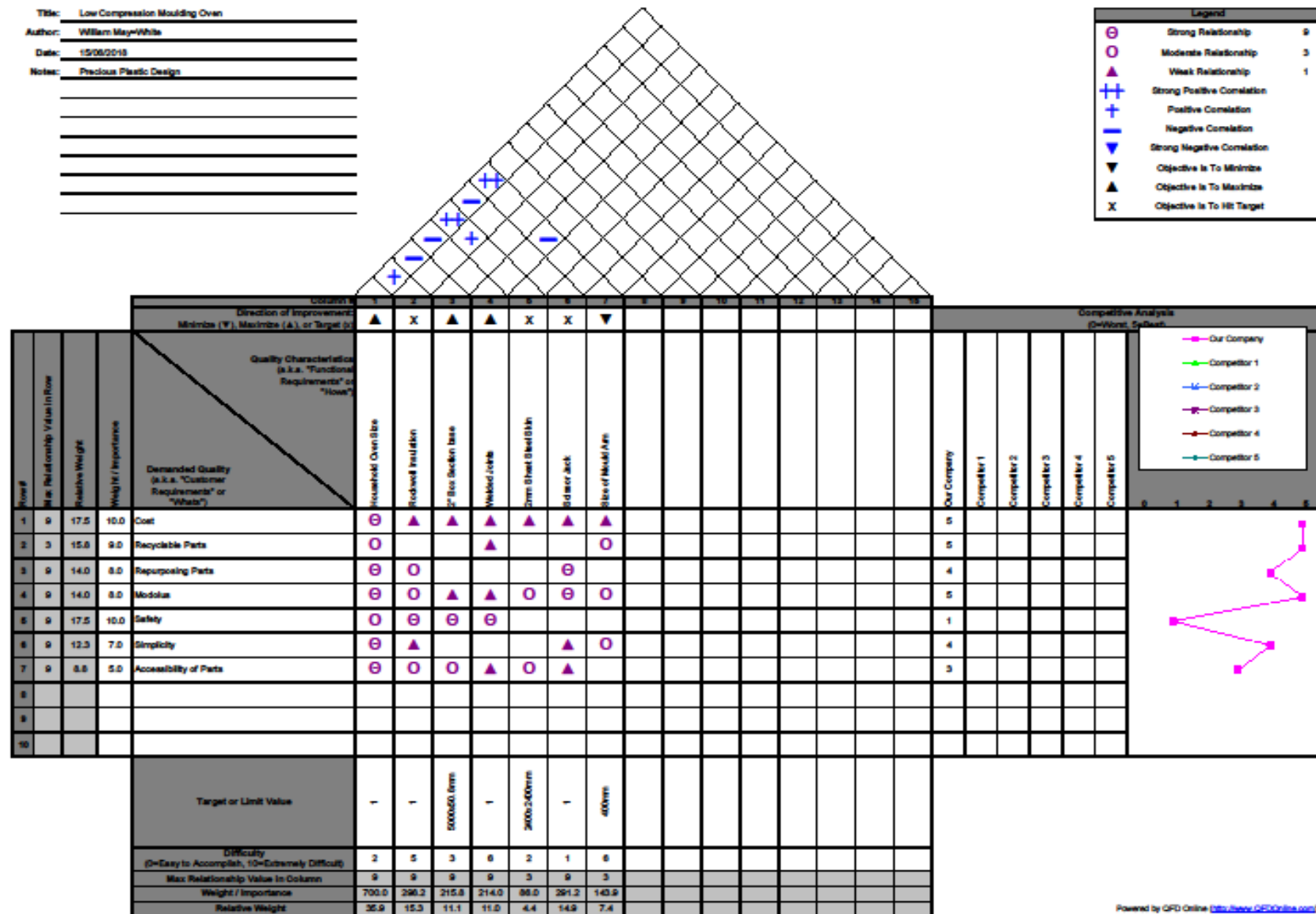
Following the processing parameters, plant maintenance and general ventilation will not control fume in all circumstances. Examples of processes/ activities where LEV is likely to be required are:

- *recycling mixed grades of polymer at pelletiser units;*
- *older machines where process controls are less reliable."*

(HSE, 2018)

This is could have massive consequences if there are high levels of toxins in the air. Due to the oven being in a confined space with potentially many people in close proximity to the machine it must have contained ventilation if it is going to be open to the public.

Title: Low Compression Moulding Oven
Author: William May-White
Date: 15/06/2018
Notes: Precious Plastic Design



Analysis

After analysing the Precious Plastic project as well as the precious plastic oven, several customer requirements have been devised with some machine characteristics. Key areas such as safety and cost will have many relationships with features of the machine. The QFD for the Precious Plastic oven states that there can be many improvements in areas such as safety but this might influence other requirements.

While the oven has many areas of which could be improved, it does fit the specification required of it in many ways. It heats and compresses the plastic in the mould. It is cheap to produce and many components can be recycled or reused. It can be easily maintained or parts replaced and almost anybody can make it with basic metal work knowledge. The oven gives levels of diversity that most industrial solutions cannot; it allows many different moulds to be used without any change in the design.

Having said that there are some issues that need to be addressed if Precious Plastic would be used by the UK public. One issue is the health and safety driven such as there is a need for ventilation, some parts of the oven must be contained so the hot surfaces are not able to be touched.

Secondly is how the recycling plant is going to be powered. Precious Plastic have the ethos of how recycling helps the environment but if the plant is run on energy from fossil fuels then it really is counterproductive. The amount of plastic that would be recycled would not be enough to offset the energy used by burning fossil fuels. Based on this then, either a

green energy supplier such as Bulb (Bulb, 2018) could be used or possibly trying to get funding off local council to become self-sufficient and sustainable.

Design

Design Specification

The design of the new compression machine will need to adhere to set out specifications.

- Low cost
- Recyclable parts
- Repurposing parts
- Easily modified/maintained
- Low energy consumption
- Low impact on environment
- Enclosed moving parts
- Hot surfaces must be insulated
- Ventilation must be present
- Easily cleaned
- No sharp edges
- Simple designed
- Easily produce with minimal fabrication knowledge
- Accessibility of parts
- Aesthetics

Several of these specifications was taken from Precious Plastics design pack. The main consideration of precious plastic's is the recycling and repurposing of components. This would be at a very high importance due to some areas around the world not having the availability of new components also not affording them.

Further high priority would be ensuring that the compression oven is safe for all users and has interlock doors, enclosed moving parts and extraction system to remove fumes.

Compression oven must be designed and manufactured with modulus components so each part can be replaced, maintained or improved.

The design must be simple in design and manufacturing process to allow people with minimal knowledge to be able to produce the machine. This will allow the Precious Plastic plant to be more accessible to countries where education in engineering may be basic and minimal.

One specification that should be considered highly is the environmental aspect. The oven should have low environmental impact, this could be in many forms. The main focus should be energy consumption, with the oven being a big energy user possible renewable energy sources should be used or a energy recuperation system should be incorporated to use the energy more efficiently.

Product Design Specifications (PDS)

1. Performance
 - 1.1. Compression oven that will be used for daily for no longer than 8 hours
 - 1.2. Should be able to produce part in approximately two hours
2. Environment
 - 2.1. The machine will be based inside, having rubber feet which will be bolted to floor
 - 2.2. The material will be galvanised to stop corrosion
 - 2.3. Ventilation will be present
3. Maintenance
 - 3.1. The machine will be based on modular design
 - 3.2. Replacement parts can be easily sourced
 - 3.3. Maintenance manual will be present
4. Cost
 - 4.1. The machine has the ability to have all components repurposed reducing cost
 - 4.2. Approximate cost is €120
 - 4.3. Design can be tailored to suit materials available
5. Competition
 - 5.1. Recycling plants and education facilities
6. Manufacturing
 - 6.1. This machine would have to be manufactured in a facility with the correct equipment is available.
 - 6.2. Machine will have to be quality tested if manufactured to ensure that all components are to be functioning correctly.
7. Weight
 - 7.1. The machine will have a very robust design so will be about 80Kg total weight
 - 7.2. Can be split into individual parts to reduce weight
8. Aesthetics
 - 8.1. Machine will be made with function in mind, but can be customised to each user..
9. Materials
 - 9.1. Base: 1" steel box section
 - 9.2. Oven: 3mm sheeting of outside
 - 9.3. Insulation: Rockwool
 - 9.4. Perspex: Guarding
10. Life span
 - 10.1. If correctly maintained then oven may work for number of years depending on condition.
11. Standards
 - 11.1. ISO 9001:2008 approved
 - 11.2. OHSAS 18001 approved
 - 11.3. ISO 14001 approved
12. Ergonomics
 - 12.1. Robust handle
 - 12.2. Elevation handle have protective coating
13. Customer
 - 13.1. Council/Schools for educational purposes
 - 13.2. Environmental educators
14. Quality

- 14.1. Machines will need to be tested
- 14.2. Ensure that all moving parts move freely
- 14.3. If machine goes into mass manufacturing then batch test will be carried out
- 14.4. Oven is in good condition and tested before used
- 15. Testing
 - 15.1. PAT testing will be carried out before production
 - 15.2. Analysis of stresses and load bearing will be carried out
 - 15.3. Critical fracture points will be found
 - 15.4. Safety factor will be determined
- 16. Market Constraints
 - 16.1. Market penetration
 - 16.2. Brand awareness
 - 16.3. Quality awareness
- 17. Company Constraints
 - 17.1. Financial
 - 17.2. Manufacturing ability
 - 17.3. Brand awareness
- 18. Social implication
 - 18.1. Could be seen as waste of money
 - 18.2. Reliant on funding
- 19. Size
 - 19.1. Overall size will be 1600mmx800mmx800mm
 - 19.2. Will need to fit into shipping container
- 20. Safety
 - 20.1. Ventilation must be present
 - 20.2. No sharp edges
 - 20.3. Instruction manual
 - 20.4. Safe use procedures
 - 20.5. Guard moving parts

PUGH Matrix

Determinates	Priority	Design 1	Design 2	Design 3
Cost	5	4	4	2
Recyclable Parts	5	4	3	1
Repurposing Parts	5	5	4	1
Modulus	5	4	3	2
Safety	4	3	2	5
Simplicity	4	4	3	2
Design	4	3	4	2
Energy Consumption	3.5	2	1	1
Environmental Impact	3	3	2	4
Accessibility of Parts	2	4	3	2
Aesthetics	1	3	2	4
Total		150	113	62

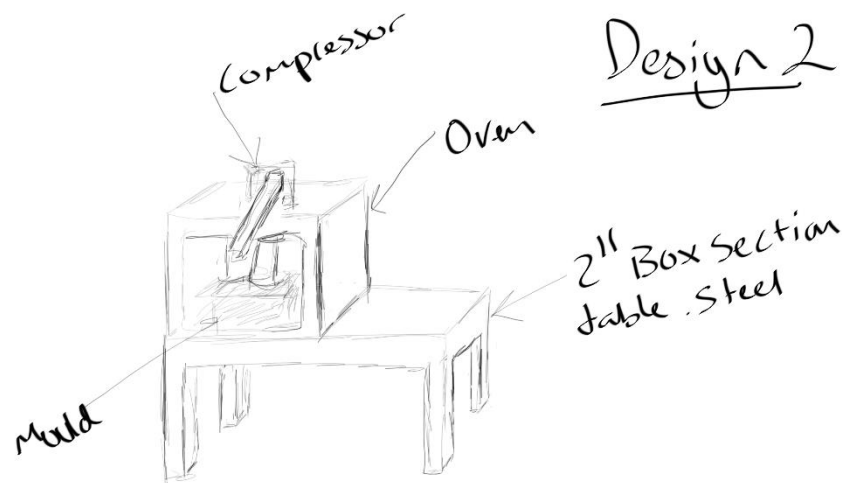


Design 1

Design one is almost identical to the Precious Plastic design, it keeps the ethos of low cost, modulus and repurposed/recycled material. It uses the same repurposed oven design, which can vary depending what is available. It is secured to the base by fasteners on each corner allowing the oven to be replaced. The base is made of 1-inch steel box section welded together to ensure the strength and rigidity required. The base size can be altered to the size or material that is available. The plate to secure the scissor jack is welded into the base, again for strength and rigidity. Due to the oven being very top heavy fixing points will be mounted on each leg to eliminate the tipping risk. The base will be guarded with 3mm Perspex, this will stop any entrapment or touching of hot parts while the oven is in use. The oven will be insulated by thermal ceramic insulation, with a 3mm steel plate as the skin of

the oven. This will keep the outside surface temperature in a safe range and will increase the efficiency of the oven.

A hole will be cut into the base of the oven so the base of the mould can meet the car jack. The mould is compressed by turning lever on the jack until the mould inside reaches the top of the oven. The hole will have a heat resistant rubber seal on which can be repurposed from other ovens, this will keep the heat in when warming up reducing energy consumption. The door will have interlock mechanism that will not open the door until a certain temperature is reached, this can be set by users but likely to be around the 80°C. Once the door has been opened a switch will be made and the ventilation system will come on to extract any fumes.

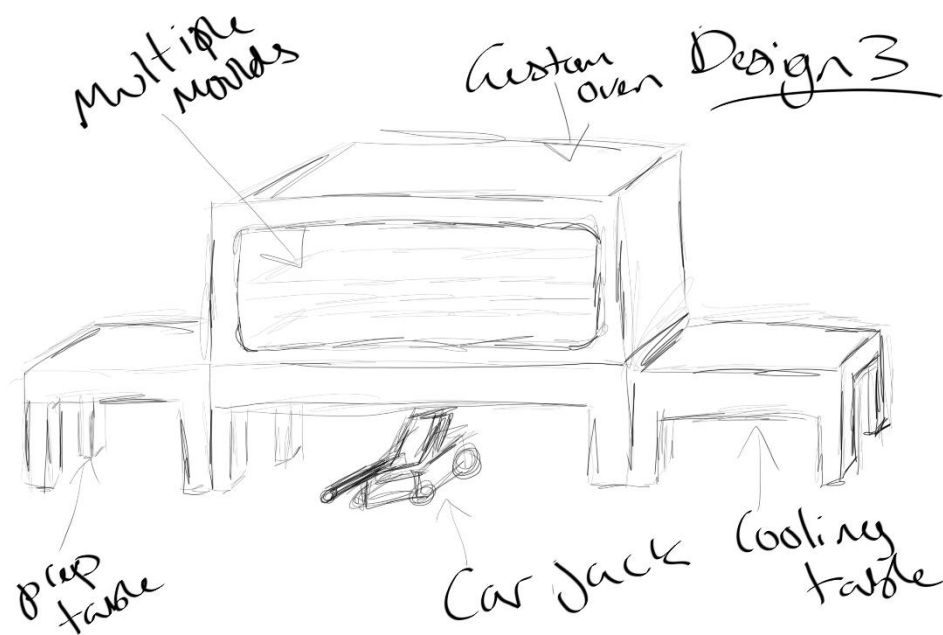


Design 2

Design two has similar features to design 1, the oven is repurposed household oven. The oven is insulated with thermal ceramic insulation with a 3mm steel skin around the oven.

The the oven will be fixed to the base by fasteners so each part can be replaced. The base is made of 2-inch steel box section welded together, again can be changed to more available material. This design has a resting table where parts may be placed or the moulds can be prepared. 3mm Perspex will guard the moving parts on the top of the oven. The door will also feature the interlock and ventilation switch as design 1. The extraction system for this design will be further away which may not extract as well.

The compression will be done by a pivot arm on the top of the oven. The mould will be fixed to the end of the arm. Once the arm is pulled down it will push the mould into the base of the oven where the other side of the mould will be positioned. The oven will have a hole at the top so the arm will be able to move. This poses a problem due to heat rising, a rubber heat resistance seal will be fixed around the hole to reduce heat loss.



Design 3

Design three is a custom-made oven, this allows for any dimensions to be achieved. The base is made from 2-inch box section, with 3mm steel plate as the table tops. The oven will be fixed to the base using fasteners. Each shelf in the oven will be on vertical runners, this will allow for multi-level moulding. The base of the oven will compress into the shelf once that has been compressed then the shelf will compress to the roof of the oven. Each level will have moulds aligned on them. Potentially this oven could have triple the outcome than the other two designs. This movement will be achieved by a car jack fixed to the base of the oven. This will ensure the base moves square to the oven and all moulds will meet evenly.

The oven will have the same safety features as the other designs, ventilation, interlock and guarding over all moving pieces. The door will open downwards due to the size of the door.

The oven will be heated by high efficient oven elements on either side of the oven.

Design Analysis

After considering the importance of the determinates of each design was scored. Design one having the highest overall. Design 1 is very simplistic design while still having safety features and the capabilities of the others. While Design 2 is very similar to design 1 but has the compression mechanism on the top which has increased heat loss over the others.

Design 3 is a much larger oven than the others which allows for multiple moulds but will use more energy and have a longer start up time. Furthermore design 2 and 3 costs more due to more material used, the main objective is to get the oven functioning for the lowest possible price, for this reason design 1 must be the design used. Design 1 would be more far more suited for the Precious Plastic project due to the size of the machine. Within the shipping container space is limited so taking up the least amount of room is very important.

While design 1 is very similar to the design that Precious Plastic originally offer, some design features have been added to allow the oven to be used by the public. Such as guarding for the moving parts and ventilation ducts to allow proper fume extraction. Other features such as interlock doors, heat timer and extraction switches have been added. This will reduce excess energy consumption, which will reduce the running cost of the project and furthermore keep people safe.

Materials

Base and Sheet Matrix Analysis

Determinants	Importance	Steel A	Steel B	Steel C
Load Capacity	2	8	6	3
Workability	6	7	7	7
Wear Resistance	6	8	5	3
Costs	10	3	5	9
Formability	4	7	6	6
Weldability	7	7	7	7

Total		213	207	229
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Steel A: Grade C1045

Carbon	0.43 – 0.50%
Tensile Strength	565MPa
Yield Point	310MPa

Steel B: Grade C1018

Carbon	0.15 – 0.20%
Tensile Strength	411MPa
Yield Point	372 MPa

Steel C: Grade C1008

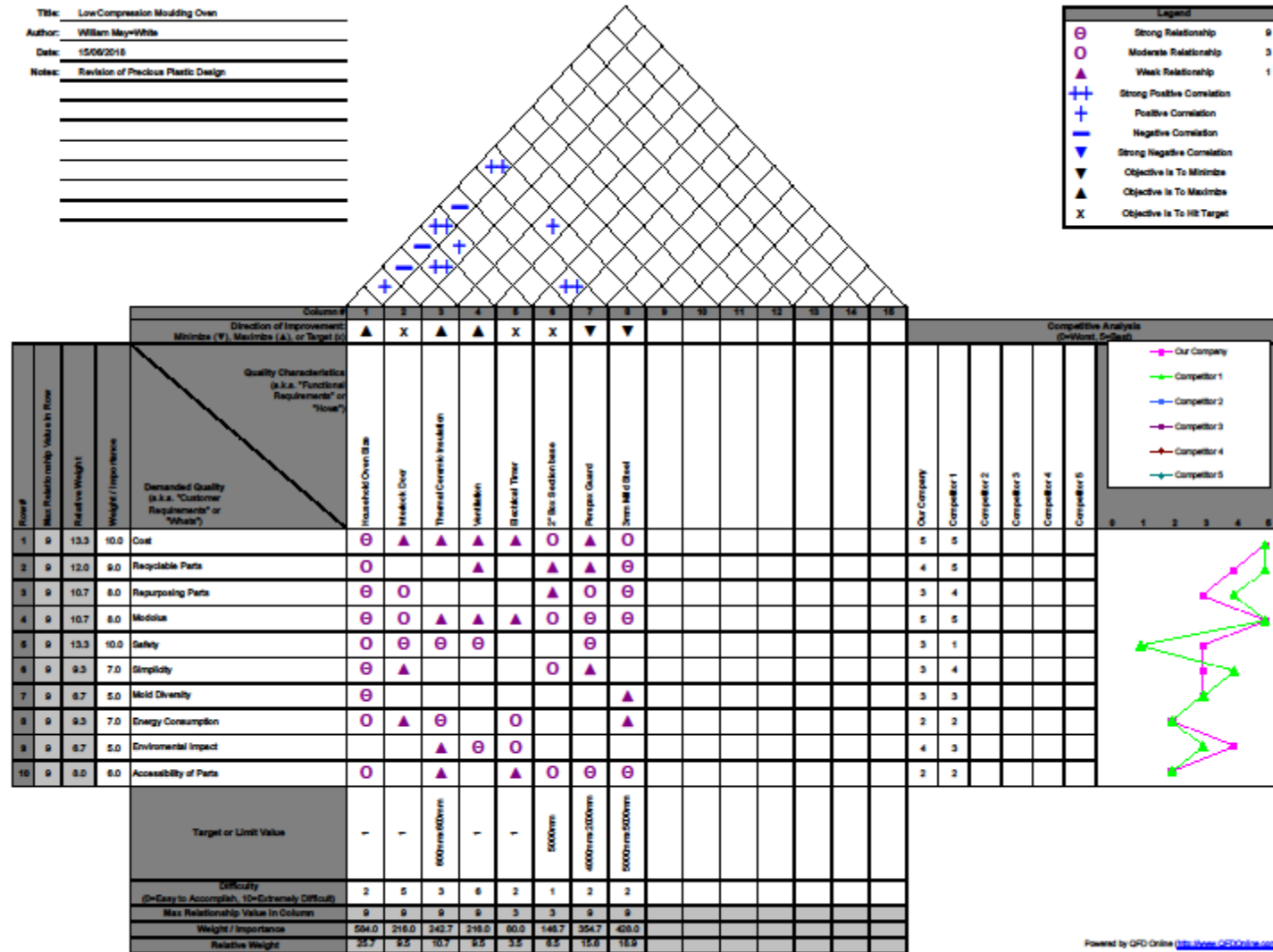
Carbon	0.05 – 0.10%
Tensile strength	262MPa (Metal SuperMarket, 2017)
Yield Point	172MPa

Analysis of Material

The matrix analysis of the materials was conclusive of which material should be used. The highest priority determinant being cost the cheaper of the steels scored the highest. Steel C has ample strength to meet the requirements and is far more available in other countries than higher strength steels.

Other material such as insulation and Perspex can be sourced based upon availability, the recommendation would be thermal ceramic blanket insulation which has: high tensile strength, low thermal conductivity and thermal shock resistance (Vitcas, 2018) which makes it perfect for the oven insulation. Also the oven skin would be recommended to be 3mm steel due to the thermal conductivity and corrosion resistance but could be changed to suit availability.

QFD



QFD Analysis

The analysis of the QFD highlighted that many requirements can be heavily influenced by the characteristics of the oven. The requirement that was affected the most by characteristics was price, this was at no surprise. The project is very price driven due to it being non-profit and volumes needed to make the project self-sustainable are high and unachievable, then cost would be a main driving factor. If characteristics are reduced or increased there will be a change in price, some characteristics such as safety features are worth spending money on.

Another requirement that was affected by all the characteristics was the modulus of the oven. The aim of this project is for people to build this machine with what they have available to them, and being able to maintain and replace parts with minimal modification. Some characteristics would need to be modified if the oven needed replacing such as insulation, steel skin and ventilation duct.

The requirement of safety had very strong relationships with multiple characteristics. By putting such safety related features such as an interlock door, ventilation, guarding and insulation will have a positive effect and would meet UK legislation (HSE, 2018)

Accessibility of components and parts is another requirement that had many relationships with characteristics. Due to precious plastic oven being open source it is useless if parts recommended are not accessible to everyone.

When the analysing the quality characteristics the oven is had the biggest effect on other characteristics, which comes as no surprise due to it being the main feature. It did have a negative effect on elements such as insulation, steel sheeting and base material due to the size of the oven determining how much material is needed.

The QFD highlighted some key areas where the revision to the compression oven has made some substantial improvements and in some key areas this can be seen in the competitive analysis section. There has been an increase in the safety of the oven, this is due to guarding, working procedure, ventilation and insulation all being incorporated into the design. The heaviest weighted requirements were cost and safety. Safety does have a negative effect on many different requirements. By adding safety features cost will go up, but due to the oven being used by the public it is a cost worth spending. Another negative effect of safety is to guarantee components are to specification they must be new, this will reduce the amount that can be recycled/repurposed.

Final Design

After carefully considering the design specification, Pugh determinates and both QFD's, the design created satisfies the required specification. While Precious Plastics design had many flaws the basic features of the oven were used, just with some modifications and revisions. The new design keeps with the ethos of repurposing as much as possible and trying to keep the cost as low as possible so people with less resources have the ability to make the machine. The new design incorporates safety systems that will make the whole experience a safer environment not just for operators but also for the environment.

Oven Features

The oven will still be a household oven obviously the dimensions of the oven determine the dimensions of the rest of the machine. The oven designed has dimensions or 500mm x 500mm, this maybe a small household oven, but after research the smaller ovens generally are more energy efficient. The dimensions of this oven are more than ample for what is needed. The base of the machine is 800mm with the oven the total height without extraction is 1310mm. The height was chosen based upon the assumption of people who would be using the oven. It would stop people over extending into the oven and possibly dropping the mould. The oven will be fixed to the base by welding the base to the base of the oven.



The jack will be extended by either the supplied bar or having an ergonomic bar with a rubber handle on the end. The recommended oven used would be around 1.5-2 KWh. The

newer the oven the more energy efficient it will be. If a newer oven around 1.5KWh could be used it would greatly reduce the energy consumption needed, also it would not need any insulation.

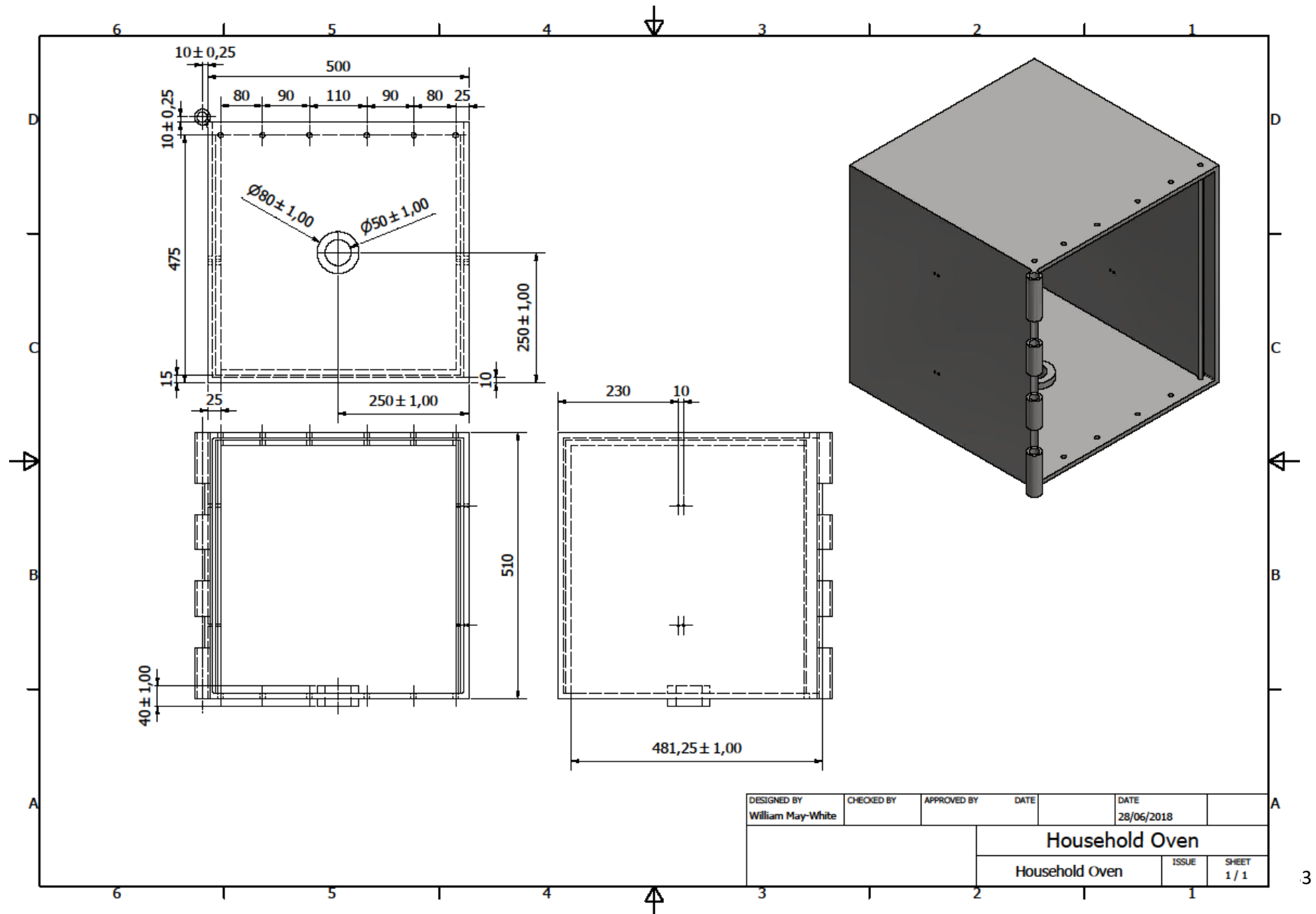
Safety System

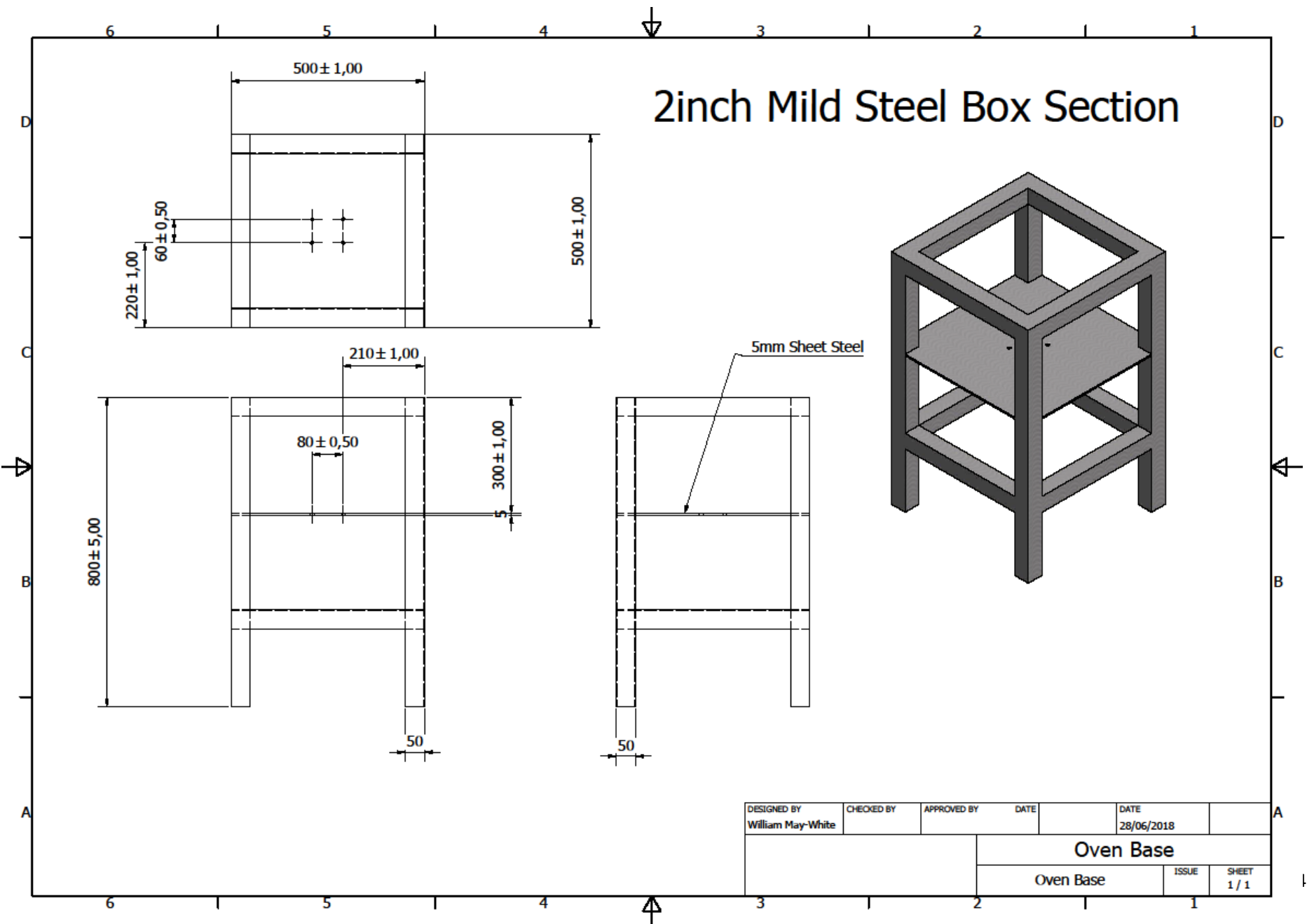
An extraction system is mounted to the top of the oven, and is fitted to an interlock switch.

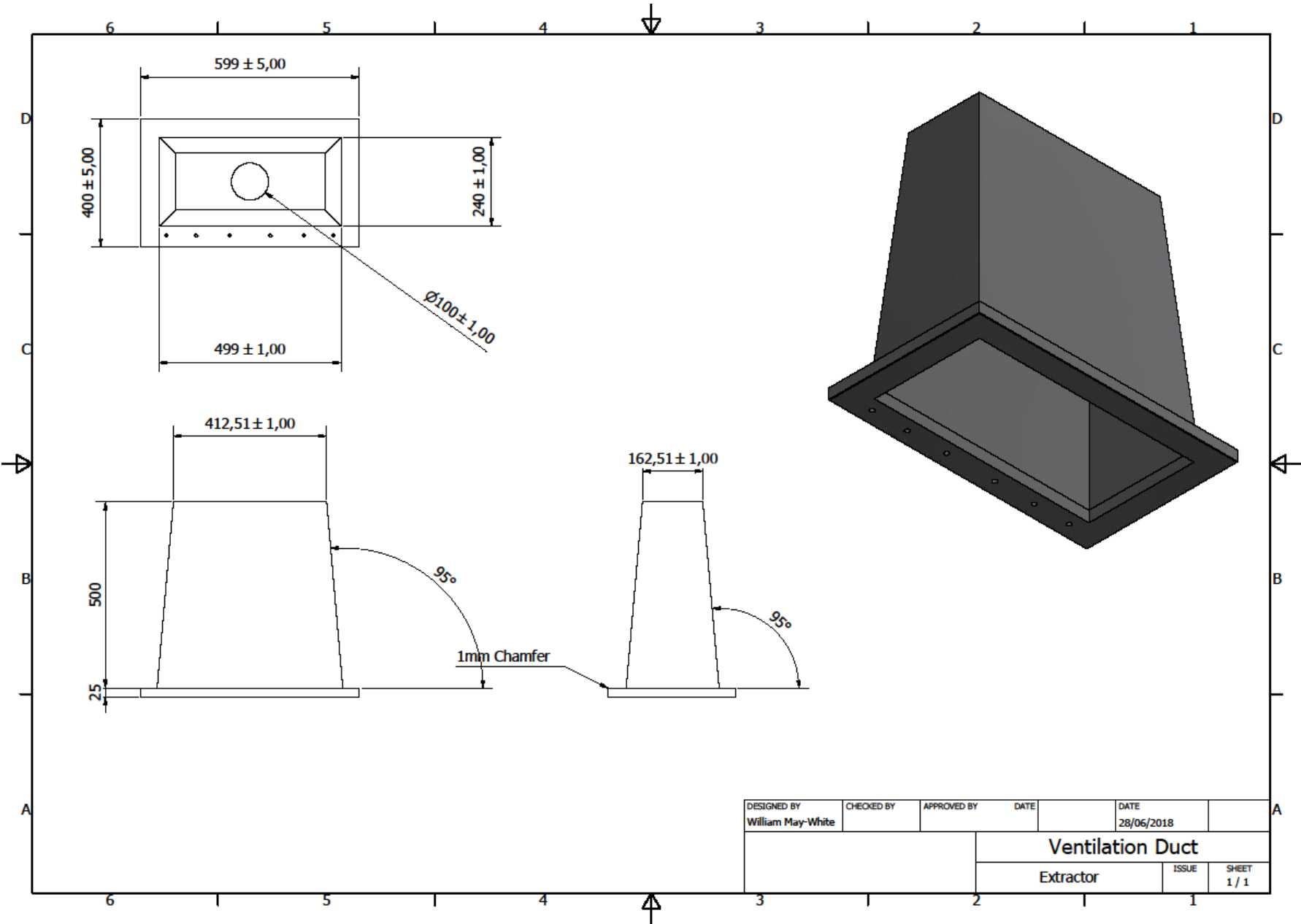
This means when the door opens the extractor will start, the system will have a timer of 3 minutes. The door would also be fitted with an interlock which will only open when the oven has reached a safe temperature for the mould to be removed. This would stop any risk of burns from handling the mould. The base would also be guarded with a chosen material. The recommended material would be Perspex due to it being transparent so people could see the workings of the jack. The base would also be able to be fixed to the floor, this could be done by extra fixing plates or welding. The oven will also have thermal ceramic insulations to keep the heat of the oven inside and allowing the outside of the oven to be touched without risk of burns. The oven will also have a timer so that the plastic will not burn and produce toxic fumes.

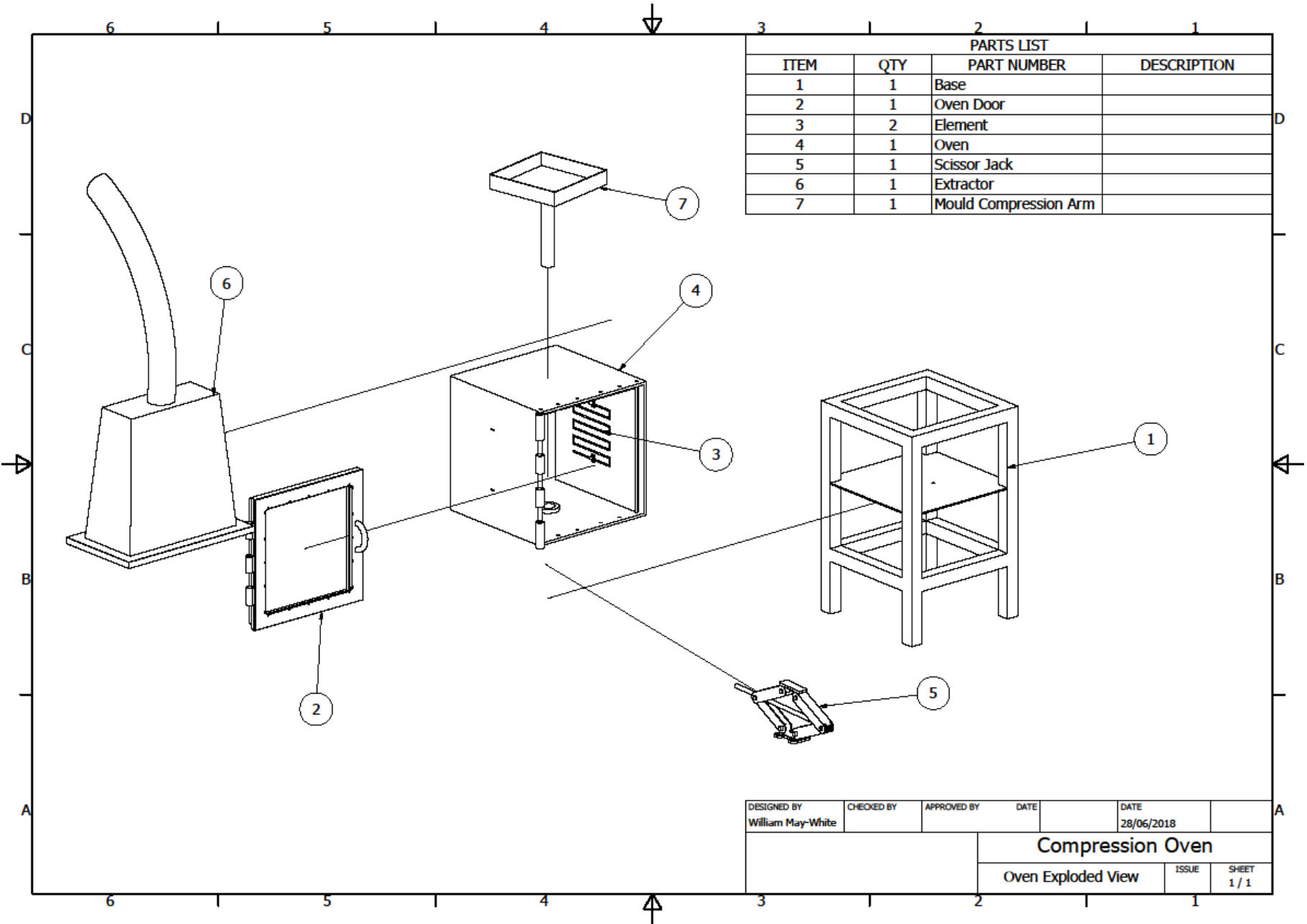
Cost

Component	Cost
Oven 0.75KWh	£129.99 (Currys, 2018)
Steel box section 6 meters	£44.79 (Metals4u, 2018)
3mm steel sheet 2000x1000mm	£85.17 (Metals4u, 2018)
Car scissor jack	£17.99 (Halfords, 2018)
Door Interlock	£29.53 (rs-online, 2018)
Insulation	£20.00 (eBay, 2018)
PID Controller	£10.00
SSR	£4.00
Thermocouple	£8.00
Power switch	£3.00
Led Indicator	£3.00
Powercord	£2.00
Total	£357.47









FAILURE MODE AND EFFECTS ANALYSIS

Item: Precious Plastic Oven Responsibility: _____ FMEA number: _____

Model: _____ Prepared by: _____ Page : _____

Core Team: William May-White FMEA Date (Orig): _____ Rev: _____

Process Function	Potential Failure Mode	Potential Effect(s) of Failure	S e v	C l a s s	Potential Cause(s)/ Mechanism(s) of Failure	O c c u r	Current Process Controls	D e t e c	R P N	Recommended Action(s)	Responsibility and Target Completion Date	Action Results				
												Actions Taken	S e v	O c c	D e t	R P N
Oven	Excess Temperature	Burnt Plastic	5		Human Error/Thermostat failure	3	N/A	4	60	Thermoal cut off switch	Maintenace	Regular Function Checks				0
Mould	Excess Temperature	Burns	8		Interlock Failure	4	N/A	5	160	Correct working procedure	Designer	Regular Function Checks				0
Compression	Excessive force	Oven Failure	9		Human Error/Thermostat failure	5	Recommended Mould Size	7	315	Reinforce oven roof	Operator	Size Checks/Working procedures				0
Spills	Excessive platics	Over flow	6		Human Error/Thermostat failure	8	Working Procedure	3	144	N/A	Operator	Working Procedure/operator check				0

Standard Operating Procedures

Precious Plastic

PURPOSE: Safe Operation of Compression Oven

INSTRUCTIONS: Safe working practices must be followed at all time.

	Instruction	Corrective Action
Step 1	Ensure mould is clean and damage free.	Report to attendant
Step 2	Weigh plastic needed for desired mould and fill.	Seek advice of attendant
Step 3	Place mould inside oven, close door ensure interlock door is secured.	Check interlock light is present
Step 4	Set oven to desired temperature using control panel and wait! Please allow time for oven to cool.	See plastic melding chart for temperature and times.
Step 5	Once interlock door signals the temperature has reach safe level open door and handle mould with heat retardant gloves.	Please ensure that the path and destination to work station is clear and handle mould with care. If help is needed please seek attendant.
Step 6	Continue with gloves, split mould and carefully eject part. Clean mould and place back on shelf.	If removing part is difficult please seek advice of attendant.

Conclusion

Overall the revised design of the precious plastic adhered to the requirements set. While very little of the main features have changed, the elements of safe systems have been added so the public can use the projects safely. This may have increased the overall price but it is a price worth paying. Due to the machine being used by the public there are many laws and regulations that must be followed if the project would want to be a success. With the introduction of ventilation, safe working procedures and guarding the oven now meets all the legal requirements for the use by the public. The beauty of the Precious Plastic project is that it can be adapted to every environment. In the UK safety features are a legal requirement, but in some places, there may not be such rules, so a basic design is needed with the possible add-on features to make the oven to adhere to laws and legislation. The oven is designed with modulus but with the increased safety features some elements would need to be modified for replacement parts such as interlock door.

The oven was costed all parts as new which totalled £357.47 which is a large sum of money when considered that cost was one of the heaviest weighted requirements in the design specification. However, many parts can be repurposed which would follow Precious Plastics ethos of reusing what is already available.

One possible problem for the project is the sustainability of it. All the machines are heavy energy consumers which will need to be funded. If the project becomes more of a business to stay open than an open source, free to use recycling plant then it loses its origin. The objective of this project is to help solve the increasing amount of unused plastic in the environment, but not at the expense of burning fossil fuels for energy. There should be emphasis on how to make

this project self-sustainable. There are many machines in the project which have motion, all which could be harnessed. Condensers could be attached to the oven to heat water, pass through a car turbo charger which could be linked to the grinder. The energy could be stored in a battery cell for the use of the lights, if the machines in the project could be linked to power each other, or power some part of the project it will greatly reduce the daily running cost of the project. While other renewable energy sources are available such as wind and solar, by harnessing the machines motion or energy expenditure it can give an educational side for visitors that they may not be aware of.

To conclude, while the idea of precious plastic is brilliant and is a step towards the sustainability of the world, some form of identity is needed. While in many places in the world this is a means of producing new meaningful products from waste which would not be recycled. In the western world it is far more feasible to recycle the plastic waste and go buy new recycled products. However, if the Precious Plastics project was for educational purposes and showing people, the effect of the waste plastic is having on the world then the project could be a very useful and meaningful project. It could possibly be a centre for school children to come and see how easy and important it is to reuse and repurpose plastics.