

A large pile of plastic waste, including various colored bottles, containers, and debris, stretches across the landscape under a dramatic sunset sky with orange and yellow hues. The waste is piled high, creating a textured surface of discarded plastic.

Polymer Processing Equipment

Manufacturing Design and
Technology (M5X01176)

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1. Index

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2. Introduction

In 1862, a chemist from Birmingham (UK) named Alexander Parks developed the first fully synthetic plastic, this was named Parkesine (1). Although this invention was revolutionary, it was only used for approximately 2 years, this was due to the high cost of producing the product and because the material was prone to cracking (1). The major breakthrough of plastic came in 1907 by a Belgian-American chemist, his name was Leo Baekeland, his product was Bakelite (2). This new product was cheaper to manufacture than its predecessor, making it attractive to organisations and it was therefore mass-produced. Its primary use was for military equipment during WW1, although Bakelite really began appearing in households during the post war period, widely used from fashion to general household appliances (2). The name 'Plastic' was given to these polymer materials circa 1925, then after WW2, chemists worked to develop new plastics, thus was born the likes of PVC, ABS and the other we know today (3).

Plastic has become the relied upon material in our day to day lives, to even imagine a world without plastic would be difficult to do, it is quite literally everywhere. One of the main uses of plastic quickly became that of packaging, therefore the growth of single use plastic soon outweighed reusable plastic products, meaning a huge amount of waste material being produced (3). Although recycling is now considered a typical process within the UK, recycling of plastic is a relatively new drive, the recycling system is fundamentally flawed due to the systematic failure of government to enforce stricter recycling laws upon local authorities and organisations. The detrimental effect of single use plastic, or more importantly the lack of product life cycle control, meant that in 2010 alone an estimated <12,000,000 metric tons of plastic waste entered the marine environment (3). Some experts have claimed that by 2050, if this problem is not controlled, there could be more plastic than there is fish in the sea. Even when we recycle general household plastic, there is no guarantee that the plastic is actually being recycled, until recently it was shipped to China and simply inserted into landfill (4). The reason for this is due to loopholes in UK laws which is exploited by local authorities who discovered that this method is easier and costs less money, although evidence has now come to light that a large amount of recycling sent abroad is in fact sent to landfill (4).

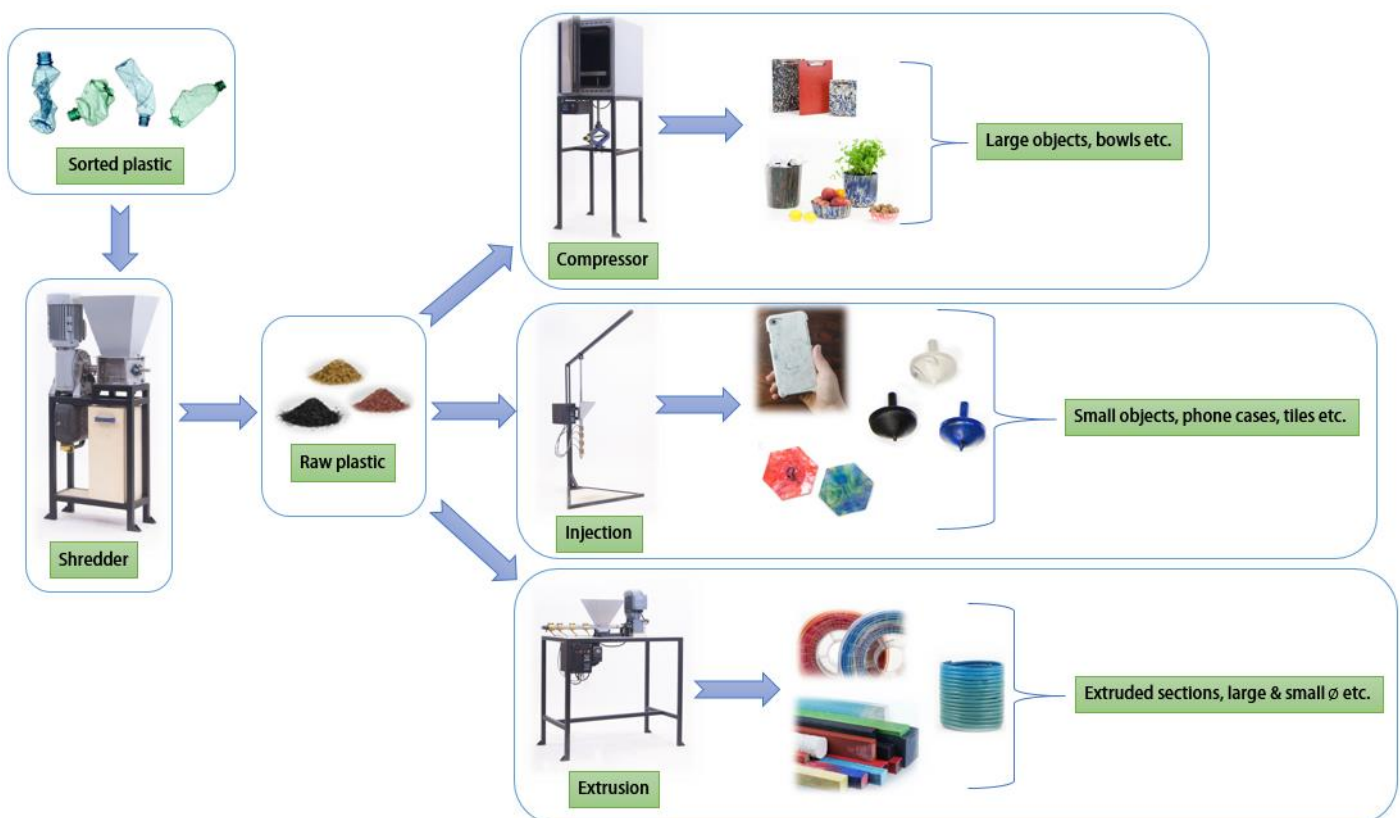
Awareness of plastic waste has become a big focus in recent years, be it from advertisement on television, to documentaries such as BBC Blue Planet 2. Recycling has become the main focus for controlling single use plastic products, however, this is a very distant 2nd to elimination of single use plastic products completely, reusable plastic is what we should be working towards (4). We need to do more to contain the pollution problem, therefore this report concentrates on the problem as it stands today, and it looks at plastic recycling equipment so that units may be set up in communities in order to bring people forward to recycle their waste. This process will bring awareness of the issue, it will also mean that the plastic will be reworked into different products that can be used, and then recycled time and time again.

3. Research

3.1. Process Overview

Precious Plastics is an organisation that is looking to reduce the plastic pollution by bringing people together to recycle their waste (5). They have generously offered a wealth of valuable information through their website and social media such as YouTube (6). The information pack contains details of end products and processes, to machine drawings and models that can aid people all over the world to manufacture their own polymer working machinery and products (7). In order to adopt and improve on the current work of this organisation, we must first understand what is currently regarded as the standard, beginning with the process itself, from waste product through to new product.

The current process by precious plastics is to set up units such as shipping containers, these shipping containers can be purchased widely from a range of suppliers online, with the cost varying greatly depending on supplier, condition and size of container. As the goal here is to improve the machinery and process, the shipping container cost, supply and condition will be disregarded for this exercise. The current process is to gather plastic waste, this is then separated into plastic types or groups, shredded, then melted down to form shapes and different end products using different machines (5).



The process is relative simple in principle, although there is much to consider with regards to safety, heating plastic can be very dangerous, if burnt, some omissions can even be very toxic.

3.3. Polymer Materials & Grades

Polymer products have specific categories and marked with their category number in order to aid with recycling. The category marking informs us of the material type, and from this we may understand the associated factors of any specific material type. For example, some materials have better recyclability properties than others, this may be related to how easily the material can be reworked due to melting temperature. Other information we may draw from the material category is the type fumes it may produce when heated, whether the material omits poisonous or toxic fumes or not. Here is a table summarising those categories (8) (9): -

ID	Type	Name	Where used	Properties
	PET	Polyethylene Terephthalate	Blow moulded drink bottles, electrical fittings, packaging film, credit cards, food containers and biscuit/chocolate trays.	Resistant to solvents, moisture & gas. Transparent in appearance.
	HDPE	High-density Polyethylene	Plastic bags, ice cream tubs, shampoo bottles, freezer bags, juice bottles, milk bottles, electrical and plumbing boxes.	Resistant to moisture and chemicals. Relatively tough but also flexible.
	PVC	Polyvinyl Chloride	Garden hose, cosmetic containers, bubble wrap, vinyl records, vinyl flooring, film, pipes and car upholstery.	A tough or strong material, ability to be solvent and clear.
	LDPE	Low-density Polypropylene	Rubbish bags, squeeze bottles, cling film wrap, beer can ring links, trays and general consumer goods containers.	Soft and flexible, waxy surface and scratches easily.
	PP	Polypropylene	Ropes, Cable insulation, garden furniture, flower pots, beer bottle crates, Tupperware containers and takeaway food containers.	Resistant to solvents. Translucent, flexible but also hard.
	PS	Polystyrene	Lenses and mirrors, cutlery, household appliances, cassette and CD cases, refrigerator liner, foamed meal trays and toys.	Moderately tough, glassy, clear and opaque.
	OTHER	All other plastics	Compact discs, medical storage containers, automotive, packaging and electronics. Material such as Polycarbonate, Nylon & mixed multi-layered.	This will vary depending on the type of plastic.

3.4. Existing Equipment



Shredder (Granulator) – As this machine shreds plastic, there are several safety factors to consider, shredding plastic can be noisy therefore a sound test may need to be conducted to ensure it is within the regulatory standards, if not, ear defenders may need to be used. Plastic being shredded may result in eye injury therefore safety eyewear may need to be available. Most importantly is the guarding from the shredding blades, the current open hopper simply is insufficient as hands can easily be placed within the machines.

Injection – Heating of the plastic is a consideration for this machine as is there is a possibility of dangerous fumes being omitted, also there is a risk of burning. There is no protection from the heated area, this could be counteracted simply with the use of guard, if the guards were transparent then the operators could still see the machine making it more interesting for users. There is no fume extraction on the machine, this should be considered to avoid dangerous fume inhalation.



Compressor – There is risk of burning when removing the plastic from the over, there is also a risk of applying too much pressure from the jack system below the oven. Excessive pressure may result in damaging the mould tool or heated plastic may seep out of the mould, thereby causing mess, fumes and possibly burns. Heating the plastic in the oven in this way may take some time, therefore the cycle time may not be as attractive to potential users as some of the other machines.

Extrusion – This is similar to the injection machine with regards to safety considerations, although without a large arm to operate the machine, it poses less of a risk relating to injury against moving parts. A consideration here would be cost, the cost of motor and the cost of the extrusion screw, these are costs that the injection machine does not have.



3.5. Health & Safety, Legislation & Regulatory Considerations

A major consideration is the health and safety legislation within the UK, the equipment should be designed as such that there is no risk of injury or harm to individuals who use it, or individuals who are in the near vicinity of the equipment. HSE has information available that outlines the practical requirements for safety, although this is mainly centred around industrial use, it is applicable in this instance also (10). We must not under any circumstance underestimate the importance of health and safety, although the whole project has the intention of promoting recycling and involving community, the health and safety aspect of this is just as important or arguably more important than that of industry. There will be untrained people of all ages using this equipment, it must be kept simple to use and safe, this must come above any cost restrictions, cost saving is always secondary to health and safety regardless of the circumstances.

Guarding – The equipment should be designed as such that there is no risk of injury to operators, this can be achieved somewhat through the use of guarding surrounding all heated areas, thereby limiting the risk of burning. Furthermore, guarding should be used to protect operators from moving parts wherever practicably possible, eliminating finger/limb traps and general collision with moving parts (11).

Controlling Fumes – When plastic is heating during processing fumes that are omitted, these fumes may be Respiratory Sensitizers, Irritants and sometimes even Carcinogenic may be omitted (12). HSE provide a list of polymers and their associated constituents in fumes: -

Polypropylene – *Formaldehyde, Acrolein & Acetone*

PVC – *Hydrogen Chloride*

Fire-Retarded ABS – *Phenol, Styrene & Butadiene*

Polyethylene (Low Density) – *Alkenes & Butane*

Polystyrene – *Aldehydes & Styrene*

Acetals – *Formaldehyde*

There are controls that may be taken to prevent (*or at the very minimum reduce*) the risk of fume inhalation: -

- Equipment temperature control and the reliability thereof
- Regular maintenance of the equipment
- Documentation in the form of checklists relating to equipment
- Documentation in the form of safe standard operating procedures
- Control over the type of material being processed

Guarding may somewhat contribute to the control of fumes, although ventilation should also be considered (12), all be it expensive, it is important to investigate this. Ventilation could be achieved through the use of a central unit, which is linked to all machines within the unit, each machine that heats plastic may not necessarily require its own system.

Noise – There may not be much noise within this facility, although the shredder machine may create some noise, and this should be considered as a health and safety risk. An estimated 2 million people in the UK are exposed to noise levels that are potentially harmful, hearing loss or damage is incurable and permanent (13). It is often caused by a prolonged period of exposure to noise, this commonly occurs gradually. The control of noise at work regulations 2005 state that action must be taken if a peak noise is to exceed 140 dB, and a general daily exposure limit of 87 dB (13). In this instance, we would be falling into the category of peak noise maximum level being 140 dB as the shredder machine may be used occasionally and not constantly. If the noise is to exceed the limit, then ear protection should be made available and it should be used at all times during the increased noise level, in practice, this would be when the shredder machine is in use.

Using equipment safely – The safe use of work equipment is also covered by legislation, this includes equipment such as hammer and knives to power presses and dumper trucks (14). It is worth mentioning that this does not apply to equipment used by the general public, however in this instance the Health and Safety at Work Act 1974 is applicable as people are using equipment supplied by someone who is indeed responsible for that equipment.

Safety documentation – There are safety documentation templates made available by HSE and others, these include general daily use of a machine checklist (14), and then a monthly inspection checklist. Further reading material is available often at a cost, recommendations for this facility may include: -

- **BS EN 201** – Plastics and rubber machines
- **PD 5304** – Guidance on safe use of machinery British Standards Institution
- **BS EN ISO 13857** – Safety of machinery
- **BS EN ISO 13857.5** – Distance guarding

In order to summarise and reiterate the findings of the research carried out in this section [3.5], all the health and safety aspects relating to fumes, noise and guarding will be predominantly the responsibility of the owner or organiser of the facility and the process and machinery within it. This is completely regardless of the fact that this facility will not be a business who employs staff, there is still a responsibility to those who are allowed to use the equipment (14).

4. Product Selection Summary

Without yet determining which machine is to be the focus, it is a good idea to look at all machines and create general design specifications for each machine, from this, we may choose one as a detailed design.

Shredder (Granulator)	
Aesthetics	Aesthetically pleasing for the operator, possibly transparent areas to see operation of the shredding process.
Cost	1. Cost of motor 2. Cost of blades
User	High interest level to user, short cycle time so there will not be much of an opportunity to become bored of the machine.
Function	To shred the plastic to a form that enables simpler processing.
Manufacturing	The blades will need to be machined or laser cut, the rest is general fabrication of sheet metal and RHS (<i>box and or angle</i>).
Material	Sheet metal, RHS, electrical power unit and motor.
Health & Safety	Guarding from the moving blades is essential.
Size	Should be of a height that users can easily insert waste plastic.

Injection	
Aesthetics	Aesthetically pleasing for the operator, this is generally open so there may not be a requirement for transparent guarding.
Cost	1. Cost of electrical and heating element 2. Cost of dies or moulds
User	Moderate to high interest level to the user, the cycle time is moderate as the plastic may melt relatively quickly. Almost constant operation is required considering the attaching and later opening of the mould tool.
Function	Melt plastic and inject into mould creating interesting new products.
Manufacturing	The electrical and heating element is a consideration, although the general body or structure is simple fabrication work.
Material	RHS (box) or HRA (hot rolled angle) for the main body, flat extrusion for some areas and sheet metal for the hopper.
Health & Safety	Consideration must be made to protect the operator from heat, protection against moving parts and protection from fume inhalation.
Size	The equipment should be of a height where the user may operate the lever to inject the molten plastic.

Extrusion	
Aesthetics	Aesthetically pleasing for the operator.
Cost	1. Cost of Motor 2. Cost of the extrusion screw
User	Of average interest to the operator, depending on what is being extruded, cycle time may vary considerably.
Function	To extrude plastic to a given shape, or into a large mould.
Manufacturing	The electrical and heating element is a consideration, if the extrusion screw is to be manufactured especially it must be a machining and possibly quite expensive to manufacture. The general body or structure is simple fabrication work, cut and weld.
Material	RHS (box) or HRA (hot rolled angle) for the main body, sheet metal and a machined or purchased injection screw. The motor must be bought.
Health & Safety	Consideration must be made to protect the operator from heat, protection against moving parts and protection from fume inhalation.
Size	This will be table mounted, or can be mounted upright depending on preference, therefore the size must cater for the orientation of the equipment.

Compressor	
Aesthetics	Aesthetically pleasing for the operator.
Cost	1. Cost of the electrics 2. Cost of the oven unless an old one is used
User	A low interest level is expected with this machine, the process is slow with a lot of waiting time, also not much can be seen.
Function	To create a medium to large moulded item by compression.
Manufacturing	The oven can be purchased new or old, modification work will need to be carried out with regards to controlling the heat. The compressor system can be activated by a simple car jack system, this can be bought new or possibly at a scrap yard. The main frame or stand is simply fabrication of some RHS (box) or RHA (hot rolled angle).
Material	RHS (box) or HRA (hot rolled angle) for the main body, sheet metal and a machined or purchased injection screw. The motor must be bought.
Health & Safety	Consideration must be made to protect the operator from heat, protection against moving parts such as the jack (it is a potential finger trap) and protection from fume inhalation.
Size	The width and breadth will be that of a conventional household oven, the height will be as such the operator may open the door easily as they must be careful in removing the product or mould tool due to heat.

Although there has been no consideration made to a vacuum forming machine by Precious Plastics, it is something that should at least be investigated.

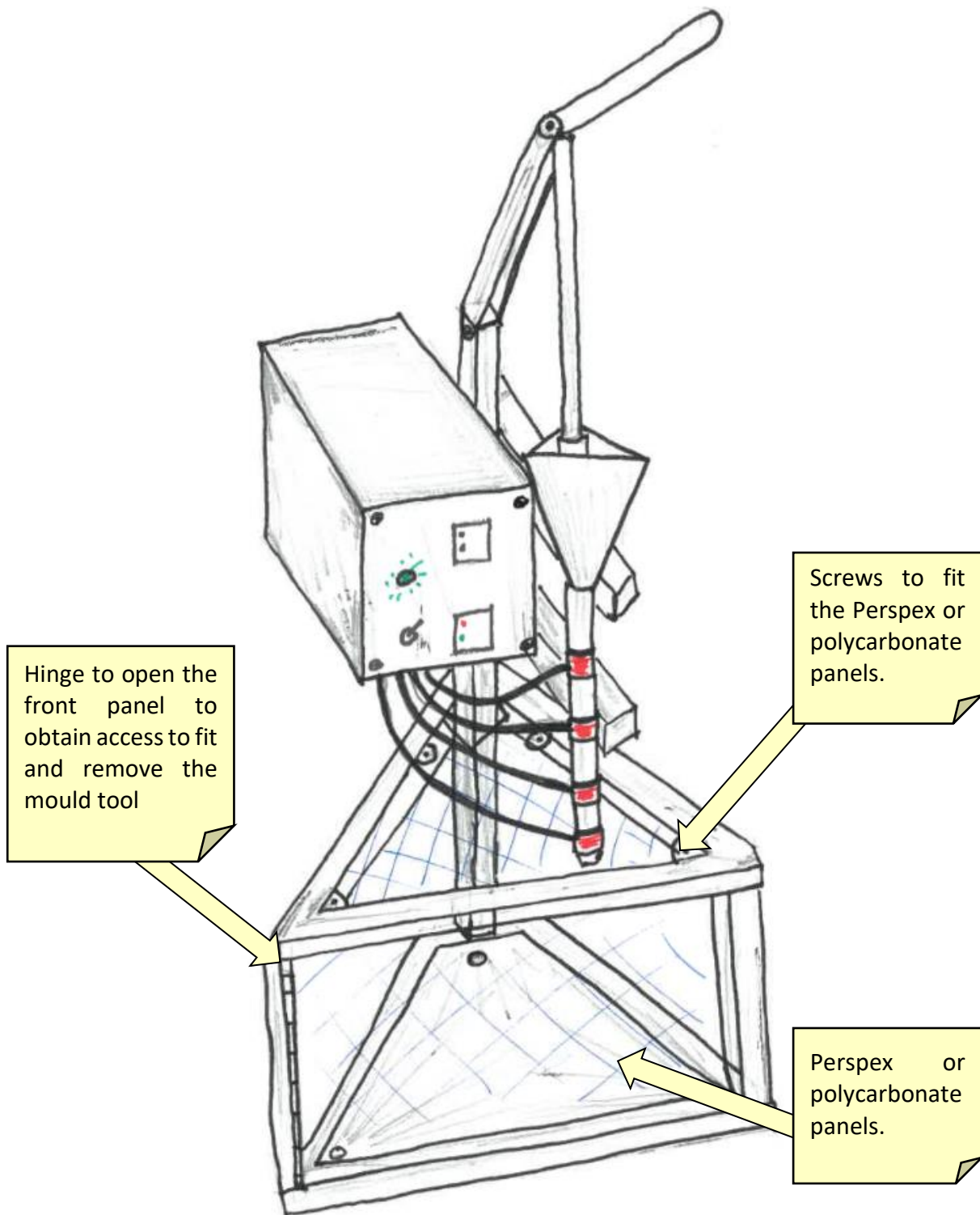
Vacuum former	
Aesthetics	Aesthetically pleasing for the operator, transparent guarding to see the forming process occur.
Cost	1. Cost of the vacuum chamber & pump 2. Cost of the heating elements
User	A very high interest level is expected with this machine, the process is moderate to fast, also the entire forming process can be seen.
Function	To create a moulded shape from a sheet of plastic.
Manufacturing	The heating elements must be purchased, the vacuum chamber and pump must be purchased, the electrics need to be considered, there are several moving parts to consider. Also, as this machine requires plastic in sheet form, a method of creating sheet plastic must be considered also within the facility.
Material	Heating elements and pump for vacuum chamber must be purchased, the rest is general fabrication of section and sheet metal.
Health & Safety	Consideration must be made to protect the operator from heat, protection against moving parts such as the tool mechanism and protection from fume inhalation. Also, there is a possibility that plastic may fall onto the heating elements, creating fire or smoke, this is a high risk to the user and nearby people.
Size	The height of this machine will be approximately stomach to chest height, the width and breadth expectation shall not be any greater than 1 metre.

Whereas the vacuum forming machine could potentially be of high interest to users due to the fact of being able to view the process of the plastic itself forming over the tool, it does come at a cost. The cost firstly of designing and manufacturing the vacuum forming machine, chamber and pump, secondly is the cost of purchasing the parts for this could also be expensive potentially. There are process associated consideration also, the material must come in sheet form therefore there will need to be a process in place to create the sheet firstly from the waste plastic. There will need to be a trimming / machining / cutting operation after the mould is created, often creating considerable waste in the form of offcuts. There is a mould tool manufacturing cost association also to consider, therefore, it is not recommended that the vacuum forming machine is to be considered at this stage.

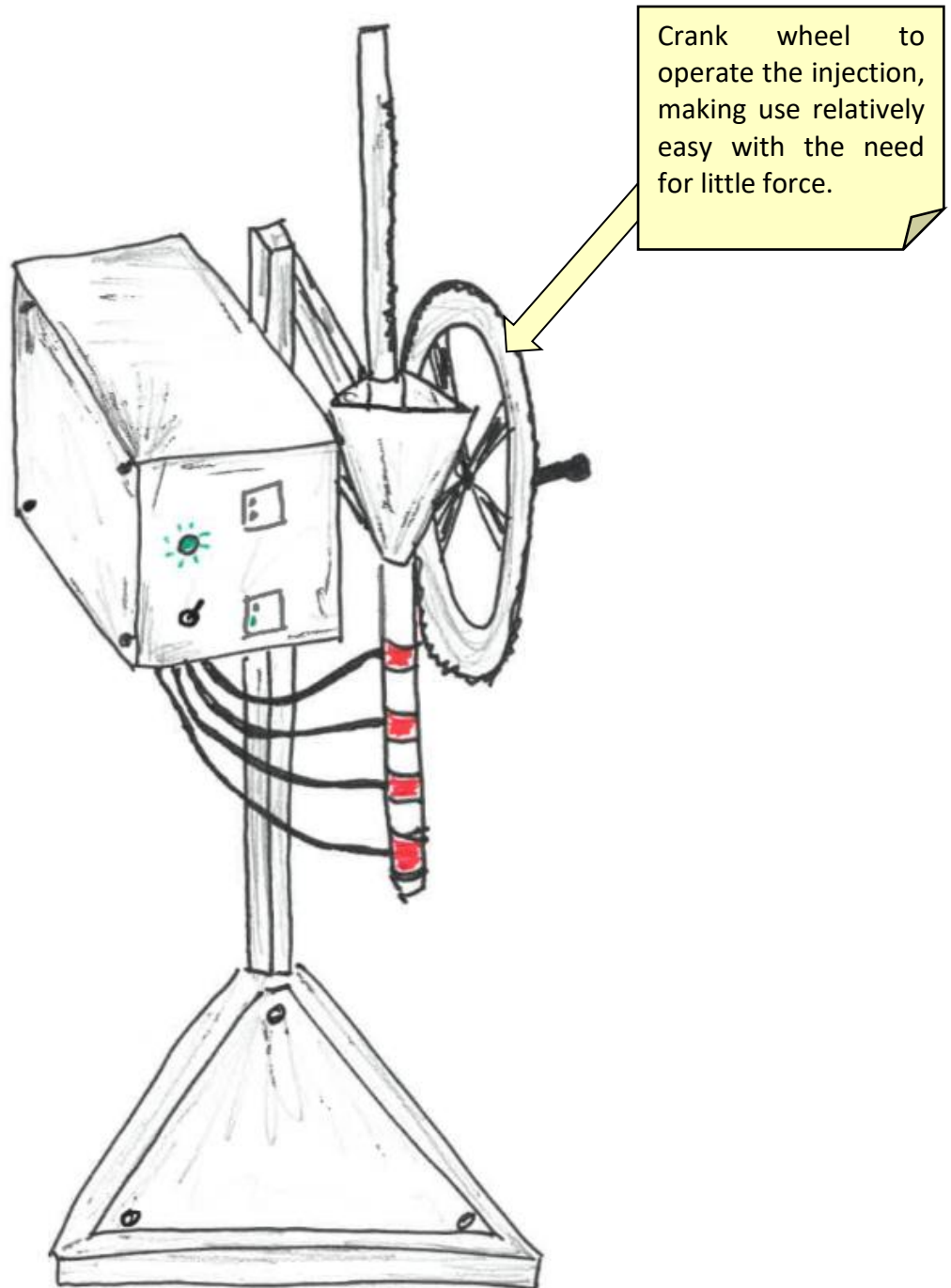
Having now considered what each machine is required to do and what the associated cost and manufacturing processes are, it is time to use this data to be innovative in creating some concept designs that could improve on the current designs.

5. Concept Design

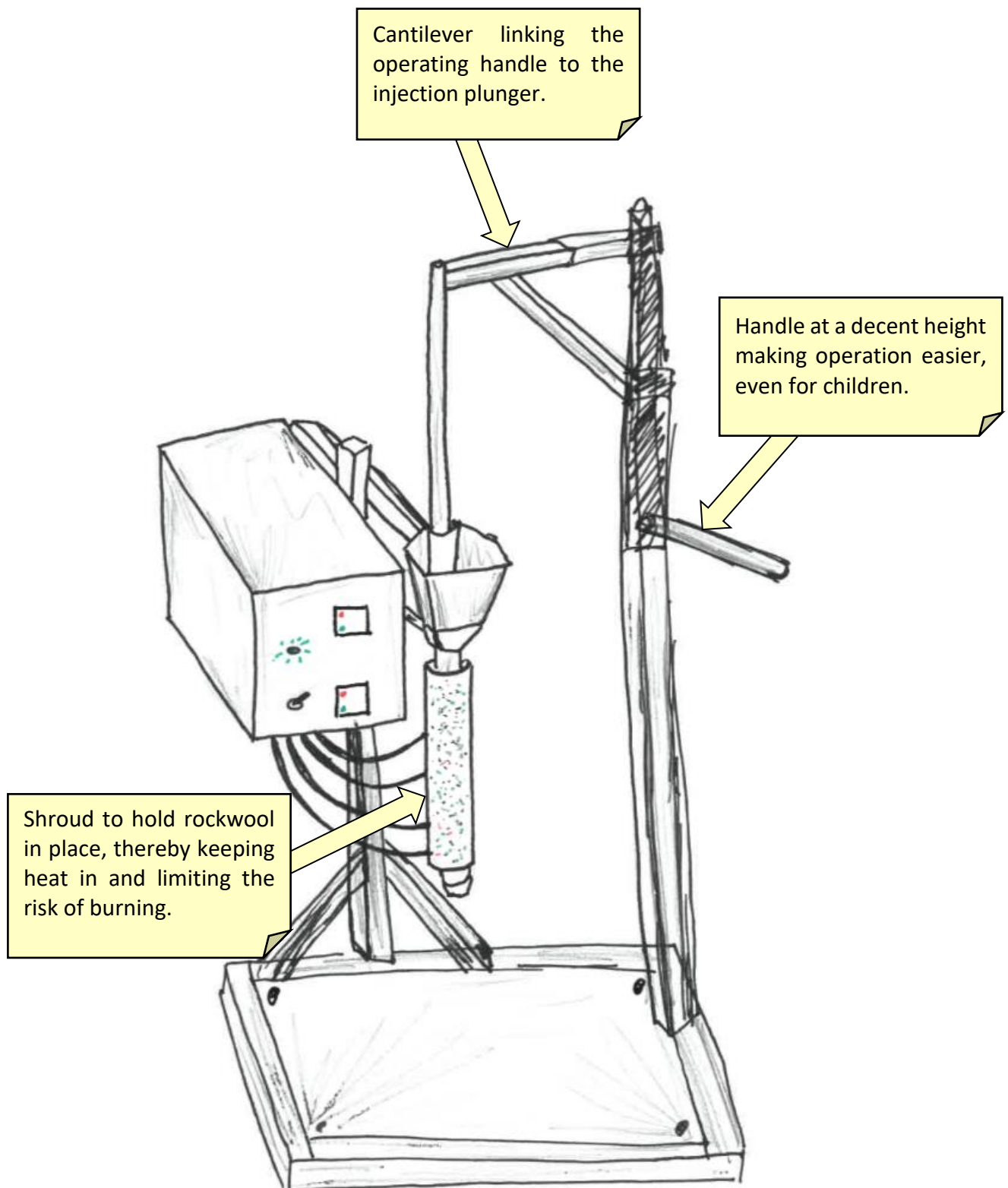
5.1. Concept 1



5.2. Concept 2

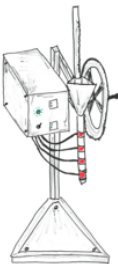
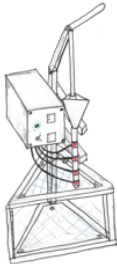
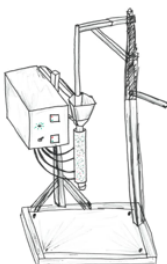


5.3. Concept 3



5.4. Analysis of Concepts

In order to choose a concept that would work the best, a Pugh matrix can be a very helpful tool and should be completed as a team activity. We take an existing design and call it the 'DATUM', all concepts are then measured against the datum. For each criteria, each concept is measured as being simply better than, worse than or the same as the datum. By doing this we can see which concept could work the best.

Pugh Matrix						
TITLE: Injection Machine			KEY			
NAME: Shaun Kilbane			+ = BETTER compared with the datum design			
DATE: 26-05-2018			- = WORSE compared with the datum design			
			S = SAME compared with the datum design			
CTS (Critical To Satisfaction or Requirement) \ Concept		Importance Rating	0	1	2	3
						
Ease of use	10	D A T U M		+	-	+
H & S - Protection from burns	10			S	+	+
H & S - Protection from fumes	10			S	-	+
Robustness	7			+	S	+
Life expectancy	3			+	S	-
Manufacturing cost - Material	3			-	-	-
Manufacturing cost - Processes	3			-	S	S
Manufacturing cost - Labour hours	3			-	-	-
Σ+			3	1	4	
Σ-			3	4	3	
ΣS			2	3	1	
Rating w/rt Datum (Overall Total)			0	-3	1	
Importance Rating Score			11	-16	28	

In this case, concept 3 has scored the highest: -

- The position of the operating handle means it can be operated by short people or children.
- The heat shroud not only acts to keep heat in, but also acts as a guard to protect against burning.
- The lid upon the hopper will prevent fumes from escaping easily.

6. Design Detail

6.1. Comparable Product Analysis



Product 1

Pros – Simple concept, easy to manufacture and cheap.

Cons – Very tall, operation difficult for short people. Large base with sharp corners.

Product 2

Pros – Compact, easy to use.

Cons – Not very secure and limited product size, limited guarding.



Product 3

Pros – Small and compact.

Cons – May be too small and not very secure, No guarding or protection.

Product 4

Pros – Compact, easy to replicate.

Cons – Not very secure and limited product size.



Product 5

Pros – Looks good and professional.

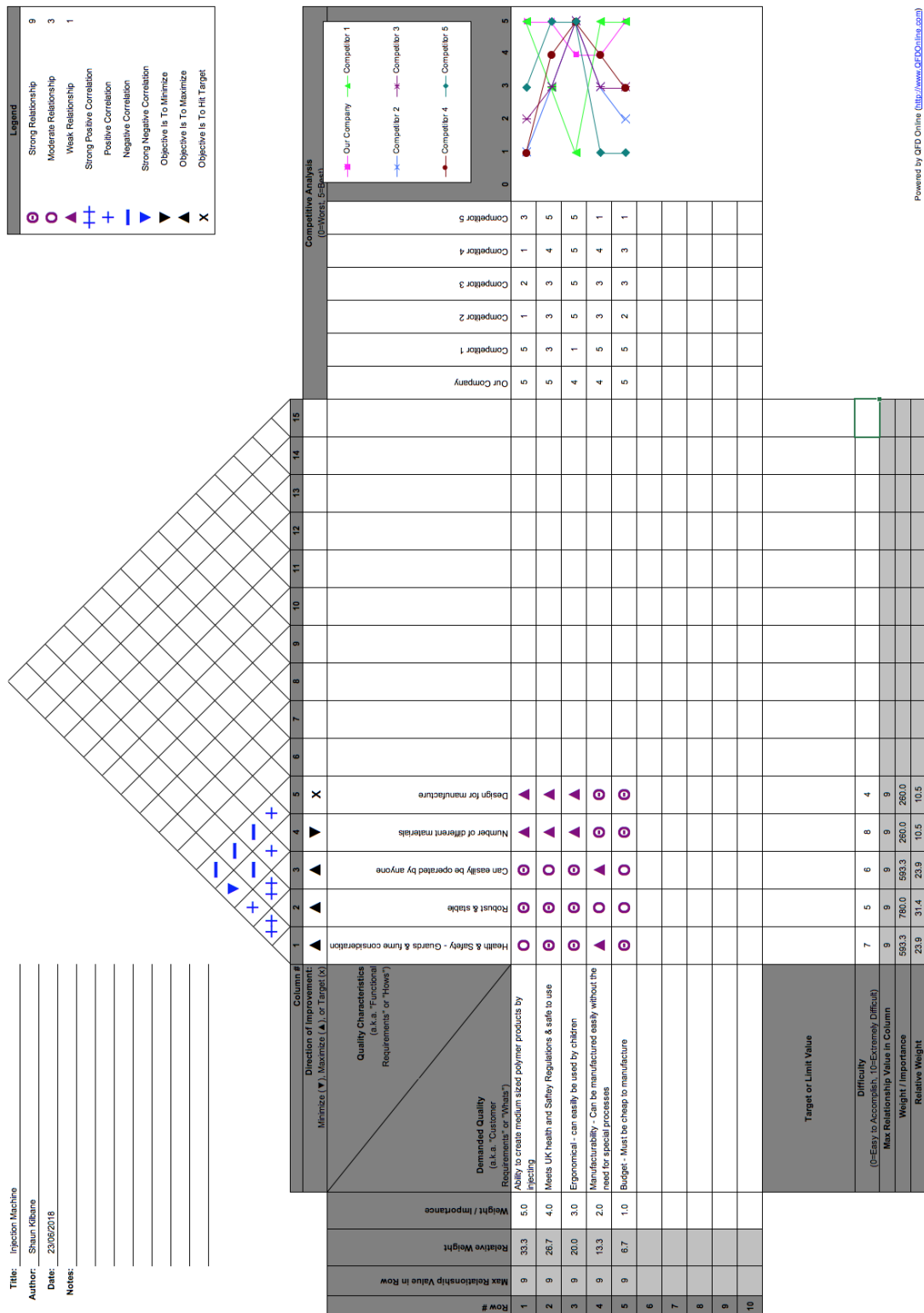
Cons – Expensive to replicate and appears somewhat over-engineered.

Upon reflection, we need to meet the requirement of functionality as per products 2 – 5, whilst maintaining product 1's characteristic of the ability to create relatively large moulds. The simplicity of product 1 is also attractive, being easy to manufacture with relatively cheap material cost. The major drawback to product 1 is that its operation is restricted to people who are of average to tall height, meaning it could not be used by children. This is of course unless a step is introduced, but then we are complicating matters by creating the possibility of a trip or fall, a step could lead to injury and is considered to be a possible health and safety issue.

Having researched and reviewed some existing product, we have a summary of their good and bad points. It may now be a good idea to carry out a HOQ (House Of Quality) analysis of the new product, and compare it to the existing ones shown above, being products 1 – 5.

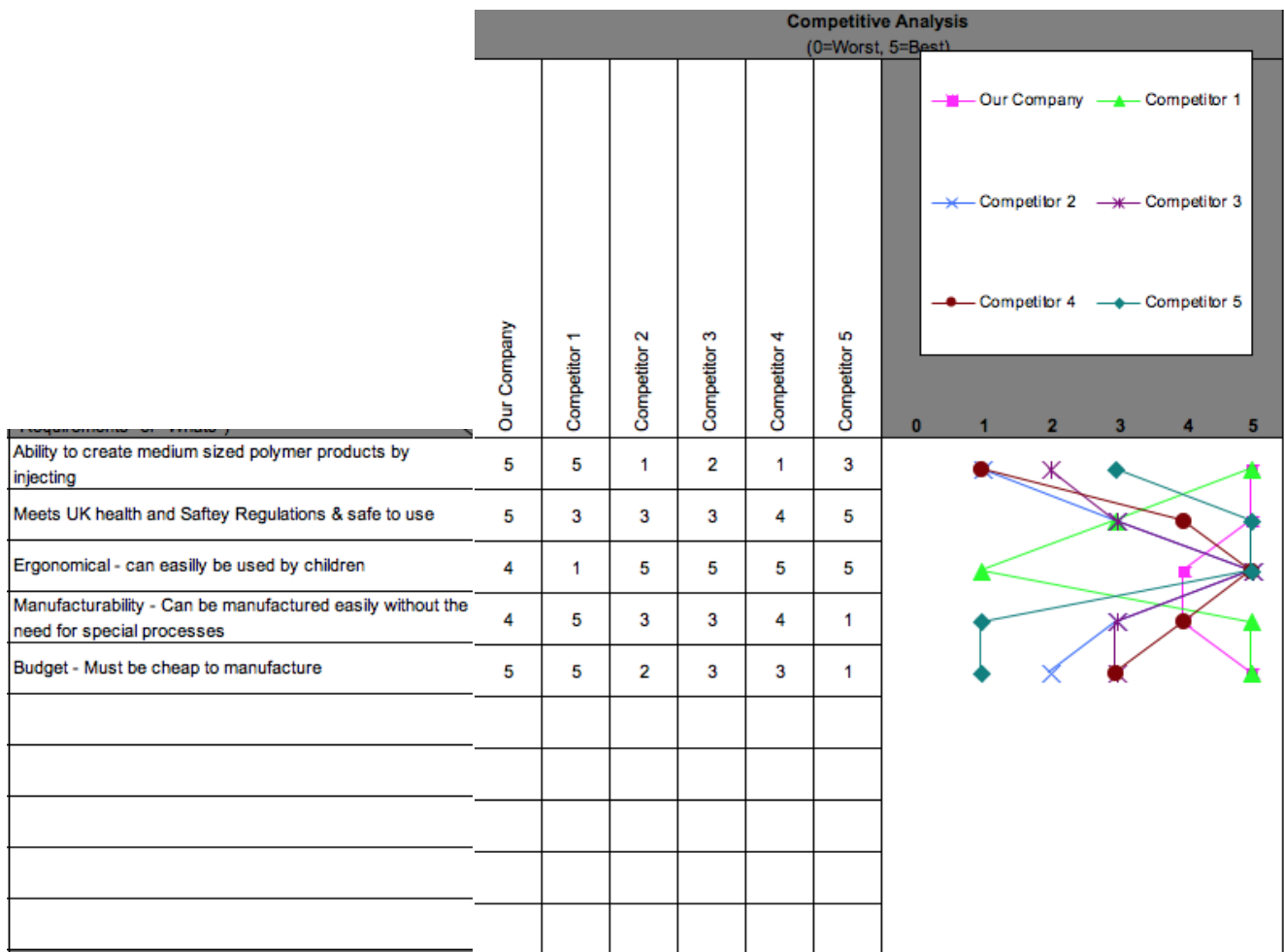
Here is the fully populated HOQ, the reason for the blank spaces is that it was only necessary to populate the document with the relevant information. Furthermore, whereas this is a good

indication as to what our requirements are and to identify what criteria may impact another, this should ideally be completed as a team so that a discussion can be carried out regarding each element. Completing this exercise as an individual means that some aspects may be overlooked, and the input of different ideas can be invaluable in determining a good design.



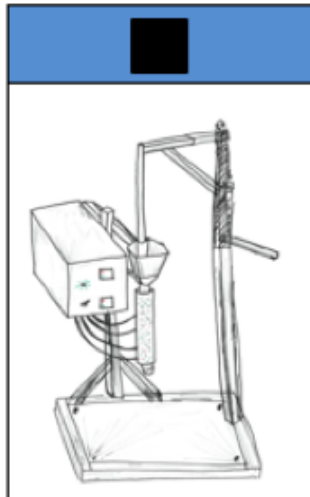
									
					Column # Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)				
					1	2	3	4	5
					▲	▲	▲	▼	X
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Health & Safety - Guards & fume consideration	Robust & stable	Can easily be operated by anyone	Number of different materials	Design for manufacture
				Demanded Quality (a.k.a. "Customer Requirements" or "Whats")					
1	9	33.3	5.0	Ability to create medium sized polymer products by injecting	○	○	○	▲	▲
2	9	26.7	4.0	Meets UK health and Safety Regulations & safe to use	○	○	○	▲	▲
3	9	20.0	3.0	Ergonomical - can easily be used by children	○	○	○	▲	▲
4	9	13.3	2.0	Manufacturability - Can be manufactured easily without the need for special processes	▲	○	▲	○	○
5	9	6.7	1.0	Budget - Must be cheap to manufacture	○	○	○	○	○
6									
7									
8									
9									
10									
Target or Limit Value									
Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)					7	5	6	8	4
Max Relationship Value in Column					9	9	9	9	9
Weight / Importance					593.3	780.0	593.3	260.0	260.0
Relative Weight					23.9	31.4	23.9	10.5	10.5

- 1 { There is a strong correlation between health and safety, robustness of the product and the ease of operation by anyone.
- 2 { The three factors already stated also correlate with the top 3 factors of the customer's requirements.
- 3 { The score given indicates the most important factors. Whereas being robust and stable has come out on top, this is considered to be a bi-product of the other two factors and should be considered as important in order to achieve the other two more serious factors.



This area is not completely relevant in this instance, if we were to be producing a product for sale on a large scale, or if we were to be producing a product for sale within a marketplace, then it is crucial to understand the competitors in order to obtain an 'edge' over them by having a better or unique product. The reason it is not completely relevant in this instance, is that we are seeking to produce one piece of equipment that may be used for recycling by one plant or unit only, if we were to put this product to market however, this section of the HOQ can be used as a very powerful tool.

Another useful tool is a QFD (Quality Functional Deployment). This tool helps us identify the important aspects of the design by significant characteristics. I have selected 3 products, my design and two existing designs for comparison.



- Key:**
- Strong positive
 - Weak positive
 - Weak negative
 - Strong negative

Design requirements

Machine guards	Reachable handle	Fume prevention	Robust structure
----------------	------------------	-----------------	------------------

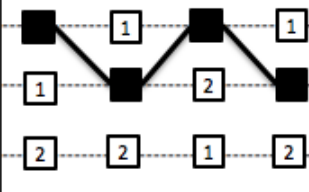
Relationship scores

- = 9
- = 3
- = 3
- = 9

Customer rating (1 = least, 10 = most important)	8	Ability to operate by all ages							2	1
	10	Safe to use							2	1
	6	Ability to create medium sized products							1	2
	3	Low cost							2	1
	5	Interesting to use							2	1

Key:

- = Company's own product
- = Competing product (CP) #
- = Competing product (CP) #



1	2	3
2		
3		

Rating Scale

Measure	Y/N	Y/N	Y/N	Y/N
Target value	Y	Y	Y	Y
Importance rating	90	144	99	123
Relative importance	4	1	3	2

The QFD has identified that the reachable handle is a very important factor of the machine's characteristics, followed closely by the machine being a robust structure, which is obvious if the product is to be used with an offset handle as intended.

6.2. Standard Parts



Digital 220V AC PID REX-C100 Temperature Controller Max.40A SSR Thermocouple

This can be purchased from eBay at a cost of £11.85 each, including free postage.

Quantity required: 2.

Solid State Relay Module SSR-40DA, 3-32V DC to 24-380V AC, with safety cover

This can be purchased from eBay at a cost of £6.55 each, including free postage.

Quantity required: 2.



Professional 1pcs Thermocouple K Type Probe Sensor High Temperature

This can be purchased from eBay at a cost of £5.99 each, including free postage.

Quantity required: 2.





Move&Moving™ 220V 150W Plastic Injection Mould Machine Electric Band Heater 45mm x 35mm

This can be purchased from Move&Moving™ through Amazon at a cost of £5.99 each, including free delivery.

Quantity required: 4.

ON/Off DPST 4 PIN Rocker Type Power Toggle Switch AC 220V 3A KN3A 1X2

This can be purchased through eBay at a cost of £3.86 each, including free postage.

Quantity required: 1.



Move&Moving™ 220V Green Black LED Indicator Light Pilot Signal Lamp AD16-22DS

This can be purchased by Move&Moving™ through Amazon at a cost of £3.99 each, including free delivery.

**13A UK Plug to 1.5mm Cable Stripped Bare Ends,
5m Black – PE01021**

This can be purchased from cpc.farnell.com at a cost of £4.00 each, with a standard delivery charge for orders < £8.00.



**Rockwool Rocklap Bright Class 0 Covered H&V
Section**

This is sufficient for a 42mm pipe, with a nominal wall thickness of 25mm, it can withstand temperatures of up to 2,500°C. This will help maintain temperature and help protect operators from burns.

This can be purchased from insulation-more.co.uk at a cost of £3.79 each.

Quantity required: 1.

Pinnacle Lynch Pins – 10mm – 2 Pack

These pins will be used to lock in place the injection arm with handle when in the open position. It will also act to stop the arm from coming off its runner and stop it from being inserted too far.

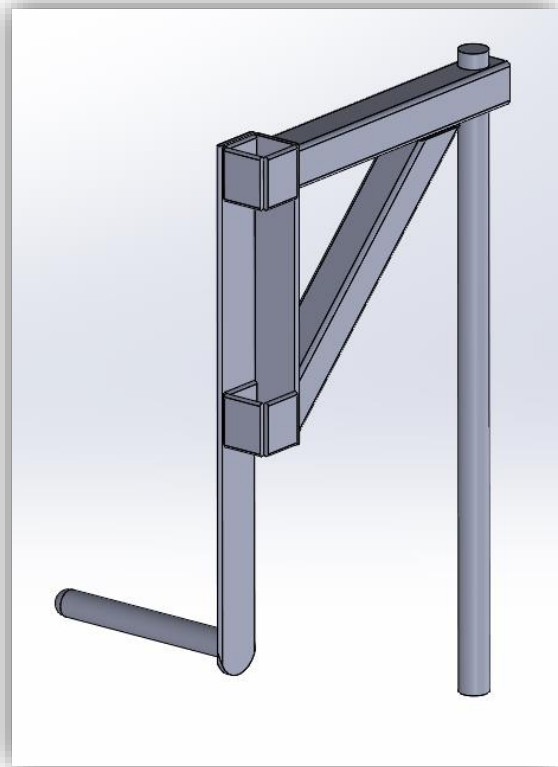
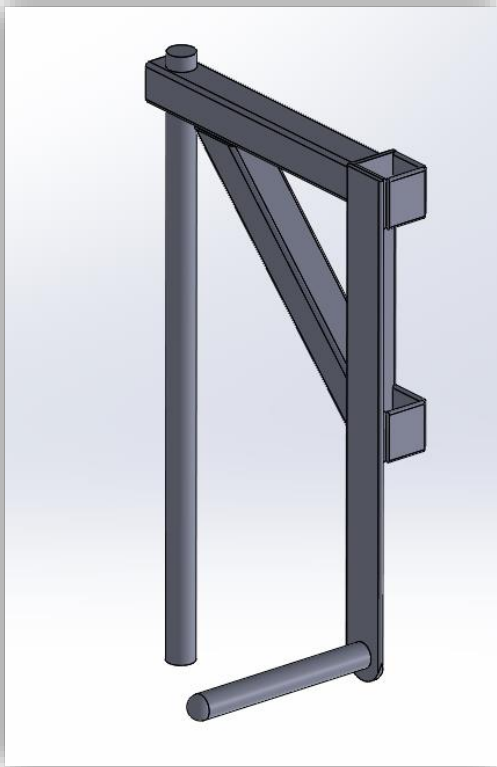
This can be purchased from Homebase at a cost of £2.99 per pack of 2.

Quantity required: 3.

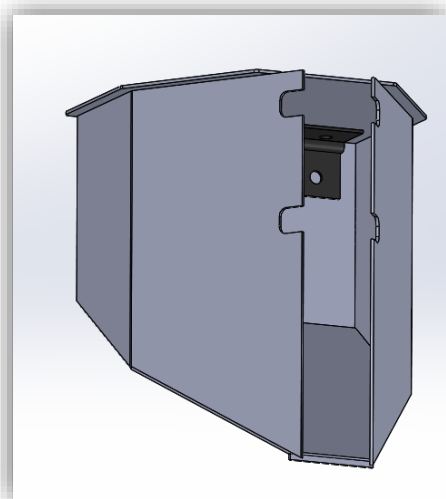
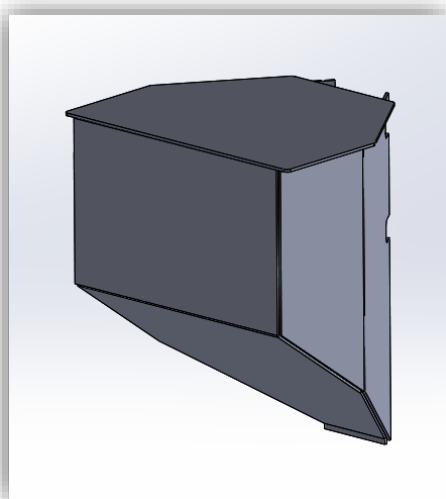


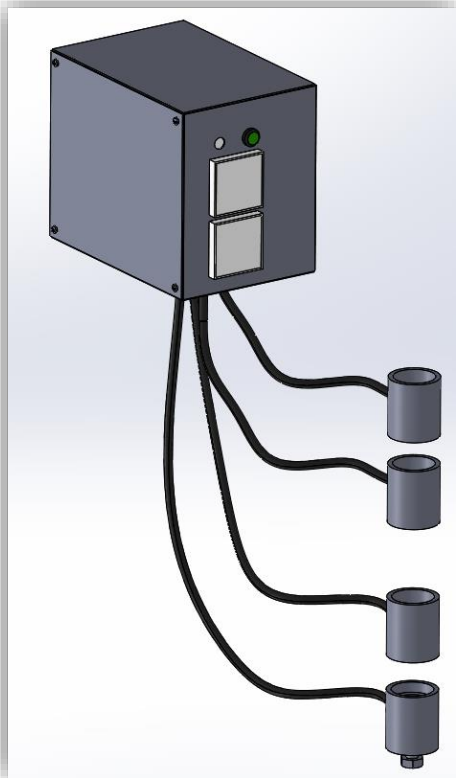
6.3. Part Design

The arm and injection plunger is to be fully welded, as per the main assembly drawings. This subassembly then travels up and down the shaft to inject molten polymer into the mould tool. The reason it is like this is that it can now be operated without the need to stretch up high to reach the handle, meaning it can be operated easily even by short people or children.



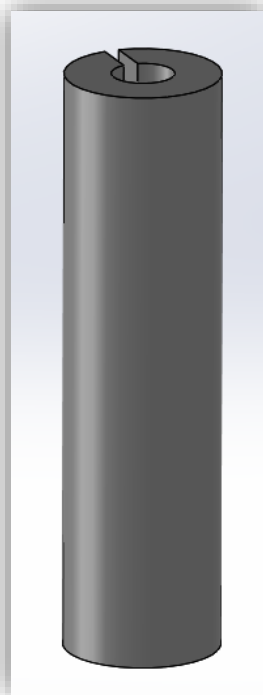
The hopper is made out of 1.2mm (18swg) sheet metal, either hot rolled or cold rolled. It is fully welded with the exception of the lid which is hinged. This will help limit the amount of fumes from escaping and will prevent impurities such as any foreign object debris from entering the injection chamber.





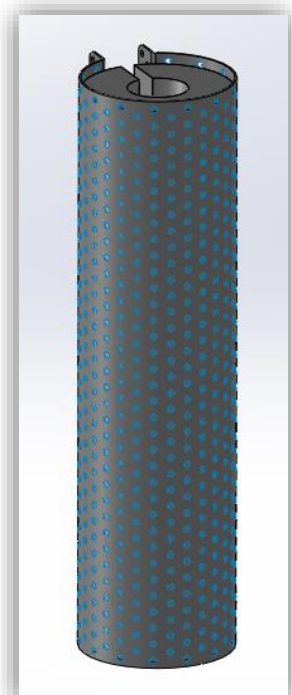
The electrics will remain the same as the precious plastics, with the exception of the box housing itself. I decided to make the side itself removable, this provides easy access to all the internal parts allowing maintenance to be carried out very easily. The other reason for making the side removable is that it makes the fitting of the box itself easier, having only 4 screws to secure the box directly to the box section behind it which is to be drilled and tapped.

It is held in place using qty. 4 of M3×5mm long & qty. 8 of M4×8mm long pan head screws.

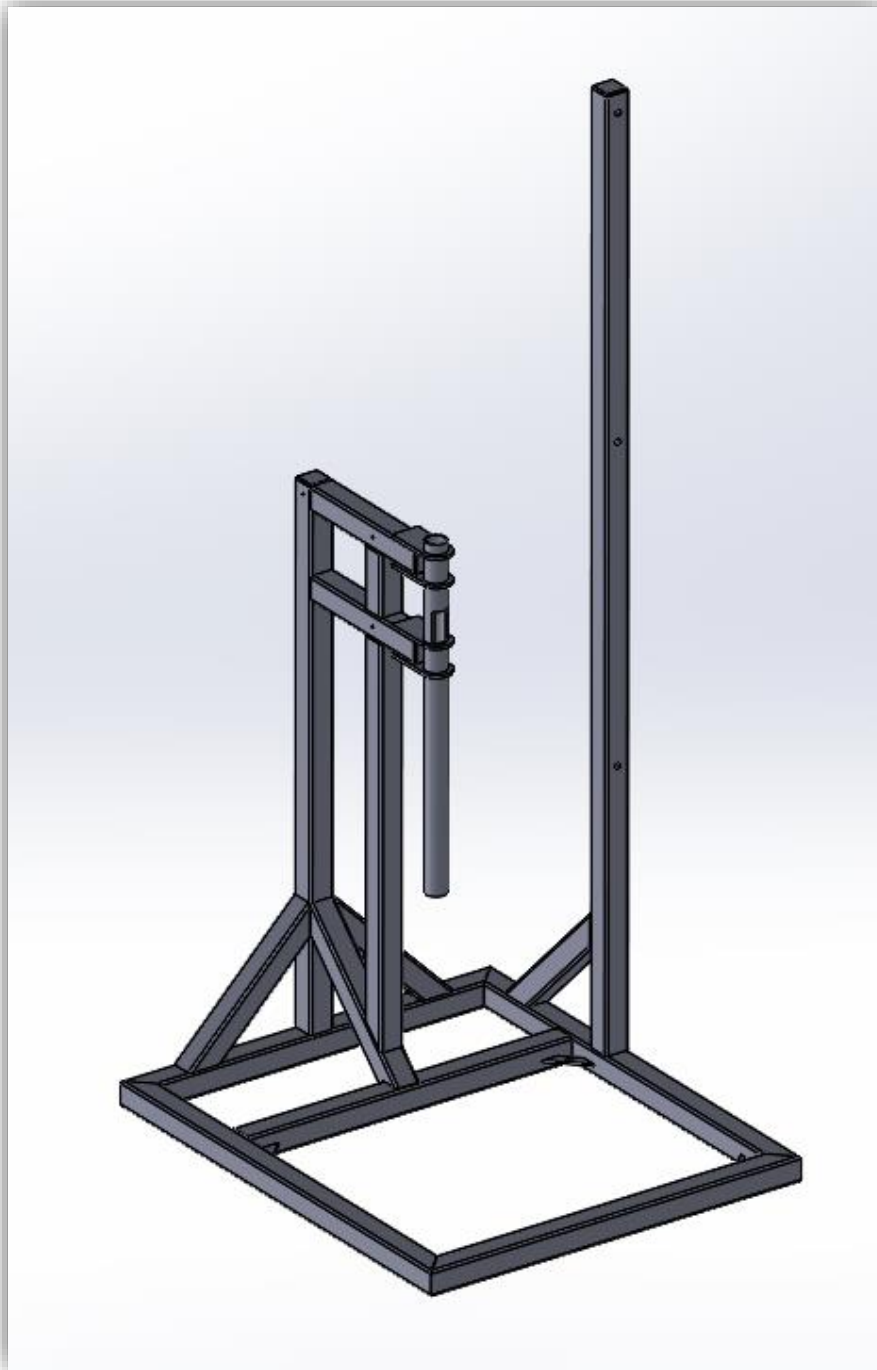


Rockwool will be used as an insulator that serves two purposes, firstly it is to prevent heat from escaping from the injection barrel, meaning it will need less time to heat up after every use. Secondly, it acts as somewhat of a guard to prevent the operator from suffering burns. It is held in place with a formed sheet metal shroud, although simple fine wire mesh would also work just as well.

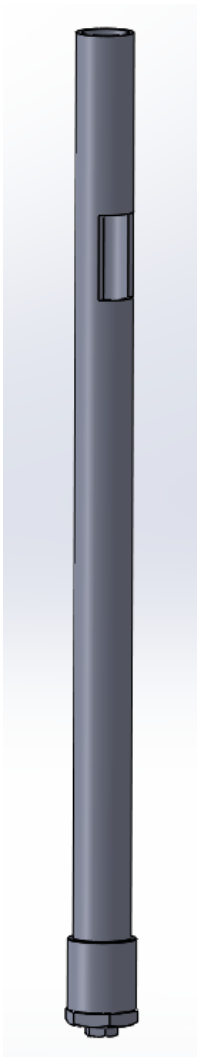
The intention is to hold this in place by inserting two M5 screws and nuts in the Ø6mm holes provided at the top and bottom of the flanges at the rear.



This entire section is to be fully welded as one piece, I have made an allowance of 1mm gaps typically between each part in consideration for general tolerance clashes. The 1mm gaps will provide sufficient room for weld penetration also. This structure is very stable and robust, each box section has an end cap to close it off, preventing water from entering and causing corrosion. It is worth noting that angle iron in hindsight may have been a better option as rolled hollow section does have a tendency to corrode in moist conditions, and without being able to see inside the section itself, it is difficult to be aware of the corrosion.



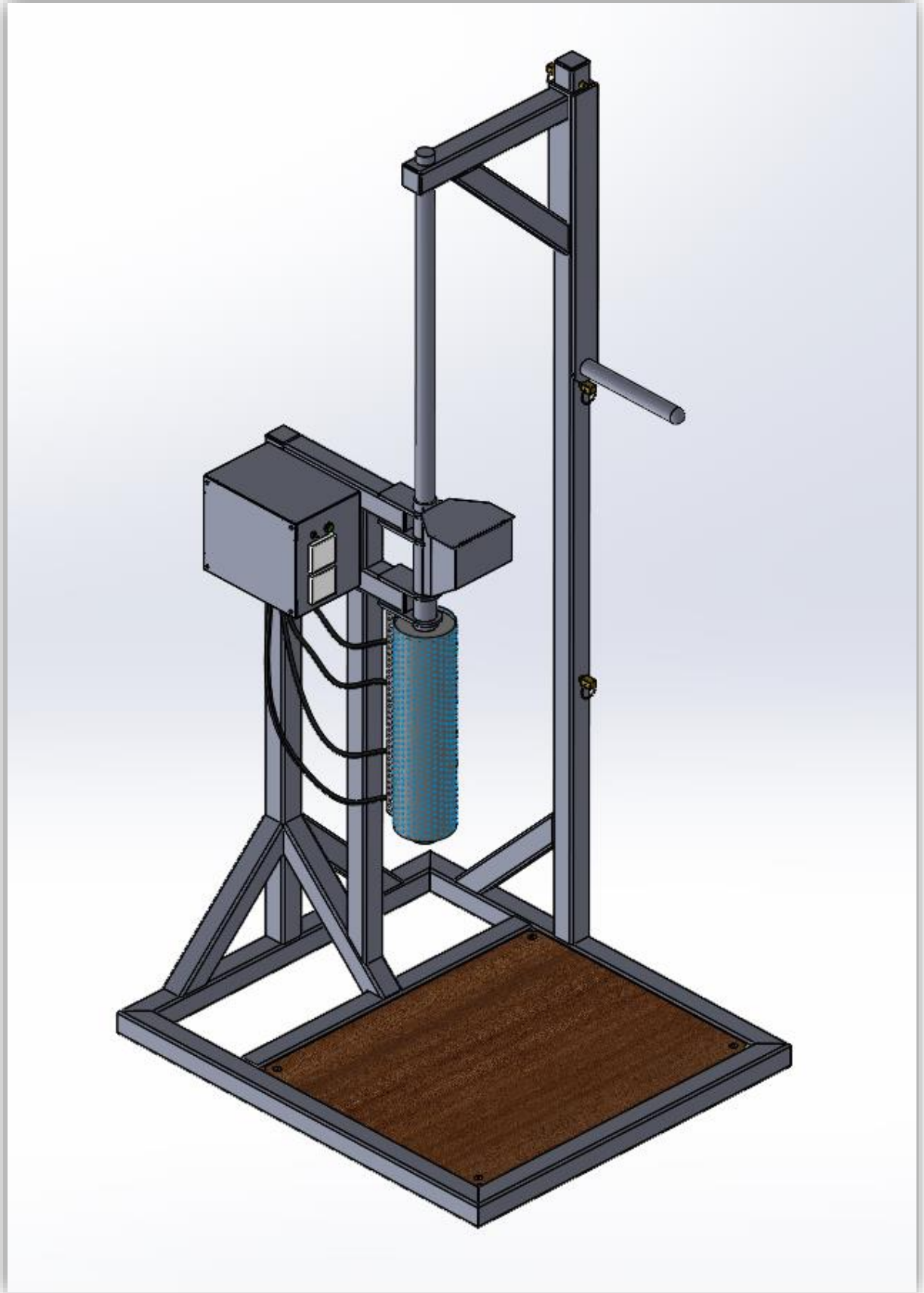
The base will be made from a standard 18mm ply board, it will be attached through the 4 CSK holes in the chamfered corners using qty. 4 of M6×20mm long screws, M6 nuts and M6 penny washers.

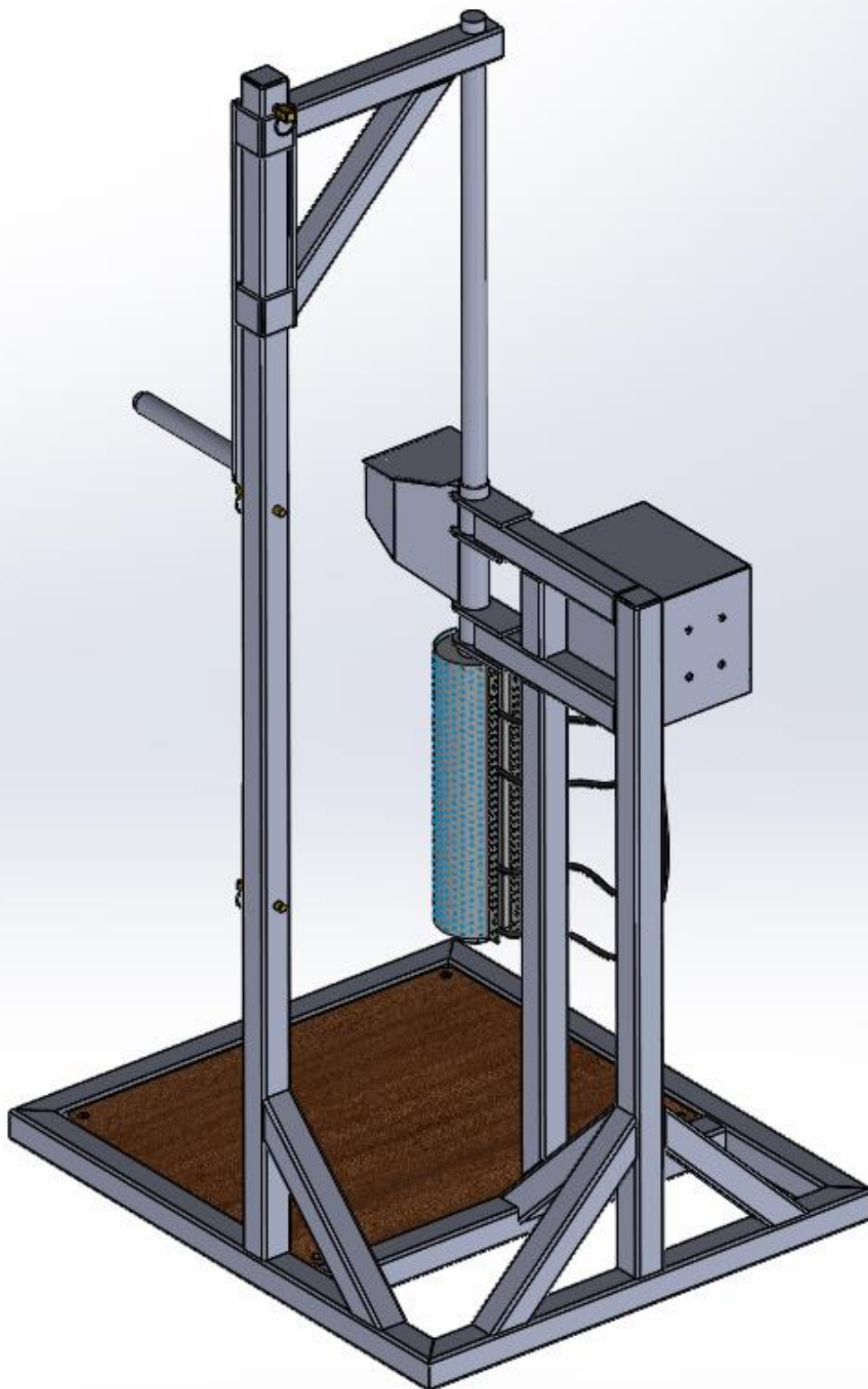


I have used the same configuration as used by Precious Plastic for the injection itself, although I would recommend using a non-return valve in the bottom to prevent plastic from returning. I was unfortunately unable to complete the research for this area as I would have liked, therefore I left it standard.

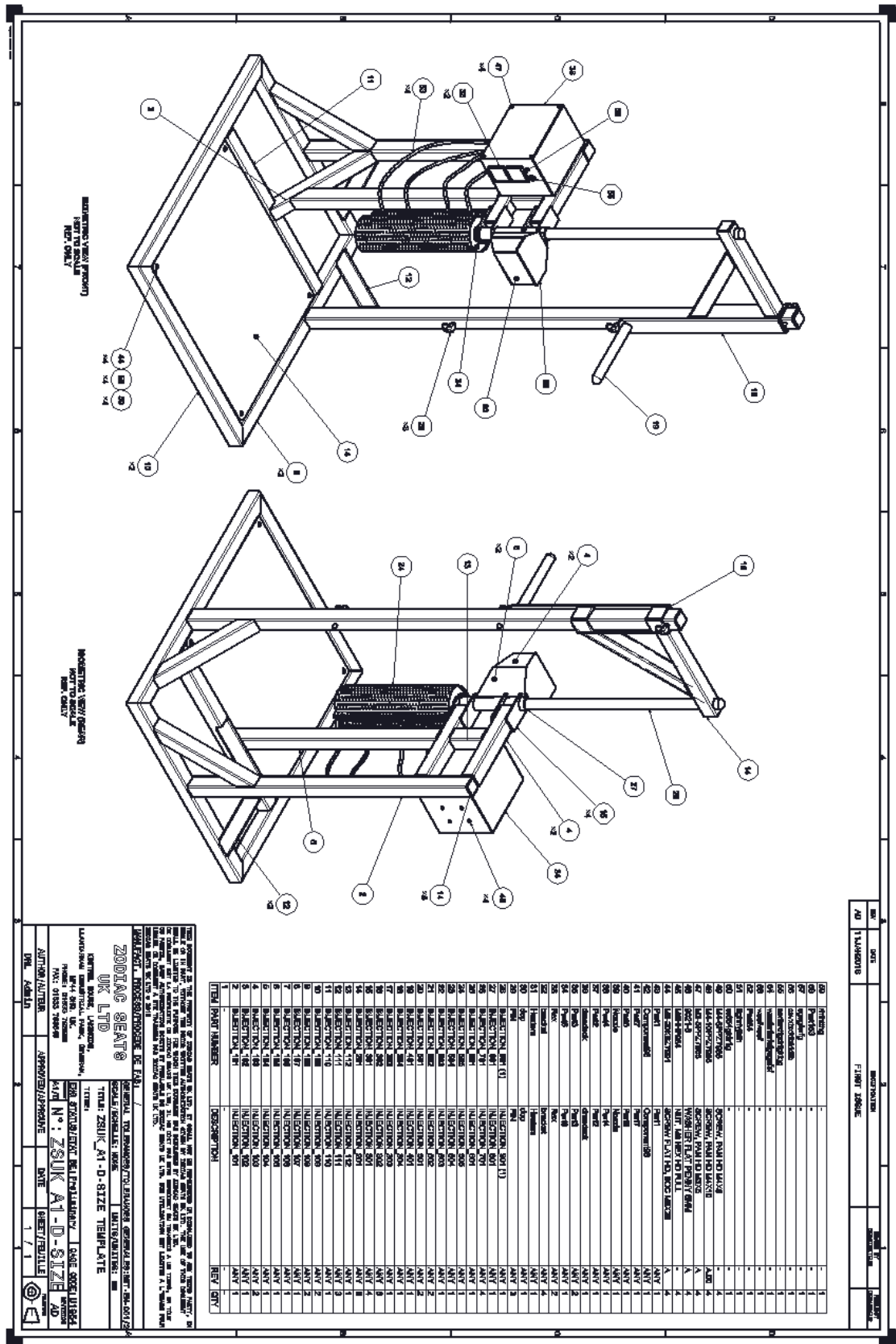
The barrel will get very hot during operation, and this is where we will benefit from the use of the rockwool and the protective guard to hold it in place as discussed earlier on.

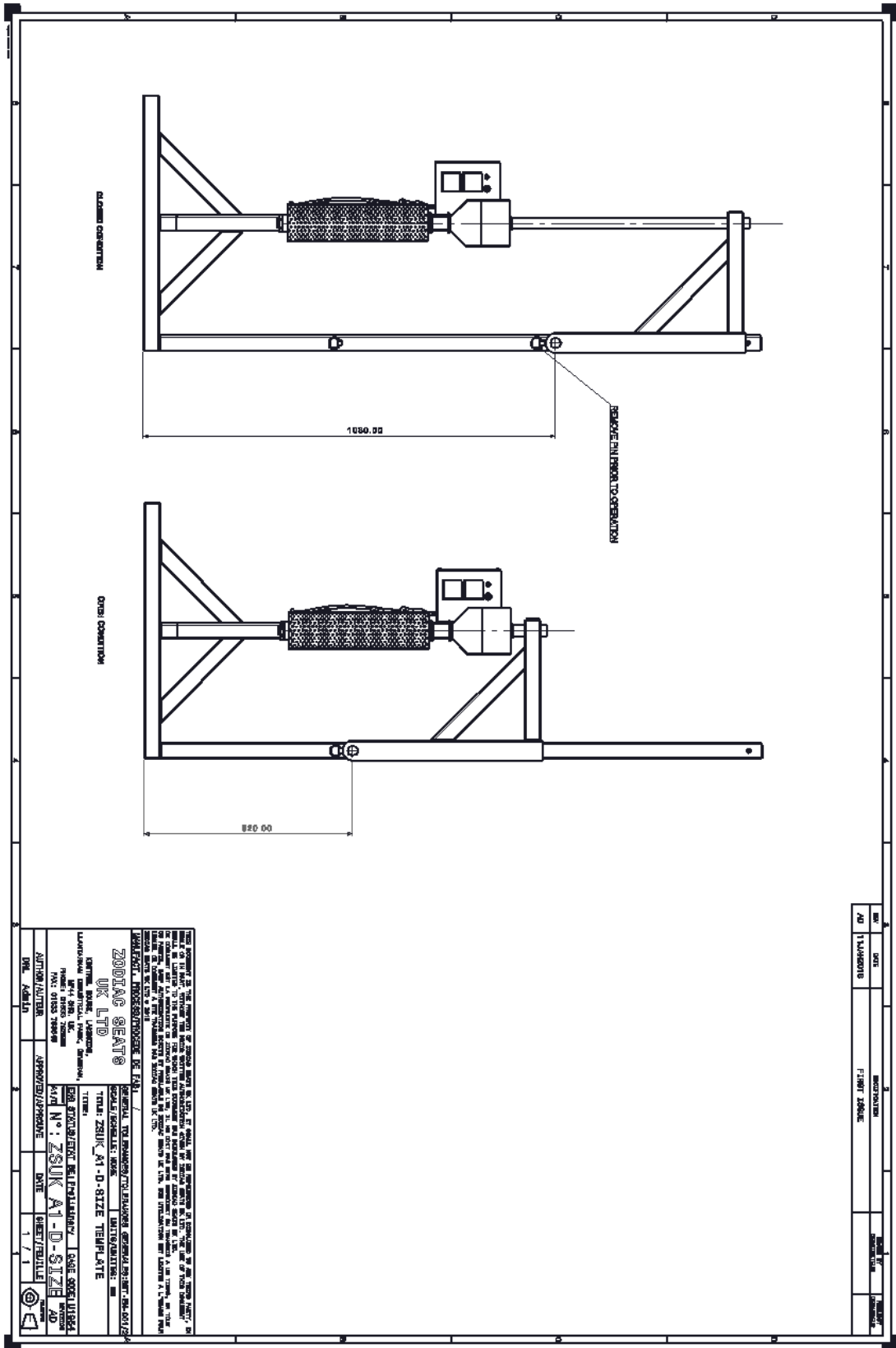
6.4. Assembly

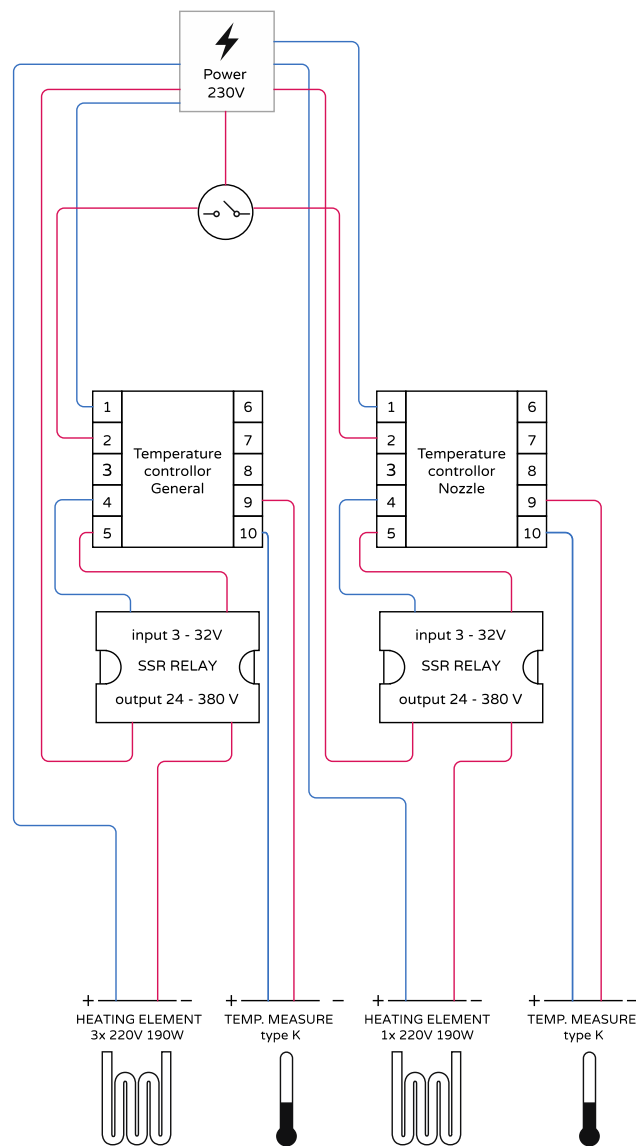




6.5. Engineering Drawings







This is a basic wiring diagram for the electrical box (15) , as used by Precious Plastic.

7. Conclusion & Appraisal of Design Solution

Upon reflection, the design that has been created will cater for individuals of most sizes, from children to adults, this is important due to the fact that children could benefit from recycling awareness from a young age. The current population are increasingly growing aware of the problem we face today with this wasteful single use consumer culture, a completely wasteless society is not likely to be possible, or at least in the foreseeable future.

The overall design does cover the main aspects that I set out to do, and those are: -

- Ease of use by anyone including children.
- Health and safety – Protection from burns and protection against moving parts.
- Interesting to use.
- Robust and solid structure.

So for those reasons, the product has achieved expectations.

With regards to the manufacturing process, the only formed part is the sheet metal shroud surrounding the rockwool that is used as a heat guard, this has two bent flanges and can be created entirely using a press break. The other sheet metal parts such as the electrical box and the funnel where the plastic is inserted, these should also be punched or laser cut, folded and welded, but for ease of manufacture, they are simple shapes that are cut possibly by guillotine and then welded. The option to omit the laser cutting or punching and the folding does mean that these can be manufactured using basic tools, eliminating the need to purchase them and therefore lowering the overall cost of manufacture.

To be critical of the design, I will start with the design selection processes, these were done solely by myself. These should never be completed by individuals, they should by right be completed by teams of people for the simple reason it is good to have input from several people. I believe that an unconscious bias may have played a part in my deciding to design a product with an arm that is reachable by anyone including children, this is because I know that for something to work, and people need to be interested in it. If this is not usable by everyone, then it will not get everyone involved, meaning there will be less recycling carried out. So for this reason that I had formed a strong opinion on early on in the project, I may have inadvertently chosen to conduct my studies in such a manner as to make this one of the main factors, although admittedly I may simply be overanalysing the situation or process.

The design could be cheaper, the amount of material used is relatively great when compared with the baseline, being the Precious Plastic injection machine. The whole idea of getting a community together to recycle is a good one, but it must be sustainable, I cannot stress this enough. Here are the 3 main make or break factors for me: -

- The project must be as such that it gets people on board and keeps them interested. This does mean that the process must be interesting, easy and make people want to come back time and time again.

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- The process must be self-sufficient financially, by this I do strongly recommend that a simple product can be manufactured for sale in order to generate cash flow. This will obviously make this unit self-sufficient first and foremost, but also it could lead to the expansion in creating several units across the country.
 - Last and by no means least, it must be safe to use by everyone. An unsafe environment will not only mean the risk of closure, but it is also a responsibility of care for other people. This is not to be taken lightly, the unit should not only seek to meet the UK guidelines, but exceed past them to ensure maximum safety at all times.

If all of these factors are met, there is no doubt in my mind that the whole project will be a success, it is not difficult in theory, but will require a lot of planning and upfront work in order to succeed.

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