Robbert van Haaften - 2021

Retractable chimney

Design report - Industrial product design - The Hague university of applied sciences.

In collaboration with Anevay Stoves

University project mentor: Edwin van meerveld

Preface

As a student of industrial product design I have gotten used to making and fixing everything myself. If I run into a problem or a product breaks, I try to solve and repair it. If I couldn't do it yet, I'd just learn how to. This led me to build my own house on wheels at the start of 2020. The complete design and building process was done in about 6 months. I started with a bare steel flat trailer and designed a completely functional lightweight home with all the appliances and features I wanted. As the primary heating solution for my mobile home, I had decided to use a wood burning stove. I wanted to design and build a wood stove myself, which is why I started researching the wood stove industry and designing a unique light-weight wood stove that would perfectly fit into my Tiny House. After a while, I found the company Anevay Stoves from the southwest of England, a small but competent business developing extremely useful and highly efficient stove solutions for outdoors and indoors. The company is mainly focussed on travel stoves and small space stoves. I contacted the company's founders Dawie and Mandy Cronje, and we discussed my design project. We decided it would be a better idea to work together on developing a new kind of product! Innovation within the small space stove market to solve a growing problem for many van-lifers and mobile home owners: having to get on the roof and dismantle the chimney manually before driving on the road. Could we design a product that can be lowered or retracted from the inside of the home, making it possible to heat your home immediately after a journey?

In this project, I will go through all the design stages and develop a new product for Anevay Stoves which can be prototyped and hopefully manufactured and sold all over Europe/the world. I am quite excited to work on this product together with Anevay, giving me the possibility as a student of design to be part of realising a new product for their company and maybe I will even be able to install an early prototype into my very own home. First, a brief overview of the Anevay wood stove company.

Rob's job tinyhouse build - Ep 15 - Lightweight steel roof,...

Rob's job tinyhouse build - Ep 14 - Lightweight exterior...

Anevay Stoves

Anevay Stoves, an English company founded in 2009 following the success of a product developed for humanitarian aid, the Frontier, a wood-burning stove of which more than 15,000 have been shipped to relief areas to produce heat for victims of poverty or war. The Frontier has been produced since 2007, and in 2009 production and sales started for consumers. In 2010, several design improvements were made and the company started to produce more and more. Anevay Stoves is based in Cornwall, UK, where they manufacture all of their products. Following the Frontier's success, Dawie Cronje, Anevay's CEO and founder, began developing a larger production line. Now, Anevay Stoves have a collection of 7 different wood burners and a wide selection of accessories & mounting kits. The Frontier has a bigger brother; the Frontier plus. There is a rocket stove for outdoor cooking called the "Horizon". In addition, there are 4 models for small spaces. All use a cylindrical vertical shape. The smallest, "Shepherd", weighs only 13.5 kg and the largest, "Tana", weighs 45 kg. The models produce between 1.7 kW and 4.5 kW. Anevay heaters also make products such as stove pipes, hoods and mounting systems. For example, they have a selection of insulated and non-selected tubes of different sizes, and composite kits. So, you have everything you need to install a new wood-burning stove.

Project leader

Anevay Stoves has over 12 years of experience in designing and manufacturing wood stoves and associated products. CEO of Anevay Stoves, Dawie Cronje, will be my project leader. Due to the great success of the Frontier, his passion has grown into a world famous company that provides many people with high quality heating systems. He works with great passion to develop high performance products for this market and make available the products that consumers are demanding.

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1. Project description

1.1 Assignment

The project assignment is to go through a design process in collaboration with Anevay Stoves with a producible new product as a result. There will be research of the current market, consumer demand and technical aspects/manufacturing possibilities. An extensive research will be done regarding wood burning stoves and their chimney systems to get a better understanding of the industry. A concept will be designed that best meets the design requirements will be determined based on the conclusions in the research phase. The concept will be worked out in detail and technical drawings will be produced to be used for prototyping. The prototype will be built by Anevay and extensively tested to be further improved. The product will be developed for a growing mobile home market. A growing trend to live "tiny" means that the demand for wood stoves that better meet the requirements of that target group is also increasing. At the end of this design project, Anevay Stoves will be able to start producing the component and sell it worldwide.

1.2 Plan of action

The assignment starts with an extensive research/analysis of the current market and products. Research will me done into the market, consumer demand and technical aspects/manufacturing possibilities surrounding this product type. Although this will be an innovative new product for the market, I am sure there are some people who have built something similar themselves. The knowledge gained through the research will be used for the different design phases. After the research, a clear target group will be set up and research will be conducted within this target group after which the design phases begin. But first, in the analysis phase, all of the findings will be elaborated and clarified. The idea phase serves to come up with various creative solutions, several of which will be elaborated in the concept phase. In the materialisation phase, the concept that best complies with the requirements is worked out into a working product and the product is prepared for prototyping and production. If possible, a prototype will be made and tested, after which design improvements can be made to perfect the functionality of each component and how they interact together. The expected batch size for this product is around 10,000 pieces.

1.3 Schedule

Wk	Tasks/assignments	deliverables
1	Start up, video call & defining project plan	schedule, project description & problem statement
2	Start research phase, diverge for design ideas	market research, technical research, target group & price estimation
3	Analysis phase, draw conclusions from research	list of requirements
4	Idea phase defining components	list of required components
5	Idea phase sketching and technical concept drawings	idea drawings
6	Idea phase working out design specifics and conclusions	component breakdown
7	Concept phase	design problem statement
8	Concept phase	fabrication analysis
9	Materialisation phase	concept mockup by Anevay
10	Materialisation phase	concept & user tests, design improvements
11	Materialisation phase	concept analysis & review
12	Documentation process & complete design report	design process documentation
13	Evaluation phase	cad model
14	Usage analysis, applying design improvements	usage test
15	Making design improvements and new prototype	technical drawings
16	Testing & finalising design	manufacturing process
17	Final presentation	life cycle analysis
18	Assembly and manufacturing guide	completed design report
19	User manual	internship evaluation
20	Completion of internship	final documentation

1.4 Product problem statement

Main problem:
There is no product solution to collapse an external chimney from the inside of the living space for transportation of a mobile accommodation unit with a heating system with chimney.

Partial problems:
- The user must disconnect and cover the chimney pipe before moving his or her living vehicle.
- The user must get on the roof and reinstall the chimney before lighting a fire in the wood stove.
- Bad weather conditions or difficult to reach locations can make removal of the external chimney hazardous and time consuming.
- A chimney that sticks out is not aerodynamic and may raise the highest point of the vehicle over the legal limit.
- Disconnected components need to be stored somewhere during transport.
- Using low profile chimneys is hazardous and might cause damage.

Problem analysis

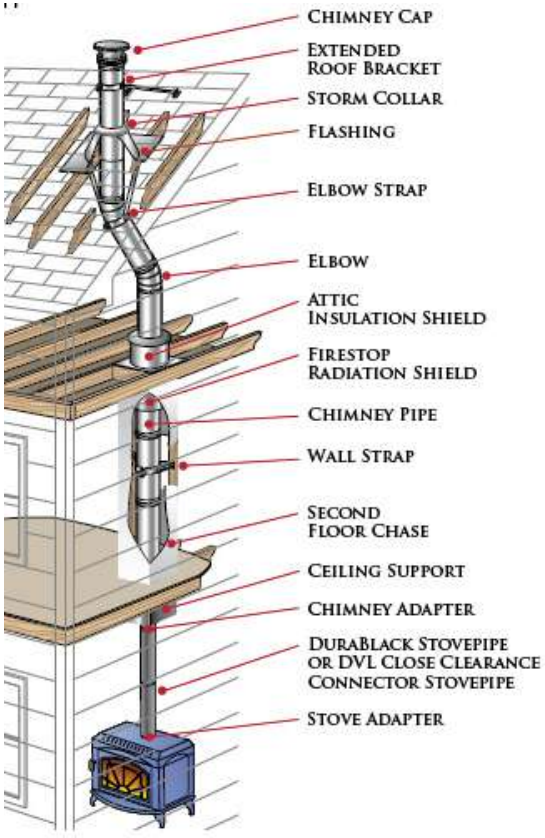
When a mobile home uses a wood-burning stove, the occupant must remove the external stove pipe and seal the open pipe at the top of the roof each time before departure. Regulations demand a minimal distance of 60 cm from the roof to the exit of the combustion gases. But it is impractical and unsafe to drive with a 60 cm chimney sticking out of your roof. To make it easier for mobile homes that move frequently to use a wood stove, we will develop a flue system that extends and retracts quickly and easily from below so the stove can be used without having to go up on the roof to install or dismantle the exterior flue system. In this project all possible solutions to the problems wil be explored and structurally, decisions will be made on all of the design choices that occur. To make the right choices, a comprehensive examination must be made of the benefits and drawbacks of each design choice. Minor design choices often play a critical role in the perfection of a product. The operation and effectiveness of the components is improved by testing and evaluating the effects that each design element brings.

2. Research phase

2.1 Technical research

During this research I will discover all there is to learn about stove flues and chimney systems. Research will be done on the manufacturing process and material choices of all components as well as possible current existing designs that are relevant to our product.

Definition:
Flue: *A duct for smoke and waste gases produced by a fire, a gas heater, a power station, or other fuel-burning installation.*
Chimney: *a vertical channel or pipe which conducts smoke and combustion gases up from a fire or furnace and typically through the roof of a building*



Two words that are closely connected: a flue is simply a passage for conveying exhaust gases from an appliance to the outdoors; a chimney is the entire vertical structure incorporated into a building and enclosing a flue, or flues, that carry off smoke, especially the part of such a structure extending above a roof. The purpose of a chimney is simply to move exhaust gases from the combustion area to the outside air, while at the same time it plays an important role in creating a good airflow. Flues get very hot during use since the gases can reach temperatures of over 300 degrees celsius. This heat is important to create a draft and suck air into the combustion chamber. The chimney needs to be weatherproof. At the top of the flue there has to be a protecting unit preventing rain from entering the pipe, called a chimney cap. The cap also ensures that any sparks will be stopped and that no rodents can start nesting within the pipe. The flue travels up through the house and will have to go through the roof structure, where the building materials have to be protected from the heat. Insulated flue sections are the solution, a double walled flue with insulation in the walls prevents the hot pipe from burning surrounding materials while keeping the flue extra hot for a more effective draft. On the exterior of the house, the connection between the flue and the roof material is kept weatherproof with a metal or flexible flashing system and often also protected with a storm collar between the stove and the cap. The flue must be perfectly air tight to prevent any gases from escaping and leaking into the house. For safety reasons, the chimney exhaust point must have a distance of at least 91 cm from the surface below and must be at least 61 cm higher than the roofline. For this project we will be developing a product that can lower the extending exterior flue so that the vehicle or mobile home can be driven on the road safely. To calculate and determine the maximum length of chimney components sticking out of the roof during transport, regulations have to be investigated. Generally it will be: the shorter the better.

2.2 Legality

All products of all types need to meet a selection of norms/standards and requirements. In Europe the CEN (European committee for standardisation) has a huge amount of documents regarding rules and standards that certain products must meet. These are documents that provide rules, guidelines or characteristics for activities or their results, for common and repeated use. Standards are created by bringing together all interested parties including manufacturers, users, consumers and regulators of a particular material, product, process or service. Everyone benefits from standardisation through increased product safety and quality as well as lower transaction costs and prices. Each European Standard is identified by a unique reference code which contains the letters 'EN'.

In this standardisation document: BS EN 13878:2019 (Leisure accommodation vehicles. Terms and definitions), all the legal requirements for transportable accommodation vehicles are listed, including specifics about chimneys. This EN norm is applicable for leisure equipment, transportable accommodation units, road vehicles, mobile homes, caravans & caravanettes, and will be important for this product.

According to BS EN 15287-1 (Chimneys - design, installation and commissioning of chimneys.), the transition from single skin flue pipe to twin wall insulated chimney/flue below a ceiling should be positioned at a minimum of 425 mm below the ceiling. The exterior distance from the roof to the opening of the flue must be a minimum of 600 mm. Abiding by these NEN standardisation rules is critical to releasing a successful product into the market. It is also possible to deviate from these standards as long as the deviation can be proven to be safe, though this will add considerable costs and time to the design project. Many existing wood stove chimney systems in vehicles are DIY made and don't follow the regulations and norms.

2.3 Market

During a design project it is very helpful to know all about existing products that have any relation with what you are designing. Often, there are vast amounts of manufacturers and models that relate to your project. In this case that's quite different. Living and vacationing in a van, camper or caravan has gotten more popular since the housing market is rising. More and more people are building tiny houses on wheels or converting busses and vans to an accommodation vehicle. Because of the technological advancement in solar power, more and more people are opting for an 'off the grid' lifestyle. Heating such living spaces with wood will save a lot of battery power! Anevay is a popular choice amongst the target group. Many vans, caravans, tents and cabins are heated by Anevay wood stove systems. There is plenty of contact with Anevay users and the owners of Anevay Stoves realise that the problem at the base of these projects occurs often and there weren't any good solutions for it yet. During this research the few relatable products that excist will be analysed and described. (The links can be found in the sources at the bottom.)

‘’Kamin Teleskop’’

A man called Mitch developed a sliding chimney system in his tiny house. It seems like he engineered it himself and has no intention of manufacturing it. He posted about the process in his blog where he also uploaded many other projects. His system and the functions of the components will be analysed.

A cubic mini wood stove is used which is connected to a single walled stainless steel tube. About 40 cm above the stove another single walled pipe with a larger diameter is found. It seems to have no seal with the inner pipe but there may be one at the top of the inner pipe. The outer pipe is moved down when





the clamp is taken off. There is a thick rubber O-ring pressed against the outer pipe by a duct clamp which is hooked on to a flange from the ceiling plate. This rubber seal is to hold the pipe in place, but also to remove any drafts since this design has a simple exterior flashing system that the outer pipe can simply slide though freely. Mitch mentioned in his blog that water penetration problems did occur with this design. Noticeable is the quite large diameter difference between the two pipes. Whas this on purpose or did he just have this available to him? If there is indeed no seal within the pipes then possibly the combustion gases will not tend to escape the transition of pipes due to its natural upward draft. Mitch’s construction also allows the rain cap to lay completely flush with the roof when collapsed. A neat and aerodynamic feature. It does not look like the end of the flue is a full 60 cm above the roof. He probably didn’t design it according to the European standards. I am curious about the material of the rubber ring. It is possibly silicone, which is a widely used material for high temperature seals. The weight of the upper pipe and rain cap is held by the ceiling plate. It seems this design flashing kit can only work on a flat roof, and will have to be manufactured to the exact roof angle to function correctly. This flue system is not insulated.

Clamping options

There are different ways a duct or pipe can be secured and/or sealed. What are the options?

1. Band clamp
A band clamp features a long, flexible band or straps to secure a hose or flexible tubing in place. This type of hose clamp is appropriate for fastening irregularly shaped or large fittings since the design of the strap enables it to surround the entire workpiece.

2. T-bolt band clamp
Also called hose clamps or T-bolt hose clamps, these are hose and ductwork clamps used for sealing fluid connections on flexible ducts and hoses. These types of hose clamp feature at-bolt tightened by a hex-nut, and give an even sealing pressure around the duct or hose for a firm seal. T-bolt hose clamps come in different sizes from relatively small to very large and you can use them on most types and sizes of hose or ducting, based on the application. To match common duct and hose diameters, T-bolt band clamps are usually available in standard sizes. Heavy-duty Those clamps commonly find use in large diameter and high vibration applications. These may include industrial machinery, agricultural irrigation, heavy trucks, off-road equipment, and HVAC duct systems among many other applications. Some types of T-bolt band clamps are fabricated for distinct hoses, for instance, silicone hose clamps which hinder hose cover extrusion.

3. V-band clamp
V-band clamps feature a “V” profile for bringing together two mating flanges. These types of hose clamp come in many varying styles and configurations, and their main purpose is to connect piping, ducting and other enclosures. V-Band Clamps provide firm fastening solutions in a broad range of applications comprising exhaust systems, engines, filters, and HVAC duct systems among others. Due to the ease in assembling and disassembling of V-Band Couplings, they commonly find use on equipment that needs frequent maintenance or service.

4. Quick release hose clamp
A quick-release hose clamp normally has a hinged snap or latch for quick disassembly. Though worm drive and other types of screw hose clamps are oftentimes termed quick release since you can easily remove them using a screwdriver. Quick-release band clamps widely find use in the home and automobile applications with modest pressures, as well as beverage, agriculture, irrigation, and marine applications, among others. The most popular type of quick release band clamp utilises a toggle latch to lock. The snap-lock quick release hose clamp comprises a screw, bridge, housing, and band, and the majority use worm gear assemblies. Certain quick release hose clamps feature gaskets and their design enables them to mount over couplings. Although the types of hose clamps highlighted above are the most popular, many other specialty types of clamps are available.

2.4 User research

Though this product is applicable to a wide variety of people and places, the persons that will be using the product will all probably have similarities in their specific requirements for this product. In the user research we will explore the different demands and selling features from the potential purchasers of the product.

In the analysis phase a target audience is described, this does not mean that there won't be customers that differ from that audience. The features of the product might specifically attract people that are living or traveling in a home that is transportable. But different audiences might be attracted due similar personal demands for their situation. For instance, a person living in a home where the maximum building height limit is reached and a fixed chimney is not permitted. Using a retractable flue might be a solution.

Below I have compiled an explanation of three most important themes with user interaction demands and possible selling features that would be good to apply to the product. During two or three years of customer communication and feedback from Anevay Stoves there has been a common interest in specific design features. I have also contacted 5 people within the target audience to ask them about their opinions on such a product.

- Ease of use

People who have used a wood stove before know the amount of work that goes into the proces. Wood needs to be sourced, dried, stored and chopped. The fire has to be looked after too. Customers would want a product which demands the least amount of time for installation, daily use and deinstallation. A system with little maintenance and reliable build quality.

- Safety

The people that are interested in starting using a wood stove, and people that are already familiar, have a big interest in product safety. For logical reasons a fire in your home might be a huge safety hazard. We have to design a product that is safety rated and abides all official safety regulation norms.

- practicality

There is a wide variety of types of people that are interested in a product like this, Young teenagers that are going on trips with a campervan or elderly people that live in a small caravan. And anything in between. The product must be usable for all ages and require little knowledge to operate. It should not require a seperate tool as it complicates operation and might get lost. The product must also be easily understandable and foolproof.

3 Analysis phase

3.1 Target audience

People with mobile homes/accommodations (like caravan, camper, tiny house on wheels) that use a wood burning stove as a heating system are the target audience. In particular those who change location often, have a badly accessible roof or are living in cold climates where the wood stove is used every day. The problem statement shows that people with transportable accommodations run into this problem and would benefit from having the solution this project aims to design installed.

3.2 Cost & retail price

To launch a new product it is important to place it in the right spot in the market. The retail price and cost price calculation are an important part of developing a new product. We need to place this product at a price range that is accessible to our target audience but at the same time set a standard for the quality of the product and the price must result in a suitable profit so production can be scaled up. Calculation of the manufacturing price is done to estimate the material and assembly costs so that a fitting retail price can be more accurately determined. The retail price must be in balance with the manufacturing costs but is also influenced by commercial costs, consumer demand and/or the existing market. If the retail price is too low there might not be enough profit to sustain the business or consumers will think it's low quality. If the retail price is too high, many consumers will not make the investment and sales will not be successful. When you have a monopoly, or are one of a kind, you can determine what consumers will pay for it and calculate the best retail price for many sales with a high profit.

For this product an expected retail price of 500 to 700 GBP is set (excluding the rain cap). Customer feedback to Anevay Stoves has given an indication to what consumers would pay for a system like this. The standard flue set is retailed at 400 to 500 GBP (depending on the diameter). Using a fairly standard 4x calculation from material and manufacturing costs means the product has to be produced for around 100-150 GBP. At the end of the design project in the materialisation phase there will be a cost price calculation based on the manufacturing process and materials needed for all the components, the assembly and packaging of the product.

3.3 List of requirements

Below are all requirements that the product must meet, a detailed list with the criteria that the product to be designed must meet. All requirements are made verifiable and will dictate which concepts are chosen or what design choices are made.

	Requirement	Verification method	Acceptance value	Remarks
1	The exhaust opening of the flue system is able to extend a minimum of 60 cm from roof level.	Component length specifications	> 10 cm < 0 cm	The distance is measured from the penetration point of the flue until the opening of the pipe (not the point of the rain cap) source: EU NEN norm: BS EN 15287-1
2	The retracting and extending operation can be executed from within the building/vehicle.	User interaction with product	/	The user can push the pipe up and pull it down from inside. This is one of the key elements to this product & based on user research.
3	When extended the connection point between single and double walled sections must be sealed to resist air leakage under low pressures of maximum 1.35 bar.	Prototype test for sealing performance	/	Ar has to be stopped by a seal, There may not be any airflow lost between the wood stove and the exhaust hole. (standard wood stove safety regulations requirements)
4	The system can collapse to a maximum height of 6 cm from roof level.	Component size specifications	> 2.5 cm < 1 cm	The highest point may not extrude more than 6 cm from the roof level where the pipe comes through. This figure is set as demand from Anevay Stoves as an important selling feature for the product & is based on the market analysis.
5	The clamp/locking system can be operated without any tools	Component functionality	/	The user should be able to unlatch the flue and collapse it with use of their hands. No tools are required for operation. This requirement is based on the user research.
6	The flashing component must withhold water from entering the roof.	Prototype test for water resistance	/	Whether extended or collapsed, there may be no water entering the seam. This is an obvious and important requirement for prevention of water damage
7	The moving flue section must be insulated with a minimum of 23 mm thick insulation fibre	Component assembly specifications	>7 mm <2 mm	The standard insulated flue sections have 25 mm rockwool insulation. This is an industry standard for this diameter flue.
8	When extended the distance from the ceiling to the insulated flue section must be a minimum of 425 mm	Component size specifications	>25 mm <0 mm	The EU norm restricts the exposed single pipe to come closer than 425 mm to the ceiling. source: EU NEN norm: BS EN 15287-1
9	The product can be installed to both 3’’ and 4’’ wood stove combustion gas outlets.	Component size specifications	/	There must be two size versions for both standard (small volume) flue sizes (8 cm & 10 cm)

4. Idea phase

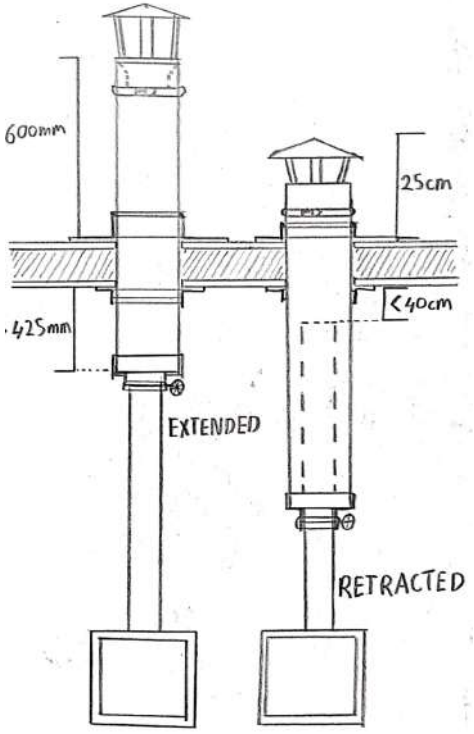
4.1 Concluding solutions for design problems

In this list, the design problems will be stated and elaborated on what choices can be made as a solution. The reasons for certain choices will be explained further in the choice matrix.

1. Is there a suitable material to use for clamping and sealing against the single walled pipe that can withstand the heat?
   Usually a silicone rubber compound is used for high temperature sealing purposes. Silicones are a group of elastomeric materials made of polymers containing silicium, oxygen, hydrogen, and carbon. Extreme temperature range and low temperature flexibility are characteristics of silicone compounds. As a group, silicones have poor tensile strength, tear resistance, and abrasion resistance. Therefore,special compounds with exceptional heat and compression set resistance are made and used for high demanding purposes. Silicone compound O-rings feature excellent resistance to extreme temperatures -50°C to + 232°C, and are resistant to hot air, ozone, UV radiation, engine and transmission oils (FVMQ), and animal and vegetable fats and oils. Silicone can be compounded to be electrically resistant, conductive, or flame retardant. Unfortunately, high powered wood stove pipes can reach peak temperatures of over 500°C. Lower powered wood stoves, which will be more commonly used with this extendable flue product, will not become that hot, but still can possibly damage a rubber seal when the stove is burning hard.

2. Can the flue be locked and sealed without a rubber compound?
   Using only a steel duct clamp will eliminate the temperature issues that occur with a polymer material. There is no situation of high pressure since the system is open on both ends. The full weight of the moving section will need to be supported with the friction between the clamp and the single walled flue.

3. To what extent will the soot (black residue) cause problems in this mechanical operation?
   After long periods of use the interior pipe walls can build up a layer of soot. "Soot" describes particles from wood that have not completely combusted in the fire, while creosote, specifically, is released from the burning wood as a flammable gas but fails to burn unless the fire temperature is sufficiently warm and is deposited as it exits the stove and the temperature drops below 250 degrees Fahrenheit / 121 celsius. Sticky creosote then traps additional carbon from the chimney smoke. To prevent soot and creosote buildup, burn only dry, well-seasoned hardwood and encourage briskly burning fires rather than slow, low-temperature flames by stoking a fire frequently or ensuring ample inflow. Because the components move alongside each other on the inside a thick layer of soot might impair the movement of the components. Because the fit between the single walled flue and interior wall of the insulated flue is not very tight, I am confident any small amount of soot won't become an issue. Implementing an extra component that brushes or cleans

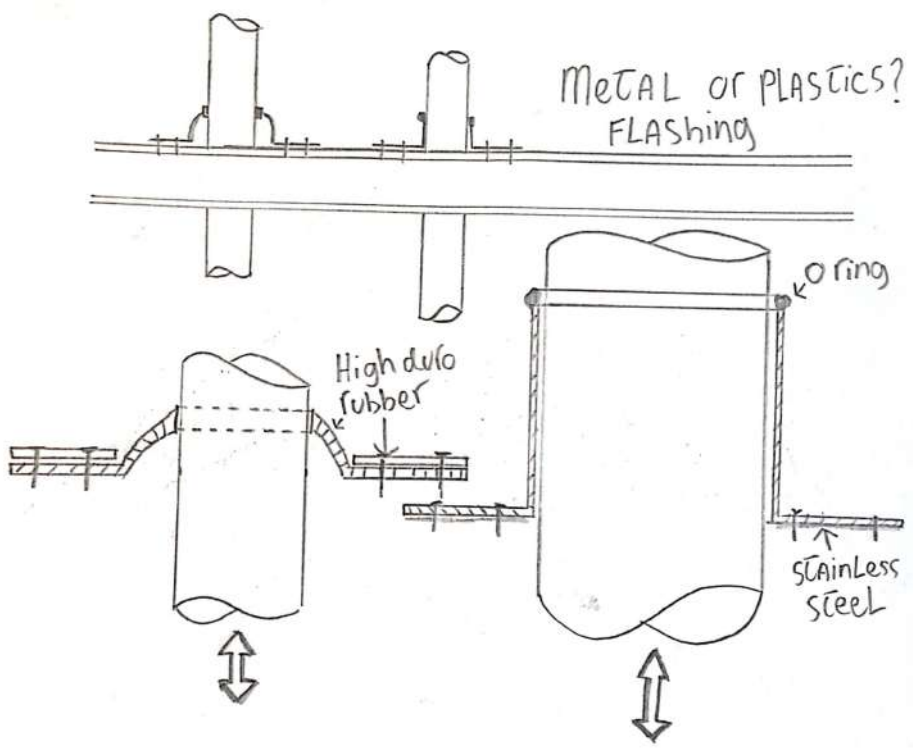


the soot from the interior insulated pipe wall can only result in movement issues and could make a mess every time you extend the flue. A proper cleaning of the inside of this component will ensure a long life and smooth operation.

4. <u>How do you maintain a watertight seal on the roof while the flue can still slide freely?</u>
   Luckily, the exterior of the insulated flue component does not get extremely hot and a rubber compound component can be implemented to create a seal, while also still allowing for free movement. Using the existing system with a flexible rubber sleeve is not suitable since the fit is supposed to be tight and downward movement of the flue will pull on down on the rubber creating a tub for water to come in and possibly also damaging the mounting plate and it's seal. We need a solid component that will not flex to keep the sealing material like an O-ring tight and aligned around the flue to have a proper and reliable seal against water. The flashing plate that will mount on to the roof would need to hold a thick rubber / foam ring that will fit snugly around the insulated flue. Giving a reliable seal against water entering the home.

5. <u>How do you maintain a gas tight seal between the two flue components that move relative to each other?</u>
   As noted in problem statement 2 there is no high pressure within the flue and generally air will be moving upwards rapidly. With a flexible sealing material like silicone a perfectly gas tight seal can be made which will not let anything through, even under high pressure. But due to the extreme heat of the flue pipe using a rubber material is not possible due to melting issues. in problem statement 2 a clarification has been made about using a steel clamp that has a tight tolerance. This will be sufficient due to the lack of high pressure.

6. <u>Can a flashing system be developed that has a variety of compatible roof angles?</u>
   Because the components will slide through each other it is important to maintain a proper right angle. Anevay offers their flexible flashing kit that can seal a variety of different angles due to the flexibility of the system, it is sealed at the very top due to a tight fit and the kit slopes outwards allowing for the pipe to enter at an angle. This system has a sliding flue and needs a solid flashing system with a seal that still allows for movement. Implementing a rubber o-ring in the flashing system requires the flue to be in a proper right angle to seal properly, it might be possible to fabricate a flashing system with a slight angle that allows the flue to come in at a small change in angle. The higher the angle relative to the flue, the more the intersection will change to an oval shape. The target group for this product is expected to mostly have a near flat roof. Campervans, caravans and other moving accomodation vehicles most often have a flat roof. To start off, a flashing system will have to be developed that is geared for a flat roof and might have the possibility of functioning on slight angles up to for instance 3 degrees. Prototype testing will show if this will be feasible.



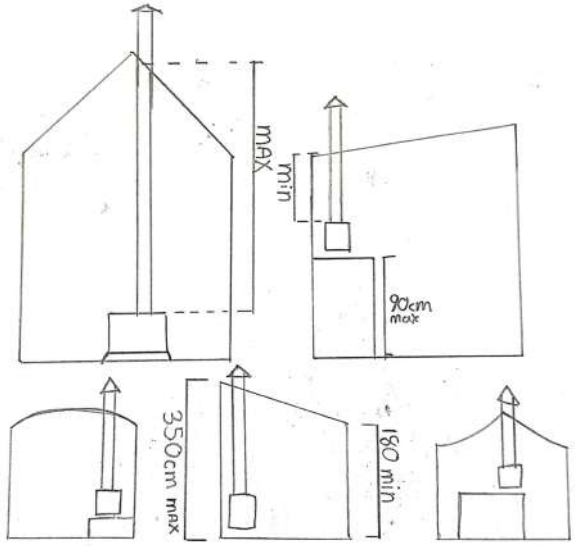
7. Can a glass fibre material be implemented in the clamp?
   Because the clamping system will often be released and tightened and will slide up and down over the single walled flue it is a good idea to prevent any scratching. We have concluded that a rubber type of material is unable to function and last properly within the clamping system due to the high temperatures. A material that can withstand this is glass, often a rope or strip made from glass fibres is used to seal the stove door. Adding a thin strip of glass fibre material can prevent scratching between the steel components and will make the sliding operation smoother. Clamping force can be decreased by implementing this component but by using a twisting quick release duct clamp the force can be set to be ample for the application. In the further design stages we will discover how this can be implemented.

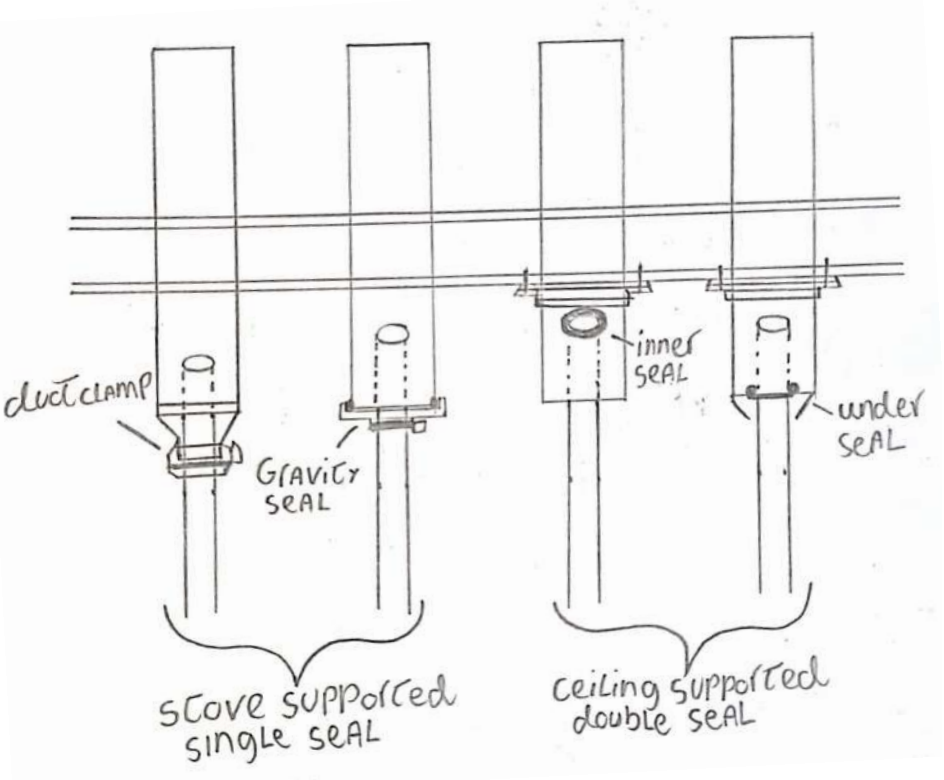
8. How short must the collapsed section be on the exterior?
   In the first stages of the design process I decided to use the existing rain cap for cost and compatibility reasons. After discussing the proposed design we decided to reduce the maximum protruding height to be under 6 cm which means that an entirely different cap needs to be designed. The height of the existing cap would extend over 25 cm above the roof. To reduce aerodynamic drag and more importantly have a safe drive it is important not to have big bits sticking out of the vehicle. This is why the 6 cm is chosen.

9. Is a twisting quick release duct clamp a better choice than a standard quick release duct clamp?
   To create proper clamping pressure with a quick release duct clamp a hook and clip are welded at an exact specified distance. To tighten a standard quick release clamp a lot of pressure is needed and the handle will snap down, fixing the flue sections together. Releasing the clamping force also will demand a little force to unhinge the hook and can make the handle flick open hard. This is a safety hazard as your fingers can get badly hurt if done incorrectly. Using a knob to tighten the duct clamp like a T-bolt band clamp will provide a controllable amount of clamping pressure and safer easy extending and retracting of the flue. It can also serve as a handle

10. Does the insulated flue or transition section need a handle component for the retracting and extending action?
    when the action of extension of retraction for this product is done by the user the insulated flue section will slide up or down. When the clamping pressure is released the weight of the top components will become apparent and will have to be supported by the user until the clamp is turned tight again. The user can use one hand to support the weight of the components under the transition component where a horizontal edge creates a good support point. the other hand can meanwhile loosen the clamp by twisting the knob of the clamp. When the user feels the weight of the components get bigger and the friction of the clamp loosen, the system can be smoothly pushed up or pulled down. One hand holding the knob, while the other supports the weight under the transition section. This is a viable solution without fabricating extra components. However, it is also possible to fabricate a knob on the opposite side of the clamp knob to create a more symmetrical appearance and function as an ergonomic way of handling the weight of the stove pipe.

11. <u>How will the system be adaptable for a range of different ceiling heights and stove heights?</u>
Because there are a wide range of different lengths between the user's stoves and ceilings it is critical to have a product that can easily adapt to the specific size. Having the single walled flue be the adjusted component in regard to ceiling height means that all other components can stay unchanged. The maximum and minimum heights from the ceiling and roof can be achieved with a specific length of insulated flue, the size would be around 60 cm (height from roof) plus 42,5 cm (distance from ceiling) plus the thickness of the roof (maximum 15 cm) which is about 120 cm. Then the single walled flue can be cut to size specific to customer demand. This component is the easiest to get and fabricate into custom lengths. Say the distance from the top of the stove to the ceiling is 1.5 meters. The single walled flue will need to be about 40 cm short of the ceiling, (1.5 - 0.4 = 1.1 m) Combining the 1.1 m section of single walled flue with 1.2 m section of insulated flue will give the right dimensions for functioning properly. in case of a thin roof of about 3 cm thickness the minimum height between stovetop and ceiling can be 115 cm. The single walled flue can be shipped to the customer at a custom selected size that fits their home. It would also be possible to have the insulated flue come in different length options too since it is merely a straight section with no special features.





12. <u>Is clamping the moveable flue component to the ceiling plate a better idea than clamping it to the single walled flue?</u>
Instead of fixing the moving section to the single walled flue and resting its weight through the friction of the duct clamp on to the wood stove it self, the moving flue section can also be locked on to the ceiling plate with a clamp which would make the weight supported by the ceiling instead of the wood stove. This would however create a couple of drawbacks. While driving many bumps will occur generating peaks in downforce. Even though the weight of the system will not be that heavy, some customers are likely to have a weak ceiling construction that is unable to hold the forces involved. Also many customers will likely have a steel ceiling (like a van) into which they do not want to screw. This will make mounting this concept unviable. Also a gas tight seal will still need to be formed between the flues and doing that without another clamp below will be difficult. For these reasons we have decided that a system that is supported through the wood stove is a better idea. The wood stove itself will often weigh quite a bit and must have a solid and strong base on which it is placed. This makes a more reliable choice to support the weight.

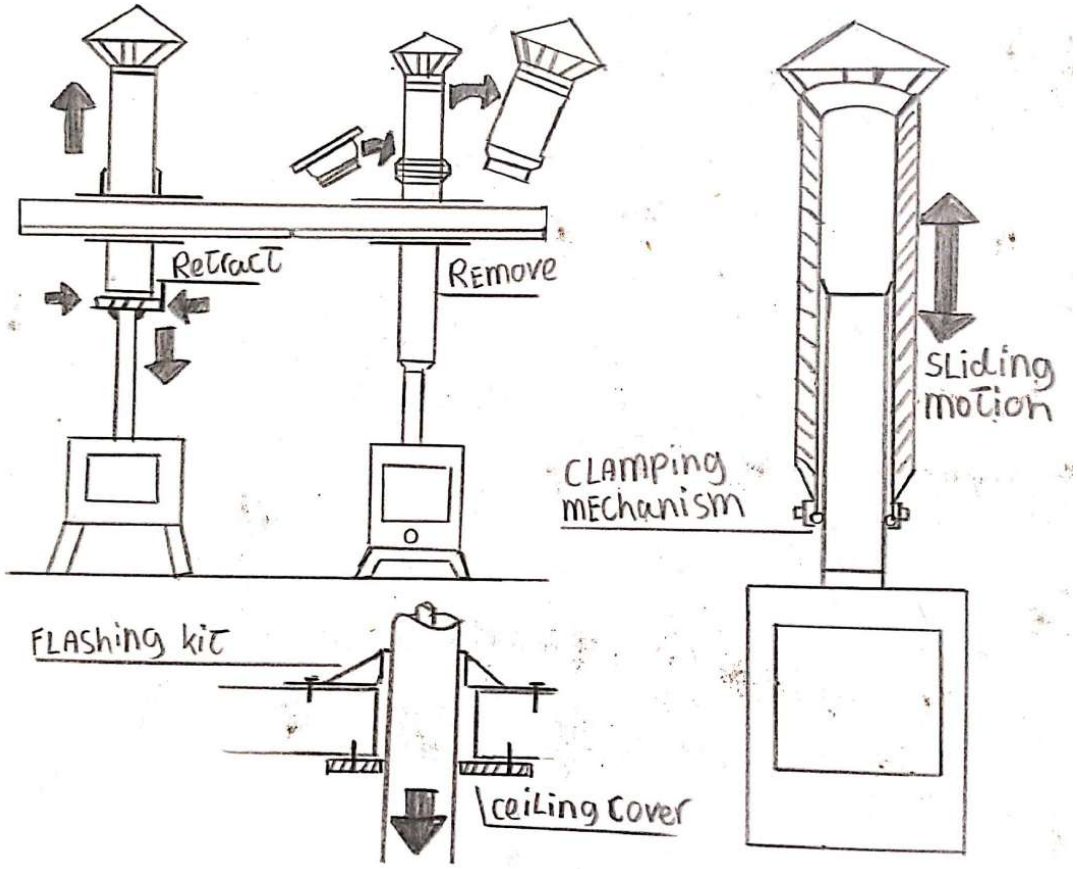
4.3 Defining components

Practically each product consists of many components. Each of them is carefully selected to fit and work for all kinds of circumstances, even those not intended for it. Materials, shapes & sizes are compared and iterations are made to perfectionise the durability, functionality and quality of the end product. To start building up the design, the different components of the product will be defined and then each of them can be developed / designed to collectively meet the list of requirements.

Each wood stove has an outlet for the combustion gases. The connection point will be connected to first: One or multiple single walled flue parts, then one or multiple double wall insulated flue parts and lastly the rain cap/anti wind cowl. through the ceiling the double walled flue will pass through a ceiling plate and flashing system. The flashing provides the waterproofing between the roof and the flue pipe. This is often a permanent seal or a very tight fit. Free movement between standard flashing components and the flue pipe is not common. That means this would need to be done differently in our product.

Duct clamps are used to connect the flue parts, two matching ridges are held together with a fitting round clamp to make a smooth and simple but strong transition between two flues.

The locking mechanism that secures the moving double walled component will also need a way to make a gas tight seal. Deciding on what material to use is very important because of the extreme temperatures.

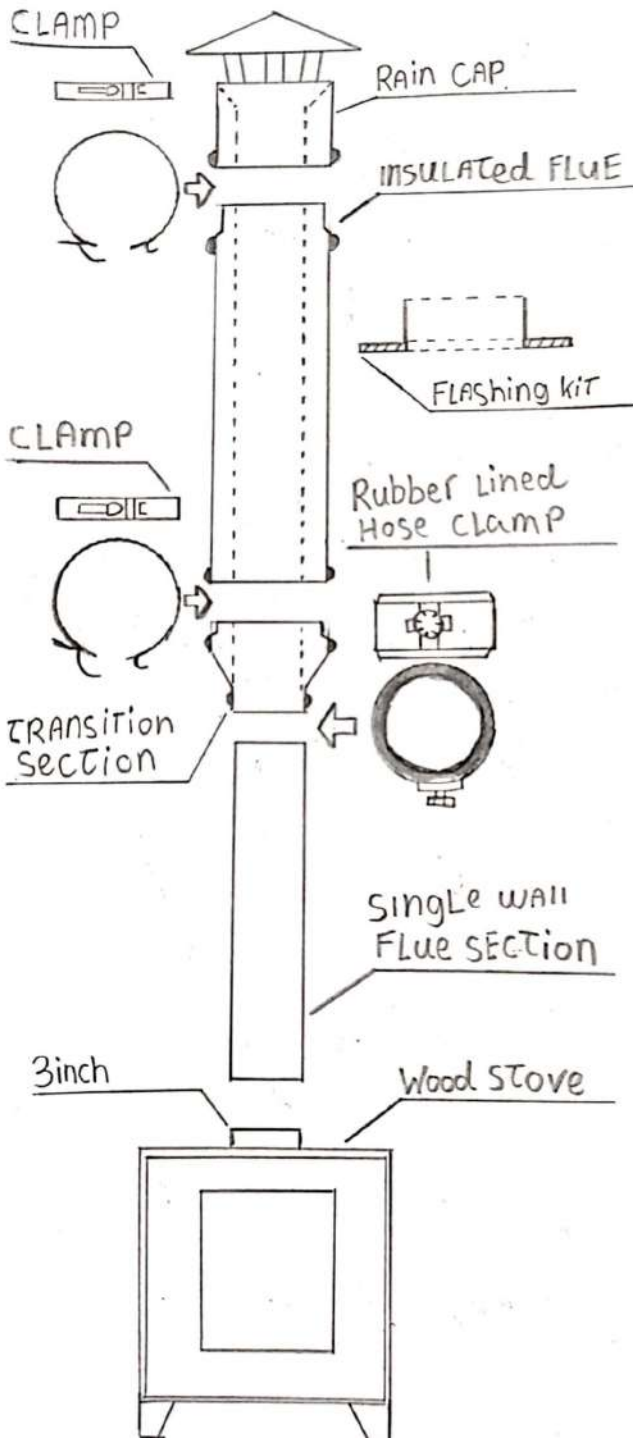


Conclusion:

The product will have to consist of a couple of different components which together form the product that operates and functions as intended. A single walled flue shall connect to a stove outlet, Drawing the air up and transitioning into an insulated flue component which guides the combustion gasses outside, at the proper height off the roof and protected from rain with a cap. The insulated flue should move up and down and should be able to be locked in place with little effort and with a reliable force. two components will guide the flue, a water sealing flashing system and the ceiling cover plate. The operation of the product has to be straightforward and accessible to almost all people. The installation should be able to be done without professional experience and with the use of an included installation manual.

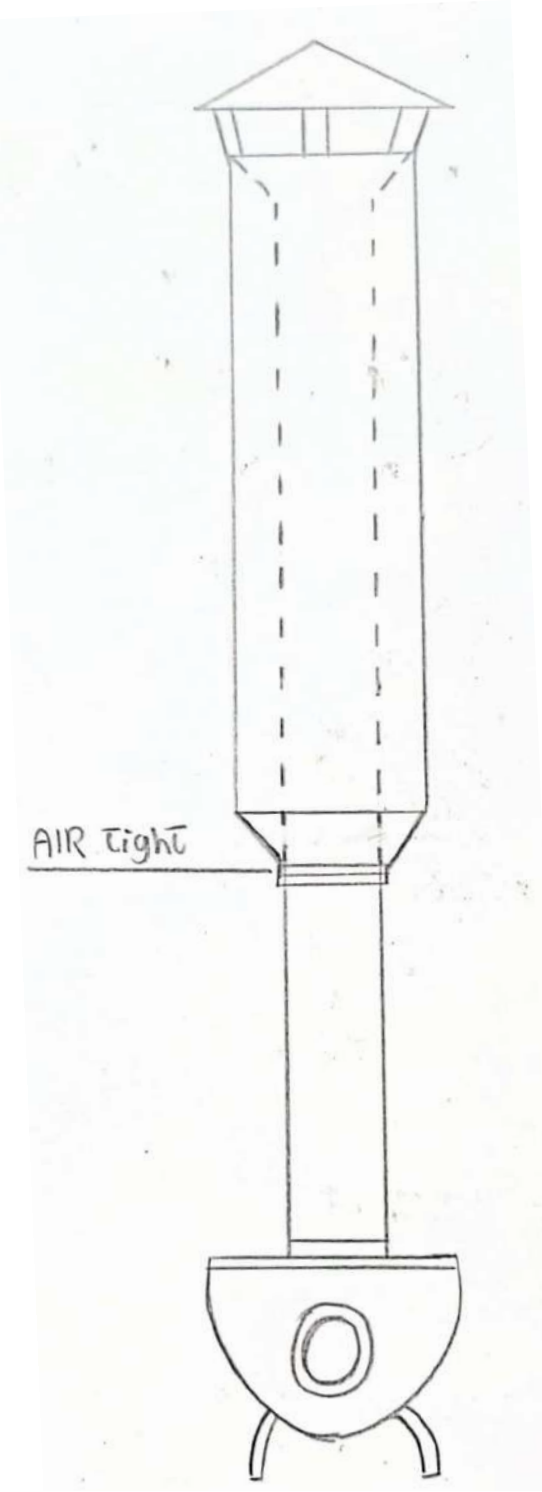
4.4 Component list:

Component	Sub-Components	Function	Location
Single wall flue	-steel pipe	Guide for sliding mechanism	On top of wood stove
Insulated flue	-Inner steel tube -Outer steel tube -Insulation	Insulates combustion gases. Slides up and down. Connects single wall flue and rain cap	Through roof
Transition section	-Inner wall & Outer wall	Create a clamping section for the sealing & locking system And transition material from thin to thick flue	Between single wall flue and insulated flue
Rain cap	-Inner wall connecting ring -Outer wall -Top cap -Connecting strips	Prevents rain from entering pipe seals insulation from outside	On the very top
Interior sealing/locking system	-Rubber compound ring -Locking/clamping system	Makes airtight seal between moving components Holds/locks the moving flue section on its place	Between single wall flue and transition section
Standard Hose clamp	-Clamp ring -Clamp lever	Connects insulated pipe and rain cap	Between insulated pipe and rain cap & double walled flue and transition section
Exterior flashing/sealing system	-Rubber ring -Flat flashing panel	Seals roof from rainwater allows up and down pipe movement while keeping a seal	On top of roof, around insulated flue



To reduce costs, it is best to use as many existing components as possible and/or make only minor changes to existing components. We can make use of the existing insulated flue component if we change the outer diameter of the single walled flue component in such a way that the single walled flue can slide through the insulated flue section. a small adjustment will need to be made to the transition section so that a rubber lined clamp can be placed over the seam between the transitioning component and the single walled flue. The clamp will hold the insulated section securely in place, designing the locking & sealing system together with the roof flashing will be the main focus of this project. The two head components in this design.

In the drawing to the left, an exploded view of the components is shown. Starting from the rain cap, which can be left unchanged from the product that anevay is selling today. That is connected with the also already used hose clamps to the double walled insulated flue section. The insulated section passes through the roof and can move up and down. It is kept in vertical orientation by the flashing kit which also seals the roof against water. This component needs to be redesigned as well as the transition section which connects to the insulated flue. This component will hold the top part of the chimney assembly. The transition section will feature a ridge to which the sealing and locking clamp can lock on to. The clamp will need to be designed and proper materials have to be selected. This component will likely need multiple iterations. The single walled flue section is simply a steel pipe that has a small decrease in diameter to accept the double walled flue section to pass over it.



4.5 Component breakdown

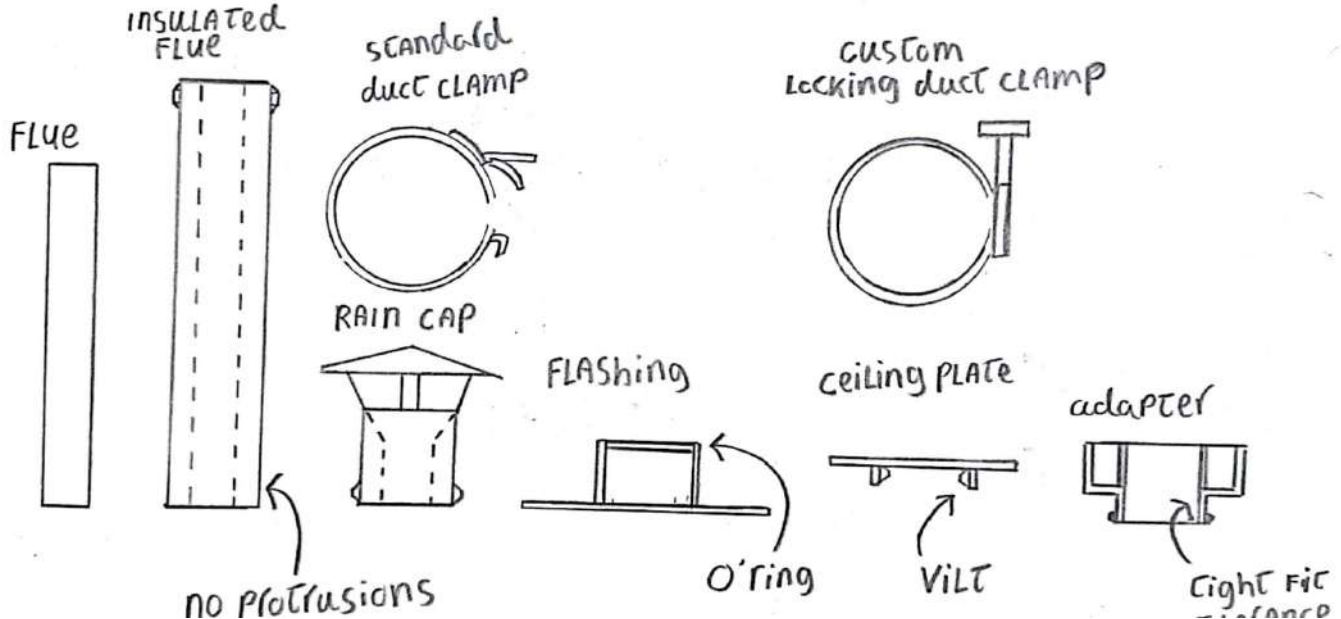
It might be possible to use a couple of existing components. If it's possible to leave them with no adjustments that would save a lot in manufacturing costs too. The to be designed or modified components are: Single wall flue section, transition section, the rubber lined locking clamp and the flashing kit. Maybe slight changes will have to be made to the insulated flue section too. Below you will find an explenation about each component & their functions and requirements.

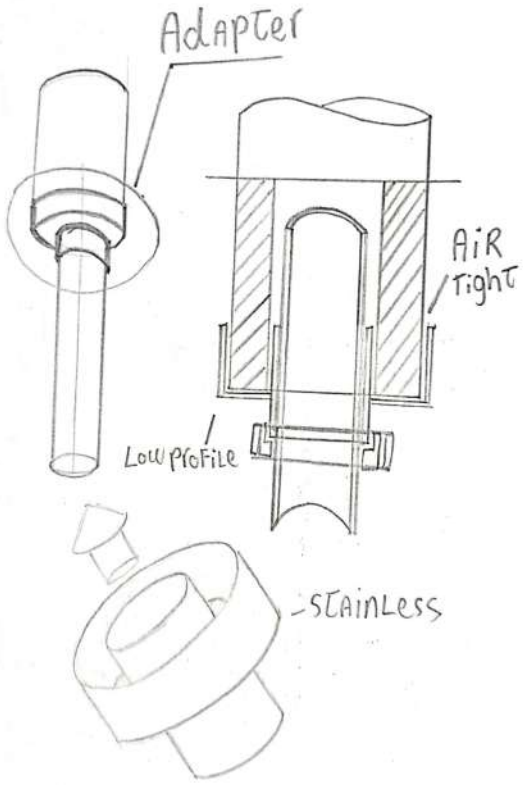
Single wall flue

This component will mount directly on to the wood stove, the bottom part will fit into the opening of the stove. This can be the standard 3 or 4 inch (8 cm or 10 cm). To maximise heat output into the living area it is preferable to have the single walled flue continue for as long as possible until eventually it has to transition to an insulated flue to pass through the roof safely. The necessary length of the single walled flue will have to be calculated for each situation, differing for low roofs and high roofs, stoves standing on the floor, mounted on a wall, sitting on a stand etc. The top part of the single walled flue is simply a cut off straight. That means that the exact necessary length can easily be manufactured by cutting an oversized flue to length.

Insulated flue

The insulated flue will need to have a specific length to be able to follow regulations for minimum and maximum distances from the ceiling and the roof. The standard 1 meter length of insulated pipe has two connecting ridges, one on each end. Because this section will be sliding through both the flashing system and the ceiling plate it needs to have a smooth end at the bottom without any protrusions. On the top the rain cap will be clamped on with a minimal amount of used space. The insulated flue therefore will be simply a clean pipe section without any features and with clean cuts on both ends, made to a specific length.



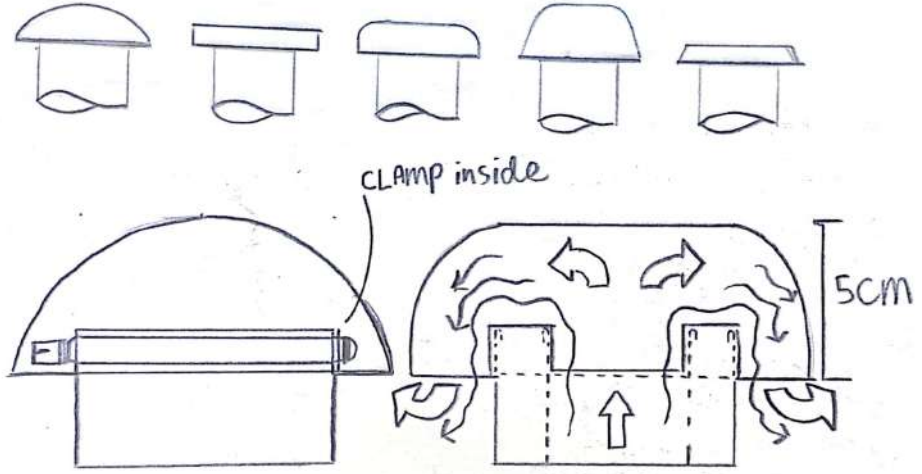


Transition section

Attaching to the bottom of the insulated flue and being locked in place to the single walled flue with the locking clamp system is the task of the transition section. Because the bottom of the insulated section has no locking ridge the transition section can snugly slide over the bottom and fit into place. This component will transition from a double walled cylinder to a single walled cylinder with an inner diameter slightly larger than that of the exterior diameter of the single walled flue. It will feature a little ridge on the bottom to hold

Rain cap

The rain cap will be a simple component that needs to lock on to the top of the insulated flue section and protect the opening from any water entering.
Because the cap will be very low profile to minimise the protruding height of the system when collapsed it will most likely be a flat or slightly curved face with a rounded or straight edge. The maximum height will be 6 cm, it would be best if when collapsed the outer rim of the rain cap will bottom out on the roof to create a very minimalistic and aerodynamic product. This means that the connection point and clamp will be situated within the height of the cover.



Locking system

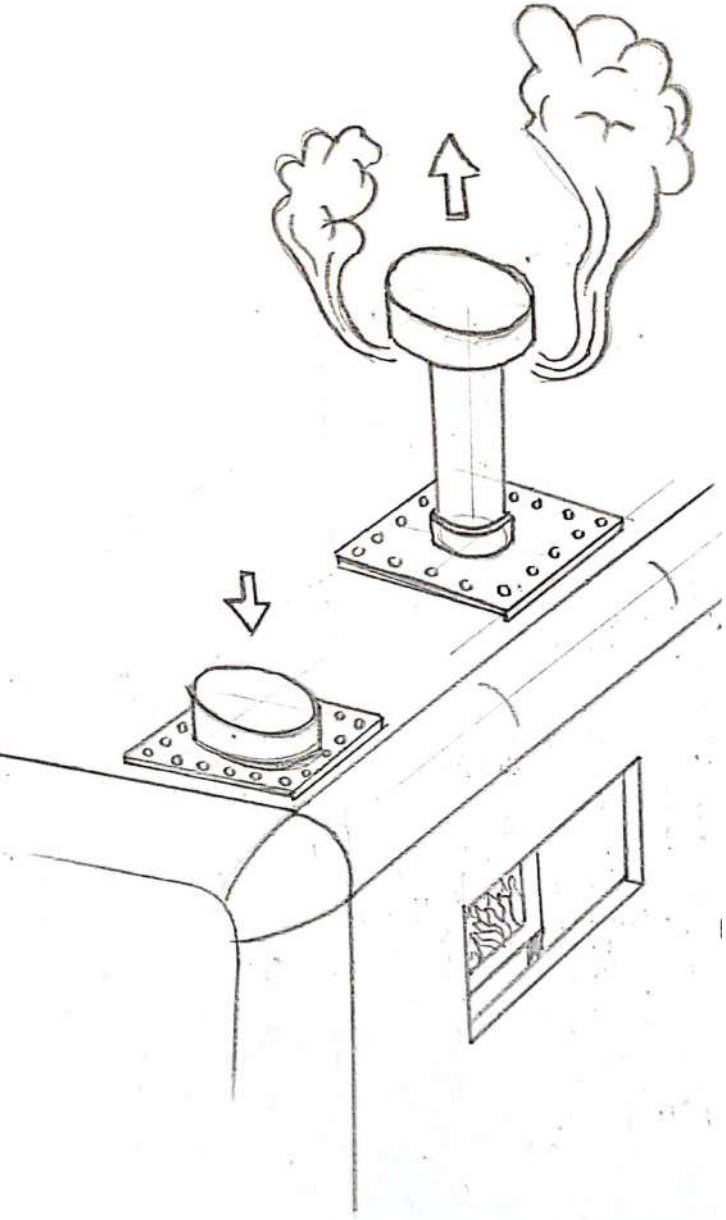
A band clamp with a rotating knob to adjust the clamping force can function as the locking system to lock and unlock the sliding double walled flue section to the single walled flue. The clamp will be held in place onto the transition section and will be able to slide smoothly over the single walled flue because of the integrated glass fibre material within the clamp. either a small notch will be made on the bottom of the transition section to hold the clamp in place or a couple of spot welds can be made to do the same.

Flashing system

a simple flat sheet with a protruding cylindrical element that is profiled and can hold a rubber o-ring to seal and hold the insulated pipe. The flat surface can be integrated and sealed to the existing roofing material and the protruding component will extend a couple of cm above the surface. to avoid streaming water on the roof surface to seep in. The protruding part must be as low as possible to minimize the protrusion of the overall system on the roof.

O-ring

A thick rubber ring with a diameter between 10 to 30 mm will be fitted on the inside of the flashing. The interior diameter of the ring shall be slightly smaller than the exterior diameter of the insulated flue. Using a thick ring will allow a larger tolerance of imperfection between the roof angle and the stove angle.

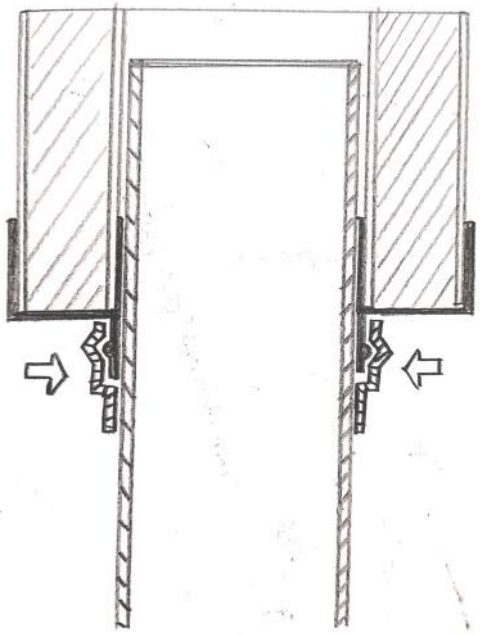


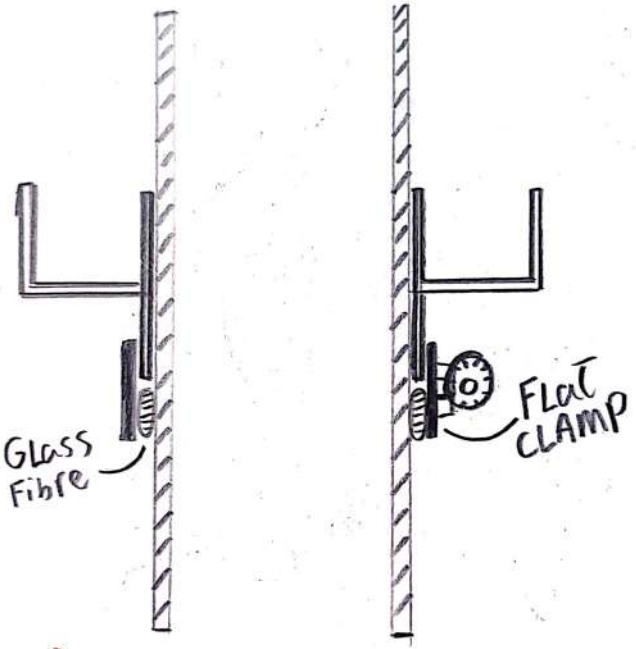
Ceiling plate

A round flat sheet of steel or other heat resistant material with a hole for the pipe in the middle and a 10/20 mm protrusion to hold a felt strip that smoothens the sliding motion of the exterior of the insulated flue. The ceiling plate can be mounted with glue or screws. A bracket can also be made.

<u>Conclusion:</u>

8 individual components with their determined function, dimensions and interaction with other components. The exact measurements and the manufacturing methods of these components will be elaborated on in the concept phase. All of the choices made to come to these designs and components will be explained in the section 'Functional design choices'





4.6 Functional design choices

The component descriptions and specifications were all options to different choices that were made to solve design problems. In this section there will be more diverging, and expand the reasoning behind design choices for this product and make a thorough breakdown of why and how the design choices will be selected and finalised. to meet all the requirements and provide for a high quality product.

Previously, in the analysis phase, a list of requirements was determined. This list plays a vital role in the making of design choices and finding solutions that comply with the requirements. What also plays a big role in the making of choices is plain logic. When a component needs to meet certain requirements and has to operate in the right way, my brain will start comparing all kinds of situations and issues that might occur with it, as well as how it might feel, sound, look or wear during its operation.

Starting out with the overall function of the product; An exhaust pipe. Simply to transport hot combustion air to the outside. The pipe would usually only go upwards, though horizontal sections or diagonal parts can also be used. The flue can exit on the side or the top of the structure. How do we make it so that it can collapse/extend/retract etc?

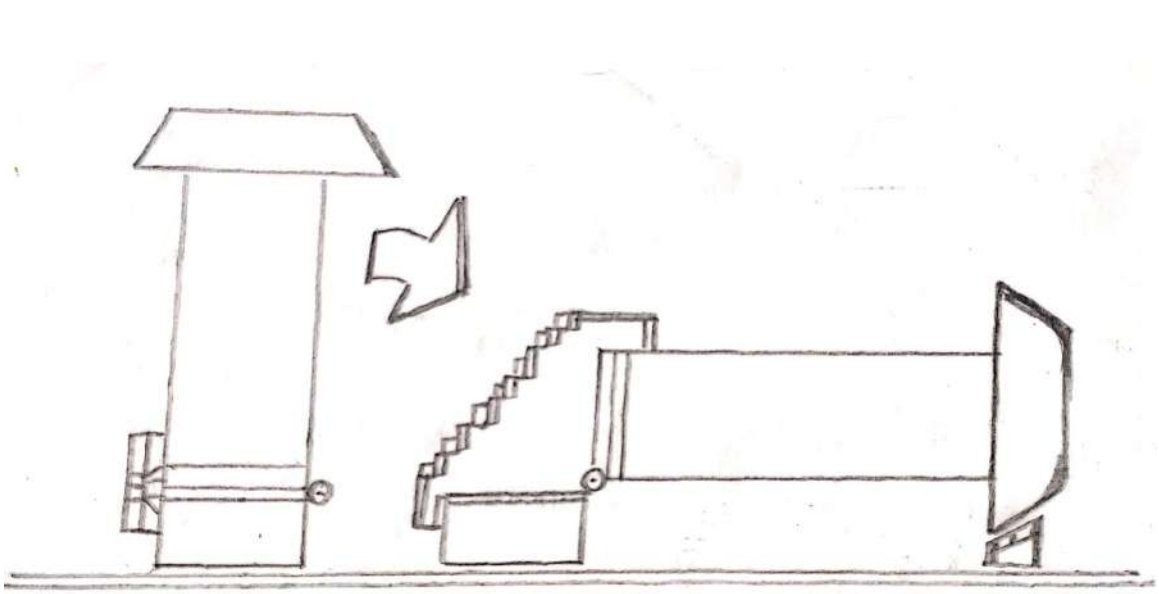
a compact telescopic exterior component without insulation that will extend the cap upwards, or a tilting flue that can lock into horizontal and vertical position on the roof? Interchangeable stacking flue components that can be added one by one from the inside and pushed outwards, or stretchy insulation that will expand when a double layered flue is extended. These kinds of wild ideas come to me quickly, but are equally quickly put away. In the next section all of these ideas and possibilities are criticised and sorted.

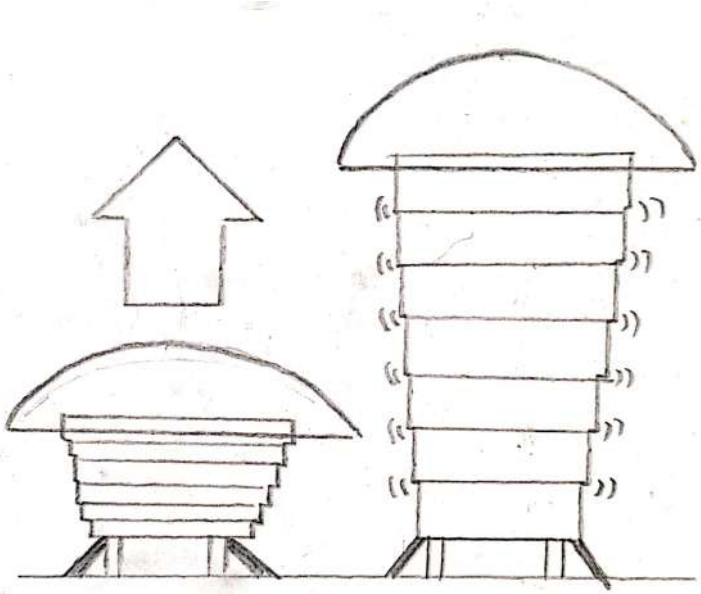
4.7 Choice matrix

A collection of design explanations & details about design choices, sorted by segment.

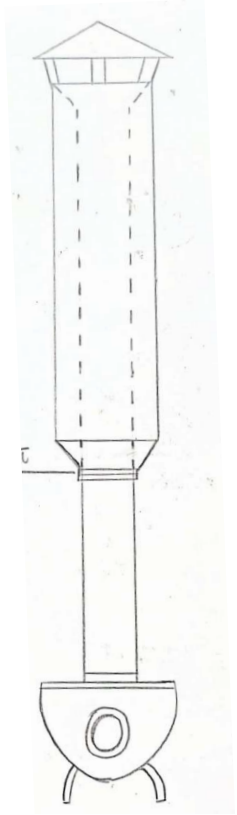
Product function
All components together form the product, what are the options for the overall function of our product? Tilting, stretching, sliding, rolling anything can be possible. The options are placed side by side and the best choice that will function properly and abide by the list of requirements will become clear.

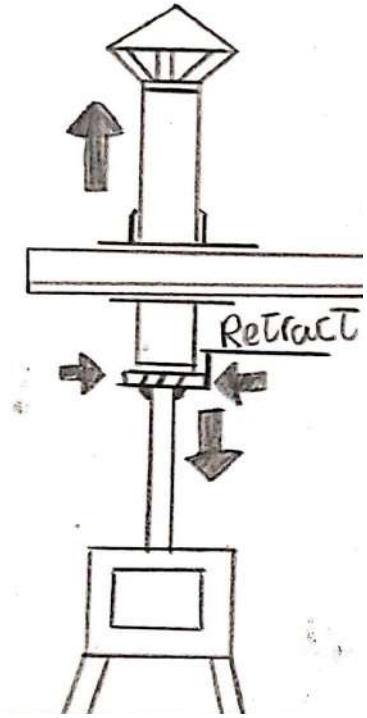
Design choice	**Elaboration**	**Pro's**	**Cons**	**Value (0-10)**
Telescopic exterior system	a fixed exterior system that can telescopically expand to raise the rain cap.	No moving components inside. Fixed flashing system	many components on the outside give a bulky end product which will protrude and be bulky. Waterproofing of all telescopic components is problematic. operation is exterior.	4
tilting exterior pipe	an exterior flue section that folds down horizontally for transport	No moving components inside. Fixed flashing system	Waterproofing issue when folded down. Operation is exterior. Still a lot of material on the roof for transport.	5.5

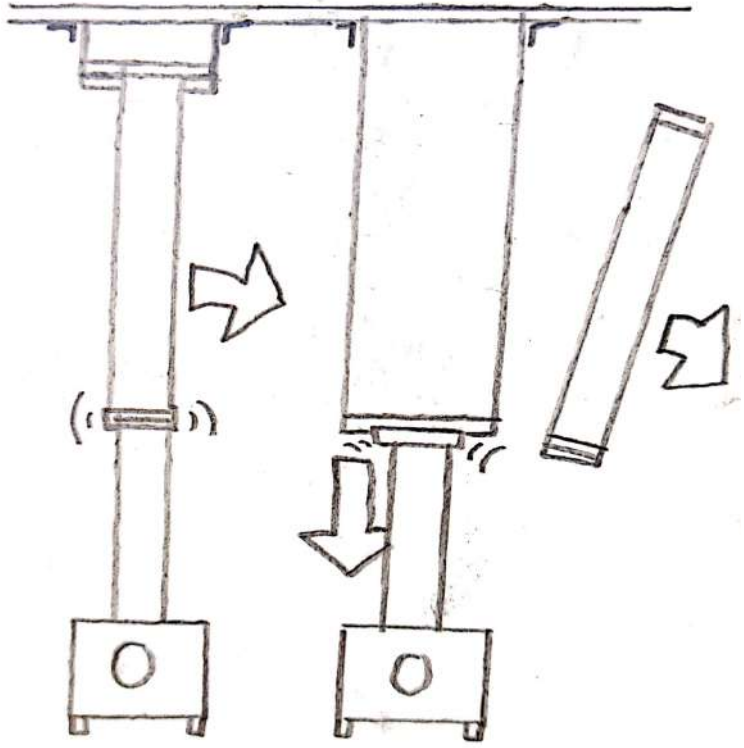




Removable interior flue	removable interior section that can be removed so the top section can slide down and replace its location. Locking it in.	No components sliding over each other. Interior operation. Can be low profile on the exterior	Need storage for the removed section during transportation. Difficult operation. more connection points	7.5
insulated flue sliding over standard flue	Insulated flue slides up and down through watertight flashing & gas tight sealing clamp over single walled flue attached to stove	Quick operation. Interior operation. can be low profile on the exterior. Not many components. Compact system.	Sliding operation demands high tolerance fits for waterproofing and requires unstepped clamping to a smooth hot surface.	8
Stretching insulation flue	An insulated stove pipe section that can extend in size with stretching insulation inside	simple operation. elegant design. Not many components	friction of sliding components. Scratching of surfaces. Gas tight fits of expendable components	6







Mounting & securing

When the insulated flue is extended it needs to be locked into place in it's extended position. It will also need to be able to be secured when in its retracted position. There are a couple different ways of realising this.

Design choice	**Elaboration**	**Pro's**	**Cons**	**Value (0-10)**
Ceiling mounted stepped lock	The insulated flue is secured onto the ceiling plate. A pin or hook can lock it in its place on selected points	No need for friction locking. No clamping contact with the hot flue surface.	Weight hanging from the ceiling. Protrusion or hole for stepped locked. Double seam necessary	5
Stove pipe mounted stepped lock	The insulated flue is secured to the single walled stove pipe. A pin or hook can lock it in its place on selected points.	Weight resting on the stove. Determined locking locations	Protrusion or hole for stepped lock might complicate production and lead to problems	6
Ceiling mounted stepless lock	The insulated flue is secured on to the ceiling. It can be locked in any position with a friction clamp	No clamping contact with the hot surface. Can be locked in any position	Weight hanging from the ceiling, double seem necessary	6.5
Stove pipe mounted stepless lock	The insulated flue is secured on to the ceiling plate. It can be locked in any position with a friction clamp	weight resting on the stove. No need for notches or holes. Can be locked in every position	Needs clamping contact to hot surface	7.5

Clamp system

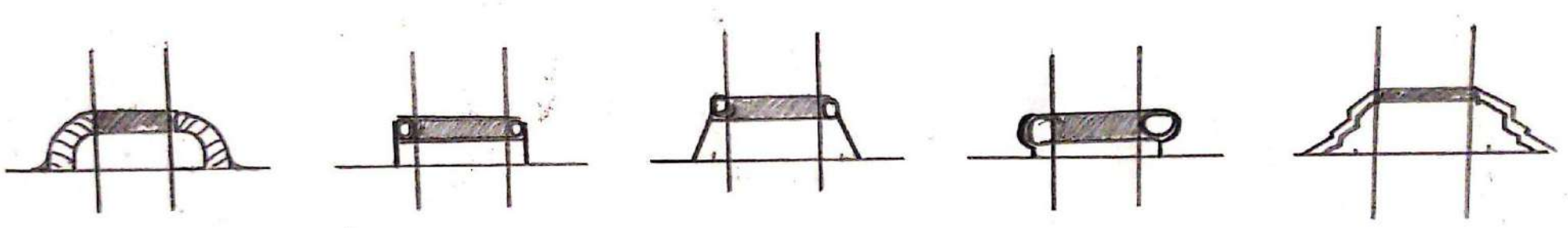
As the moving insulated flue section needs to stay in its position, a clamping system must apply significant force to the full circumference of the single walled flue. This is a surface that can heat up to 600 degrees celsius.

Design choice	**Elaboration**	**Pro's**	**Cons**	**Value (0-10)**
Quick release clip clamp with silicone sealing ring .	A quick release duct clamp that operates with a clip which locks the ring on a specific diameter. A silicone component will be pressed against the flue to create friction and a seal.	Quick operation. Good friction and sealing.	Silicone may damage or burn due to heat. Clip clamp has no adjustable force. Pressure on clip is dangerous when opening or closing.	5.5
Gravity clamp with gravity pressure activated friction.	A system which activates it's clamping force when downwards pressure is put on it.	Simple operation. Automatically adjusts pressure with weight.	Not reliable during the road with bumps. Difficult to get enough friction without using rubber.	4.5
Notched or stepped system.	In the extended position and in the retracted position are protrusions or holes where a pin or hook can lock the insulated flue into position.	Precise operation with determined locking locations. no need for a clamping force.	Holes or protrusions may drive costs up and might affect airflow or create leaks. difficult to get air tight fit without clamping.	6.5
Screwed quick release clamp with glass fibre sealing ring.	A metal band clamp with a small knob that when twisted tightens the clamp. Which is lined with a glass fibre felt strip on the inside.	Heat resistant. Safe and adjustable operation. Easy to create lots of friction.	Screw knob sticking out.	8

Flashing system

To guide the insulated flue section through the roof material and prevent water or air from entering the home, the flashing system has a critical function.

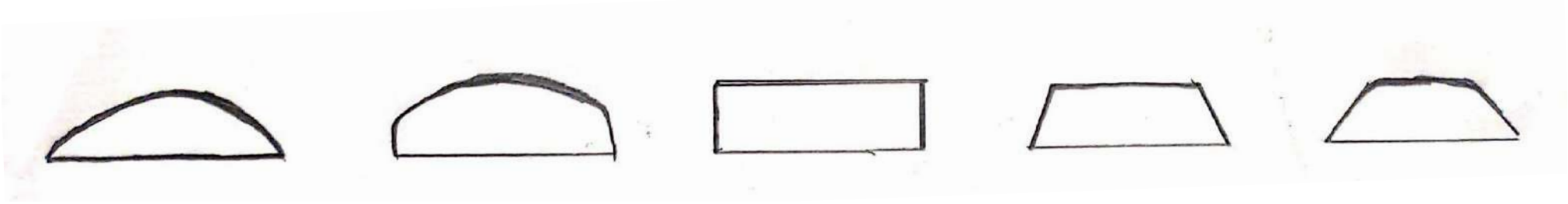
Design choice	**Elaboration**	**Pro's**	**Cons**	**Value (0-10)**
Rubber gasket coned sleeve.	Traditional style anevay flashing with thin rubber in a cone shape and adjustable hole sizes.	Similar to existing product.	Won't allow for movement of the pipe or will have a bad seal.	3
Thick polyurethane cylindrical flashing.	A thick rubber component with cylindrical protruding ring which holds and seals the insulated flue.	Durable and simple system. Sealing ability by the material itself.	Needs proper tolerance for right fit. Might be too tight to move. Can leak due to gaps.	4
Steel coned flashing with o-ring	Flat metal component with protruding section that slightly cones inwards & O-ring on the top.	Good sealing ability with O-ring. Allows for sight angle of flue. Simple manufacturing.	Needs slightly more vertical space.	7.5
Steel straight flashing with o-ring.	Flat metal component with straight cylindrical protruding section. & O-ring on the top.	Good sealing ability with O-ring. Simple manufacturing. Allows for a low profile rain cap.	Does not allow for slight change in angle of flue.	7
Thick ring sealing flashing.	Metal flashing component that holds a thick flexible and moldable foam/rubber which generates slight pressure on the insulated flue.	Excellent water tight seal with pressure between materials. Allows for considerable angle difference between pipe and roof.	Might get too tight/sticky after a while without use. Might need lubrication. needs more space and might raise total extruding size.	8



Rain cap

To achieve a low profile protrusion on the roof when the chimney is retracted it is essential to design a rain cap that mounts on to the insulated flue which not only provides protection against rainfall, but also allows for sufficient airflow. To use a stainless steel component is the best viable option as it is lightweight, thin, strong and durable. Stainless steel resists heat well and withstands the elements of nature on the exterior perfectly.

Design choice	**Elaboration**	**Pro's**	**Cons**	**Value (0-10)**
sphere shell	perfectly spherical cap piece	simple and elegant curve. Easy airflow	must be large diameter and will have large height	6
flat with straight edge	flat cap with cylindrical edge	low height. Easy manufacturing	Airflow doesn't have smooth path	5.5
double curved	slightly curved cap with smaller radius curve down to almost vertical	unique shape and good airflow	complicated manufacturing	6.5
slight cone without edge	slightly angled cap without any edges. Open sides	very good airflow without vertical border	rain can enter the flue with winds or while on the road due to not having a closing vertical edge	4
flat with tapered edges	flat cap with slightly tapered edge around	low height. Easy manufacturing, slightly better airflow than straight edge	airflow might not be sufficient due to low height	7



4.8 Recapitulation

five of the most determining design choices have been elaborated and the most suitable option has become clear. In this section the conclusions will be drawn and the design will be specified so that the CAD model and technical drawings can be made in the concept phase.

For the overall function of the product it is clear that manufacturing a sliding system with two flue components is the best choice. The single walled flue is directly mounted to the stove and can be made to the specific length to fit the user's living space. The other ideas are to conversome or require many components and or difficult operation. The choice that follows all requirements is what has been chosen. The moving flue component will slide up and down and will be able to lock into place by creating friction on to the inner flue. This clamping system is critical to the functionality of the product. It has to be user friendly, reliable and robust. multiple design options for the clamping system have been evaluated and the most suitable choice is made. A flat band clamp that can be tightened with a knob which is connected to a threaded bolt will ensure an adjustable clamping force and easy operation. On the inside of the clamp a glass fibre strip will make up for the diameter difference between the components, provide a smooth sliding operation and function as an air tight seal between the transition component and the single walled flue.

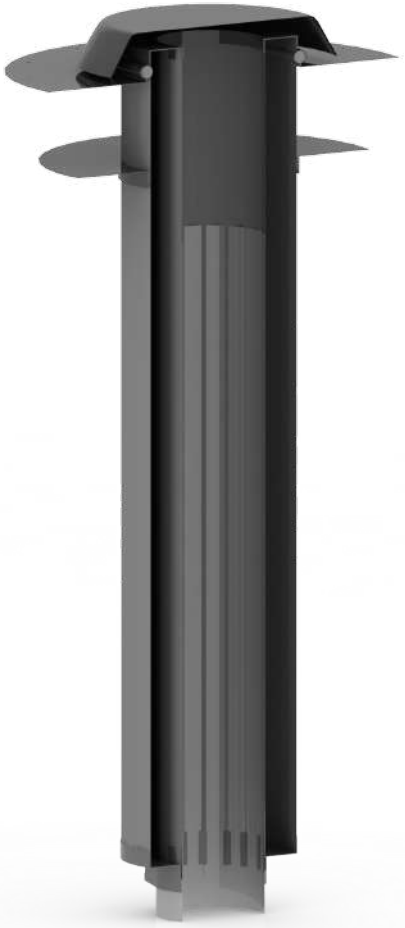
The exterior of the insulated flue will move up through a ceiling plate which can feature a (replaceable) felt-like material to make the sliding action smooth and clean any residue from the exterior. then the flue passes to the exterior through a thick rubber/foam ring that is retained by the flashing system. This provides an equal pressure against the circumference of the insulated flue, generating a water resistant seal yet allowing for up and down motion.

When the system is retracted, a rain cap shall cover the protrusion of the flashing system and accomplish a very neat and low profile appearance on the exterior and allow for air to smoothly pass over & past its aerodynamic shape. When extended and in use, the combustion air can smoothly and with minor flow restriction move out from under the cap.

Now that all the overall functionality and design specifications are finalised for a first iteration prototype, the 3d model and technical drawings can be made. In the idea phase we have diverged a lot, looked at many different aspects of the product and brought them together. Now it is time to converge, make decisions and start materialising. Before the materialisation phase we go through the concept phase in which the technical details and drawings are made, and a prototype is made by the

Anevay company engineers.

5. Concept phase

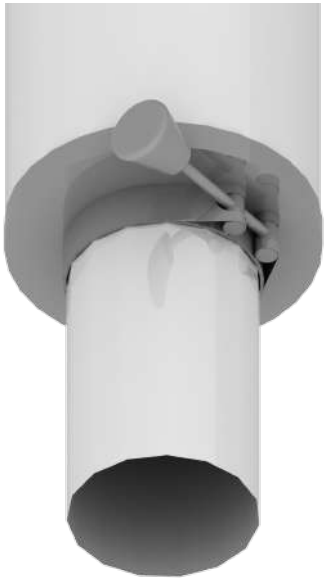


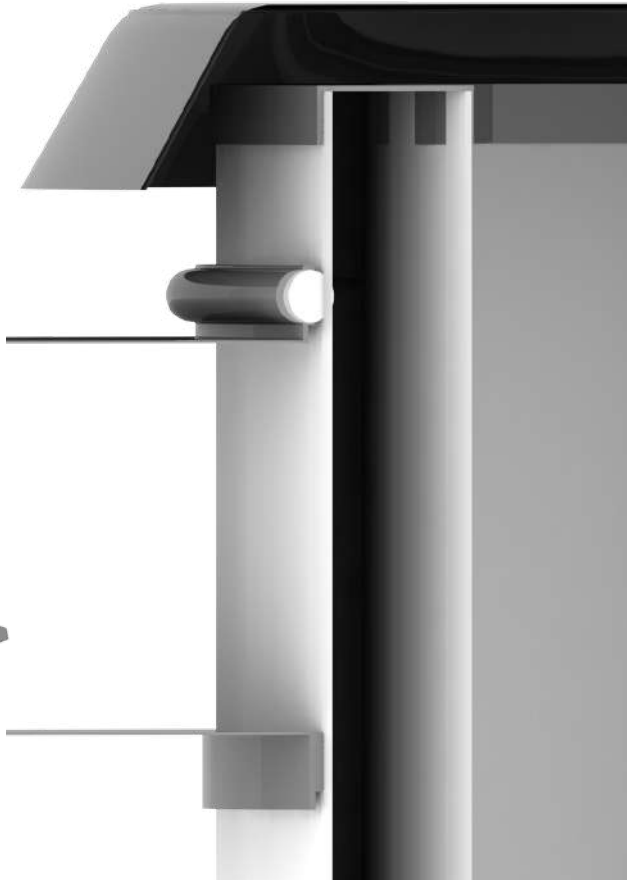
Now that the general design has been thought out and all different components have been considered and thought through thoroughly, the concept phase can begin. In this chapter the reproducibility of the product will be explored, all components will be technically specified and modelled in a computer aided design program (CAD). A first prototype will be made and tested to discover all the possible design problems that may occur. This prototype will be analysed and redesigned as a second iteration, or single components will go through one or multiple iterations to finally construct the 'final concept' which can be manufactured and user tested before putting the product to market.

5.1 CAD Model

To start out the concept phase, the dimensions of the components will be specified, as well as the way they fit together and how they are manufactured. The first concept has been designed and will be made ready for prototyping where we will reproduce as accurately as practically possible the components of this concept. With those components a series of tests can be done to receive structural design and functional feedback to implement on the second concept, the next iteration.

Each component has been modelled in Solidworks so that the detailed technical drawings can be made to send over to Anevay Stoves in England for prototyping. Using solidworks to model the product and see it's components interact with each other has given a good visualisation of the complete product and even showed me some more possible design problems that can be improved with further iterations.

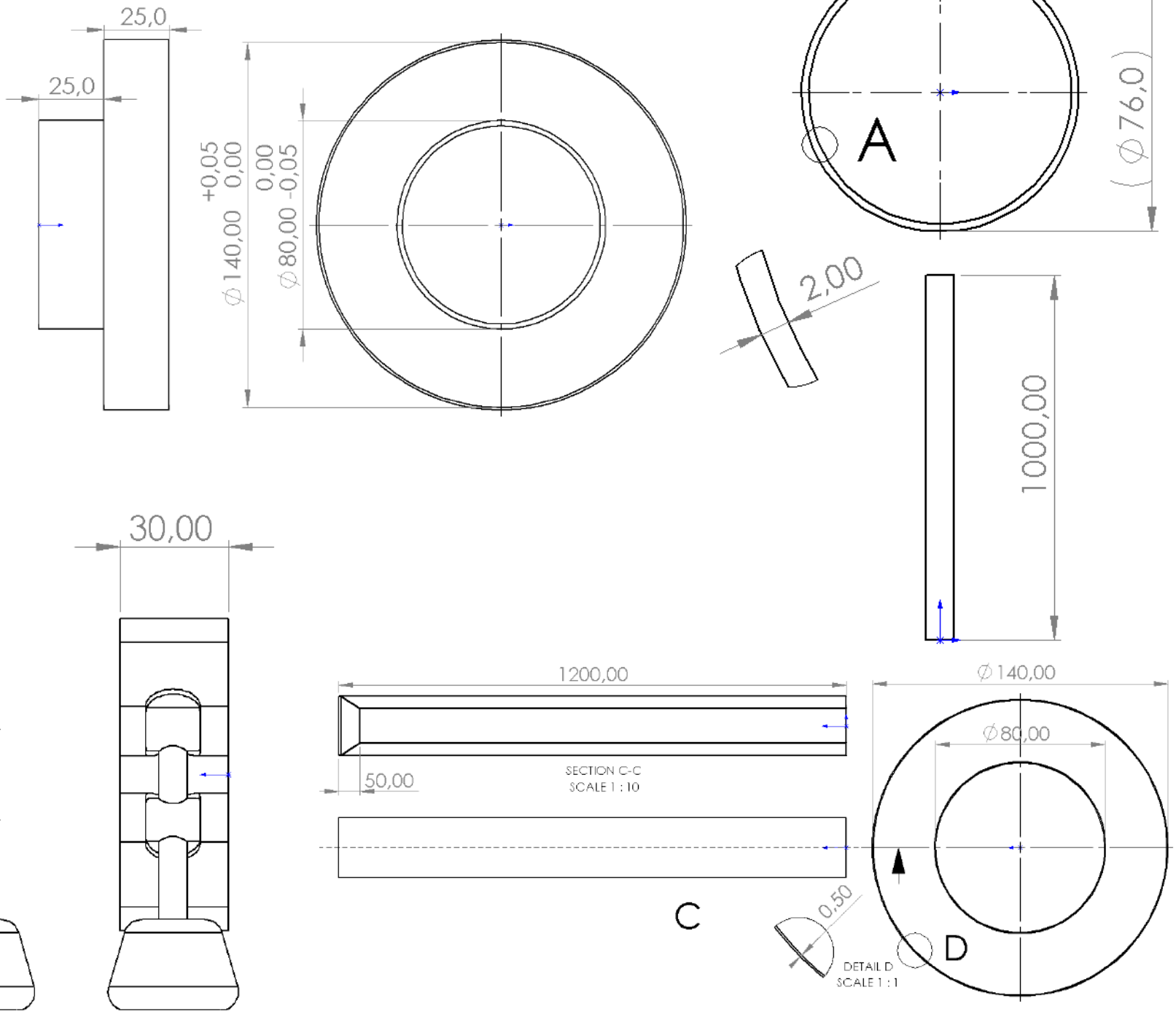




5.2 Technical drawings

The cad model has been updated and all the components can be drawn into blueprints for manufacturing.

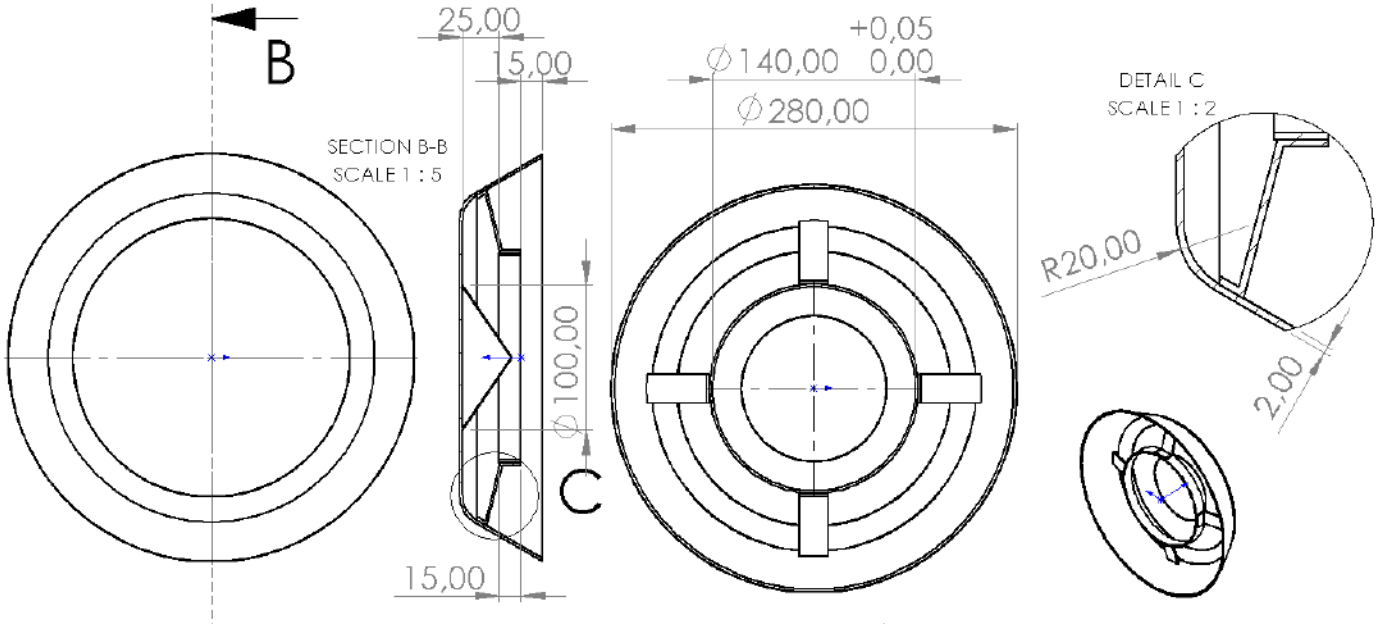
The technical drawings specify all dimensions necessary for manufacturing of the components. The final size may differ slightly due to outsourcing of component manufacturing such as the clamp.

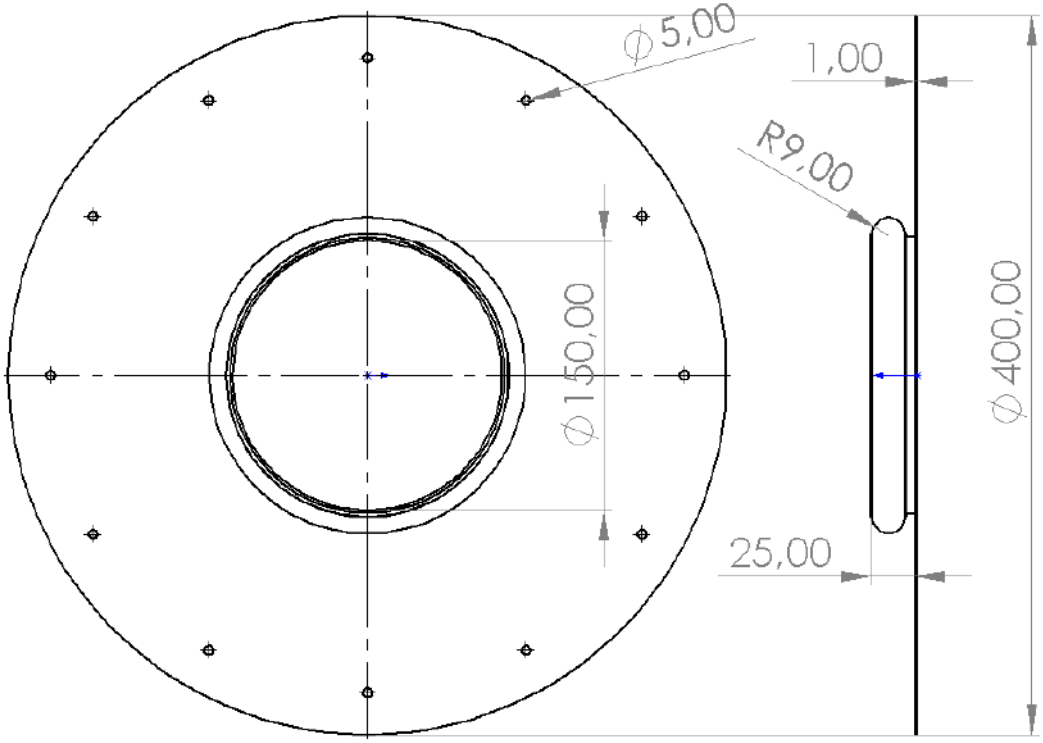


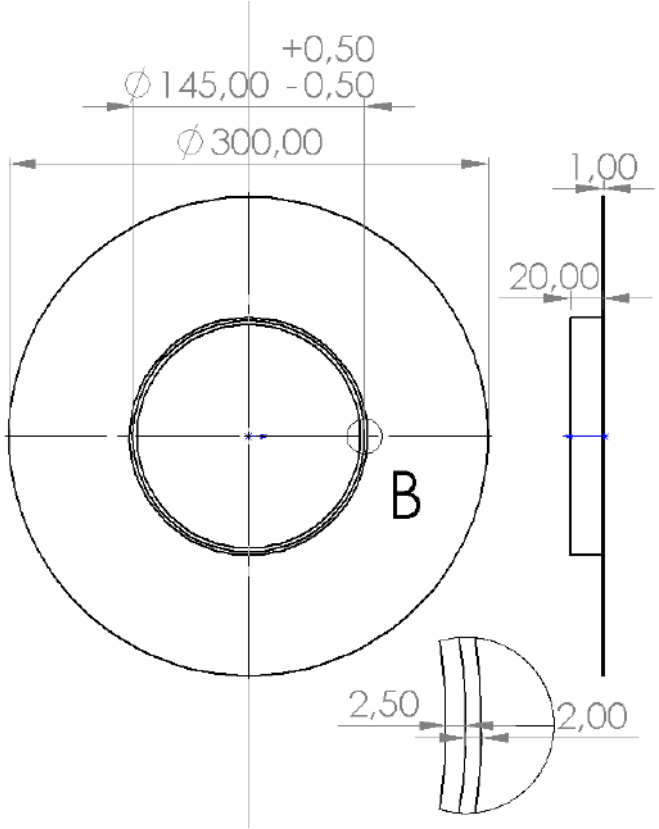
Each component is defined and the necessary dimensions are given, including important toleranced dimensions for components that need to fit together tightly. the scales of the drawings are not the same. To make the components fit on the drawing together. different scales are used.

Cross section views and detailed views are incorporated in the drawings for clarification.

The specific materials and Manufacturings steps for each component is specified in the next section.







5.3 final concept proposal

to finalise the concept phase there will be an evaluation of the design and a proposal for prototype testing to continue with design iterations. As seen in the technical drawings above there are 7 main components which will be manufactured in house or ordered / outsourced to make this product. Some of these components include additional materials such as the glass fibre strip in the clamp, the O-Ring within the flashing and some felt to line the inner side of the ceiling plate. The sub components within each component also need to be welded together or fitted in their location. All of these steps require time and money, the materials needed will be listed in the materialisation phase as well as the manufacturing methods and costs.

Before paying big money to manufacture a large volume of components and custom making molds or tools for the manufacturing process, there will need to be some prototyping and testing done. All the components interact with each other and only if it all works flawlessly after testing and iterating, can the mass production begin. To test the functionality of this design we can produce some of the components and test their interaction between each other.

First off a set of flues with the right diameters can be cut to size and the clearance between them checked. A T-bolt band clamp can be ordered to the right size and a strip of glass fibre attached to the inside. The friction of it's locking force can be tested on the inner flue. Using slightly different sized fibre strips and / or weave roughness. Then necessary twisting force has to be calculated and ergonomically tested with a small knob that can be twisted by hand. The motion between the flashing and the insulated flue has to be thoroughly tested by ordering a couple slightly different sized o-rings and testing the friction and seam of them against the exterior of the insulated flue. The ceiling plate and the sliding interaction between it's felt lining and the exterior flue can be tested by simply trying out a couple slightly different sized felt strips.

If possible the small dimples can be made into a single walled prototype tube and the tolerance between it and the inner wall of the insulated flue will be checked. If possible a complete working prototype can be made and user tested with a selected group of participants to perform a good user test and evaluate the user interaction with the product.

6. Materialisation phase

6.1 Manufacturing & Cost analysis

Almost all components of this product are new and customly designed for its purpose within our product. Anevay Stoves has a team of and a beautiful workshop where most of their products are made. To successfully produce this retractable chimney system Anevay must be able to efficiently and effectively produce the components for this product with the use of already owned, or newly made tools. Each component will be able to be produced in high quantities. An explanation of the production process and technical information about the component and its dimensions is made below. The technical drawings have already been displayed above. Some components and subcomponents can be outsourced from specialist companies / manufacturers. Along with the manufacturing method and material list, A calculation of costs is made of each component.

single walled flue section

Materials:
-rolled sheet steel (2 mm x 1000 mm x 238.8 mm (2 x π x 76) = 238.800 mm2 = 0,238m2
-Heat resistant black paint / enamel.

Manufacturing:
-The sheet of steel is forged together by forming rolls & welded with electrodes.
-The pipe is cut to length and edges cleaned up.
-The edge of one side is stamped with dimples.
-The formed pipe is prepared and coated with a durable high temperature resistant enamel coating.

Cost:
-Material costs: €9,50
-Production costs: €3,50
-Total component cost: €13,-

Insulated flue section

Materials:
-0.5 mm stainless sheet steel (0.5 mm x 1200 mm x 251.3 mm) & (0.5 mm x 1200 mm x 439.8 mm)
-Compacted rockwool insulation fibre (0,53m2)

Manufacturing:
-The sheet metal is formed by rollers to the right diameters (80 mm & 140 mm).
-The stainless steel is cut to width and welded.
-The sections are cut the length by a saw or disk.

-The rockwool insulation is cut to size and placed around the inner pipe.
-The outer pipe is pressed over the insulation.

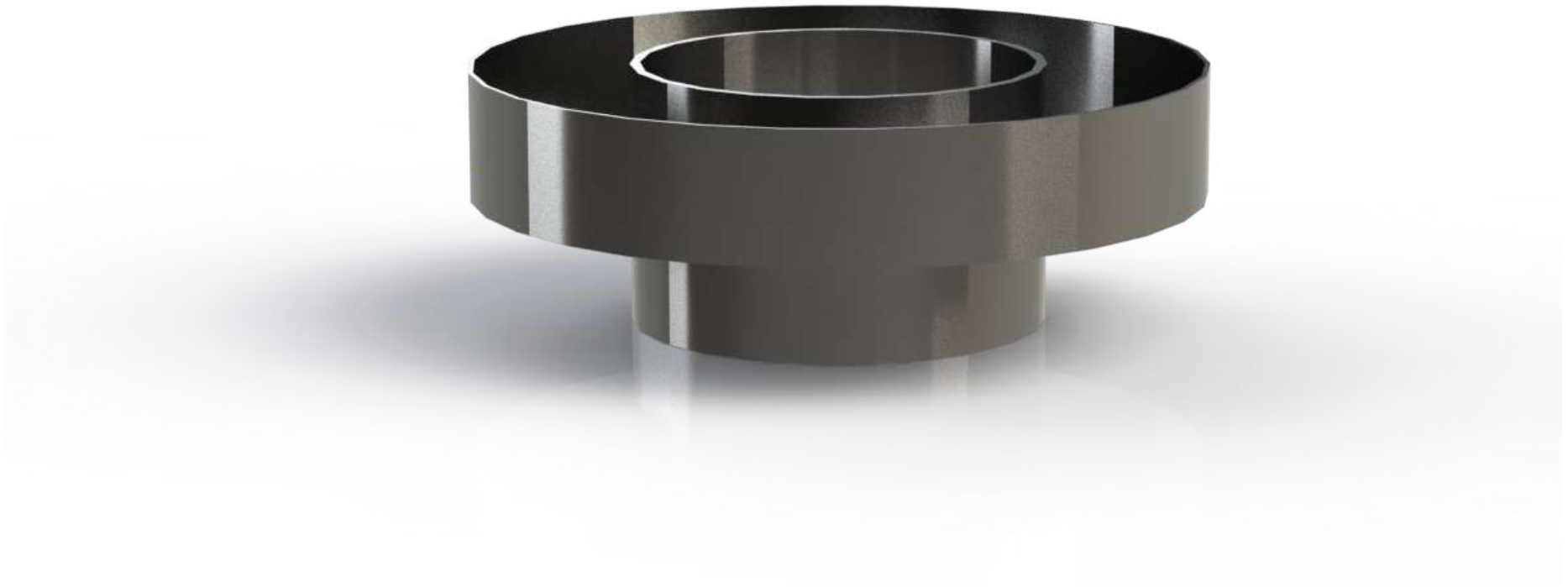
Cost:
-Material costs: €18,-
-Production costs: €5.5
-Total component cost: €23,50

Transition section

Materials:
-stainless sheet steel. (140 mm x 140 mm x 1 mm)
-stainless steel pipe. (80 mm ⌀ x 50 mm x 1 mm) + (142 mm ⌀ x 25 mm x 1 mm)

Manufacturing:
-The steel sheet is laser-cut to a ring shape of the right dimensions.
-The pipe is cut to specified lengths.
-The 3 components are welded together.
-Tolerances are measured.

Cost:
-Material costs: €6,30
-Production costs: €5
-Total component cost: €11,30

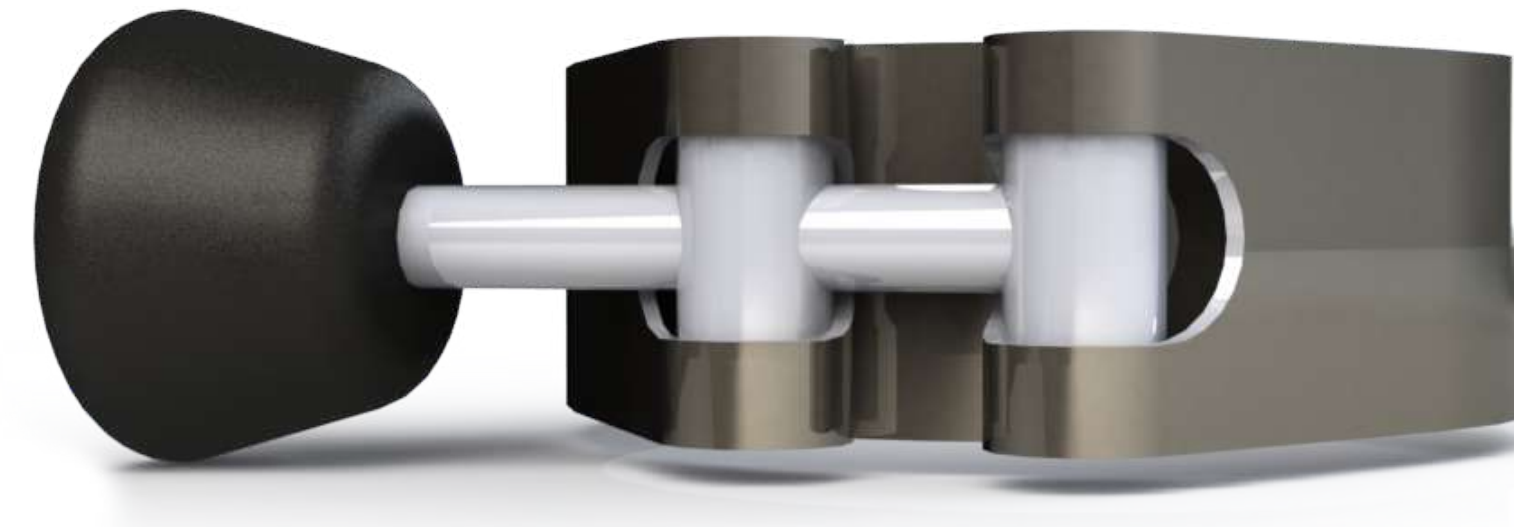


clamp

Materials:
-Stainless steel pipe (140 ⌀ inner diameter 1 mm thickness & 15 mm width)
-Threaded steel component M10
-Knob.
-Glass fibre strip (2 mm thickness x 15 mm width).
-steel rod (15 mm ⌀ x 30 mm)

Manufacturing:
-The stainless strip is formed to the right diameter and cut to length.
-Two sections are laser cut and bent to form the housing of the steel rods which hold the m10 bolt.
-The bent sections are spot welded to the formed strip at the right location.
-Steel rod is cut to 25 mm length and holes are drilled through.
-M10 female thread is tapped into one of the rod pieces.
-The knob is glued to the M10 threaded bolt.
-The glass fibre strip is mounter on to the inner surface of the stainless steel with an adhesive
-The rod sections are placed in their determined locations and the threaded bolt is inserted.

Cost:
-Material costs: €4,60
-Production costs: €18,50
-Total component cost: €23,10



Ceiling plate

Materials:
-Stainless sheet steel (300 mm x 300 mm x 1 mm)
-Stainless steel pipe (145mm ⌀ inner diameter, 1mm thickness & 20 mm width
-Self adhesive felt strip (88 mm x 15 mm)

Manufacturing:
-The stainless steel sheet is laser-cut to it's determined shape
-A 25mm wide section of the pipe is cut.
-The round section is welded to the flat sheet.
-Tolerances are checked.
-The felt strip is cut to length and placed onto the inner surface of the steel ring.

<u>Cost:</u>
-Material costs: €8,50,-
-Production costs: €6,-
-Total component cost: €14,50

Flashing system

Materials:
-Stainless sheet steel (400 mm x 400 mm x 1 mm)
-Stainless steel profiled ring (150 mm ⌀ interior diameter, 25 mm width)
-Rubber o-ring (inner diameter 256 mm, thickness 18 mm Durometer 40A)

Manufacturing:
-The stainless sheet is laser-cut to it's determined shape.
-Holes are drilled in the sheet for mounting.
-The profiled ring is spot welded to the flat sheet with protruding tabs from the profiled steel ring
-The rubber 0-ring is inserted

<u>Cost:</u>
-Material costs: €13,-
-Production costs: €9,60
-Total component cost: €22,60

Raincap

Materials:
-Stainless sheet steel (320 mm x 320 mm)
-Stainless steel pipe (140 mm ⌀ interior diameter, 1 mm wall thickness & 15 mm width).

Manufacturing:
-The steel sheet is cut to it's determined dimensions and spin formed to its specific shape.
-The edges are trimmed and rounded over.
-The coned inner component is also spin formed.
-4 small brackets are cut and bent to specified dimensions.
-A ring of 15mm width is cut from the 140 mm interior diameter stainless steel pipe.
-All components are welded together to form the rain cap.

Cost:
-Material costs: €9,40
-Production costs: €12,-
-Total component cost: €21,40

6.2 Production price

Combining all the material prices and manufacturing costs of each component gives us a total production cost of: €129,40 to produce all the separate components. The components must also be assembled to form the complete product. Most of the assembly will be done at the location of installment. The flashing & ceiling covers will need to be mounted and the flue sections will simply slide into place. The product will be shipped with most components separately in the box, though some of the subcomponents will need to be assembled together in the factory. The insulated flue will need it's ends covered. The transition component is spot welded to one side and the rain cap is spot welded to the other side. This is the final product assembly. The components will need to be packaged, marketed and shipped.

The manufacturing costs of all individual components is expected at €129,40, The final assembly will not be much more than €5,60 per unit. Packaging the components to be shipped is expected to cost €5,- (based on current packaging prices with other Anevay products.)

Now that the required financial input is calculated there can be a proportional profit margin can be added. The standard profit margin for Anevay's current products is 300% on top of the combined production costs. (3x)

129,40 + 5,60 + 5,- = €140,- > €140 x 3 = **€420,-**

The Anevay Stoves retractable 3 inch chimney system for transportable homes & leisure vehicles can be sold for a price of €420,- + shipping.

production	Single flue	Insulated flue	Transition section	clamp	Ceiling plate	flashing system	raincap	Assembly	Packaging	**TOTAL**
Material cost	€9,50	€18,-	€6.30	€4.60	€8.50	€13,-	€9.40	x	€5,-	**€74,3**
Manufacturing	€3,50	€5.50	€5,-	€18.50	€6,-	€9,60	€12,-	€5.60	x	**€65.70**
Combined	€13,-	€23.50	€11.30	€23.10	€14.50	€22,60	€21.40	€5.60	€5,-	**€140**

6.3 Prototyping & testing

Dawie Cronje, founder & CEO of Anevay Stoves has made working prototypes of some of the individual components. The reason for these builds is to experience the feeling and interaction between the components to test it's capability, functionality and ergonomics. An important factor with this product is the up and down motion, and the durability and smoothness of the operation. The first test was that of the sliding motion and movement between the interior flue and the insulated flue. A steel pipe with 76mm exterior diameter has been used to check proper clearance with the standard 3 inch insulated flue. The inner flue slides through without any friction but shows that the small clearance can quickly lead to the edge of the single walled flue scraping on the inside of the insulated flue. This feedback can be used for a design iteration.

A sheet metal component is also cut to the size of the flashing kit with the centre cutout for the insulated flue to slide through. A mockup model is constructed of the top section with a conical shaped rain cap (not to right concept dimensions) but it has the same exterior diameter as the proposed rain cap component. The sliding motion through the flashing can be imitated as seen in the pictures to the right.

Unfortunately the people at Anevay Stoves have a very busy season with little time for prototyping on design concepts. In the final concept proposal a series of prototyping suggestions are made which hopefully soon can be made and tested, before the end date of this internship project, though i am definitely open to stay operational with the development of this product after the internship has ended and further develop this project into the market.

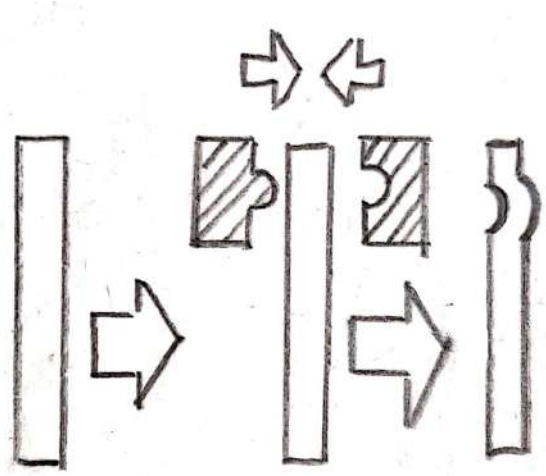
Despite the (until now) shallow amount of prototyping done, during a series of design meetings, proposals for design changes have been made. In the next segment we will go over the ones that have been implemented already. There will surely be more in the future after more thorough testing and prototyping.

6.4 Design iteration improvements

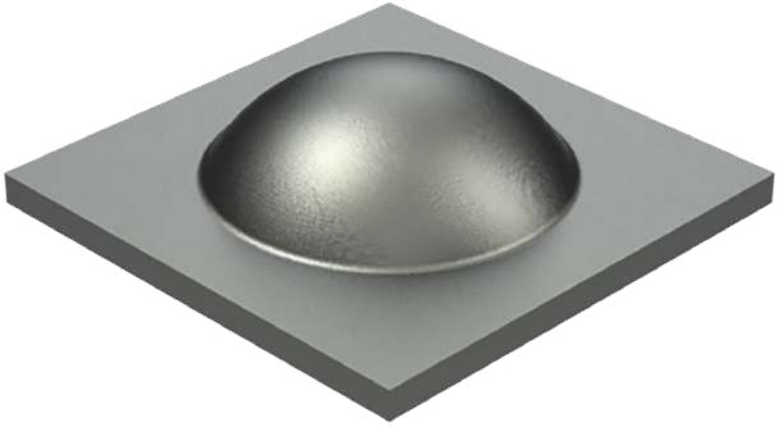
With testing of prototypes and further detailing with manufacturing and production, some design improvements always appear. Tolerances can be too big and the part may not fit correctly or too small and cost too much in manufacturing. The ergonomics of the product can feel differently than expected or the weight / balance might be ergonomically incorrect. During the prototyping done up till now there have been a couple of improvements to the functionality of the product.

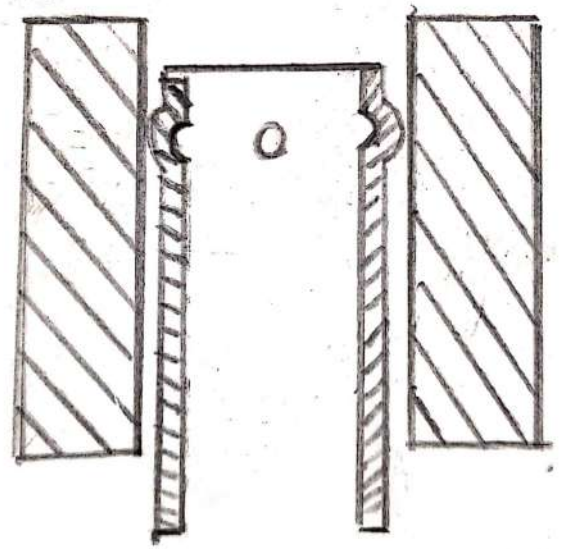
- Inner flue alignment

The exterior diameter of the single walled flue will have an exterior diameter of 76 mm. The interior diameter of the insulated flue is standard 80 mm. That leaves a 2mm space around the circumference of the flue. Because the inner diameter of the transition section narrows down one millimetre, and the clamp compresses a glass fibre strip against the exterior of the flue, the bottom section of the insulated flue will stay perfectly centered in relation to the interior flue. When the insulated flue is retracted and lowered down over the interior flue, the top ridge will likely scrape the interior surface due to non-perfect alignment. That is to be expected as the distance that the insulated flue slides over is around 60 cm. Alignment over such a long distance to a precision of 2 millimeters is, especially in a vehicle / home that is transported over the road often, quite difficult.



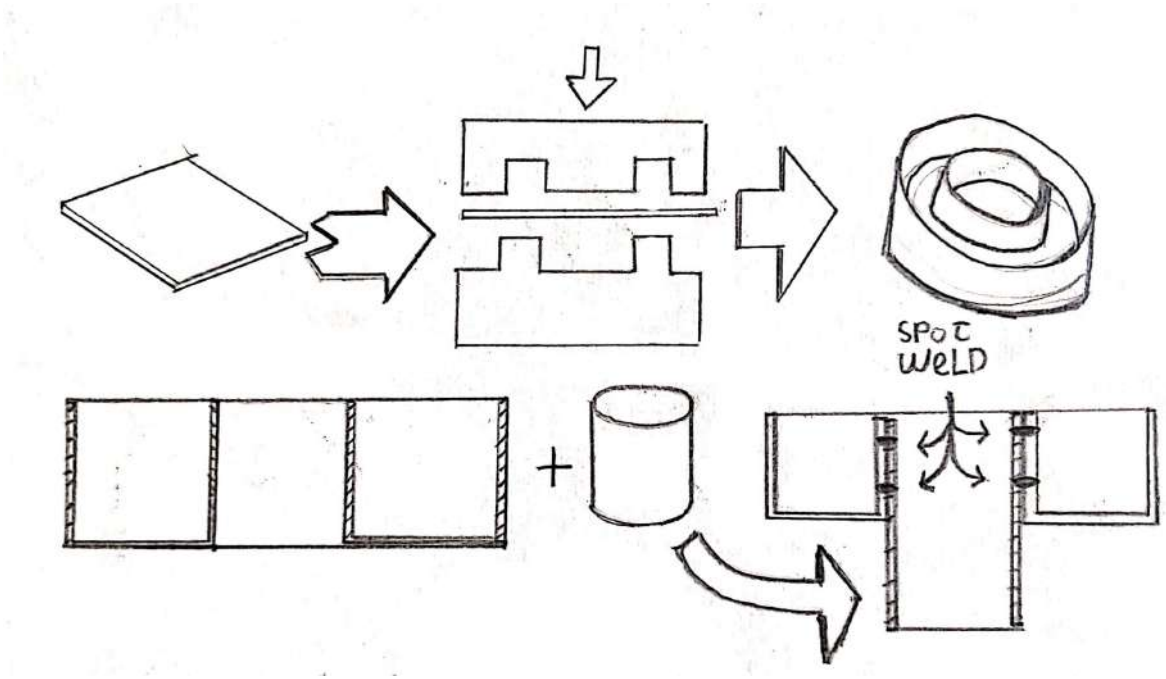
Even though the flashing kit and ceiling plate should hold the insulated flue straight and vertical, when extended there can be significant forces against the flue. A good solution for this problem is to add 3 or 4 small dimples at the top of the single walled flue. Or to make a small flange on the edge which gives it a slightly larger diameter. This will also prevent any scratching to occur on the exterior of the inner flue.



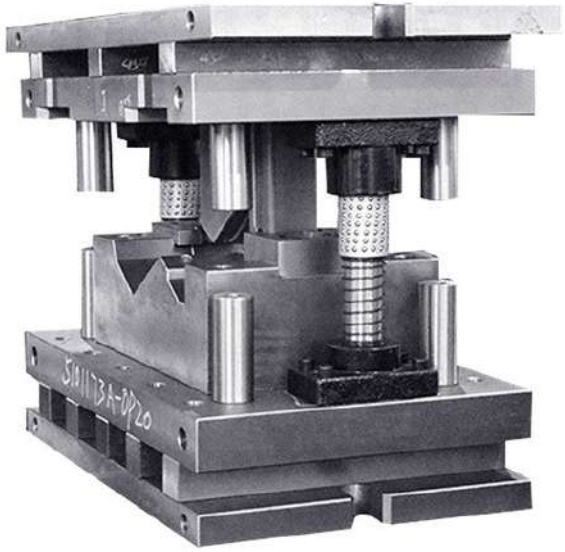


- Transition section manufacturing

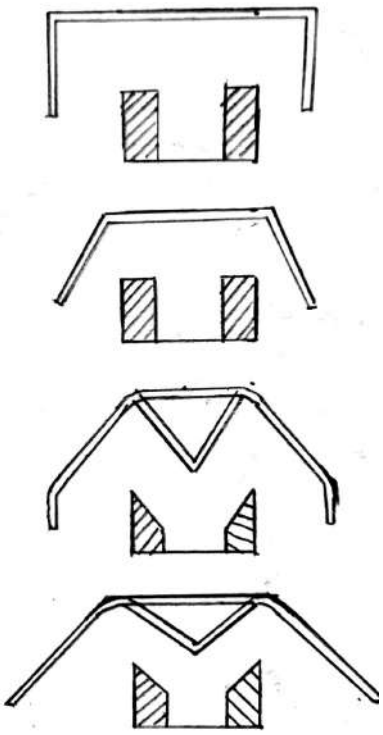
After evaluating the manufacturing methods with Anevay Stoves there has been concluded that a change in manufacturing method must be applied. Whereas previously there would be 3 components that are welded together, now it can be realised with just two. Using welding techniques that weld along the parameter of the tube or edge of the sheet steel is difficult and often needs very high expertise or an expensive machine.



Spot welding is a much more accessible and reliable method of mounting thin sheets of (stainless) steel. The transition section will compile of a ‘’u shaped’’ ring which can be stamped from a single sheet of stainless steel. A section of stainless steel pipe is then inserted in the inside and spot welded together. This also creates a strong connection since the entire weight of the insulated flue and rain cap will be supported by this weld. The perimeter of the interior rim is spot welded.



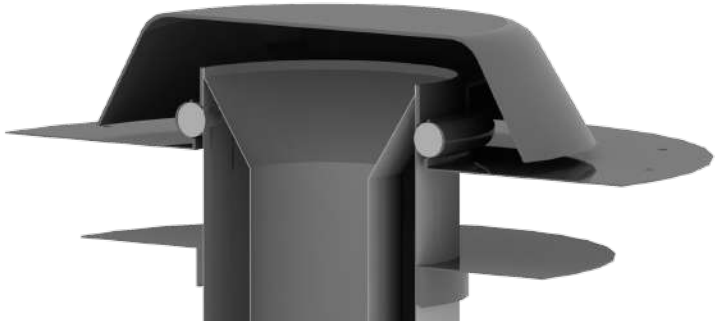
- Airflow resistance

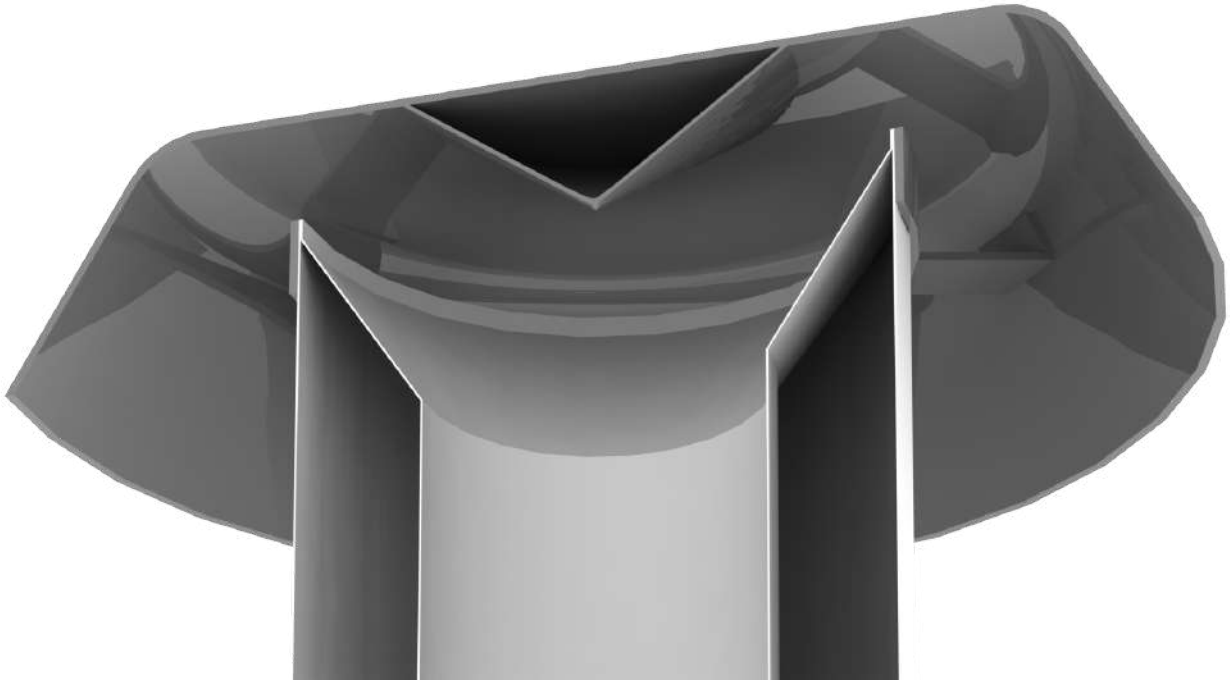


The wood burning stove only works well when the chimney system creates some drag. This drag gets stronger with longer pipes as the big volume of air heats up and rises, new air will be sucked in through the stove. This fuels the burning process and makes for an efficient and high temperature burn. The combustion gasses don't have much distance to travel in this system as the roof to which our target audience will install this product in is often quite low. To maximise the airflow there must be no reduction in airflow. Luckily the system is very compact and incorporates no horizontal sections or bends. When the gasses leave the stove exhaust it moves straight up outside. The only change in direction will happen at the end, Against the rain cap. To make sure that there is no reduction in airflow, a calculation will need to be made on the shape of the rain cap.

determining the surface area of the cross section will give us the base for the calculation. As the interior diameter of the insulated flue is exactly 80 mm, the surface area of that cross section is: $\pi \times r^2 = \pi \times 40^2 = 5026.5\ mm^2$. For the hot combustion air to flow properly around a corner without losing it's flow rate the surface area must be over twice as large as the five thousand square millimetres. The narrowest point is where the combustion gasses have to flow over the ridge of the insulated flue. The diameter of this edge is 140 mm. The surface of a ring with the same diameter and 25 mm width is 10995.2m2. Just over twice as much area. 25 mm is the perfect distance for keeping a low profile and allowing for proper airflow. To reduce turbulence and make a smoother pass around over the ridge of the insulated flue a design change is made, The inner flue pipe can be tapered outwards and join together with the exterior pipe, giving space for a conical component in the rain cap. This will allow for the combustion gasses to be directioned straight out evenly throughout its circumference.

All design changes have been updated in the technical drawings.





6.5 Product evaluation

It is important to look back and reflect on the product that has been designed. If it is what you aimed for in the beginning, and if it abides to the requirements that have been made at the start. To see if the product has a successful design, all of the requirements will now be reviewed. The requirement is referenced by subscripting their numbers as listed in the list of requirements.

Our product is a retractable chimney system which can be pulled down from the interior living space $_{R2}$ to minimise the protruding distance from the roof to 6cm $_{R6}$. When not in use or during transport on the road. To use the wood stove, the flue can be extended upwards to a height of >60 cm above roof level $_{R1}$. The flue is locked in it's extended or retracted position with a T-Bolt band clamp that is loosened and tightened with a knob $_{R7}$. The exhaust gases can not escape between the moving components due to a pressurised seal $_{R7}$. The clamp that locks and seals the chimney is connected to a transition section which holds the insulated flue. It should always be extended to a maximum of 425 mm below the ceiling $_{R8}$. The moving flue section is insulated with 25 mm rockwool fibre $_{R7}$ to protect the roof and prevent any damage or fire. The insulated flue is The components can be manufactured to fit both a 3'' and 4'' stove exhaust $_{R9}$. The product is built with durable and high quality materials and requires little to no maintenance. It will be safety rated and abides to all European standard product safety norms.

The product follows all the requirements that have been formed in the analysis phase.

6.6 Incorrect use

Each person is different and will interact differently with a product. It is almost certain that a product will undergo all kinds of improper use during its lifetime. It is a critical task as a designer to think ahead and secure the safety of the product, even with improper use. When the safety of a product is able to be compromised there has to be a clear indication and warning within the user manual. Such as ‘’No not leave the product in direct sunlight’’ with a product that may build up pressure due to heat. Or ‘’Do not disassemble’’ with a product that uses high voltage DC wires. These warnings can be vast and expansive, even with a small product. To avoid any kind of manufacturer damage claim when an accident happens. Microwaves now say ‘’Do not put live animals in the microwave’’ since a woman once tried to dry her cat’s hair and the poor cat melted from the inside. Resulting in a multi million dollar claim.

The Anevay Stoves retractable chimney mounts on to wood burning stoves as well as other fuel burning heating systems. That means there is fire and heat involved with the product, as well as potential toxic gasses such as CO1. A thorough warning list has to be written and implemented in the product documents. Touching the bottom flue when the fire is burning might cause a second or third degree burn. There’s nothing we can change to reduce it’s danger. Common sense is also key when handling these products. There are a couple of design features that have been integrated to reduce safety concerns during improper use.

The most obvious mistake that can be made is to light the fire without extending the chimney. Leaving the rain cap almost flush with the roof and hot combustion gasses coming in contact with the roof’s surface. The system is designed in such a way that when retracted all the way down there is still a 3 mm gap between the roof and the edge of the rain cap. This will make it possible for a little bit of air coming through, preventing a total blockage which will result in a smokey living area. Because of the reduced airflow the user will likely notice some smoke coming back out of the stove itself and realising that the system is not extended. The stainless steel flashing system is 400 mm in diameter, The rain cap is 280 mm in diameter. Resulting in a 60 mm stainless sheet extending outwards from the rain cap. The hot combustion gasses and small debris will therefore not damage the roof material and will also reduce the safety risks when operated in the retracted position.

A key part of the operation with this product is the clamping system which fixes the insulated flue in its position. when the user does not apply sufficient clamping force when mounting the chimney in it’s extended position, It can be possible that it slides down. Therefore a recommendation to apply downwards pressure after clamping will be added in the user manual. This way a secure clamping force is always achieved. When locking the chimney in the retracted position it is recommended to let the flue come down until it is stopped by the rain cap that comes in contact with the flashing ring. Then lock the clamp to secure the flue. This way it is not possible that the flue can be knocked down in any way during transport on a bumpy road. When the insulated flue does drop down by accident the force will be absorbed by the rubber O ring due to the rain cap ring being welded on the exterior of the insulated flue. Normally the friction of the clamp will reduce the velocity of an incidental fall. It will therefore be recommended to never leave the clamp untightened.

6.7 Project reflection

Despite the current pandemic preventing students from working as interns at a company and interacting with each other in person, this project has been a great experience for me. The guidance I have received through the university with my project mentor Edwin has been very helpful and progressive. Online conversations about the progress and constructive feedback made me confident for the design project and gave me assurance of my process and what I could improve. This process would not have been possible without the assistance of Dawie from Anevay Stoves. During our long video calls we were able to discuss all of the questions I had and the progress I made. He gave helpful and constructive feedback so that I could keep working functionally on the important things of the project. Of course it would have been great to be able to go to England and be able to design and prototype in their workshop in Cornwall. Maybe in the future when the product is prepared for production I might be able to travel there and help with preparing and putting the product into the market.

Many of the skills and experiences that I accumulated during the industrial product design study were used during the design process for Anevay's retractable chimney. visualisation in the form of drawing / sketching was a bit different than normal as this product did not require a large amount of aesthetic designing or have a lot of freedom in its shape and appearance. The drawings that I made were largely blueprint-type of technical drawings with explained mechanics and sizes etc... Using paper to draw the components gave me a clear way to freely explore all possible solutions, after which I could draw them in solidworks. The CAD modelling for this project was not very challenging as i have done more complicated 3D designs in past projects, though the techniques used to build the models were new for me and i still was able to learn useful new things during the process.

I'm very happy that i've found an internship project in this product category as I've gotten quite interested in wood burning stoves and natural heating systems in the past year, as well as transportable homes. Combining the interest in both to create a unique new product that might be a great succes is very thrilling. The skills that I have improved the most are definitely planning, documentation and clarifying my thoughts & choices. I have the habit of thinking everything through in my head and determining which design choices are possible or what solutions would work better, without documenting my thought process and clarifying why I make choices. During this project there were many of them. I could document the explanations in a couple different ways. This helped me to learn better ways to express my thoughts in an understanding way which also helps me to improve my self-reflection.

I'm very excited to see Anevay continue developing the product and hopefully launch it successfully, maybe even patent the product type as there might still be a possibility for a market monopoly. I'm Sure that when i visit my aunt just an hour away from Cornwall, UK. I will visit the Anevay company and I can see the retractable wood stove functioning in real life.

As a closing note I would like to thank all the people involved in this internship project and for working together to realise it.

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