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Solar-powered multipurpose hammermill

Construction guide delivered to **FIRST PRODUCTS ENTERPRISE**, in fulfilment of the project 'Design and development of direct-coupled photovoltaic powered agri-processing machinery' funded by Agri-Tech Catalyst

April 2020

Dr Marcelo Precoppe

Solar-Powered Multipurpose Hammermill

Construction Guide: Part 1

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Table of contents

About this guide

This guide is part of the project entitled *Design and development of direct-coupled photovoltaic powered agri-processing machinery*, funded by Agri-Tech Catalyst (Innovate UK). It was prepared to instruct Mr Emmanuel K. Duah (First Products Enterprise's Managing Director) on how to build a novel solar-powered multipurpose hammermill to be used for cassava processing. The Construction Guide is separate in 2 parts. Part 1 instructs the construction of the hammermill itself. Part 2 instructs the construction of the cyclone separator and its filter bags (Figure 1).

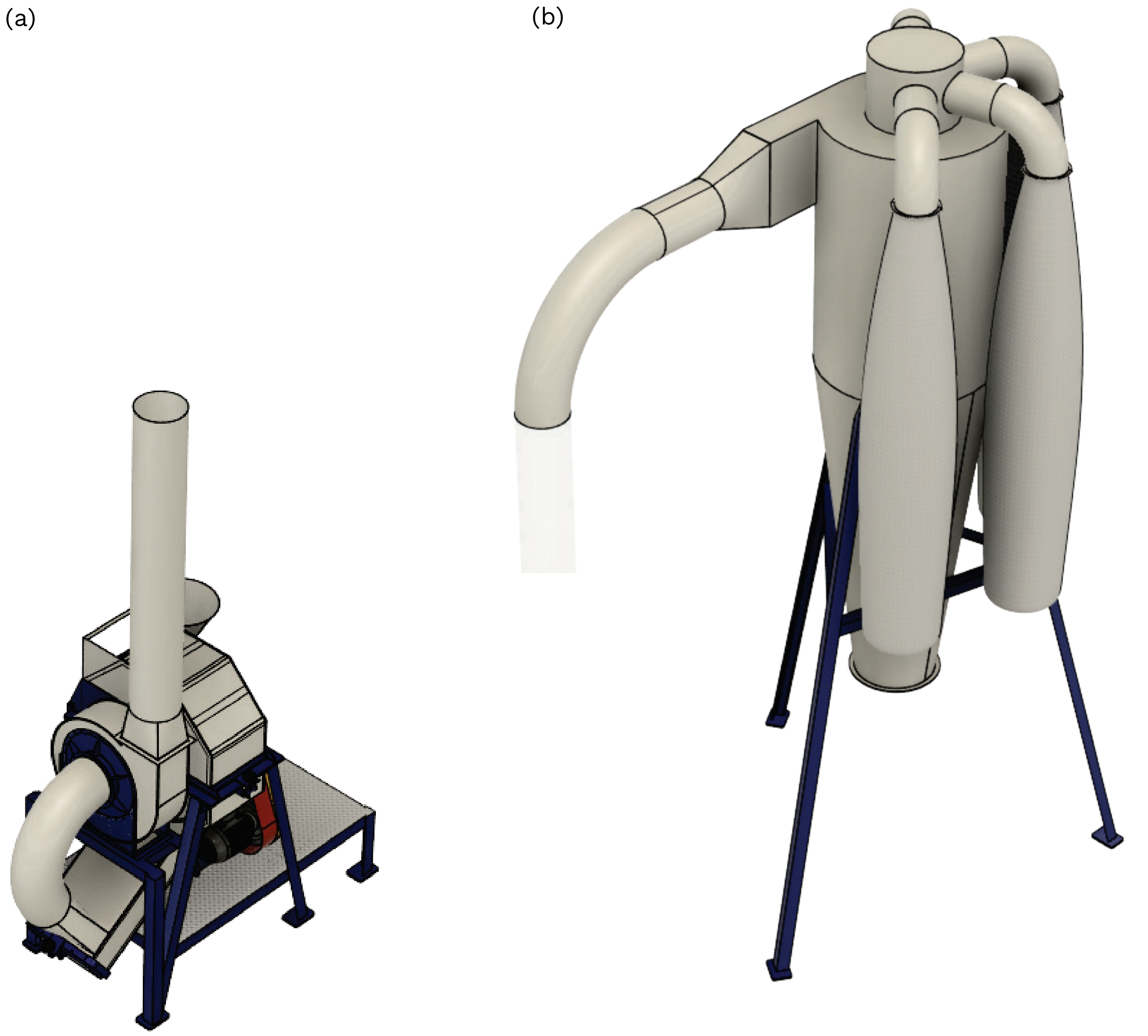


Figure 1 *The multipurpose hammermill construction guide is divided into Part 1 (a) and Part 2 (b).*

Introduction

Cassava (*Manihot esculenta*) is a perennial root crop native to the central region of South America. Nowadays cassava is cultivated throughout the humid tropics and is the main source of calories for many people living in those regions, particularly for those living in Sub-Saharan Africa.

Cassava has a short shelf-life, and two days after being harvested becomes unsuitable for human consumption. For this reason, the roots are usually processed into flour; a dried product which can be used later as the basis for many dishes. During the cassava flour production, the roots are peeled, grated, pressed, pulverized, dried, and milled (Figure 2). Cassava processing centres in Africa are usually small-sized enterprises, and their expansion is constrained by the lack of appropriate, affordable, and efficient processing equipment. The objective of this guide is to instruct First Product Enterprise, a manufacturer of cassava processing equipment in Ghana, to building a solar-powered hammermill that can be used to grate the cassava root, to pulverize the pressed mash and to mill the dried cassava grits.

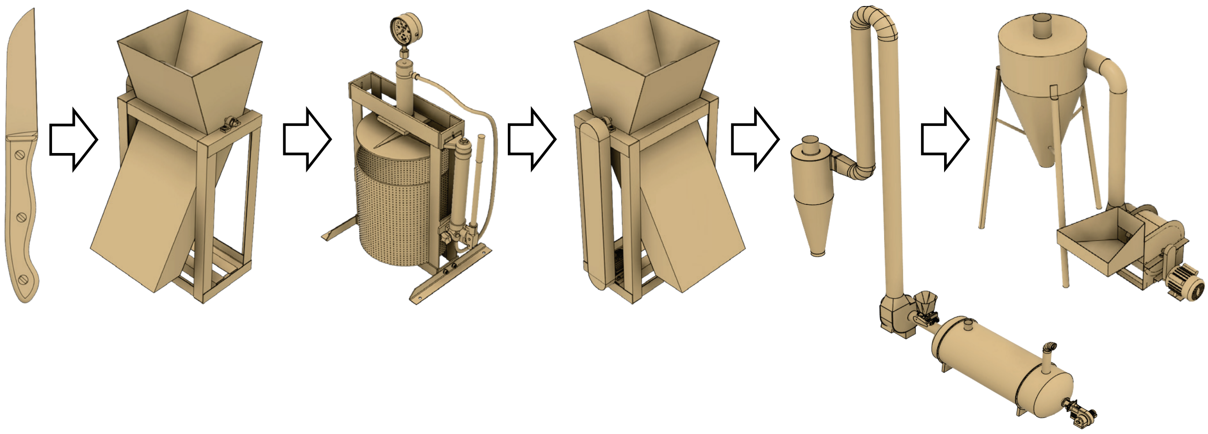


Figure 2 *Cassava processing requires peeling, grating, pressing, pulverizing, drying, and milling.*

Hammermills

Hammermills are one of the most used equipment for food size reduction. They are composed by *hopper*, *case*, *rotor*, *rods*, *hammers*, *sieve*, *fan,* and *cyclone*. The *hopper* feeds the product into the *case.* Inside the case, the *rotor* and the *rods* spin at high speeds. At their periphery, the *hammers* are attached and swing in a circular path. The hammers hit the product entering the housing, reducing its size by impact. The product leaves the housing when is small enough to pass through the *sieve* at the bottom. Particle size is adjusted by changing the opening size of this screen; a screen with larger openings results on larger particles. If the product is wet, it moves down by the force of gravity, but if the product is dried and therefore light, a *fan* is used to generate forced-air, that conveys the product. When the product is conveyed by forced-air, at the end a *cyclone* is used to separate the material from the conveying air. A cyclone can feature one or more bag filters to collect small particles that otherwise would remain mixed with the air.

Overview of the solar-powered multipurpose hammermill

The multipurpose hammermill was designed to be able to grate the cassava root, to pulverize the press cake and to mill the dried cassava grit. The equipment has two parts, the mill itself and the cyclone separator with bag filter (Figure 3). Appendix 1 provides further details.

Figure 3 *Overview of the multipurpose hammermill and the cyclone separator, with bag filters.*

Grating and pulverizing operation

For grating the cassava roots, and for pulverizing the press cake, the equipment operates with its lower hatch door open (Figure 4), with a coarse screen, and with the rotor turning clockwise (Figure 5).

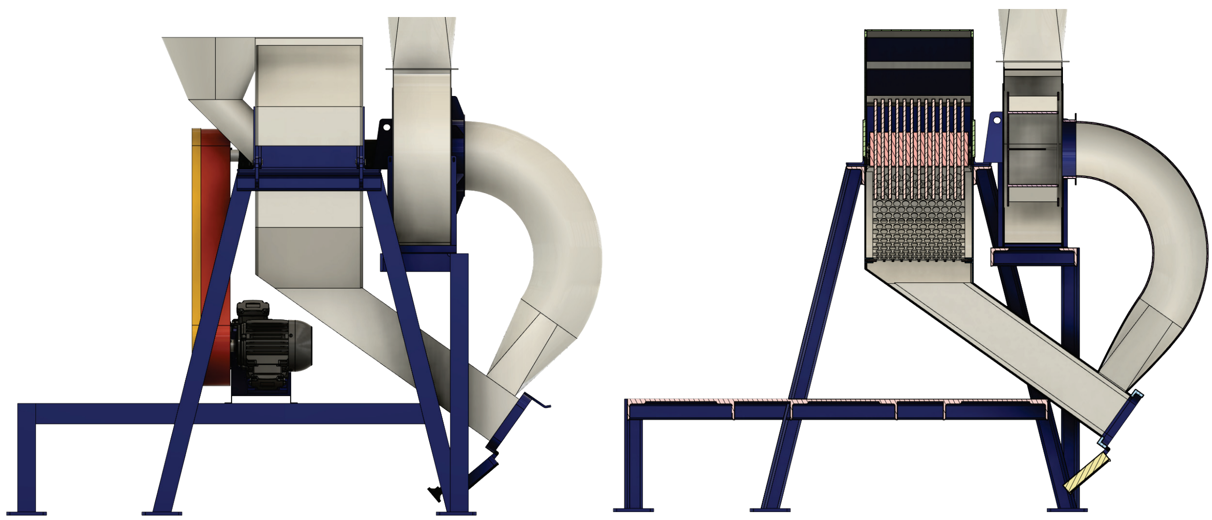


Figure 4 *During grating and pulverizing operation the lower hatch door is kept open.*

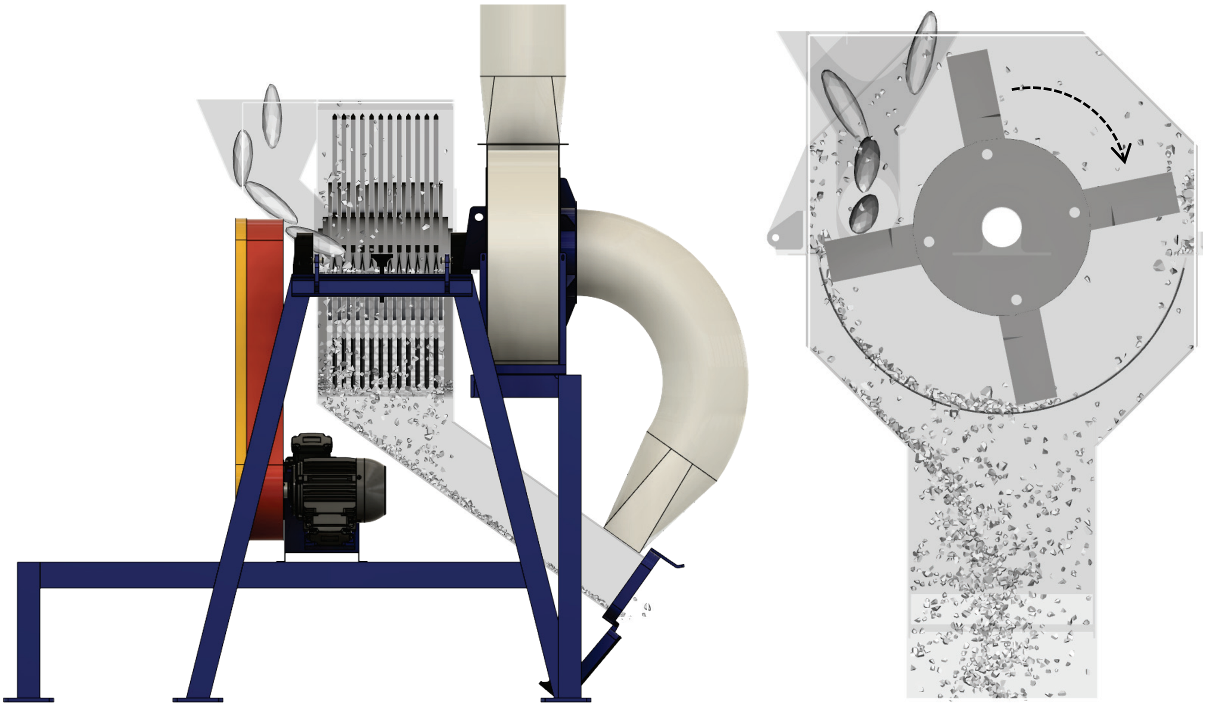


Figure 5 During grating and pulverizing operation the rotor turns on a clockwise direction.

Milling operation

For milling the dried cassava grits, the equipment operates with the hatch door closed (Figure 6), with a finer screen and with the rotor turning anti-clockwise. With this set-up, the fan creates a forced-air (Figure 7) that conveys the dried product (Figure 8).

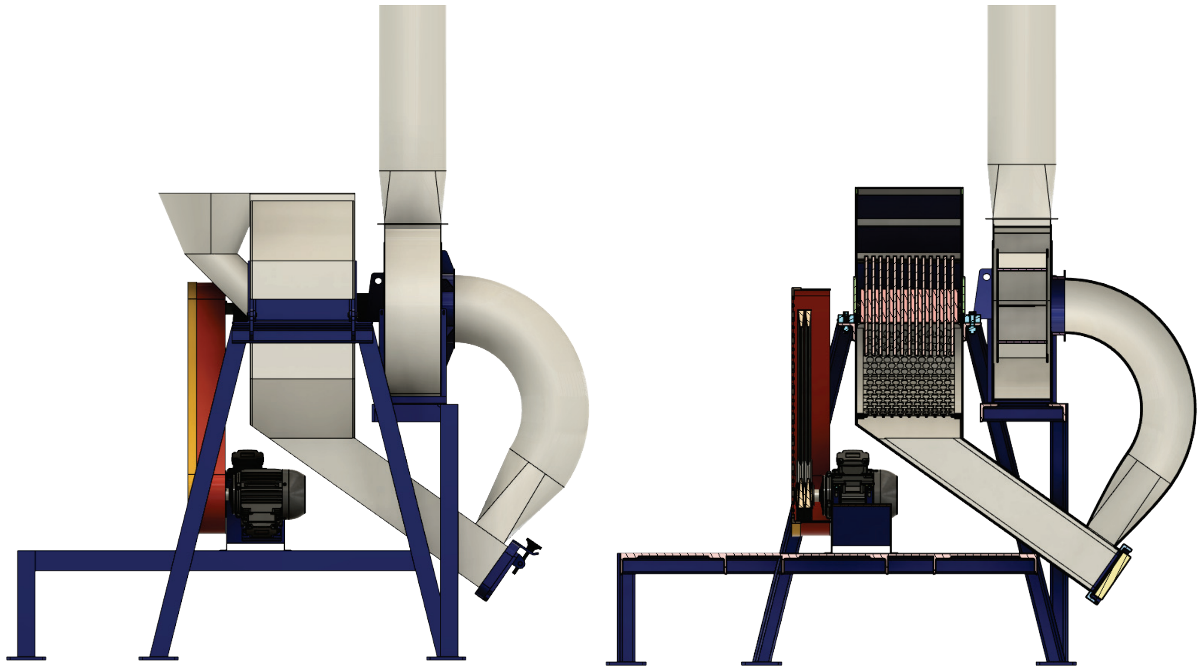


Figure 6 During milling the lower hatch door is closed.

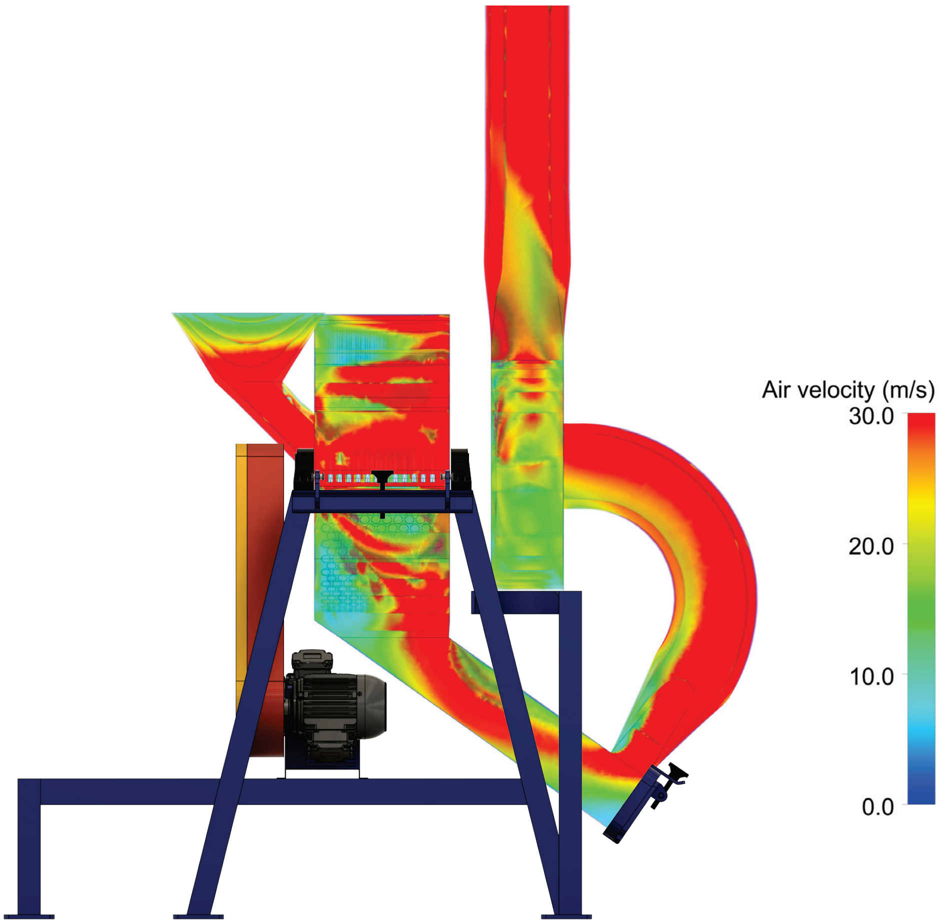


__Figure 7__ With the hatch closed the fan creates a forced-air that conveys the product.

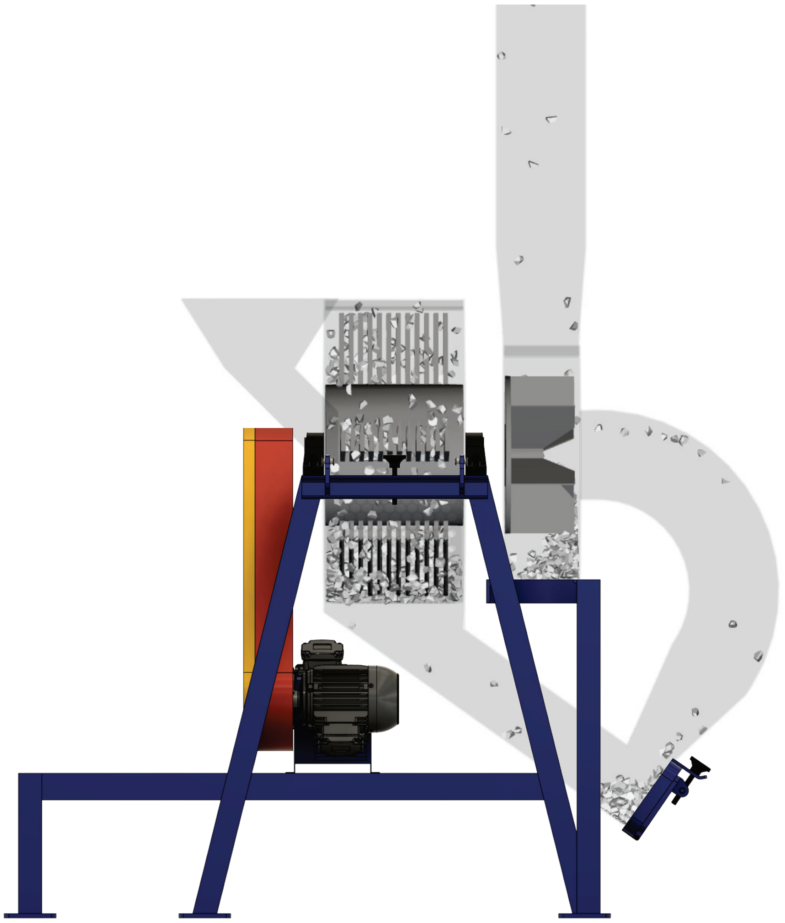


__Figure 8__ During milling the product is transported by the forced-air generated by the fan.

Motors and energy supply

The mill is powered by two electric motors connect to the same shaft by a pulley and belt drive system (Figure 9). The motors are powered by direct-current (DC) generated from photovoltaic panels. No batteries or inverters are used.

Figure 9 *Two DC motors, combined, drives the shaft using a pulley and belt drive system.*

Queries related to the DC motors and the photovoltaic installation should be directed to Dr Aditya Parmar via email (a.parmar@gre.ac.uk) or WhatsApp (+44 7956 820457).

Equipment components

Hopper

The feeding hopper was designed to handle the fresh cassava roots, the pressed cake, and the dried grits. Figure 10 provides an overview of the feeding hopper and more details are provided in Appendix 2. Dimensions should be obtained from the 3D CAD file available at https://a360.co/2RUJvXP.

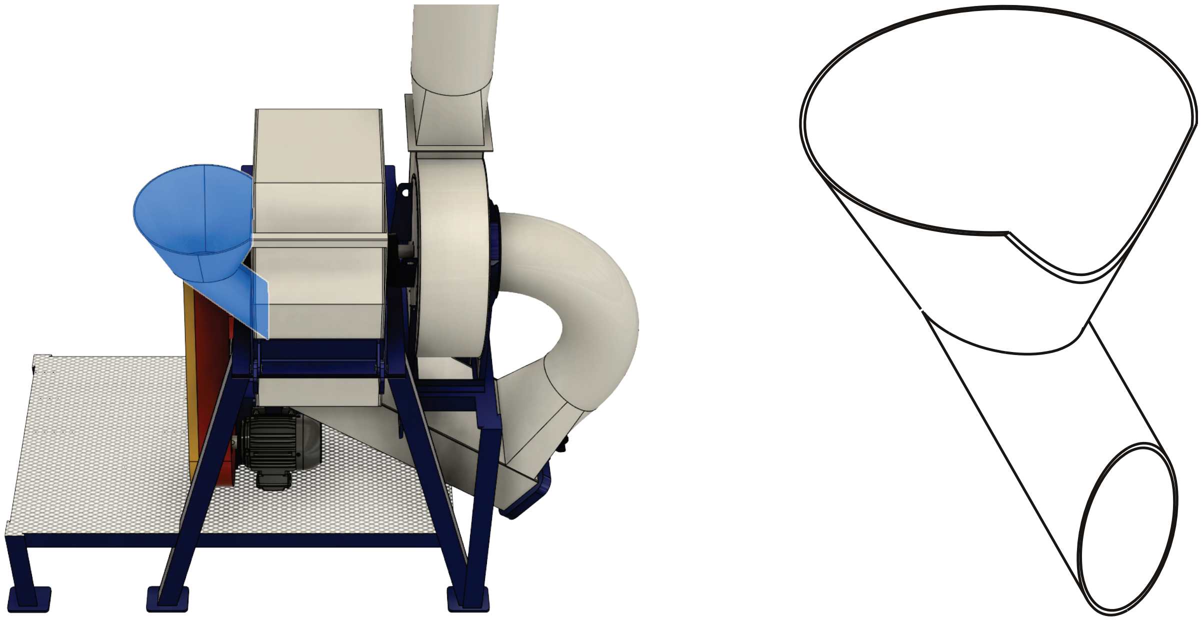


Figure 10 *Feeding hopper of the multipurpose hammermill.*

Case cover

The upper part of the case has hinges and a lock mechanism (Figure 11) allowing it to be open (Figure 12). At the inside deflectors are placed to promote impact and thus increase efficiency (Figure 13). Further details are presented in Appendix 3 and Appendix 4 (exact dimensions should be obtained from the 3D CAD files available at https://a360.co/2RUJvXP).

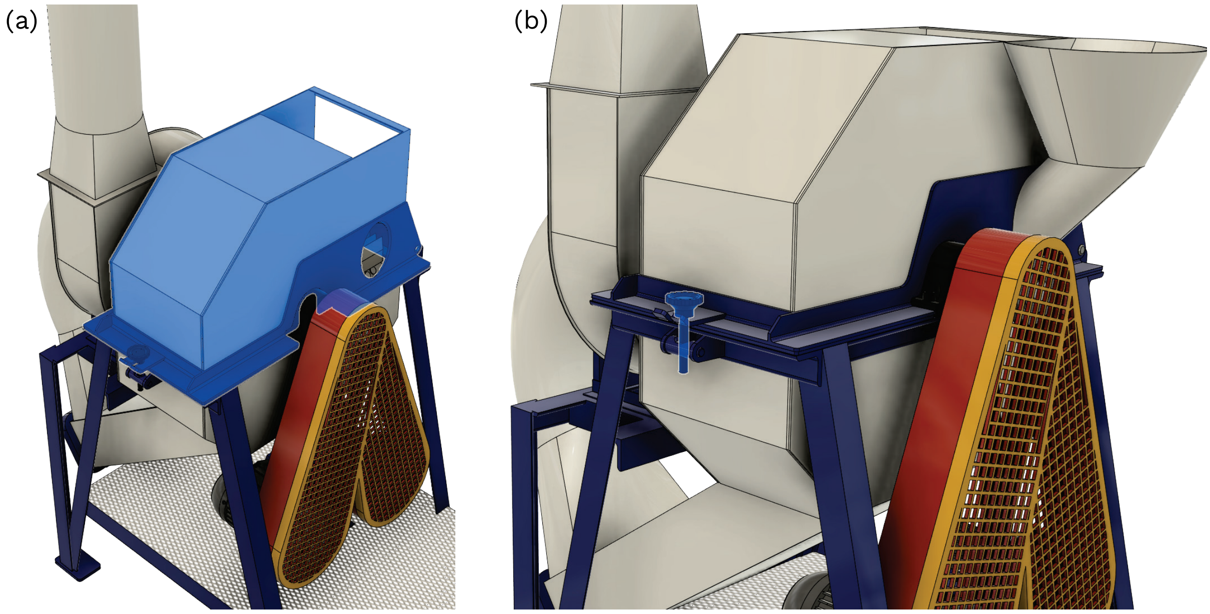


Figure 11 *Hammermill case cover (a) with a lock mechanism (b).*

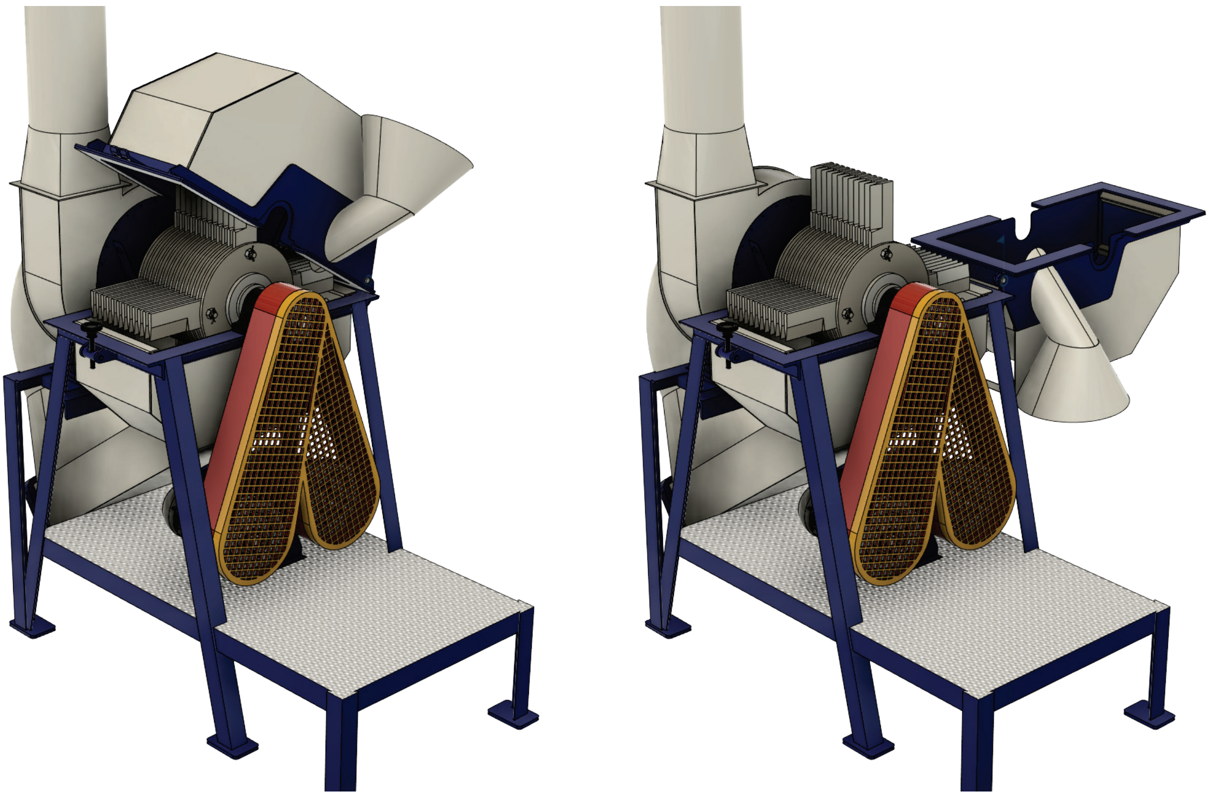


Figure 12 *Case cover opens for easy replacement of the screen.*

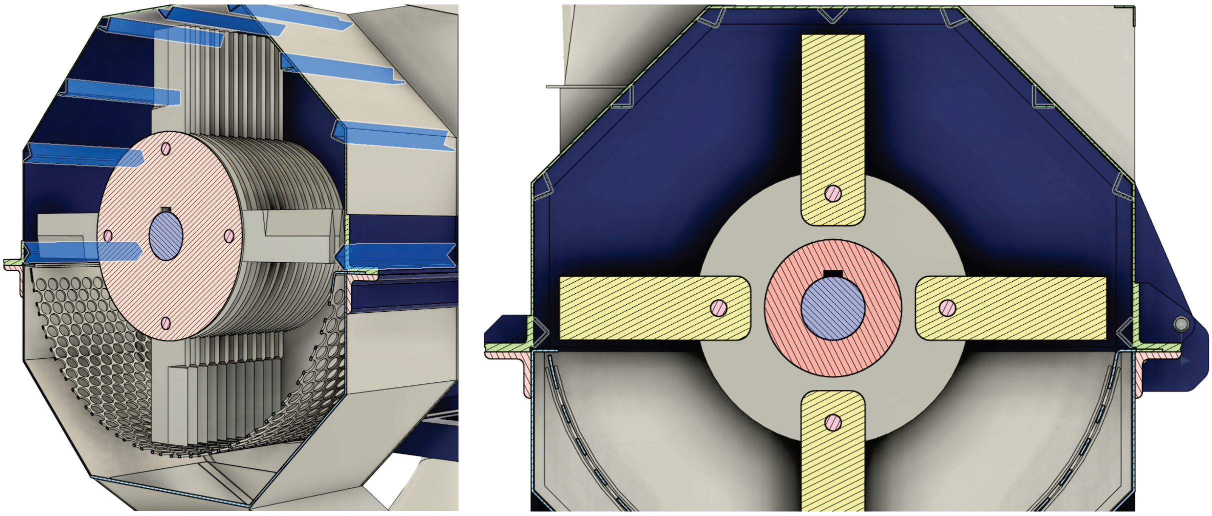


Figure 13 Deflectors are used to promote impact and increase milling efficiency.

Rotor, rods, and hammers

The mill uses a total of 44 hammers, attached to the rods (Figure 14). One side of the hammer is sharpened like a knife and the other side of the hammer is flat and blunt (Figure 15). Further details are presented in Appendix 5, Appendix 6, Appendix 7, Appendix 8, and Appendix 9. Exact dimensions should be obtained from the 3D CAD files available at https://a360.co/2RUJvXP.

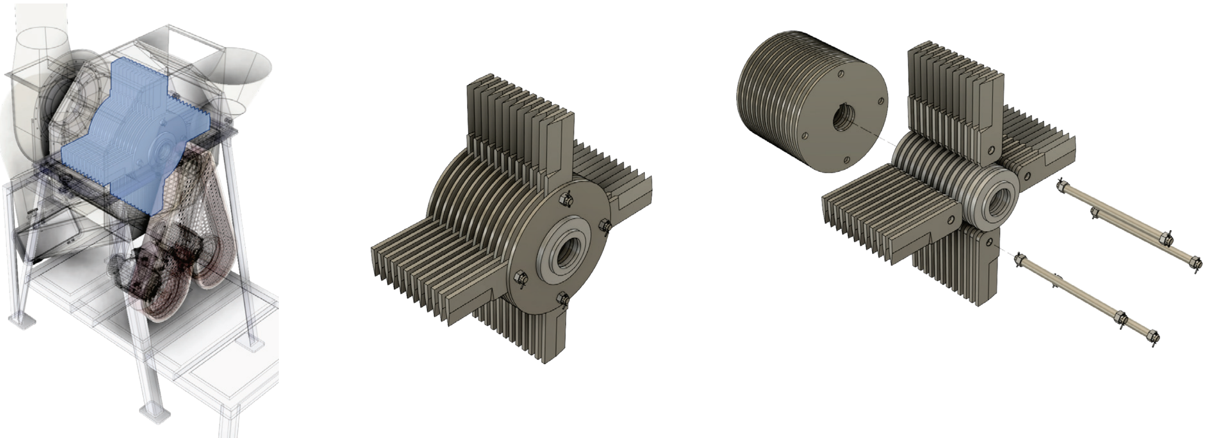


Figure 14 Rotor and rods holding a total of 44 hammers.

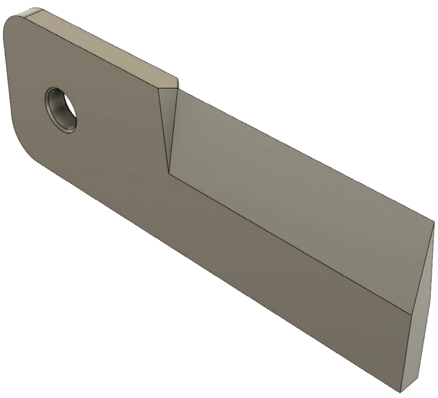


Figure 15 Hammer with one side sharp for grating/pulverizing and the other side flat for milling.

Drive system

The mill is powered by 2 DC motors placed on a stand and mounted on racks (Figure 16). Power is transmitted from the motor to the shaft by a system of pulleys and belt. The drive pulley is twice the size of driven pulley, and all belt drive components are enclosed under a safety guard (Figure 17). Further details of the drive system are presented in Appendix 10, Appendix 11, Appendix 12, Appendix 13, and Appendix 14. Exact dimensions should be derived from the 3D CAD files available at https://a360.co/2RUJvXP. It should be noticed that adjustments need to be made in the dimensions of the motor stand and motor rack, according to the physical size of the DC motor, as those dimensions were not known at the time of writing.

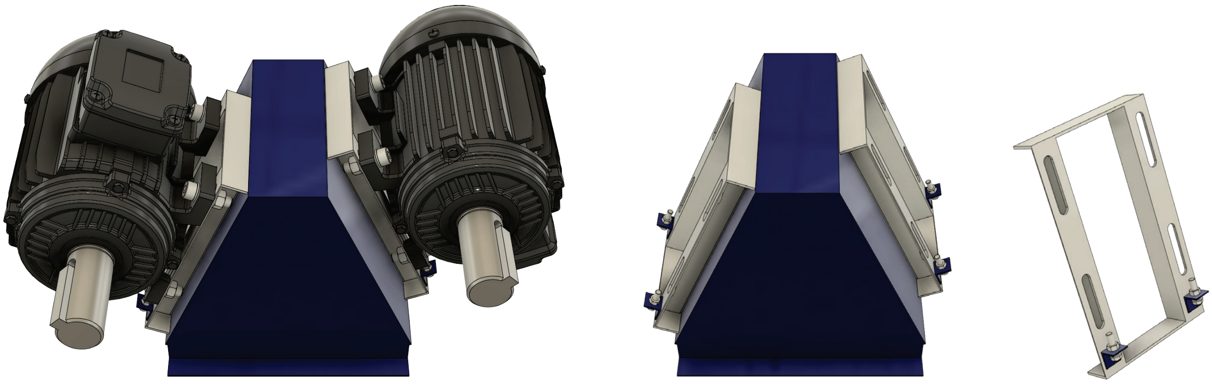


Figure 16 *DC motors are placed on a stand and mounted on racks.*

Figure 17 *Power is transmitted by a system of pulleys and belts enclosed under a safety guard.*

Screen

The screen controls the size of the obtained particle. A larger aperture should be used for grating the fresh roots and pulverizing the pressed cake. A smaller aperture should be used for the milling operation. The screen can be easily changed by opening the case cover (Figure 18). Appendix 15 provides further details. Exact dimensions should be derived from the 3D CAD files available at https://a360.co/2RUJvXP.

Figure 18 *Screen of different aperture should be used according to the operation.*

Wet solid outlet

When the mill is used to grate the cassava root or to pulverize the pressed mash, the hatched door should be open, allowing the product to come out (Figure 19). Further details can be found in Appendix 16 and Appendix 17. Exact dimensions should be obtained from the 3D CAD files available at https://a360.co/2RUJvXP.

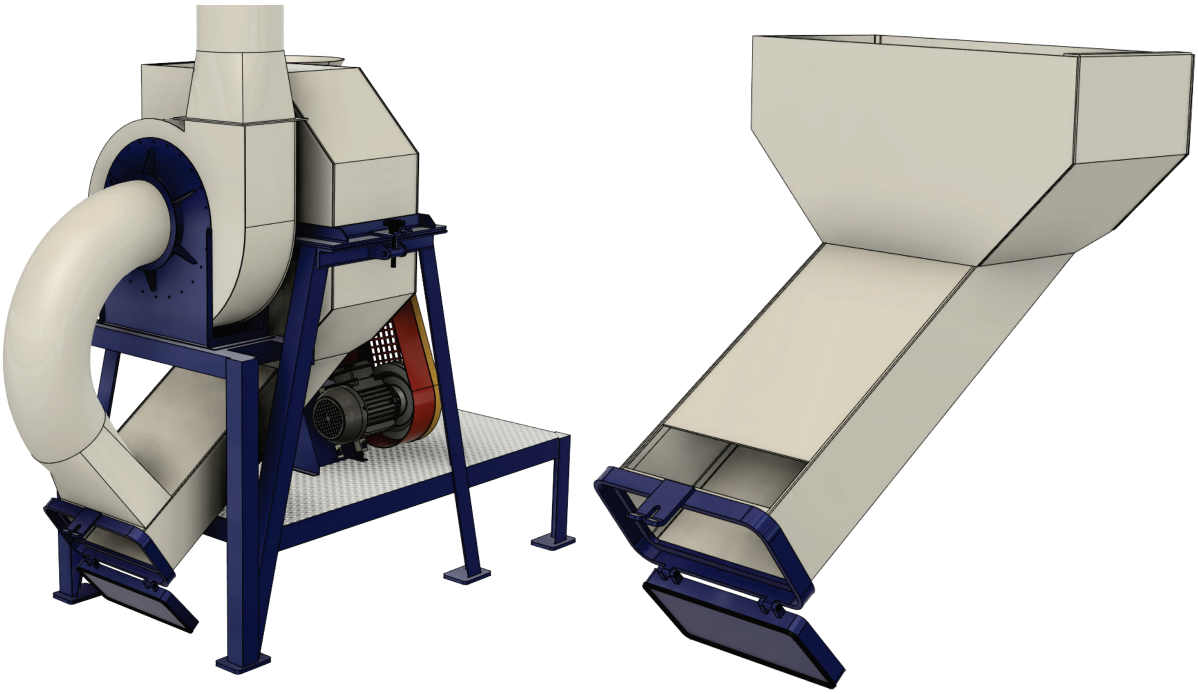


Figure 19 *When the mill is used for grating or pulverizing it operates with the hatch door open.*

Fan

The fan is a centrifugal blower with straight-blade impeller (Figure 20). The impeller is connected to the same shaft that turns the rotor. When the mill is used to grate the cassava roots or pulverize the pressed mash, the impeller turns clockwise and has no function on inducing the air (but acts as a flywheel). When the equipment is used to mill the dried solid the fan generates forced-air that conveys the product.

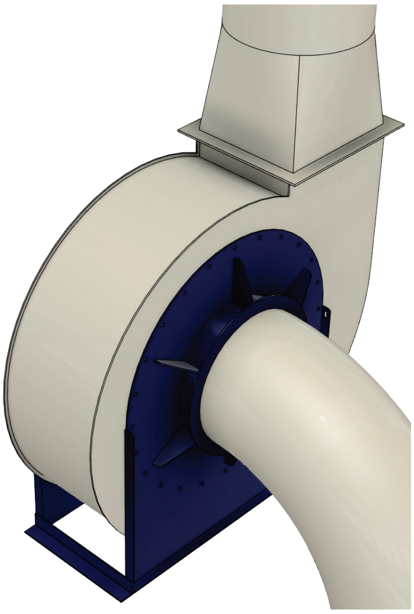
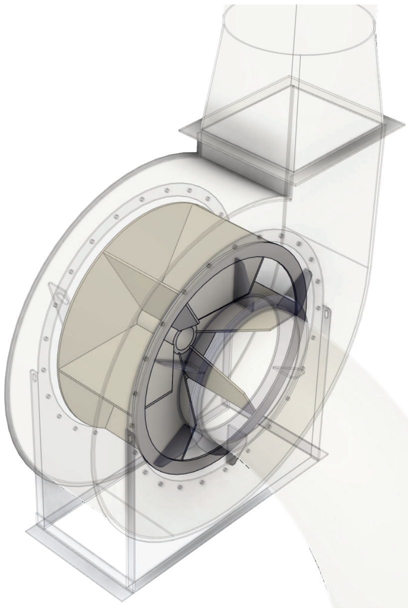



Figure 20 *When used for milling, the fan induces the air needed to transport the product.*

During the milling operation, the hatch door must be closed. It is important to stress that the hatch door must be properly built to be airtight when closed. If air can pass through the hatch door when it is closed, the mill will not operate properly. Further details of the fan are presented on Attachment 18, Attachment 19, and Attachment 20. Details on the impeller can be found on Attachment 21. Exact dimensions should be obtained from the 3D CAD file available at https://a360.co/2RUJvXP.

Base

The mill sits on a metal base as shown in Figure 21. It includes a step to facilitate the operator on accessing the hopper. The floor of the step is made of corrugated anti-slippery metal. Details on the design of the base are presented on Attachment 22 and exact dimensions should be obtained from the 3D CAD file available at https://a360.co/2RUJvXP.


Figure 21 *Metal base provides support to the mill and step makes easier to reach the hopper.*

Control panel

The equipment control panel should have a switch that regulates the direction of the motors and thus allow selecting between grating (or pulverizing) and milling operation. The control panel should also have an emergency stop button (Figure 22). Questions regarding the solar installation and the DC motor wiring should be direct to Dr Aditya Parmar.

Figure 22 Control panel allows selecting between grating (or pulverizing) and milling.

Construction material

All parts that come in direct contact with the cassava solid should be built with a material that does not exchange components with the food, does not react with detergents, and can be easily cleaned, therefore, food-grade stainless-steel is recommended. Parts that do not come in contact with the material, like the base structure, if not made of stainless-steel, must be coated with corrosion-resistant paint. The hammers should be built of manganese-steel or any other hard-wearing food-safe material.

Equipment dimensions

Dimensions should be obtained from the 3D CAD file available at https://a360.co/2RUJvXP. The files are stored in a 3D cloud service provided by Autodesk, is free to use, does not ask for registration and does not require to use of Autodesk programs (i.e. do not need Fusion 360). The link allows to visualize the 3D CAD file, make measurements, create cross-sections and exploded views, all direct from an internet browser such as Google Chrome (Figure 23). It works best when opened from a computer, but it can also be accessed from a phone. Also, the file can be downloaded and opened using a 3D CAD software installed locally (i.e. SolidWorks, CATIA, Inventor, etc).

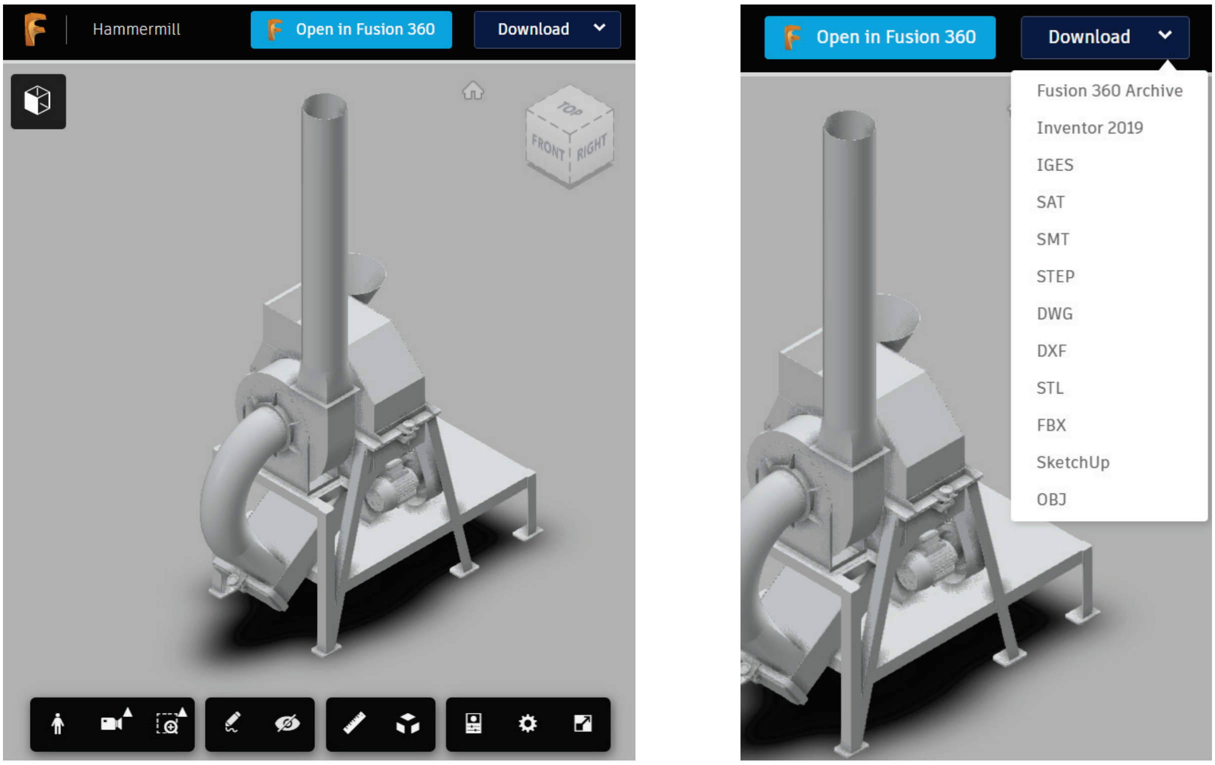


Figure 23 Accessing, visualizing and downloading the 3D CAD file from the cloud.

Modifications to the design

The experience of First Products Enterprise on building hammermills is highly appreciated. It is strongly encouraged that Mr Emmanuel K. Duah analyses the proposed design and make suggestions for improvements. However, any modification needs to be approved by Dr Marcelo Precoppe by email (m.precoppe@gre.ac.uk) or WhatsApp (+44 7903 128440).

Construction Guide Part 2

After building the hammermill and installing at FRI Food Processing Centre, Mr Emmanuel K. Duah needs to run some preliminary test as follow: he should test grating some fresh cassava and test pulverizing some pressed mash. Based on his experience, Mr Emmanuel K. Duah should determine if the rotation speed of the hammers is correct or if it needs to be increased or decreased. The speed of the rotation is adjusted by changing the size of the pulleys of the drive system.

Once the correct speed has been determined and the pulley replaced, Mr Emmanuel K. Duah should close the hatched door and perform air velocity reading with an anemometer as shown in Figure 24. Only after Mr Emmanuel K. Duah has sent the air velocity measurements, Part 2 of the Construction Guide can be prepared. Mr Emmanuel K. Duah should acquire a new anemometer from a reputable supplier, its cost will be covered by the project.

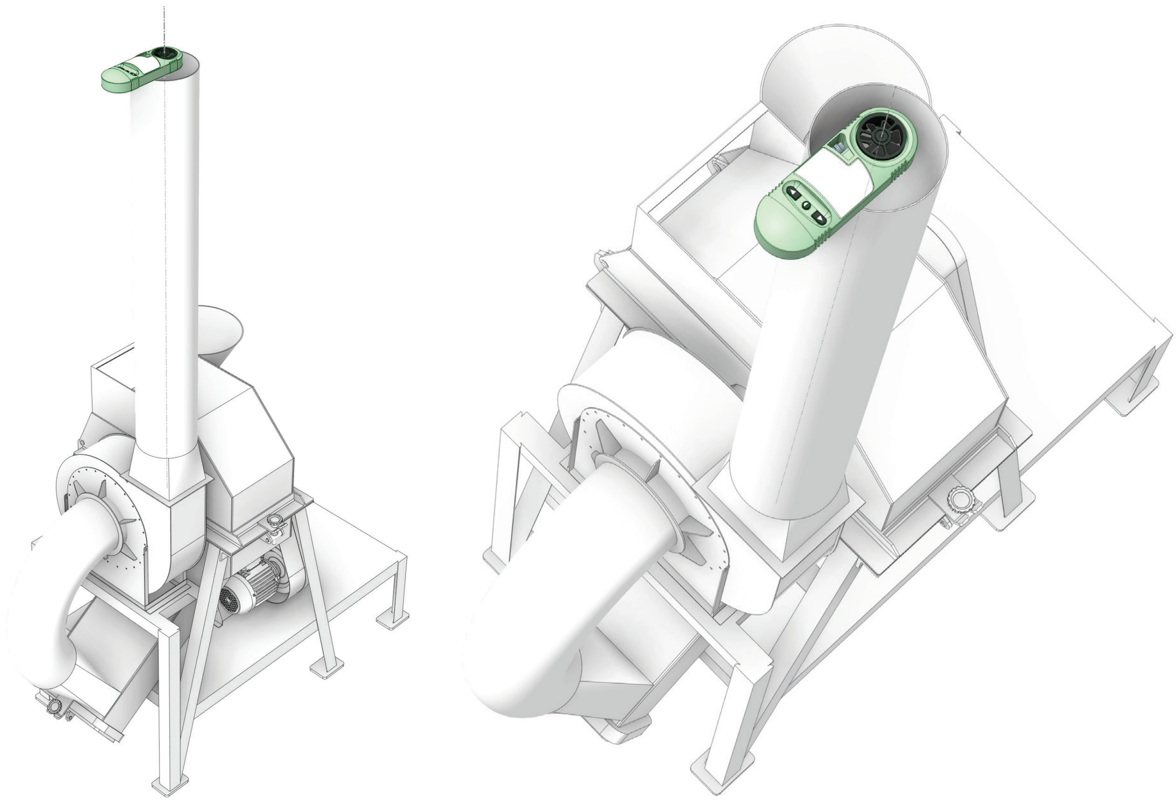


Figure 24 *Air velocity measurements with an anemometer need to be done once Part 1 is built.*

Finances

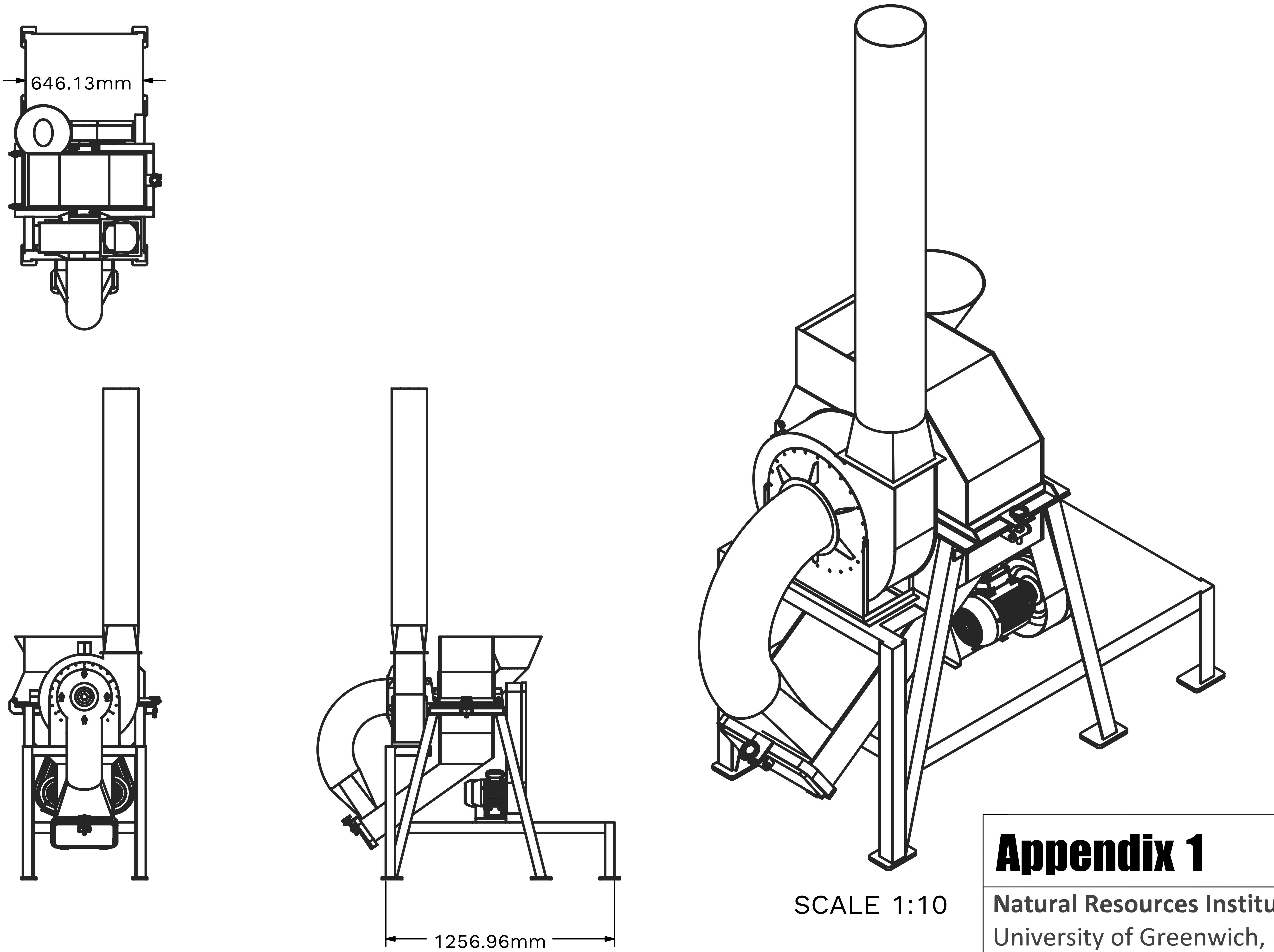
The construction of this equipment is part of a project funded by Agri-Tech Catalyst. Therefore, the cost for building this mill will be covered. All queries related to funds should be directed to Mr Alan Brewer (PSECC Ltd) via email (Alan@psecc.co.uk) or WhatsApp (+44 751977203).

Timeframe and work plan

First Product Enterprise should conclude the construction of Part 1 (described in this guide) before 31 of May 2020. The equipment should thereafter be installed at FRI Cassava Processing Centre, and connected it to the solar power system. Before 30 of June, Mr Emmanuel K. Duah should perform the preliminary test (described in this guide) and send the air velocity measurements to Dr Marcelo Precoppe, who will prepare Part 2 immediately. First Product Enterprise should conclude building Part 2 before 30 of July. Table 1 shows the work plan that needs to be followed.

Table 1 *Work plan for construction of the multipurpose hammermill.*

Tasks	May 2020	June 2020	July 2020
First Product Enterprise builds Part 1 of the multipurpose hammermill			
First Product Enterprise performs preliminary tests and sends to Dr Precoppe air velocity measurements			
First Product Enterprise builds part 2 of the multipurpose hammermill			



Appendix 1

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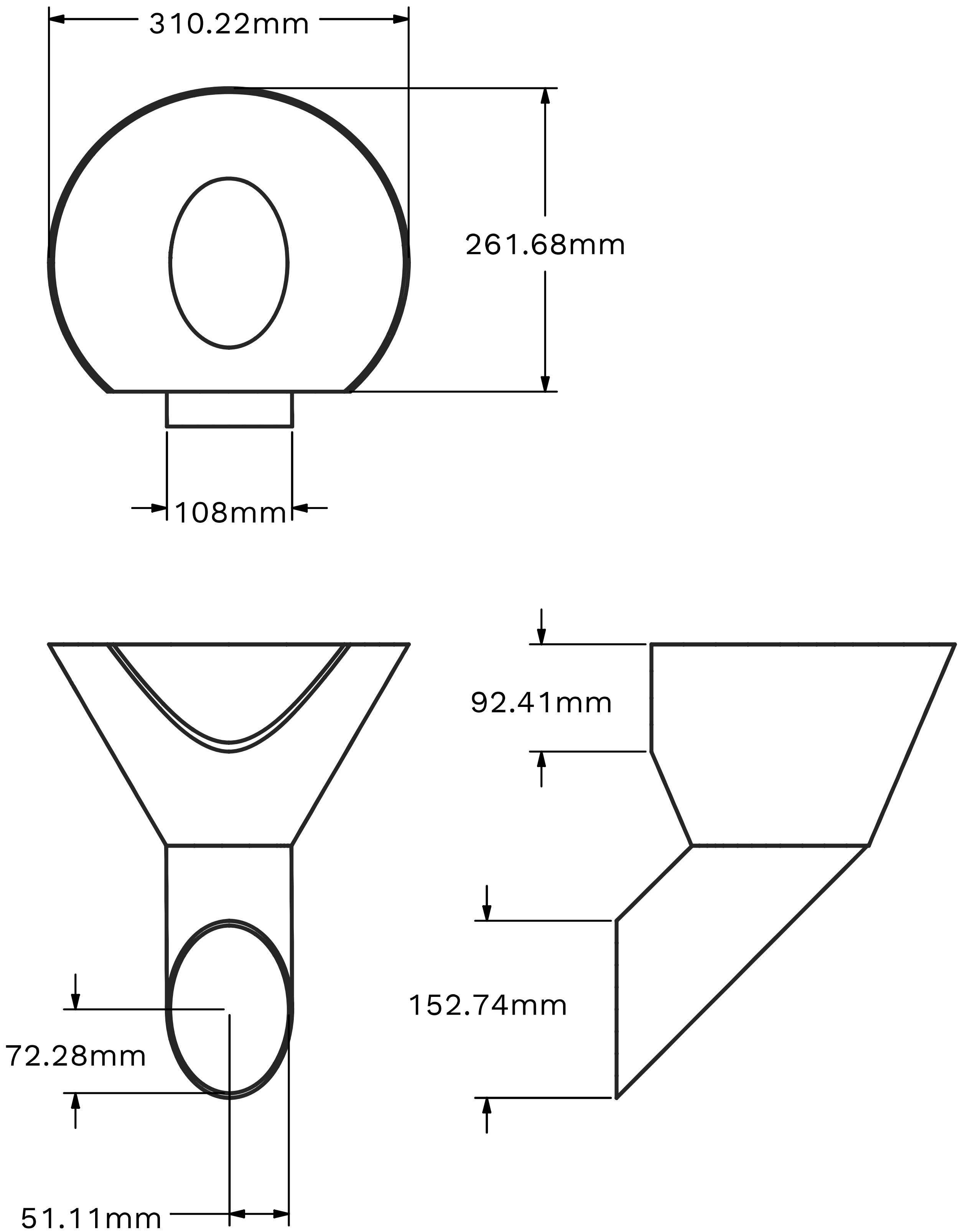

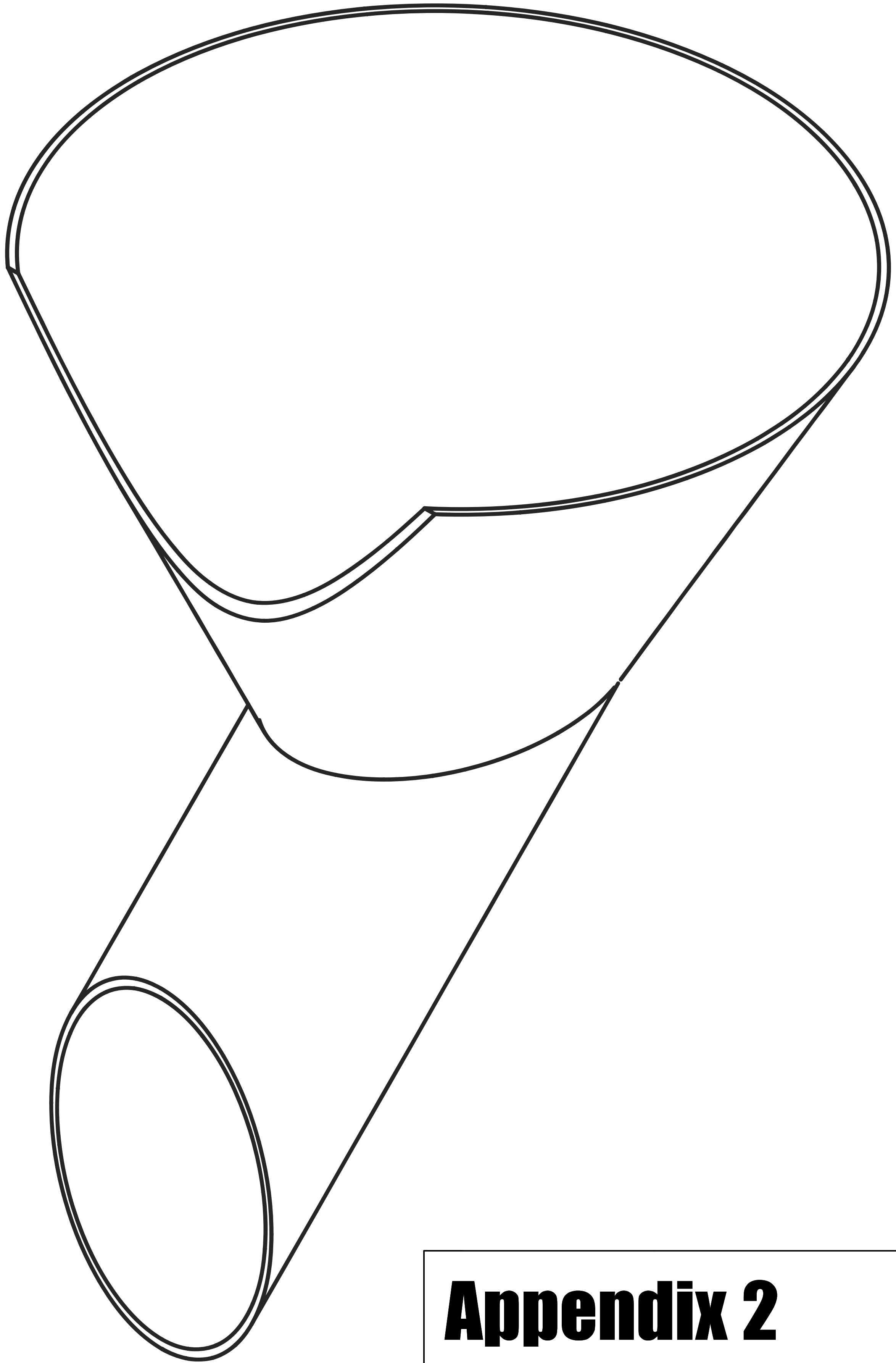

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Appendix 2

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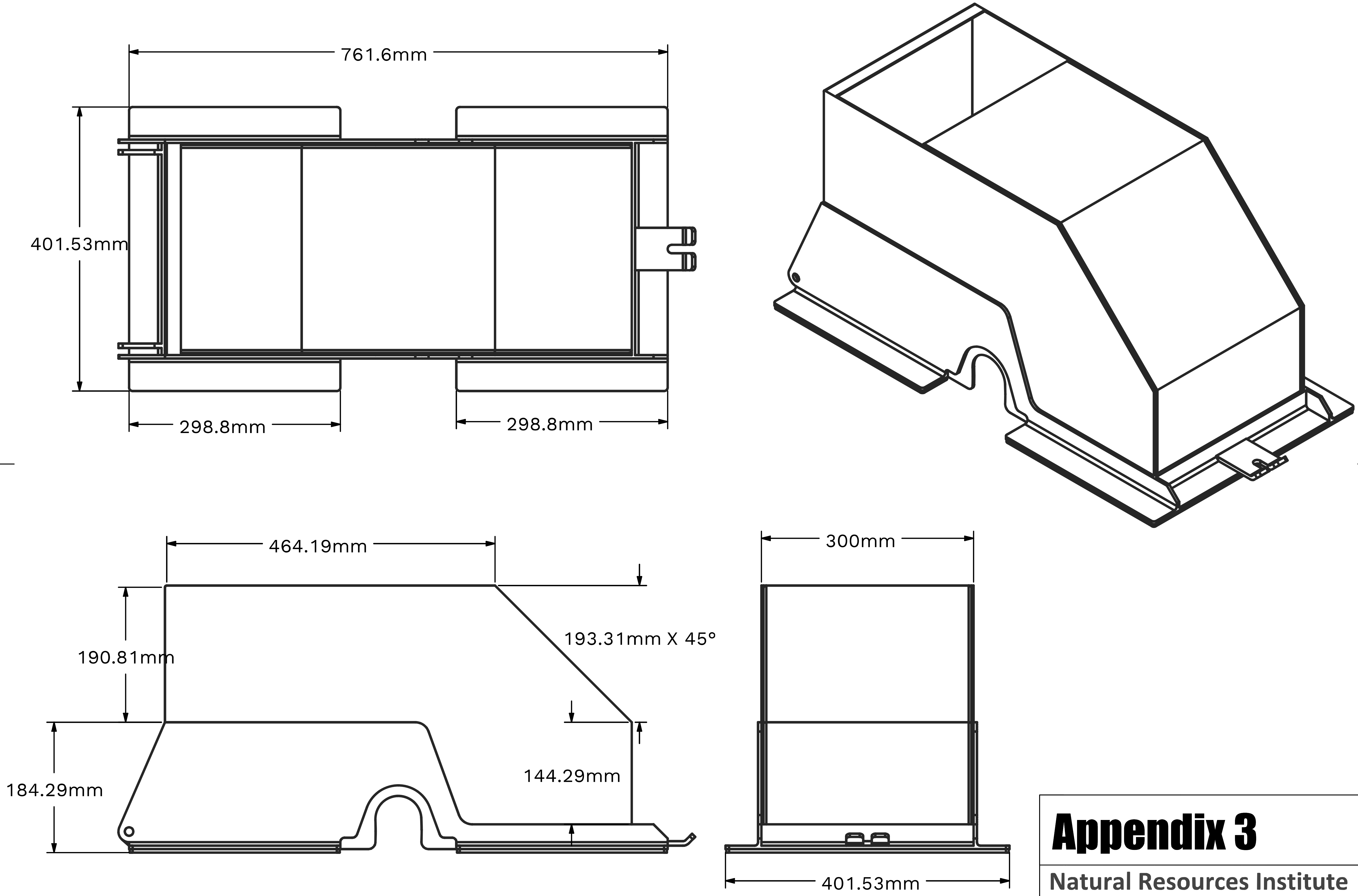

Appendix 3

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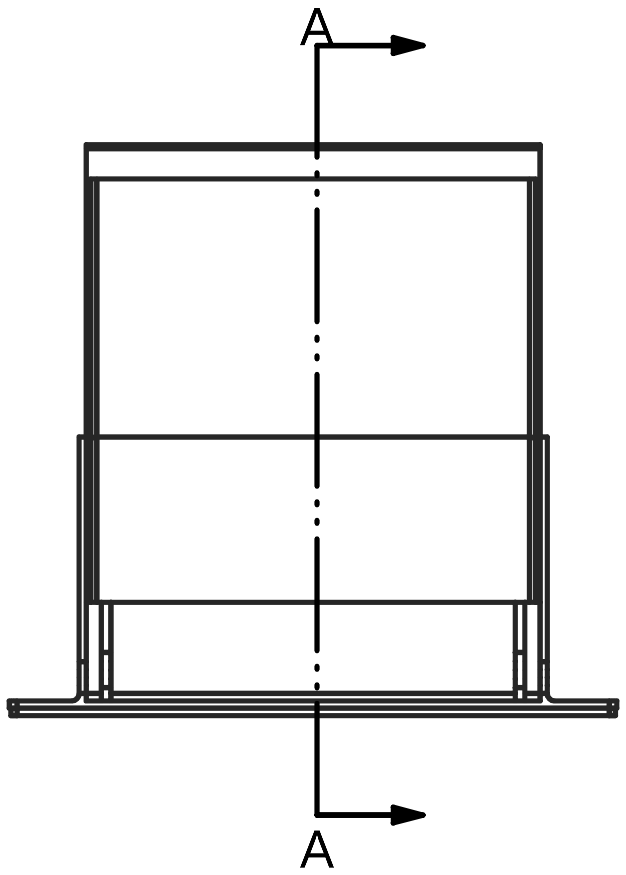

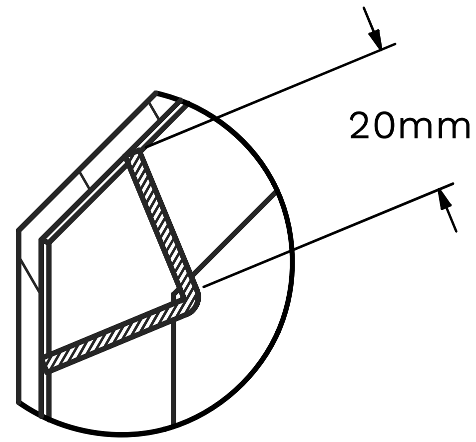

DETAIL A
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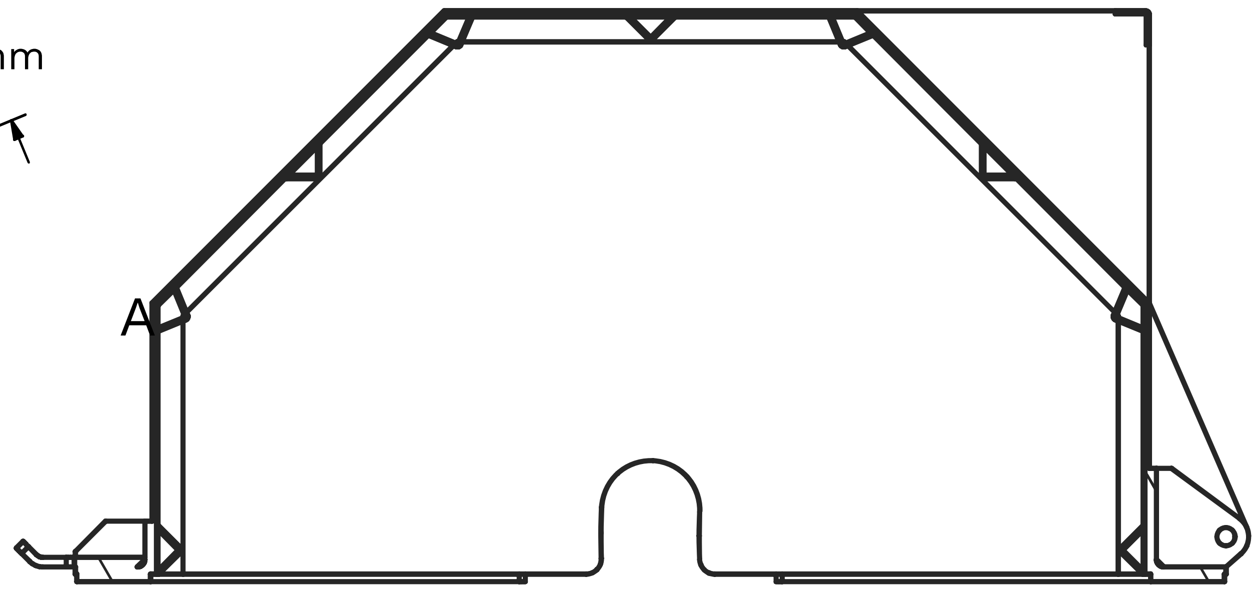
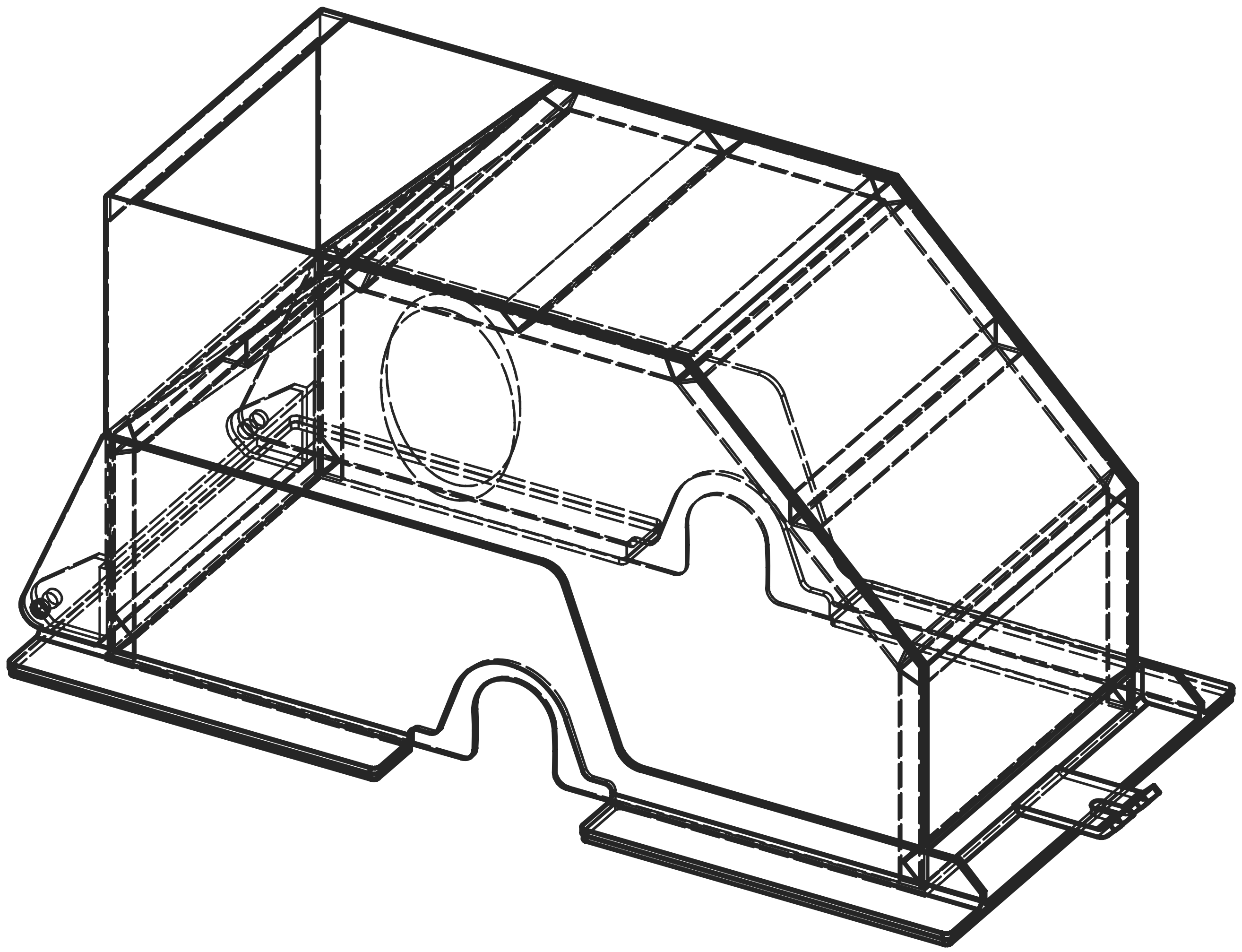
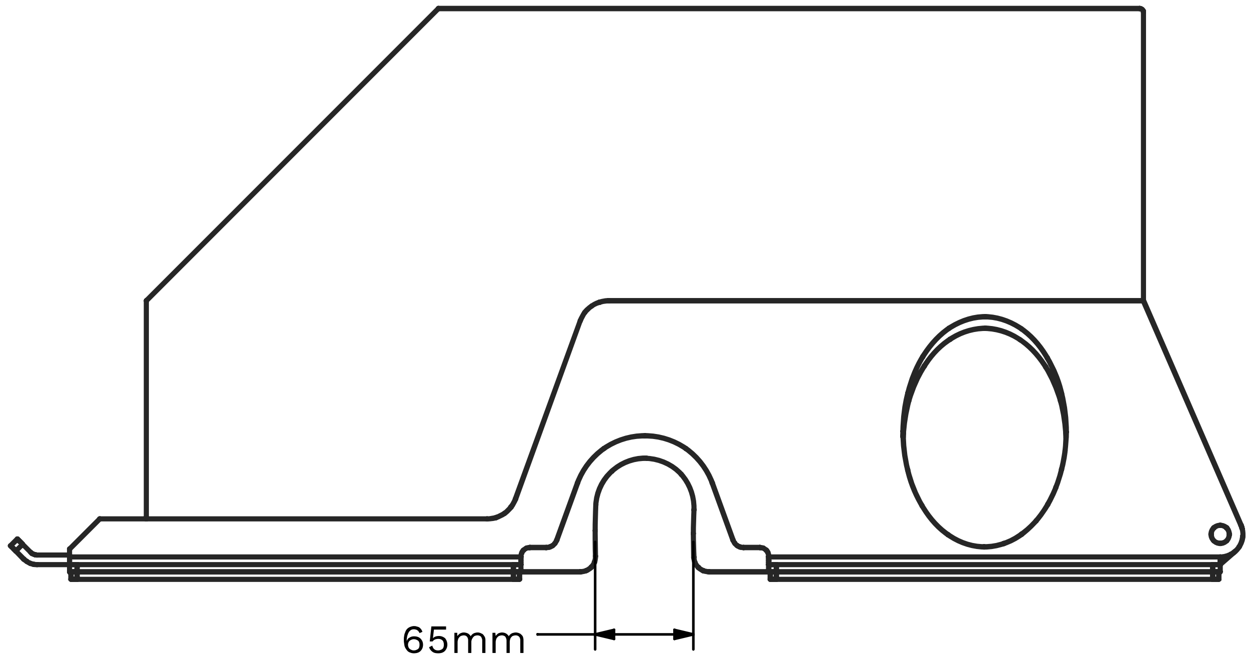


SECTION A-A





Appendix 4

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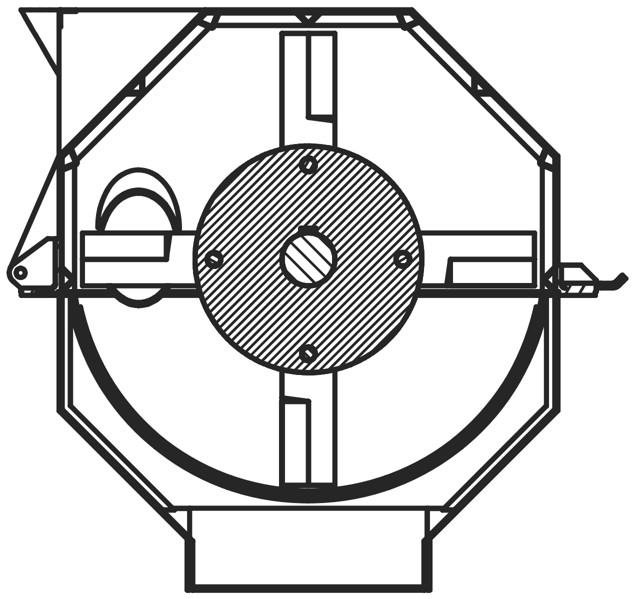
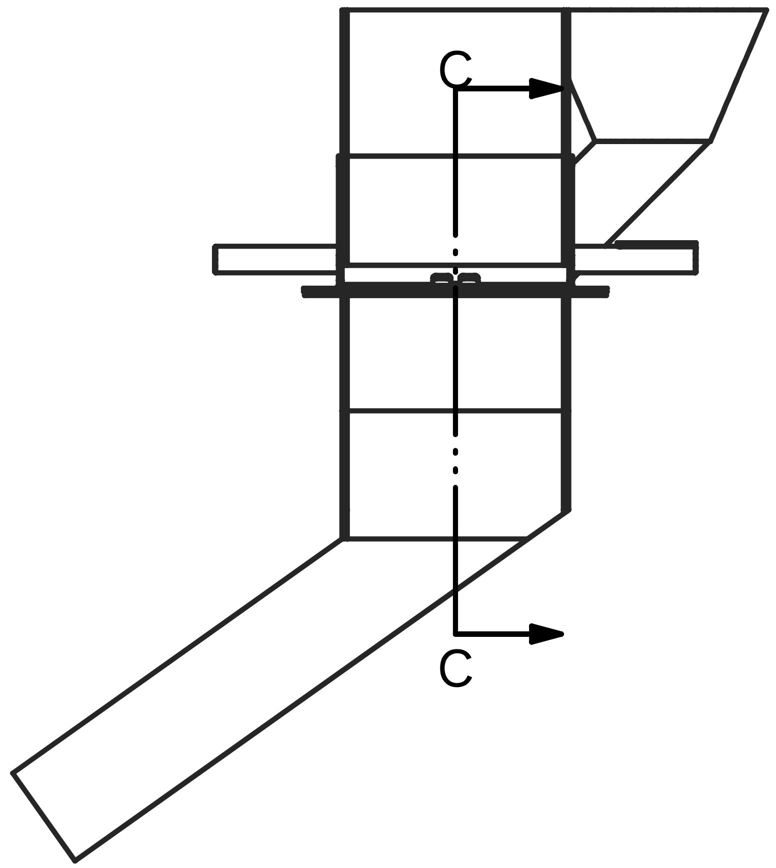
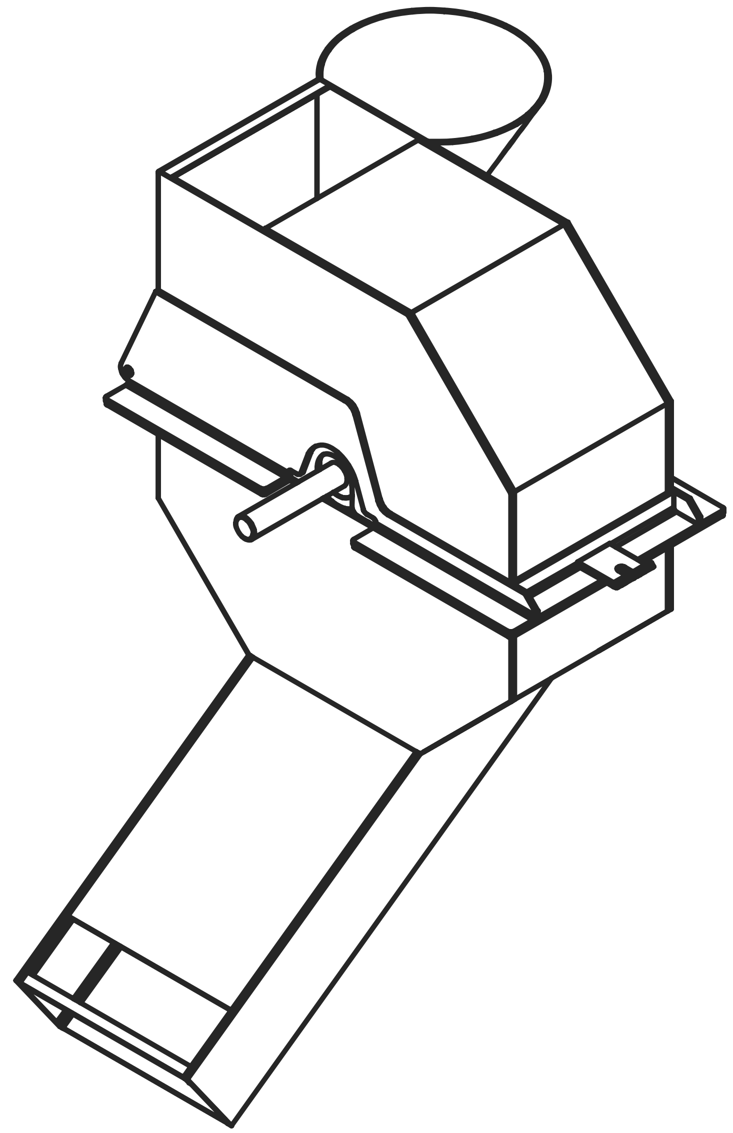
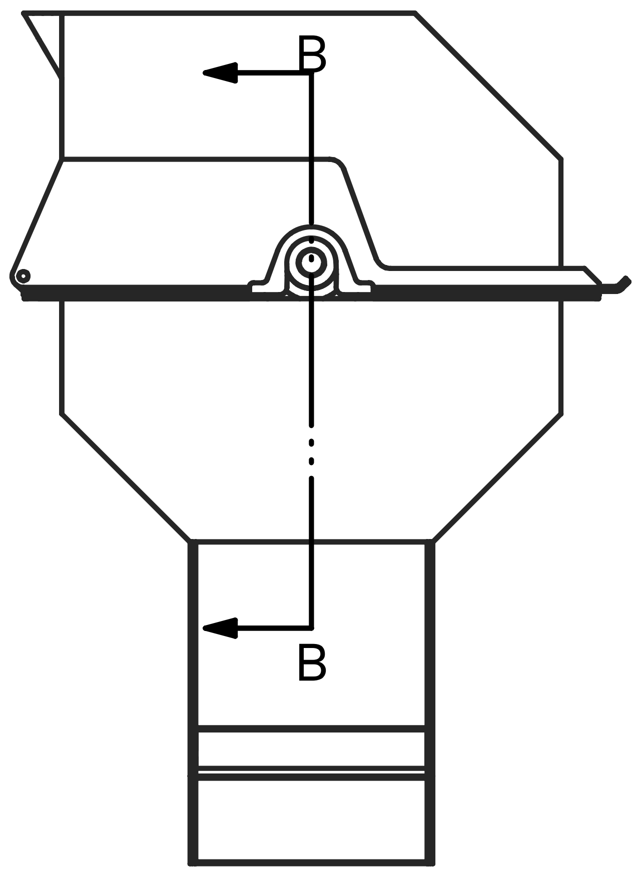
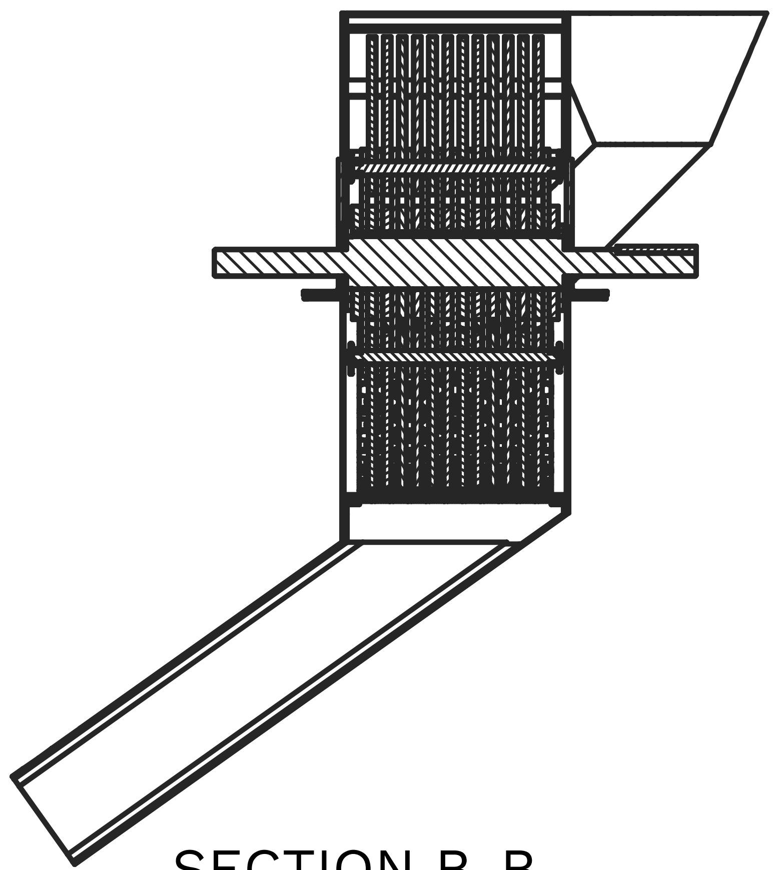


SECTION C-C









SECTION B-B

Appendix 5

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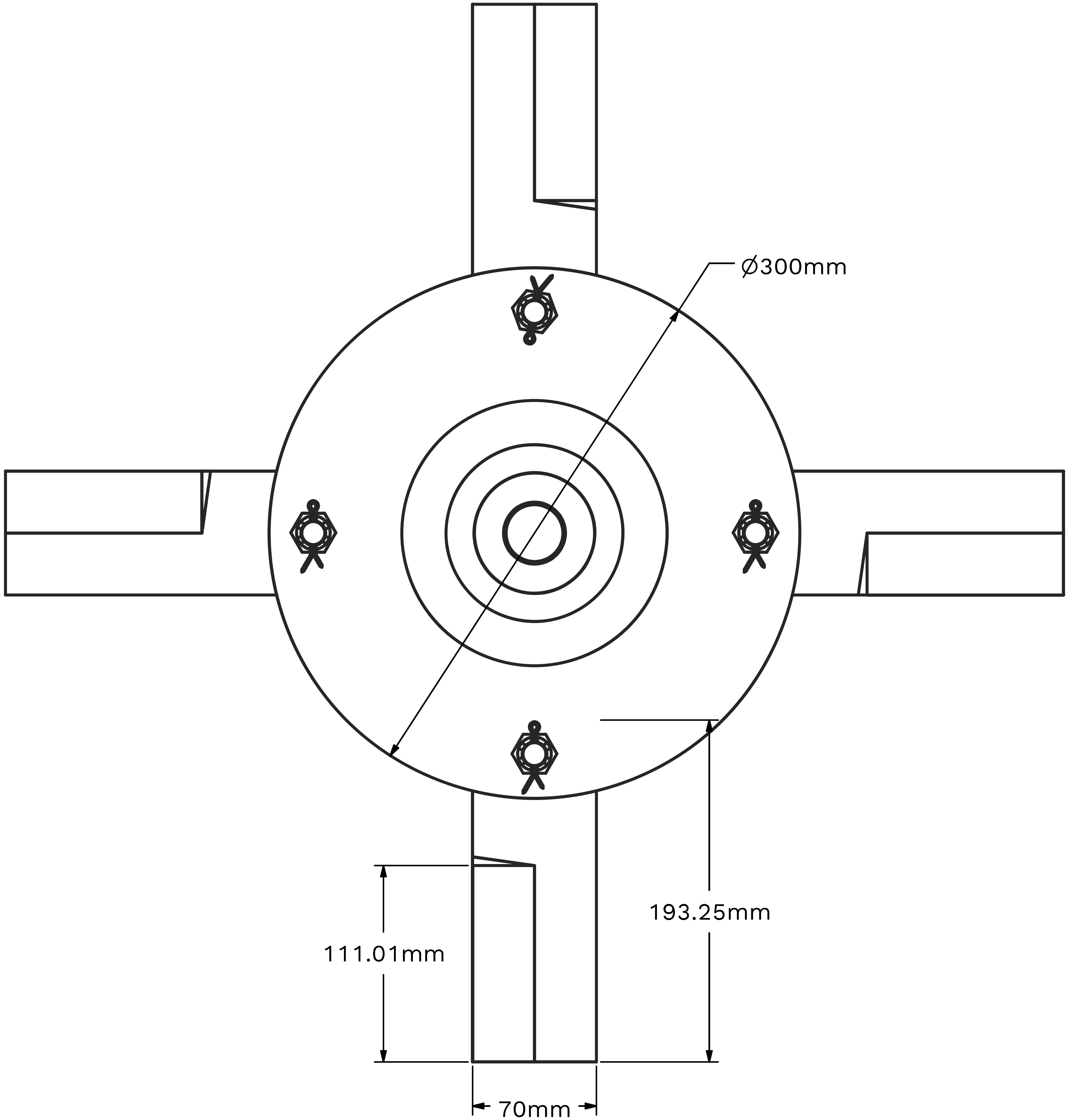

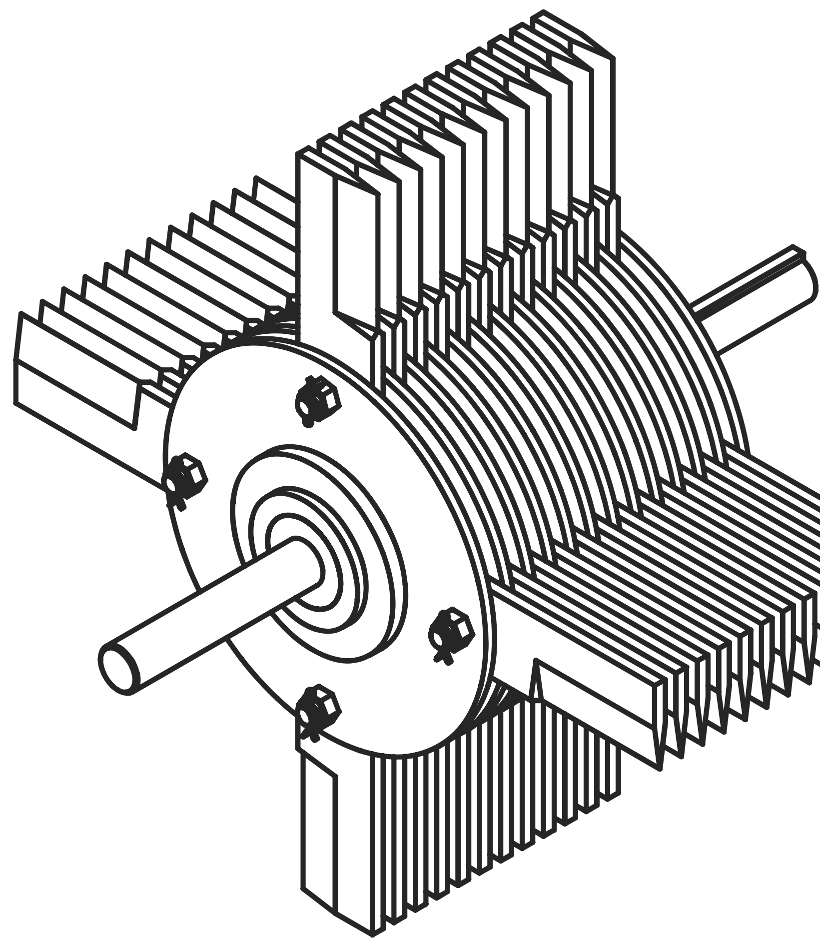

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Appendix 6

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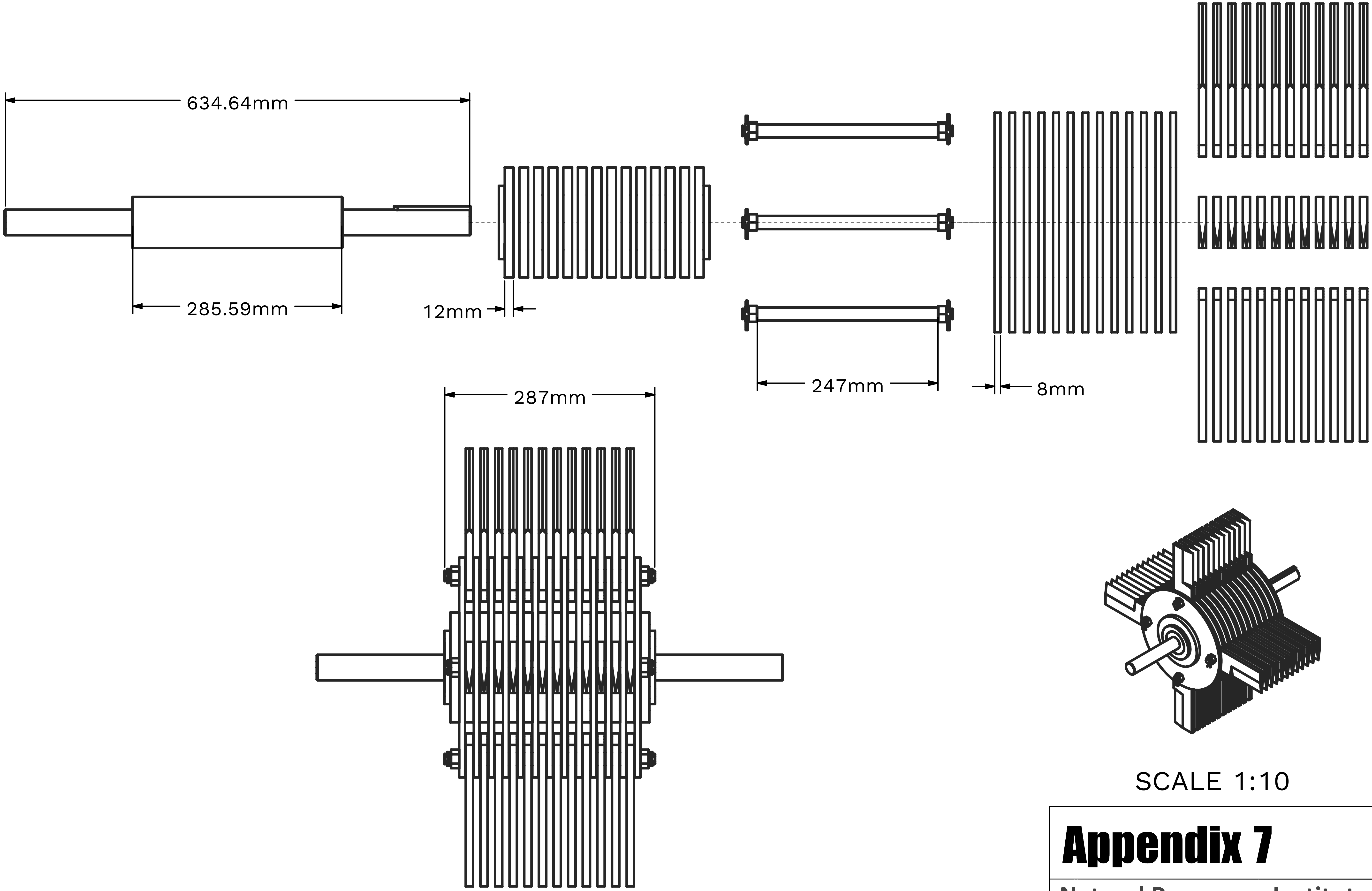

Appendix 7

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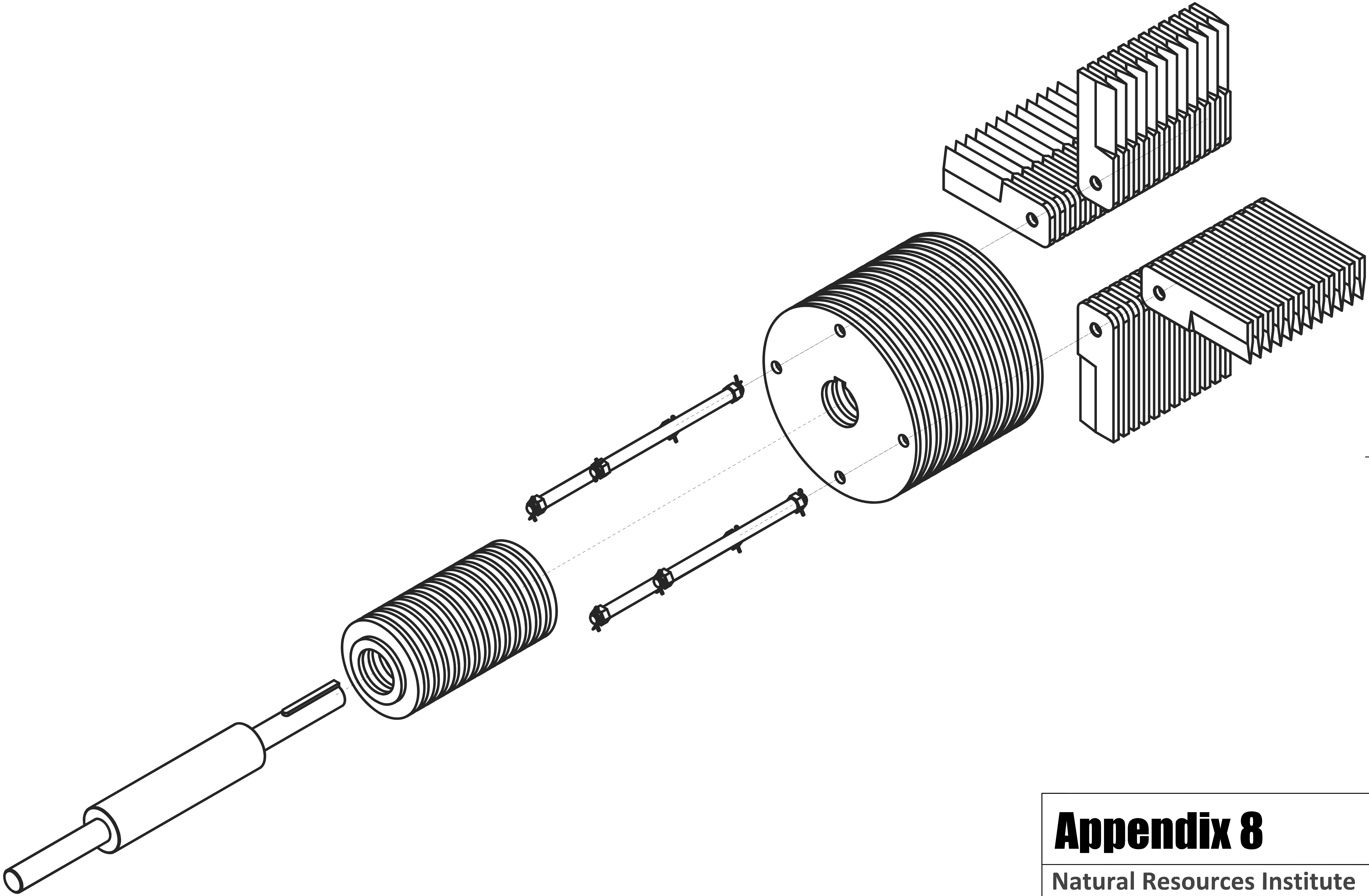

Appendix 8

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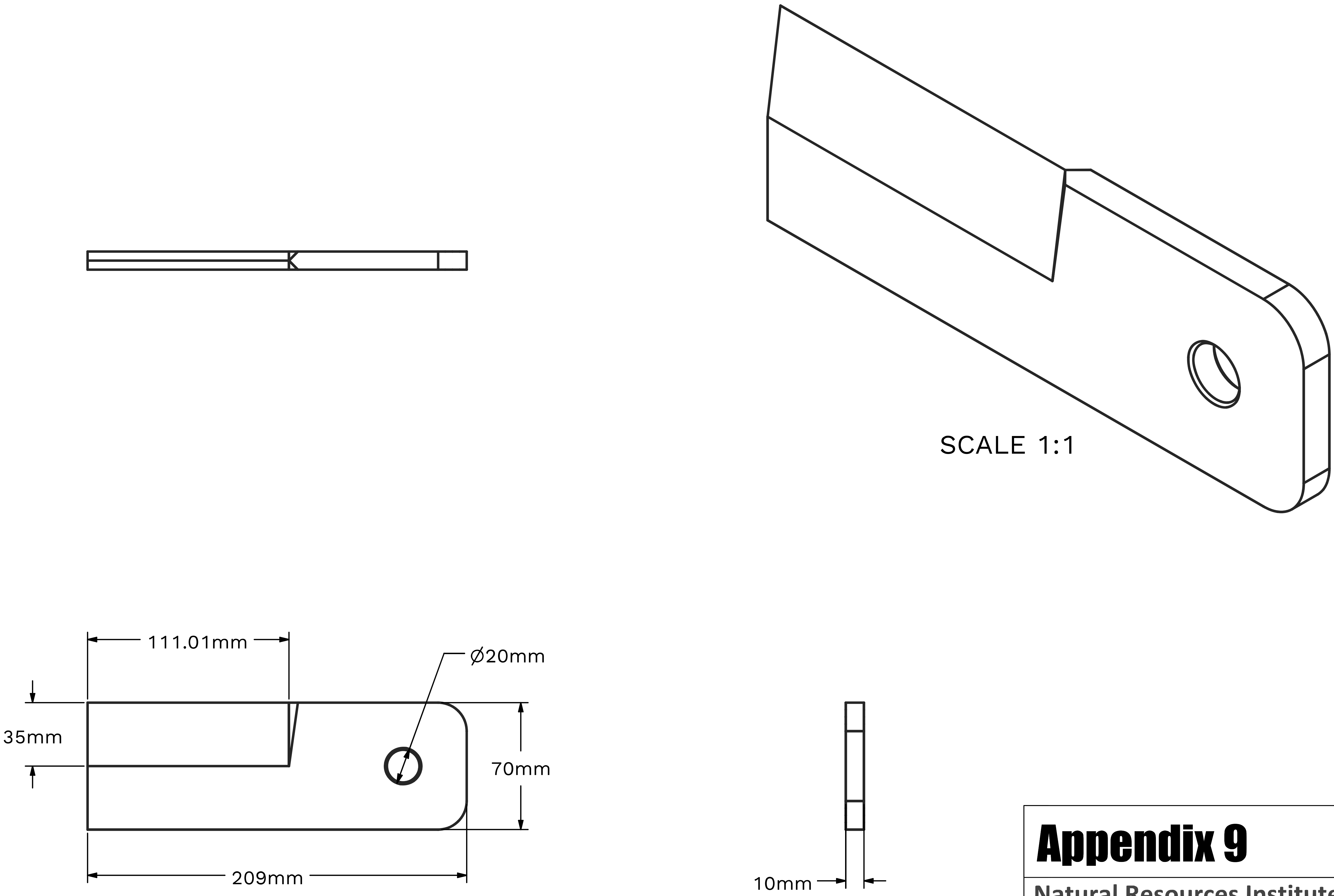

Appendix 9

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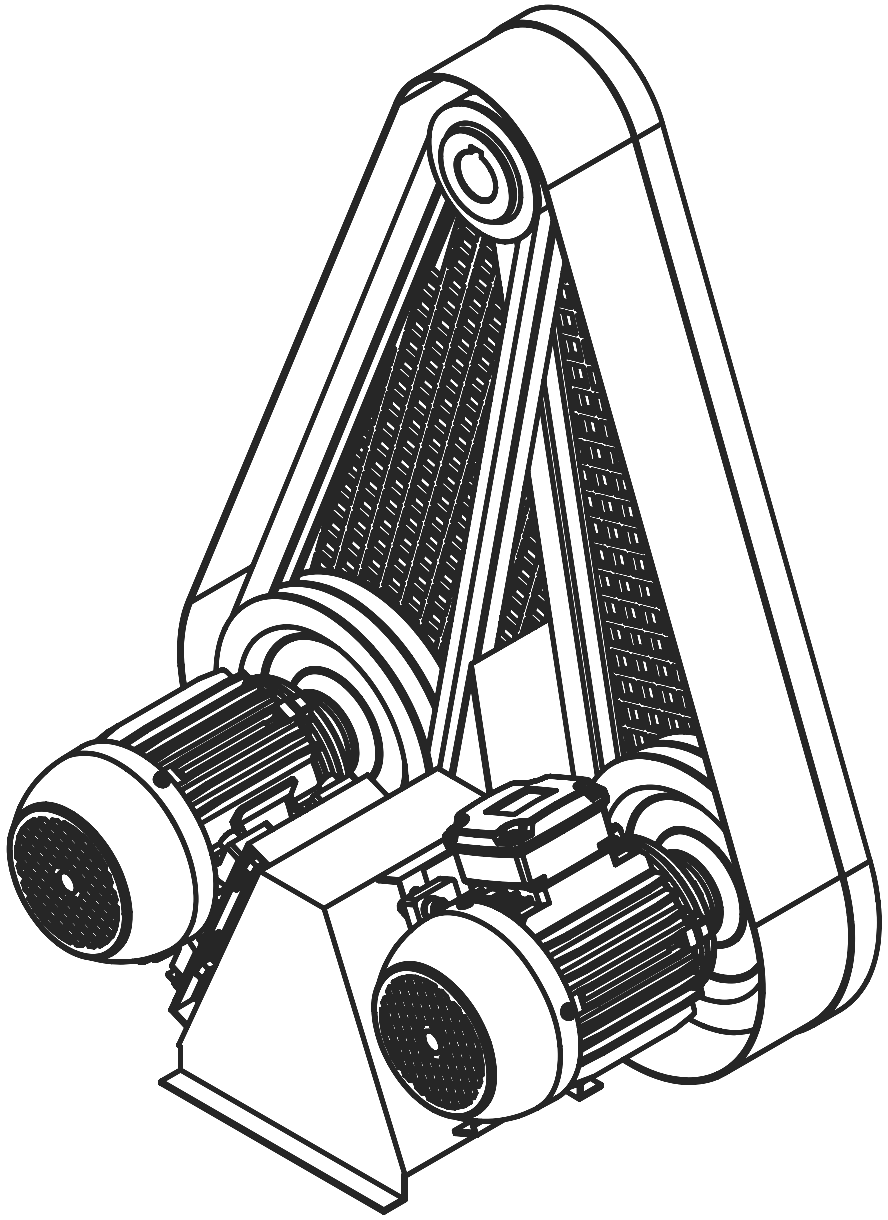

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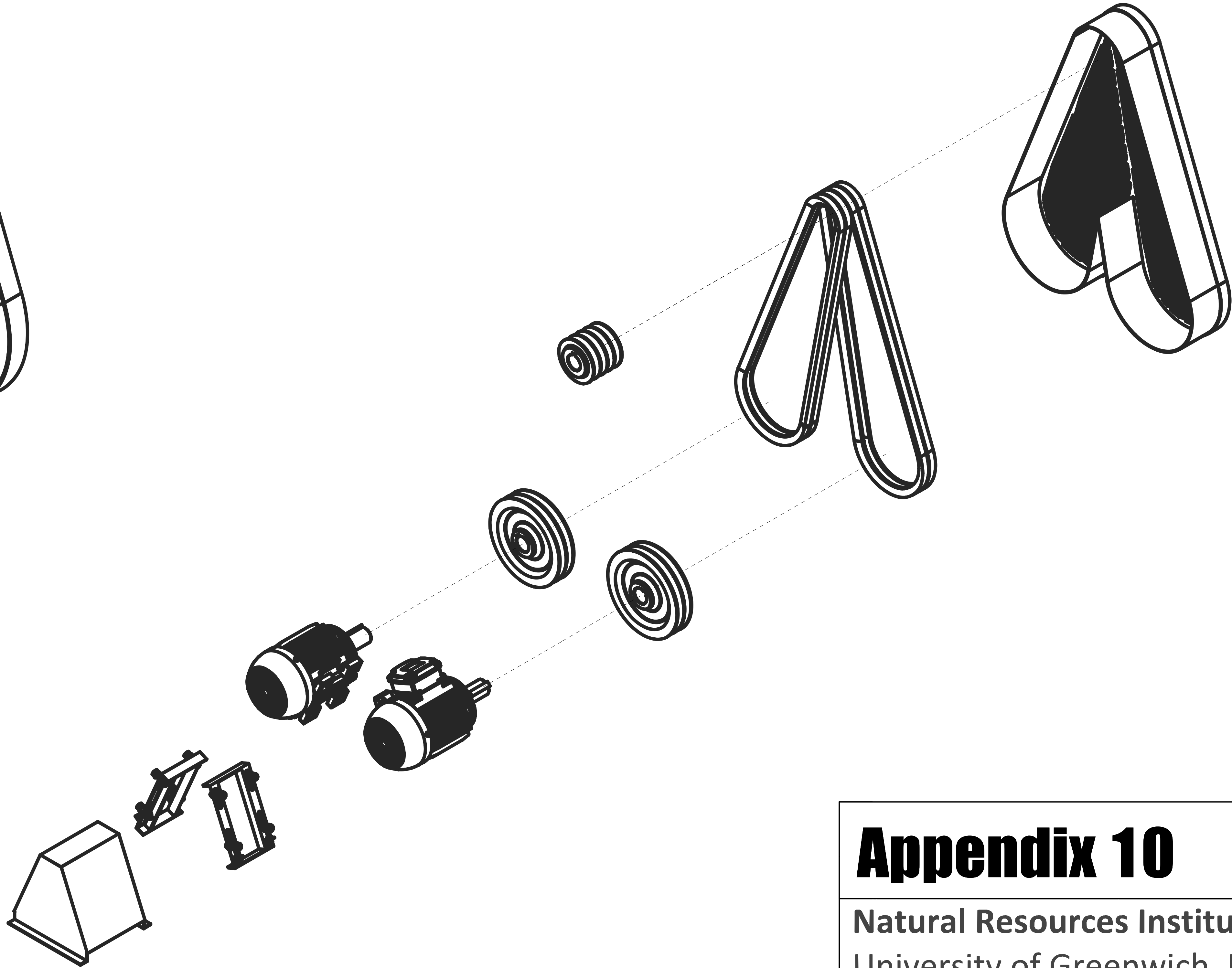

Appendix 10

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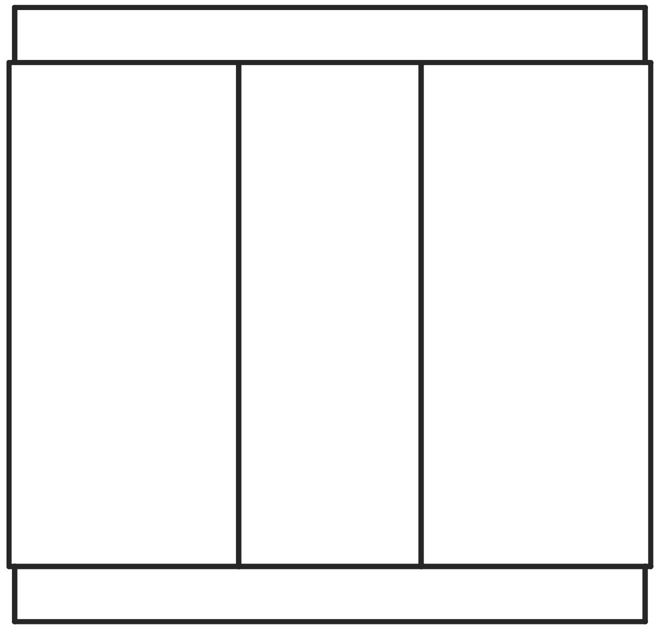
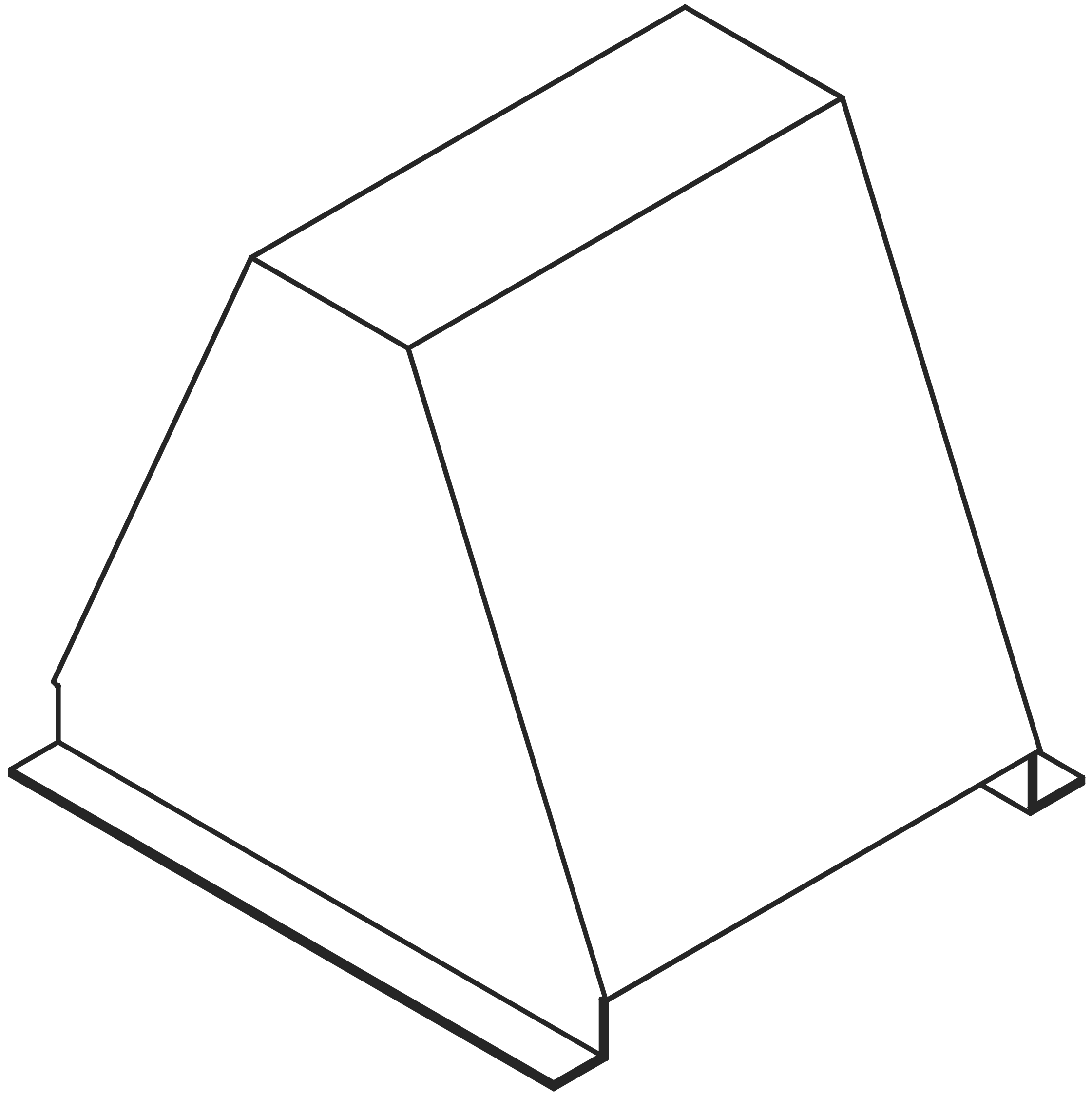
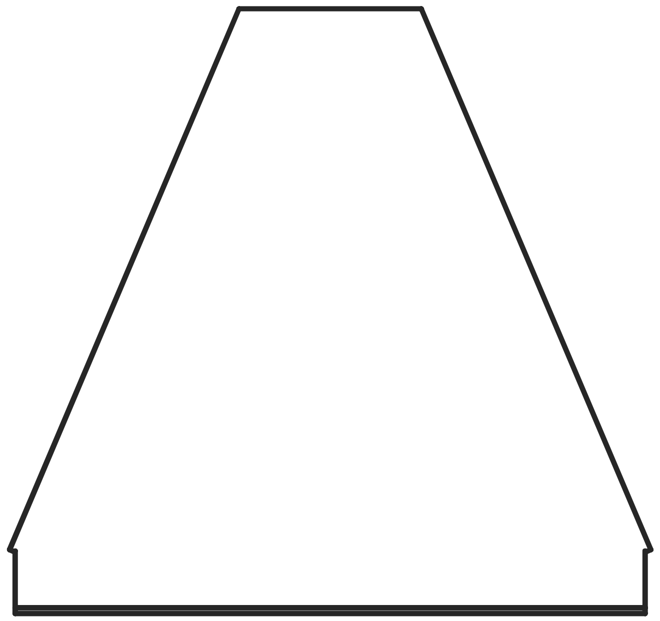
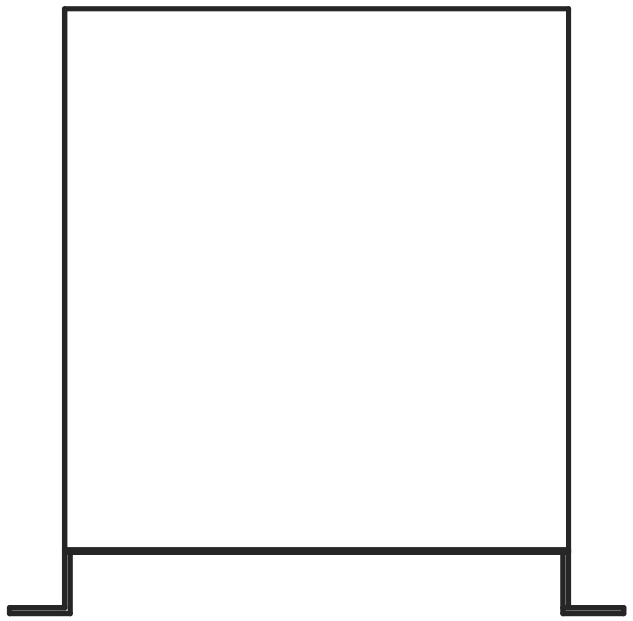
Not on the scale, dimensions should be determined according to the size of the DC motor.





SCALE 1:2





Appendix 11

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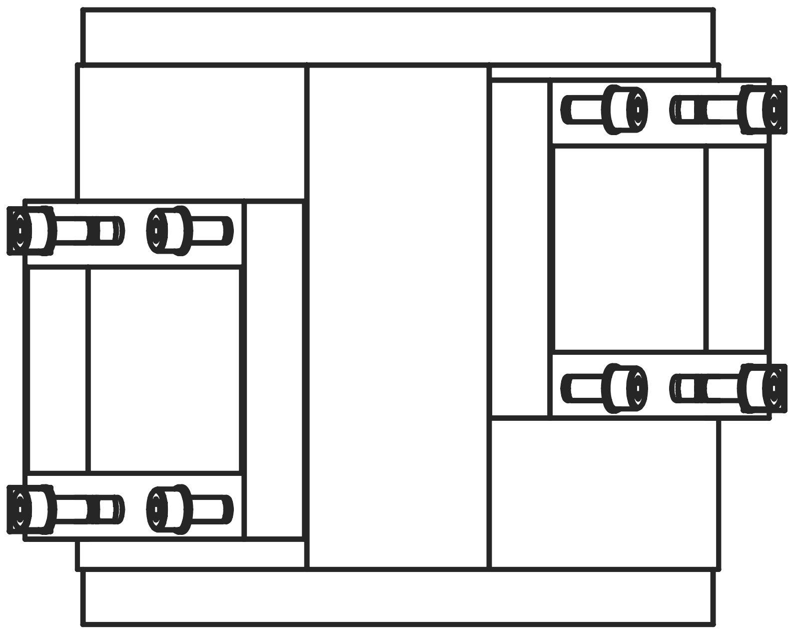
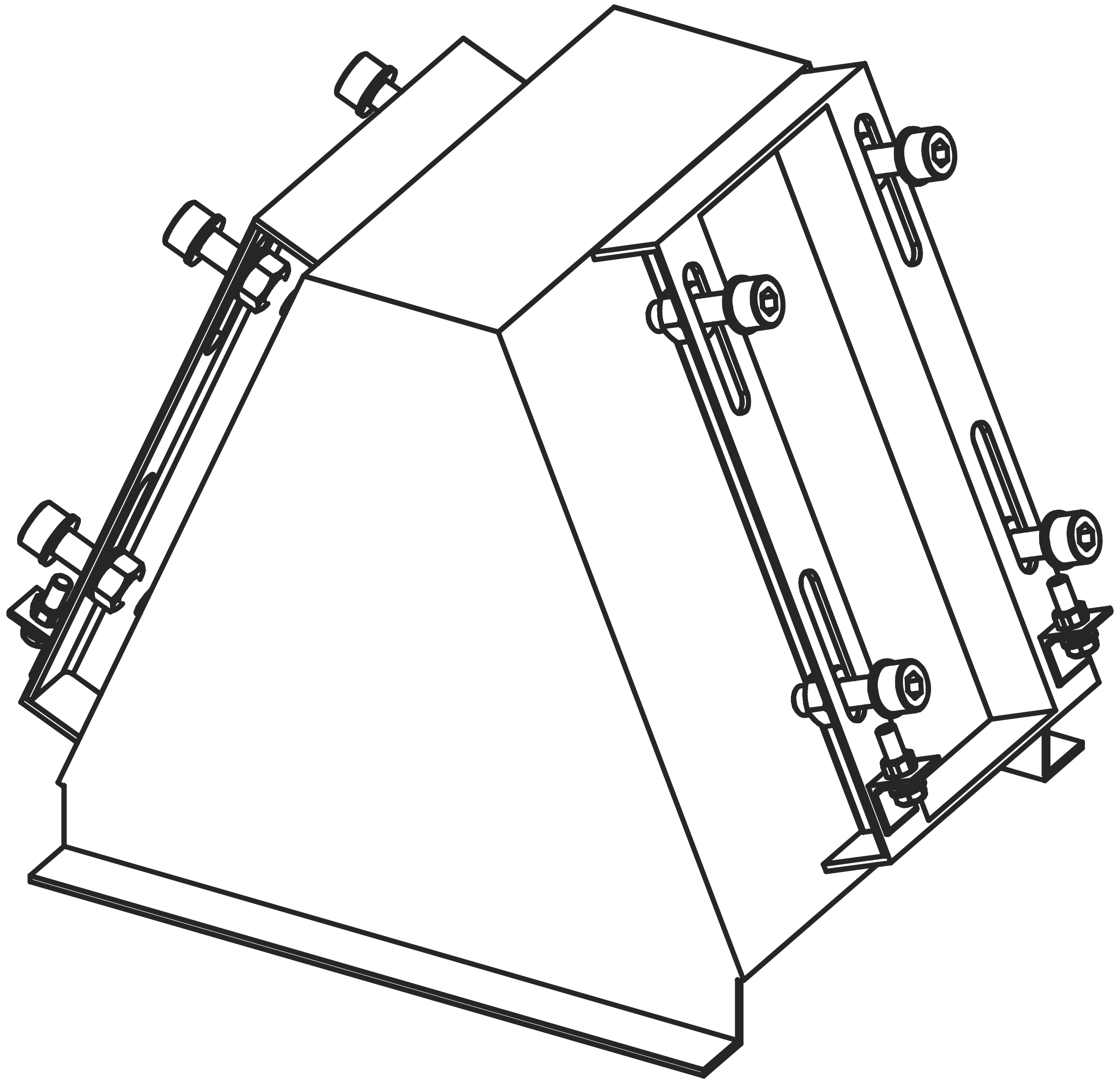
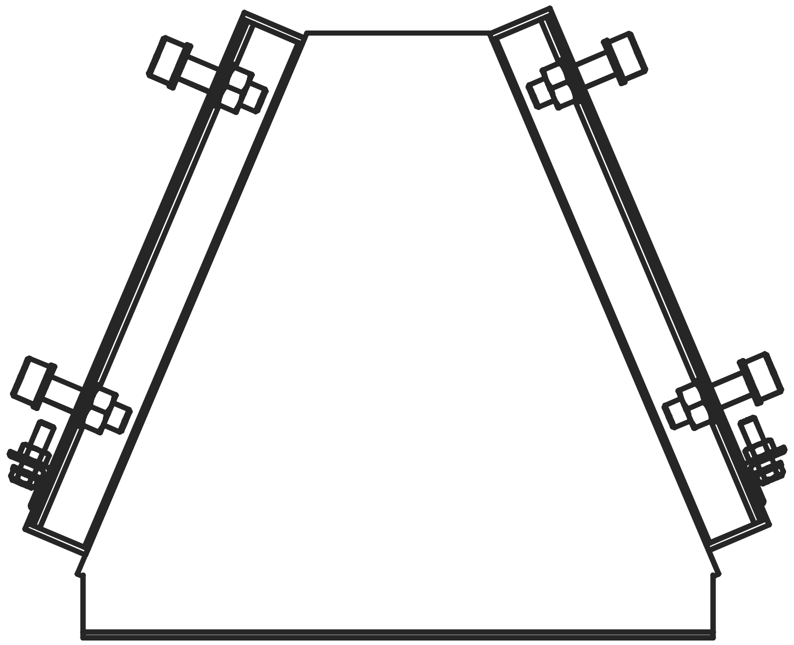
SCALE 2:5	SIZE A3

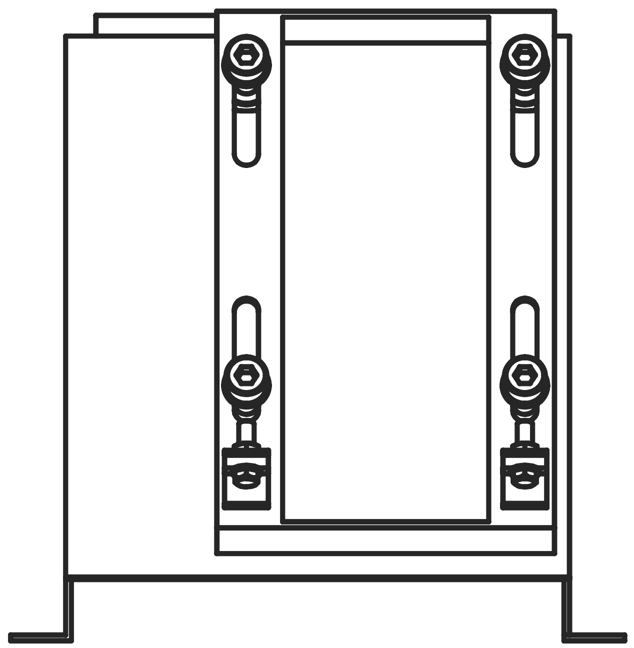
Not on the scale, dimensions should be determined according to the size of the DC motor.





SCALE 1:2





Appendix 12

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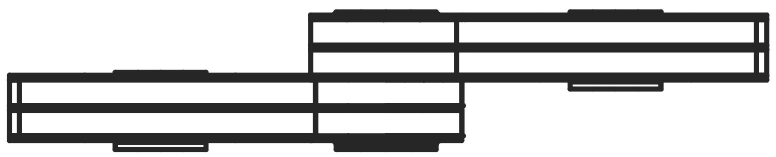
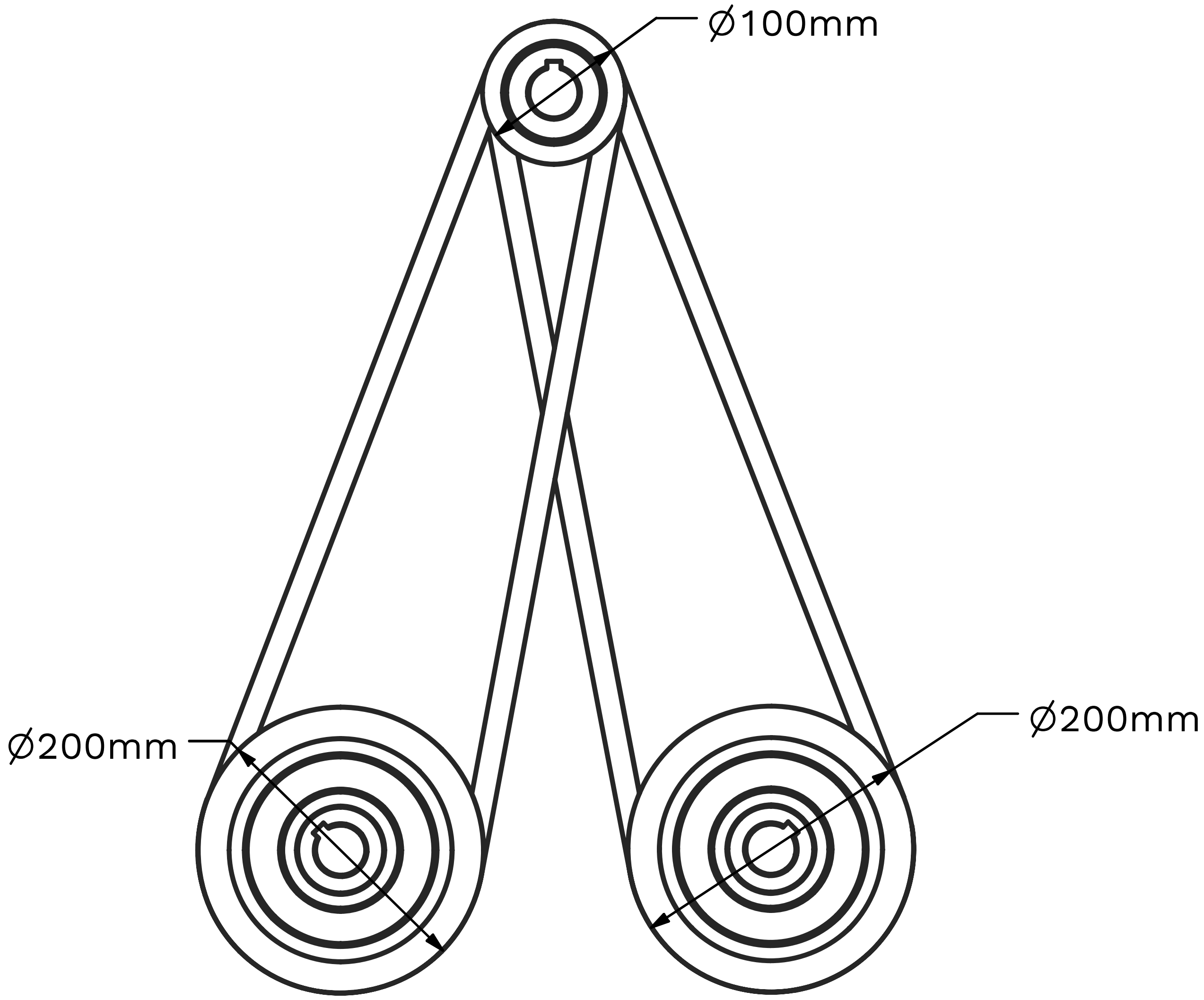
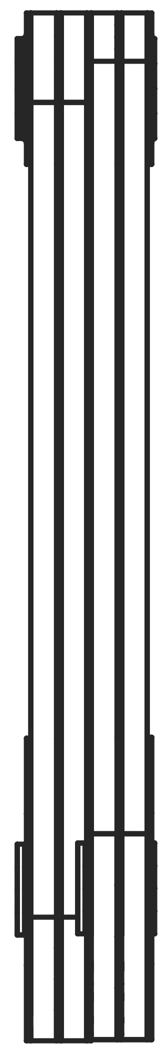
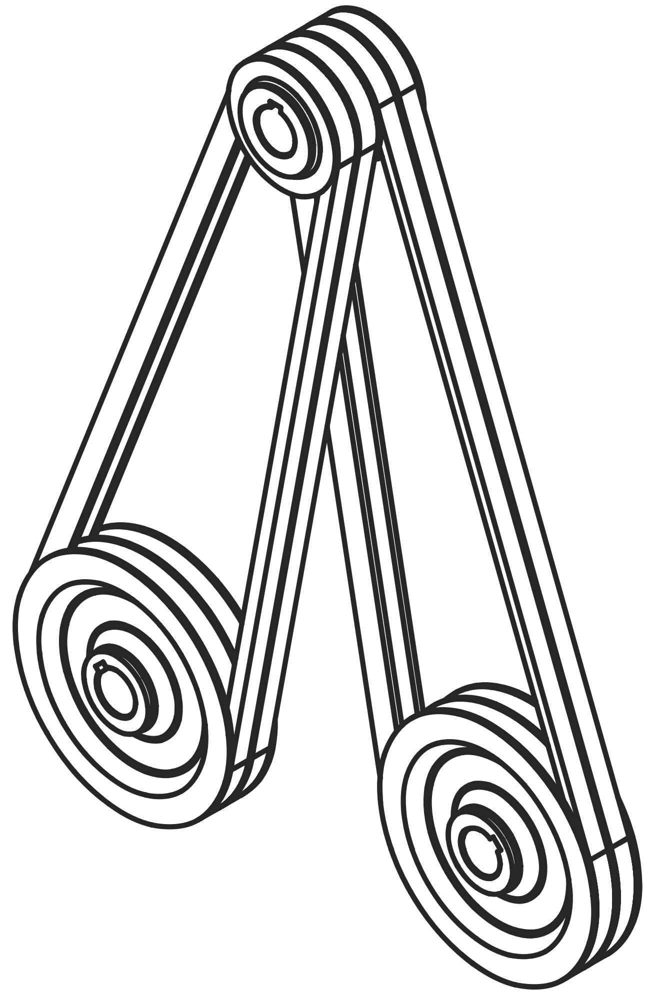
SCALE 2:5	SIZE A3









Appendix 13

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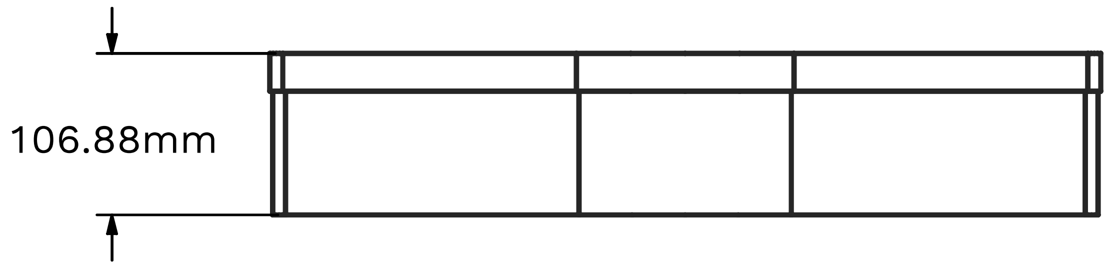
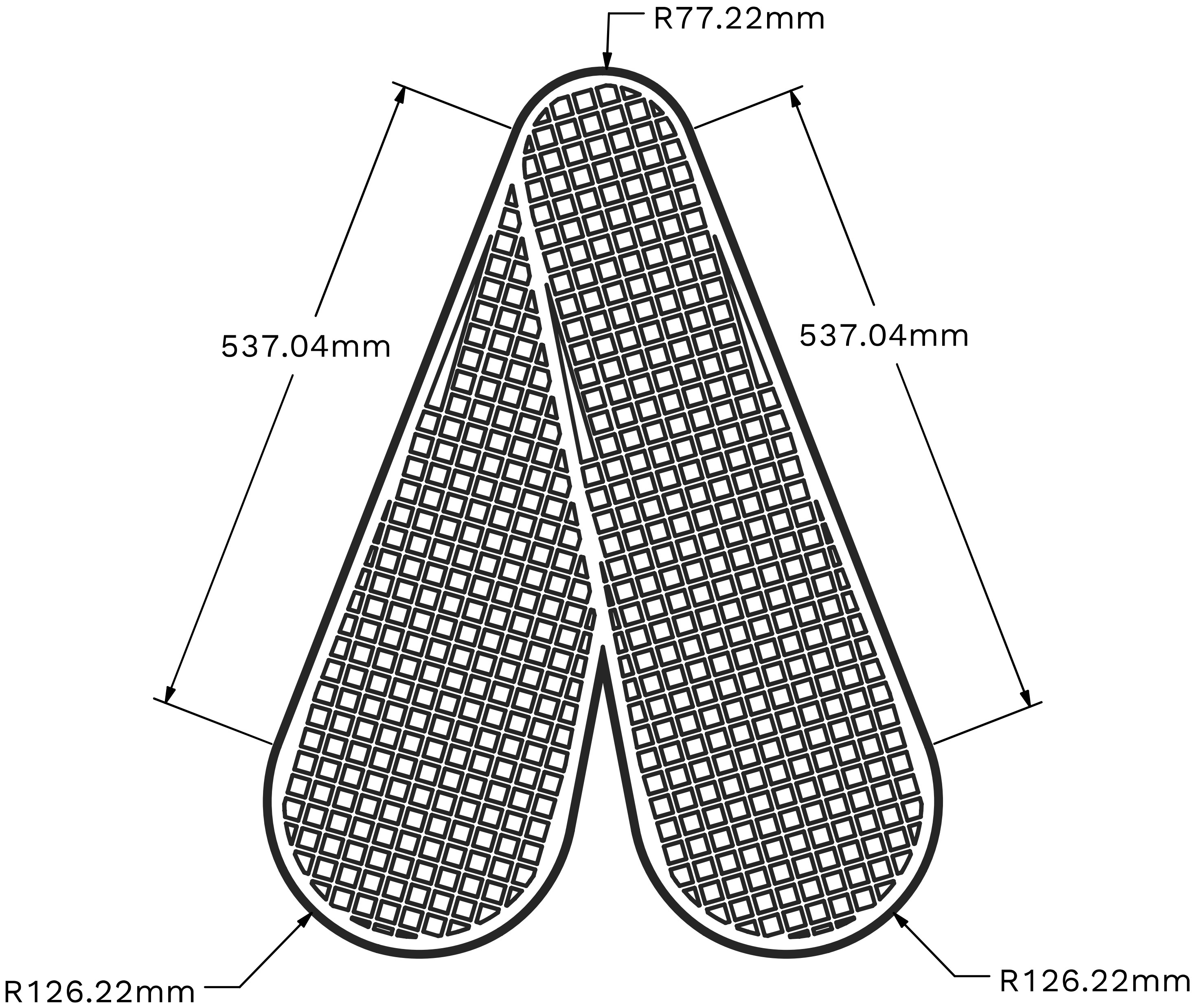
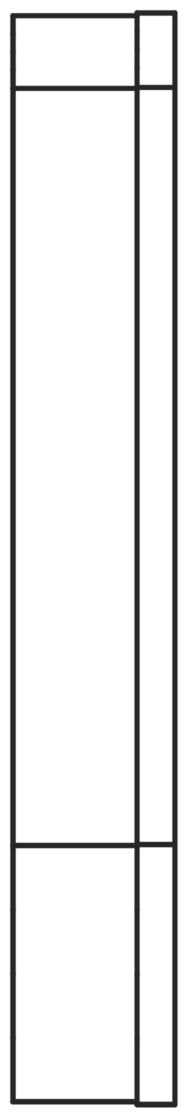
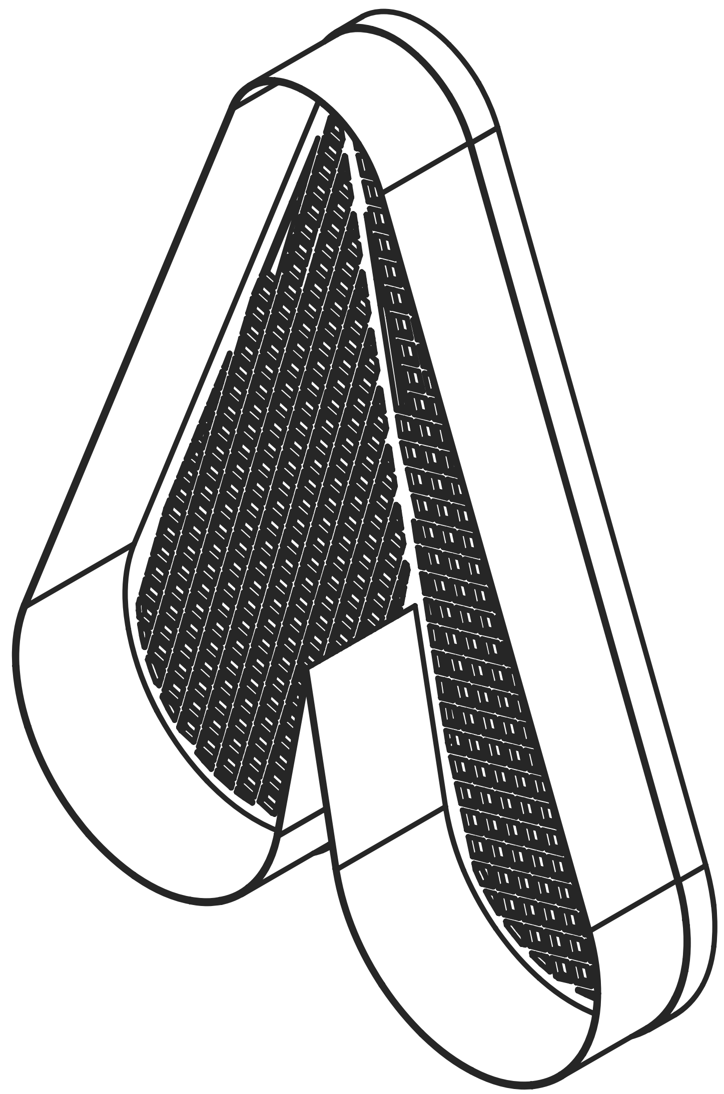
SCALE 1:5	SIZE A3









Appendix 14

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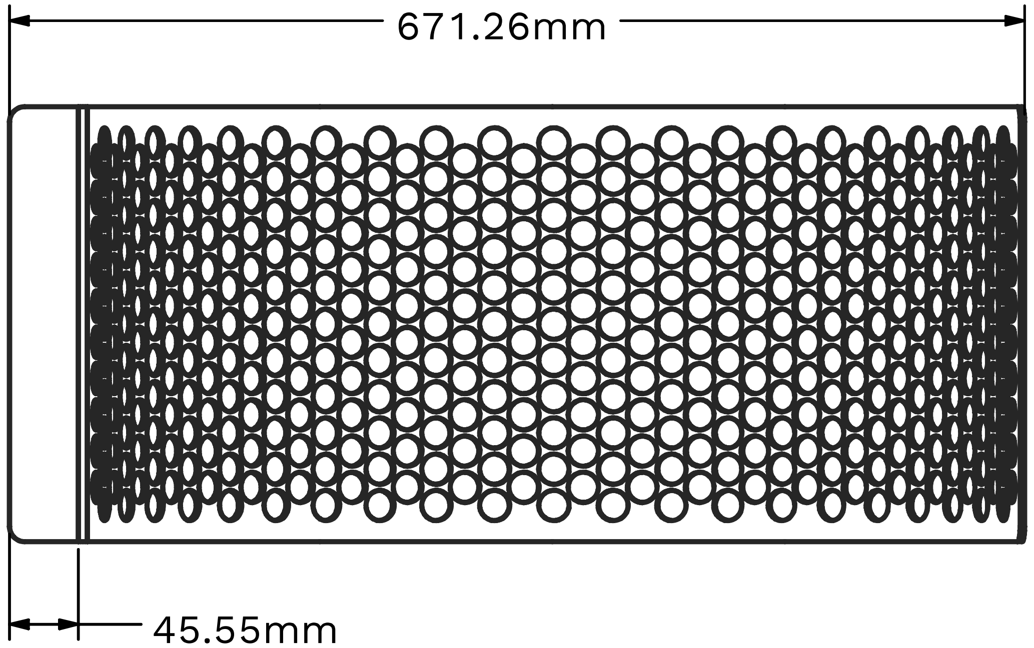
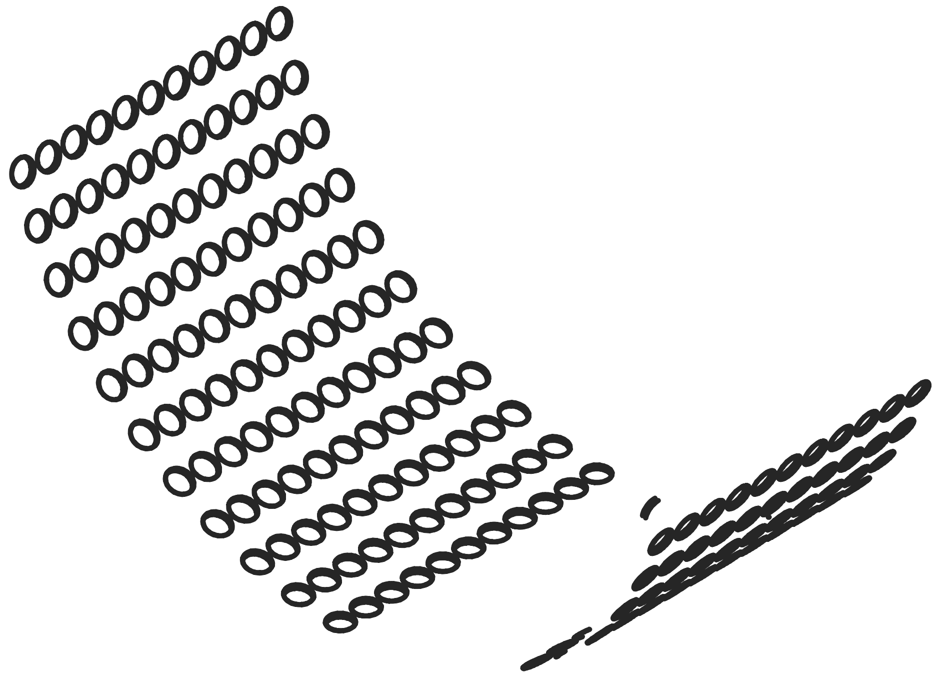
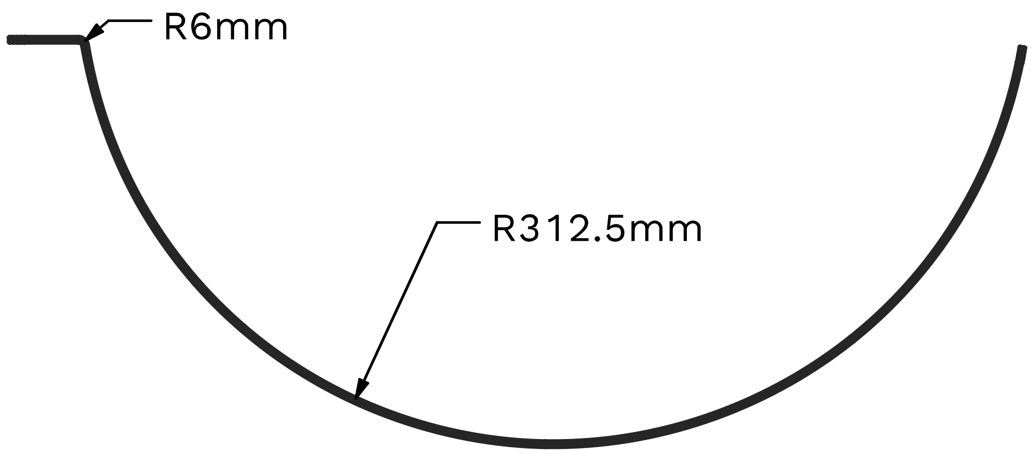
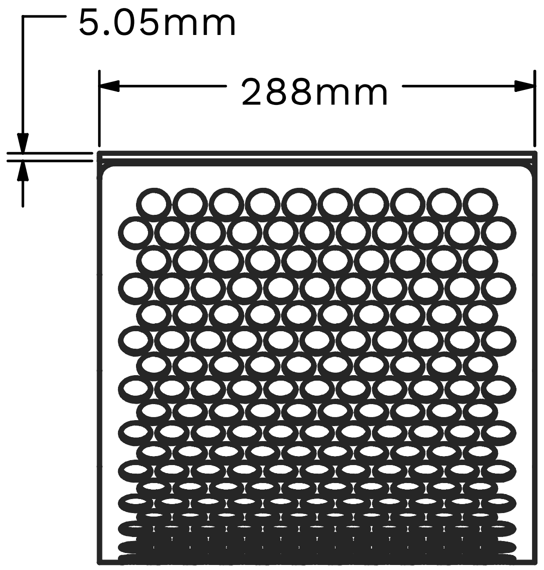
SCALE 1:5	SIZE A3

Mesh size for grating cassava roots: 20 mm, **10 mm**, **5 mm**
Mesh size for milling dried cassava grits: **0.5 mm**









Appendix 15

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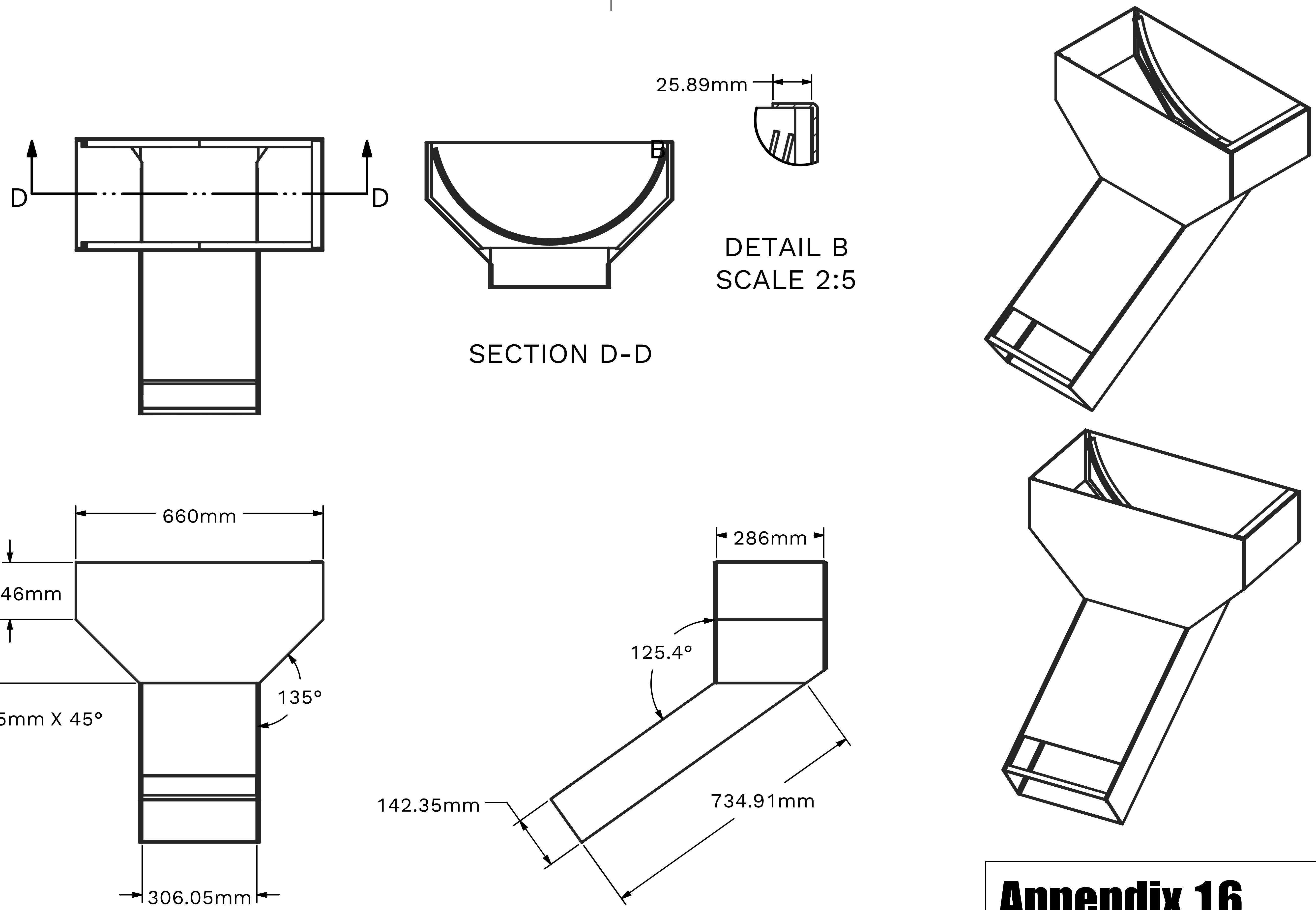
SCALE 1:5	SIZE A3



Appendix 16

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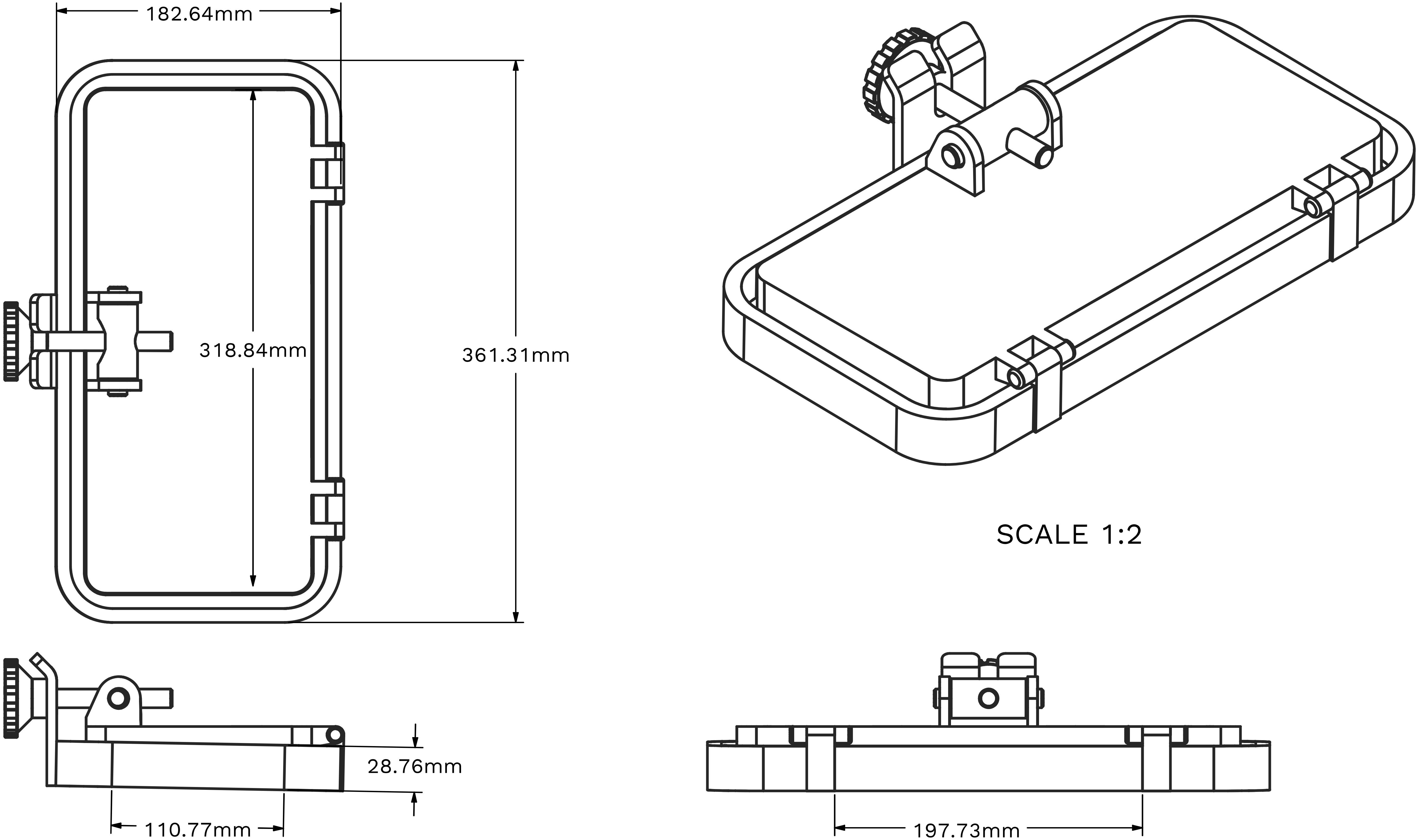
SCALE 1:10	SIZE A3



Appendix 17

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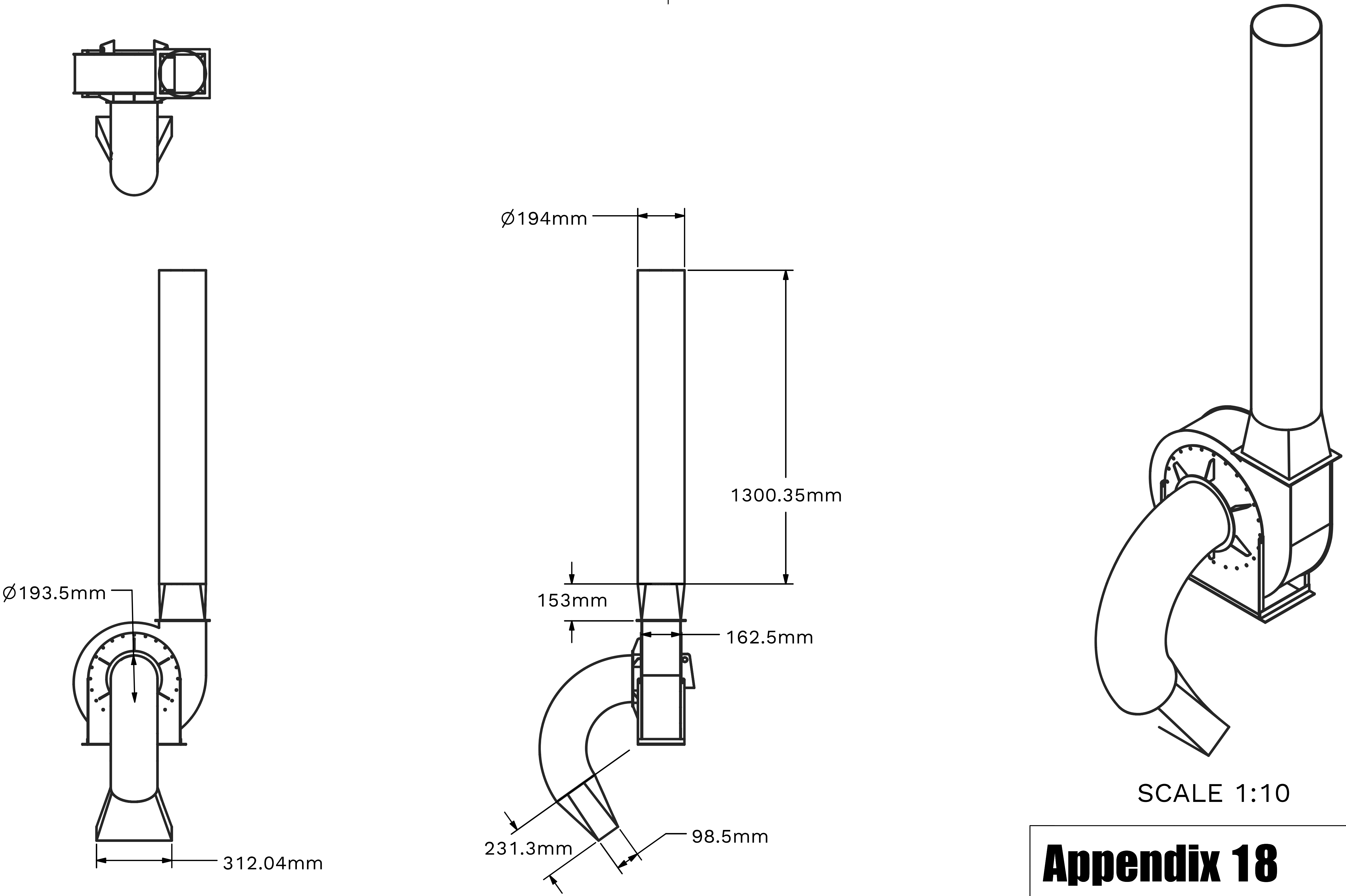
SCALE 2:5	SIZE A3



Appendix 18

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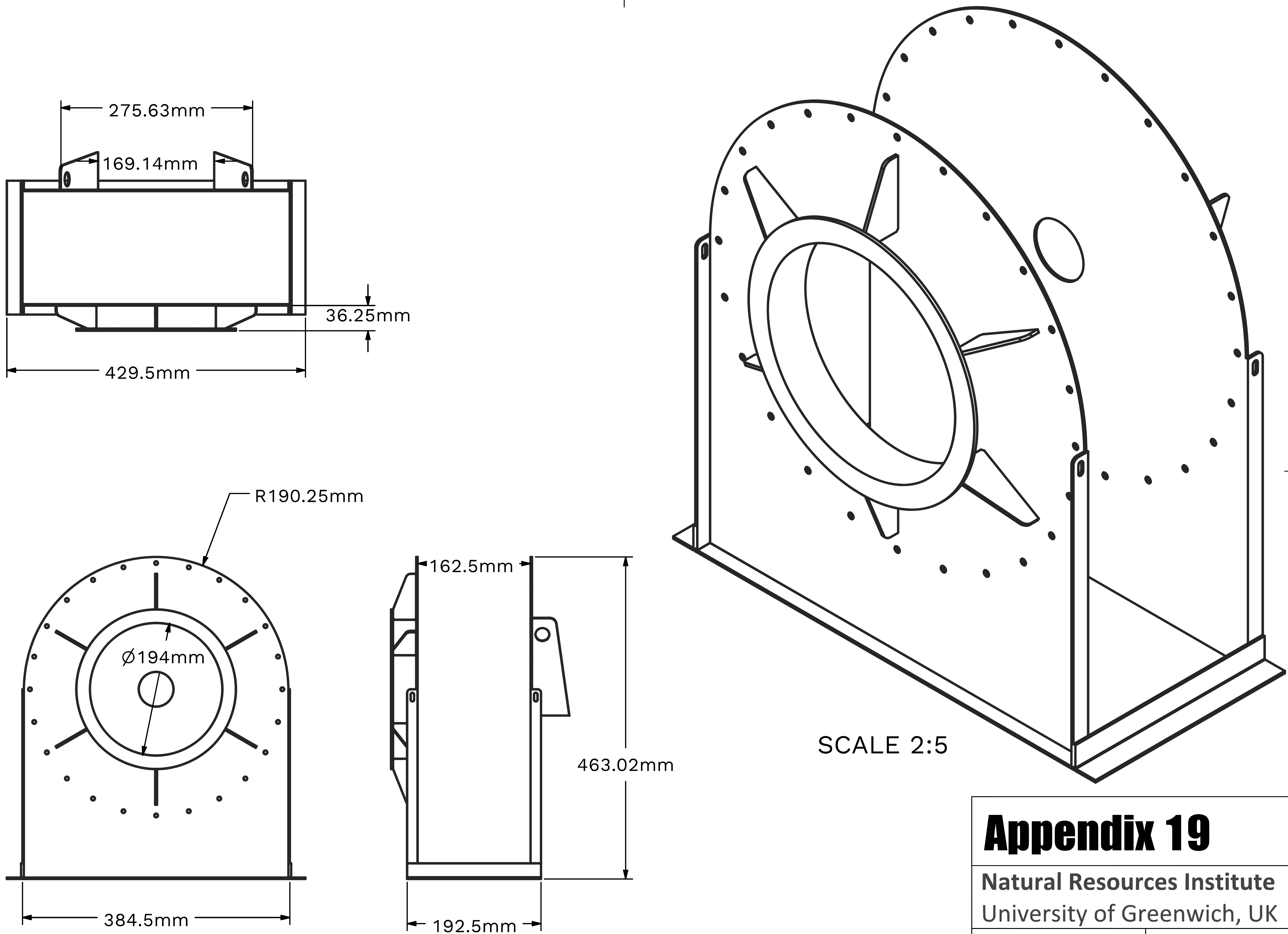
SCALE 1:15	SIZE A3



Appendix 19

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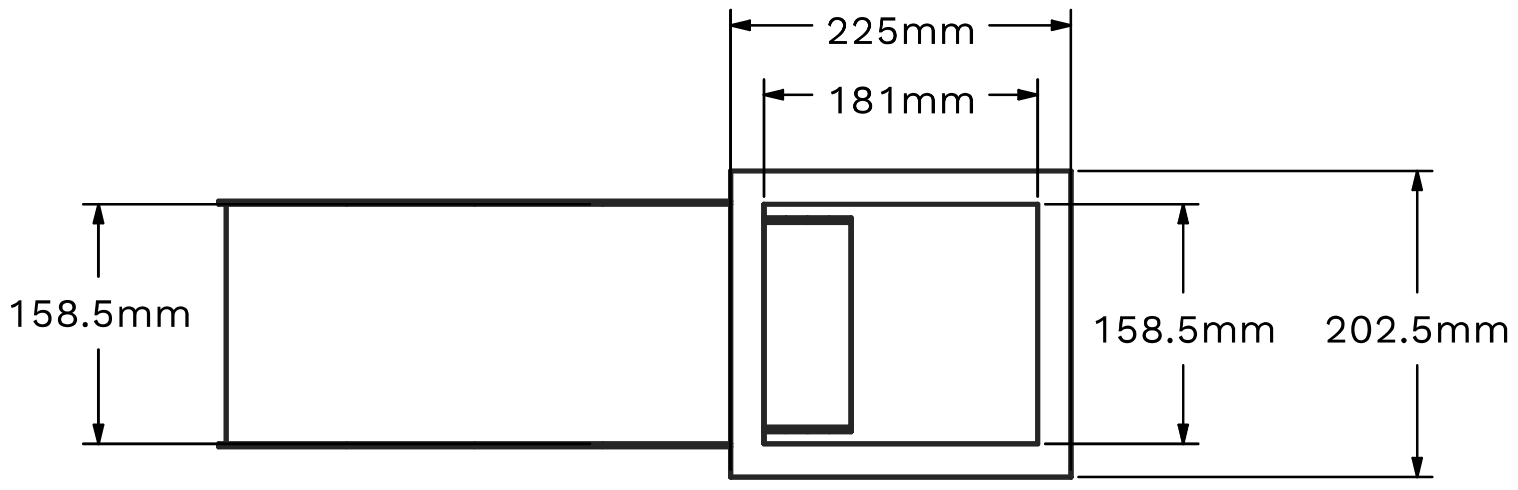
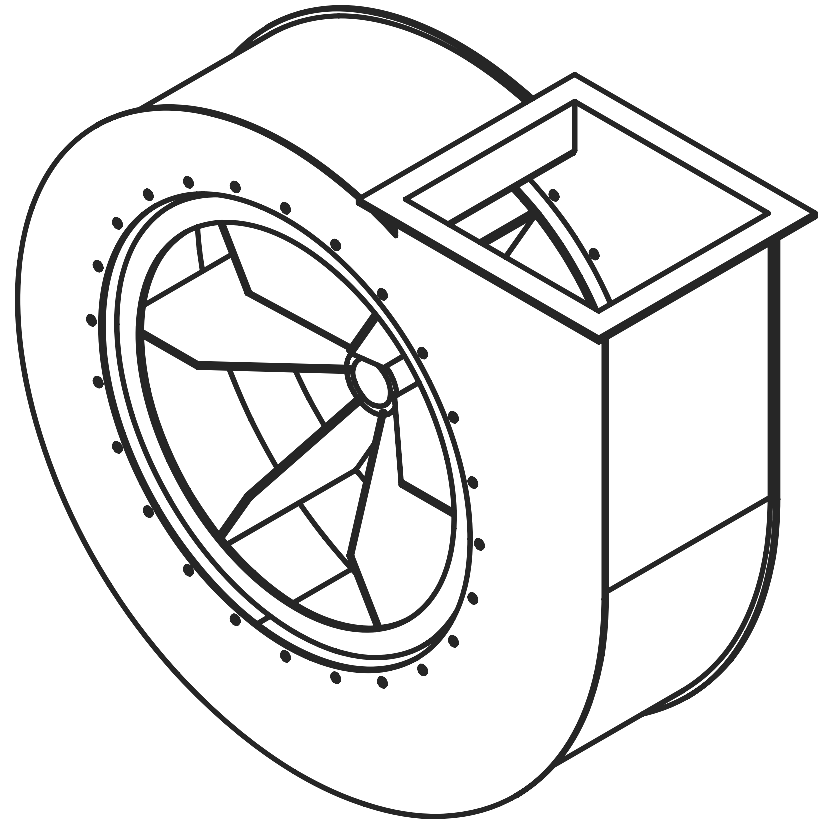
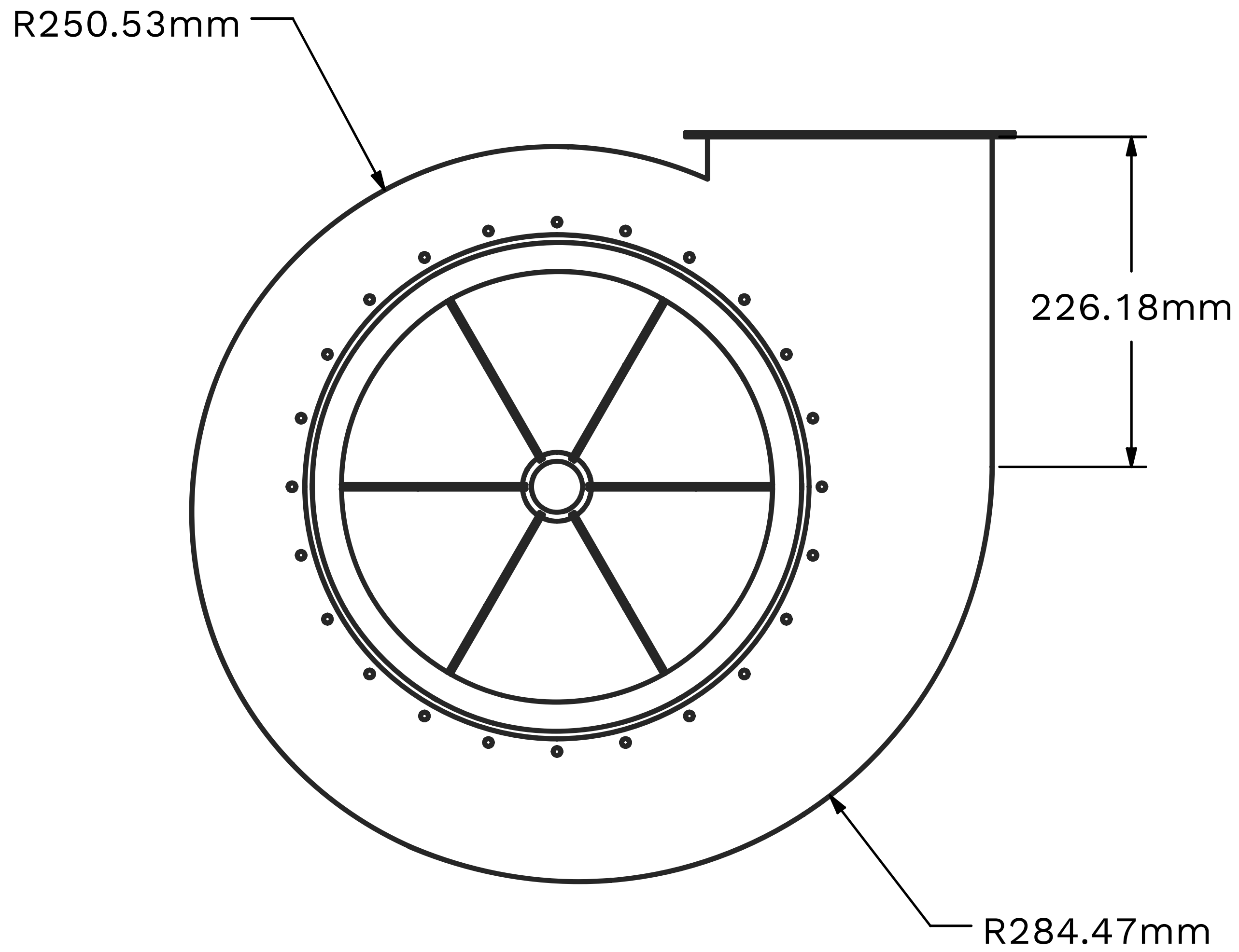
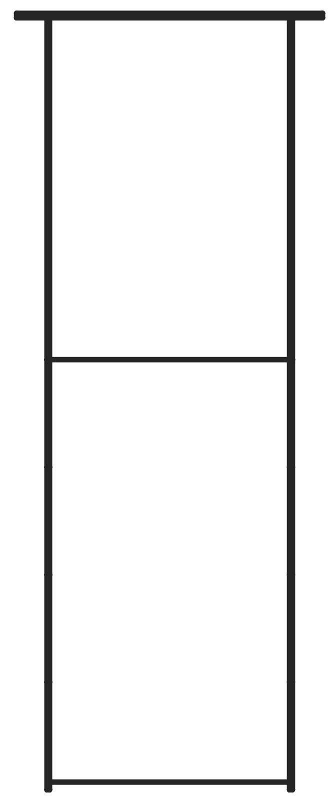
SCALE 1:5	SIZE A3









Appendix 20

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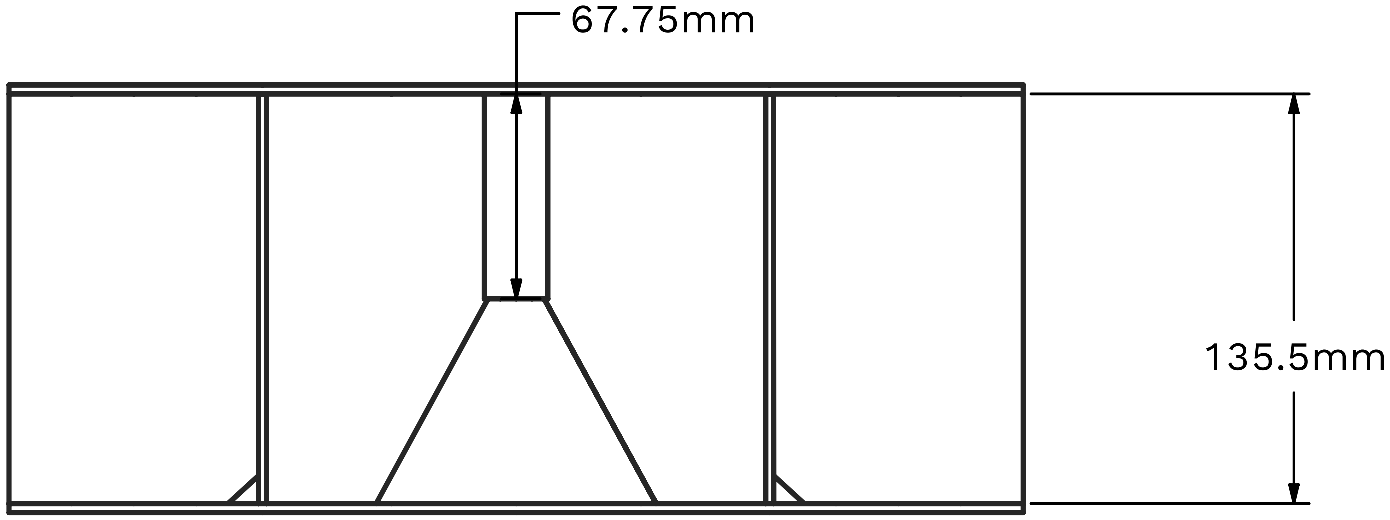
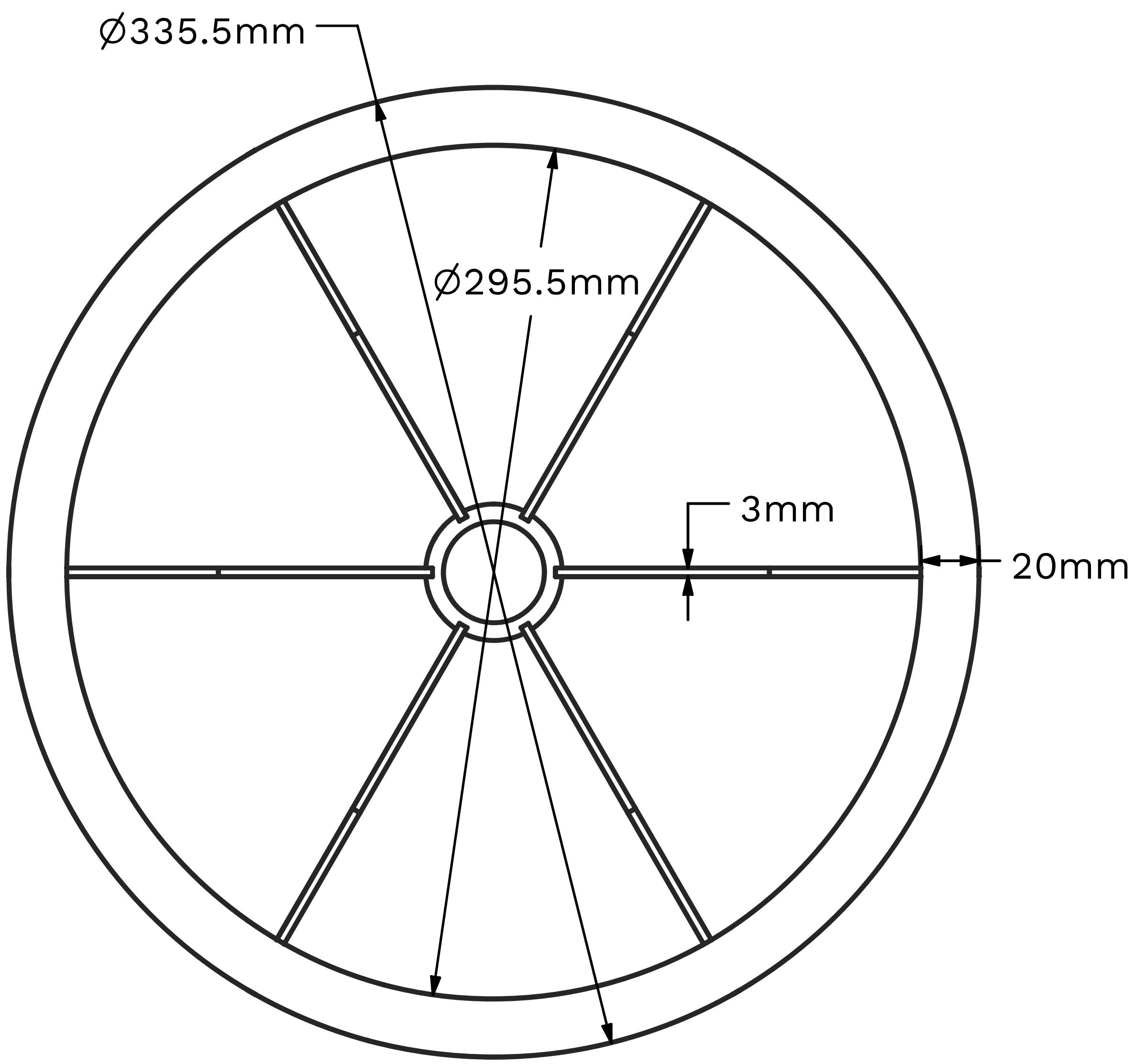
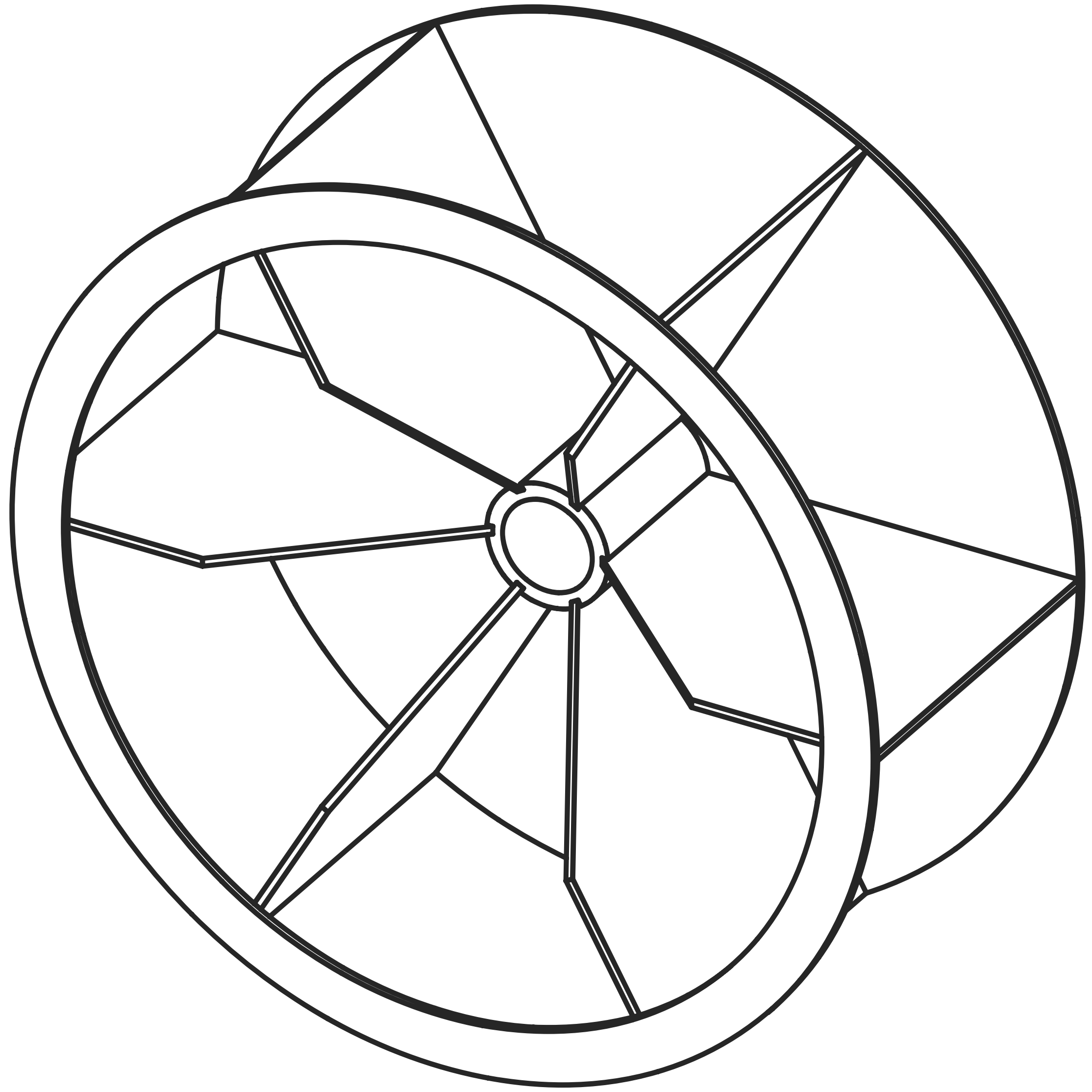
SCALE 1:5	SIZE A3







Appendix 21

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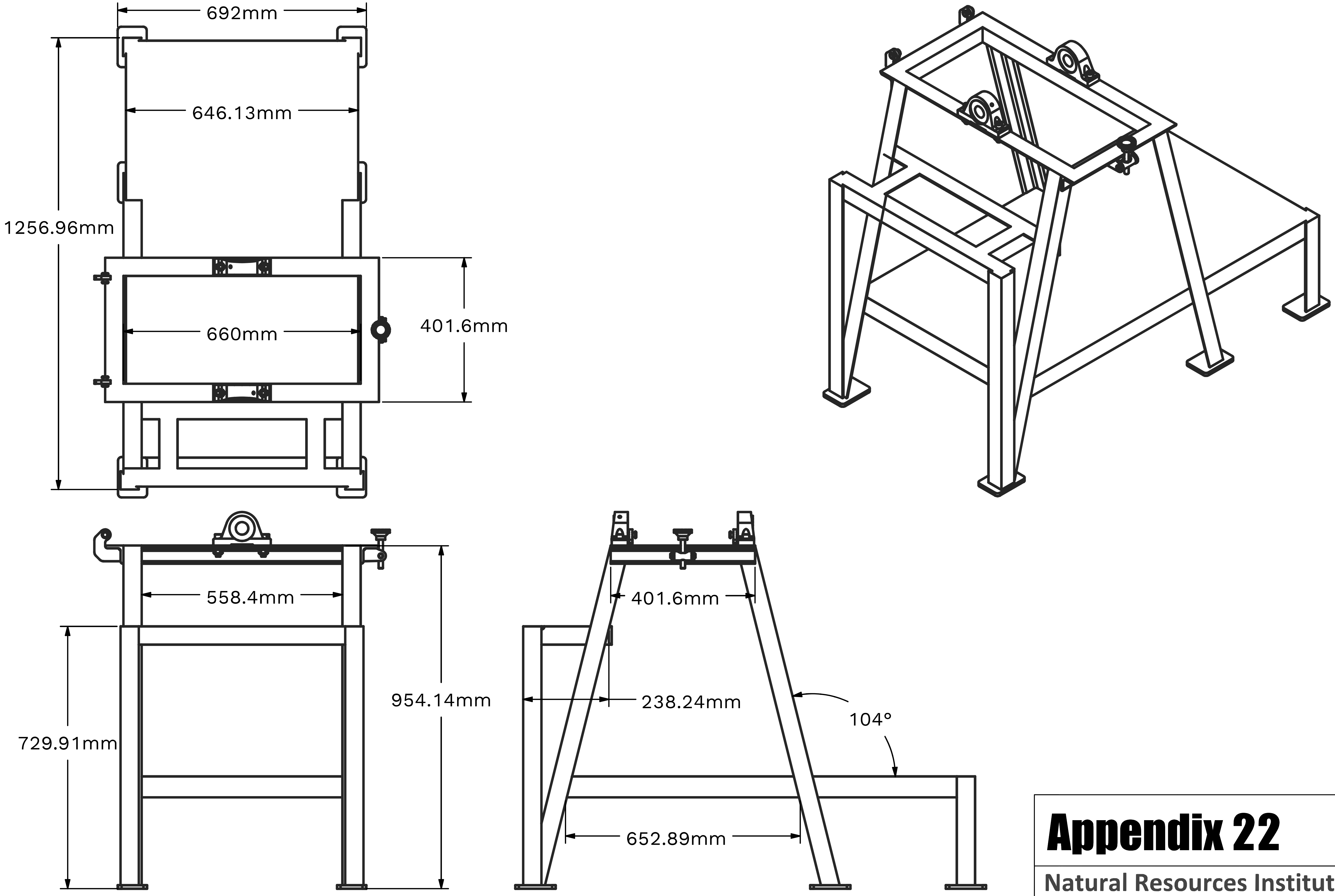
SCALE 2:5	SIZE A3



Appendix 22

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SCALE 1:10 | SIZE A3