RTB Working Paper

Construction guide of a small-scale pneumatic dryer to process cassava

Dr Marcelo Precoppe

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RESEARCH PROGRAM ON Roots, Tubers and Bananas
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LINKS TO 3D CAD FILES

ENTIRE ASSEMBLY

https://a360.co/38gGgkP or https://bit.ly/3mrBR3L or https://adobe.ly/3h3zkLY or https://adobe.ly/3rmrNN8

HEATING UNIT

https://a360.co/3my2CU5 or https://bit.ly/38k3SFa.

FAN

https://a360.co/3arH7lp or https://bit.ly/2Wolz0Z.

FEEDING SYSTEM

https://a360.co/3p7NMWb or https://bit.ly/37vvzeZ.

DRYING DUCT

https://a360.co/2WpijT1 or https://bit.ly/3mtAbGY.

CYCLONE

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INTRODUCTION

To process cassava into flour, the roots are peeled, grated, pressed, pulverized, dried, and milled. For drying, the best choice of equipment is a pneumatic dryer, also known as flash dryer. Pneumatic dryers have low capital and operating costs, and they are easy to build and are simple to operate. Large-scale pneumatic dryers for cassava processing are nowadays efficient because it has been subject to development for a long time. In contrast, small-scale ones, of a size suitable for small-size enterprises, are in the early stages of development, and most commercially available ones, are incorrectly dimensioned.

Pneumatic dryers are a continuously operated type of dryer, where wet solids are constantly loaded, and dried solids are constantly unloaded. In pneumatic dryers, drying occurs at the drying duct, while the solids are being transported pneumatically. Pneumatic dryers are classified as a convective dryer, however, in this dryer, hot air is not only used to remove moisture, but also to transport the material. In convective dryers in general, the energy performance is dictated by the heat transfer between solid and the hot air, the better the contact between them, the better the energy performance. In pneumatic dryers in specific, because the material is suspended in the air, the solid–hot air contact is total, and thus the heat transfer is optimum, explaining its high energy efficiency. However, pneumatic dryers must be properly dimensioned to operate efficiently.

Windwood Millers Ltd. (www.windwood.co) is a small-size cassava processing enterprise located in Lira, Northern region of Uganda. It is an established business supplying 400 tonnes of cassava flour, on an annual basis, to the domestic biscuit and brewery industries. Windwood Millers uses firewood powered pneumatic dryer to dry cassava, but their dryer was not correctly dimensioned, and consequently, its energy efficiency is very low. The objective of this working paper is to provide the instructions for Windwood Miller to build a properly dimensioned, and thus highly efficient pneumatic dryer.

PROPERLY DIMENSIONED PNEUMATIC DRYER

OVERVIEW

Pneumatic dryers are composed by a **heating unit**, a **fan**, a **feeding system**, the **drying duct**, and a **cyclone**. The dryer described in this construction guide was designed to operate in Lira, and local historical data on ambient air temperature, air relative humidity and air pressure were used in the calculations. The equipment was dimensioned to dry cassava from a moisture content of 45% on a wet basis (wb) to a moisture content of 12%wb. The throughput of the dryer was designed to match Windwood Millers existing firewood powered pneumatic dryer, delivering 150 kg of dried product per hour. Because the correct dimensioning of this dryer it is expected an energy efficiency 60%, meaning that to produce 1 kilogram of dried product 0.1 litres of diesel will be consumed. In addition, the dryer was designed to fit in the same room where the existing dryer is located, and Figure 1 shows the available floor area for the equipment. To facilitate construction and reduce its total height, the drying duct was divided into 3 vertical meandering sections, as shown in Figure 2. Drawing Sheet 1 provides an overview of the dryer, however exactly dimensions should be obtained from the 3D CAD files that can be viewed and downloaded from https://a360.co/38gGgkP or https://bit.ly/3mrBR3L. In addition, the 3D assembly in CATIA V5 format can be downloaded from https://adobe.ly/3h3zkLY and in STEP format can be download from https://adobe.ly/3rmrNN8. Appendix 1 provides instructions on how to download them.

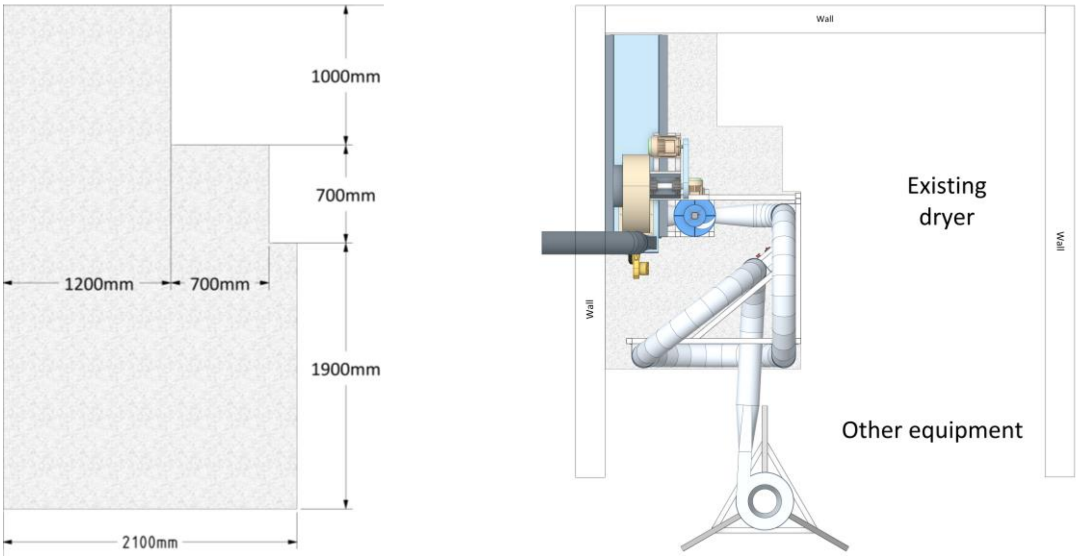


Figure 1. Floor area available for the installation of the dryer.

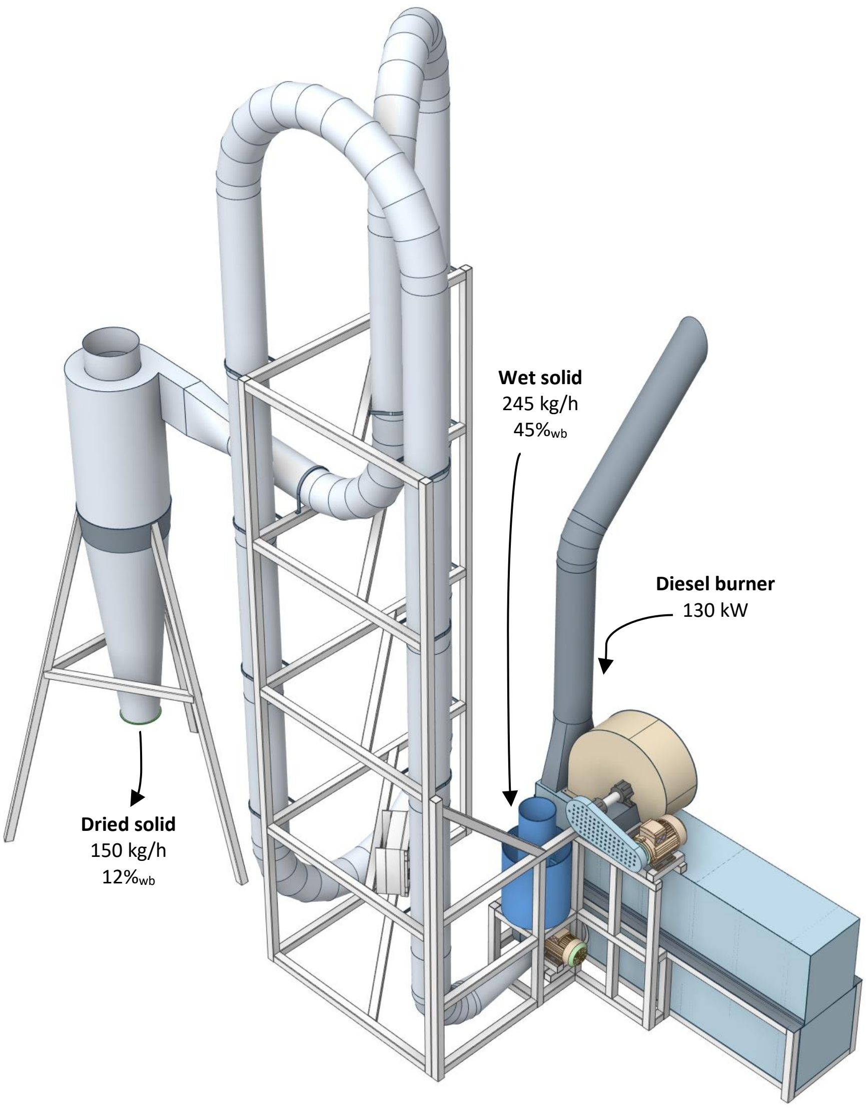


Figure 2. Overview of the dryer to be built by Windwood Millers in Lira, Uganda.

During the dryer construction, it is important to note that all parts that come in direct contact with cassava grits must be built with food-grade stainless steel. Parts that do not come in contact with the cassava grits, like the supporting structure, does not need to be made of stainless steel but must be coated with corrosion-resistant paint.

HEATING UNIT

The heating unit has the function to warm-up the air. The unit consists of a burner, a combustion chamber, and a heat exchanger (Figure 3). Figure 4 shows details of the shell-and-tube heat exchanger, where the heat that the burner has generated is transferred to the drying air. It contains a bundle of parallel tubes enclosed in a shell. A turbulator, placed inside each of the tubes, increase heat transfer surface further. The burner to be used with this heating unit should have a power of 130 kW. An example of a suitable burner is the Bairan model B14, or Riello model 40G.

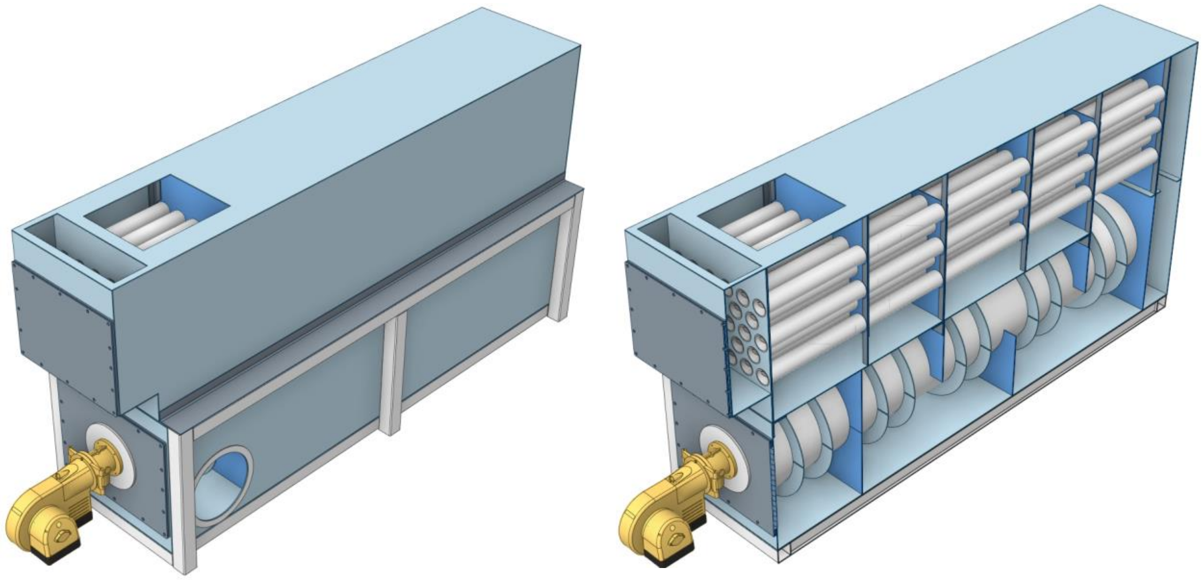


Figure 3. The designed heating unit, composed of a burner, combustion chamber and heat exchanger.

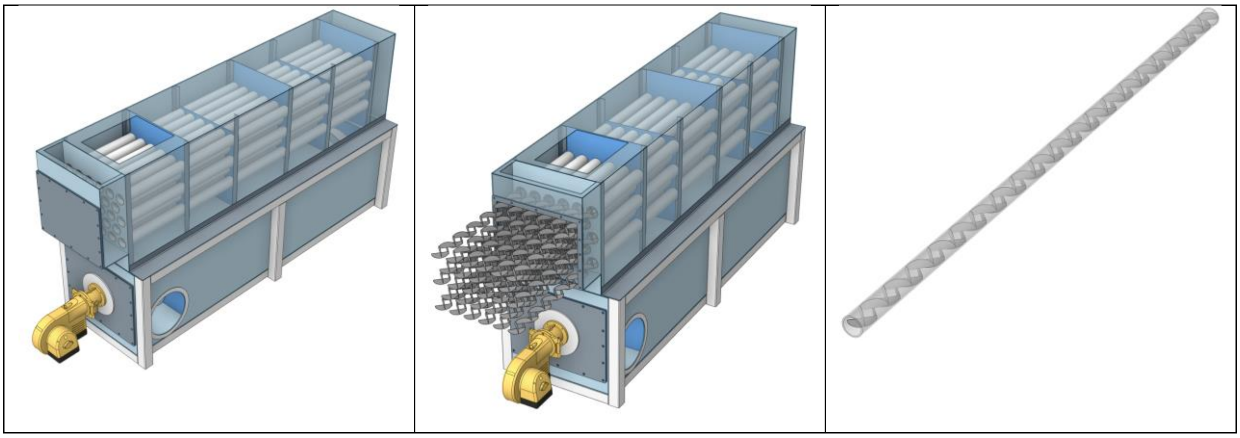


Figure 4. Shell-and-tube heat exchanger with turbulator inside the tubes to the increase heat transfer surface.

Drawing Sheet 2 provides an overview of the main dimensions of the heating unit, but exact figures should be obtained from the 3D CAD files that can be visualized and downloaded from https://a360.co/3my2CU5 or https://bit.ly/38k3SFa.

FAN

The fan has the function to induce the air. The designed fan is a centrifugal blower with a squirrel-cage impeller (Figure 5). It should be powered by a 5 HP three-phase electric motor, using V-belt transmission. All belt drive components must be enclosed under a safety guard. The impeller should have a speed of about 950 rpm, but the exact rpm, and consequently the pulleys' sizes, need to be determined by trial and error, using an anemometer to measure the air velocity (see Appendix 2 for a detailed explanation on the procedure). Drawing Sheet 3 provides an overview of the main dimensions of the fan, but exact figures should be obtained from the 3D CAD files, that can be visualized and downloaded from https://a360.co/3arH7lp or https://bit.ly/2Wolz0Z.

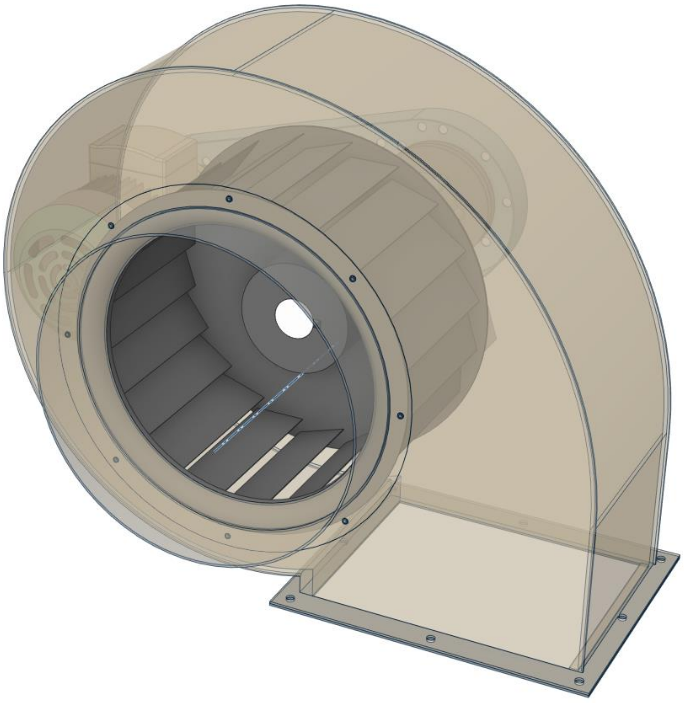


Figure 5. Single inlet centrifugal fans to generate the forced airflow.

FEEDING SYSTEM

In pneumatic dryers, the material should be introduced to the drying duct in a controlled, specified rate, and should be well dispersed with the airstream. Wet cassava grits have poor flow properties, and to avoid material bridging or ratholing, the hopper should have vertical walls. As shown in Figure 6, the material outlet o the feeder is a central orifice in the bottom of the hopper. Directly above this orifice, a cylinder lodges the motor and gearbox that moves the flow aid device. The flow aid device has a curved shape and as rotates, moves the material to the outlet. The rotational speed of the flow aid device should range from 14 rpm to 40 rpm, and therefore the correct combination of motor, gearbox and speed-controller must be employed. The feeding rate is controlled by changing the rotational speed of the flow aid device. Calibration must be performed to identify the rotational speed that would feed 245 kg/h to the dryer. Appendix 3 explains the calibration procedure.

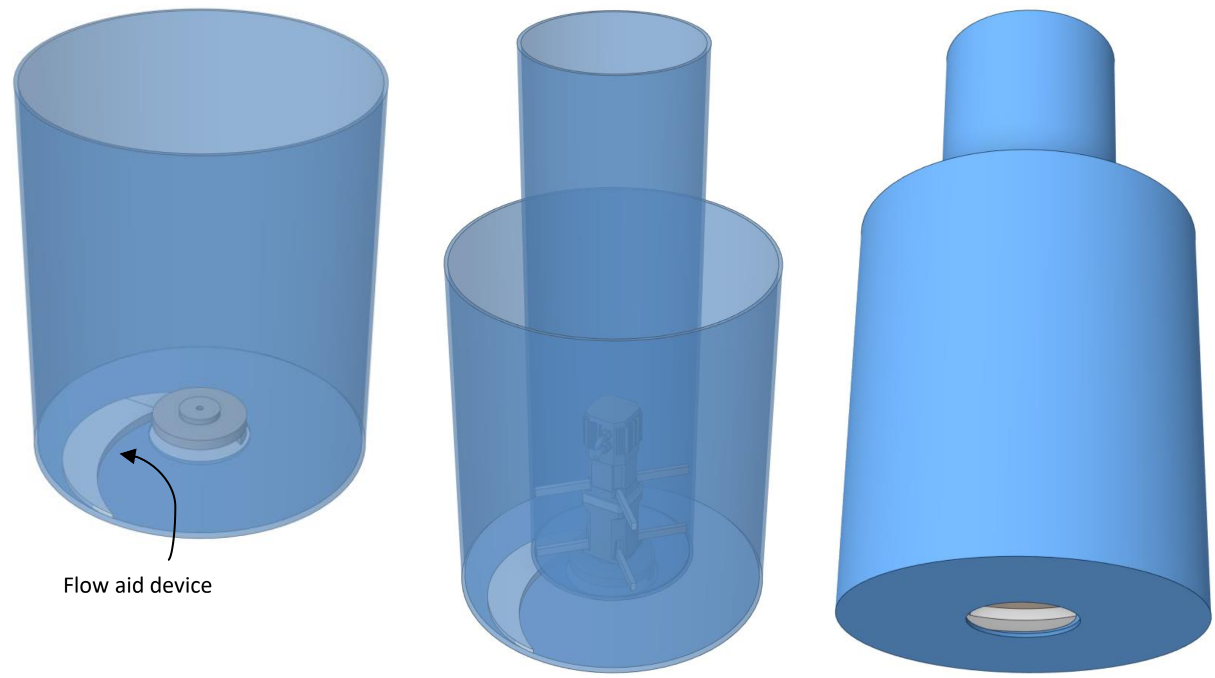


Figure 6. For wet cassava, the hopper of the feeding system must have vertical walls to avoid flow problems.

Because pneumatic dryers must be fed with non-lumpy material, after the feeder, a disintegrator must be present to break any agglomerated material developed, assuring a steady stream of finely divided solid that disperses evenly into the airstream (Figure 7).

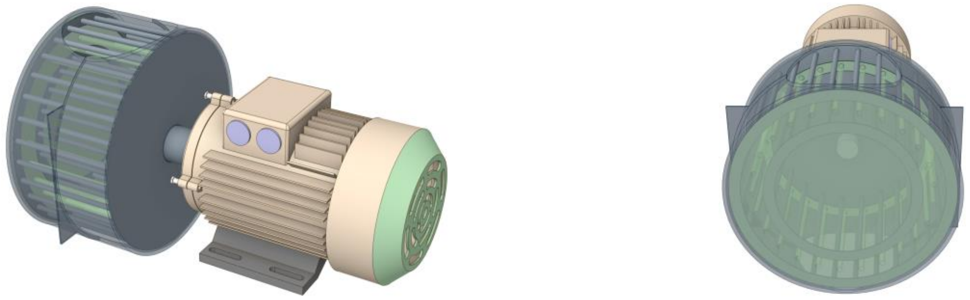


Figure 7. Disintegrator placed after the feeder to assure the material is introduced to the dryer free of lumps.

In addition, to assure a negative pressure and a sucking force at the feeding point, a venturi is used as shown in Figure 8.

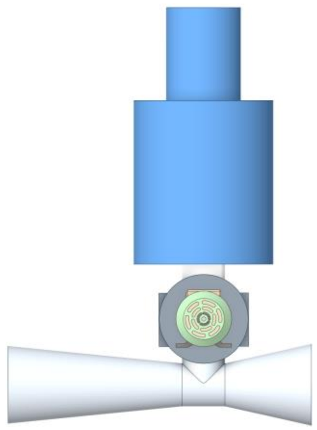


Figure 8. Venturi to assure negative pressure at the feeding point.

Drawing Sheet 4 shows the feeder, disintegrator, and venturi main dimensions, but exact figures should be obtained from the 3D CAD files that can be visualized and downloaded from https://a360.co/3p7NMWb or https://bit.ly/37vvzeZ.

DRYING DUCT

The drying duct must be long enough to provide the required residence time for the material to reach the target moisture content. In addition, the drying duct must be thermally insulated to reduce heat losses. Figure 1 provides an overview of the drying duct and its supporting structure, and Drawing Sheet 5 shows its main dimensions. However, exactly figures should be obtained from the 3D CAD files that can be visualized and downloaded from https://a360.co/2WpijT1 or https://bit.ly/3mtAbGY.

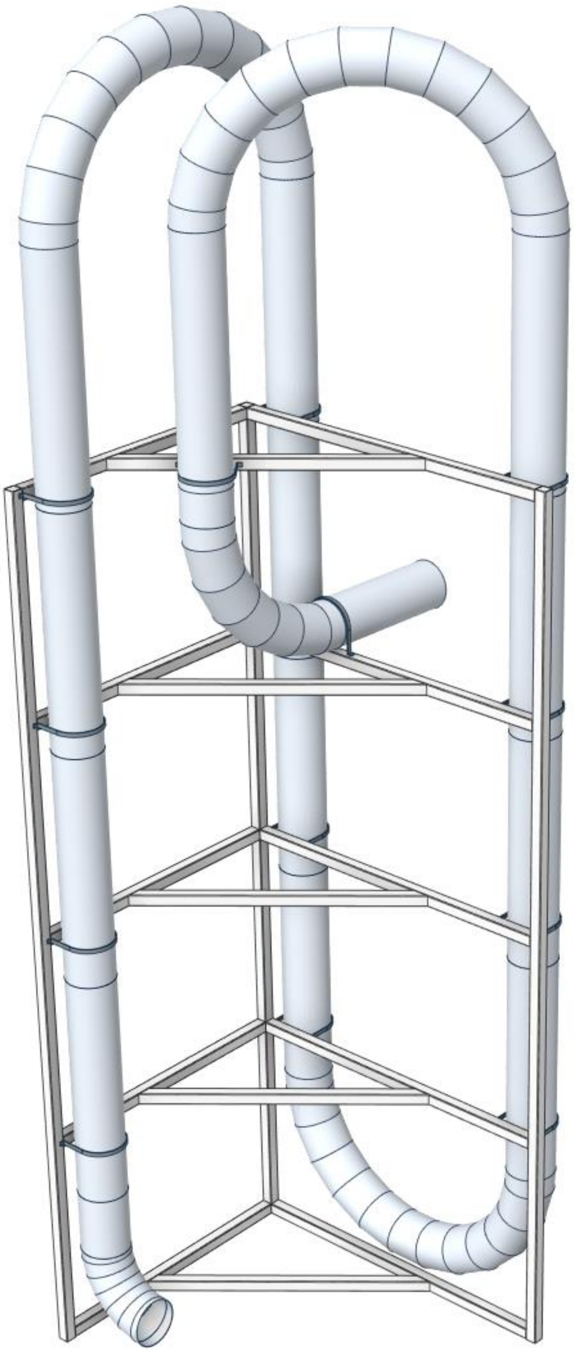


Figure 9. Drying duct divided into 3 vertical meandering sections to reduce its total height.

CYCLONE

The cyclone has the function to separate the dried solid from the airstream. The dried cassava grits leave the cyclone from its bottom, and the air exits from its top. The cyclone was dimensioned using the Stairmand High-Efficiency design. Figure 10 provides an overview of the cyclone and Drawing Sheet 6 shows its main dimensions. However, exactly figures should be obtained from the 3D CAD files that can be visualized and downloaded from https://a360.co/3mwmpU3 or https://bit.ly/34plDli.

Figure 10. A cyclone located at the end of the drying duct separates the dried solid from the air stream.

CONTROL PANEL

The control panel should have a main switch and an emergency stop button. It should also have individual switches to turn on and off the burner, fan, feeder, and disintegrator as shown in Figure 11. The burner must be thermostatically controlled, and the temperature sensor should be placed at the cyclone air outlet.

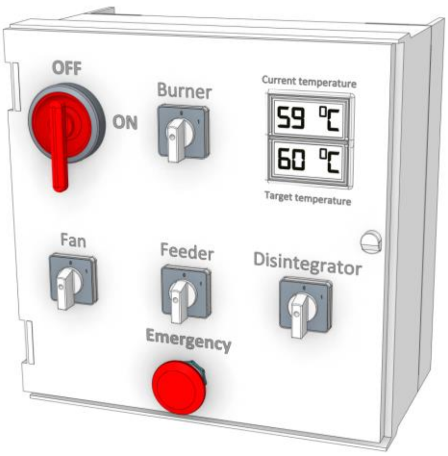


Figure 11. Control panel with main switch and emergency stop button.

DRYER OPERATION

The objective of any drying operation is to reach the target moisture content, consistently, obtaining a product of high quality and with the minimum energy use. In most drying operations, better energy performance is obtained with higher drying air temperature. In pneumatic dryers, due to the good contact between material and hot air, the evaporation rate is high, and consequently drying time is short, allowing using elevated air temperatures, without overheating the product. To assure high efficiency and no detrimental effect on product quality, the thermostat should be set at 60 °C. The temperature sensor must be placed at the cyclone air outlet, as this provides better control of the drying air temperature and makes it account for variations on the moisture content, or the amount, of solid being fed to the dryer.

Reaching consistently the target moisture content is of primordial importance on any drying operation. The product must be neither under dried nor over dried during the entire time. This is achieved by having a constant drying air temperature (controlled by the thermostat that turns the burner on and off), a constant feeding rate (controlled by the feeder) and a constant moisture content of the wet solid being introduced to the dryer. The moisture content of the wet solid being introduced to the dryer is controlled by the dewatering operation. Dewatering is a solid-liquid separation and for cassava, it is usually done with presses, thus it is a mechanical compression method, also referred to as expression. In this process, water is squeezed out from the material by mechanical action. Dewatering is an important step in cassava processing because it substantially reduces the amount of water that would otherwise need to be removed by drying, a much more energy-intensive process. To remove 1 kg of water from the cassava by mechanical dewatering, 60 kJ of energy is needed. In contrast, to remove the same amount of water by drying, 4000 kJ of energy is needed. For this reason, as much moisture as possible should be removed mechanically before the material is sent to the dryer.

In summary, in pneumatic dryers, a dried product of uniform moisture content is achieved by limiting fluctuation in the temperature of the drying air, minimizing variations in the feeding rate of wet solid, and assuring a uniform moisture content of the wet solids fed to the dryer.

WORK-PLAN AND SCHEDULE

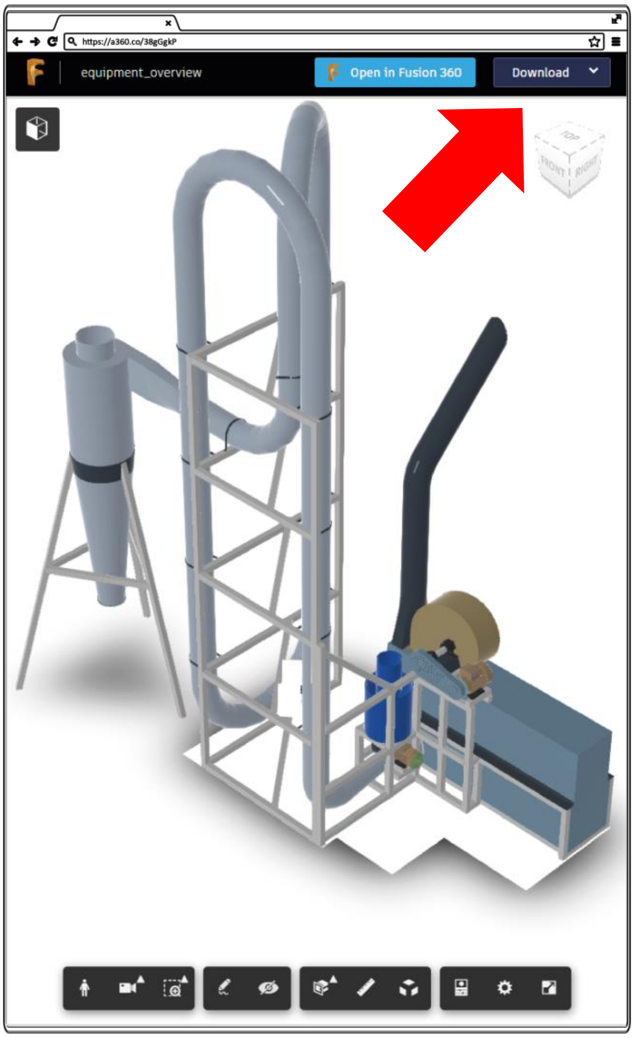
Following the instructions in this construction guide and the dimensions from the 3D CAD files, Awiko Engineering Ltd. will manufacture and install the dryer at Windwood Millers, who will finance and coordinate the activity. After air velocity adjustment and feeding rate calibration are completed, the equipment will be tested, troubleshot, and finally, its performance will be compared with the performance of Windwood Millers' current firewood powered dryer. Table 1 shows the work schedule.

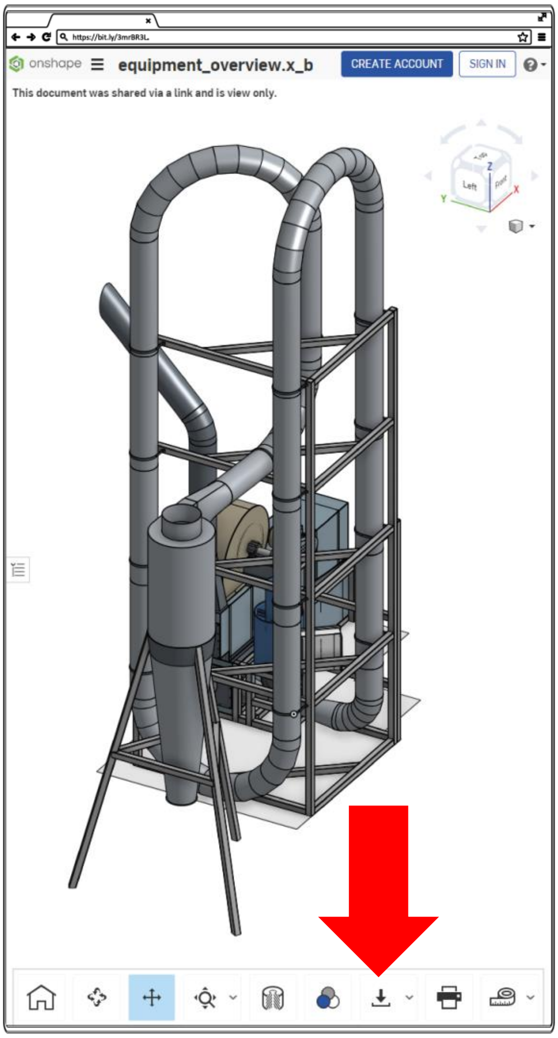
Table 1. Work-plan schedule.

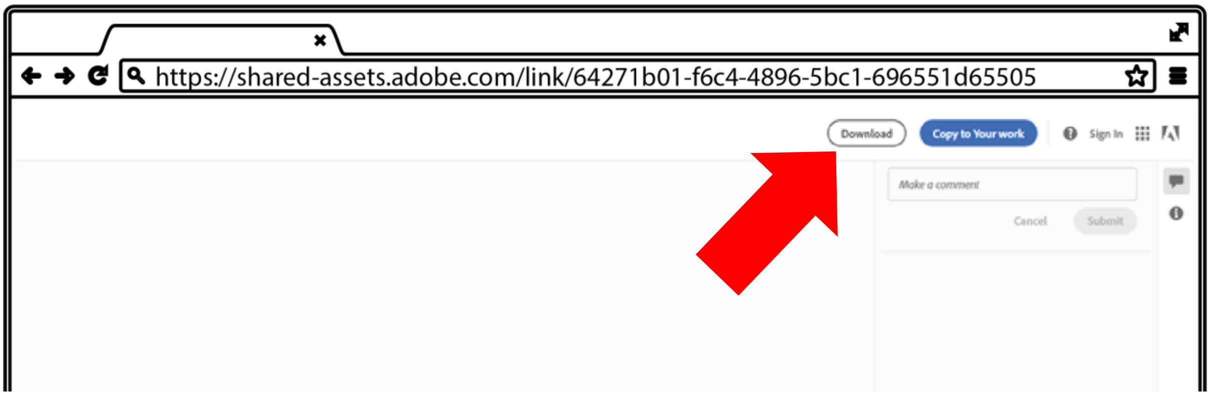
Activity	Responsible	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21
Dryer construction	Windwood Millers	■	■	■				
Dryer installation	Windwood Millers			■	■			
Air velocity adjustment	Windwood Millers					■		
Feeding rate calibration	Windwood Millers					■		
Testing and troubleshooting	Windwood Millers						■	
Performance evaluation	NRI							■

APPENDIX 1: HOW TO DOWNLOAD 3D CAD FILES

The 3D CAD files are stored on two different 3D cloud services, and in none of them, registration or additional software is needed. The files can be visualized directly from the browser or downloaded and opened locally, using any 3D CAD software. To download it, click at the "Download" button, and choose the desired format, as shown below.







APPENDIX 2: HOW TO ADJUST AIR VELOCITY

The speed that the fan impeller rotates determines the amount of air passing through the dryer, and the air velocity inside the drying duct. The amount of air passing through the dryer and the air velocity inside the drying duct has a great impact on the dryer operation and its efficiency. Therefore, it needs to be correctly and precisely adjusted. The dryer will still work with the incorrect air velocity, but its energy efficiency and the quality of the product will be significantly jeopardised. The speed of the fan impeller is adjusted by changing the sizes of the pulleys of the drive system. A variable frequency drive is not needed because, once the correct rotational speed has been identified, it will not need to be changed again.

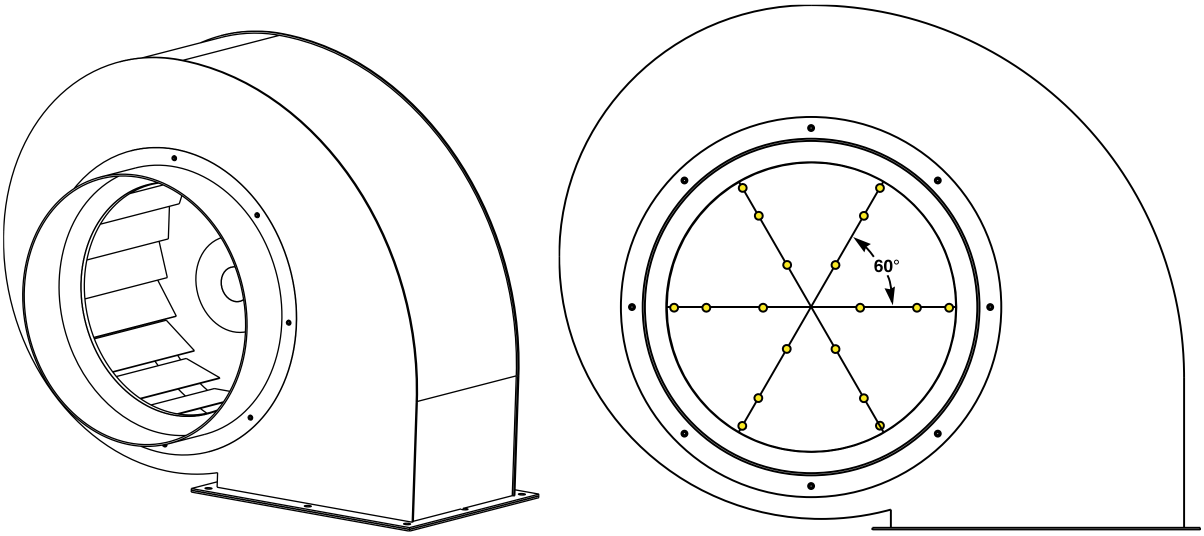
MATERIAL NEEDED

- Anemometer (device to measure air velocity)

PROCEDURE

Step 1. Switch the fan on.

Step 2. At the fan inlet (air intake) perform 18 air velocity measurements over the cross-sectional area as shown below:



Step 3. Note down the 18 measurements and calculate the average.

Step 4. If the average air velocity is lower than 2.5 m/s, increase the rotational speed of the fan impeller by reducing the size of the driven pulley. If the average air velocity is higher than the 2.5 m/s, reduce the rotational speed of the impeller by increasing the size of the driven pulley.

Step 5. Once the average air velocity at the fan inlet is 2.5 m/s, the correct air amount of air passing through the dryer and the correct air velocity inside the drying duct has been achieved, and no further change on the rotational speed of the impeller should be made.

APPENDIX 3: HOW TO CALIBRATE FEEDING RATE

The dryer was designed to be fed with 245 kg of wet cassava grits per hour. The dryer will still work, and the target moisture content might still be reached, if more than 245 kg/h of wet solid is fed to it, however, its efficiency will decline substantially, as the dryer will operate out of its design point. Similarly, the dryer will still work, and the target moisture content might still be reached if less than 245 kg/h of material is fed. However, again, efficiency will decline. Therefore, it is important to perform this calibration and assure a steady feeding rate of 245 kg/h. The feeding rate is controlled by the rotational speed of the flow aid device. Higher the speed, the higher the feeding rate.

MATERIAL NEEDED

- 490 kg of wet cassava grits with a moisture content of 45%wb
- 10 bags (sacks)
- Weight scale
- Stopwatch

PROCEDURE

Step 1. Divide the 490 kg of wet cassava grits into the 10 bags, using the weight scale to make sure that each bag contains 49 kg of product.

Step 2. Switch the entire dryer system on, and waits until it warms up.

Step 3. Once a steady-state has been reached, add an entire bag (49 kg) to the feeder, and at the same time start the chronometer of the stopwatch.

Step 4. At the moment that the material finishes and the feeder becomes empty, stop the chronometer, and note down the time elapsed.

Step 5. If the time elapsed was longer than 12 minutes, increase the rotational speed of the flow aid device. If the time elapsed was shorter than 12 minutes, decrease the rotational speed of the flow aid device.

Step 6. Repeat this procedure until the rotational speed that makes the feeder empty in 12 minutes is identified. This is the rpm that provides a feeding rate of 245 kg/h. Operate the dryer always at this feeding rate and do not make further changes the rotational speed of the flow aid device.

DRAWING SHEETS

DRAWING SHEET 1
Dryer overview

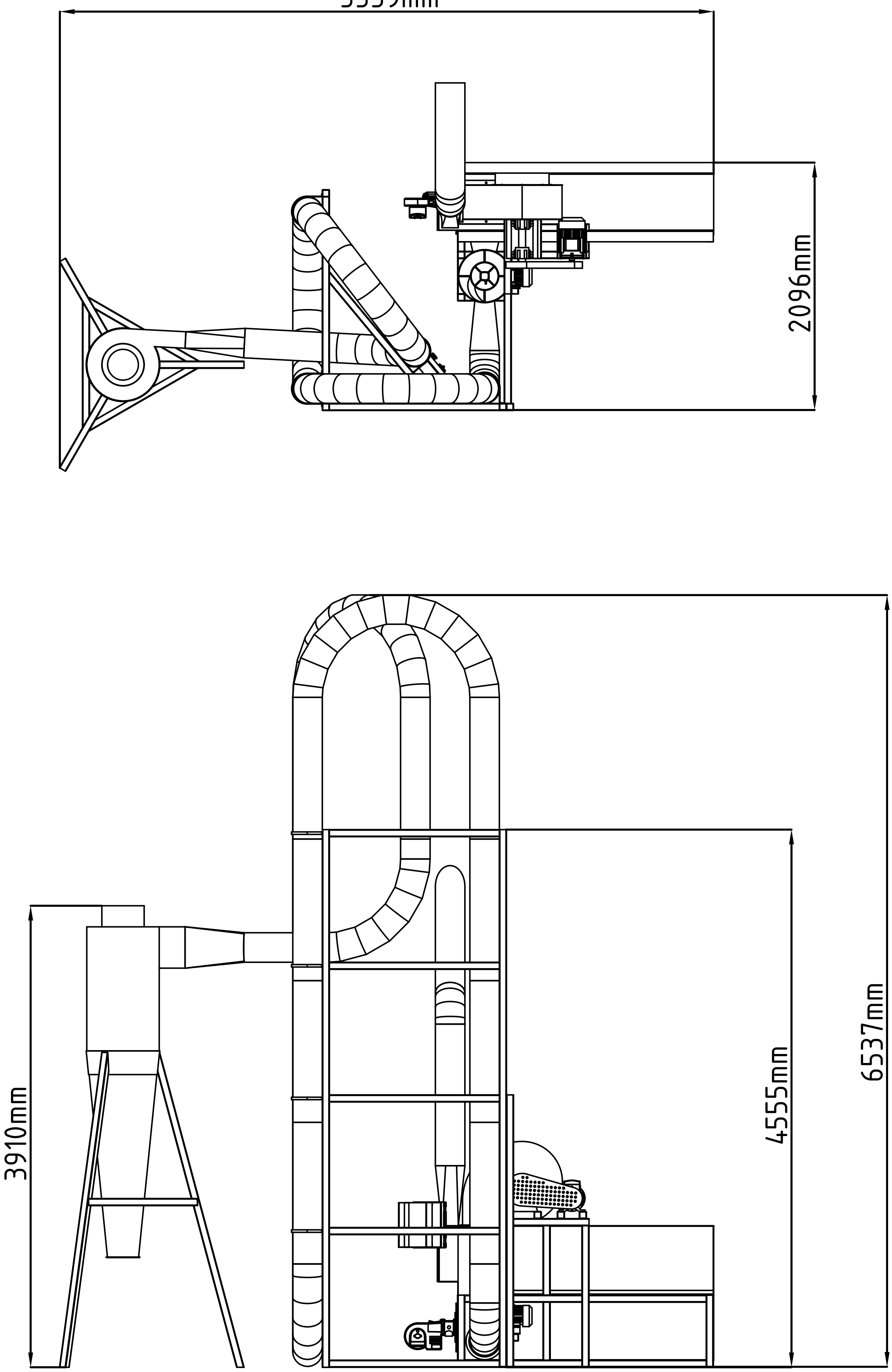
DRAWING SHEET 2
Heating unit

DRAWING SHEET 3
Fan

DRAWING SHEET 4
Feeding system

DRAWING SHEET 5
Drying duct

DRAWING SHEET 6
Cyclone



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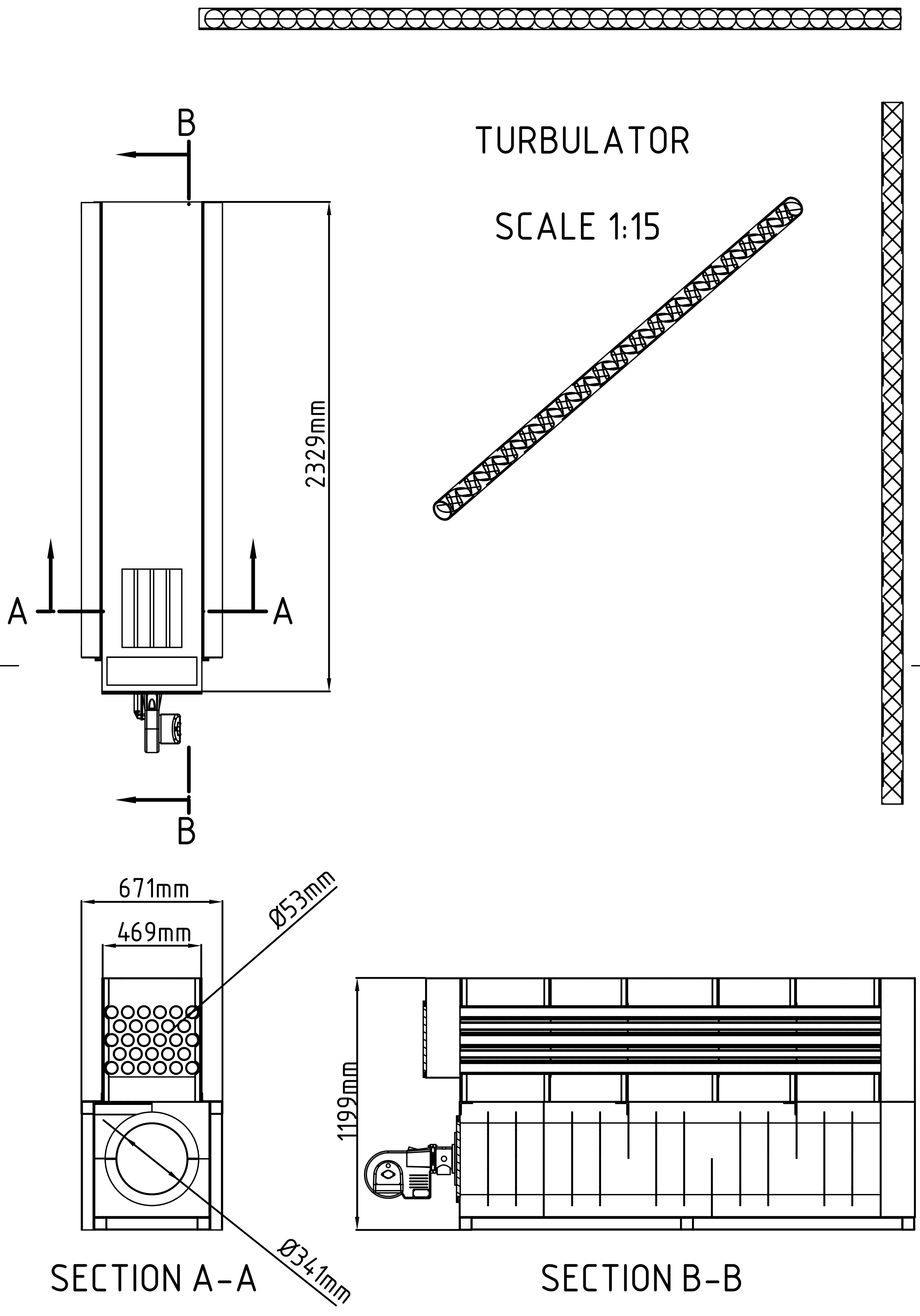

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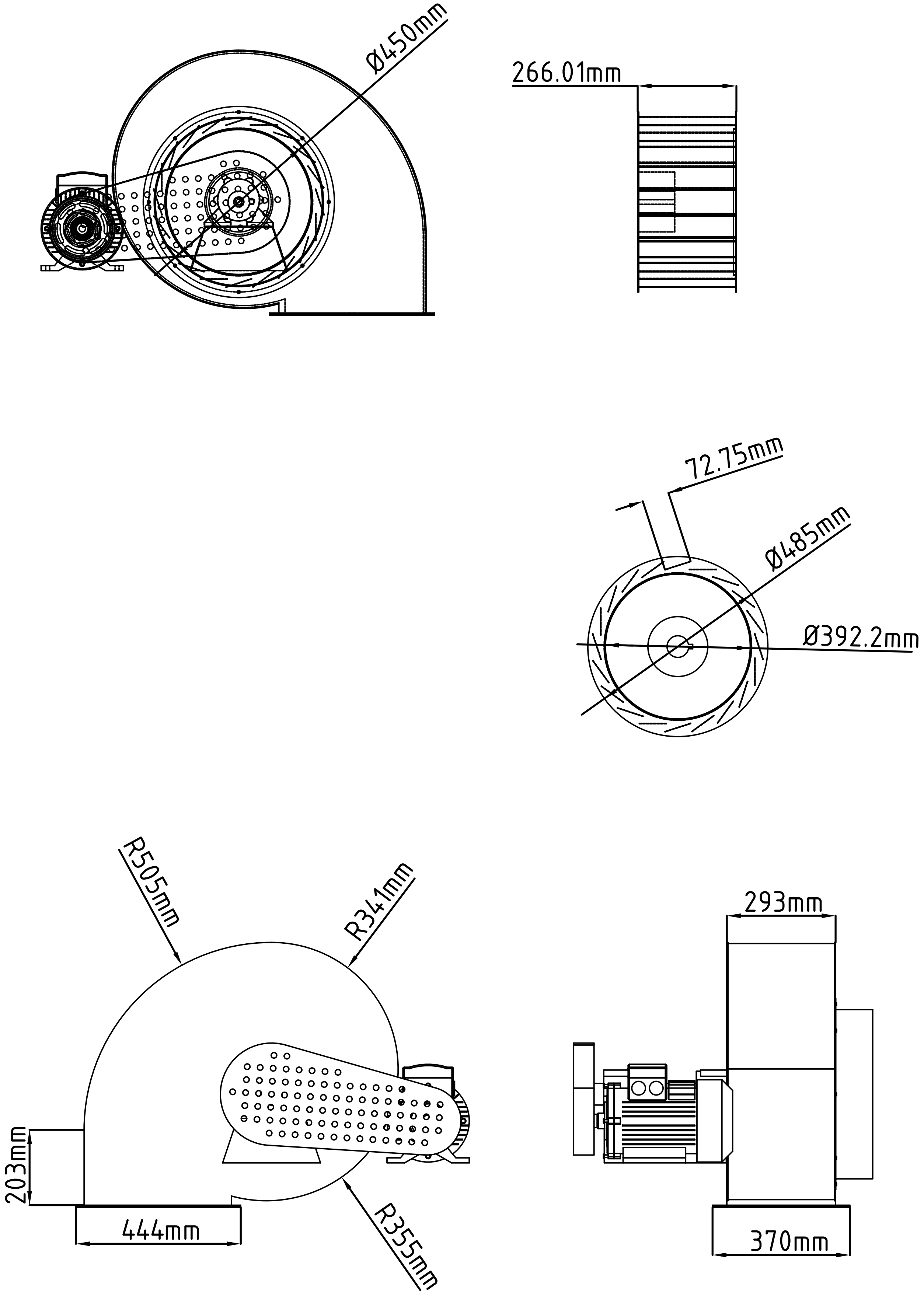
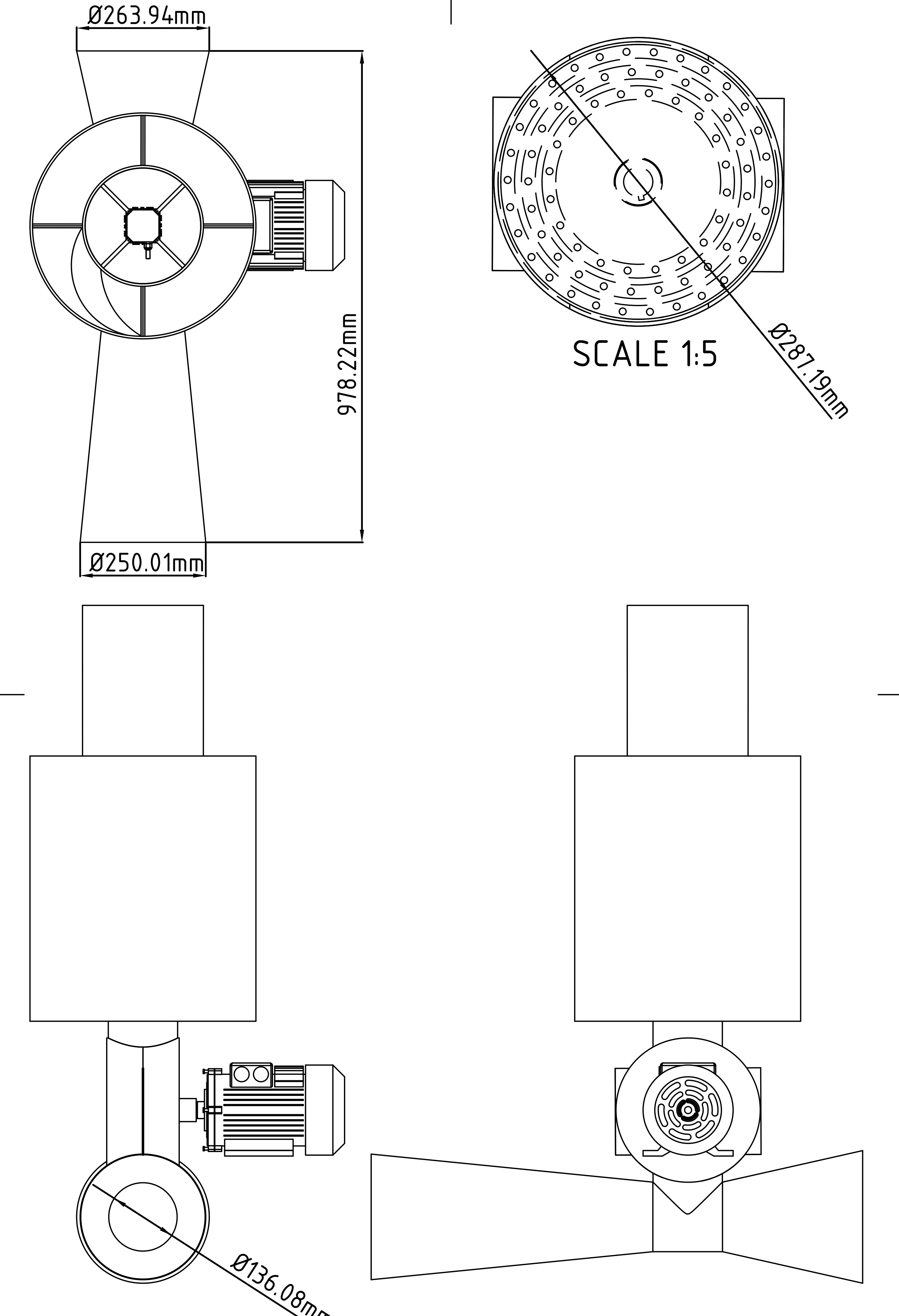


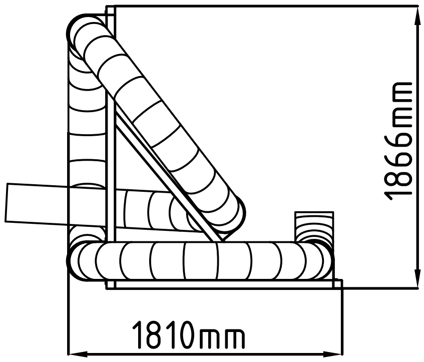
SCALE 1:15 | SIZE A4 | DRAWING SHEET 3

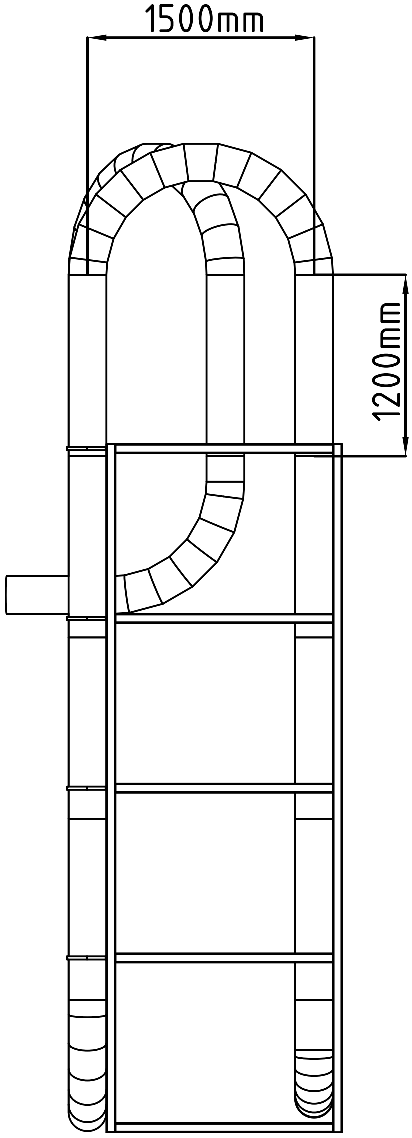
CGIAR RESEARCH PROGRAM ON Roots, Tubers and Bananas

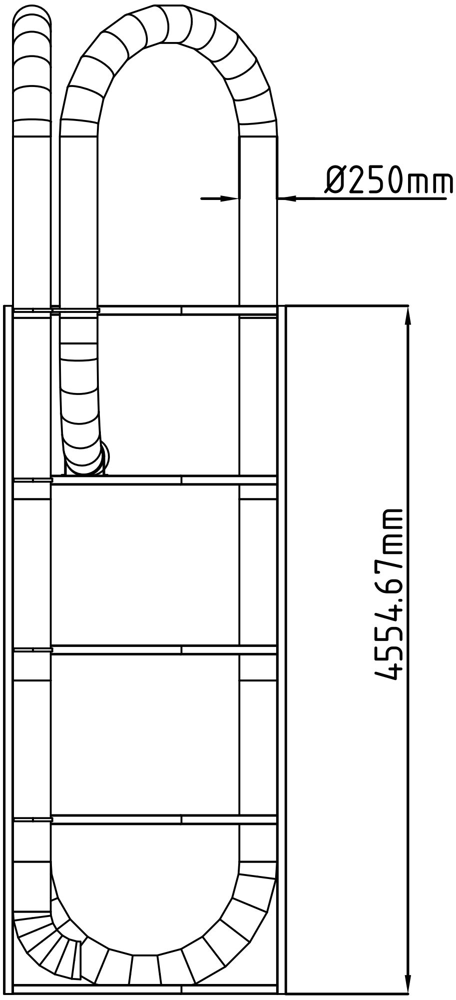


SCALE 1:10 | SIZE A4 | DRAWING SHEET 4

CGIAR RESEARCH PROGRAM ON Roots, Tubers and Bananas







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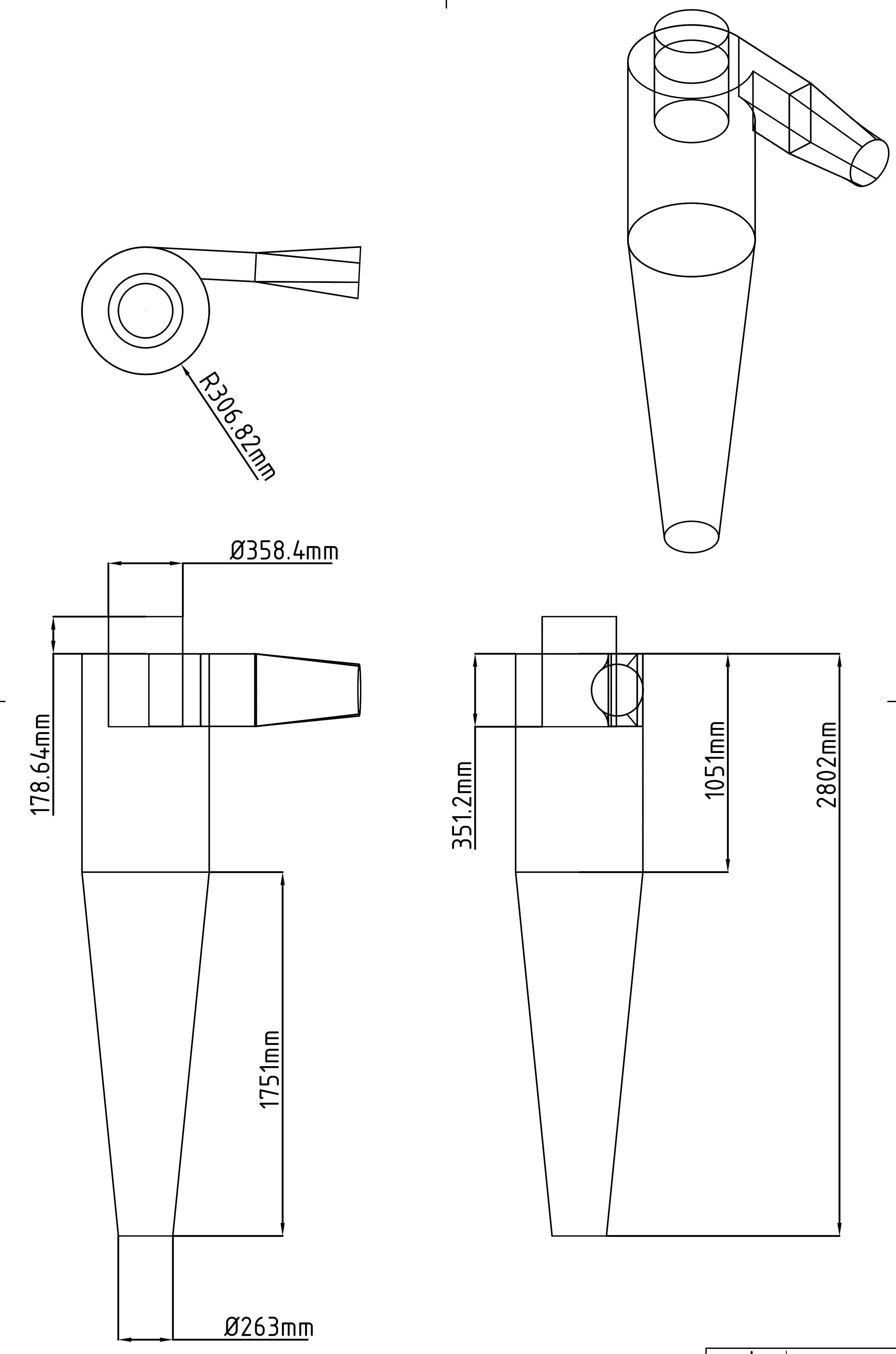

SCALE 1:25 | SIZE A4 | DRAWING SHEET 6

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