Capacity building on dimensioning, designing and operating small-scale pneumatic dryers

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Summary

This document reports the third trip made to Ghana, that aimed to build capacity on dimensioning, designing and operating pneumatic dryers to process cassava. During this trip, the construction of a small-scale pneumatic dryer was finalized at Hormeku Engineering Works and the equipment was tested plus troubleshoot. It was subsequently installed at Tropical Starch Company Limited, where the workers learned how to operate it. These activities are the fruit of a cooperation between Cassava: Adding Value for Africa Phase II (http://cava2.org) and the CGIAR Research Program on Roots, Tubers and Banana (www.rtb.cgiar.org).

Background

The most suitable type of equipment available for drying cassava is a pneumatic dryer, also known as a flash dryer. Pneumatic dryers are used to process cassava in many tropical countries. The high evaporation rate, and the consequent short drying time, provided by this type of dryer, allows using elevate air temperatures, and achieve superior levels of energy efficiency, without overheating the material or jeopardising product quality. The main components of a pneumatic dryer are *burner*, *heat exchanger*, *feeder*, *centrifugal fan*, *drying duct* and *cyclone separator*.

Burners are devices that burn fuel to produce heat. The heat generated by the combustion is used to warm air via a heat exchanger. For small-scale cassava processing, diesel is the most common fuel type used.

Heat exchangers are devices that transfer heat from the combustion gases to the drying air. The fluids are separated by solid walls that prevent mixing. Heat exchangers efficiency depends largely on the surface area between the two gases. Several types of heat exchangers are used in food processing, but the most common types are the double-pipe and the shell-and-tube heat exchangers. Double-pipe heat exchangers are the simplest type and consist of two concentric pipes. They have limited heat transfer surface and consequently lower efficiency. Shell-and-tube heat exchangers consist of a bundle of parallel tubes enclosed in a shell. This configuration allows a wide heat transfer surface and consequently higher efficiency.

Feeders are devices that introduce materials into the dryer at a controlled and specified rate. For pneumatic dryers, it is important that the feeder promotes good dispersion of the material in the airstream. Wet cassava grits are highly cohesive and can easily agglomerate into lumps, for this reason, the equipment must be carefully designed to avoid them.

Centrifugal fans are used to induce the air. They are typically driven by an electric motor using belts for power transmission. The fan can be installed at the base of the drying duct (positive-pressure conveying) or at the end of the drying duct (negative-pressure conveying).

Drying duct is where the wet solid is dried. The heated air stream is responsible for both, transporting and drying the solid. It is important that the drying duct is long enough to provide the time needed to achieve the desired moisture content. A drying duct of incorrect length would result in low energy efficiency. Drying duct should be enclosed with thermal insulation.

Cyclones are devices that separate particulate material from the airstream using centrifugal sedimentation. Cyclones are present in diverse industrial processes and in pneumatic dryers have the function to separate the material from the drying air.

Dryer construction and installation

The diesel burners acquired, model B26, manufactured by Bairan, has a minimum power of 118 kW and a maximum power of 308 kW (Figure 1). During the training of the equipment manufacturer, burner power requirement was calculated, and it was decided to acquire the model B14. This model would be more suitable as it has a minimum power 89 kW and a maximum power of 172 kW, however, during dryer construction, the only model readily available in Accra was the B26.

Figure 1 *Diesel burner to produce the heat needed for drying.*

A provisional heat exchanger was fitted to the dryer (Figure 2). The unit was manufactured in 2017 by Hormeku Engineering to be used with another equipment. The construction of a properly dimensioned shell-and-tube heat exchanger awaits the drawings from CIRAD engineers.

Figure 2 *Heat exchanger produced by Hormeku Engineering temporarily fitted at the dryer while awaiting the drawings of a suitable shell-and-tube heat exchanger, being designed by CIRAD engineers.*

The feeder was built with a hopper that features vertical walls and a cylindrical shape (Figure 3a). A rotating blade, powered by a geared motor, prevents arching and ratholing. The hopper has a capacity of approximately 250 kg of wet solid. The material discharge flow is controlled by the size of the outlet orifice and not by the rotational speed of the blade (Figure 3b).

Figure 3 *Feeder with a hopper of cylindrical shape and rotating blade, that prevents material arching and ratholing.*

The centrifugal fan, installed at the base of the drying duct, was coupled with a 7.5 kW three-phase motor. It features a straight-blade impeller (Figure 4a) combine with a cage mill (Figure 4b), to disintegrate potential product lumps, assuring good material dispersion.

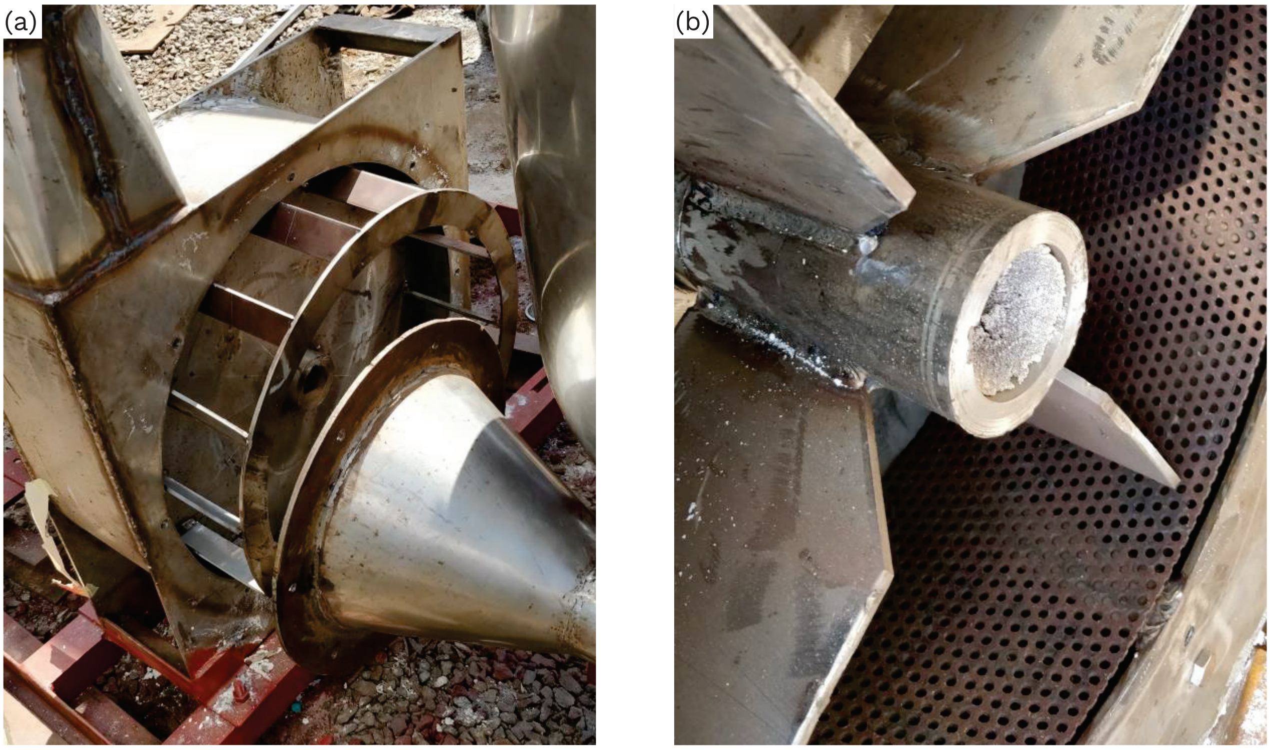

Figure 4 *Centrifugal fan with straight-blade impeller (a) integrated with a cage mill (b) to assure product dispersion.*

The equipment’s 18 meters long drying duct was segmented to allow installation without the need of a crane (Figure 5a). The ducts were thermally insulated with 50 mm thick glass wool batt, enclosed in a single bundle (Figure 5b), shield by aluminium sheets (Figure 5c).

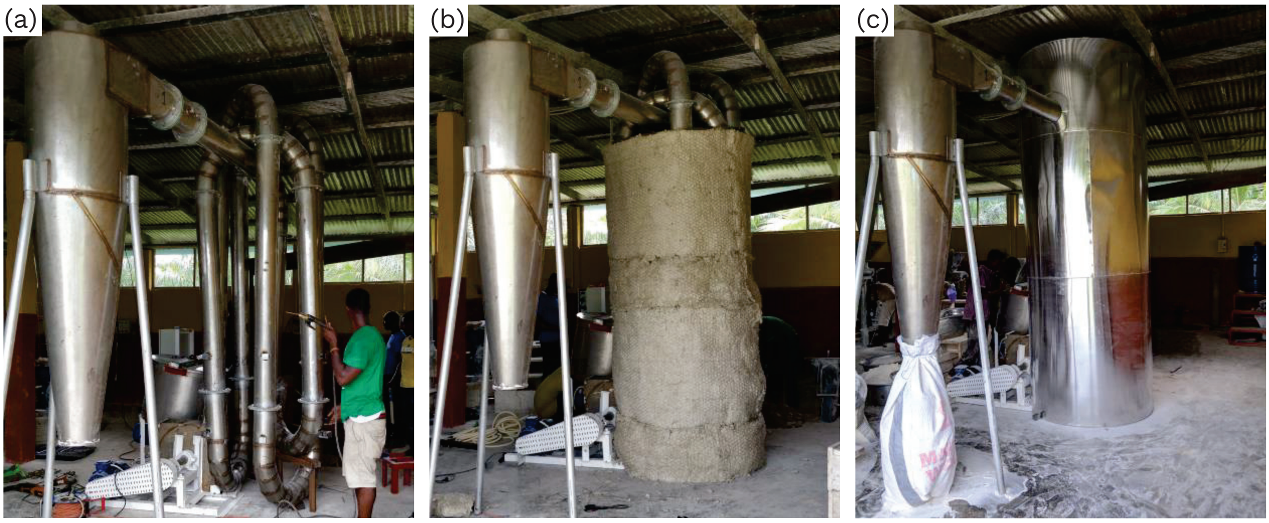

Figure 5 *Segmented drying duct (a), insulated with glass wool batts (b), shielded by aluminium sheets (c).*

The dryer's cyclone was dimensioned following the Stairmand standard, it has a diameter of approximately 0.6 m and a height of approximately 2.3 m. During drying operation, no dust was observed coming from the air outlet, suggesting high collecting efficiency.

Dryer troubleshooting

Before installing the dryer at Tropical Starch processing centre, the equipment was tested while still at Hormeku Engineering floor. Problems were identified at the feeder and at the section where the material is introduced to the dryer.

At the feeder, it was observed product caking. This was attributed to the design of the blade (Figure 6a) and its rotational speed. The problem was solved by redesigning the blade (Figure 6b) and replacing the geared motor with one of lower speed.

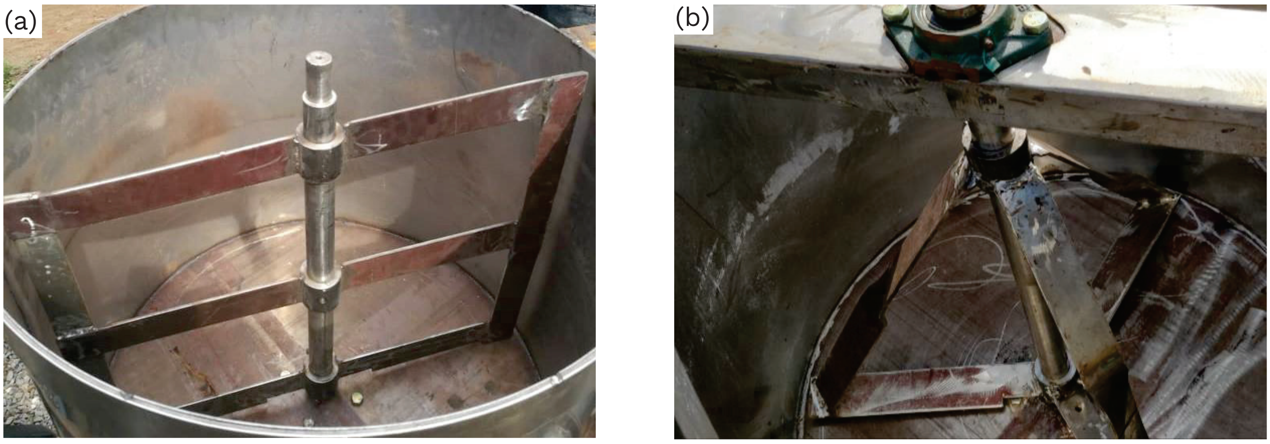

Figure 6 *The blade at the feeder hopper (a) was replaced with a design that does not promote material caking (b).*

At the section where the material is introduced to the dryer, it was observed problems with product conveying. The issue was solved by replacing the 0.2 m diameter duct (Figure 7a) with one of 0.1 m diameter (Figure 7b).

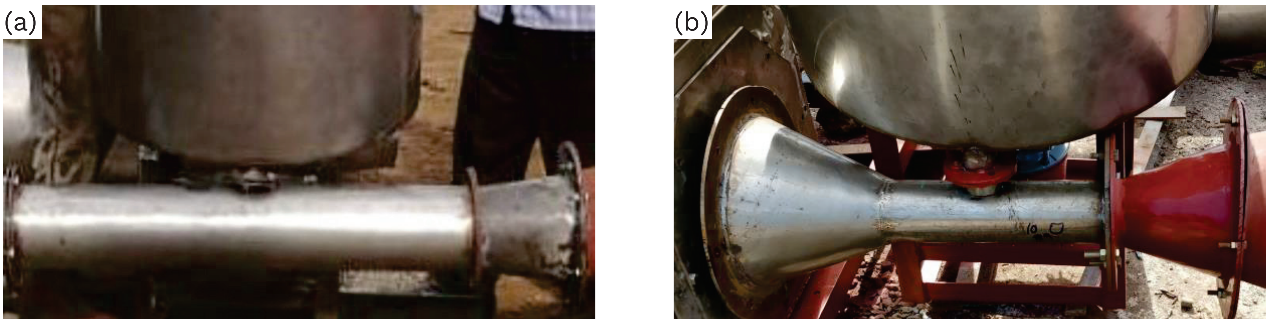

Figure 7. *The 0.2 m diameter duct at the section where the product enters the dryer (a) was replaced with one of smaller diameter (b), increasing air velocity and solving product conveying issues.*

User's training

The management team of Tropical Starch processing centre were trained on dryer operation, maintenance and safety. Activities were split into two parts: first theoretical, while the dryer was still at the equipment manufacturer. The second part, after dryer installation, was practical. The theoretical part aimed to help them understand the operating principles of the equipment, its advantage over a flatbed dryer, and what is required to achieve a uniform product. A selection of the slides presented can be found in Appendix 1. The practical training focused on learning how to operate the dryer to achieve maximum energy efficiency and uniform product quality.

The training encompassed mechanical dewatering, and the development of a pressing protocol, to assure consistent moisture content of the wet solid being fed to the dryer. During training, it became evident that mechanical dewatering is a major bottleneck of the cassava processing operation. The screw operated press used (Figure 9a), has an inferior throughput than the press that uses a hydraulic jack (Figure 9b) and can reduce moisture content only to 45%, in contrast with 35% achieved with the one that uses a jack. However, workers dislike the jack operated press because of its elevated work drudgery.

Figure 9 *Screw operated press with lower throughput (a) and jack operated press with higher work drudgery (b).*

To address the low throughput and inferior reduction on product's moisture content when using the screw operated press, alternatives were brainstormed with staff from both, Hormeku Engineering and Tropical Starch. An idea that emerged was of a system that uses chain hoist, as shown in Figure 10. This equipment would be able to apply the same level of force than the one operated by jacks, with higher throughput, and less work drudgery. Both, equipment manufacturer and cassava processor, are interested in building a prototype and testing it.

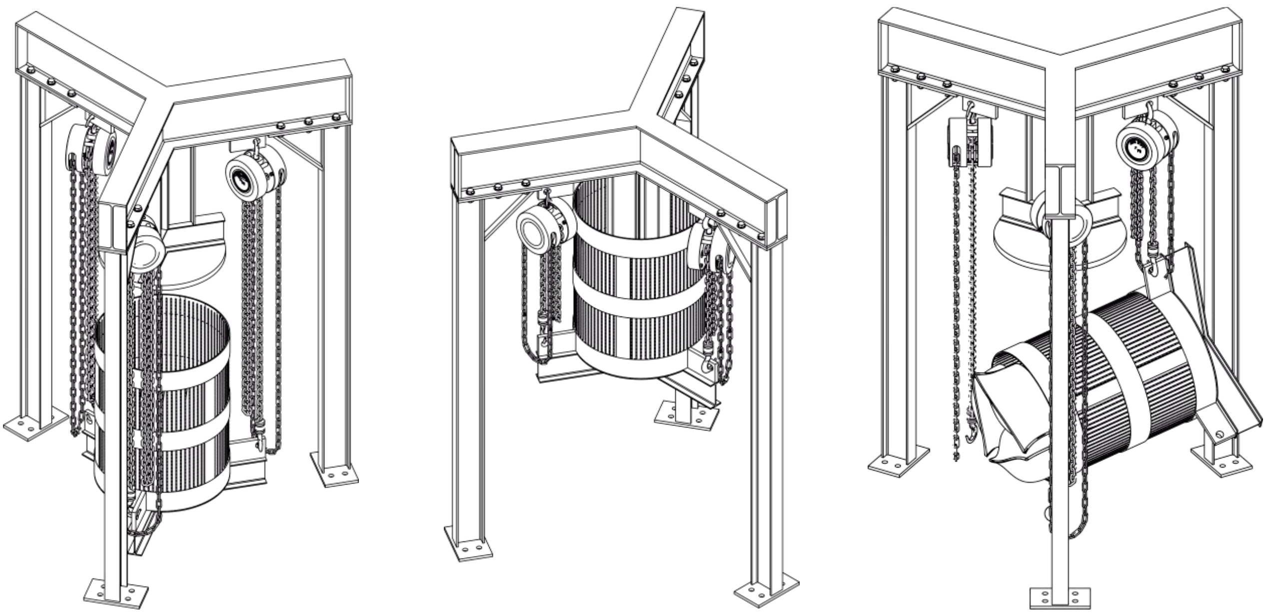

Figure 10 *Concept of a press for mechanical dewater of cassava that uses chain hoists instead of hydraulic jack.*

Equipment manufacturer closing training

To assure knowledge retention, a concluding workshop was prepared for the technical team of Hormeku Engineering. A custom-made Microsoft Excel spreadsheet was developed (Figure 8) to assist them on properly dimensioning upcoming new orders for pneumatic dryers.

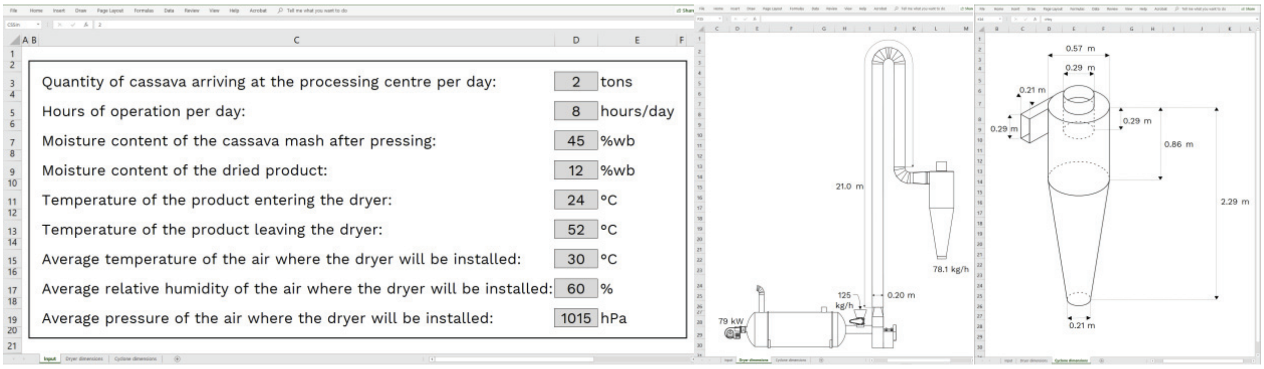

Figure 8 *Microsoft Excel spreadsheet developed to aid equipment manufacturer in dimensioning pneumatic dryers.*

To promote competitive pricing, another equipment manufactured of cassava processing machinery, named First Products Enterprise, was involved. Their technical team visited the dryer during its construction, troubleshooting and final assembly. In addition, a workshop was conducted to explain the dryer working principles and how to use the custom-made Excel spreadsheet to dimension it. According to both equipment manufacturers, building cost of the dryer can be less than USD 10,000 depending on its throughput and size.

Follow-up activities

While the dryer is working well, and the Tropical Starch management team have reported 50% less fuel consumption than their flatbed dryer, it is important to assess the energy performance of the equipment. For the processing centre, a suitable period to evaluate it would be on May 2019. Concomitant, to eliminate the bottleneck of mechanical dewatering, a prototype press that uses chain hoist could be built, tested and evaluated. Finally, to substitute the provisional heat exchanger by the one prepared by CIRAD engineers, a workshop with equipment manufacturers could be organized, helping them to learn how to dimension and design shell-and-tube heat exchangers. Thereafter the heat exchanger could be built, installed and evaluated. Table 1 shows a tentative schedule for those activities and Table 2 their estimated cost.

Table 1 *Tentative schedule for follow-up activities in 2019.*

Activities	May 2019				June 2019				July 2019			
Dryer energy performance assessment	■	■	■									
Construction of chain hoist press		■	■	■								
Performance assessment of chain hoist press				■	■	■						
Training on designing shell-and-tube heat exchangers						■	■	■				
Construction of shell-and-tube heat exchanger								■	■	■		
Performance assessment of shell-and-tube heat exchanger										■	■	■

Table 2 *Estimated cost for the follow-up activities in 2019.*

Activities	Staff time (days)	Operational (USD)
Dryer energy performance assessment	10	0.00 (HEIF)
Construction of chain hoist press	10	6,000.00
Performance assessment of chain hoist press	10	2,000.00
Training on designing shell-and-tube heat exchangers	10	2,000.00
Construction of shell-and-tube heat exchanger	10	6,000.00
Performance assessment of shell-and-tube heat exchanger	10	4,000.00

Appendix 1

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Design of a pneumatic dryer for cassava processing

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Introduction

Pneumatic dryer

Appendix 1

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Introduction

Pneumatic dryer

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Burner

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Heat exchanger

- Double-pipe

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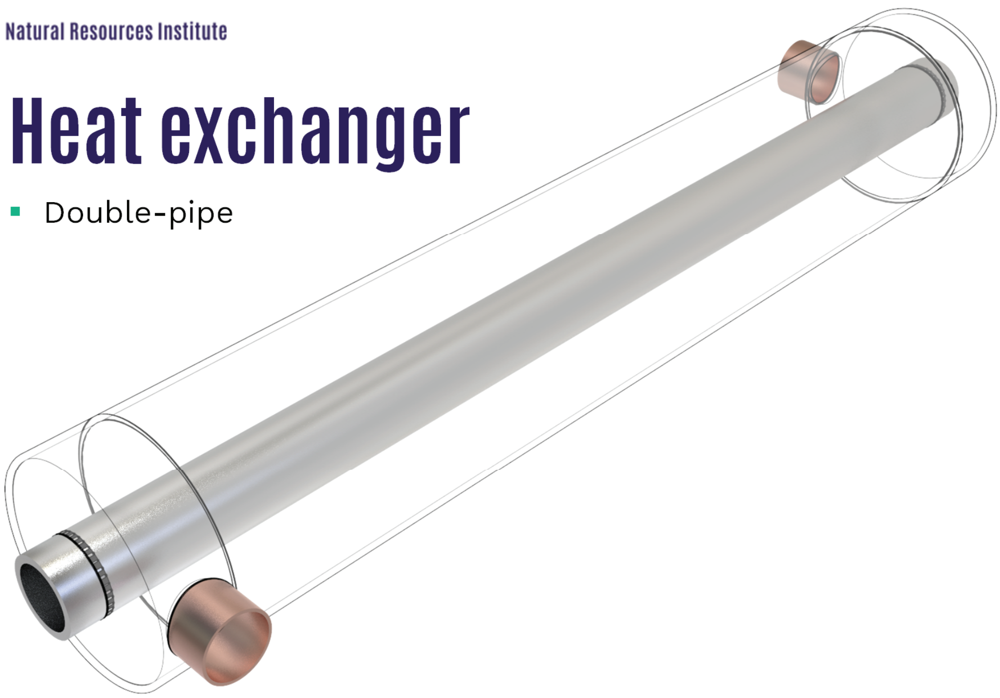
Heat exchanger

- Double-pipe



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Heat exchanger

- Shell-and-tube

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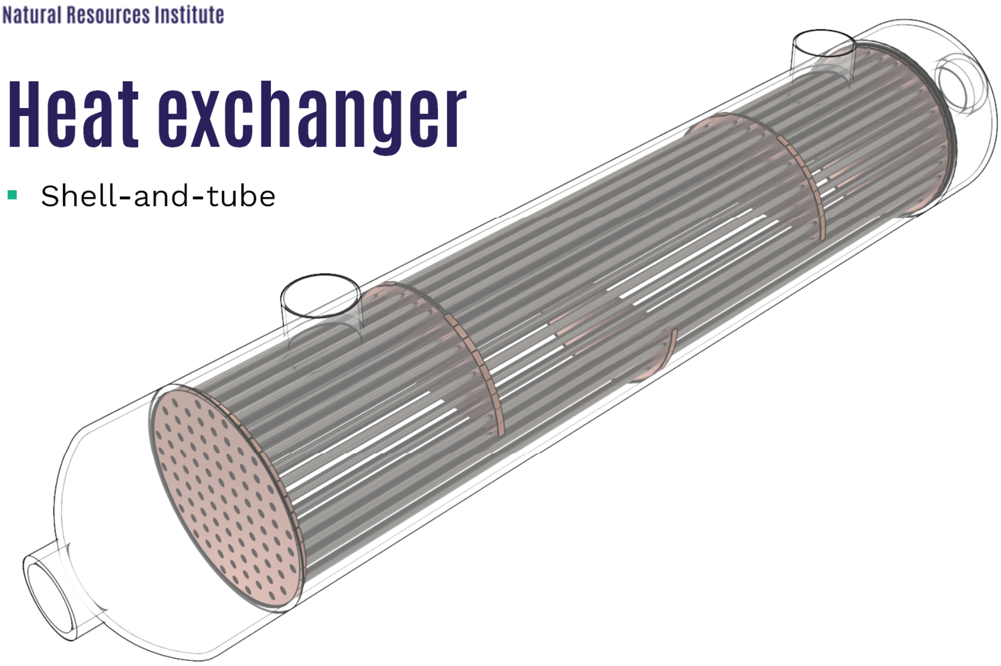
Heat exchanger

- Shell-and-tube



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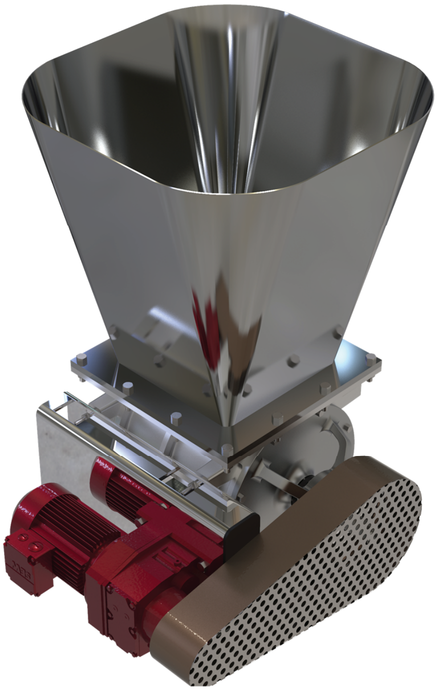
Feeder



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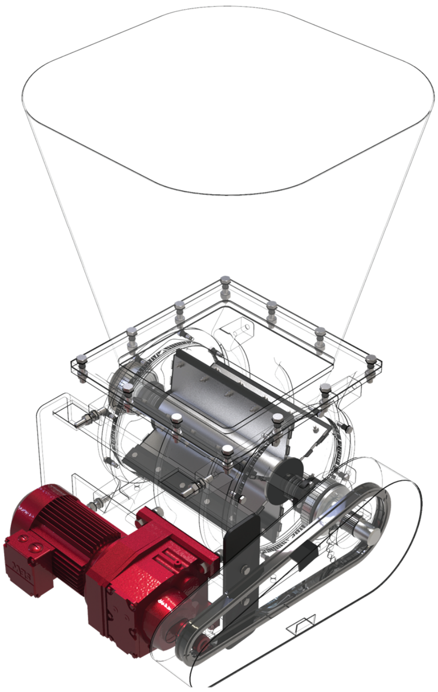
Feeder



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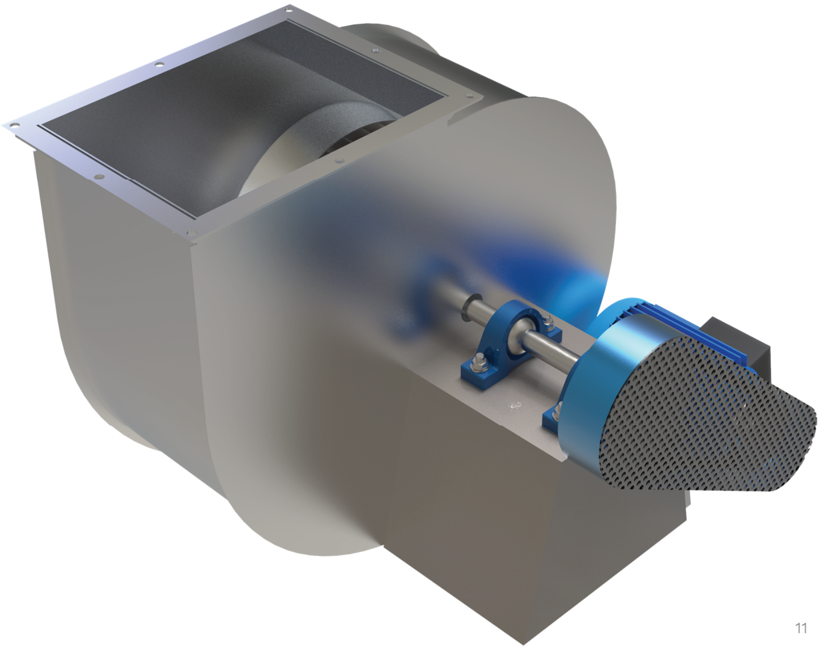
Fan

- Centrifugal



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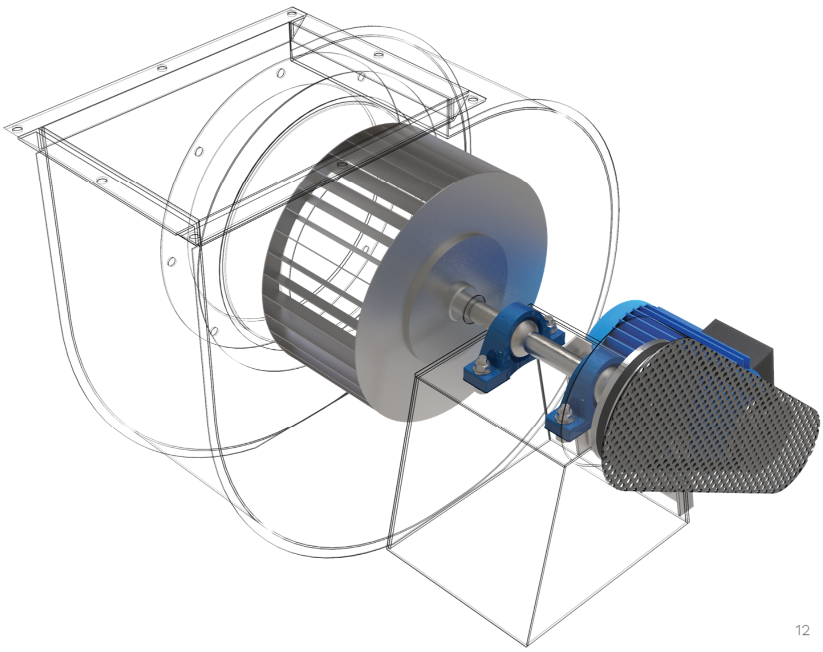
Fan

- Centrifugal



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Fan

- Backward-curved impeller

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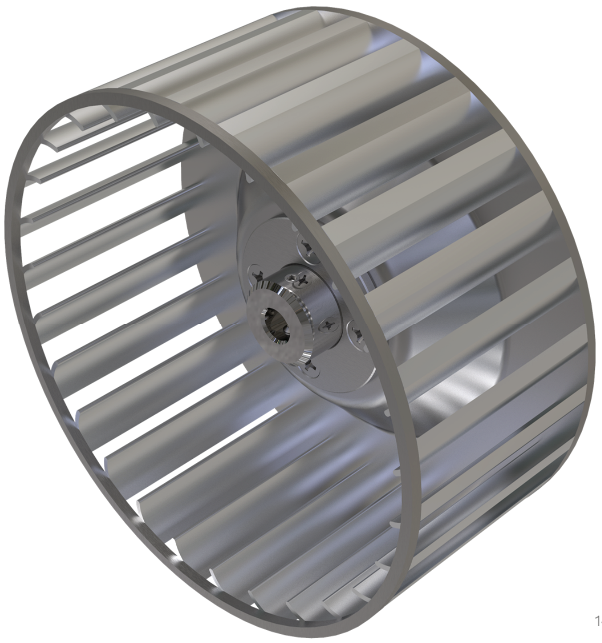
Fan

- Forward-curved impeller



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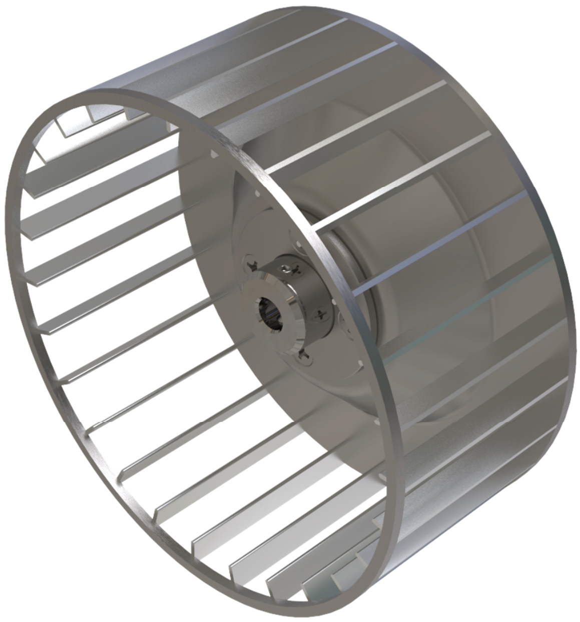
Fan

- Straight-blade impeller



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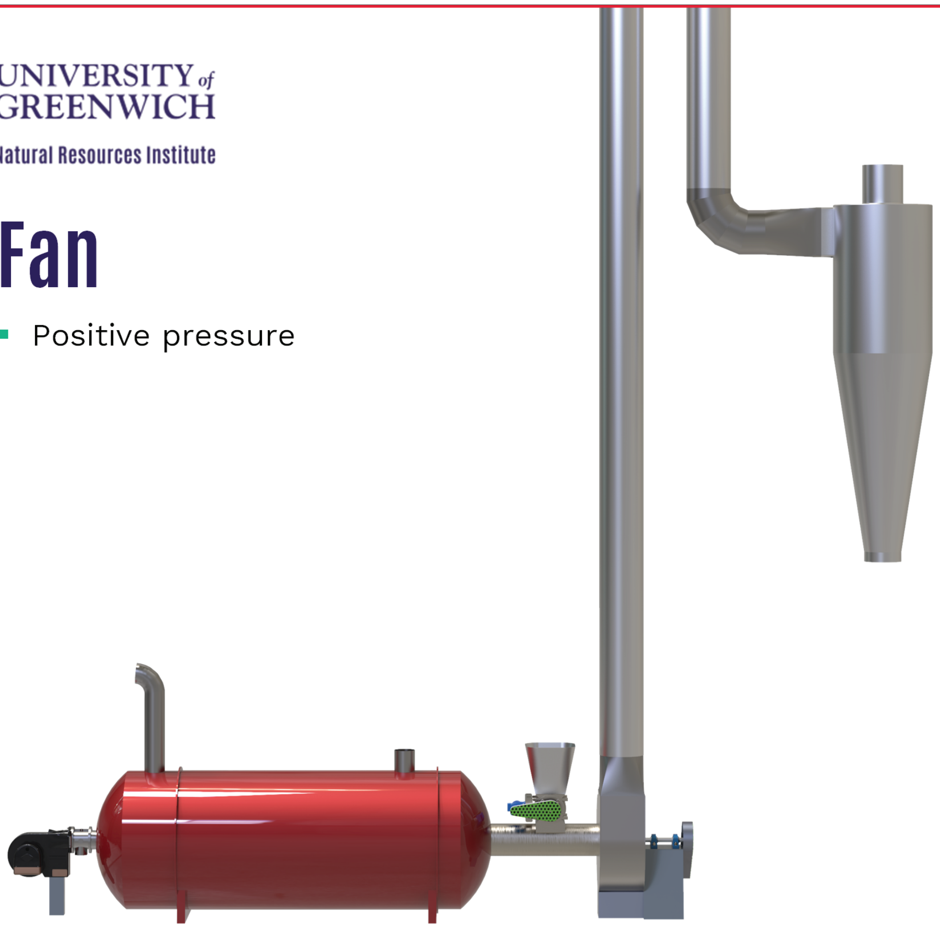
Fan

- Positive pressure



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Fan

- Negative pressure

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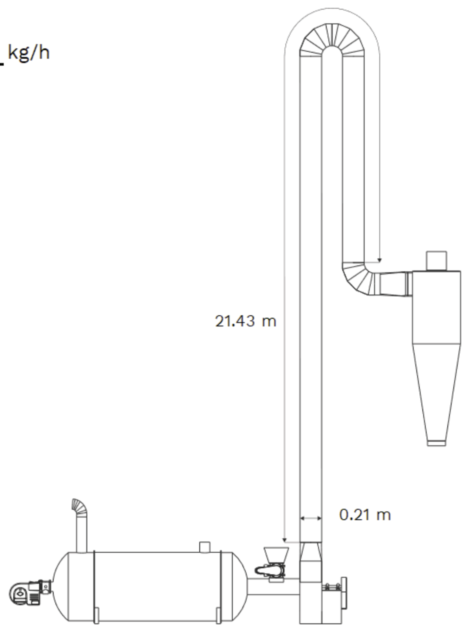
Drying duct

Dryer wet solid mass flow **150** kg/h



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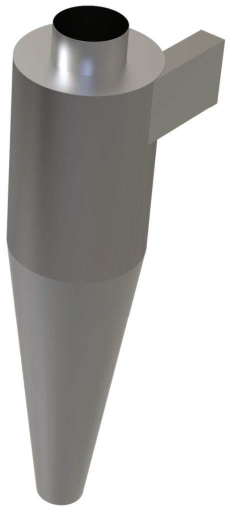
Cyclone separator



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Cyclone separator

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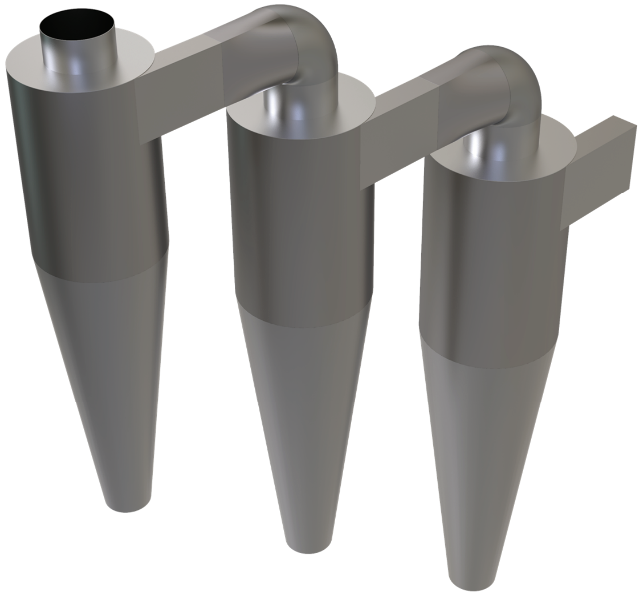
Cyclone separator



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