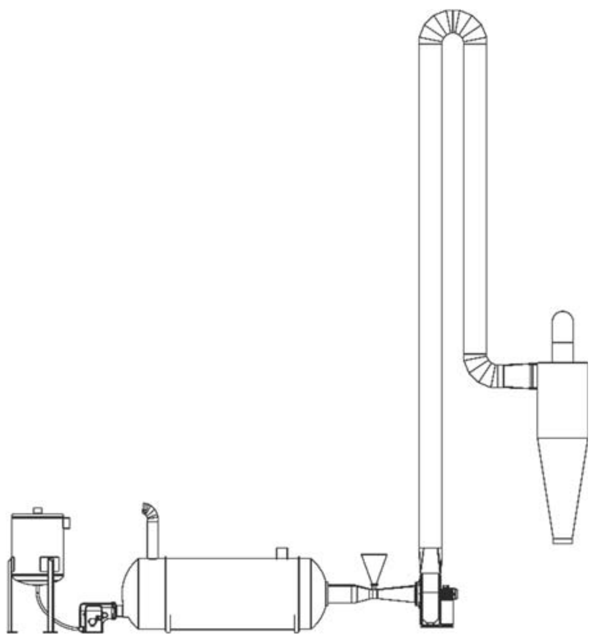
CASSAVA: ADDING VALUE FOR AFRICA PHASE II

Training-course-report: Determining Energy Efficiency of Dryers



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May 2018

UNIVERSITY of GREENWICH
NRI | Natural Resources Institute
IITA Research to Nourish Africa

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Justification

Large-scale pneumatic dryers, used for cassava processing, have been developed over a long period of time, and are nowadays highly efficient (Sriroth et al., 2000). In contrast, small-scale dryers, are still on early stage of development and presents low energy efficiency (Precoppe et al., 2017). The objective of this training course was to strength Nigerian equipment manufacturers and service providers capacity on determining the energy efficiency of dryers.

Methodology

The course was anchored on the constructivist learning theory (Piaget & Inhelder, 1969; Vygotsky & Cole, 1978) and knowledge was built based on the previous experiences of the participants. Learning activities included real measurements and practical calculations.

Agenda

The training course took place in a meeting room at Green Legacy Resort, Abeokuta, Nigeria. It was done over 2 days, 18th and 19th of May 2018. The opening ceremony was conducted by Prof Lateef Sanni and had the honour presence of Prof Felix Salako, Vice-Chancellor for the Federal University of Agriculture, Abeokuta (FUNAAB), as shown on Fig 1.

Fig 1. *Training course open ceremony with FUNAAB Vice-Chancellor, Prof Felix Salako.*

A total of 15 engineers, composed of equipment manufacturers and service provided, attended the training course (Fig 2).

Fig 2. *Equipment manufacturers and serviced providers during the training course in Abeokuta, Nigeria.*

After the opening ceremony the objectives, methodology and content of the training course was presented (Appendix 1).

In the first day, measurements and efficiency calculations, were done using a domestic hair dryer. In the second day, the principles learned from the hair dryer were applied to a pneumatic dryer. Participants successfully calculated the energy efficiency of the dryer shown on Fig 3.

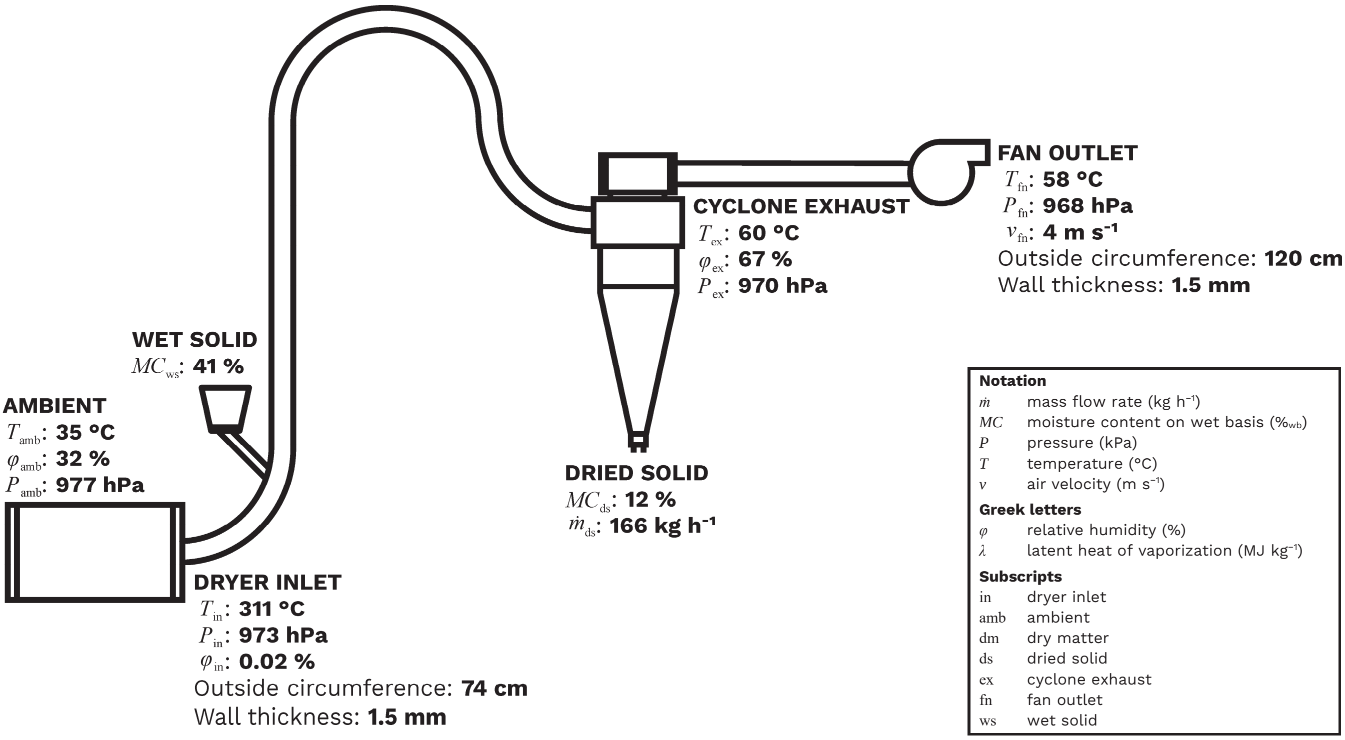
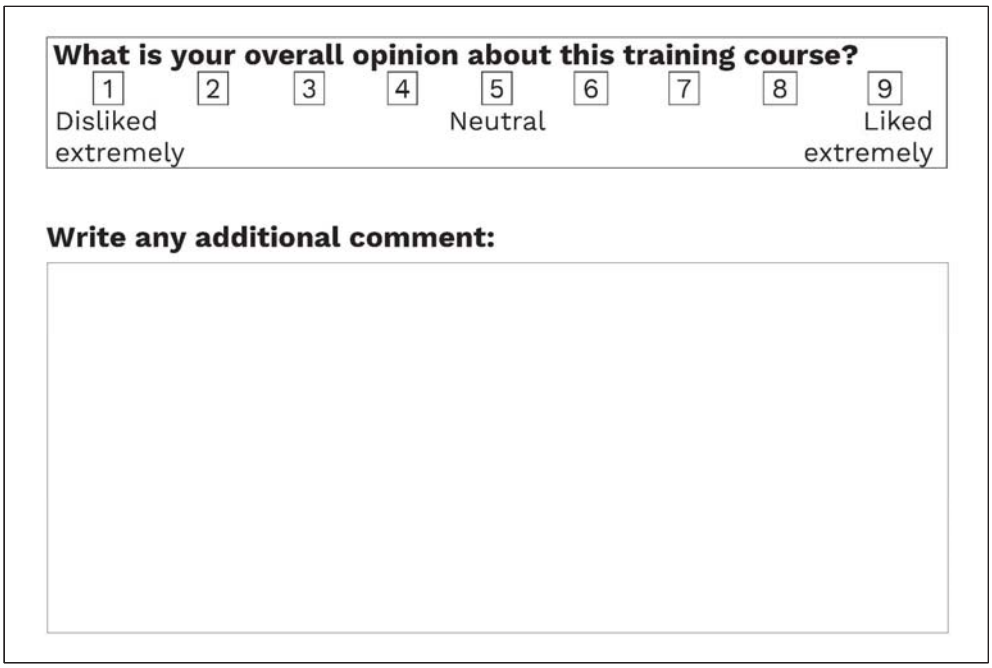


Fig 3. *Illustration of a pneumatic dryer including data needed to determine its energy efficiency.*

In the end of the training course an evaluation form was handed to the participants (Fig 4). In this hedonic scale, 1 means ‘disliked extremely’ and 9 means ‘liked extremely’. The training course scored 8.8 ± 0.4. At the field for additional comments, all participants manifested interested on follow-up training courses (Appendix 2).



What is your overall opinion about this training course?

1 2 3 4 5 6 7 8 9

Disliked extremely — Neutral — Liked extremely

Write any additional comment:

Fig 4. *Evaluation form handed in the end of the training course.*

Subjects

The training course was problem-centred and not content-oriented. During the practical exercises, the following subjects was explored:

- Air absolute humidity and enthalpy
- Air density and air mass flow rate
- Material moisture content
- Material mass flow rate
- Heat input rate
- Water evaporation rate
- Heat used for moisture evaporation
- Energy efficiency

A summary sheet was handed to the participants (Appendix 3) and for the calculation of the heat rate used for moisture evaporation, it was suggested to use the cassava heat of sorption instead of the latent heat of water vaporisation. This allows accounting for the energy required to overcome capillary forces bounding water molecules (Fig 5).

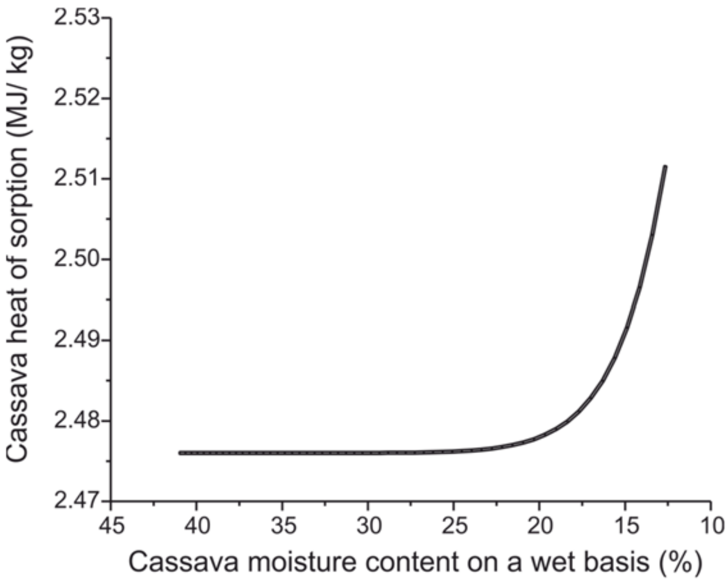


Fig 5. *Relationship between cassava moisture content and the energy needed for water evaporation.*

Participants also strengthened their knowledge on the main components of a pneumatic dryer (Appendix 4) and on properly defining system boundaries, according to objectives of the study (Fig 6).

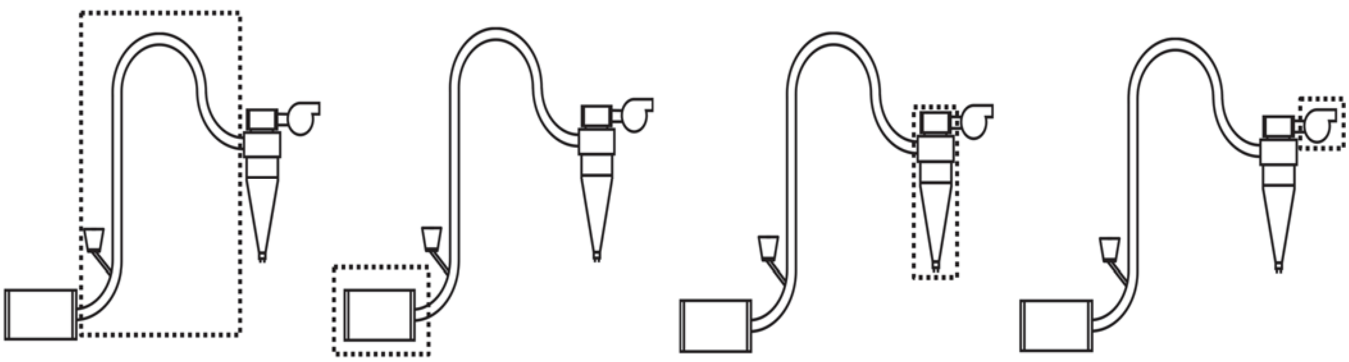


Fig 6. *Illustration of pneumatic dryers using different system boundaries, according to the objective of the study.*

Finally, participants learned about the measurements and data collection needed to determine energy efficiency of pneumatic dryer (Fig 7).

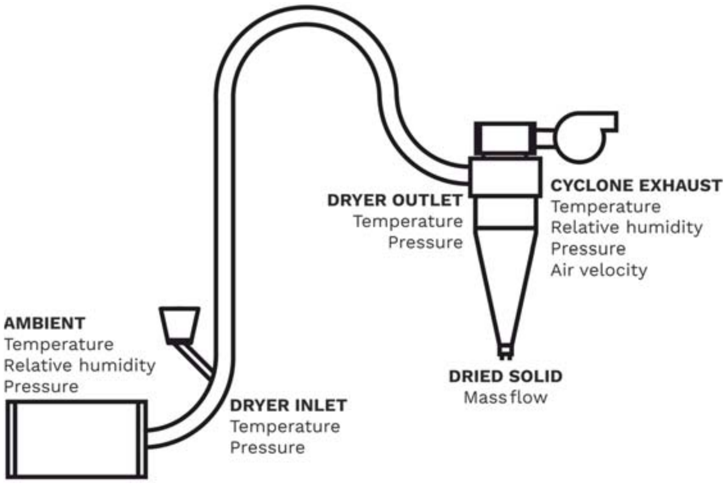


Fig 7. *Measuring protocol to determine energy efficiency of a pneumatic dryer.*

Outcome

Equipment manufacturers and service providers strengthened their knowledge on determining the energy efficiency of dryers. They all stated that trainings like this are very important and beneficial. All of participants expressed interest on following-up training courses. Two main topics were requested: (a) advance training on energy performance evaluation of dryers; (b) properly designing and dimensioning a pneumatic dryer. It has also been discussed about creating an online forum using CassavaTech.com platform. The forum would allow them to exchange their calculations and experiences on the topic.

References

Piaget, J., & Inhelder, B. (1969). *The Psychology of the Child*. New York, NY: Basic Books.

Precoppe, M., Chapuis, A., Müller, J., & Abass, A. (2017). Tunnel Dryer and Pneumatic Dryer Performance Evaluation to Improve Small-Scale Cassava Processing in Tanzania. *Journal of Food Process Engineering*, 40.

Sriroth, K., Piyachomkwan, K., Wanlapatit, S., & Oates, C. G. (2000). Cassava starch technology: The Thai experience. *Starch - Stärke*, 52, 439–449.

Vygotsky, L. S., & Cole, M. (1978). *Mind in Society: Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.

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Appendix 1

Welcome to the course

Determining energy efficiency of dryers

Objectives

- Learn to determine the energy efficiency of dryers

2

Appendix 1

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Method

- Two-days intensive-course
- Hands-on
- No lectures
- No PowerPoint
- No training material
- No certification of conclusion

3

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Prerequisite

- Attend the entire course

4

Appendix 2

What is your overall opinion about this training course?

1	2	3	4	5	6	7	8	9
Disliked extremely				Neutral				Liked extremely

Write any additional comment:

Dr macedo is a wonderful teacher, I Really enjoy his lecture and understan it.
Very interesting class. Keep it up.

What is your overall opinion about this training course?

1	2	3	4	5	6	7	8	9
Disliked extremely				Neutral				Liked extremely

Write any additional comment:

Marcello is a wonderful teacher but ~~time~~ duration of the training is short.
It will be nice for continuity of this program and a kind of follow-up action.

Appendix 2

What is your overall opinion about this training course?

1	2	3	4	5	6	7	8	9 ✓
Disliked extremely				Neutral				Liked extremely

Write any additional comment:

This program is good. We need to to keep it up more of it at interval of three months.

What is your overall opinion about this training course?

1	2	3	4	5	6	7	8	9 ✓
Disliked extremely				Neutral				Liked extremely

Write any additional comment:

This training was highly impactful and foundational for me, Dr. Marcelo did very well but I want to suggest that subsequently 2-days is too small for this kind of training.

Appendix 2

What is your overall opinion about this training course?

1	2	3	4	5	6	7	8	9 ✓
Disliked extremely				Neutral				Liked extremely

Write any additional comment:

Very informative,
I enjoyed it. It helped me understand more about calculating dryers.
All looks logical, can we come up with a computer program that once all data are measured and inputed, calculate all that is needed?

What is your overall opinion about this training course?

1	2	3	4	5	6	7	8	9 ✓
Disliked extremely				Neutral				Liked extremely

Write any additional comment:

The Traning is good
I will want more of time to hands
But the food need to be work on

Appendix 2

What is your overall opinion about this training course?

1	2	3	4	5	6	7	8	9
Disliked extremely				Neutral				Liked extremely

Write any additional comment:

This training was quite educational and informational, More of it should be encourage, with more time allocated for in depth discussions in the future

What is your overall opinion about this training course?

1	2	3	4	5	6	7	8	9
Disliked extremely				Neutral				Liked extremely

Super

Write any additional comment:

The course is very useful and Interesting; the presenter has proved that is a master of Knowledge in the discussion. His way of Impacting knowledge is highly encouraging.
This course only cover a segment of the Flash Dryer ie the Drying Duct; the other part are also needs to be taught therefore, necessitating further programme.
In addition, when other parts are covered, it is necessary to visit Industry where the practical of it on reality need to be done.

Appendix 2

What is your overall opinion about this training course?

1 2 3 4 5 6 7 8 ~~9~~

Disliked extremely — Neutral — Liked extremely

Write any additional comment:

1. There Should be follow-up Seminar/workshop on it i.e it should be a Continuous exercise.
2. Practical workshop Should be Organised once in a while.
3. Manuals/Documents should be worked on as against next work shop.

What is your overall opinion about this training course?

1 2 3 4 5 6 7 8 ~~9~~

Disliked extremely — Neutral — Liked extremely

Write any additional comment:

I suggest a follow up training and to include other areas of dryer components like blower selection, Heat exchanger evaluation, Cyclone design and evaluation.
Possible on-line can be suggested such that a date will be fixed for participants to be on Skype while the lecturer will present his paper.
Also Nigeria Engineers and fabricators need more exposure to instrumentation use in Cassava processing equipment development.
I appreciate the training and the organizer, the trainer is fantastic.

Appendix 2

What is your overall opinion about this training course?

1	2	3	4	5	6	7	8	9
Disliked extremely				Neutral				Liked extremely

Write any additional comment:

I really enjoyed the course and it exposed to me more the technicalities ~~of~~ on flash dryers. I would have love to have more technical details on the design of each unit of the flash dryer for the purpose of uniformity and better efficiency. Onece again I enjoyed it and will like like to talk to the trainer latter.

What is your overall opinion about this training course?

1	2	3	4	5	6	7	8	9
Disliked extremely				Neutral				Liked extremely

Write any additional comment:

This is a nice following up training to an earlier Workshop. A further follow up is suggested to keep the learning experience momentum sustained. Nice training. Coordination by Dr Marcello.

Appendix 3

Determining energy efficiency of dryers

A two-days intensive-course facilitated by Dr Marcelo Precoppe

Crop Postharvest Technologist | Food and Markets Department | Natural Resources Institute | Faculty of Engineering and Science | University of Greenwich

Absolute humidity (g_{water} $kg_{dry\ air}^{-1}$)

The absolute humidity (Y) can be calculated from measured values of temperature (T) relative humidity (φ) and pressure (P).

Air enthalpy (kJ $kg_{dry\ air}^{-1}$)

Enthalpy of the air (h) can be calculated from measured values of temperature (T) relative humidity (φ) and pressure (P).

Solid moisture content on a dry basis (kg_{water} kg_{dm}^{-1})

Solid moisture content on a dry basis (X) is measured at the lab, most commonly using the oven method.

Solid mass flow rate on a dry basis (kg_{dm} h^{-1})

The solid mass flow rate on a dry basis ($\dot{m}_{dm}$) is calculated from dried solid output rate ($\dot{m}_{ds}$) and the dried solid moisture content (MC_{ds} or X_{ds}).

Air density (kg m^{-3})

Density of the air (ρ) is calculated from measured values of temperature (T) relative humidity (φ) and pressure (P) Calculated from air temperature relative humidity and pressure.

Air mass flow rate on dry basis ($kg_{dry\ air}$ h^{-1})

Air mass flow rate ($\dot{m}_{air}$) measured air velocity and cross-sectional area plus the calculated is calculated air density (ρ).

Heat input rate to the dryer (kW or MJ h^{-1})

Heat input rate ($\dot{Q}_{in}$) is the energy provided to the dyrer, and is calculated as shown:

$$\dot{Q}_{in} = \dot{m}_{air} \cdot h_{in}$$

Where $\dot{m}_{air}$ is the air mass flow rate, h_{in} is the enthalpy of the air at the dryer inlet and h_{amb} is the enthalpy of the ambient air.

Water evaporation rate (kg_{water} h^{-1})

The water evaporation rate ($\dot{m}_{w}$) is calculated based on the solid mass flow rate on a dry basis ($\dot{m}_{dm}$) and the difference between the wet solid moisture content on a dry basis (X_{ws}) and the dried solid moisture content on a dry basis (X_{ds}):

$$\dot{m}_{w} = \dot{m}_{dm} \left(X_{ws} - X_{ds} \right)$$

Heat rate used for moisture evaporation (MJ h^{-1})

Heat rate used for moisture evaporation ($\dot{Q}_{w}$) is obtained by multiplying the water evaporation rate ($\dot{m}_{w}$) with the latent heat of water vaporisation (λ):

$$\dot{Q}_{w} = \dot{m}_{w} \cdot \lambda$$

Energy efficiency (%)

Energy efficiency (η) is the ratio between the heat rate used for moisture evaporation ($\dot{Q}_{w}$) and the heat rate supplied to the dryer ($\dot{Q}_{in}$):

$$\eta = \frac{\dot{Q}_{w}}{\dot{Q}_{in}}$$

Appendix 4

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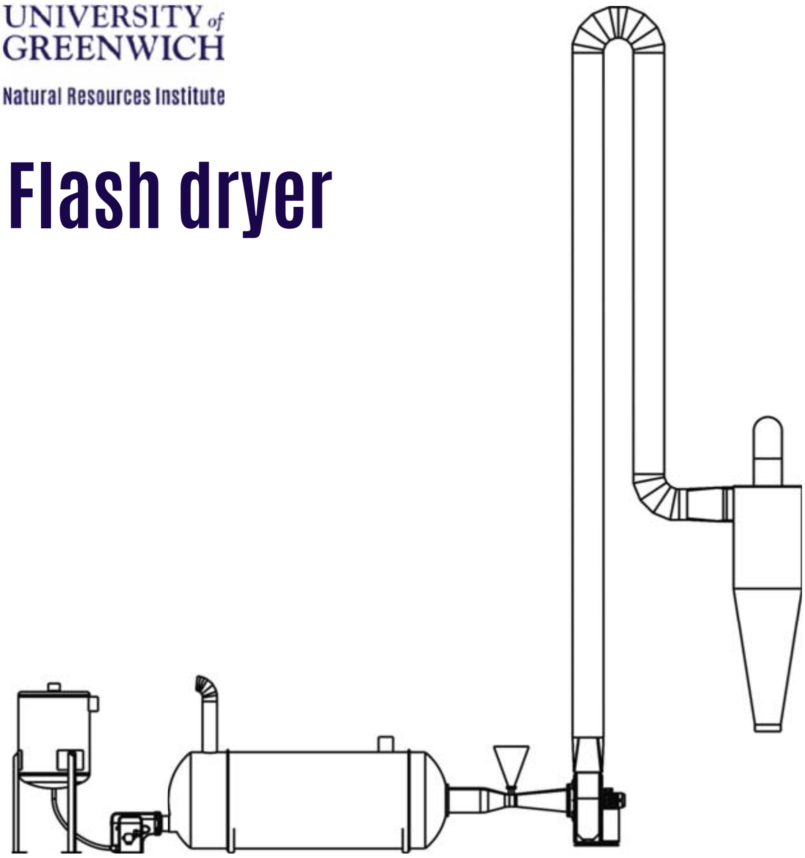
Flash dryer



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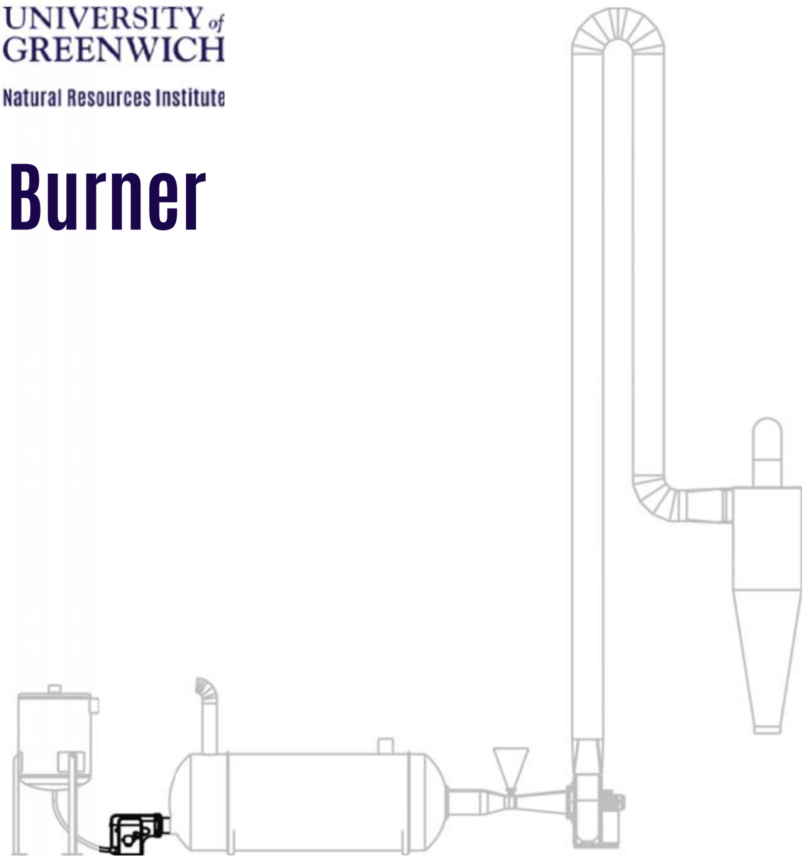
Burner



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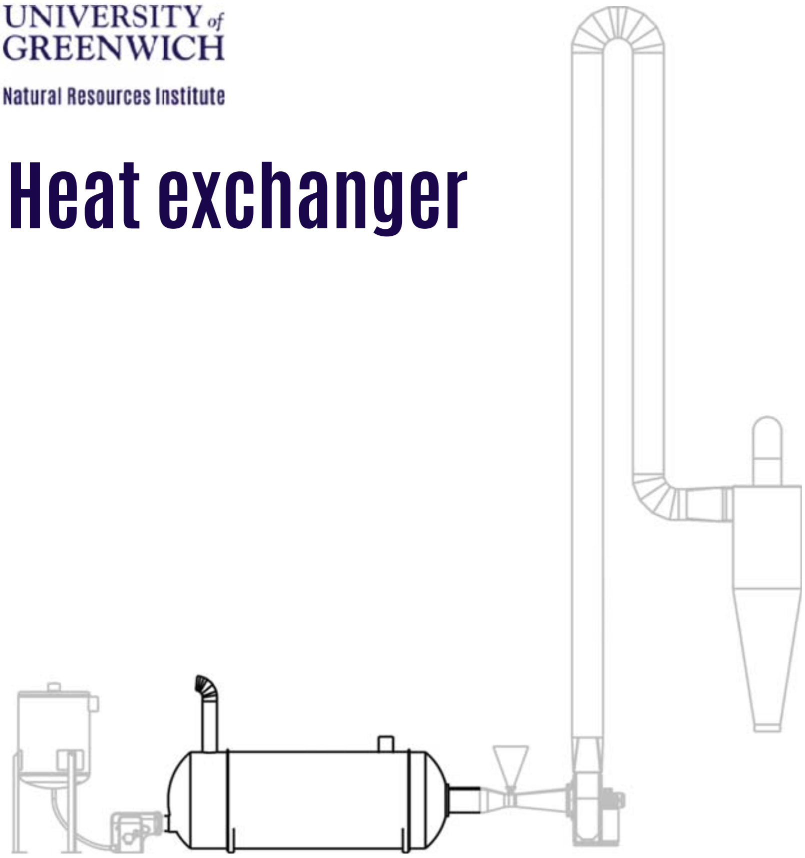
Heat exchanger



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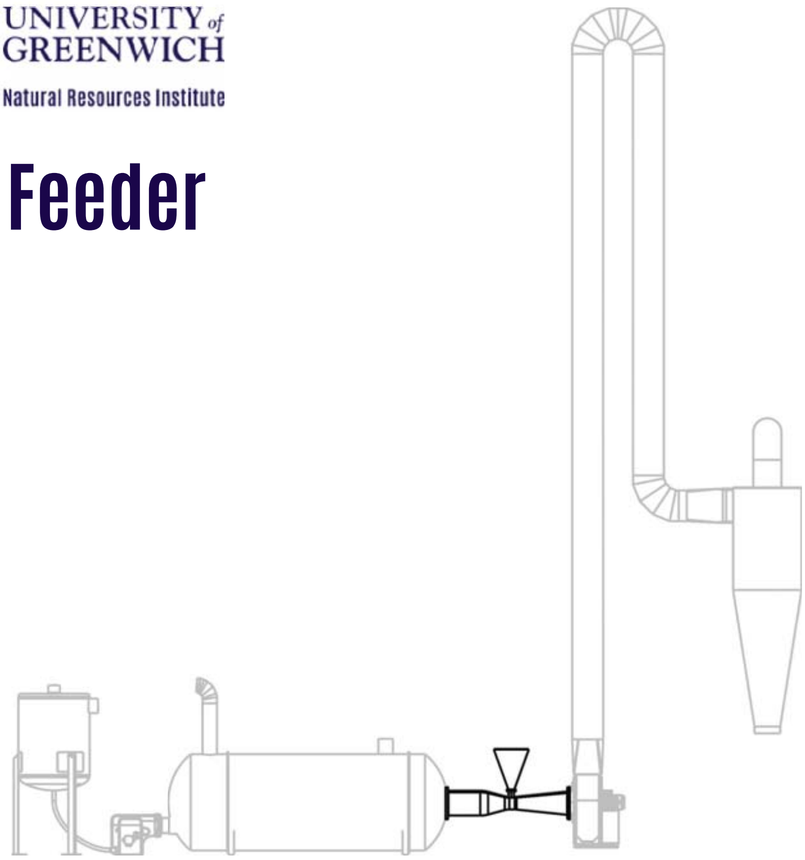
Feeder



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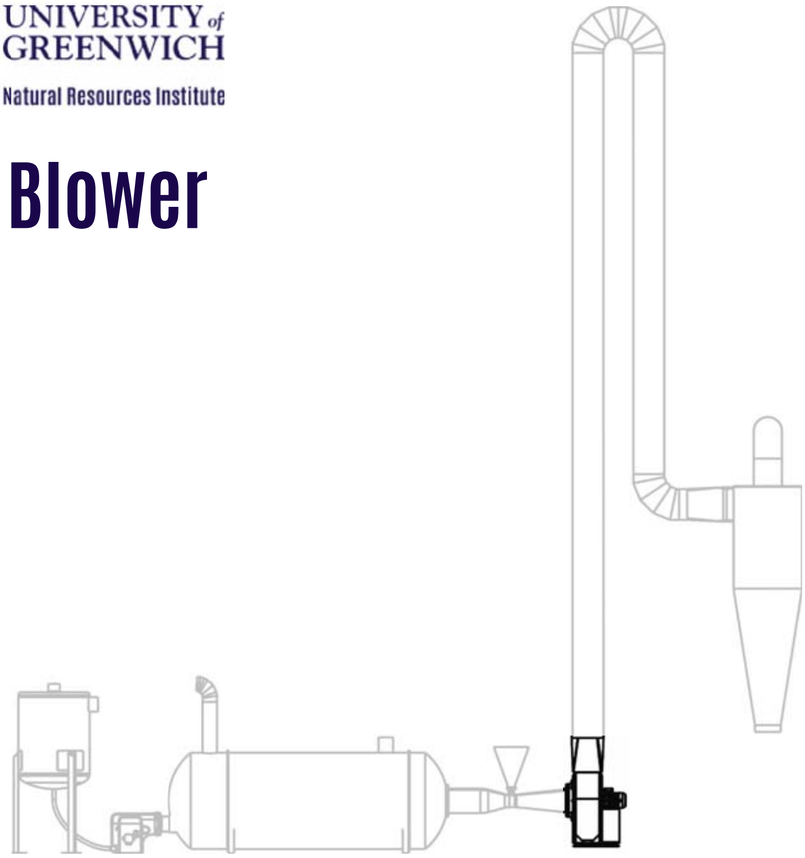
Blower



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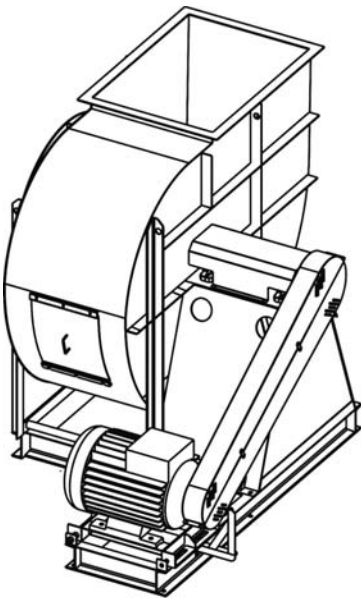
Blower



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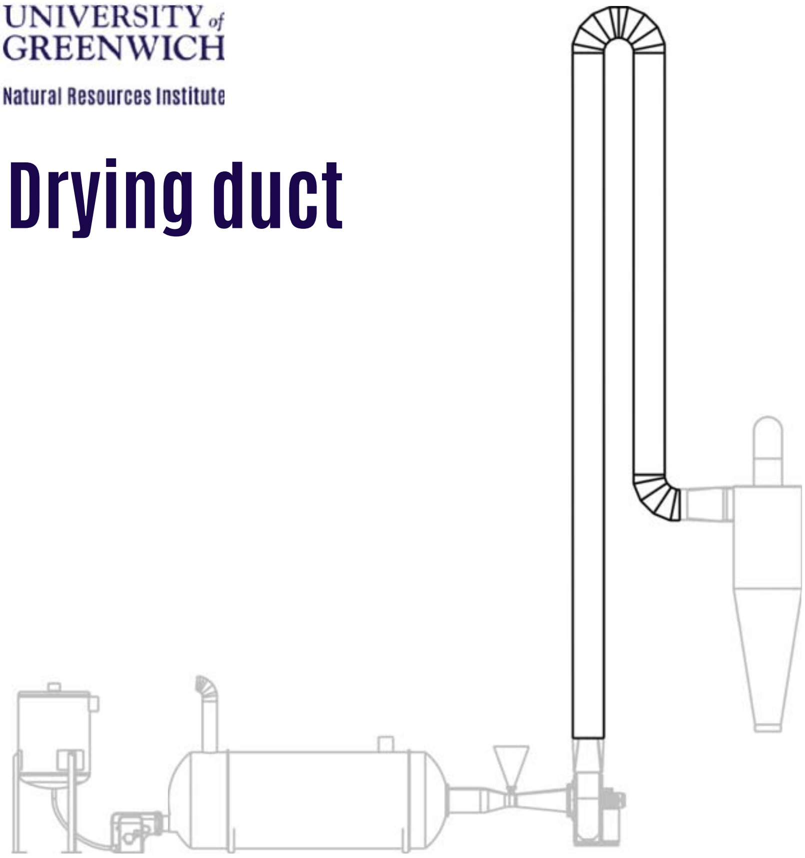
Drying duct



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Cyclone separator