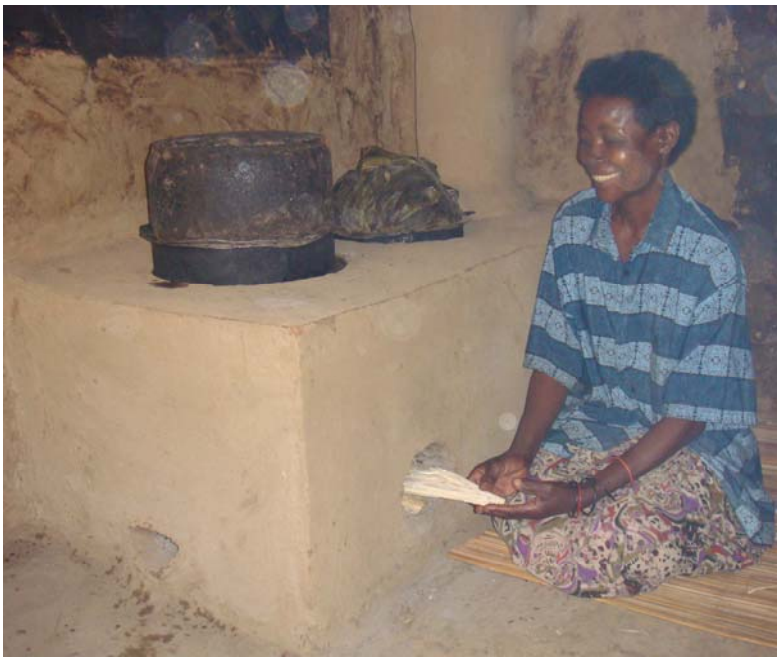
CONSTRUCTION MANUAL FOR THE FIREWOOD SAVING HOUSEHOLD STOVES

THE ROCKET LORENA & SHIELDED FIRE STOVES



MINISTRY OF ENERGY AND MINERAL DEVELOPMENT

PROMOTION OF RENEWABLE ENERGY & ENERGY EFFICIENCY PROGRAMME

With the Support of the German Technical Cooperation

THE REPUBLIC OF UGANDA

MINSITRY OF ENERGY AND MINERAL DEVELOPEMNT

August 2008

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Ms. Beatrice Nambale and Ms. Nakabugo cooking with the Rocket Lorena and Shielded fire stoves respectively at Kigayaza parish, Kangulumira sub county, Kayunga.

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Acknowledgement

This publication is attributed to the work done by several players.

- The initial work on the firewood saving rocket stoves in Uganda was done through the Energy Advisory Project (EAP) in the Ministry of Energy and Mineral Development (MEMD), supported by the German Technical Cooperation (GTZ).

- The rocket – elbow combustion chamber was invented by Dr. Larry Winiarsky at Aprovecho Research Centre, Oregon, USA. Peter Scott of Aprovecho cooperated with GTZ – EAP to introduce it in Uganda in 2003.

- The prototype rocket stoves were developed and tested at the premises of the Uganda Industrial Research Institute in 2003 – 2005 and at the Faculty of Technology Makerere University Kampala in 2007. The support from Dr. Izael Pereira da Silva of the Centre for Research in Energy and Energy Conservation (CREEC) is acknowledged.

- Some of the innovations in the stove construction method have been adopted from the stove artisans based in the districts where the stoves have been disseminated in Uganda including Bushenyi, Rakai, Mukono, Wakiso and Mbale.

- This revised edition of the household stove manual has been published with the support of the GTZ - Promotion of Renewable Energy and Energy Efficiency Programme (PREEEP), for use as a training tool for stove artisans.

Introduction

Uganda faces a biomass energy crisis marked by an increasing imbalance between the supply and the demand for the firewood by households, institutions and industries. One of the most effective strategies to sustainably contribute towards the reduction of this problem is through an extensive dissemination of biomass energy efficient technologies.

The improved biomass energy efficient technologies have been developed to improve energy efficiency for household, institutional and industrial practices. They include the domestic and institutional firewood stoves and the firewood baking oven. The improved household rocket stoves have efficiencies of 30 % (average) compared to the traditional (open) 3-stone fire stove at 15.6 %, in a laboratory high power water-boiling test[1].

These improved stoves help the users to have firewood savings of 50 – 60 % when compared to the traditional (open) 3-stone stove[2]. This implies that the amount of firewood used by a family in one day with a traditional 3-stone fire can be used for 2 – 3 days with the rocket stove. Yet another benefit of these stoves is that they reduce kitchen smoke hence minimising the effects of indoor air pollution. Furthermore the socio-economic advantage of the stoves is that they are cheap and are built using local materials including clay and anthill soil for the body whereas insulating materials include grass and sawdust.

The main objective in developing the improved firewood stoves is to achieve relatively efficient firewood combustion and maximising heat transfer to the food being cooked.

The purpose of this manual is to provide to all interested parties a practical tool to use in the construction of improved firewood stoves i.e. the rocket – lorena and the shielded fire rocket stoves.

[1] MEMD – EAP Records: Makerere Stove Testing Report, January 2008
[2] MEMD – EAP Records: (a) Impact Monitoring study, The Rocket Lorena Stove Dissemination in Bushenyi District, Britta Malinski, January - May 2006. (b) Household Rocket Stove Kitchen Performance Tests in Mukono & Wakiso Districts, June 2008

The Technical Modifications in the Rocket Stove Design

Following the impressive performance of the prototype rocket stoves in comparison with the traditional 3-stone fire stove, the Ministry of Energy and Mineral Development (MEMD) through the Energy Advisory Project (EAP), disseminated several hundreds of thousands of the rocket stoves to alleviate the challenge of firewood scarcity especially in the rural regions of Uganda.

The feedback obtained through the subsequent monitoring[3] indicated that the livelihood of the rocket stove users had significantly improved because of firewood savings, reduction in cooking time and reduction in indoor air pollution among other factors.

However it was also observed that most of the rocket stoves did not have firewood shelves because the materials from which they are made are scarce in the rural communities. The absence of firewood shelves reduced the combustion efficiency and consequently most of the rocket stoves were not utilised optimally. Furthermore it was noted that some of the stove construction materials, e.g. sawdust and vermiculite, that had initially been recommended were generally scarce in many communities.

The GTZ regional workshop on household energy[4] held at Mulanje Malawi in March 2007 highlighted several technical aspects that required a design review in order to enhance stove performance, durability and user satisfaction. The proposed modifications included the possibility of using an air inlet that is separated from the firewood magazine (bypass air inlet). With this modification, the firewood magazine is built in such a way that it suspends the burning tips of the firewood above the bypass air inlet, to simulate the function of the firewood shelf.

From October to December 2007, GTZ – EAP built prototypes of the modified rocket stoves with bypass air inlets and tested them in comparison with the original rocket stoves that are fitted with firewood shelves. The performance results indicated that the performance of the rocket stoves with the bypass air inlet is equivalent to that of the original rocket stove with the firewood shelf.

It was concluded that:

- For optimum performance, the rocket stoves should hence forth be disseminated with a bypass air inlet to simulate the function of the firewood shelf. This will provide the remedy for the absence of firewood shelves, whose construction materials are scarce.
- The rocket stoves should until further notice be built with plastic soils and grass because this combination of stove construction materials is readily available in most of the rural communities. Additionally it has been proven that the rocket stoves built with grass are more durable than those built with sawdust insulation.

This revised stove manual (August 2008 edition) describes the step-by-step construction procedure for the modified mud rocket stoves with the bypass air inlet.

[3] MEMD – EAP: Impact Monitoring study, The Rocket Lorena Stove Dissemination in Bushenyi District, Britta Malinski, January - May 2006

[4] GTZ Report : GTZ Workshop on Household Energy, Mulanje, Malawi, 8 – 13 March 2007

Disclaimer

Whereas relative to the traditional 3-stone (open) fire place the firewood rocket stoves are believed to offer significant benefits to the user(s) including firewood savings, reduced time for cooking and reduced indoor air pollution and whereas this stove construction manual is believed to be a useful tool for instruction in the procedure for the construction of firewood mud rocket stoves, neither the Uganda Ministry of Energy and Mineral Development nor the German Technical Cooperation assumes responsibility for the completeness or usefulness of the information herein. Additionally neither the Uganda Ministry of Energy and Mineral Development nor the German Technical Cooperation assumes liability in respect of any claim(s) that may arise in the event of any injuries and / or damages that may occur during the design, construction, use, misuse, maintenance and / or malfunction of any stoves that may be constructed on the basis of the design or procedure described herein.

Basic Facts about the Improved Household Rocket Firewood Stoves

The improved household rocket firewood stoves are able to achieve maximum transfer of heat to the food because they heat at least 90 % of the saucepan's surface area and have insulation around the combustion chamber and the fire passages to minimise heat losses.

Advantages

1 Saves money

The household rocket stove uses less firewood than a traditional 3-stone open fire. The amount of firewood used by a family in one day by the traditional 3-stone fire stove can last used for 2 - 3 days with a rocket stove.

2 Cooks faster

The rocket-stove fire produces more heat than a 3-stone fire stove and therefore cooks food more quickly. Additionally, the two-pot rocket Lorena stove gives the option of cooking more than one dish at the same time, cutting down on total cooking time.

3 Less smoke

Because of their design, the rocket stoves produce very little smoke. Only a bit of smoke is produced during the lighting process or if wet wood is used.

4 Easy to use

Once lit, the rocket stove fire will not go out unless the user stops adding firewood. There is no need to blow at the flames to keep the fire alight as with a 3 – stone fire.

5 Safe to Use

Rocket stoves are safer to use because the fire is shielded. There is less likelihood of accidents or burns to the user and children.

6 Affordable

Rocket stoves are constructed using locally available materials like anthill soil or sand for the body, and sawdust, ash or grass for the insulation.

7 Heat Retention

These stoves retain heat for a significant period of time which enhances efficiency during simmering and they can be used as food warmers.

8 Environmentally friendly

These stoves use less firewood and therefore contribute to the reduction in the deforestation rate. The rocket stoves are less pollutant because of their nearly smokeless operation.

PREPARATIONS BEFORE BUILDING A HOUSEHOLD MUD ROCKET STOVE

1.0 SHELTER

Ensure that there is a kitchen in place to house and protect the stove to be built from intrusion and extreme weather conditions e.g. rain.

2.0 TOOLS

Table 1: The tools required when building the improved firewood stoves

N	Tool	Purpose
1	Hoe	Digging foundation base and mixing ingredients
2	Shovel or Spade	Mixing ingredients
3	Jerry can	Fetching water
4	Sieve (4 mm)	Sifting ingredients
5	Basin *(karaayi)*	Measuring materials by volume and carrying mixtures
6	Trowel / blunt machete	Smoothing plaster / stove finish
7	Measuring Tape / ruler	Taking measurements
8	Machete *(Panga)*	Cutting and sizing grass, banana stems and stove body
9	Spirit level (optional)	Inspecting horizontal level for laid bricks / stove finish
10	Plumb line (optional)	Inspecting vertical alignment for laid bricks / structure
11	Try Square (optional)	Inspecting right angled corners
12	Wheel barrow	Carrying construction materials to stove construction place

Table 2: Recommended Safety Gear[5]

N	Device	Purpose
1	Nose Mask	Protection against inhaling dust during sifting
2	Overalls / work clothes	Protection of clothes during work
3	First Aid Kit[6]	Treatment for injuries

[5] Recommended for use where available.
[6] Professional workshop practice recommends that a First Aid kit should be in place.

3.0 STOVE CONSTRUCTION MATERIALS

Table 3: Materials used in stove construction and their alternatives

	Materials	Options	Quantity	
			Rocket - Lorena	Shielded Fire
1	Anthill soil	Clay*	8 – 12 wheel barrows Or 25 – 30 basins	4 – 6 wheel barrows Or 8 – 15 basins
2	Dry chopped grass	Sawdust, dry chopped banana leaves	4 – 6 wheel barrows Or 13 – 15 basins	2 – 3 wheel barrows Or 4 – 8 basins
3	Mud bricks♣	-	60 – 80 bricks	10 bricks
4	Water	-	7 – 10 jerry cans (20 litres each)	4 jerry cans (20 litres each)
5	Banana stems	Long grass bundles, papyrus[7]	3 stems	2 stems

4.0 COLLECTION AND DELIVERY OF MATERIALS

Buy or collect all the construction materials and deliver them outside the kitchen where the stove is to be built.

5.0 MAPPING OUT THE STOVE POSITION IN THE KITCHEN

Choose a corner in the kitchen to be occupied by the stove. This will save it from accidental damage and it will also be useful in minimising direct intake of cold air.

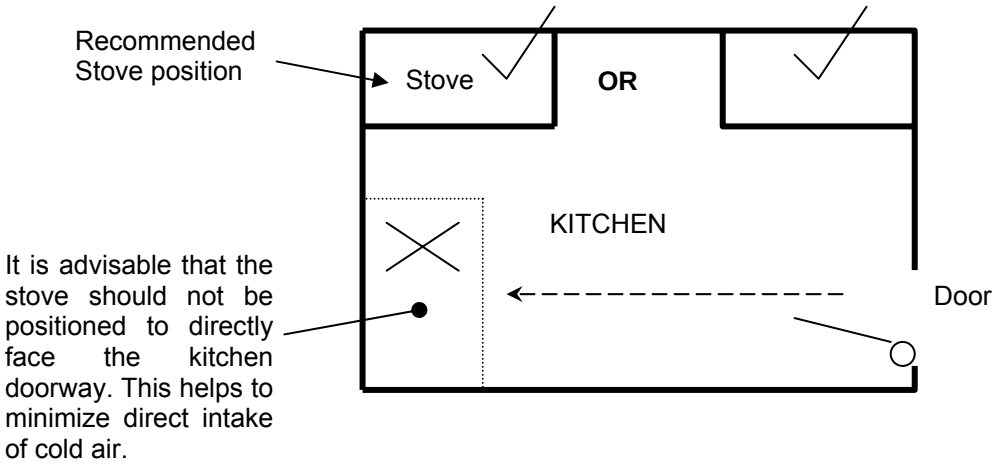


Diagram 1: Positioning of the stove in the kitchen space

* Recommended to use when not contaminated with so much sand and plastic soil

♣ Can be used when soil is scarce but a homogenous stove is preferred

[7] When grass bundles or papyrus are used for moulding the combustion chamber and fire passage, they should be removed immediately after construction.

NOTE:

It is advisable that one week prior to stove construction, a 120 cm X 120 cm X 30 cm high platform be built in the kitchen corner that will be occupied by the stove. On this platform, the stove will be constructed. This will help to keep the stove out of reach for very young children.

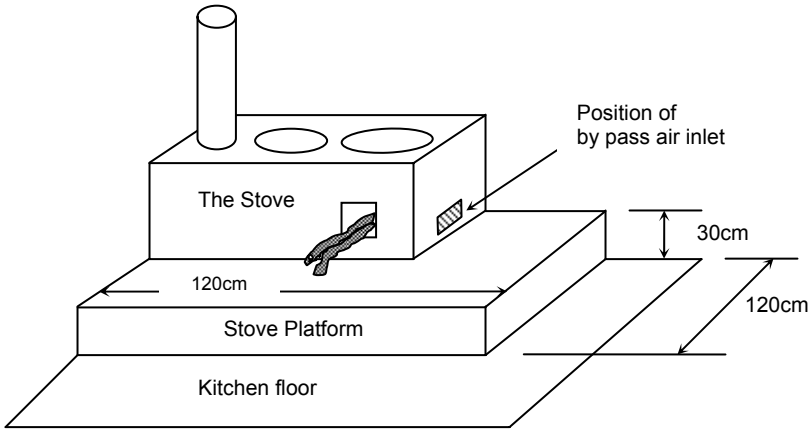


Diagram 2: Platform structure for stove construction

6.0 MATERIALS PREPARATION

Prepare the construction materials, at least two days before the time for stove construction. The preparation procedure will depend on the materials combination chosen as described below:

6.1 Grass and anthill soil (clay option)

6.1.1 Use a machete to chop the dry grass into small pieces of approximate length 1cm. This should be done carefully to avoid injuries.

Photo 1

6.1.2 Crash the anthill soil into smaller granules, and sort it to eliminate stones, sticks and other unwanted materials.

Photo 2

6.1.3 Mix the chopped dry grass and anthill soil in a volumetric ratio 1:2 (or with clay soil in a ratio of 1:1).

Photo 3

6.1.4 Slowly add water to the mixture to make it mouldable.

Photo 4

In the event that grass is not available in your place, you may use any of the following stove construction materials combination depending on availability:

6.2 Sawdust and Clay (Option)

6.2.1 Crash the clay into smaller granules and sort it eliminate stones and sticks other unwanted materials.

6.2.2 Sort an equal amount of sawdust to obtain fine particles.

6.2.3 Mix the sawdust and clay in a volumetric ratio 1:1

6.2.4 Slowly add water to the mixture just to make it mouldable.

6.2.5 Blend the mixture using feet similar to the way it is locally done when preparing mud for brick making.

6.3 Dry banana leaves and clay or anthill soil (Option)

6.3.1 Separate the stalk and mid-rib from the lamina. Use the dry lamina of the dry banana leaves.

6.3.2 Use the machete *to* chop the dry lamina into small pieces of approximate length 1 cm.

6.3.3 Crash the clay or anthill soil into smaller granules and sort it to eliminate stones and sticks other unwanted materials.

6.3.4 Mix the chopped lamina and clay or anthill soil in a volumetric ratio 1:1

6.3.5 Slowly add water to the mixture just to make it mouldable.

6.3.6 Blend the mixture using feet similar to the way it is locally done when preparing mud for brick making.

PART 1

HOW TO BUILD THE SHIELDED FIRE ROCKET STOVE

Photo 5: A typical shielded fire stove

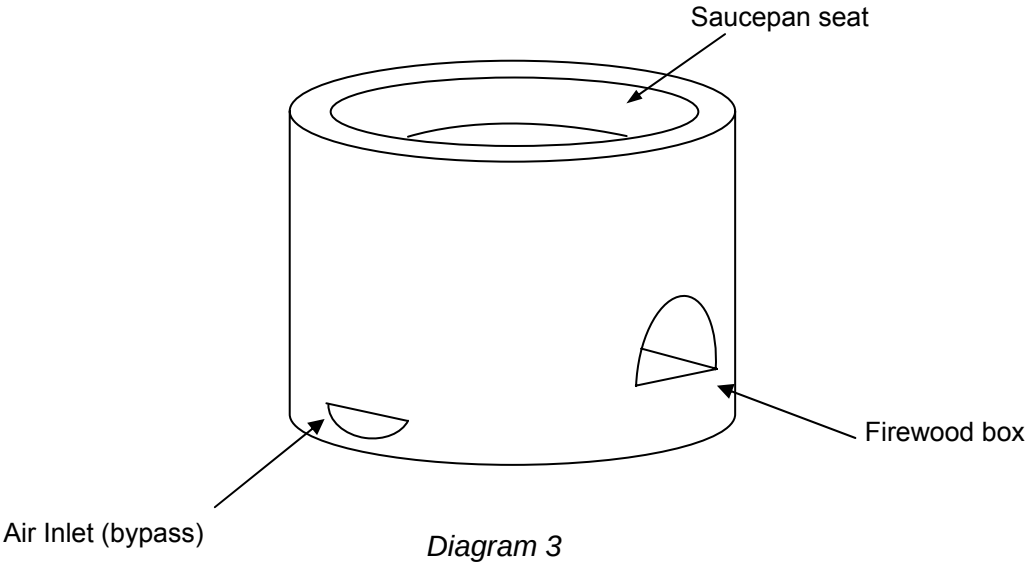


Diagram 3

HOW THE SHIELDED FIRE ROCKET STOVE WORKS

Below is the section view of the stove showing how it is intended to function. The saucepan cavity for the shielded fire rocket stove should be deep enough to allow the saucepan to be submerged into the stove cavity. This increases heat transfer to the saucepan.

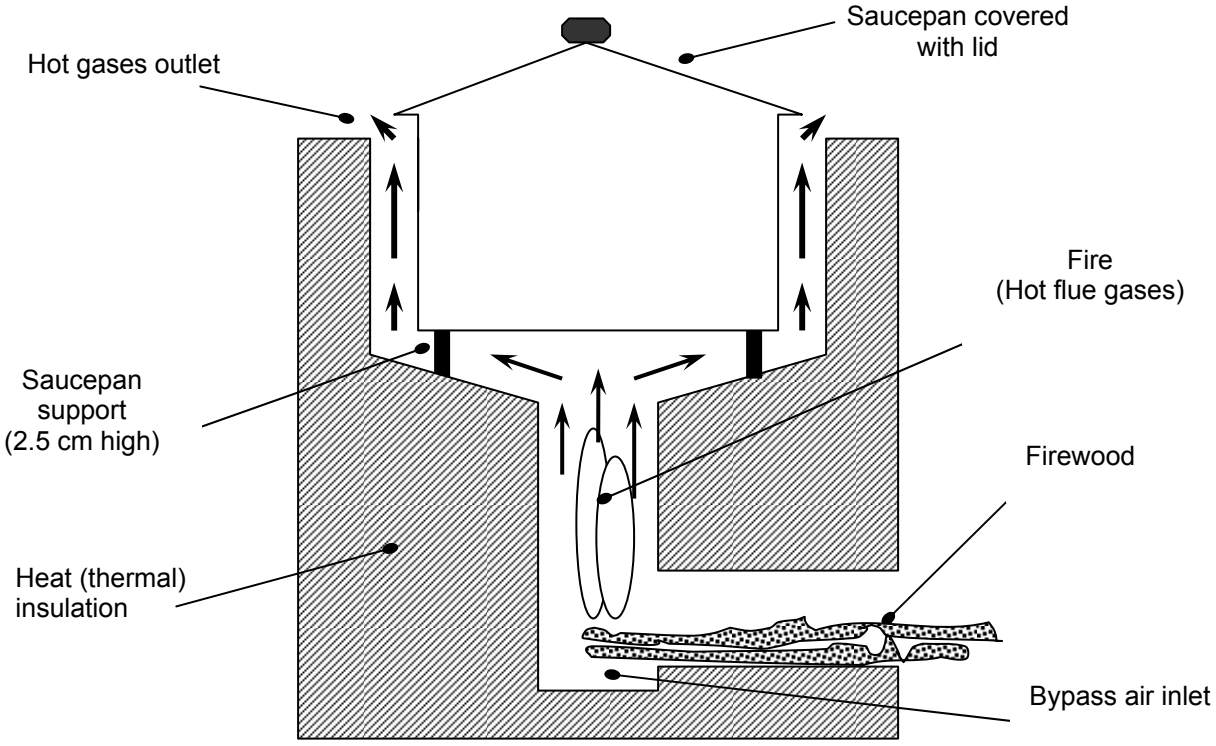


Diagram 4: Sectioned view of the Shielded fire rocket stove

7.0 Building the Shielded Fire Rocket Stove

The size of the stove depends on the size of the saucepan to be used in cooking.

Example:

For a home that frequently uses a saucepan of 3.5 litres with a diameter of 26 cm, the combustion chamber will be 12 cm X 12 cm (or circular option diameter = 13.5 cm).

The stove designed for a 26 cm diameter saucepan will have the resulting outer diameter = 50 cm (Calculation shown on the next page).

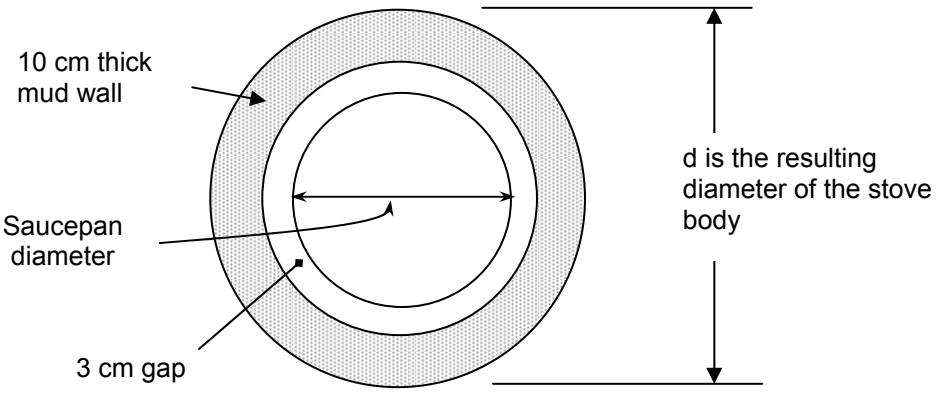


Diagram 5: Stove wall thickness

7.1 Laying the stove foundation

- Using the mixture in 6.1.5 lay down a 6 cm high base for the stove, bordered by the marked outline.
- Lay the foundation to 6 cm high soil-grass mixture (an alternative is the use of sawdust – clay mixture).
- While setting the foundation care should be taken to ensure that the combustion chamber is centred.

If the saucepan diameter = D, the resulting stove base diameter d = D +24 cm, and the combustion chamber width = J.

For example when using a saucepan of 26 cm, the resulting stove diameter d = D + 24 = 26 + 24 = 50 cm.

The combustion chamber width J = 12 cm for squared or 13.5 for round shaped chamber from the tables on the last page.

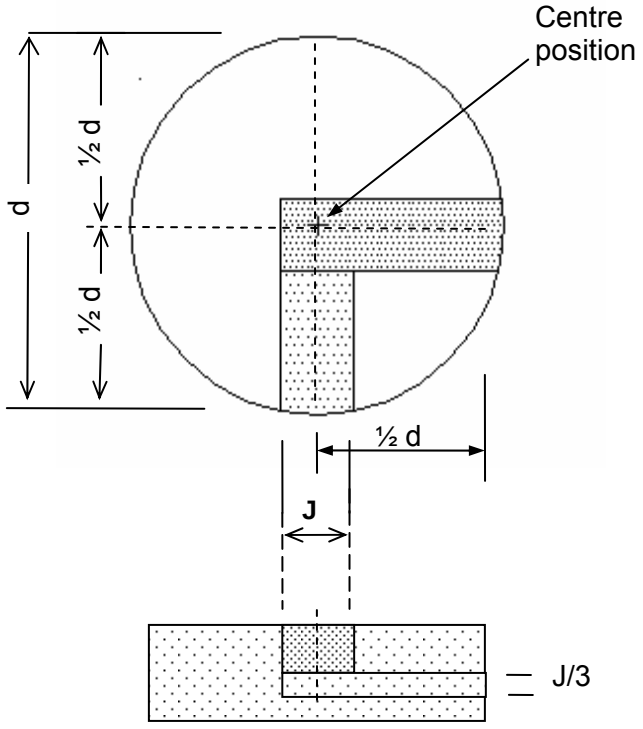


Diagram 6: Setting the combustion chamber position at the base

NB: While bricks may be used, experience has shown that stoves that are constructed using a homogeneous soil - grass mixture are more durable.

7.2 Constructing the combustion chamber:

- Cut a banana stem, and remove its outer layers to reduce its diameter to approximately13.5 cm.
- Cut it into segments one of which is to be positioned vertically and the other one horizontally as shown on the next page.
- The vertical one should be equal to the value of H given in the appendix, (i.e. 30 cm for this worked example). It is recommended that the core of this stem should be removed without distorting its cylindrical shape. This will ease its removal from the stove body at a later stage.

Photo 6

- The length of the horizontal one should be equal to ½ d plus 10 cm so that it can easily be removed later when the stove is dry.
- Note: 1/2 d = stove radius.
- Measure off the horizontal length (38 cm) and diameter (13.5 cm) of the horizontal stem, using a measuring tape read off one third (4.5 cm) of the diameter. Using a machete, split the stem to obtain two pieces as illustrated in photo 7.
- The smaller piece (4.5 cm thick) will form mould for the air inlet while the bigger one (9 cm thick) will form mould for firewood inlet.

Photo 7

Example:

- Using a saucepan of cooking capacity 3.5 litres with diameter D = 26 cm, the combustion chamber will be 12 cm wide and 30 cm high. This implies that: J = 12 cm, H = 30 cm.
- The stove diameter, d = 50 cm
- Therefore ½ d = ½ X 50 = 25 cm.
- The length of the horizontal stem then becomes ½ d + 10 cm = 25 +10 = 35 cm.
- Using a measuring tape, read off one third (4.5 cm) of the diameter of horizontal stem. Using a machete split the stem to obtain two pieces. The smaller piece (4.5 cm thick) will form the mould for the bypass air inlet while the bigger one (9 cm thick) will form the mould for firewood inlet as illustrated in the next section.

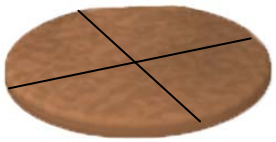
7.3 Determining the centre of the stove

- With the stove foundation already laid as shown in fig 1

Fig. 1

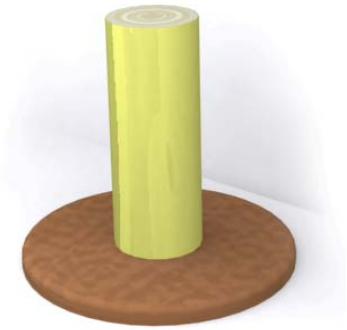
- Draw two perpendicular lines across the diameter of the stove foundation and mark their point of intersection. This will be the centre of the stove foundation as illustrated in figure 2.

Fig 2



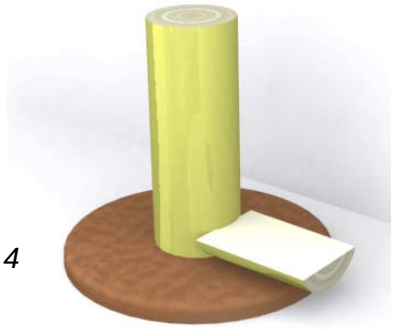
- Place the vertical banana stem at the centre of the stove foundation.

Fig. 3



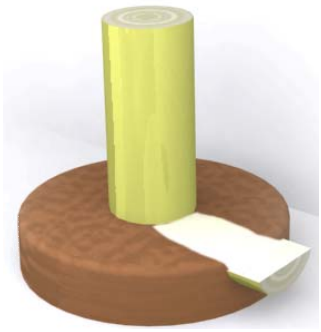
- At the stove foundation level, place the smaller piece of 4.5 cm thick banana stem to form mould for the bypass air inlet at a right angle (90^0) to the vertical stem as shown in the figure 4.

Fig. 4



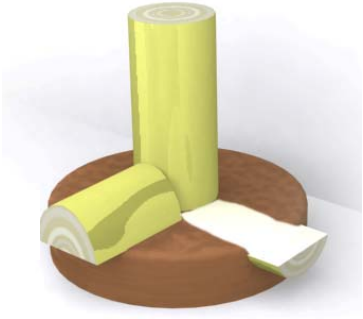
- Build the soil – grass mixture around the banana stems up to the level of the flat face of the inverted stem as illustrated in figure 5.

Fig. 5



- Position the bigger banana stem (9 cm thick) perpendicular to the bypass air inlet mould. Ensure that its flat surface faces downwards to form the mould for the firewood inlet (magazine). See figure 6.

Fig. 6



7.4 Constructing the stove body

Continue constructing the stove using the soil – grass mixture up to the height of the vertical banana stem. Level the top of the stove structure as illustrated in figure 7.

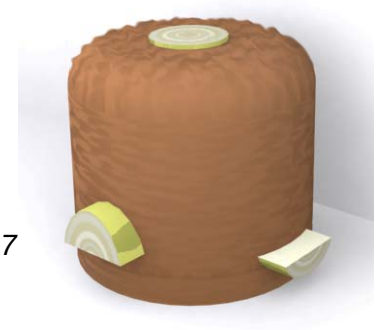


Fig. 7

7.5 Constructing the saucepan cavity

- Wet the outside of the saucepan using a mixture of wood ash and water to ease its removal at a later stage.
- Position the saucepan such that the centre of its bottom sits at the centre of the vertical banana stem (figure 8), and then place a considerable weight e.g. a piece of brick or stone in the saucepan to hold it in position.

Fig. 8

- Fill the space around the saucepan with the insulation mixture as shown in figure 9 up to the height of the saucepan rim.

Fig. 9

- Remove the saucepan carefully by rotating back and forth while lifting it out. (Fig 10).

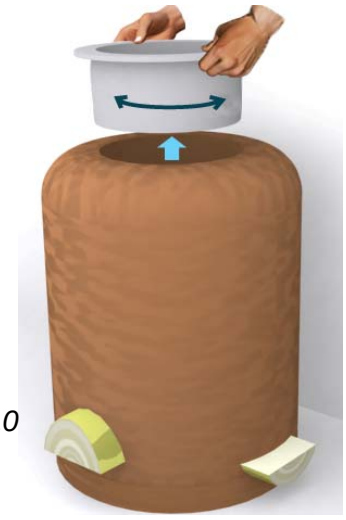


Fig. 10

- Cut out a 3 cm thickness of the mixture layer off the saucepan cavity to enlarge it and give room for the fire (flue gas) to flow around the saucepan cavity during stove use in future.

Fig. 11

- Inside the saucepan seat, build 3 saucepan supports equidistant from the centre of the combustion chamber with a uniform angular spacing of 120^0 as shown in figure
- These will hold the saucepan high enough to allow the fire (hot flue gases) to flow from the bottom to the sides of the saucepan during stove use in future.

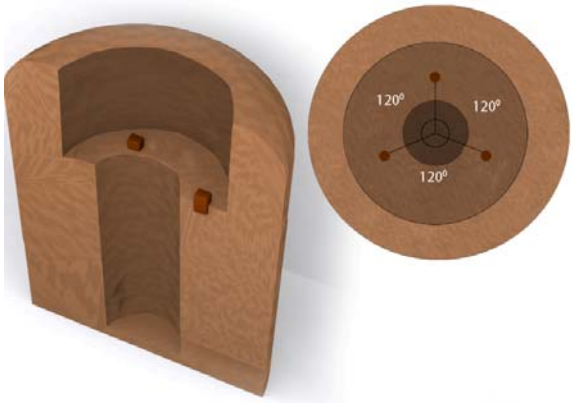


Fig. 12

7.6 Finishing the stove construction

- Plaster the stove body to give it a good finish. You may use any of the materials that are used to plaster mud walled huts e.g. a mixture of sap from sweet potato vines, silt and water or a mixture of sand, cow dung and water etc. This helps to prevent the stove body surface from developing cracks and it also makes it fairly watertight.

- Use wet fingers, a wet trowel or banana stem cuttings to smooth the finish such that the stove is completely without cracks.
- Ensure that the stove's top surface is uniformly horizontal. Use the spirit level if available (optional).

- Leave the stove block to dry for 4 weeks, while covered with a watertight material e.g. polythene sheet or banana leaves.
- Protect the stove from sunshine and rain**.**
- Restrict children and animals from accessing the stove during the drying process.

After 4 weeks of drying:

- Remove the now shrunk banana stem pieces from the stove body.
- Smooth the fire (hot flue gases) passage including combustion chamber and air inlet using wet hands.

Note:
By this time the stove body may have cracked during the drying process, seal the cracks using the original form of mixture that was used in stove construction.

Fig. 13: The finished shielded fire rocket stove

For details on, stove usage, cleaning and maintenance, refer to the sections 9 and 10 on pages 26 - 28

PART 2

HOW TO BUILD THE HOUSEHOLD ROCKET LORENA STOVE

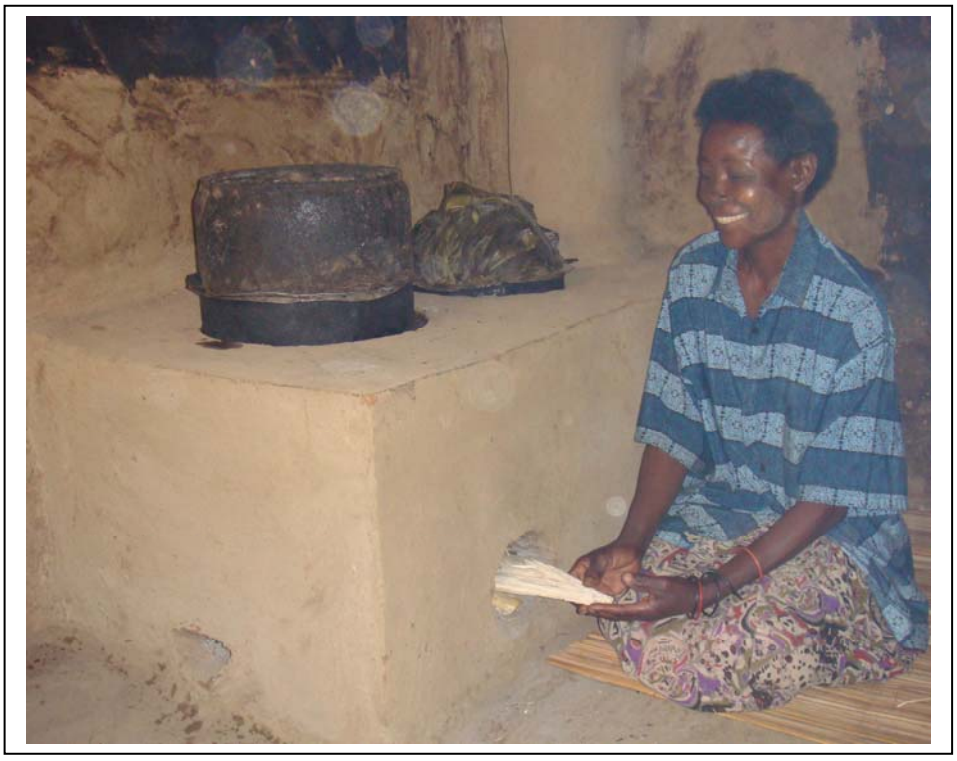


Photo 8: A Rocket Lorena two-pot stove in use

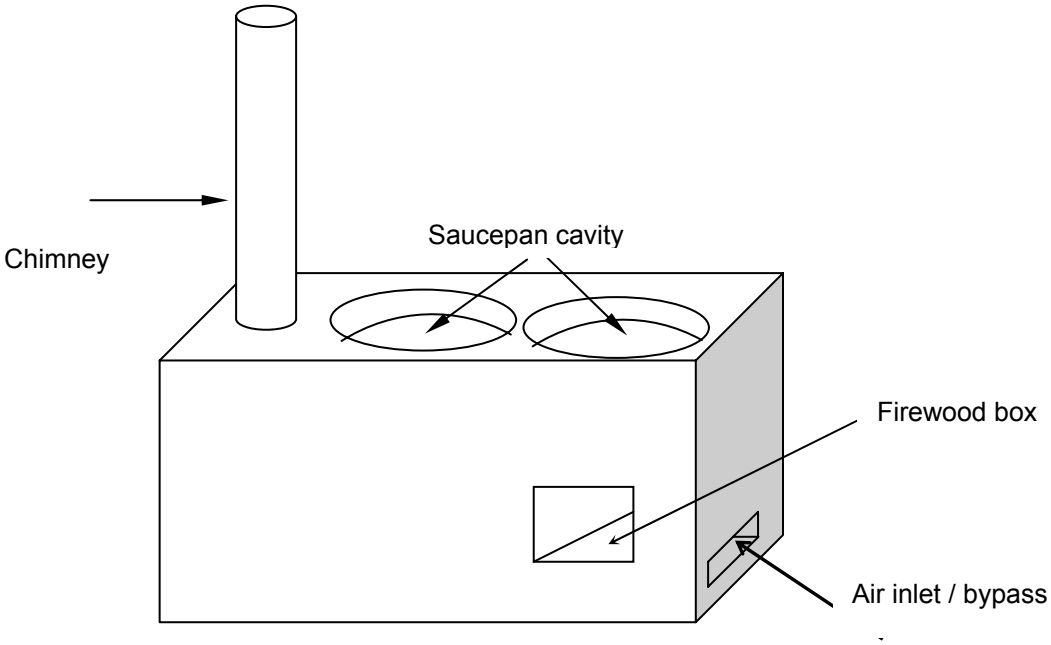


Diagram 7: Structure of the Rocket Lorena two-pot stove

HOW THE ROCKET LORENA STOVE WORKS

Below is the sectioned front view of the rocket lorena stove, showing how it is intended to function. The saucepan cavity is deep enough to submerge the saucepans into the fire (hot gases). This increases the surface area of the saucepan in contact with the fire (hot gases) hence improving heat transfer into the saucepan. This stove uses the rocket elbow combustion chamber with a side inlet for air which improves the air - fuel ratio and combustion efficiency, resulting into an almost smokeless operation. Thermal insulation is obtained by mixing of grass in the stove construction materials using appropriate ratios. During stove use the grass burns out and it creates air pockets which give the stove body a thermal insulative characteristic.

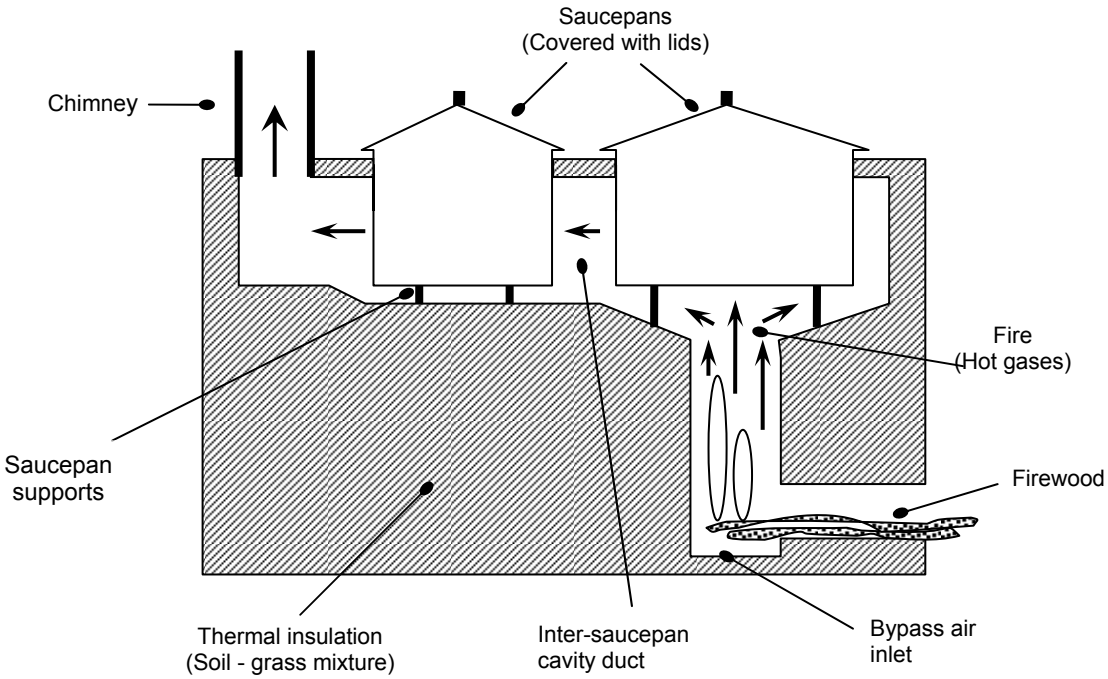


Diagram 8: Sectioned view of the two-pot Rocket Lorena stove

8.0 Building the Rocket - Lorena Stove

The size of the stove, combustion chamber and chimney will depend on the size of the big saucepan that will be used when cooking with it. This relationship is shown in appendix 2 (page 30) which should be referred to at the beginning of stove construction. This relationship is based on saucepan dimensions commonly used in Uganda.

Example:
For a home that frequently uses two saucepans of capacity 3.5 litres and 2.5 litres and diameter 26 cm and 23 cm respectively, the bigger saucepan should be positioned directly above the combustion chamber while the smaller one takes the other position. The size of the combustion chamber will be 12 cm X 12 cm or circular option diameter = 13.5 cm. The inner diameter of the chimney will also be 13.5 cm.

The stove design for 3.5 litre bigger and 2.5 litre smaller saucepans will have the resulting outer dimensions = 107 cm X 56 cm.

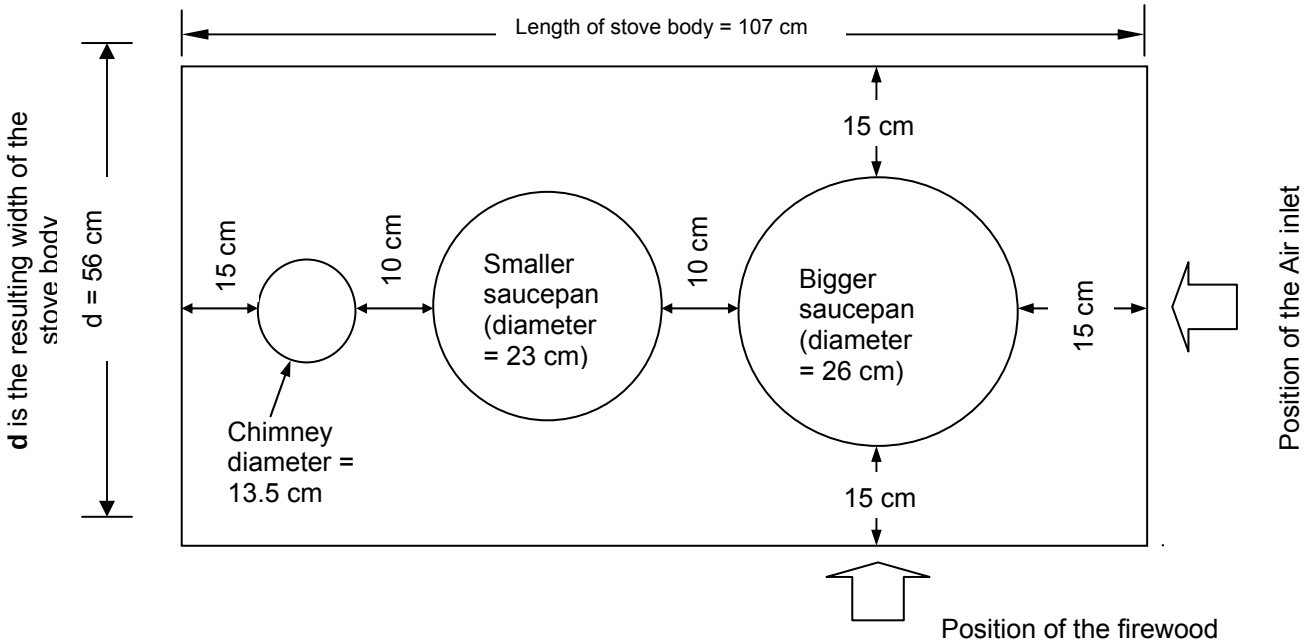


Diagram 9: Sketch of the stove plan

Draw the outline of the stove foundation illustrated in diagram 9. The bigger saucepan should be positioned directly above the combustion chamber while the smaller one takes the other position. In the event that a measuring tape is not available, use your palm width. The width of your palm approximates 10 cm. For the 15 cm measurement use 1½ palm widths.

8.1 Wet the marked out position to be occupied by the stove. Using the mixture in 6.1.5 above, lay down a 6 cm high base for the stove, bordered by the marked out line.

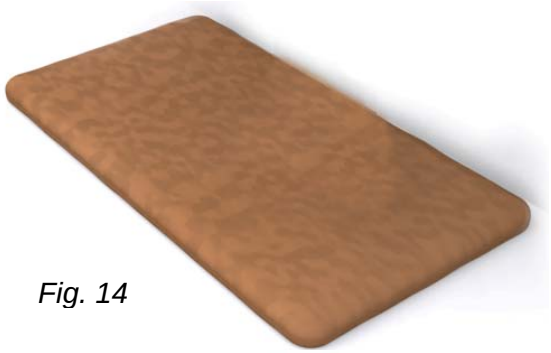


Fig. 14

8.2 While setting the foundation, the combustion chamber base should be catered for as shown. E.g. if the bigger saucepan diameter is 26 cm, use 13.5 cm wide banana stem for mould (appendix 2). Vertically insert the banana stem.

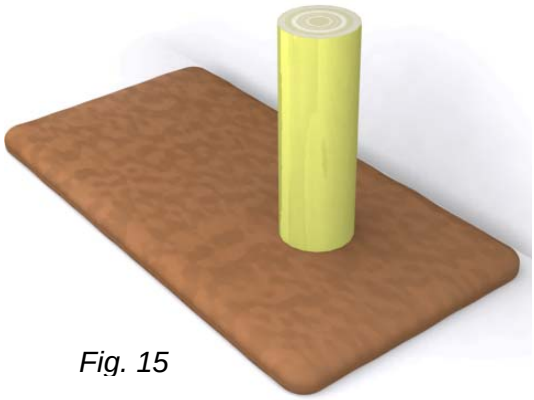


Fig. 15

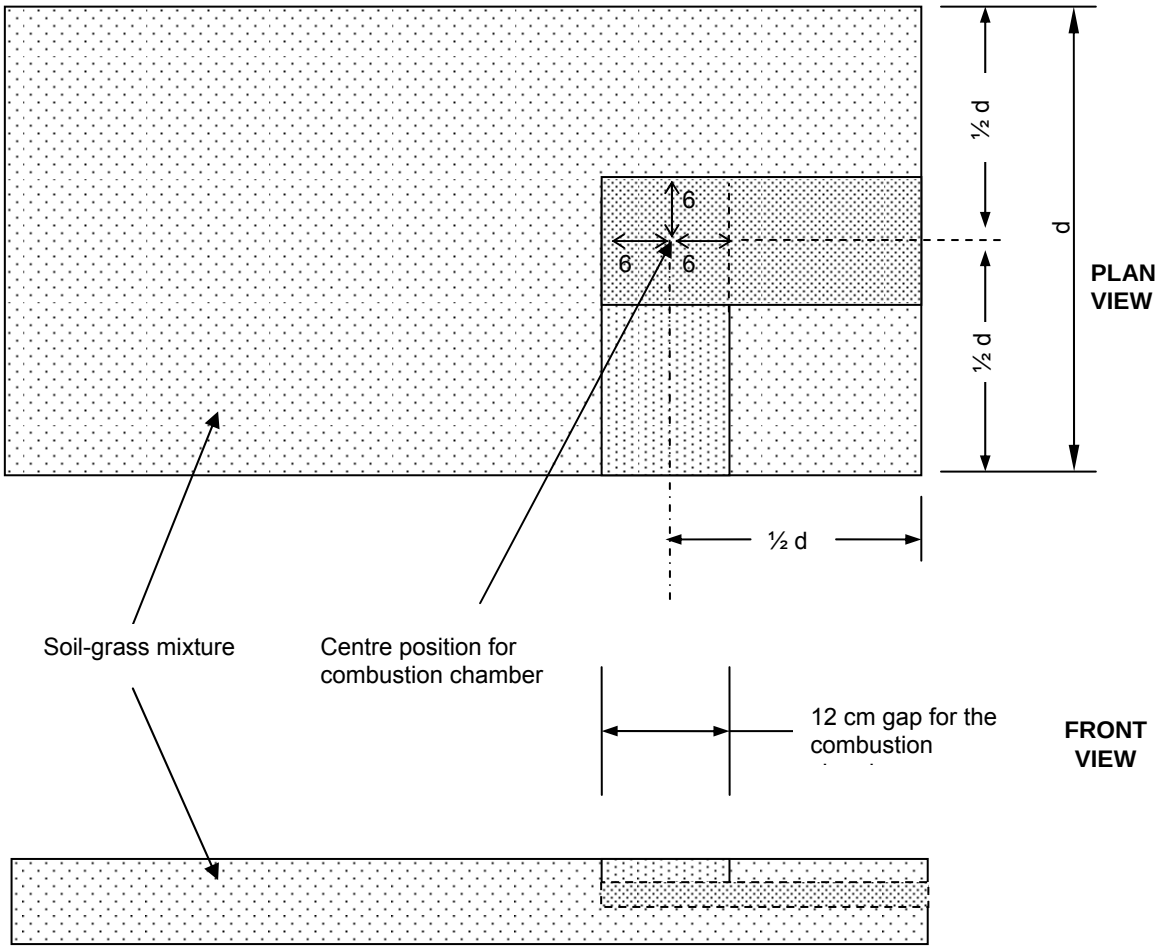


Diagram 10: Plan and front view of combustion chamber position

You will need some material to mould the combustion chamber shape during stove construction.
In order to build a square cross section combustion chamber of 12 cm x 12 cm for support use square cross section bricks of same size (12 cm x 12 cm) covered in polythene material.

For option of circular combustion chamber use diameter = 13.5 cm.
(For details of the calculation, refer to appendix 1).

8.3 Building the combustion chamber

The worked example of the 3.5 litre (26 cm diameter) and 2.5 litre (23 cm diameter) saucepans will be illustrated with the construction of a stove with a circular combustion chamber of diameter 13.5 cm.

- Cut a banana stem, and remove its outer layers to reduce its diameter to approximately 13.5 cm.
- Cut it into segments one of which is to be positioned vertically and the other one horizontally.
- The length of the horizontal one should be equal to half of the stove base width (½ d) plus 10 cm.
- The **vertical** one should be equal to the corresponding value of H given in appendix 2. It is recommended that the core of this stem should be removed without distorting its cylindrical shape. This will ease its removal from the stove body at a later stage.

Photo 9

Example:

Using a 26 cm diameter saucepan, combustion chamber = 12 cm wide, H = 30 cm; which implies that:

- The height of the vertical banana stem is 30 cm.
- The stove width is (26 +30) = 56 cm = d.
- Therefore ½ d = ½ X d = ½ X 56 = 28 cm.
- The length of the horizontal stem then becomes ½ d + 10 cm = 28 +10 = 38 cm

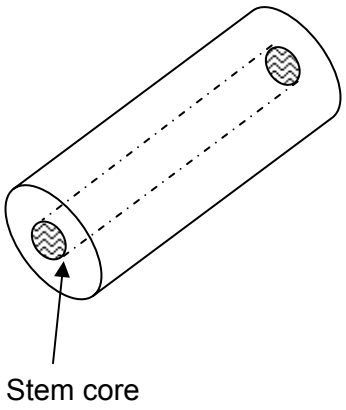


Diagram 11

After measuring off the horizontal length (38 cm) and diameter (13.5 cm) of the horizontal stem, using a measuring tape read off one third (4.5 cm) of the diameter. Using a machete, split the stem to obtain two pieces as illustrated in photo 10.

The smaller piece (4.5 cm thick) will form mould for the air inlet while the bigger one (9 cm thick) will form mould for firewood inlet.

Photo 10

As illustrated in figure 16, place the smaller (4.5 cm thick) banana stem at the base perpendicular to the vertical one in the direction of air inlet with the flat surface facing up.

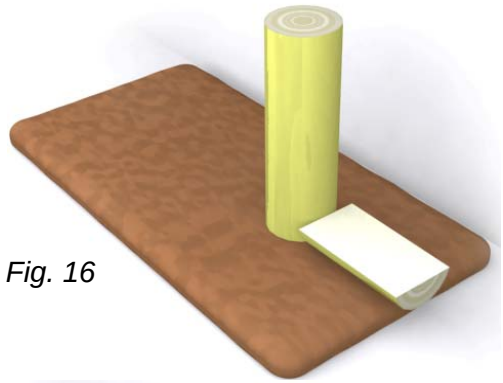


Fig. 16

Continue building the stove structure with the mixture to level with this banana stem as illustrated in figure 17.

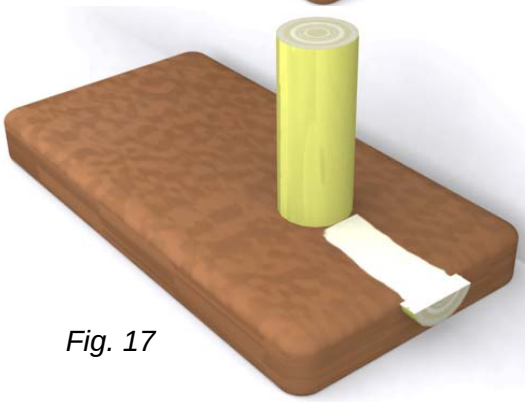


Fig. 17

Place the bigger (9 cm thick) banana stem at that level such that it is perpendicular to both the vertical and the air inlet as illustrated forming the firewood magazine with the flat surface facing down. See figure 18.

Note: Ensure that the banana stem pieces remain in their original position

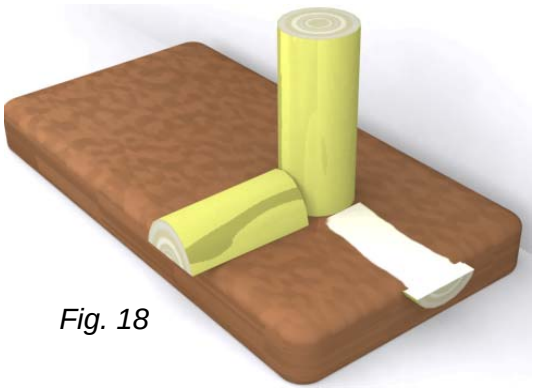


Fig. 18

8.4 Continue constructing the stove body up to the level at which the vertical banana stem just gets covered as shown in figure 19.

Fig. 19

- Measure out the positions of the saucepans, the chimney and the 10 cm gaps between them.
- Position the big saucepan such that the centre of its bottom sits at the centre of the vertical banana stem. Raise the adjacent space for the smaller saucepan using the insulation mixture to get level at the top of the saucepans (Figure 20).

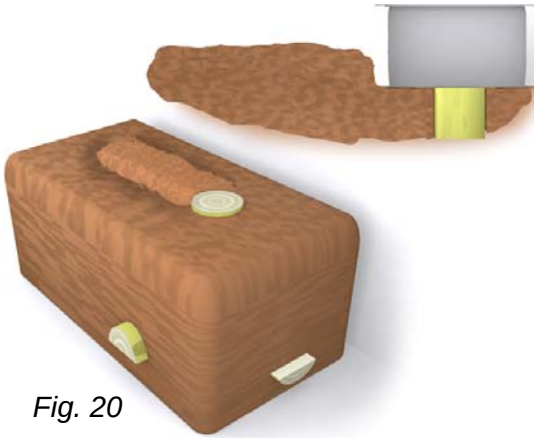


Fig. 20

- Then put the smaller saucepan in the other position (as shown) and level the top of the two saucepans (Figure 21).
- Place horizontal banana stem segments each of length 10 cm between the saucepans and the chimney position (Figure 21).

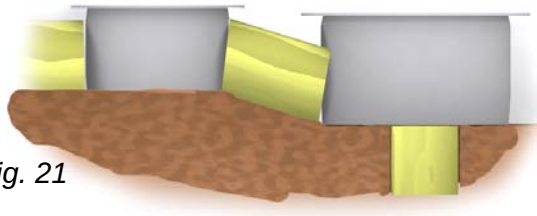


Fig. 21

- Place a vertical banana stem of height 100 cm to 130 cm, depending on the height of the kitchen roof, for use as a mould for the chimney (Figure 22).

- <u>Note:</u> The diameter of all the banana stems should also be equal to the one used for the combustion chamber i.e. 13.5 cm.

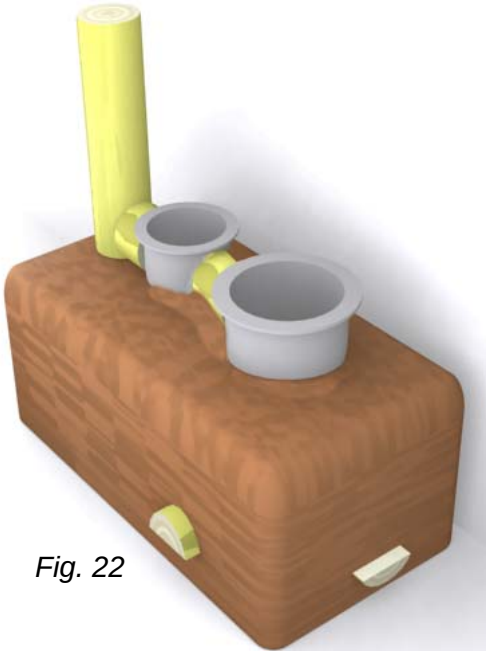


Fig. 22

8.5 Constructing the saucepan cavities

- Place bricks in the saucepans to hold them in position, as shown and fill the space around the saucepans with the insulation mixture. In case bricks are not available, you may use stones of equivalent size (Figure 23).

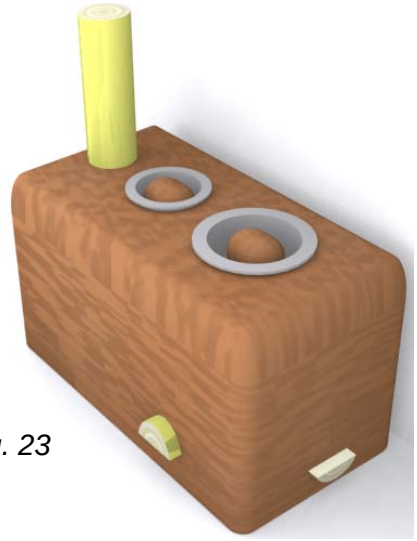


Fig. 23

- After all the saucepan body is covered by the mud, remove the saucepans carefully by rotating back and forth while lifting out as shown in figure 24.

Fig. 24

8.6 Constructing and shaping the Chimney

- Determine a suitable height on the vertical stem for bending the chimney. A height of 75 cm – 100 cm is recommended (depending on the height of the kitchen roof).
- Then cut a V-shaped dent in the vertical banana stem as shown in figure 25.

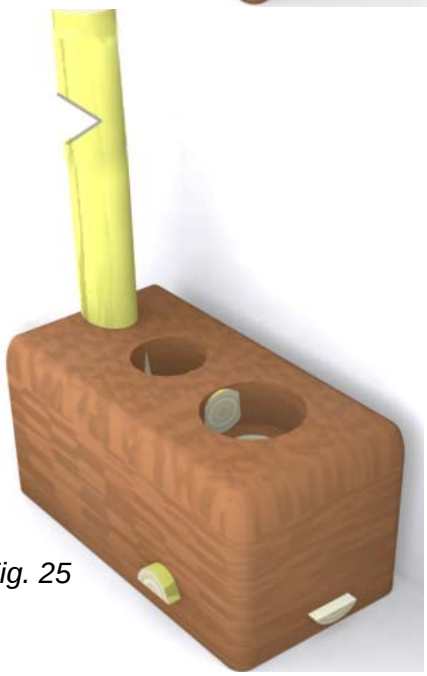


Fig. 25

- Bend the stem as shown in figure 26.
- Use banana fibres or sisal strings to fasten the bent banana stem to form a corner in the chimney mould.

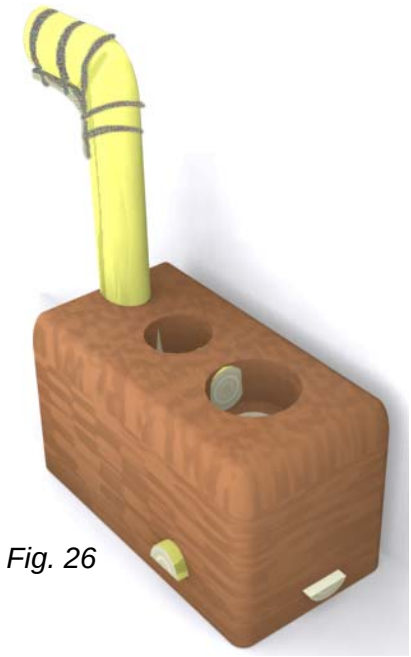


Fig. 26

- Determine the chimney exit position on the kitchen wall. It is recommended that this position is at least 60 cm (2 ft) below the roof level.
- In case the kitchen wall is short, adjustments may be made but it is recommended that the distance between the chimney exit and the roof should not be less than 45 cm (1.5 ft).
- Make a hole in the wall and direct the banana stem to through as shown in the diagram 12.

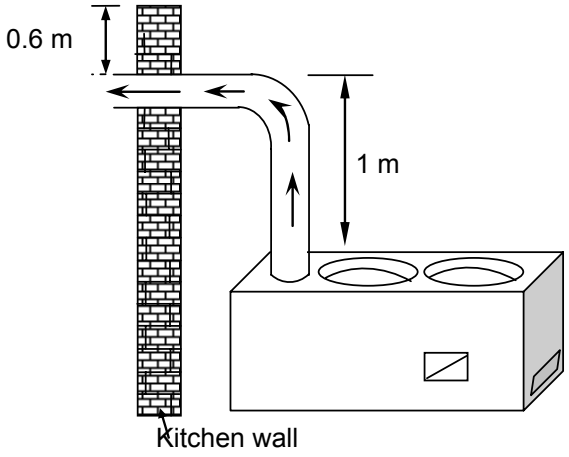


Diagram 12

- Roll some of the insulation mixture in your palms and begin to build them coiling on to the banana stem as shown in figure 27.

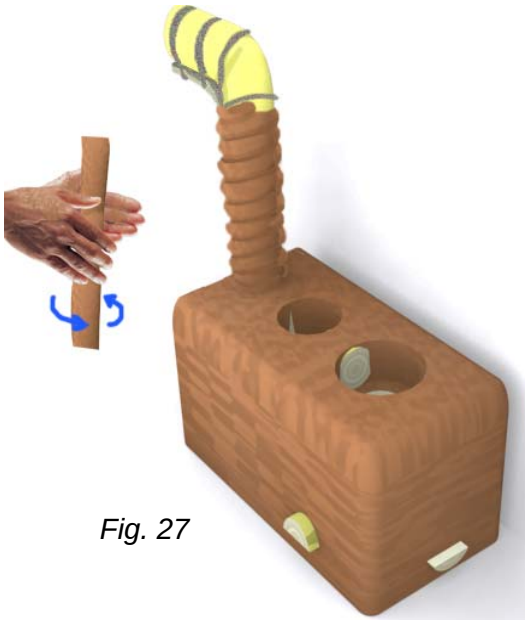


Fig. 27

- Smooth out the ridges in the chimney tower to get a regular shaped chimney as shown in figure 28.

Fig. 28

8.7 Shaping the Saucepan Cavities

This should be done after 5 - 7 days of drying.

- Using a measuring tape, measure off 2.5 cm of the saucepan cavity. Then using a spoon, scoop out a material thickness of 2.5 cm to create the saucepan ring as shown in figure 29.
- If you do not have a measuring tape, use the length of the first segment of your index finger, which approximates 2.5 cm.

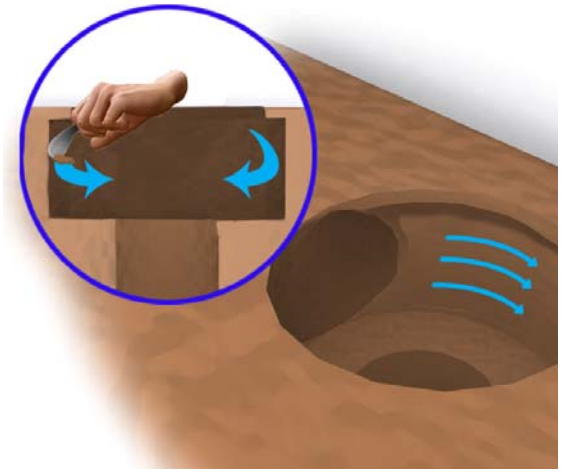


Fig. 29

- Using the insulation mixture, build 3 saucepan supports of 2.5 cm high each, inside the bigger saucepan seat and 2 supports in the smaller one as illustrated in figure 30.
- The supports in the bigger seat should be equidistant from the centre of the combustion chamber with a uniform angular spacing of 120^0.

Note:

- Only 2 saucepan supports are fixed in the smaller saucepan cavity to minimizing obstruction of fire (flue gas).
- The saucepan ring offers additional support to stabilise the saucepan.

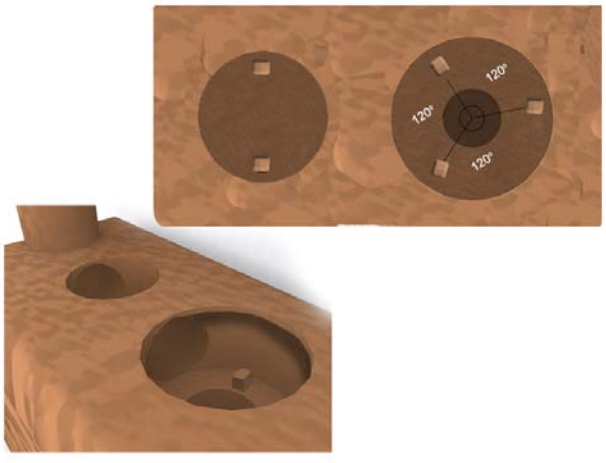


Fig. 30

8.8 Finishing the stove construction

- Plaster the stove body to give it a good finish. You may use any of the materials that are used to plaster mud walled huts e.g. a mixture of sap from sweet potato vines, silt and water or a mixture of sand, cow dung and water, etc.

- Use wet fingers, wet trowel or layers of a cut banana stem to smooth the finish such that the stove is completely smooth without cracks.

- If available use the spirit level to inspect and ensure that the top surface of the stove is horizontal. The use of the spirit level is optional.

- Leave the stove block to dry for 4 weeks, while covered with a watertight material e.g. polythene sheet or banana leaves.

- Protect the stove from sunshine and restrict children and animals from accessing it during the drying process.

- Continue to insert the saucepan and rotate it back and forth to maintain the size of the saucepan cavities during the drying process. It is recommended that this should be done at least twice in a day i.e. in the morning and evening.

After 4 weeks of drying;

- Carefully remove the now shrunk banana stems from the stove body i.e. the shrunk banana stem from the chimney, firewood inlet, bypass air inlet, the vertical part of the combustion chamber, and the fire passages between the saucepans.

- Smooth the hot gases passage using wet hands.

Photo 11

Photo 12

Fig. 31

8.9 Shaping the by pass air inlet

Use a knife or sharp tool to shape the air inlet after removing the banana stem. Ensure that the dimensions are restored to the recommended size after drying, by cutting and smoothing the inside of the passage. The final shape should have a height equal to 1/3 of the original banana stem diameter i.e. 4.5 cm.

Note:
The outside smoothing of the stove body should be regularly done using the methods commonly applied for the finishing of the mud walled huts in the rural communities e.g. a mixture of sap from sweet potato vines, silt and water; a mixture of sand, cow dung and water; or a mixture of charcoal powder and sap from sweet potato vines etc.
This helps to prevent the stove body surface from cracking and it also makes it fairly watertight and fine looking all the time.

Photo 13: The Finished Rocket – Lorena Stove

For details on, stove usage, cleaning and maintenance, refer to the sections 9 and 10 on pages 26 - 28

9.0 USING THE STOVES

Photo 14: Using the rocket Lorena stove

Photo 15: Shielded fire rocket stove in use

The stove is now ready for use. It is suitable for use in cooking common types of food including bananas *(matooke)*, potatoes, cassava, beans, *posho* etc.

It may not be suitable for use in roasting maize, cassava, meat etc.

When using the stove it is advisable to use small amounts of dry split firewood. It is also important to observe the following recommendations:

9.1 Efficient cooking practices

- Always use dry firewood split into thin pieces. Wet firewood loses its heat value in driving off excess water. It also produces a lot of polluting smoke.
- Always use a saucepan lid to cover food when cooking. This creates cooking pressure leading to faster softening of food and saving fuel.
- Cut the food into smaller pieces. The technique reduces the amount of energy required to cook.
- Soak the dry-preserved foods (beans, peas, etc) for at least 5 hours, before starting to cook. This cuts down the amount of energy to cook such kind of food.
- Avoid filling too much water in the saucepan. It takes a lot of energy to boil it, hence fuel wastage.
- Light the fire after preparing the food for cooking.

- Put out the fire immediately after cooking to avoid firewood wastage.

9.2 Cleaning the stove

The stove should be cleaned only when it is not in use (i.e. it should be cold).

- **Saucepan seat(s) and fire passages**
  Use a soft broom or bundled soft grass to sweep out the soot and ash from the saucepan seats at least twice a week.

- **Combustion chamber**
  Use a scooper or small stick to remove the wood ash from the firewood feed chamber through the air inlet (bypass). This should always be done before lighting the fire.

- **Air passage/ Inlet**
  This should be cleaned daily before lighting the fire. All the ash and wood pieces must be removed using a scooper or small stick.

- **Chimney (for the Rocket – Lorena Stove only)**
  Get a dry banana leaf; remove the lamina from the mid rib. Bend the mid rid at many points along its length to make it soft. Insert it into the chimney from the top (outside the kitchen). Push it down the chimney and lift it out several times. This will remove the soot from the chimney. Collect the soot from the bottom of the chimney through the second pot seat and remove it from the stove. This should be done every 2 weeks to prevent clogging.

Note: The chimney is brittle because it is made from mud. Care should be taken to avoid breaking it during the cleaning process.

Summary of stove cleaning schedule

Stove Part	Frequency of cleaning	Purpose	Tools
Saucepan seats	At least twice a week	Remove soot and ash	Bundled soft grass or broom (dry)
Chimney	After 2 weeks	Remove soot	Dry Banana leaves bundled
Air inlet	Daily	Remove wood ash and charcoal	Scooper or Small stick
Combustion chamber	Always before lighting fire	Remove wood ash	Scooper or Small stick
The stove body	At least twice a week	Remove dust	Soft grass broom (dry)

10.0 STOVE MAINTENANCE AND REPAIR

It is advisable to perform regular stove inspection to identify faults and provide the necessary remedy to check further damage.

Stove Part	**Fault to be checked**
Chimney (rocket – lorena)	Wear and tear
Combustion chamber insulation	Cracks, wear and tear
Firewood magazine	Wear and tear
Saucepan seat	Wear and tear
Saucepan supports	Wear and tear
Stove body	Cracks, wear and tear

The Rocket – Lorena and Shielded Fire Stoves will bring joy to your home!

APPENDIX 1

Calculation to determine the diameter of a circular combustion chamber

For a circular combustion chamber equivalent to a 12 X 12 cm combustion chamber,

12cm X 12 cm = 144 cm^2
Similarly π X r^2 = 144 cm^2, from which r^2 = 144 ÷ 3.14 = 45.8 cm^2,
Consequently r = $\sqrt{}$ 45.8 cm^2 = 6.8 cm and diameter = 2 X r = 2 X 6.77 ≈ 13.5 cm

Alternative moulds:

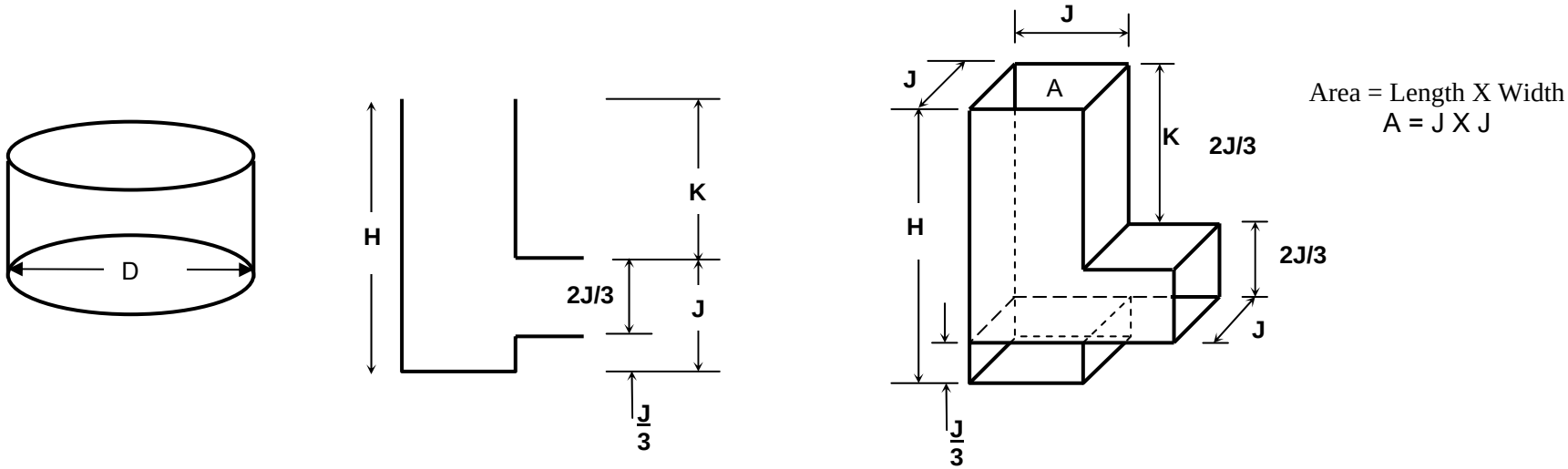
In case banana stems are not available, the stove builder is advised to improvise with any other appropriate moulds for the fire and air passages.

- However such moulds should be considerably easy to remove from the dried stove body without causing damage to the brittle structure.
- The dimensions of the moulds should always match with the recommended size of the fire and air passages.

APPENDIX 2

RELATIONSHIP BETWEEN SAUCEPAN / POT DIAMETER AND COMBUSTION CHAMBER

Pot Diameter D (cm)	Pot capacity (litres)	J (cm)	K = 1.5 X J (cm)	H=K+J (cm)	Banana stem diameter (cm)	Chamber Area (cm^2)	Chamber Sizing
Up to 20	Up to 2.7	11	16.5	27.5	12.4	121	11 x 11 cm
21 - 27	2.7-7.5	12	18.0	30.0	13.5	144	12 x 12 cm
28 - 30	7.5-9.8	13	19.5	32.5	14.7	169	13 x 13 cm
31 - 35	9.8-15.7	14	21.0	35.0	15.8	196	14 x 14 cm
36 - 40	15.7-24	15	22.5	37.5	17.0	225	15 x 15 cm
41 -45	24-35	16	24.0	40.0	18.0	256	16 x 16 cm
46 - 50	35-47	18	27.0	45.0	20.3	324	18 x 18 cm



The rocket elbow combustion chamber

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