Introduction of Rocket Stove Technologies (Institutional stoves, Household stoves and insulative refractory bricks) Into Mozambique

March- July 2004

Draft Report

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Please note: the plans for the stoves described below are available on a limited basis. Please contact ProBEC for more information

Material Outputs

ProBEC, in cooperation with World Food Program, has developed a new institutional stove for Mozambique. The MangiMangi stove was first produced in December of 2003. It was given the name 'MangiMangi' (which means 'fast' or right away in Shona) by the residents of Manica province. Initial response has been very favorable. Users report that the stove is :

- Efficient: uses 80% less wood than their open fire
- Fast: **boils 40L of water in 30min with 2kg of wood**
- Clean: produces almost no visible smoke
- Inexpensive (approx US$150) and very low maintenance.

In the last 6 months, **12 MangiMangi Institutional stoves have been produced by SAVEPLA**, our stove partners in Chomoio.

- **2 MangiMangi stoves were made for Formigas del Futuro**

One was the original 60 L MangiMangi shown above. The second was the taller 80 L double walled MangiMangi (see photo left). These stoves have been used consistently since December 2003. Although the cement/vermiculite liners have had to be replaced, the school has been very happy with the stoves. The 60L stove was retrofitted with clay/ sawdust bricks and delivered on Aug 31st by Bacaiman and Zana. The 80L stove will have to be used as is until the new bricks are ready at Ceramica Villa Pery.

- **Three (two 60L and one 80L) MangiMangi Stoves were produced and sold to ADPP in Chomoio**. These stoves were modified and replaced on Aug 31st

- **Four 60L MangiMangi stoves were built for WFP**. See following notes in WFP stove section

- **Two 60L MangiMangi stoves were produced and sold to Concern International**. These stoves have not yet been picked up. These stoves were made with vermiculite and cement, a combination that we no longer recommend. In October, when the clay sawdust bricks are ready, the combustion chambers will be reconstructed with the new ceramic bricks and High Temperature Zimbabwe cement.

- **One MangiMangi stove was produced and sold to Cubitsirana**
- They have used the stove for 1-2 months and are very happy with it. They also report an 80% fuel saving compared to their traditional open fire. This stove will also need to be retrofitted with sawdust/clay bricks as soon as possible

Since its introduction in December 2003, a number of improvements have been made to the stove:

- Fixed wood supports -to support longer pieces of wood - have been added
- Triangular brackets have been attached to the 3 legs to increase stability
- The combustion chamber has been changed from vermiculite /Portland cement bricks to locally made sawdust/clay bricks lined with High Temp Zimbabwe (HTZ) Cement/ sand mortar
- The stove still uses a small amount of vermiculite/cement to insulate the top plate. More experimentation is needed to develop a vermiculite free insulating top plate.

Stoves for WFP

4 MangiMangi stoves were originally made for WFP.

- **One stove was sent to Sofala in Dec of 2003**. According to WFP reports they liked the stove for cooking rice but were not using it for cooking Nsima. The explanation given was that the stove was not stable enough for cooking Nsima. The stove should be picked up, retrofitted with stove stabilizers and with clay/sawdust bricks that are being produced at Ceramica Villa Pery.

- **One stove was sent to Gondola School**. Atanasio Augusto visited the school two weeks after delivery and reported that the stove was working perfectly; that it was able to cook nsima as well as rice; and that the cook was happy with the stove. This is stove #3

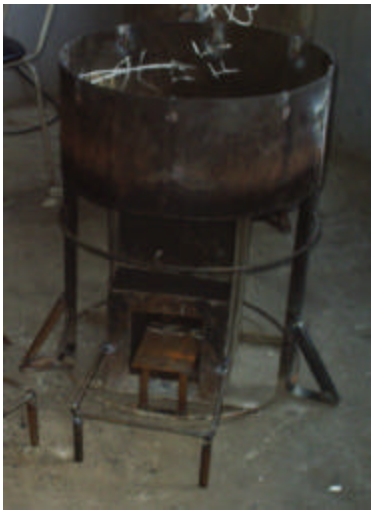
- **One stove still remains -as of August 31st - at WFP Beira headquarters**. This stove was damaged in transit and/or was not deemed suitable for cooking and so was never placed in a school. This stove

should also be picked up, retrofitted with stove stabilizers and clay/sawdust bricks

- **One stove still remains at Savepla**. This stove is awaiting new clay/sawdust bricks. Because there has been some confusion due to stoves being moved around so much, Savepla might need to be convinced that one of the stoves at their workshop belongs to WFP. I feel that there is consensus between WFP and myself that WFP still has one stove at Savepla.

Five stoves have been numbered (with an arc welder) to ensure better tracking of the stoves. When referring to bricks, the numbers and letters refer to the recipe used to make the sawdust/clay bricks. See attached excel sheet for specific recipes.

Stove #1

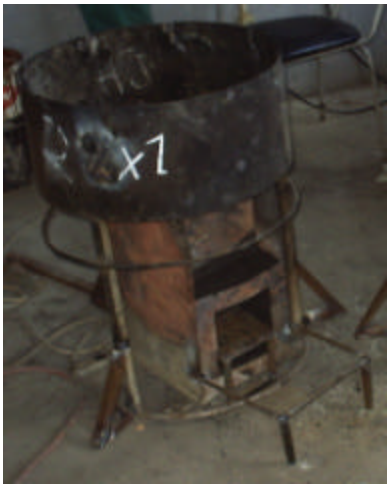


This stove is for Formigas del Futuro. It was built with lower grade clay/sawdust bricks. The liner bricks (with the exception of the two entrance bricks - 'E' on the left and 'C' on the right) were made with common brick clay last year. Although I am skeptical about the durability of these bricks, I thought it would be helpful to make one test stove using these lower quality bricks. If these bricks are successful, than it will greatly simplify production.

The bricks are mortared together with 3 sand: 1 HTZ Cement: 1 water

This stove was to be delivered on Aug 31st.

Stove #2



Note: the chalk mark says 2*1, but the arc weld says #2. 2*1 refers to the mortar mixture

This stove was collected from ADPP on Aug 22nd. This was one of the 3 stoves that were sold to ADPP for 10 million Meticais, (approx US$420) in March 2004. As can be seen from the photo, the metal body had sustained some heat damage from the stove being used after the cement vermiculite bricks had worn away . The stove generally suffered from cook and student abuse. The stove was brought back to Savepla in August and reconstructed with the higher

quality clay/sawdust bricks. It was mortared together with a 2 sand: 1 HTZ cement: and .75 water mixture. The top plate was filled with the cement/vermiculite insulation. The stove used:

Floor bricks: "5" Bricks
Bottom Sidewalls: clockwise from left to right - E, B, B, 3 8.
Above stove entrance: Brick 11
Middle course: Bricks A and B.
Top course: Bricks 31,32 (clay/sawdust/**cement** bricks, very fragile)

Stove #3

One MangiMangi stove was originally sent to Gondola, Manica in December 2003. The stove was used consistently for cooking rice but not for Nsima. The reason for the stove not being used is uncertain. Lynn Miller and Paola, from the Chomoio office, said that the stove could not be used to cook Nsima because it was not stable enough. The cook, on the other hand, told Atanasio Augusto that the only problem was that the stove was too short.

To address both of these concerns we built a step for the cook and added stove stabilizers. It appears that these new changes have addressed the height and stability issues as WFP is satisfied with the stove and wants to order 10 stoves from SAVEPLA

Stove #3 was mortared with a 3 sand: 1 HTZ Cement : .75- 1 water

Stove #4

Savepla originally produced this stove as part of the three stoves purchased by ADPP. Unfortunately the stove diameter was too small to fit ADPP's pots. The stove sat unused for three months until I came back. The stove was picked up on Aug 20th . and retrofitted with ceramic bricks.. This stove is designed for the taller aluminum 80 L pots that ADPP and WFP both use.

The bricks were mortared together with 5 HTZ cement: 2 water. The bricks were lined with a mixture of 2 sand: 1 HTZ Cement: .75 water.

Stove #4 is the single walled version of the double walled stove (see photo right) that was originally made for Formigas del Futuro. More testing is necessary to compare these two stoves but for the moment I would recommend using the single walled stove as it is cheaper and probably only slightly less efficient.

Stove #5

This Stove was originally produced for WFP and sent to Gondola. Unfortunately it was used before the mortar had dried which caused it to crack. When stove #3 was delivered, this stove was picked up and returned to Savepla on my last day in Mozambique. Instructions were left to retrofit the stove, Mark it with a #5 and then deliver it to ADPP on the 10th of September during Zana's first visit back to Chomoio.

Instructions were left to mortar the stove with a 1 sand: 1HTZ Cement: .75-1water mixture.

MangiMangi Construction

General notes

- The bricks should be lightly moistened on any surface that will receive mortar. Too much water and the stove wont dry for months and too little water will cause cracking in the mortar. Ideally the stove should be left to dry in the shade for two days. If the bricks are moistened properly than the bricks should remain moist, without additional water, for the first 24 hours. If the bricks become dry in the first 24 hours then a small amount of water should be applied.

- **The recommended material for the institutional stoves in Mozambique is now the clay/sawdust brick from Ceramica Villa Pery**. These bricks should be mortared together with sand and the HTZ Cement. The actual proportions of these materials will become clearer in the next few months as we collect more data from our test stoves.

- We need to make some tests using a local high temp mortar but for now, the HTZ Cement is a suitable mortar.

- The top plate will still need to be covered with the cement vermiculite mixture. Experiments should be made with mixing the HTZ Cement and sawdust to see if we can use that as a suitable replacement for the vermiculite.

Way Forward for WFP

WFP should order stoves to fit specific pots (i.e. if a school has 2 60L pots and 1 80L pot then they should order at least one 60L stove and one single walled 80L stove. This is important. The stoves will be much more stable and efficient, if the pots fit the stoves exactly.

WFP has expressed interest in having a couple of brick MangiMangi prototypes built so they can compare that stove design with the portable metal version. This can be done in January, upon my return, or earlier if Zana can be mobilized to build the stove.

Way Forward for Savepla

- We need to link SAVEPLA with a larger partner. They suffer from a lack of resources, for purchasing materials and equipment, as well as access to transportation. A more established partner could overcome some of these hurdles and allow them to expand their business.

- In the short term ProBEC should liaise with ProCIP to assist with transportation. At present they need assistance to collect bricks from Ceramica Villa Pery, and to bring materials to the bread oven construction site (e.g. 2-3 days per month for the following 4 months).

- Savepla needs to have someone (such as Zana) inspect the stoves before they are delivered to the customer. Quality control and customer follow up have , so far, not been the strength of Savepla

- As always Savepla is desperately in need of business and marketing assitance

Suggested Way Forward For Zana

- make links with GPZ .

- Coordinate stove order with WFP. If possible we should try to convince WFP to buy between 10-50 stoves in the next 6 months. We should contact Nina and Angela as well as Atanasio and Lynn to pursue the stove order

- Contact Albertino at Ceramica villa Pery to find out when the bricks will be ready for pick up. Once the new bricks are ready then we can retrofit the two stoves for concern international , the tall 80L stove at Formigas del Futuro , the stove at Cubitsirana, and the WFP stove at SAVEPLA

- We need to assess the durability of the various mortar mixtures. At present we have 4 different recipes (see stove s 1-5) and we need to decide which is working the best after 3 months and then use that for the upcoming WFP stove order.

- HTZ Cement will need to be purchased for the new stoves

- Contact Albertino of Ceramica Villa Pery for information about cast iron producers in Beira

- Link Savepla with DED small business program

- Monitor production at Savepla to ensure quality control

- Savepla made a couple of household stoves for the headmaster of Formigas del Futuro (Senora Doka). Follow-up on these stoves would be helpful

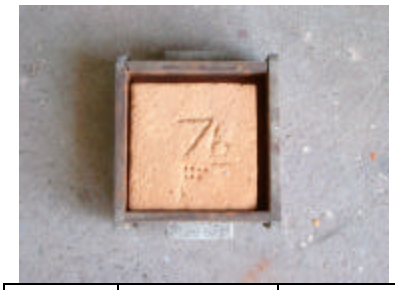
- Zana needs to spend at least 4 days a month in Chomoio working on institutional stoves in the next few months

Brick Production

Since Nov 2003, we have made two large batches of sawdust clay bricks. Over 90 test bricks have been produced at Ceramica Villa Pery, Chomoio, Mozambique. 60 of these bricks are now being field tested in the MangiMangi stoves. The test bricks that we made had a density of between .5 g/cc and 1.1 g/cc. The bricks between .5 g/cc and .6 g/cc were rejected, as they were too fragile. The bricks between .9 g/cc to 1.1 8 were also discarded as being (suspected) poor insulators as well being too heavy for a portable stove. Three bricks were tested by Dale Andretta of SEA Ltd to establish the thermal conductivity of the bricks.

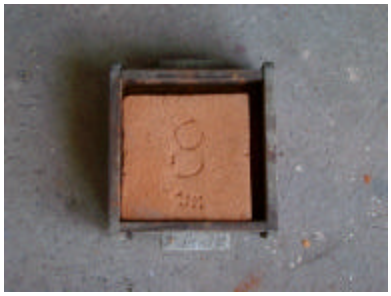
University of Dayton is also conducting thermal shock , 3 point bending and compression strength testing of these bricks but the data is not yet available

Here are the results from the 3 bricks that were sent to Andretta.



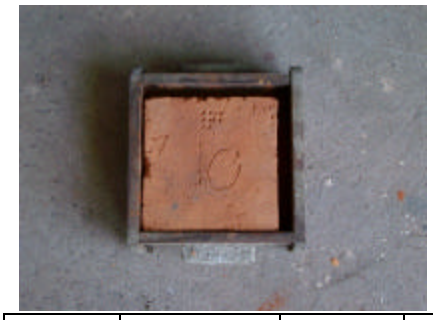
Clay **Bag 2**	Sawdust	water	Pre fire weight	Post fire weight	volume	Actual density	**Thermal conductivity m*K/W**
700	500	600	1800	625	973	.64	**9.2**

Tile # 8



Clay **Bag 1**	Sawdust	water	Pre fire weight	Post fire weight	volume	Actual density	**Thermal conductivity m*K/W**
800	500	600		700	978	.71	**8.3**

Tile # 10



Clay **Bag 1**	Sawdust	water	Pre fire weight	Post fire weight	volume	Actual density	**Thermal conductivity m*K/W**
1100	500	600		940	1009	.93	**6.6**

As you can see from the above charts, a small increase in the quantity of clay in each brick results in a large increase in the density and a corresponding decrease in the insulative value (thermal conductivity) of the brick. These 3 samples were made in November 2003.

In March 2004, we made another batch of test bricks (see attached excel sheet) and found that we could increase the strength of the mixtures by allowing the clay/ sawdust/water to sit overnight before being formed into the bricks. A few bricks from this batch have also been sent for testing at University of Dayton.

In August 2004 we placed an order for enough bricks to make 50 MangiMangi stoves. This requires:

300-29cm*19cm*6 cm bricks
200- 18cm*18cm*6cm bricks
100- 29cm*29cm*6cm bricks

(Note: these are the mould measurements and the fired brick sizes will be smaller)

The ratio for the mixtures is

- 12.5 kg dry clay, pounded and sifted through a 2mm screen
  7.5kg of dry sawdust sifted through a 2mm screen
  12.5 kg of water

This is left to sit overnight and then formed into bricks.
Then dried for at least two weeks

Then fired for 2-3 days at 950 degrees Celsius

These bricks will be ready by mid-October and will be used to fulfill the impending WFP contract. These bricks can also be used to fulfill other stove orders.

Albertino, the owner of Ceramica Villa Pery was not able to quote us a price on the bricks, although he has always been very supportive of the project and in the past he gave me a rough estimate of US$0.20 per small brick. The bricks should be paid for by ProBEC and then sold to SAVEPLA as needed

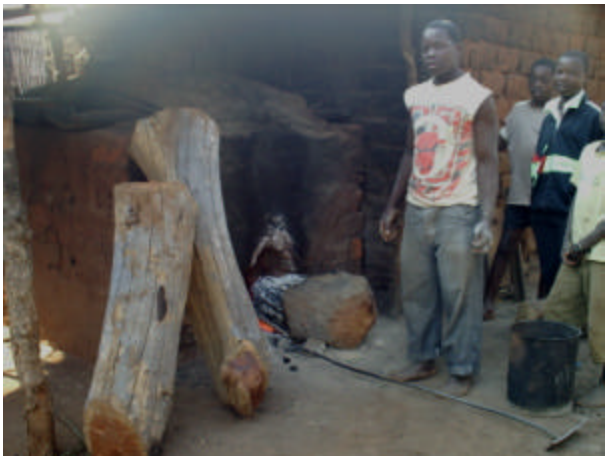
These bricks will be mortared together with a mixture of HTZ Cement , the ratio to be decided after the current field test to assess which is the ideal HTZ cement /sand mixture.

Rocket Roll Oven

Since December 2003 we have made three prototypes of the Rocket stove Portuguese roll oven.

The second prototype, built in April, was favorably received by the baker and the owner of the bakery, Senor Joao. At first Senor Joao was reluctant to try the new design, but after a little prompting by Werner Klaus, the baker used the oven for two months and was very pleased with the design . The Rocket roll oven used less wood than the traditional oven and cooked the rolls in 15 minutes instead of 20 .

Werner Klaus reported daily fuel consumption of 30,000 Meticais with the new oven (each small log costs 10,000 Meticais)



compared to 100,000 Meticais for the traditional oven . When I inquired about fuel consumption a month later, the bakers reported that the fuel consumption of the traditional oven was only 80,000 Meticais (40,000 Meticais for each large log . It is unclear what caused this discrepancy between our figures but even considering the lower figure for the

traditional oven, the new oven still offers a 62% fuel savings. It is estimated that the new Rocket Bread oven will reduce their annual fuel costs from US$ 1327 to US$498 thus saving the bakery approx US$830 per year. The third prototype, built in August, incorporates another set of improvements. A fourth prototype will probably be required before we have a final marketable design See attached report for more information.

Household stoves

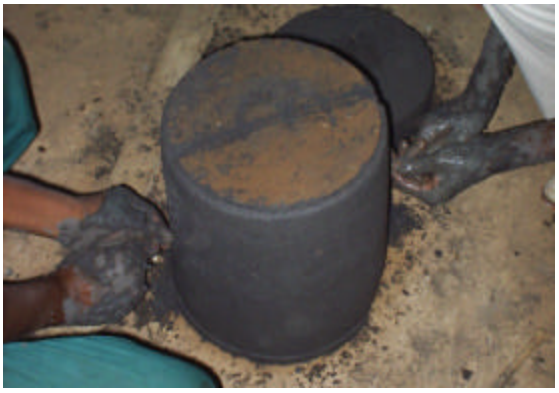
Note: The cement/vermiculite household stove has been discontinued.

A number of household test stoves were made at Ceramic Villa Pery in March 2004 . These were made with sawdust and clay.

A 110 mm diameter pipe is cut on a 45-degree angle and then placed inside a 30cm by 30cm Bucket.

The bucket is then filled with clay sawdust. The mixture is tamped firmly into place.

The pipes are then carefully removed from the bucket.



The bucket is turned upside and removed, leaving the stove inverted. A wire is used to cut the stove in half. The stove is dried for three weeks and then fired at 950C for two days. See above brick recipes for possible clay sawdust recipes.

These stoves still need to be placed inside of a metal bucket or inside of a mud stove and then tested. They offer one potential for building a cheap (US$1-2) and insulative rocket stove liner.