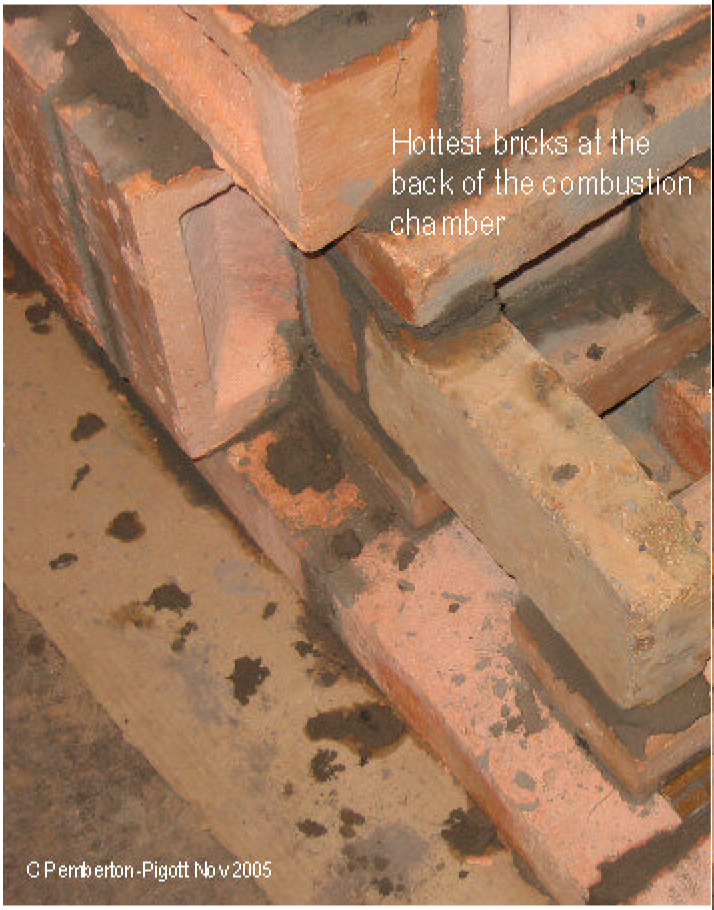
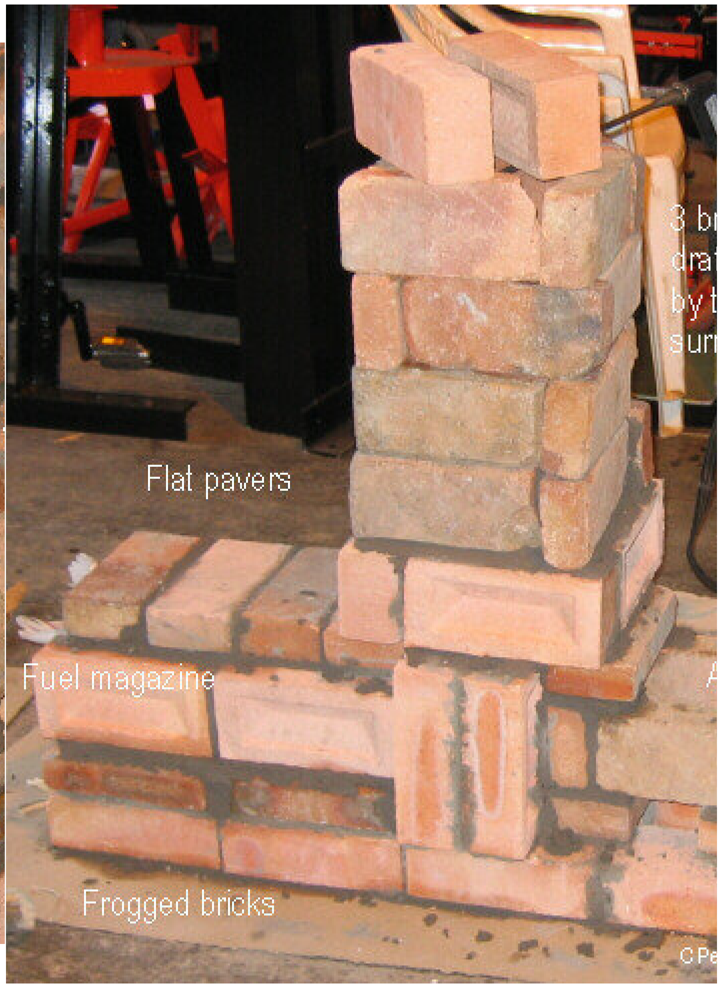
DISLOCATED ELBOW ROCKET STOVE

Crispin Pemberton-Pigott, Swaziland, November 2005



DISLOCATED ROCKET ELBOW STOVE AIR INLET



DISLOCATED ROCKET ELBOW STOVE BRICK LAYOUT

Dear Large Scale Cookers

Following on from a visit to Swaziland by Peter Scott during which we built two largely brick institutional Rocket Stoves I have been training the builder further at another neighbourhood orphan care point (NCP). One of the anticipated problems is that the expansion of the WFP training will be carried out by the builder who is himself not very experienced at all dealing with the absence of, and understanding of, a variety of materials which might be used to advantage in such a stove.

There is a great deal riding on the success of the project in question. WFP Swaziland has bent over backwards to accomodate cooking in their food distribution programme. They plan to build several hundred stoves and the last thing we want is for 'locally adapted' stoves to start falling apart after a year or so. There is some serious money going into this and they are being placed in many inaccessible places.

As a result I have been working on a fuel magazine and air supply that can be entirely made from local high quality under-fired bricks known as 'fickets'. I found that in the upper part of the combustion chamber these bricks reached a surface temperature of 150 C and the outside of the brick reached 75 C. This was the situation after 1 hour of burning. The highest outside temperature of a brick after 2-1/2 hours was 180 C in the immediate region of the burning fuel.

While a great deal of effort has gone into the development of home-manufactured insulative bricks for the combustion chamber, there is nearly no chance of that happening in this WFP progject. We were happy to convince them to build permanent stoves at their 250 sites.

The 'k' value (thermal conductivity value) of brickwork is about 0.5 and of dense brick, about 1.6. What matters is not the numbers but the effect the dense or lighter bricks have on the fire. I found the losses into the bricks to be amazingly low. First, the thermal conductivity of the bricks is not very high and second, the temperatures on the inside of the combustion chamber walls are not all that high either. With the air allowed to flow into the combustion chamber unimpeded the gas temperature at the pot level was about 210 C. With the air flowing through the fuel blocked with paper, the temperature rose immediately to the 350-390 range. This effect was repeatedly demonstrated over a 2-1/2 hour period.

A number of possible scenarios were considered when trying to explain the low temperatures, however the most obvious is that with a large stove (1 metre high) there is a lot of draft and the excess air ratio gave direct evidence to support the view that the low temperature was due to the drafting in of a great deal of cold air. The excess air ratio was consistently in the 800-1000% range when operated normally. When choked in the fuel magazine, it dropped to 300-400% and two effects were repeatedly

observed: First, the temperature of the gases in the 'chimney' (where the pot is) rose, as expected, in direct proportion to the reduction of air, and second, the CO /CO2 ratio doubled in direct response. The amount of visible smoke usually (though not always) decreased with a drop in air flow, probably because of the increased flame temperature and a higher 'residence time' for gases inside the combustion zone. The less the air supply, the longer the flames, the higher the temperatures, the less the visible smoke.

This was the general rule. I never got the excess air below 280%.

While the CO level rose dramatically (I view a doubling as dramatic) it rose from a very low level. With excess air at 800% the CO level was usually under 2% and at 350% EA it is about 4%. I find the 4% quite acceptable for a simple clay brick stove. The significance is that the Delta T rose (for a boiling pot) from 110 C to 260 C (approx). This means that the heat transfer efficiency is severely downgraded if the excess air rises to such high levels. Whether the measurments were taken at an appropriate place is not really important, it is the effect of the rise in gas temperature that air control brings that is of great interest because it means a lot of fuel might be saved using an air-controlled Rocket Stove at a cost of some extra CO (and possibly particulates?).

These measurements were taken with a relatively large fire in a 165mm square combustion chamber, burning pine. The excess air ratio rose above 1000% when the fire was reduced and my unit will not give a figure above that.

When the air is allowed to run free, a small fire saw the chimney temperature (pot level) drop to the 160 range. I repeat that the number here is not as significant as the fact that unimpeded air flow greatly reduces Delta T. Closing the air flow through the fuel magazine allowing air to enter through its channel only, immediately doubled (or more) the indicated gas temperature and Delta T.

To simplify the construction, even at the expense of adding mass, and also to enhance durability for years to come, I worked for some time on various arrangements of bricks, two of which are posted on Stoves as animations.

The result of Friday's work is somewhat more radical. I found that even with the poor conduction of heat through the bricks (amounting to perhaps 25 watts per brick on average) there was enough heat coming out of the combustion chamber to raise the incoming air by 20 deg C, thus creating preheated primary air at 45 C which increases the flame temperature by the same amount., reducing CO.

Pre-heating is accomplished by using a brick stack that is quite stable, wide and relatively self-supporting even when the cement and or clay holding it together has separated or fallen out. Thus constructed, the space between the outside walls and the fuel magazine/combustion chamber does not need supporting elements between them, and the space can be left empty. Air is a formidable insulator with a 'k' Value of 0.024. Very little heat gets to the outside walls if the warm air is drawn into the fire. By making a number of slit-like openings in the brickwork approximately at the level of the bottom of the pot (by leaving out the mortar between the brick ends used in the outside wall) cold air can enter the empty space around the combustion chamber.

As I wanted to be able to correct the flame position normally seen in a Rocket Stove (it brushes against the far side of the combustion chamber because all the air enters from one side) I brought the air to the fuel from the 'back'. This was accomplished by leaving spaces in the brickwork that allows air to travel down and under the far side of the combustion chamber.

A separate channed leads outside so ashes can be removed. The channel is blocked by a loose brick when the stove is in use. With the air now entering the hollow bottom of the stove, getting preheated by 20 degrees and then entering the fuel burning area from the 'back', the flame is driven to the centre of the combustion chamber and kept away from all its walls. I think partly because of the open area between the fuel sticks and the back wall, there is a natural tendency for the flames to avoid hitting the 'front' bricks of the combustion chamber. When the air is allowed to enter along the fuel supporting shelf, the flames are again driven towards the back, but not as much as when the air all enters from one side as in the standard Rocket elbow.

As there is no longer an air passage under the fuel shelf, I filled in the space with bricks, saving the cost of the metal shelf and removing at the same time the possibility of losing the part.

I have christened the layout a 'dislocated Rocket elbow' because of the relocation of the air passage to the opposite side and the removal of the shelf. To reiterate, the air does not come to the fire along the horizontal channel at the back, it enters through a hole in its top layer and descends into the channel, passing along the hottest bricks in the stove as it does so. The channel is only used to clean out ashes and unburned charcoal.

All this is accomplished with only 45 bricks or pavers (they used in about equal numbers). The four outside walls can be made of bricks or blocks in a

1 metre square. In our case we are going to use bricks because of cost.

The resulting construction is stable and can be made accurately by a brick layer with little training. There is no insulative materials involved at all, there being no bricks with suitable properties available. If and when they come on the market, we will swap the existing bricks for the new ones at critical points and carry on with the same layout. Thus no re-training will be required.

The advantages of this system seem to be:

- reduced training time

- physically strong final construction with no 'fiddling' at all

- increased flame temperature (from preheating)

- durable combustion chamber materials

- no on-site decision making required from unskilled staff about

materials and layouts

- no need for sawdust or vermiculite or other insulation in the lower

section of the stove

- there is no metal fuel shelf to lose or replace

- a pick-up truck can deliver exact quantities of materials bought from

established suppliers around the country to each NCP with a known final product quality and predictable performance

- it seems to have a higher gas temperature because of a lower excess air

ratio and thus a good heat transfer efficiency.

The disadvantages of this system seem to be:

- I liked the sliding shelf when I want to light the fire though I admit

I didn't struggle to light it using only one match.

- the clean-out is at the back or the sides (depending on how it is layed

out) and not the front which might be inconvenient in some kitchens

- I think it will have a lower overall performance that a Rocket stove

with a lot of light insulation, however in this environment durability is considered far more important than the highest possible fuel efficiency.

Fuel is available, repair services are not.

- It requires a thin slab of concrete to separate the upper (pot-level) section of the stove from the lower air pre-heating section. It makes the upper construction far more predictable and accomodates huge cast iron pots more easily. This slab is cast at the same time as the slab that serves as the base. As we are working literally in open fields each stove will have a cement base so the thin slab can be made at the same time. Both will cure before construction starts.

Other points:

- It is expected that one stove will take two days to make: one for the

base and thin slab, and the other to build the stove. Where two stoves are being built it is very likely they can both be made in the same two days as the construction is less complicated than you might expect if you have worked on these large units before.

I look forward to others repeating the layout and testing the performance more accurately. I will post an animation of the brickwork later in the week.

Best regards

Crispin

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LIBHUBESI - OPPOSED AIR AND FUEL FLOW

Crispin Pemberton-Pigott, New Dawn Engineering, Swaziland, December 2005

Dear Friends

The wood is coming from the left and the air comes from the right. Note that because of the sticks (which interferes with the air flow up the left side of the combustion chamber) the wind blasting from the right does not carry the flame as far to the left (front) as the air from under the sticks would carry the flames to the right.

The 'opposing flow' idea works really well and when you block the 'stick air' as well with a newspaper or rag, the air continues to perform better because it pushes the flames back to the front.

I have not had much time to work with it, BUT it seems that it may do a better job of burning the sticks 'at the end' by blowing hard on the very tips, as it might give a hotter burn, a lower charcoal waste level and you can see there is no tendency to run the flame up one wall.

I was surprised by how low the preheating level was, given that it is made from solid bricks.

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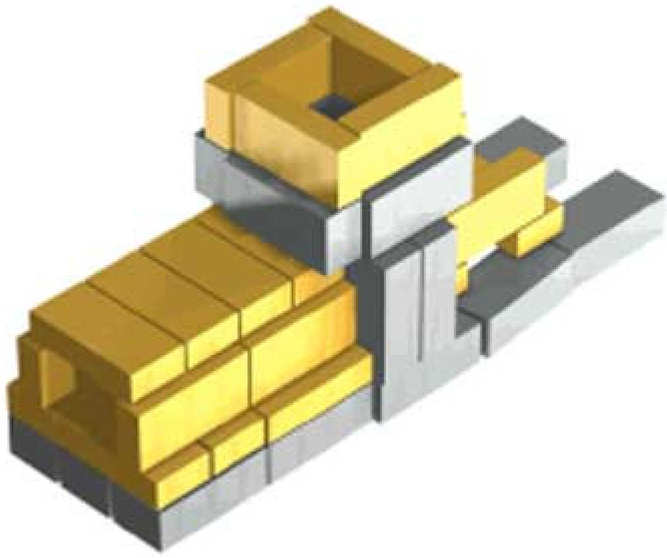
Links

Building the Libhubesi - the Lion - Stove

Libuhubesi - First Tests

Dislocated Rocket Elbow Stove

VIDEO (Requires Video Player such as Windows Media Player, or Real Player



OPPOSED FLOW: FUEL INLET LEFT SIDE - AIR INLET RIGHT SIDE

LOWER SECTION SHOWING FUEL FEED HOLE

AIR INLET AND CLEANOUT HOLE