FIRST STOVE MAKING ATTEMPT

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Our first attempt working with a local welder to make a gasifier stove based on the Champion TLUD design by Paul Anderson. We had difficulties with it to start. With some practice and adjustments with suggestions from Kirk Harris and Huck things got better. See our later report "Stove Test - Cooking Plantain Porridge" Testing 1st Stove

Materials: old metal drum (3000 franc). See Picture Below

Equipments: metal cutting and welding machine

We start by making an outer cylinder. Our welder measured the required length (with several cm extra)of metal to be folded into a cylinder of 18.5cm diameter using a metal ruler. He marked the metal with another metal piece. Then he cut the drum using machine (see picture below).

He then tried to make the round shape of a cylinder by hammering the metal piece (see picture below) but was not very successful.

We remade the cylinder by joining two pieces (by welding) of metal pieces, each made into a half circle. The cylinders turned out to be much rounder this time. We did not use any nail or screw in the process. He then measured the holes and cut it again using his machine.

After making both cylinders, he measured and cut a round metal piece to go under the inner cylinder. I asked him to cut the metal piece bigger so that it can actually wrap the bottom part nicely. I also requested him to join both cylinders together. He did this by welding a few long round metal pieces

across the two cylinders so that the position of the inner cylinder is fixed. He then welded the grate into the inner cylinder and make holes on it using the same welding machine

After finishing this part, we make the concentrator lid. This is done by measuring the top part and the side part separately and weld them together. We also made the riser separately. We welded three rebars onto the riser as pot stand. However, we felt that the riser is still very unstable to support the pot, so we decide to weld the riser onto the concentrator lid.

So we are ready to test it. We used wood pieces cut to similar length and filled the gap with dried leaves.

Perhaps the wind is too strong, it is very difficult to light any materials. So we removed some wood for more spaces and borrowed some palm wastes and kerosenes. The fire lighted well this time but it seems to have difficulties to spread to those wood materials. Cary thinks the wood is not dry enough but Timothy insisted they are, and suggested that maybe better wood type is required.

So after getting a reasonable fire, we planned to start cooking. But another problem we faced is everytime we put on the concentrator lid, the fire will go off after a few seconds. This occurred for several times.

So after some discussion, we decided to make the inner hole of the concentrator lid bigger (as big as the riser diameter), and also cut some holes into the riser in order to have some air space under the pot. See pictures below

These modifications prove to be useful. The fire kept on burning after the concentrator lid was put on it. However, another problem surfaced is there was a lot of smoke emitted from the stove, as if the fire is not burning well. When someone took out the concentrator lid and blew it hard into the cylinder, only was the smoke reduced. But then the smoke came back again after several minutes. When the fire stabilized, the firewood has burned almost halfway. It would not boil half a pot of water after more than 20 minutes so we decided we have to prepare more wood and try it again the other time. However, the pot of water was quite warm, even though not boiling.

The current major problem seems to be

1. Difficulty in lighting materials evenly
2. Inefficiency in burning causing a lot of smoke and difficulty in cooking.

There are a few differences between your design and our prototype

1. The inner cylinder was not elevated inside the outer cylinder, but on the ground level as outer cylinder
2. The hole of inner cylinder is 4cm from its bottom, instead of 3cm, but the hole is not obstructed at all when placed inside outer cylinder.
3. We did not make a protrusion of the primary hole. I was thinking we can insert some stick into the primary hole when we want to close it.
4. The modification to the concentrator lid and riser

What do you think is the problem and how can we improve it, especially in terms of materials and techniques? Will lifting the whole stove above ground (as if there is a tripod) help or not really? Some people suggest that we should make the primary hole larger, will that likely to help?

Should we use fill the hole compact with wood, or should leave some gaps?

We are doing the test again on Wednesday (tomorrow). So it would be nice if you can give any suggestion before that.

Email From Kirk Harris

Huck,

A few comments

<u>Overall consideration:</u> The primary air must travel through the fuel from the bottom of the stove to the burn, so make sure there is no restriction impeding its movement.

This was partially done when the concentrator hole was enlarged. Also there should be plenty of room under the grate for the outside air to get to the grate (I cannot tell from the photos how much room is under the grate).

The grate may need more holes to allow enough primary air in, but do this after you do the other things just in case the existing holes are adequate. If you choose, you can punch the holes upward so the bent metal will hold the wood slightly above the grate to allow better air circulation. This is not so important, but helps.

The packing of wood is important. It should not be tight and should not have leaves packed into the spaces. This will restrict the primary air flow. Place the sticks into the inner can (reactor) and lightly shake the stove. If the sticks don't rattle they are packed too tight, and will restrict the primary air. The sticks should just barely rattle to provide the best packing. Chopping the sticks into lengths of 3 or 4 cm., and using like pellets, though more work, will allow easier loading, easier starting, and better burning.

Round sticks with bark are difficult to start burning. Splitting the sticks or some of the sticks in half, will allow more surface area to burn and allow easier starting.

Clean cut ends on the sticks can be difficult to start burning because of limited surface area to burn, but they will eventually start burning.

Shorten the sticks to below the top of the inner cylinder. This will leave room for kindling and tinder. The kindling should not be so tall as to block the concentrator hole or the secondary air entrance. Use the same principles to start the fire as with a bottom lit open fire, first tender, then kindling, then the main wood. Place the kerosene soaked tender on the full top surface of the wood. Cover the whole surface. Loosely place kindling over it to catch fire from the tender. Light the kerosene/tender on fire. Add kindling as needed until the main wood catches fire. A starting cone or a 30 to 40 cm. piece of stove pipe placed on top of the stove will create more draft to help start the fire faster and with less smoke. Starting the fire at the top and letting it burn down allows a slower burn (no bonfire like if lit at the bottom), more even heating, more efficient burning, and a longer burn time that is great for cooking.

The square hole in the side of the inner cylinder should be covered because it can cause uneven burning. All of the primary air should come from the bottom grate. If a door is used then when the fuel is reduced to charcoal, the door can be opened to insert wood to extend the burn time. The stove is then being used as a rocket stove.

The wood is not burning like an open fire. The wood is being heated in a low air container to a temperature where the sap and other volatiles boil off. This becomes a burnable gas which burns when the secondary air is added in the

top part of the stove. When the stove gets going, the flame will not be at the wood level but above it in the top part of the stove. This is a gas stove, not a wood stove. The gas is being made by heating the wood. The wood is actually smoldering in a layer (called a pyrolysis front) which moves slowly downward through the load of wood. This seems strange, but it is a very efficient way to burn the fuel. It burns the smoke. Smoke is the gas after it has cooled, and it is very burnable.

Because this is a gas stove, it is affected by the wind which can blow the gas away. This stove should be used in a place that is protected from the wind or a wind screen can be used when it is windy.

Once all the volatiles are gone, the skeleton of the wood is left behind. This is the charcoal, often called char. It will burn with a blue, barely visible flame. The burning charcoal is very hot and will burn a hole in the stove after a few burns. To increase the life of the stove, pour the hot char out. It can be burned in a charcoal stove, cooled and kept for later burning, or used to improve the soil.

This is an excellent effort for a first stove.

Respectfully,

Kirk

Pearly and Cary did a second test. Their report is shown below with responses from Kirk in blue and comments from Huck in red.

Second Stove test

We did the second stove test today. Compared to the first stove test, the wood was spilt into much smaller sizes and they were inserted like pellets.

Are the chunks of wood round with bark and clean cut ends? This will not give enough surface area to allow it to ignite easily. I think there may be a translation problem here. Split means to divide the wood from end to end along the grain, leaving two pieces the same length as the original piece. Splitting the wood will expose a rough surface which is easier to ignite, which should help. Rough surfaces on the wood will work better than smooth surfaces because of increased surface area. Also the sharp corners of wood created by splitting will heat up and ignite faster, and will ignite the thicker part of the wood.

We soaked a few of the wood with kerosene before covering the top with them. When we lighted it, we spread the fire evenly on top using some palm waste. It lit up pretty well. We put the pot with water on top of it immediately and it burnt with almost no smoke.

Good progress.

However, it took almost 19 minutes to boil only 1.5 liter. The water was only brought to weak boiling for a few minutes and then there was only light simmering after.

This can be caused by the pieces of fuel being too smooth and round so they have trouble igniting. Also the grate may need more holes to let in more primary air. I would increase the primary air by adding holes to the grate and perhaps think about enlarging the hole letting primary air get under the grate.

When the water starts boiling, there is a lot of smoke emitted from the stove. However, when I removed the pot and placed it back again, the smoke went out.

I suspect the flame blew out in the wind you mentioned. TLUDs are very sensitive to the wind blowing the wood gas away. The pyrolysis front down in the wood is independent of the secondary flame above. If the secondary flame goes out, the pyrolysis front will continue to produce wood gas which will cool and become smoke, a lot of smoke. If this is what happened, you are fortunate that it started again. Self restarting is a good thing that only happens if the charcoal is hot. If it happens again and doesn't restart, toss a lit match into the riser to restart it.

The total time heat is emitted from fire is approximately 40 minutes only. We removed the remaining fire and firewood when we can see the grate from top. When we did that, the fire is not in blue and some wood is still in its original shape. But I do not want to destroy the grate so I removed it at that point.

The metal will not be damaged until the charcoal becomes red hot. Don't worry about damaging the metal until then. The blue flame only occurs with the red hot charcoal.

From this second test, although we successfully boil the water, I do not think the fire intensity and burning length is sufficient for any traditional food which typically needs higher fire intensity for 1-2 hours. In fact, it is not even sufficient to boil spaghetti.

Adding more holes to the grate and exposing more rough surface area and edges on the wood should solve this.

Questions:

1. What is the usual performance of TLUD stove compared to ours? When a TLUD the size of your stove is working properly it should be able to bring 5 liters of water to a rolling boil in about 18 minutes and hold it at a simmer for 30 to 45 minutes. Adding turn-down methods will decrease the fuel use and increase the simmer time to the 1 to 2 hours that you need. Kirk's design for the top of the stove allows turn down. It is very interesting but a bit more complicated to build. I will send you his paper on this. But I wouldn't try to do it now. We should start with the simplest stove.

2. Without modification of stove, can we improve the parameters by techniques? For instance, should we increase the amount of firewood placed inside? More primary air and preparing the wood with more rough surface and edges should improve the performance adequately for basic use. Beyond this, there are some stove design improvements that will give you the performance you need.
3. TLUD stove cooking was described as a batch cooking process. Can we remove the pot in the middle of cooking and add more firewood to increase fire intensity? This will not be needed once the stove is working properly.
4. How to determine the right time to remove the char to maximize cooking time but minimize damage to the grate? When the flames go out and the char glows red hot it is time to pour it out. You could also make the grate and inside cylinder replaceable and sacrifice them to burn the char, or place a liner around the inside of the chamber to take the damage and then replace it when needed.
5. In the future can we increase the fire intensity and burning time by using a stove of much bigger size? This will not be needed once the stove is working properly. A stove this size will have plenty of fire power for your needs.
6. What are the reasons for the presence of much smoke when the water is boiling? I suspect the secondary flame went out. Another possibility is that the stove was producing more wood gas than the secondary system could burn.
7. When the firewood is halfway burnt, should we remove the riser and place the pot on top of the outer cylinder instead to improve cooking efficiency? No. The flame is at the top of the stove just under the riser, not at the fuel level. The flame does not move down as the wood stack drops. The flame is a gas flame not a wood flame.

Tomorrow morning I am going to try to do some small cooking with a family. I will try to place more wood into the stove. Split the wood to expose more rough surface area first.

However, if the parameters cannot be improved significantly, we cannot really promote it for the use of family in Besongabang. There is a small potential to promote it as a bachelor's stove still, if we can slightly improve the parameters. Your stove has not yet reached its full potential. It will work much better in time.

Here is the wood I used. It is 7" long. ½-1 ½" thick.

Here it is packed into the stove. It is about 1” below the top of the inner cylinder. Lighting material goes on top of this.

If any of your wood was left at the end of your burn there is a problem. I think you should be extra careful to get very dry wood. We should eliminate that possibility. We can deal with moist wood later.

This stove would normally cook for about 45-60 minutes.

The performance you are experiencing is definitely not normal for the Champion TLUD. How close are you to the dimensions in the plans?

I have 3 stoves here (purchased) including the Champion TLUD as made by Servals (in the picture above and same as the plans I sent you), the SilverFire Hunter gasifier from SilverFire and the SilverFire Survivor rocket stove from SilverFire. I will be doing tests with all 3 of them during the next week. We already did one test with the Champion with an 8 quart pot with 5 liters of water.

I will send you the results of our test as soon as I get them from the other team members.

This should give you a good reference point.

Don't get discouraged. We will get better performance. There are ways to get longer cook times from the gasifier stoves but we will also want to build some rocket stoves and these may be easier for getting longer (or shorter) cook times. They have a lot to recommend them.

Pearly and Cary's response 6/11/2014
I have included a photo of the stove just before we threw the charcoal as it was burning red hot and we didn't want to ruin the grate.

I will include in a separate email a photo of the stove as it is about to be lit.

Cary
Here's another photo. As Pearly said, we split the wood the way Kirk described.

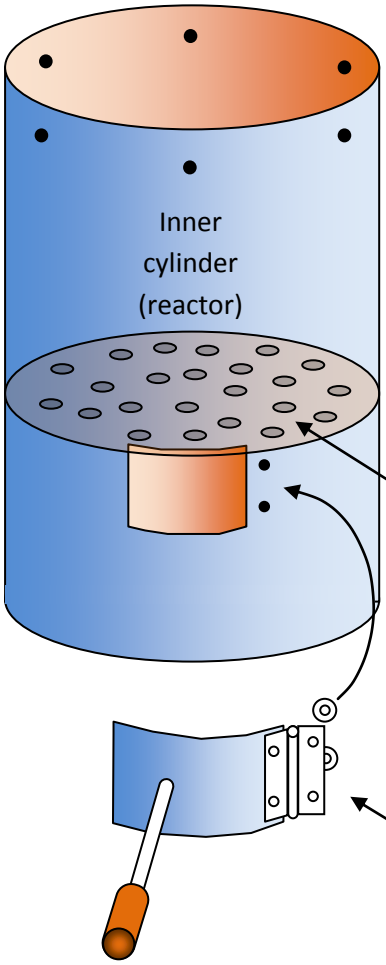
If you zoom in a little you can hopefully see the way the wood is split as well as the extra pieces of wood in the bottom of the frame.

Cary

From Kirk 6/11/2014

Once the stove is working properly the following will help.

You stated the need for a 1 to2 hour burn time. The below changes will allow the stove to be adjusted from high to low to save fuel and provide the 2 hour burn time.



TLUD stoves are difficult to turn down to low power for simmering. The flame cools and goes out at low power levels. These holes allow small pilot flames beneath the main flame which support the main flame, keeping it hot and maintaining flame presence during turn-down. This allows the stove to be turned down to low power for simmering. Less fuel is used and so you will have a longer burn time. You will need this to get the 2 hours of cooking time.

Six holes: 4 mm diameter holes, evenly spaced around the reactor, located 2 cm below the top.

With the door to adjust the primary air, lots of holes should be put into the grille. This will enable both very high and low power levels.

This door will give your stove adjustability to low power for simmering. It will adjust the primary air, which will adjust the amount of wood gas being produced, and thus the size of the secondary flame. Pushing the lever to the right will increase the power and left will reduce the power. It will work in concert with the pilot flame holes above. The washers will space the hinge out to allow the door to shut.

Email from Pearly 11/9/2014

Hi Huck, please find my report attached. These might be the first times we actually have achieved gas burning and we have some quite impressive results. The important question is what to do next with the stove.

Also i discussed a little about chimney with Timothy. From his experience with mud, he said we should be able to build long chimney more than two meters but we should lean it on the wall. Does that make sense to you? Now i am asking timothy to try to locate nearer clay soil because we need much of them. While the lorena stove seems complicated, i am thinking about trying the much simpler Shielded Rocket Stove first, the one with single pot and without chimney. I don't think that stove will fail, just that we cannot guarantee it works better than open fire. Timothy said that he is eager to make mud stove, but he is honest that he will not be happy if the first stove made fails. Cary and I like the mud stove because it is cost free and it is close to villagers' habit.

I am working on the budget simultaneously, so it would be no problem to plan about the mud stove. We can do the real making later.

Let me know what you think. For me personally i am fine with to do the mud stove now or not. But i would like to eventually make a rocket stove and the TLUD stove work at least for some people when i am still here. I feel that i have responsibility towards our welder and Timothy in trying to help them achieve some benefits from our stove-making. And considering the speed of progress of things here it is in our interest to start asap.

Pearly

Here is Pearly's report with comments from me in red and comments from Kirk Harris in blue

Third and Forth Stove Tests (11/9/2014)

Today we did two stove tests. From our past experience, our problem is the lack of regular flame, so this time we decided to pack the wood vertically so that it can have a consistent burning surface down the inner cylinder. But we make sure the wood has uneven surfaces so that they can easily catch fire. We do that by splitting wood with machete.

This is how we pack the wood prior to third stove test. From this picture one can see that although we tried to pack the wood vertically, the upper part is still quite loose (having much cavity).

When we managed to light the wood and put the pot on top, the fire was not burning consistently in the beginning. The fire almost went off and we had to remove the pot and encouraged more air in.
Did you make more holes in the grate (to let more primary air in)?
Also, I think you need to let the fire catch pretty well before putting the combustor on.
So the pot of 1.5 L of water took 18-19 minutes to boil. However, after these initial minutes, the flame started to burn very well in a consistent manner (Cary and I made some discussion in between. Her idea led me to guess that this is the real gas burning, while previously we were probably only relying on wood burning). So we filled up another pot with 1.5L of water and we got it boiled in *8-9 minutes*.
With that result, we did another test right after. This time, I was too ambitious and packed bigger wood in a much more compact way (so that there is not so much cavity in the upper part of the inner cylinder). However, this failed to work as the flame simply won't burn for long. (I am guessing the wood pieces are too big and the compact arrangement has blocked the primary air). So we spilt the wood into smaller pieces and we removed some wood so that the arrangement was looser. We also placed more smaller wood pieces to fill cavity in the upper part.

In the past stove tests, we usually soaked a few pieces of small wood with diesel and then spread them on top of the wood packed, but they hardly covered the whole surface. After lighting it, we will then spread the fire evenly further with palm wastes. However, this time I did something differently. In order to make sure the fire will burn this time, I soaked 3 times amount of materials (both wood pieces and palm wastes) with diesel, and when I poured onto the top of the packed wood, they have formed a nice layer covering the whole surface. (I am sorry I did not capture a picture of this one). In my stove I tore up pieces of paper and sprinkled them with a good amount of charcoal lighter fluid (I

am sure similar to diesel or kerosene) and put the paper on top of the wood in a layer 1-2" deep. The wood was very dry. It lit pretty quickly and evenly. My guess is that anything that lights easily (paper does, or thin wood) and stays lit for maybe 3-5 minutes will work. Kirk knows best.

You all know as much as I do about this now.

We lit the wood and this time, the fire was burning very well and consistently right from the beginning. It took about *6-7 minutes* to boil 1.5L of water. After that, Timothy continued to use it to heat his food. This not only consistent, but strong flame continued for about 30 minutes.

This is what we want. The gas flame is fascinating to watch and very good for cooking. There are a lot of different gasses which form wood gas. The main flammable gasses are Hydrogen and Carbon monoxide (partly burned carbon) with a little methane. When the flame cools off you can probably smell the heavy aromatic hydrocarbons. Also they hurt your eyes. They burn at about 735 C, which means your flame is below that. A good hot flame will be around 900 to 1000 C. When the flame stops and transitions to hot coals, it can be difficult to keep the flame alive since the wood gas is diminished and the coals are not yet hot. It takes a hot flame going into the transition to transition cleanly. The hot coals are carbon which burns into carbon monoxide which then burns into carbon dioxide, forming a difficult to see blue flame. It is easier to see at night. The stove is still operating as a wood gas stove, but the gas is carbon monoxide rather than hydrocarbons. The stove must remain hot or the carbon monoxide will not burn. This poisonous gas can do serious harm in an enclosed kitchen.

In between, the flame went off once, but when we removed the pot and fanned it for a while, the strong consistent flame resumed. After 30 minutes, only the red hot charcoals were left, emitting heat. These red hot charcoals seem to be able to burn for hours. I waited longer just to see how long it will burn but it does not show any sign of dying down. After another 30 minutes, I stopped the test (afraid it is too hot for the stove) by blocking the primary air. Picture below shows the burning charcoal. The gas that rises from the wood needs a consistent high temperature to stay lit. When you put the pot on it can cool the gases and they can go out (they can also blow out from wind). Removing the pot will let it get hot again assuming there is some source of heat below. It may be that the pot is too close to the flame. If the pot is in the flame it can cool it and even if it keeps burning the combustion is not as complete and you get more emissions (maybe seen as smoke but maybe not very visible). I am saying this from a theoretical perspective. Kirk can give much better practical comments.

Conclusion:

We might actually have really achieved gasification burning these two times, but not the previous times. We seems to have relied on wood burning previous as the flame was not consistent and most of the time small. The fire burning in the fourth stove test was very visible, strong and consistent. Timothy and I were very impressed. The strong fire can be retained for only 30-35 minutes. But the long charcoal burning might be able to cook some of the traditional dishes. The charcoal produces lots of radiant heat. This requires the pot to be closer as the radiant heat transfer drops off rapidly with distance. There will also be hot air rising from the charcoal but I'm not sure how effective that is for heating the pot. The comments I have seen is that people can continue simmering (i.e. low temperature cooking) with the charcoal in the bottom. If I understood Kirk's previous suggesting he suggested moving the charcoal so that it is closer to the pot.

I believe this was Dr. Anderson. He has done a lot of work on this.

There are a couple of other gasification stoves that use the charcoal (for simmering) without moving it. I will check on those. There is also an adaptation of charcoal stoves where the charcoal from a gasification stove is passed into a separate container. As far as I understand these have not been very successful, but I don't know much about them. The more persuasive arguments I have heard recommend using the charcoal in the stove.

I don't know whether I will be able to replicate this test exactly. The key seems to be the layer of material soaked with diesel. What do you think? And what should be our next step with this current stove?

You have a working stove. I suggest you get with the young lady and get some experience cooking. Try different dishes, things cooked in pots like stews and soups, foods fried in frying pans and stir fry

foods. Whatever are traditional foods in Cameroon. Getting some practical experience will enable you to customize your design for Cameroon.

(It is probably my fault that I mentioned to that young lady some time ago, after my discussion with Huck, that if she helped us to test the stove and gave feedback, I might be able to gift her the stove at the end of all our testing and modifications. But if this is not feasible for strong reasons, I can still explain to her). I am in favor of gifting the stove if that is OK with everyone. However, I still have my reservations about people using stuff that is not functioning as well as we would like. Unless they understand this clearly and have an inventive approach to this, i.e. they assume this is a test and they will modify it.

Be sure you get some experience using it before giving it away. In a few weeks/months she can give you long term use results which can be very helpful.