Report on Improved Dung Burning Stove in Tibet—July 16 to August 4, 2006
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Aprovecho was asked by GTZ to look at and suggest improvements for the traditional stove being used in Tibet for cooking and house heating using animal dung. Aprovecho spent the Fall/Winter of 2005 looking at dung combustion and coming up with a combustion chamber that will burn dung efficiently. I will refer you to our report on that research but will focus here on my work in Tibet.


Traditional Dung Cooking/ Heating stove

Synopsis:

My work in Tibet consisted in three stages, (1) Upon Arrival in Lhasa I talked with our Tibetan partners as to any cultural and logistical restraints there were for stove modifications. From this I made a variety of prototypes with GTZ's stove partner and students from the vocational school in Damshung. (2) I brought those prototypes up to the higher altitude, dung burning location of Nakchu to test and get feedback from dung stove users. (3) From these tests and observations I refined the prototype stoves.

From this testing I am able to make some general suggestions as to changes that could be made to the traditional stove. There are two areas of improvement for the traditional dung burning stove. Either the combustion chamber can be improved or the part of the stove that functions as a heat exchanger to the room can be improved.
I made a modified rocket stove combustion chamber that burned the dung more efficiently. It will require further testing and adaptation to the local environment before I would recommend making this change to the stove as it requires a change in the user's cooking and heating habits, but I highly recommend us following this up with further work as it's potential benefits to the stove are great. The most promising area for modification was with the heat exchanger of the stove. By making a modification to the smaller variety of the traditional stove I saw an improvement from 49% to 67% (a 37% increase from a fuel consumption standpoint). A similar modification to the largest traditional stove saw an improvement from 69% to 79% (a 14% increase). The potential fuel savings of this modification will need to be weighed against the increased cost (both financially and logistically) in making these changes.

First a small review of efficient stove design:

We look at an efficient stove as having two elements (1) Complete combustion and (2) Good heat transfer. Another way of saying this is that to have an efficient stove you have to first get all of the potential energy of the fuel turned into heat and then get that heat to go where you want it to go.

Complete Combustion: To get complete combustion we wish to have the right amount of fuel and oxygen mix in the presence of flame with adequate heat. Any excess of fuel or cold air will take away from the available heat needed for complete combustion.

Good heat transfer: To get as much heat as possible into what we are heating we want to (1) increase the surface of the hot flue gasses, (2) force the hot flue gasses to pass as close as possible to the to be heated object, (3) keep the flue gasses moving fast to disturb the boundary layer of still air that surrounds the to be heated object and (4) insulate wherever there is heat being lost.

Whenever I evaluate a design I ask the question if there can be changes made that increase combustion and heat transfer. To that end I have looked at the traditional Tibetan dung stove and asked if there is any simple changes that can be made to increase these two things. While people can come to accept a new design if it a great improvement this often takes extra time in marketing and education. Whenever possible I look to keep the design as similar to the traditional stove from the user's perspective as possible. For my first tests here I have made one alternative combustion chamber design and two alternative heat transfer design changes giving us 6 different stove configurations to evaluate for production costs vs. efficiency benefits.

1) Stove w/ unmodified combustion chamber and unmodified heat transfer section
2) Stove w/ unmodified combustion chamber and 1st modified heat transfer section
3) Stove w/ unmodified combustion chamber and 2nd modified heat transfer section
4) Stove w/ modified combustion chamber and unmodified heat transfer section
5) Stove w/ modified combustion chamber and 1st modified heat transfer section
6) Stove w/ modified combustion chamber and 2nd modified heat transfer section

Traditional combustion chamber without (left) and with (right) insulated liner. Insulation is 3 cm of dung ash.

Technical Note: One way of improving combustion involves insulating the combustion chamber to raise the temperatures in the combustion zone. In stoves where the combustion chamber is also part of the heat transfer section, as in the Tibetan stove, there is the danger of losing heat transfer while increasing combustion and in the end having a less efficient stove. Our goal will be to improve both aspects of the stove but only the test will tell us in the end.

Traditional Heat Exchanger

Modified Thin Heat Exchanger

Large Modified Heat Exchanger

Small Traditional Stove

Modified Small Stove

Testing the stoves:

There are three aspects of a stove that concern us. How clean burning it is, how much fuel is consumed to do a job, and how well it is liked by the user. With the equipment I had on hand I could not test the combustion of the stove at this time, though I could make a value judgment by way of visible smoke produced and by the temperature of the combustion chamber. My testing mainly focused on comparing the fule consumption of the stoves. I also did not have a lot of time to spend on user satisfaction. If a change is made that will be something that will have to be explored. Two aspects that give us a good indication of the fuel efficiency of the stove are the temperature of the heat transfer surfaces and the temperature of the exiting flue gasses.

Testing Protocol:

To evaluate the efficiency of these variations with only the basic equipment of a scale, an IR temperature meter, and a digital thermocouple thermometer, I devised the following testing protocol:

1 - Weigh out 4 - 500 gram bundles of dung
2 - Pick 10 spots along entire body of stove that represent a given area of the heat transfer section of the stove. Note these locations and the area they represent (in square meters) on data collection sheet
3 - Start the fire with the first 500 grams and when the dung is burning start the 10 minute timer.
4 - At the end of the first 10 minutes add the second 500 gram bundle of dung and reset timer.
5 - At the end of the second 10 minutes add the third 500 gram bundle of dung and reset timer.
6 - Record temperatures along the 10 spots of the stove body at 2.5, 5, and 7.5 minutes.
7 - At the end of the third 10 minutes add the forth 500 gram bundle of dung and reset timer.
8 - Record temperatures along the 10 spots of the stove body at 2.5, 5, and 7.5 minutes.

In the end we will have 6 readings for each of the 10 areas of the stove. I have made a Excel spreadsheet where I enter these data to get a approximate efficiency for each stove as well as a comparison of the temperature of the exiting flue gasses. It is important to note that these results are not exact as I do not know the exact energy content of the dung. But I believe these numbers are relatively accurate and more importantly are accurate for comparing the different versions of the stove.

Testing with vocational students

Results:

Refer to the table at end of report for results data.

Let me start by pointing out what is good news for many Tibetans. The largest Tibetan dung stove is actually quite efficient at getting heat into the room <u>if it is not overloaded with fuel</u>. **From the experiments I did I found that almost 70% of the energy in the dung can be getting into the room**. I believe that people complain about how much dung they need for two reasons. First it is because dung is a very low energy per volume fuel and therefore even if you got 100% of its energy into the room it would be a lot of dung. Secondly, like most of us, the Tibetans do not want to have to be constantly adding fuel to the stove and therefore tend to overload the combustion chamber, creating a cool and inefficient fire. This being said I believe we can make some improvements and we should next looked at the production costs (in expense as well as construction difficulties) in making these changes.

As I described in the initial section there are two key ways we look to improve a stove. This is either by improving its combustion efficiency or by improving its heat transfer efficiency. I will address each question separately.

Combustion Chamber:

There are two reasons to improve a combustion chamber. The first is that it cleans up the hazardous smoke that is emitted from a stove. As this is a chimnied stove we may find this less important. But as we know there is a growing black cloud over Asia cause in part by inefficient household stove. The second reason is that improved combustion does increase the available energy for heat transfer as well as the quality of heat transfer.

The first avenue I explored for improving combustion was to add a simple insulated sleeve to the bottom of the combustion chamber. I hoped this would increase the temperature of the combustion chamber a bit and increase the heat transfer. As I mentioned earlier this ran the risk of taking away some of the heat transfer area of the stove and not increasing the overall efficiency. <u>As we can see from the table of results I think this turned out to be true and I would not recommend making this change.</u>

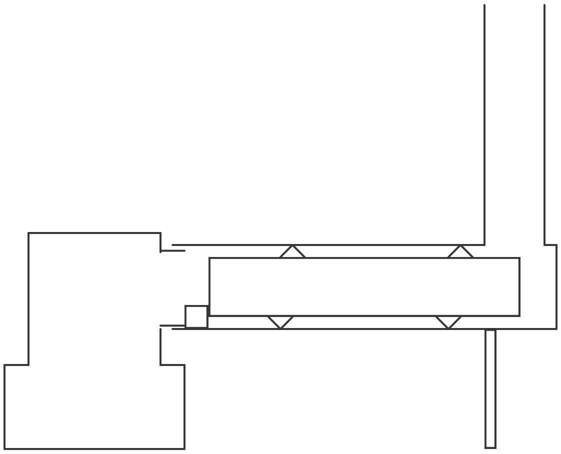
The biggest problem I found with the combustion of the dung was that the users are putting too much dung in the combustion chamber to be efficiently burned. To this end I made a rocket style version of a combustion chamber which would induce efficient metering of the fuel. While it will take further work in developing a model that will not turn away users it would greatly improve the stove's performance and I believe this warrants further effort.

Prototype rocket Elbow:

While the prototype rocket elbow worked well once lit we would have to work on making it slightly easier to use and maximizing the size of the combustion chamber so that we can maximize user satisfaction without damaging efficiency

Heat transfer:

Changes to the heat transfer area of the stove showed the most promising area for beneficial and easy modifications. By adding a displacer into the center of the heat exchanger of the stove we were able to force the hot flue gasses to pass closer to the metal of the stove and give up more of its heat to the room. For this modification it is important to keep the gap between the displacer and the wall of the heat exchanger correct. I used pieces of angle iron to maintain a 1.5cm gap throughout the heat exchanger. One important aspect of this modification is that it will have to be cleaned periodically as soot will build up in the heat flow path. This may be extra work that the users will not want to do but it will keep the heat exchanger working at optimal efficiency. The traditional stove now does not require cleaning as it is a large air space but for that reason quickly looses its effectiveness as a heat exchanger as soot is built up upon the wall. As the chimney of the stove is already maintained in this way I would hope that this would not be a problem. I Made two variation of modified heat exchanger. The larger heat exchanger with a displacer inside showed the best potential for energy efficiencies but the thinner version of the heat exchanger (see photos and results) resulted in high efficiencies with minimal amounts of metal.



Photos of building Heat Exchanger:

From the outside the stove will look the same as the traditional stove

On the inside we will place a "displacer" so that the hot flue gasses are forced to pass closer to the walls of the heat exchanger

This "displacer" is put inside the heat exchanger of the stove

"spacers" keeping 1.5cm spacer

It is very important to keep the gap between the displacer and the heat exchanger correct. We will weld on spacers to do this

Weld on 4 - 1.5cm spacers to the bottom of the displacer and two - 1.5 cm spacers to the sides and top

Remember to make the end of the heat exchanger removable and put a handle on the displacer for periodic cleaning.

Initial fuel consumption tests of the modified heat exchanger show a 37% improvement for the smallest stove down to a 14% improvement for the largerest stove

1.5 cm space kept by spacers

A few important points:

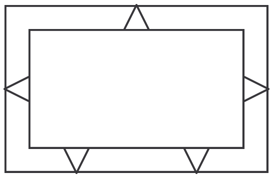
1- Make sure the heat exchanger and the displacer are made square so the distances are correct

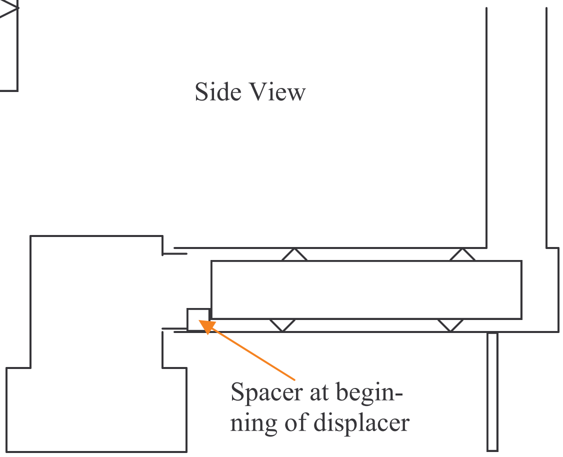
2- Place a spacer at the beginning of the displacer to make sure it does not block the exit from the combustion chamber (see below)

3- Let the stove user know that this will have to be cleaned periodically but that it will use much less fuel

4- It does not mater how big the heat exchanger is, as long as we make sure to make the displacer 3 cm less wide and tall (1.5cm on all sides)

End View





Other Considerations:

There is one other aspect of the stove that I would like to touch on before wrapping this up. As I visited users of the stove in the field I noticed that they were not using a cap on the chimney. I was told that this was because of the wind in the area. I also noticed that the back of the stove was the first part of the stove to burn out. It became evident that because of the lack of a chimney cap the rain was entering into the stove and causing the back of the stove to rust out prematurely. I would recommend that some effort is put into seeing if the chimney caps can be designed to withstand the wind. I have work in many windy climates and see no reason that a way of attaching the cap can not be made to make it sturdy enough to withstand the wind. This simple addition will greatly extend the life of the stove and make it work better as the wind will not be allowed to blow back down the chimney.

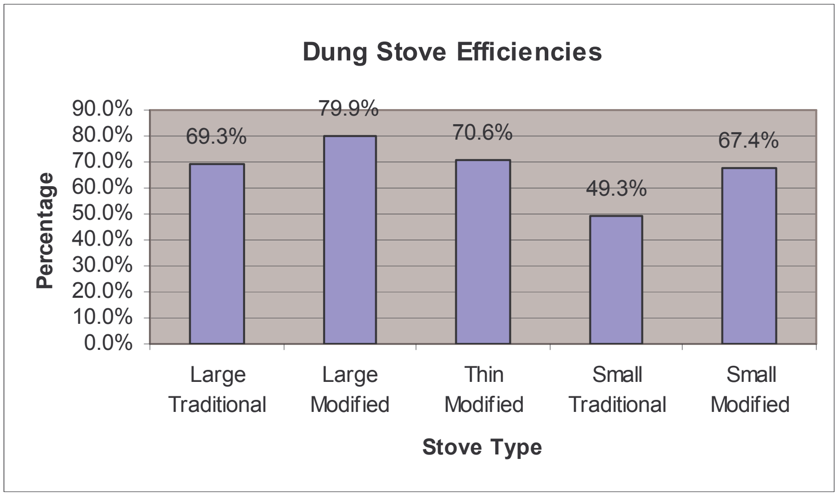
Conclusion:

As I have stated before in this report I divide my recommendations into two categories. Whether or not a modification should be made to the combustion chamber of the stove and whether or not a modification should be made to the heat exchanger of the stove.

As far as the combustion chamber goes I think we will need to experiment further and work more with the users in Tibet before I could recommend a change at this time. As GTZ and Aprovecho have found from their other work introducing the rocket stove combustion chamber this is something that often requires a large "in the field" presence to work with the users and come up with a rocket stove combustion chamber that will fit their needs. **This having been said I believe the possible benefits from this change are great enough to warrant further research and if Osman or someone in Tibet wants to experiment with the prototype rocket combustion chamber I left behind I would love to work from here with that individual to come up with a working desing**.

As far as the heat exchanger of the stove goes I believe we should move ahead with building the stove with this change. As I stated before the potential benefits in increase efficiency become less as the stove gets larger but even in the largest of stoves the potential for fuel savings warrants making this change. Beyond the initial fuel savings there is also the fact that the efficiency of the heat exchanger should remain optimized as the user will have to periodically clean out the efficiency damaging soot from time to time for the stove to work.

As a recap on the potential benefits of the modifications, the smallest of the traditional stoves increased from 49.3% efficiency to 67.4% with the addition of the modified heat exchanger. From a fuel savings perspective this is a 36.7% increase in efficiency. To build the smaller modification we need to use about 2/10ths of a square meter of metal to make the displacer. The largest variety of traditional stove increased from 69.3 to 79.9% with the addition of the modified heat exchanger. This represents a 15.3% increase in efficiency. The modification for the largest variety of stove requires the use of about 1/2 of a square meter more of metal. The thin modified heat exchanger kept the efficiencies relatively high (70.6%) while reducing the amount of metal needed (about 1/4 of a square meter less metal then the traditional stove.



Final comparison of Experimental Changes to Tibetan Dung Stove

Large Traditional Stove (80 cm)	Efficiency: 69.3%	Final Chimney Temperature: 81.8
Large Traditional Insulated combustion chamber	Efficiency: 67.5%	Final Chimney Temperature: 86.8
Modified Heat Exchanger normal combustion chamber	Efficiency: 79.9%	Final Chimney Temperature: 69.0
Modified Heat Exchanger Insulated combustion chamber	Efficiency: 73.9%	Final Chimney Temperature: 67.5
Modified thin Heat Exchanger Normal combustion chamber	Efficiency: 70.6%	Final Chimney Temperature: 108.8
Modified thin Heat Exchanger Insulated combustion chamber	Efficiency: 69.1%	Final Chimney Temperature: 98.3
Smaller Traditional Dung stove (45 cm long)	Efficiency 49.3%	Final Chimney Temperature: 119.3
Smaller Traditional Dung stove Modified Heat Exchange	Efficiency 67.4%	Final Chimney Temperature: 111.3