FROM LA LORENA TO LA ESTUFA DE DONA JUSTA

Rethinking the Latin American Cookstove
by Dean Still

When appropriate technologists began to look at the fuel efficiency of three stone fires an assumption was made that favored the new stoves they were introducing. The three stone fire was viewed as "very wasteful of fuel. (Wood Conserving Cook Stoves, VITA, 1980). Early estimates of the efficiency of the open fire were very low, usually between 3% and 7%.

These estimates can be true of open fires, which are outside in the wind. But, many people either cook inside or protect the fire from wind. In these cases, the three stone fire performs more efficiently. Expert users can get reasonably high efficiencies from their home cooking fires.

Our latest Spring 1999 experiments with the three stone fire resulted in a average fuel efficiency of 11.2%. The testers were amateur U.S. college students who were trying to do their best. Trained fire operators can usually do better. Even the amateurs sometimes scored much higher than their average. The range of scores in ten tests was from 7.6% to 17.8%. Experts would obviously tend to score in the higher ranges of efficiency.

The Advantages of the Open Fire

How can we design a stove that beats the open fire? First, let,s list the advantages of the three stone fire when compared to some stoves:

- **No heat is absorbed into the mass of a stove body. High mass stoves can absorb heat that could have gone into the pot.**
- **Fire hits the bottom and sometimes the sides of the pot, exposing a lot of the pot to the heat.**
- **Sticks can be fed in at the appropriate rate assisting complete combustion.**

How to Achieve More Complete Combustion

Every stove suffers because it has some mass. But a stove can achieve better combustion than an open fire. The good stove helps to make hotter and more efficient fires by doing the following things:

- **Insulates around the fire. A hot fire burns up more of the combustible gases and produces less smoke.**
- **Limits the cool air that lowers temperatures in the area of combustion.**
- **Pre-heats the air before it enters the fire.**
- **A chimney creates draft assisting combustion.**
- **Forces the user to meter the fuel.**
- **Forms a grate out of the sticks of wood.**
- **Escaping smoke passes through flame and combusts.**

How to Get More of the Heat Into the Pot

Although flames sometimes touch the pot in an open fire, the stove can improve upon the efficiency of heat transfer in the following ways:

- **Force the heat to contact as much of the pot as possible. Increase the maximum surface area exposed to hot flue gases.**
- **Insulate around the fire everywhere except where it touches the pots.**
- **Make the heat contact the pots for as long a time as possible. Prolong the dwell time.**
- **A greater percentage of the heat enters the pot if there is as large a difference in temperature as possible between the pot and heat source. Go for a big Delta T,.**
- **It helps if the pot is as conductive as possible**
- **Heat contacting its surface is as hot as possible**

The Rocket Stove

The Rocket Stove is designed to do all of the preceding things to both A.) Achieve more complete combustion and B.) To force as much heat into the pot as possible. The Rocket stove attempts to burn up as much smoke as possible and then uses a skirt to force the hot flue gases to rub against both the sides and bottom of the pot. The Rocket stove is also made with low mass materials if available and is well insulated, if possible.

Forcing the hot flue gases against the pot is very important when trying to save fuel. The Rocket stove cleans up a lot of the smoke but it is only about as fuel efficient as a well run open fire. In amateur tests conducted in the Spring of 1999, the Rocket stove without a skirt averaged 12.5% efficiency. (Again experts can score higher.)

A Skirt Greatly Improves Heat Transfer to the Pot

But, when a skirt was added (a simple cylinder of metal around the pot, under the handles) the average amateur efficiency rose to 23.6%. The skirt is very important for fuel efficiency. In fact, fuel efficiency in a stove is usually much more effected by heat transfer to the pot than it is by improving combustion efficiency.

Stoves with Chimneys

The Rocket stove tries to reduce smoke by improving combustion. But, if people are well off enough to afford a chimney then all smoke can be removed from the living quarters.
The old Lorena stove had one great thing going for it: the smoke was removed from the kitchen in a chimney. Inhaling smoke is very bad for one,s health, so even though the Lorena wasn,t very fuel efficient, smoke removal was a great contribution in and of itself.

In fact, there are many NGO,s including the World Health Organization who might conclude that removal of smoke is more important than fuel efficiency. Recent studies confirm what has been obvious for decades: that smoke inhalation does cause a host of medical problems including very serious respiratory illnesses. Smoke inhalation is dangerous. It is very important to reduce exposure to smoke!

Problems with the Lorena Stove

The Lorena stove was originally designed by a group of volunteers in Guatemala including consultants from Aprovecho. Ianto Evans, a founder of Aprovecho, wrote the book Lorena: Owner Built Stoves published by Volunteers in Asia in 1979. The Lorena continues to attract friends but there are several problems in the Lorena design that have been corrected in later Aprovecho stoves with chimneys. These problems are:

- **The fire directly contacts the very heavy mass of the stove body, which absorbs heat, robbing it from the pot.**
- **The combustion chamber is uninsulated. The cold walls cool the fire causing smoke.**
- **The fire flow path does not intimately touch the pots. It flows horizontally past the pot resulting in poor heat transfer. The walls of the fire tunnels are uninsulated.**

Earth Is Not Good Insulation

The designers of the original Lorena thought that earth was insulation. They did not understand the difference between mass and insulation. Good insulation is made up of little pockets of air separated from other tiny pockets of air by a lightweight, relatively non-conductive material.

Earth, especially rammed Lorena, doesn,t contain many pockets of air. Good insulation resists the passage of heat; thermal mass does the opposite, absorbing heat. Instead of using sand and clay near the fire now, Aprovecho designers use natural insulation, like wood ash. And instead of rushing the fire past the pots, the hot flue gases are forced to rub against the metal surface, which greatly increases heat transfer.

The DonaJusta Stove

This year, in 1999, Aprovecho was invited to assist two non-governmental organizations in Honduras to design and help build a stove that has a metal griddle covering the stove,s top. This plate of steel is called a "plancha in Spanish. The original plancha stove was designed in 1995, with help from Rogerio Miranda and PROLENA/Honduras.

The Aprovecho version of the plancha stove includes a Rocket-type insulated firebox and a chimney. A one-inch gap forces the hot flue gases to pass directly underneath the metal griddle. Our tests have shown that this stove is 16% efficient when used with three pots. Hot flue gases are also forced to pass directly underneath the metal griddle. The following diagram points out the design features of this type of improved plancha stove named after Dona Justa. (Dona Justa helped to design, build, and test this stove in Honduras.)

Tests show that this stove is about 16% efficient when used with 3 pots . The plancha griddle is very good at transmitting heat to the pots. The thin metal is a great conductor of heat. But, for the same reason, **wherever the plancha is open to air, where it isn,t touching the bottom of a pot, heat easily leaves and heats the room instead**. But, 16% is an improvement over the open fire and no smoke should enter the kitchen.THe efficiency of this stove can be increased by narrowing the plancha so it is only as big as the pot itself. The efficiency can also be improved by cutting holes in the plancha so the pots can 'see' the fire. We cal this the Estufa Justa de dos hornillas and it has an efficiency of 23% when used with 3 pots.

The Justa stove does many of the same things that the beautiful old cast iron cooking stoves did. These stoves now cost more than a thousand dollars in the U.S. But a Justa stove can cost less than 20 dollars to make. (Aprovecho designers jokingly call it our Y2K preparedness stove.) We plan to install this stove and one quite like it in the kitchen of the Aprovecho dormitory replacing our dependence on propane.

The stove that will stand next to this stove is the Justa profunda. In this stove the pots are sunken below a metal or cement plancha. A tight fit between the metal and pot seals the smoke into the stove. Skirts surround the bottom and sides of the pots, under the stove top, forcing the heat to contact more of the pot. If the gap is optimal and the same cross sectional area is maintained (to assure steady draft) as heat travels past the sides and bottoms of all the three pots, this stove can reach efficiencies of 35%. See the 'Dona Justa stove' page for more information.

The efficiency of this stove is highest because the greatest amount of heat is striking the most surface area of the pots. Like the previous stove, both combustion chamber and fire flow path are insulated with wood ash, perlite, vermiculite, or fluffy earth.

These 4 stoves: the Rocket, the Dona Justa, the Dona Justa de dos hornillas, and the Profunda stove demonstrate more or less efficient ways to help create a reduced or smoke free kitchen. The Rocket stove can be a useful option if, for economic or other reasons, a chimney is not going to be used. Of course, the chimney is preferable when cooking inside as it takes all of the smoke away from the cooks.

Fuel Efficiency in Stoves

The draft created by the chimney allows us force the heat through a narrow opening beneath the second and third pots, increasing the success of efforts aimed at heat transfer. Tall chimneys are a big help when sucking heat through a circuitous maze of heat exchangers inside a stove. The deflector in the burners aims the heat at the pot and they do seem to be helpful.

Forcing heat to contact the sides as well as the bottoms of the pots dramatically increases fuel efficiency. For better fuel efficiency, insulating the fire flow path is also essential. Imagine if the fire flow path were perfectly insulated so that no heat was lost or absorbed. By exposing sufficient pot surface area to hot flue gases we can be sure that a very high percentage of the heat cooks food. Theoretically, we need to leave only enough heat in the chimney to assure draft throughout the stove. In this perfect stove, efficiencies could be well over 50%.

The perfect stove would not loose heat into the stove body. It would be so well insulated that heat would not be lost by conduction, convection, or radiation. And all this captured heat would be forced to brush against a large percentage of the surface area of the pots, efficiently heating them up, until the exit temperatures out of the chimney were very low. Almost all the heat would be in the pots, leaving only enough to continue the draft. (Exit temperatures should not fall much below 250F.)

In the real world, perfect insulation is hard to come by. And it is very hard to have people accept stoves that bury most of the pot in the fire tunnel. For these reasons, even good stoves with chimneys usually succeed in getting only 15 to 30% of the heat into the pots.

Using more pots to pull heat from the fire increases efficiencies. More than three pots are hard to heat, however. The fourth pot will warm but it,s not likely to boil. Of course, it,s nice to heat wash water semi-automatically and the fourth burner is perfect for low temperature jobs like these.

These stoves can be built with low mass ceramic parts. A co-op in Honduras (Nueva Esperanza) makes durable stove parts from sand, clay, horse manure and tree gum. Or the internal stove parts can be made from thick steel pipes, replaceable thinner steel, 430 stainless steel, which holds up in stove use, etc.

The internal parts are surrounded by insulation, which can be wood ash, pumice rock, perlite, vermiculite, fluffy soil, etc. This combination makes for a highly insulated stove. The outer, durable box can be made from brick, Lorena, cement block, etc. The mass of the stove body is thermally isolated from the heat of the fire by the insulation.

If the internal parts are made from heavy amounts of Lorena mix, concrete, or simply mud and clay, then the overall efficiency of the stove will drop considerably due to absorption of heat into the mass. Even high mass stoves will benefit, however, from many of the design patterns suggested in this chapter.

If it is possible, it is a good idea to design a stove to achieve as complete combustion as possible. Even though chimneys carry smoke out of the room, it is not a complete solution if the smoke enters the neighbor,s house through the doors and windows. Designing for "complete combustion always seems preferable. Insulate around the combustion chamber, use a shelf, include a Rocket style chimney above the combustion chamber.

The options and suggestions put forth in this article summarize a couple of decades of stove designing and testing. The general understanding of how stoves work has matured a lot since the early days of the 1970,s. Hopefully these design patterns will come in handy if you need a wood burning stove.

For cultural and economic reasons we have been using these stove designs in Honduras. What follows is a discussion of other stove designs that we have made at out research center, but have not yet produced in the field.

<u>A COMPARISON OF STOVES</u>

Preliminary data mostly produced in the spring of 1999 that should only be used to indicate trends and does not establish exact relationships.

Rocket stove	13%
Rocket Stove /Partial skirt	23%
Rocket stove full skirt	36%
Three stone fire **1** pot	11%

Lorena **1** pot	5%
Lorena **5** pots	10%
Estufa Justa **1** pot	5%
Estufa Justa **3** pots	16%
Estufa **5** pots	20%
Estufa Justa de dos hornillas **1** pot	10%
Estufa Justa de dos hornillas **3** pots	23%
Justa profunda **3** pots	35%

<u>Test Protocol:</u>

Use two pounds of dry wood. FIll pots 2/3 full, in this case each held 5 pounds of water. Assume that two pounds of of dry wood contains 17,200 Btu's. Measure the effect of the burning by measuring both sensible and latent heat. Latent heat is measured by weighing water after the tst and assuming it takes 1005 Btu's to evaporate a pound of water. THe percentages shown above are the percent of toatal Btu's released from from the wood that warmed and boiled the water in the pot(s).

<u>Summary</u>

Generally, the importance of surface area of the pot expose dto hot hot flue gases is shown. AS well the low mass stoves perform better than high mass stoves. And it is shown that efficiencies rise as more pots are used. The use of a full skirt on a single pot, however, comes close to equaling the performance of a partial skirt on three pots.

Back to Stove Page | **Back Home**