Increasing fuel efficiency and reducing harmful emissions in traditional cooking stoves

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Introduction

In 1976 consultants from the Aprovecho Research Center helped to design the Lorena stove in Guatemala. The massive, earthen Lorena stove has been built in many countries since then. The design has some attractive features: the stove is made from rammed earth so material costs are low, its chimney removes smoke from the kitchen and it can be attractive. However, further studies at Aprovecho have shown how to improve the stove. More modern designs can achieve better fuel efficiency while producing fewer emissions and less smoke.

Dr. Larry Winiarski, Technical Director at Aprovecho, has devised a set of design principles which can be adapted to many types of cooking stoves so that while the outside of a particular stove may look the same, the stove becomes more efficient. These principles are described below; the design principles can be applied to many stove designs including bread ovens, heating stoves,water heaters, incinerators, kilns and dryers.

The latter part of this article describes a set of cooking stoves which are based on these principles, and are now proving very successful in Nicaragua, Honduras, El Salvador and Guatemala. Another version of the stove is described in this edition in the article by Rogério C. de Miranda and Frances G. Tilney entitled *The modernization of small business through the Ecostove in Nicaragua.*

Design principles resulting in improved fuel efficiency

- Insulate everywhere around the fire and hearth except where it touches the pot(s) – the next section describes what materials make good insulators.
- Force the hot gases to rub against the outside of the pot(s) by creating small channels with narrow gaps that follow the shape of the pot(s) – otherwise the flames will just warm the escaping air.
- Get the pot near to the hot flames. Intense heat is much better at heating food than moderate heat.
- Use pot materials which allow heat to pass through quickly and easily to the food, so if possible, use metal pots rather than ceramic.
- Increase the speed of the hot gases as they hit the pots. Faster hot flue gases punch through the still air that surrounds the pot(s).

Earth is not 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. Air is very, very light and cannot absorb and hold a lot of thermal units of heat. Heat passes much more slowly through separated pockets of air than through packed earth. Wood ash, pumice rock, perlite, vermiculite, dead air spaces, etc. are good insulators. Good insulation slows down the passage of heat.

Earth is heavy and dense, and does not contain pockets of air, so it is not a good insulator – it does the opposite and absorbs heat, robbing the heat from the pot. Before experiments proved that we were wrong, Aprovecho stove designers thought that earth was good insulation. We did not understand the difference between a heavy dense material that absorbs heat, and insulation – which does not.

In mud stoves, the flames, and all the heat they contain, are in direct contact with the heavy earthen walls, which rob heat from the pot. Also, the heavy walls around the fire itself cool the fire, causing smoke. Instead of placing sand and clay near the fire now, Aprovecho designers use natural insulation, like wood ash or pumice rock or homemade insulative fire bricks.

Getting more heat into the pot

Replacing mass with insulation and forcing hot gases to rub against the pot dramatically improves fuel efficiency. Increasing combustion efficiency helps to reduce smoke. Making sure that hot gases scrape against as much of the pot(s) surface area as possible determines, to a large degree, the fuel efficiency of the stove. In many older stoves, the hot gases are not forced to rub against the pots. Instead, hot flue gases flow past the pots in big spaces and most of the heat escapes without cooking food.

These principles can be applied to most stoves. The following sections show how these ideas have been put into practice.

The Winiarski 'Rocket' stove design

Basic rocket stove

Rocket stoves are based on a combination of simple principles:

- The combustion chamber is insulated in order to keep the fire hot (above 650°C) to burn the wood more completely, thereby reducing smoke (which is fuel that has not burnt completely).
- The combustion chamber and interior stove parts are as insulative and lightweight as possible. Heavy materials in contact

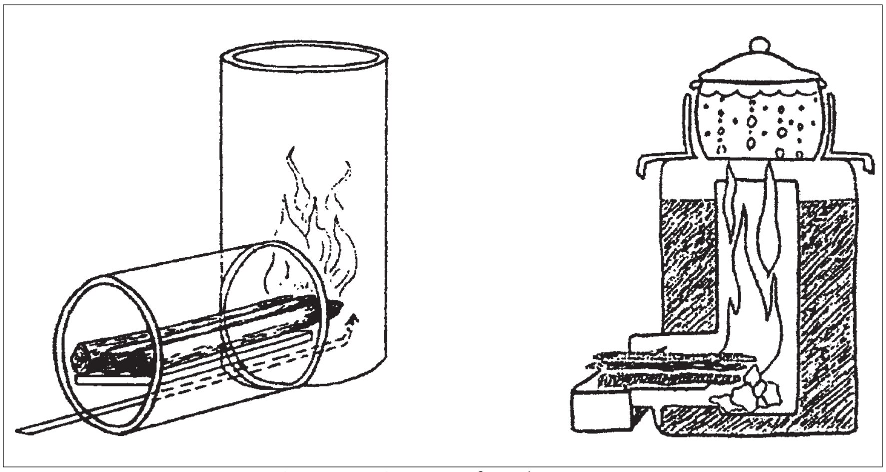

Figure 1: Diagram of Rocket stove

with hot flue gases absorb heat that could have been used for cooking.

- The 'elbow' is an important part of the Rocket family of stoves. Made in the shape of the letter L for horizontal feed, or the letter J for vertical feed, fuel is fed into a combustion chamber, placed at the bottom of a short internal chimney.
- Wood is burned at the tips and is pushed in towards the fire as it burns. This limits the amount of wood being heated and the amount of volatile wood oils being driven off at any given time, so that they all get burnt completely. Pushing the sticks of fuel into the combustion chamber as it is burnt ensures that the fuel is fed into the stove at the correct rate, creating cleaner combustion, reducing smoke. The feed opening is sized to prevent too much fuel in the combustion chamber, and arranged to force much of the incoming air to pass through the burning fuel rather than over it. Too much air just cools the fire. As the air moves through the burning fuel, it is heated, which helps to keep the fire above 650°C assisting more complete combustion.
- A 'skirt' surrounds the pot on all sides. A small gap (about 7mm) between the skirt and the pot forces hot flue gases to scrape against the sides of the pot, which greatly increases heat transfer. The hot gases contacts the sides of the pot as well as the bottom. Putting insulation around the skirt decreases heat loss even more.

Rocket stove with internal chimney and combustion chamber

- A shelf supports the sticks of wood so that air can enter from underneath the sticks. Creating a grate from sticks entering the fire helps to diminish smoke and burn up the charcoal. The feed magazine (horizontal pipe through which the fuel is fed) protects the fire from wind and creates some preheating of air which rushes in under the sticks as the air is pulled up the internal chimney.
- The short insulated interior chimney, placed above the fire, creates a strong draft that helps the wood to burn fiercely and cleanly. It also makes the stove easier to light and to use. To get the fire going, it is best to have several thin sticks burning at the same time so that the draught will fan the flame rather than extinguish it. Once the combustion chamber is very hot, it is good to have two or three medium sized sticks filling the combustion chamber as they give heat to each other and the fire between the sticks will be much hotter. However, it is possible to burn just one thick stick at a time.
- Adding an external chimney to a simple Rocket stove (as shown in Figure 2) is accomplished by partially submerging the pot into the body of the stove. The top of the stove is formed to allow the pot to be placed snugly inside, usually down to the level of the handles on the pot. The gap between the pot and the stove body is about 6mm. The external chimney exits from the side of the stove body which also surrounds the Rocket elbow. The Rocket elbow is surrounded with insulation, usually wood ash. Using insulation, like wood ash, pumice rock, vermiculite, or perlite also seals cracks in the combustion areas.

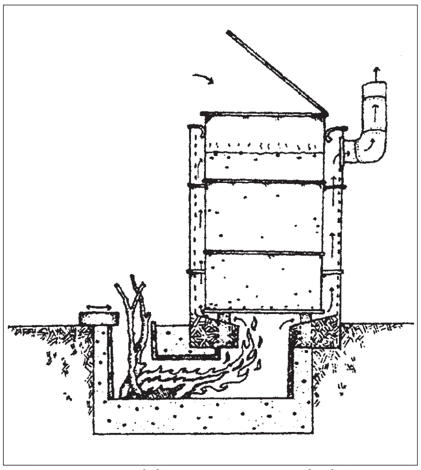

Figure 2: Adding an external chimney

The pot is located 20mm above the short internal chimney above the combustion chamber. The intense heat, in contact with the pot, increases efficient heat transfer.

- Removing smoke from a room is only a partial solution if the smoke then pollutes the village. Hot, rapid fires reduce escaping smoke before it enters into shared spaces. Where possible, Rocket stoves use external chimneys to remove the smoke from the interior of the house. However, where chimneys are not used, the stove itself can reduce harmful smoke.

Refractory Materials

The Rocket stove principles encourage high temperatures in the combustion chamber. Most materials are degraded by high temperatures, even stainless steel will be damaged over time. Ceramic parts can be made, however, that will last for years in Rocket elbows. Ken Goyer, an Aprovecho researcher, has developed a mixture that makes durable stove parts: it is kiln-fired, refractory, and highly insulative. This mixture comprises:

- 2 parts ordinary clay, like earthenware, that melts at a low temperature
- 1 part clay that melts at a higher temperature to add strength.
- 1 part cement. This holds everything together until it is fired in the kiln and adds more strength.
- 4 parts fine sifted organic matter, like sawdust. This burns out making the ceramic light weight and provides air pockets for insulation.

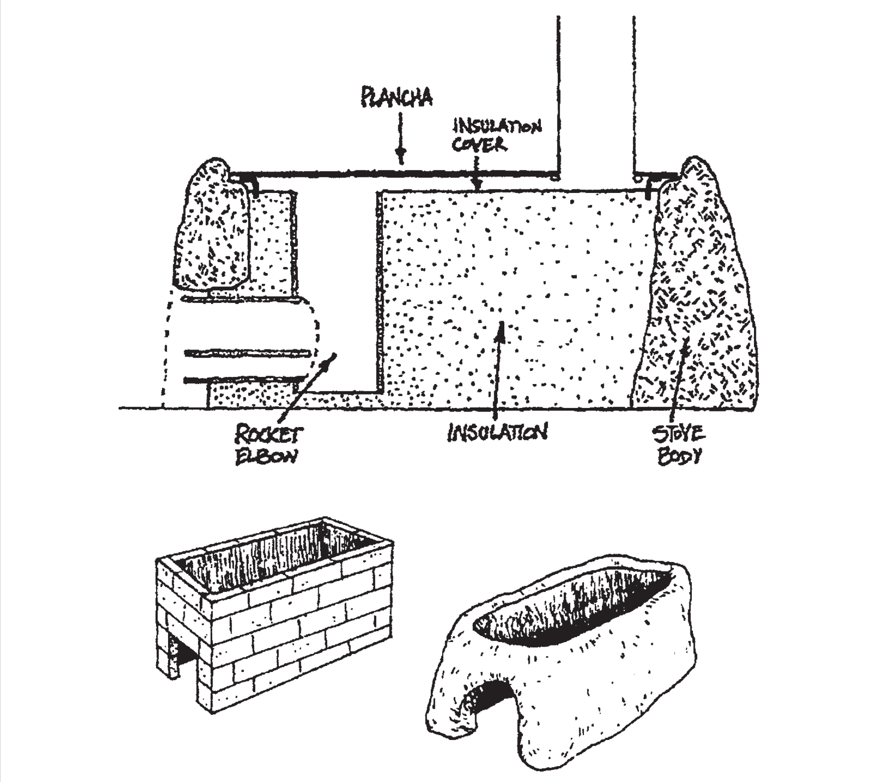

Figure 4: The Doña Justa stove

Non-Theme

A women's co-operative in Honduras called Nueva Esperansa makes long lasting refractory ceramic stove parts from a mixture of clay, sand, horse manure and tree gum.

Using the Rocket stove principles

The new Lorena stove

For three years now, Aprovecho has been working with local groups in Nicaragua, Honduras, El Salvador and Guatemala to develop and build various types of Plancha (griddle) stoves. Plancha stoves allow the user to fry tortillas, keep pots clean, and to cook using multiple pots. Flue gases are removed from the kitchen through a chimney. This work has been largely sponsored by Trees, Water and People. Organizations in Central America working on griddle stove projects include Ahdesa, Prolena Nicaragua, CLUSA, Fundacion Vida, HELPS International, the Peace Corps and the Godchild Project.

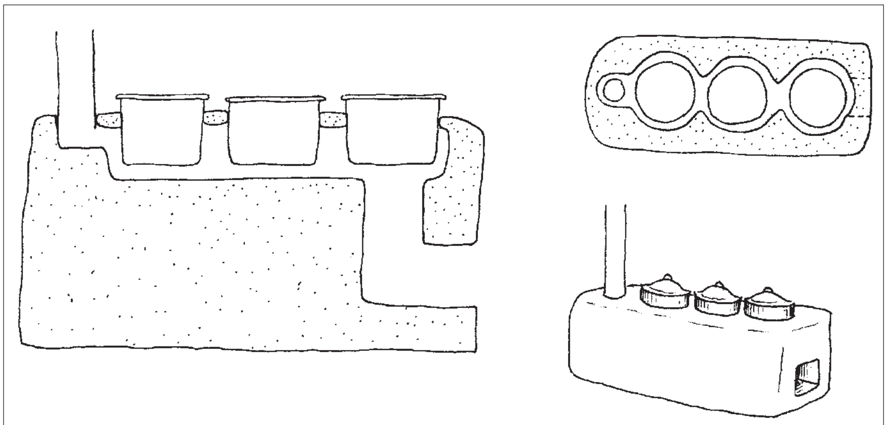
Figure 3: The new Lorena stove

The Doña Justa stove

The 'Rocket stove' version of the Plancha stove includes a Rocket type insulated firebox and chimney. Hot flue gases are forced to pass directly underneath the metal griddle (Figure 4). The diagram points out the design features of this type of improved Plancha stove named after Doña Justa. (She continues to improve, build, and test this stove in Honduras.)

The pots can either sit on top of the griddle, be placed over holes cut in the griddle, or be partially submerged into the griddle. When more of the pot is directly exposed to heat, efficiencies rise. The griddle is supported on top of a box built from ordinary brick, lorena mix, sheet metal, or any inexpensive material like adobe, etc. An insulative material like wood ash isolates the heat from the high mass stove body. If the chimney is cement, it can be a part of the box, supported by four walls. The heavy chimney is placed behind a wall of brick that allows hot flue gases to flow freely into the bottom of the chimney. If the chimney is made from lightweight sheet metal it can rise directly out of a hole cut in the griddle.

Griddle stoves with submerged pots

Partially submerging the pots under the griddle can double the efficiency of heat transfer. The efficiency of this type of stove is highest because the design allows

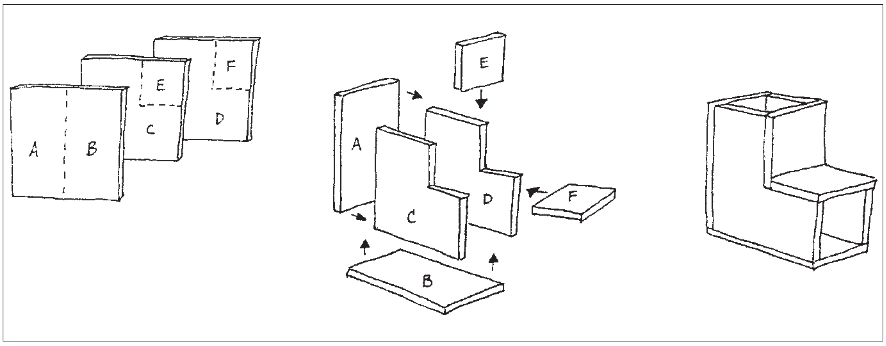

Figure 5: Baldosa tile combustion chamber

the greatest amount of heat to strike the increased surface area of the pots. The most efficient griddle stove with multiple pots can achieve efficiencies of more than 40%. Sheet metal or insulative ceramic material form walls near the pots to create a 6mm gap so that the hot gases are forced to rub against the pots. Like the other stoves, both the combustion chamber and fire flow path are insulated.

The HELPS stove

In Guatemala, an inexpensive soft brick tile called a baldosa (Figures 5 and 6) is used to make the combustion chambers in the beautiful and inexpensive HELPS molded cement Plancha stove These insulative ceramic combustion chambers make the stoves easier to start and faster to heat up compared with dense materials like cast iron or normal brick.

HELPS

JPG

Figure 7: The HELPS stove

Women in the village of Santa Avelina, Guatemala who tested both versions of the HELPS stoves, much preferred the lower mass ceramic parts, which boiled water more quickly (Figure 7)

Who are using the stoves?

Up to the present time:

- PROLENA has built 1,750 EcoStoves and plans to build 3,000 by the end of 2002 in Nicaragua;
- AHDESA has built more than 500 Justa stoves in Honduras;
- TWP/Guatemala has built 160 Justa stoves; and FUDEMCO has built 40 Justa stoves in El Salvador.
- TWP is funded to build 1,300 Justa stoves next year in Honduras and 500 stoves in Guatemala. TWP will finance the construction of 500 Justa stoves in El Coco, El Salvador over the next two years, as well.

It is reckoned that the number of women using their Justa and EcoStoves is well over 90%.

Summary

There is always a need for variations in stove design. One village may insist that pots stay clean. A village fifty miles away may need greater fuel efficiency. Rocket stoves can change to meet local needs but the essential design principles remain the same. Working with local people, it is important to be flexible in designing stoves to meet local needs. Not changing the outward appearance of the traditional stove can be helpful in gaining acceptance of the new technology inside the stove.

HELPS

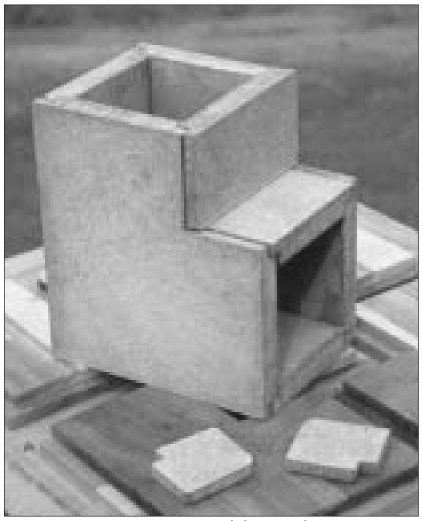

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Figure 6: Baldosa tile combustion chamber

All of these Rocket stoves demonstrate various efficient ways to cook while creating a reduced or smoke free kitchen. The simple Rocket stove can be a useful option if, for economic or other reasons, a chimney is not going to be used. The added chimney removes all of the smoke and for that reason is always preferable. The Plancha stoves and the New Lorena stove also contain design features that are novel and important:

- The Rocket elbow assists cleaner, more complete combustion.
- The heat flow path is directed through narrow channels that force hot gases to scrape against pots increasing heat transfer efficiency.
- The entire heat flow path is low mass and insulated, lessening heat absorption into the stove body.
- The small, well insulated combustion chamber under an internal insulated chimney allows the use of fewer sticks since the fire does not tend to die out as easily.

For further information, please contact: Dr. Larry Winiarski, Technical Director, Aprovecho Research Center, 80574 Hazelton Road, Cottage Grove, Oregon 97424, USA. Apro@efn.org http://www.efn.org/~apro. For further information on Rocket, Down-draught and wood-burning stoves see: 'Building and using an efficient cookstove' by Dr Winiarski – Boiling Point no 23, 1990