DESIGN MANUAL

ROCKET BOX COOK STOVE

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1. Abstract 4
2. Need Identification 4
2.2 Household Cooking 5
2.3 User Constraints: Affordability 5
2.4 Fuel Efficiency 5
2.4.1 Environmental Benefit 6
2.4.2 Savings: Money and Time 6
3. Evaluation Procedure 6
4. Conceptual Designs 7
4.1 The Winiarski 'Rocket' Stove Design 7
5 Final Design Selection. 8
Comparison Alternative Stove Designs 8
5.1 The Lorena Stove 8
5.2 Ramp Combustion Chamber e.g. Pop Wuj Stove 9
5.2.1 Fuel Savings: Determining the Efficiency of Ramp Combustion Chamber and other Improved Stoves 10
5.2.2 Ramp Chamber Stoves: Advantages and Disadvantages 10
5.3 ONIL Stove 11
5.3.1 ONIL Stove: Advantages and Disadvantages 11
5.3.2 Elena's modified ONIL Stove 12
5.3.4 Masonry Rocket Box 12
5.3.5 The Doña Justa Stove 12
5.3.6 The Ecostove 14
5.3.7 The TecoTour Stove 14
6. Detailed Design 14
6.1 Stove Efficiency Tests 14
6.1.1 Test format 14
6.1.2 Stove Models tested 15
6.1.3 Summary of Results 16
6.1.4 Boiling Water on the Back Cook Rings 17
6.2 Combustion Chamber Design ("firebox") 18
6.2.1 Materials and their Arrangement 18
6.2.2 Sizing the Combustion Chamber 19
6.2.3 Dimensions 19
6.2.4 Firewood Support 23
6.3 Design: Plancha 24
6.3.1 Plancha Sealing 25
6.4 Stove Body Design 26
6.4.1 Materials 26
6.4.2 Frame Dimensions 26
6.4.3 Dimensions: Làminas 29
6.5 Pumice Stone Insulation 30
6.6 Chimney Design 31
7 RB User Feedback from Nueva Alianza 31
7.1 General Results 31

7.2 Information Gathered 32
7.2.1 Current and previous means of cooking. 32
7.2.2 Time spent gathering wood each week. Wood savings (10, 13) 32
7.2.3 Cooking with the Rocket Box 32
7.2.3.2 Size of the combustion chamber (36) 32
7.2.4 Quality Control 32
7.2.4.2 Modifications made by Users 32
7.3 Recommended areas for investigation 33
7.3.1 Rocket Box Design 33
7.3.2 Management of Stove Donation Projects 33
8 Further Study 33
8.1 Combustion Chamber Height 33
8.2 Soot channel 33
8.3 Plancha Sealing 34
8.4 Position of the Pot rings ('hornillas') 34
8.5 Pot Skirts 34
8.6 Chimney Temperature 34
8.7 Stove Financing 34
Conclusion 34
Appendix (A) Efficiency Tests: Rocket Stove and Mynor Stove 35
Appendix B: Questionnaire (in Spanish) 38
Appendix C: Nueva Alianza survey notes 45
AC1 Time spent gathering wood each week. Wood savings (10, 13) 45
AC2 Cooking habits compared to before RB introduction (21) 45
AC2.1 Heating the front and back cooking rings (23-24) 45
AC2.2 Making tortillas (26-27) 45
AC2.3 Size of the plancha (28) 45
AC3 Quality Control 45
AC3.1 Stove Body 45
AC3.2Sealing the Plancha 46
AC4 Affordability (32, 33) 46
Appendix D Management of Stove Donation Projects 46
Appendix E Water Boiling Test Results 47
E.1 Comparative table of average values for the different stoves 47
E.2 Rocket Box Test Results 47
E.3 Modified Rocket Box (longer combustion chamber) test results 48
E. 4 San Mateo Stove (Comparison Plancha Stove) Test Results 49
E.5 Temperature data on back cook rings during water boiling tests 50
E.5.1 Temp. data on back cook rings – average values from various tests 50
References 51

Notes and Glossary:

AIDG *–Appropriate Infrastructure Development Group.*
Hornilla – *Cooking rings on the stove*
Lámina - *Galvanized sheet steel (24 gauge) used to make the stove body*
Nixtamal – *Corn boiled for tortillas*
Plancha – *Metal griddle cooking surface*
Pollo - *A sand or stone platform for an open fire*
RB - *Rocket Box Stove*
R & D Research and Development
WBT Water Boiling Test
Xelateco *– A renewable energy manufacture/ installation business set up by AIDG Guatemala*
Xela *–Quetzaltenango*

1. Abstract

The AIDG improved stove project was undertaken in response to the perceived need for improved stoves in Western Guatemala. After several iterations, the result of the project is the Rocket Box stove, a metal-bodied stove which incorporates the Rocket combustion chamber into a portable and attractive design centered on the cooking needs of the Guatemalan people.

The Rocket Box is produced and sold by XelaTeco. User feedback surveys have been used to test the implementation of design parameters and inform future work.

2. Need Identification

The health, environmental, and economic costs of the traditional open-fire method of cooking used in Guatemala have been widely documented. In order to provide a product that could effectively contribute to solving the associated social problems, the specific cooking habits and economic situation of the Guatemalan people were taken into account. AIDG evaluated these specific needs through a combination of literature review, interviews with experts, and interviews with possible users.

2.1 Health

The health issues at stake focus on smoke in the kitchen. According to *HELPS International*, carbon monoxide poisoning is the number one cause of unintentional poisoning deaths in the world. Dangerous amounts of CO can accumulate when the fuel is not burned properly as in an open fire, or when rooms are poorly ventilated. Carbon monoxide poisons by entering the lungs and displacing oxygen from the bloodstream. Interruption of the normal supply of oxygen puts at risk the functions of the heart, brain and other vital body functions.

In the United States different municipalities have different criteria on which to base estimates of air quality; most governed by the Environmental Protection Agency (EPA). Most US codes uses the term "good" to describe air with less than 9 parts per million (ppm) of carbon monoxide (CO), "fair" to describe air with between 9 and 15 ppm, and "poor" to describe air with greater than 15 ppm CO. HELPS has measured CO concentrations of 160 ppm in homes in Guatemala where the cooking is done on open fires.
(http://www.onilstove.com/benefits.htm.)

As referenced by the same source, according to the World Health Organization, one out of five children in Guatemala does not live to age 5. They further state that the leading cause of death in this age range is acute respiratory infection.

The Rocket Box is also hoped to reduce the problem of burns from small children falling into the fires, or women's clothes catching alight. For this reason it is important for the stove body not to heat up substantially. In addition it increases comfort and safety for women by elevating the fire from floor level.

2.2 Household Cooking

Cooking on an open wood fire is the norm in rural areas in Guatemala. The fire is often built on a platform of sand/ stone with two or three cinder blocks; metal struts are used to balance the cooking pots in between the blocks. It's known locally as a 'pollo.'

Big famillies are typical, meaning household cooking will need to feed up to ten people. The typical diet in villages requires slow cooking for several dishes including nixtamal (corn to be made into tortillas once ground.) Nixtamal is cooked in a relatively large pot, which the stove dimensions, should accommodate. In addition to corn and tortillas, other foods frequently cooked include beans, tamales, vegetables, coffee, and occasionally meat. However women also need an ample smooth surface for making tortillas. This is usually done with a 'comal' a clay or metal surface made for the purpose. The ideal stove should provide a cooking area large enough to prepare slow-cooked dishes and tortillas at once.

2.3 User Constraints: Affordability

In 2008 Purchasing Power Parity (PPP) in Guatemala was rated by the World Bank at $4, 690 per capita; this ranks 134th out of 210 countries[1] (World Bank, 2009.) For the RB to be a marketable product in Guatemala it must cost no more than families in rural areas are willing to pay.

2.4 Fuel Efficiency

The large consumption of wood required by the open-fire method has been a principal cause of deforestation as well as a burden on family finances for those that have to buy firewood. 67% of Guatemala's estimated 1,591,593 families rely on wood energy—wood and charcoal—to prepare their daily meals (Report on Human Development, 1999.) Moreover, it is calculated that Guatemala loses an estimated 2,460 hectares of tree cover annually to fuel wood consumption. (CONAMA/GEF-UNDP, 1999).

Wood in Guatemala is generally bought in bundles sized as a *'tarea'* or a *'manojo'*. A tarea has 24 lengths of firewood. A manojo, has 10 lengths measuring roughly 30-40cm by 5cm, and costs 10 Quetzales. From interviews in the village La Florida, AIDG estimates that the average family uses 10.9kg of wood per day (AIDG

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[1] PPP takes into account differences in the relative prices of goods and services and therefore provide a better overall measure of the real value of output produced by an economy compared to other economies. PPP Gross National Income is measured in current *international* dollars which, in principal, have the same purchasing power as a dollar spent on GNI in the U.S. economy.

Internal Research Report: ***Wood use in Rural Guatemala**.)*. If we estimate that a length of firewood (measuring 50cm – 100cm by 5cm) weighs 500-1000g, this means that a family uses between 11 and 22 pieces per day.

However, the *'tarea'*, can be an arbitrary measurement which varies according to the community. Costs also vary in different parts of the country:

- San Lucas Sacatepequez: Q75 for 80 pieces
- Jalapa: Q40 for 100 pieces
- Chiquimula: Q50-Q60 for 100 pieces
- Coban: Q35 for 100 pieces

2.4.1 Environmental Benefit

Burning wood releases carbon dioxide, a greenhouse gas, into the atmosphere. If the source of wood is not replenished, then this creates a net emission of greenhouse gases and additionally contributes to deforestation. This latter effect is further associated with increased soil erosion.

2.4.2 Savings: Money and Time

The introduction of efficient cook stoves has significant potential to decrease the labor-intensive task of collecting fuel wood, positively impacting issues of human rights and gender equality. Fuel collection times in rural Guatemala average 64 minutes per household per day, with the burden falling most heavily on the poorest quintile of the population at an average of 108 minutes per household per day (Heltburg, 2003). 36% of this collection time belongs to children, who are often responsible for water collection as well, which can reduce time spent studying or at school.

Rural households that buy fuel spend an average of 104 Quetzales per month (Heltburg, 2003), so a 50% reduction in fuel use would save 624 Quetzales per year (about 83 USD), or 1.7 Q/day. This reduction would lead to significant savings in an area where 75% of individuals in rural areas live on less than 1.50 USD (or 11.25 Q) per day (Heltburg, 2003). The time and monetary savings associated with improved cookstoves offer an important step towards poverty alleviation.

3. Evaluation Procedure

Although the underlying goal of the improved stoves project is to provide a product that will mitigate the social costs of cooking with open fires, this goal cannot be reached if the product is not used by the target market. For this reason, needs that are directly related to user experience will take a priority in evaluating conceptual designs. The ranking of the needs is as follows:

1) A cooking surface that allows the preparation of tortillas.
2) The elimination of smoke from the kitchen.
3) A low price accessible to people with limited disposable income.
4) A relatively large cooking area that allows the preparation of several foods at once.
5) The reduction of the use of firewood, creating an economic benefit.
6) A body that doesn't heat up substantially, reducing the danger of burns.
7) An appearance that is attractive to potential customers.

4. Conceptual Designs

The Rocket Box stove is a portable, high-efficiency wood burning stove. It uses a Rocket combustion chamber for high-efficiency combustion and pumice as insulation to make sure that the heat goes only where it is needed. The body is sheet steel. The cooking surface is 18” wide by 24” long, and has removable rings for allowing direct contact of the flame or hot air with the pots or pans being used for cooking. A large front ring allows food to be bought to a boil and two smaller back rings are for simmering/ keeping food warm. A 4” tubular metal chimney takes the smoke away from the person cooking.

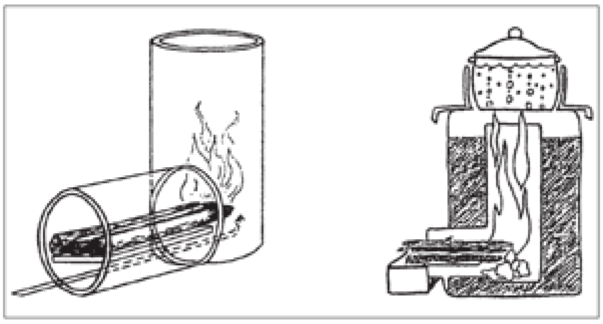
The Rocket Box Stove is designed to be efficient and mobile. Many traditional stoves in Guatemala are constructed from blocks and bricks. Using a metal box makes the stove strong, durable and not too heavy.

4.1 The Winiarski 'Rocket' Stove Design

The following design principles are attributed to Dr. Larry Winiarski, Technical Director at Aprovecho. They are outlined on:

http://www.hedon.info/IncreasingFuelEfficiencyAndReducingHarmfulEmissionsInTraditionalCookingStove

- *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 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, fuel is fed into a combustion chamber, placed under 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 they burn 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.*

The first four principles are reflected in Rocket Box design, although it doesn’t feature the pot skirts. Other internal chimney Rocket stove design principles featured by the Rocket Box include:

- *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.*

http://www.hedon.info/IncreasingFuelEfficiencyAndReducingHarmfulEmissionsInTraditionalCookingStove

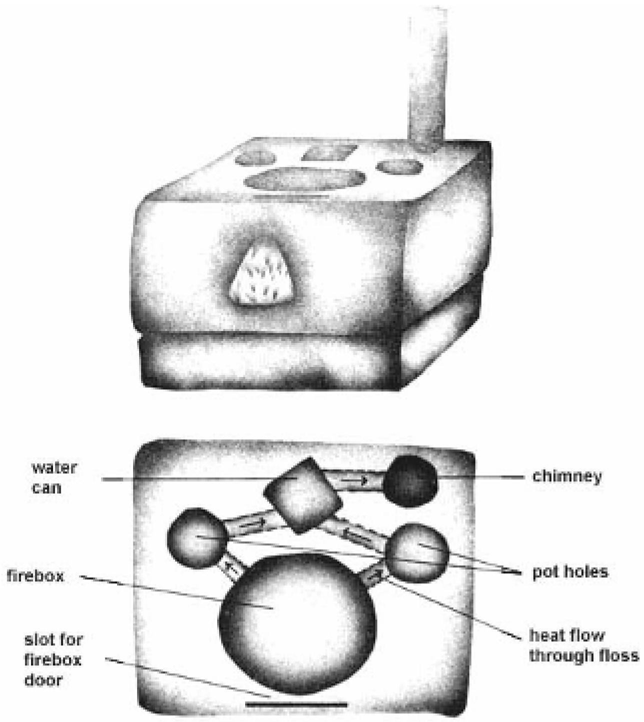
5 Final Design Selection

Comparison Alternative Stove Designs

Improved stove projects in Guatemala encompass a huge variety of models. Common design parameters are smoke extraction and some mechanism for fuel efficiency.

5.1 The Lorena Stove

This was designed for Guatemala in the mid 1970s. In 1985 over 90% of improved stoves in Guatemala were Lorena stoves (ESMAP, 2004.) The original design is massive and made from rammed earth (or clay and sand), keeping costs low. The design was subsequently copied in many countries.



How the Lorena stove works

However: *earth is heavy and dense, and does not contain pockets of air, so it is not a good insulator. In earth or 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. (www.hedon.info , 2007)*

As a result Lorena designs have been modified to improve fuel efficiency. Modified designs reflect the development of Aprovecho's stove technology principles *(www.hedon.info , 2007)*:

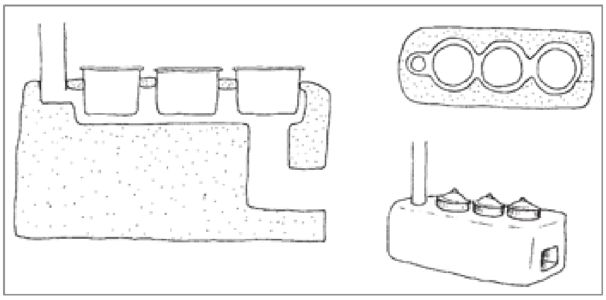
- *Insulate everywhere around the fire and hearth except where it touches the pot(s) - Good insulation is made up of little pockets of air separated from other tiny pockets of air by a lightweight relatively non-conductive material. Air is very, very light and cannot absorb and hold a lot of thermal 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.*

- *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 materials which allow hot air 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).*

Aprovecho's modified Lorena design, developed and built with local groups across Central America, is shown in the drawing below.

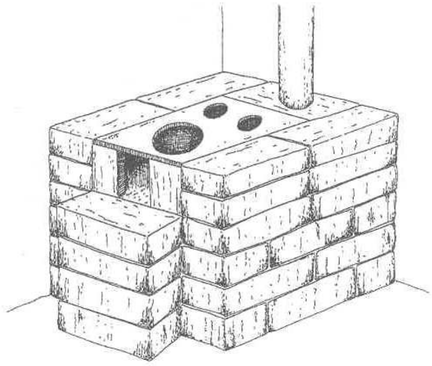


5.2 Ramp Combustion Chamber e.g. Pop Wuj Stove

Many organizations in Guatemala promoting improved stoves follow the 'baffle' masonry stove design with a generous cooking surface. Smoke is extracted though a chimney and fuel use is reduced by the "baffle" combustion chamber. Specific programmes based on this design include Tezulutlán (Baja Verapaz, late 1990s) and the Pop Wuj Spanish School stove project (Xela.)

Pop Wuj, a Spanish language school with an outreach program, has been building stoves for 20 years under the direction of Mynor Arrivillaga. These *plancha* stoves are built on a cement/ cinder block base of cement filled with dirt. The top levels are built from brick and the combustion chamber ramps up from the front to the back of the *plancha,* until only eight centimeters remain between the floor of the chamber and the metal plate at the back of the stove. A smaller internal volume means that the heat generated by the fire travels more directly to the metal plancha and thus is used more efficiently. A chimney takes smoke out of the back of the stove, and the small front entrance to the combustion chamber is covered by a door.

Tezulutlán Stove Construction



5.2.1 Fuel Savings: Determining the Efficiency of Ramp Combustion Chamber and other Improved Stoves

Mynor Arrivillaga, pioneer of the Pop Wuj stove project, claims the stove reduced fuel use by 50%. According to the evaluation by ESMAP (2004) of the Tezulutlán project, family firewood consumption in Quiaté and Pahoj fell by 50%-67% after introduction of the stoves.

However, Boy et al. (2000) found that a basic *plancha* stove is actually less efficient than an open fire, and the introduction of a baffle (combustion chamber sloped upwards towards the back) yielded efficiency test results comparable to an open fire. As shown in Appendix A, tests by AIDG indicated that more wood is needed to cook beans in a pressure cooker for 45 minutes in the Pop Wuj Stove than on an open fire.

Krieger (2007) reports that:

Households with these stoves, however, reported a 40% drop in fuel use. There are a myriad of possible reasons for this discrepancy. The stoves allow women to perform multiple cooking tasks simultaneously that previously had to be performed sequentially on an open fire, reducing total cooking time... Naumoff and Kaisel (2003) report significant amounts of reporting bias in both households with improved stoves and control homes using open fires for cooking. The process of selecting an improved stove design is therefore complicated because neither boiling water tests (and other efficiency tests) and reported fuel use provide a complete picture of fuel usage.

5.2.2 Ramp Chamber Stoves: Advantages and Disadvantages

Many people favor the stove because it is easy to use, has generous cooking space, and has good heat distribution even at the rear opening of the plancha (3 hole, 18” x 32”). It succeeds in removing smoke from the cooking area. While the pumice and clay may provide some insulation, the stove body overall absorbs heat and may emit it throughout the night, warming the house in colder climes (perhaps useful in certain regions in the Western Highlands).

However there is debate over the fuel savings generated. The Pop Wuj model requires a delay of forty days after construction before use so that the cement surface can dry without cracking and so the *plancha* does not warp. The Pop Wuj stove is not cheap, costing 1200Q (installed). The Pop Wuj stove programme reportedly relies on volunteers to build the stoves on site. For AIDG's business based model of technology dissemination, installation time would add to costs considerably. The Rocket Box is much less labour intensive, and can be mass produced in a workshop, instead of through lengthy on-site construction. Their mobility means they can be distributed in local markets. This reduces costs, facilitates quality control, and increases profitability for producers like Xelateco.

5.3 ONIL Stove

The ONIL stove is manufactured by HELPS. It retails to individuals for 750Q. According to information on its Website, HELPS offers two models: the plancha stove and the nixtamal stove (cost, 400Q). The plancha is 18" x 24"with two cooking rings for pots and space for tortillas. The nixtamal stove (5.3b) is for large pots.

The main difference between the ONIL plancha stove and the Rocket Box is that the stove body is made from cast concrete, molded in fiberglass molds (as opposed to a metal stove body.) The stove top is a metal plancha. The fire is contained in a clay combustion chamber and this is insulated with pumice, with a galvanized steel chimney to remove smoke from the house. HELPS claims that the stove reduces fuel consumption by 70%.

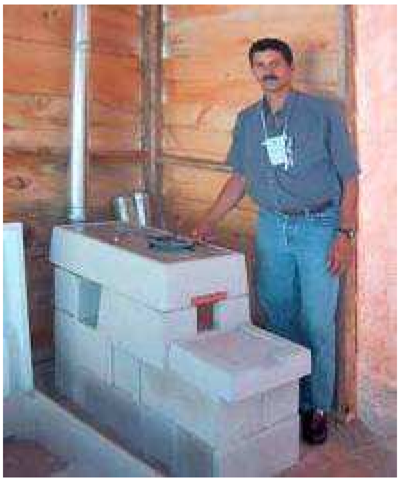


Photo 5.3a ONIL plancha stove

Photo 5.3b ONIL Nixtamal stove

5.3.1 ONIL Stove: Advantages and Disadvantages

As shown in 5.3a the plancha stove features a surface outside of the mouth of the combustion chamber to prevent wood from falling. This could overcome complaints that the small size of the combustion chamber makes it harder work to keep the fire going. The picture, taken from the website, gives the impression that the plancha stove is installed or supplied together with a pre-specified support structure to take it up to a level comfortable for cooking. One benefit of having the stove at a predetermined height would be to facilitate guidance on installing the chimney so it comes out the roof. This can be a problematic issue for stove projects in communities. The use of concrete would overcome the potential for a metal stove body to heat up risking burns.

At 750Q this stove is cheaper than the Rocket Box. The stove body is precast, creating the potential for workshop fabrication and circumventing installation time. However, the appearance of the concrete has had acceptance problems with potential customers. However the existence of separate *plancha* and *nixtamal* models may mean that households in Guatemala can not do all their cooking with just one of the two: the '*plancha*' maybe too small for large pots and the '*nixtamal*' is unsuited for tortillas. This issue, which also applies to the Rocket Box, may mean that stove owners cook on an open fire at times.

The stove body is precast, creating the potential for workshop fabrication and circumventing installation time. However AIDG's selection of a metal body is intended to improve appearance. In addition, Kruger (2007) reports the problems experienced with in trying to cast a masonry rocket box:

"*The plastic [mold] components, used for the inside front walls and the chimney cavity, buckled ... some of the wood frame was built with screws on the inside (so they got stuck in the concrete) which made it extremely difficult to remove the wood ... The front wall was broken while trying to remove another part of the mold ... misalignments caused the wood to be embedded in the concrete frame..*"

HELPS claim to prioritize proper training in stove use and maintenance: *Wood management such as drying the wood and splitting it to proper size is taught by the HELPS stove technician* (HELPS website.)

5.3.2 Elena's modified ONIL Stove

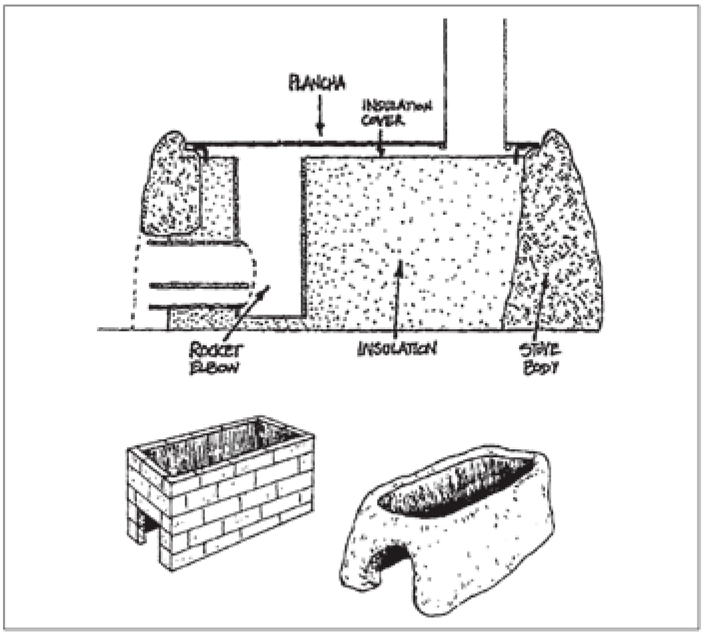
Elena Krieger modified the ONIL design to feature a 18"x 36" plancha during her work as an AIDG intern in 2007.

5.3.4 Masonry Rocket Box

Test Rocket Box constructions with concrete instead of metal for the stove body are discussed in 5.3.1. ESMAP (2004) in their account of the evolution of efficient stoves in Guatemala report that: "*using metal parts opened up as a potential way to address problems of quality control and durability of clay materials…the first chimneys experienced problems; poor quality construction resulted in cracking."*

5.3.5 The Doña Justa Stove

This is defined by commentators as "the Rocket stove version of the Plancha stove"; a masonry stove with a Rocket type insulated firebox and chimney, forcing hot flue gases directly underneath the metal griddle. Doña Justa continues to improve, build, and test this stove in Honduras (www.hedon.info) The 2 hole plancha (18"x 24") is supported on top of a box built from ordinary brick, "lorena mix", 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 plancha.



The Doña Justa stove

50% reduction in fuel consumption is reported (Miranda and Tilney, 2001). A study from Berkeley found that it reduced the concentration of PM 2.5 in the kitchen from 87-94%, depending on the model (Charron, 2005).

Plenty of information on the Justa Stove is available at www.tve.org. The "Rocket Elbow" combustion chamber is formed from two ceramic cylinders made from a mixture of clay, manure and tree resin: *A recent development is to use commercial tiles that can be cut to size and used – the advantage of this is that they only cost $2 to 3, instead of the $8 to $10 cost of the hand-thrown ceramic elbows*. Another difference with the Rocket Box is the inclusion of a channel under the chimney to catch the soot, enabling easy cleaning (photo 5.3.5a.) The concrete bock stove base is generally built to leave space fuel wood storage.

5.3.5a Justa Stove: channel under the chimney to catch the soot

According to the same website they cost around $50 each in materials: "*labour is generally free as the women themselves build them in around half a day.*" Self-building is regarded positively because it means

"*Individual stoves can be adapted to suit the cooking styles and preferences of the local women*." However, in evaluating Tezulutlán stoves built by users ESMAP (2004) reports problems of quality control: "*in many cases, there were differences between these stoves, mainly in terms of the size of the opening for inserting wood into the firebox.*"


Justa Stove: sealing the plancha

The same as with the Pop Wuj Stove, the Justa does not sit well with AIDG's strategy of supporting workshop-orientated businesses.

5.3.6 The Ecostove

This is a metal bodied version of the Justa Stove. In all likelihood it is very similar to the Rocket Box. The main difference would be the use of ceramic cylinders for the combustion chamber. It features the soot channel; this inclusion in the Rocket Box design would be worth investigating to facilitate maintenance. The EcoStove is supplied in Nicaragua by Prolena for 800Q.

5.3.7 The TecoTour Stove

As described by Krieger (2007), "*the design put a rocket stove baldosa tile combustion chamber into the Pop Wuj stove body... The side and back walls are identical to the Pop Wuj model, while the front has been modified to accommodate the lower entrance to the combustion chamber...design[ed] like that used in the ONIL stove*." It was insulated with pumice.

Like the Pop Wuj Stove, this stove was built on-site and is simple enough to be constructed by volunteers. However since the time of the project AIDG's focus has concentrated on disseminating technologies through businesses.

6. Detailed Design

6.1 Stove Efficiency Tests

6.1.1 Test format

In order to compare different stove designs, stove developers have created a variety of standardized tests designed to measure the efficiency of wood burning stoves. Over the years these protocols have been refined as different issues have come to light, and different needs addressed. In order to asses the efficiency of the rocket box stove, the water boiling test protocol developed by Bailis, Ogle, MacCarty, and Still for the Shell Foundation's Household Energy and Health Program was followed. This test involves three phases: a "cold start" phase where a fire is started and water boiled beginning with a cold stove; a "hot start" phase where the same thing is done but with the stove already warm from the previous fire; and a simmer test, where water is maintained as close to 3 C below boiling as possible. This test is designed to give some hard numbers about stove efficiency and wood use. By weighing the wood used and the charcoal produced during each phase, and the amount of water boiled and steam generated, thermal efficiency can be calculated.

In contrast, AIDG has previously developed a bean test, which is designed to provide relative efficiency data and be closer to actual cooking use. This test suggested that the AIDG rocket stove is about twice as efficient as an open fire. These results should be considered when evaluating the WBT results. Results are presented in Appendix A as a means of comparison with the Pop Wuj stove.

All of the water boiling tests were performed under less than ideal conditions. Standard protocol was deviated from in the following ways: instead of weighing the pot with water to determine the amount, the water was poured out of the pot and its volume measured in 250 ml increments. This was used both to measure the water at the beginning of each phase, as well as to measure the water after the completion of each phase. In addition, due to this, the water cooled down significantly in between the hot start and the simmer test. When measuring water at the end of the test phases, a significant amount (estimated around 20 - 100 ml) was spilled. The tests were performed outdoors under a roof. As a result wind conditions varied during the test and also affected the results. The wood used for testing was classified as average soft wood (conifer.) It should be noted that water boils at 92° C in Xlea, where the testing was carried out.

Due to the above reasons, the results listed in the tables should be taken as a lower bound on the efficiency. Another note is that boiling times improve vastly with the use of lids, forbidden by the water boiling test protocol; however it is likely that most cooks would use lids, reducing cooking time and fuel consumption. After conducting the tests AIDG contacted the Aprovecho institute as we were surprised by the low results. According to Dean Still of Aprovecho it is not surprising that a plancha stove (such as the Rockt Box) would not perform well in W.B. Tests. Although such stoves are is great for making tortillas, the hot gases are flowing horizontally through the rings and under the plancha, meaning heat transfer is only fair.

The stove's performance when used to cook beans, rice, and vegetables was good.

6.1.2 Stove Models tested

As well as the standard Rocket Box, these tests were carried out on:

- A Rocket Box modified so that the combustion chamber was 5cm longer
- A metal plancha stove of the design commonly available in Guatemalan hardware stores. The plancha is the same size as the Rocket Box. The stove is empty on the inside, apart from a ½" lining of bricks along the stove wall; this whole space constitutes the combustion chamber

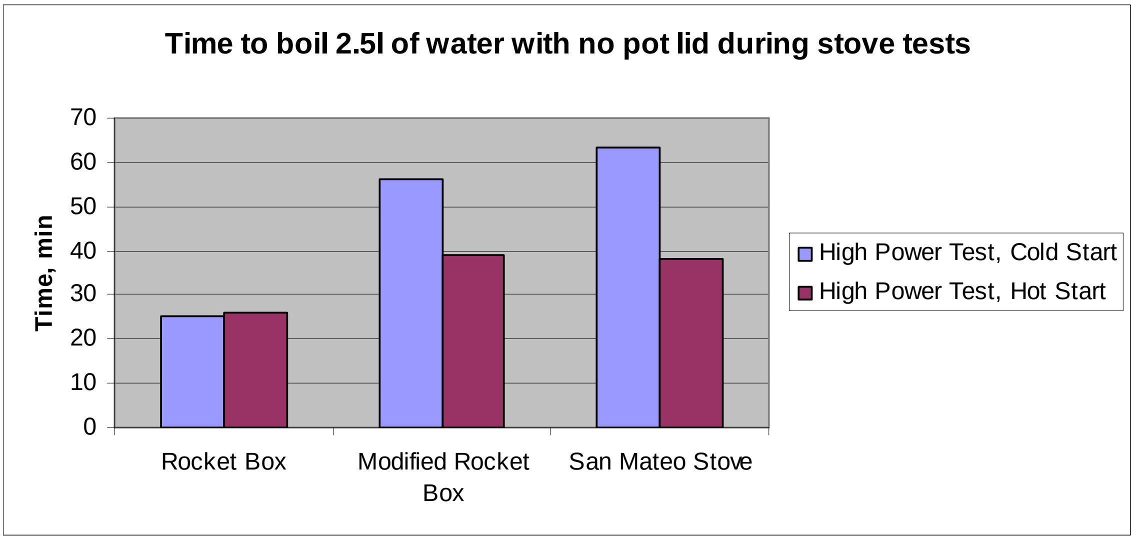
A Rocket Box with a longer combustion chamber was tested in response to customer feedback (see Section 7.) However it was not possible to make each side wall from a single baldosa tile due to the sizes in available supply. The use of two baldosas in construction of each side wall, and the lack of uniformity in firebox width may have negatively affected results.

The third plancha stove, bought from *Taller San Mateo* near La Esperanza, Quetzaltenango, was tested so that the Rocket Box's performance could be evaluated comparatively. On the graphs this is referred to as the 'San Mateo' stove.

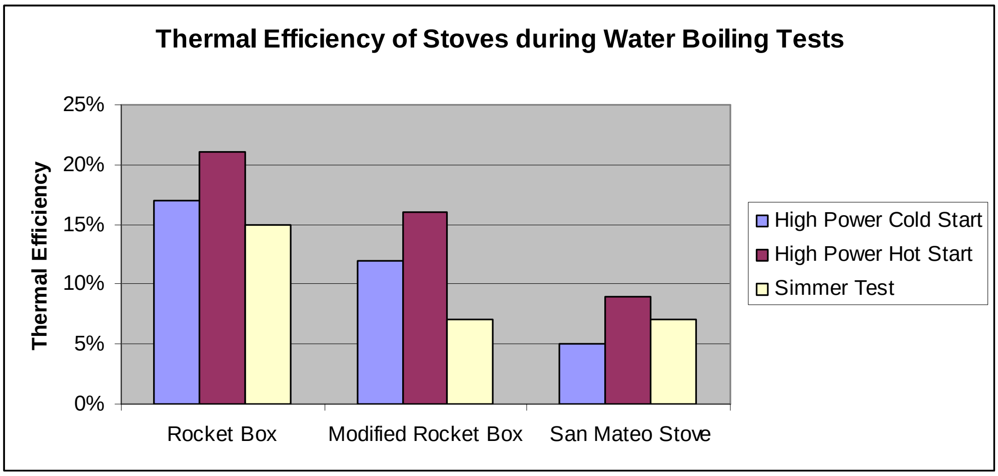
6.1.3 Summary of Results

In all three tests, the Rocket Box thermal efficiency is shown to be higher. It uses less wood and takes less time to boil water. Modifying the Rocket Box to have a longer combustion chamber generates efficiency losses. For the Hot Start High Power test the difference in performance is less significant, but for the Cold Start test the Modified Rocket Box used considerable more fuel and took over twice as long to boil. Thermal efficiency during the Low Power (Simmer) Test was dramatically reduced.

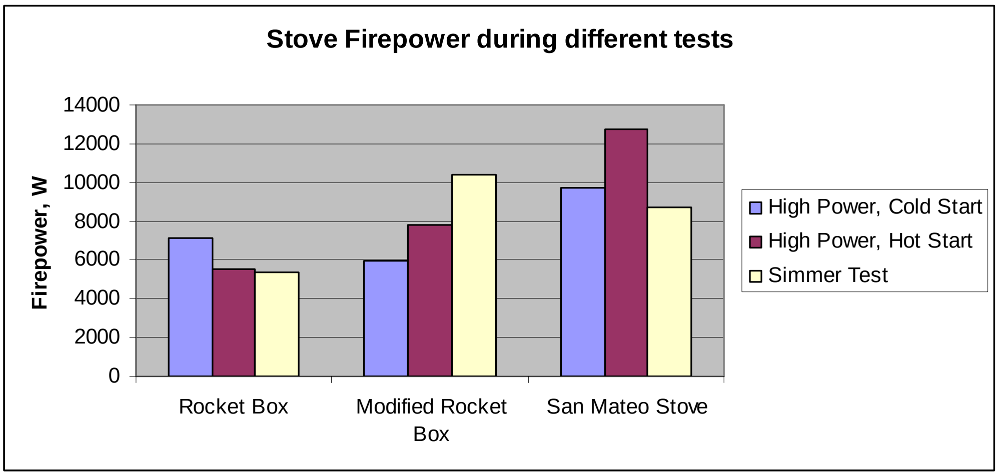
The comparison plancha stove uses far more wood and takes longer to boil water than both Rocket Box models. However both the longer-firebox-Rocket Box and the comparison stove scored 7% for thermal efficiency during the Simmer Test. The graphs below show average results from 3 Water Boiling Tests.



Note: Time recorded is the time to boil pot# 1 on the principal cook ring at the front of the stove.



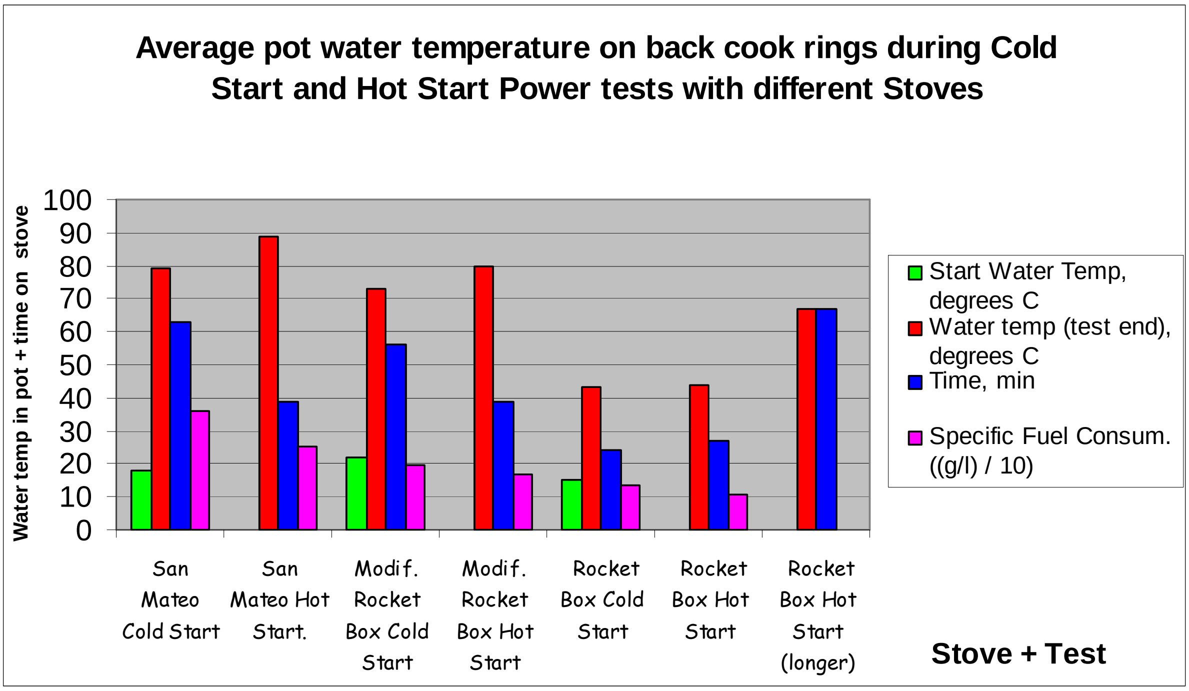
Note: For the High Power Tests, thermal efficiency takes account of temperature of pot# 1 (2500l, front of stove) and pots # 2 and #3 (2000l each, back of the stove.) For the Simmer Tests, thermal efficiency only takes account of Pot # 1.



Full results for the Water Boiling Tests are given in Appendix E.

6.1.4 Boiling Water on the Back Cook Rings

It should be noted that these tests do not fully represent the stoves' back-cook ring boiling performance. The back cook rings on the Rocket Box take a long time to reach a high temperature. Back cook-ring heating improved with a longer combustion chamber Rocket Box. The San Mateo, after initial delays in heating up from cold, is much more effective for cooking on the back cook rings.



Notes: 1. Pots on the back cook rings had 2000l of water ('pots #2 and #3')

2. The results represent average results for three water boiling tests for each stove (one for the San Mateo Stove.)

3. The time allowed for pots #2 and #3 to heat on the back cook ring is the time pot # 1 takes to boil on the front cook ring (the duration of the High Power Tests).

4. Water temperature on the back cook rings was not usually recorded during Simmer Tests as this is not required by the WBT format. However the pots were left on the stove after the Hot Start Test for the Rocket Box giving the last result on the graph.

6.2 Combustion Chamber Design ("firebox")

6.2.1 Materials and their Arrangement

This combustion chamber design is almost identical to that used in the ONIL stove manufactured by HELPS International. It made from stock baldosa fire bricks or floor tiles, with no mortar or other sealants between the joints, allowing the tiles to expand and contract with temperature changes without putting stress on the joints and tiles.

The back wall bricks are notched so that they prevent the side walls from falling inward (photo 6.2.1.a). They are also thicker than the other bricks to prevent damage from wood being pushed in too hard.

6.2.1a Firebox: notched back brick wall

6.2.2 Sizing the Combustion Chamber

There is a relation between the area of the mouth of the combustion chamber and the air space below the plancha (width ways.) This should apply to the air space for the whole stove. Rocket Stove design, as developed by Aprovecho, recommends a constant cross-sectional area throughout the places where air and combustion gases flow.

This is based on the desire to maintain a constant velocity throughout the gas flow in the stove. As changes in velocity in a fluid flow cause energy losses, it is thought that energy can be more efficiently transferred to the cooking surface in the form of heat if the velocity is constant. It is also thought that a more efficient flow of exhaust gas will promote more efficient fuel combustion[2].

The area of the mouth of the combustion chamber is 168cm^2 therefore the space below the plancha, as looked at from the front of the stove, should be the same. With a 48cm wide plancha, a 3.5cm space should be maintained. Heat is strongest at the point of the flame. This means the tower should be high enough for the flame to be almost not touching the plancha.

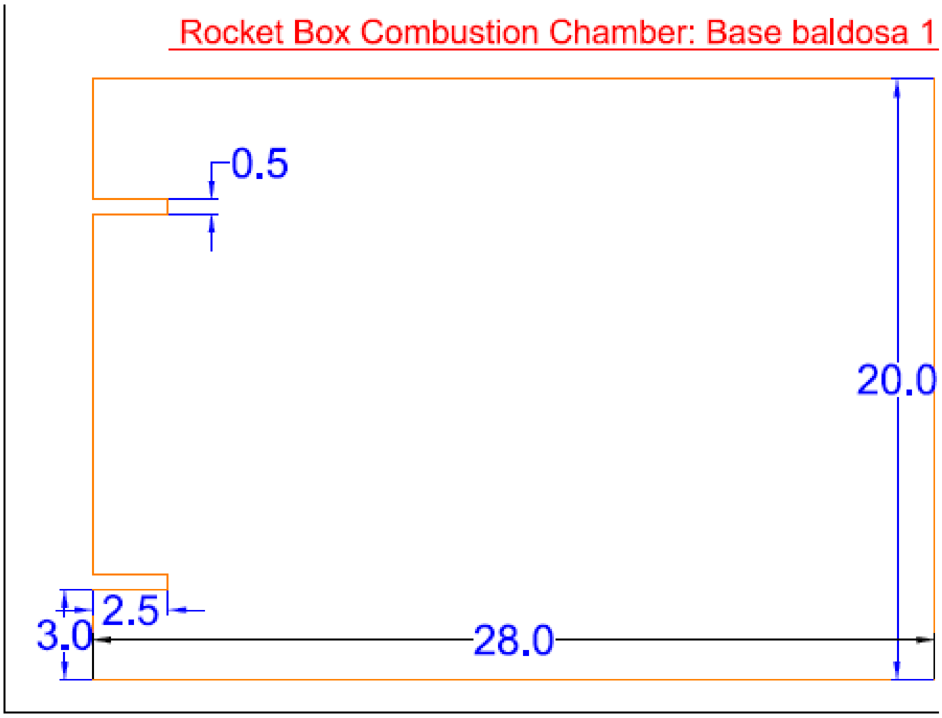
The height of the chamber tower should be 2 or 3 times that of the height of the entry to the chamber. The combustion chamber mouth is 14cm high by 12cm wide. Therefore it's important to ensure that the height of the chamber tower is between 28cm and 42cm. A 1: 2½ ratio seems to work best. This is to help ensure a good draft and efficient burning, and is based on recommendations found in the document "*Design Principles for Wood Burning Cook-stoves*" from the Aprovecho Research Center. The tower of the existing Xelateco Rocket Box is 28.5cm high; therefore investigation with a slightly higher combustion chamber (and stove body) would be worthwhile.

The ratio between the stove and the combustion chamber can change, but always ensure the square relation between the air space and the stove mouth. The combustion chamber of the existing Rocket Box Stove is 24.5cm long. At the time of writing efficiency tests are being carried out with a prototype 30cm long chamber, in the hope of making it more convenient for users to keep the fire going.

6.2.3 Dimensions

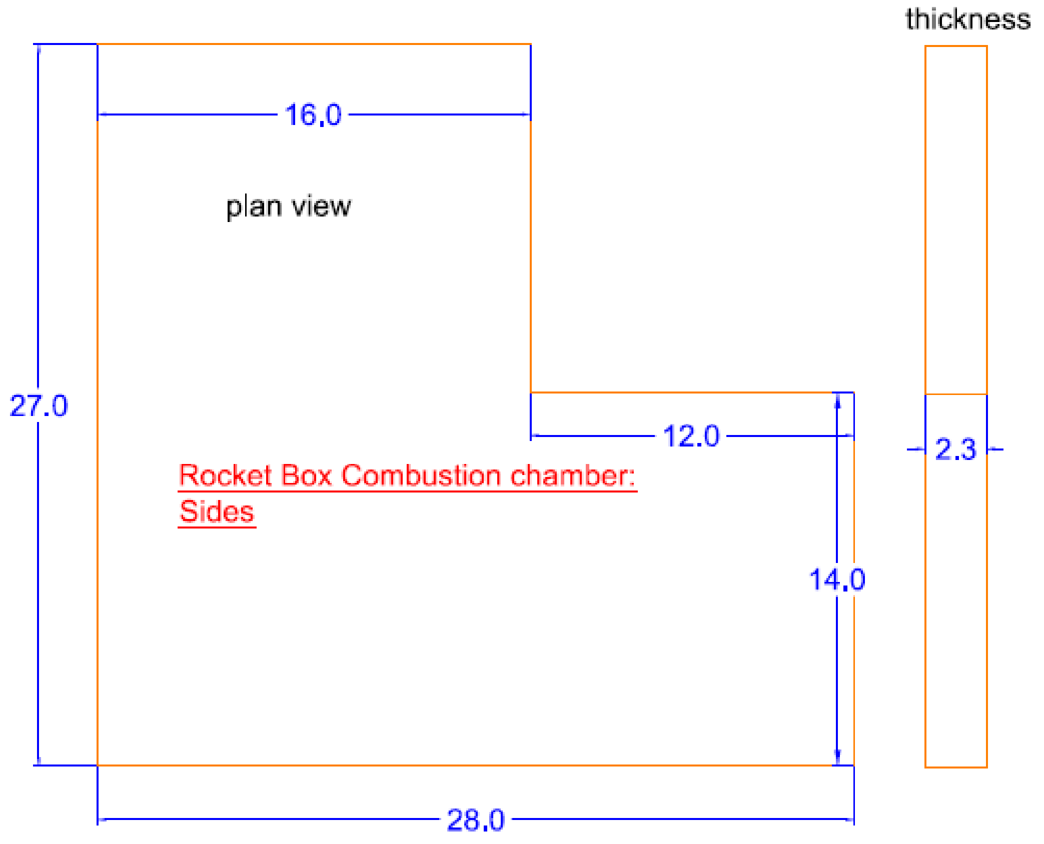
The length, height, and width of the combustion chamber are determined by the size of the commonly available baldosa bricks.

[2] This is based on the principal of the conservation of mass. Applied to a fluid flow, this principle dictates that in a continuous stream in an enclosed space flow rate is constant. Flow rate = fluid velocity x cross-sectional area. Therefore it is necessary to maintain constant cross-sectional area in order to maintain a constant velocity.



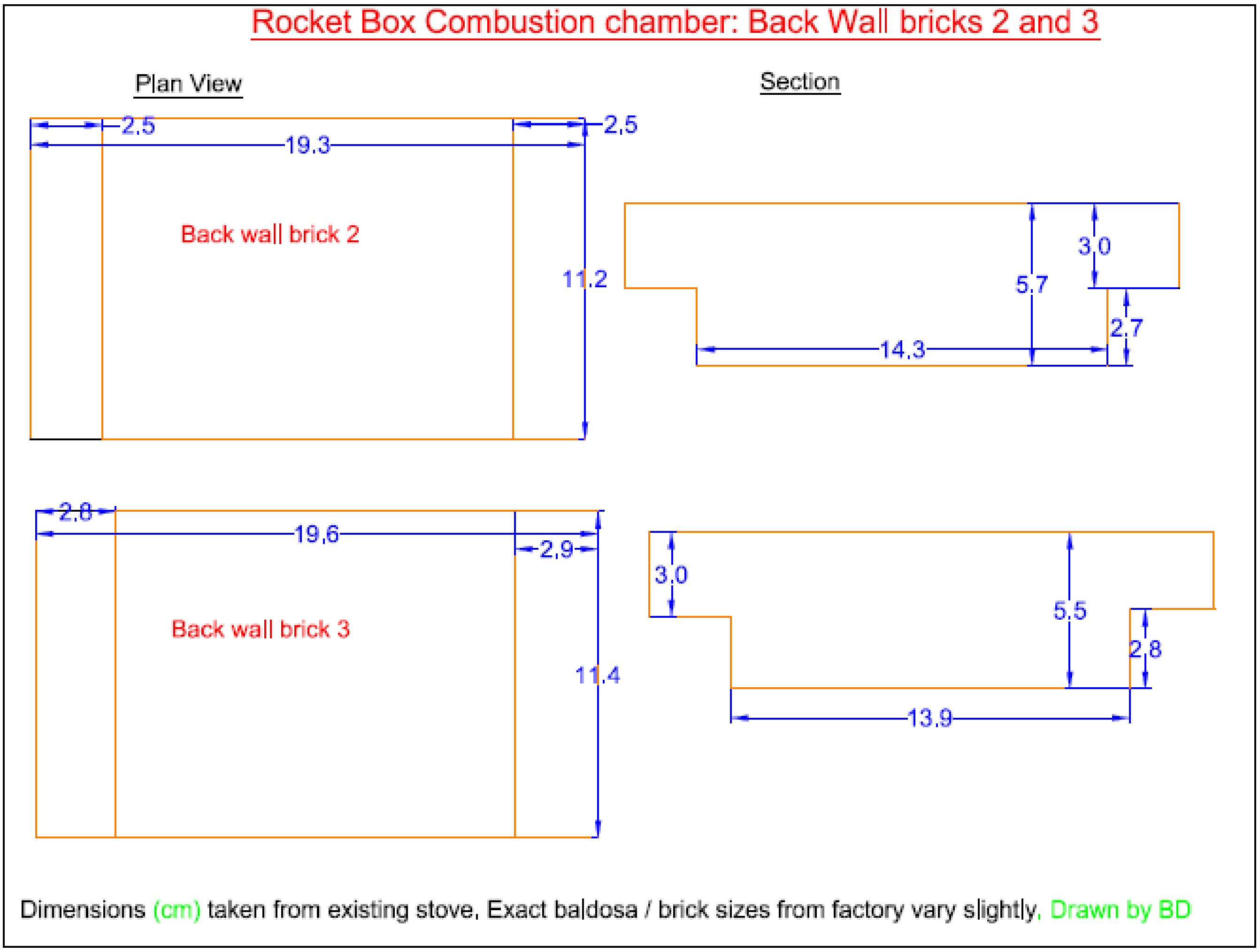
The base is made from is cut from 1" x 20cm x 28cm baldosa tile ('*Base baldosa* 1'). The front side is notched to slot into the angle iron. The side walls sit on top of this.

The side walls are cut from 1" x 27cm x 28cm baldosa. They are identical.

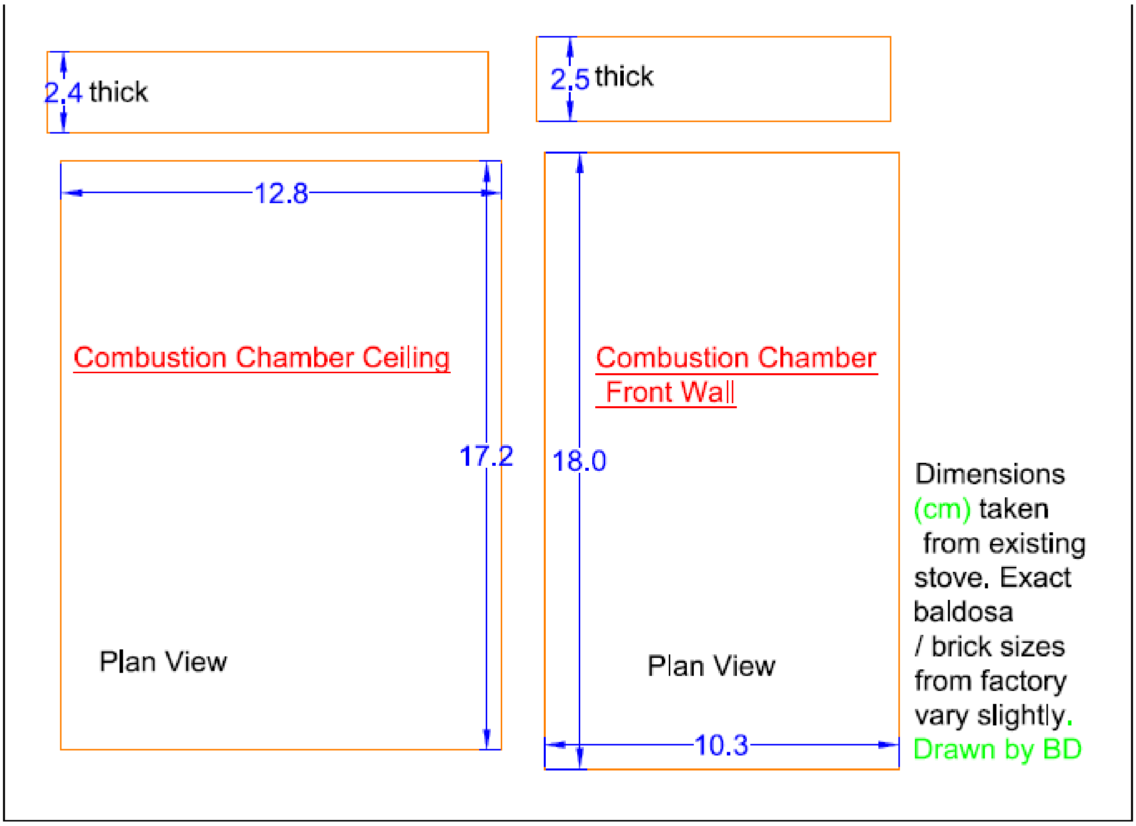


Dimensions (cm) taken from existing stove. Exact baldosa / brick sizes from factory vary slightly. Drawn by BD

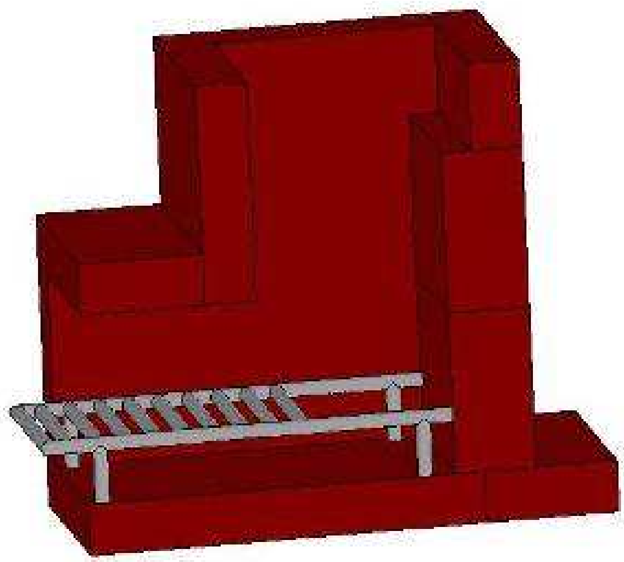
The back wall bricks are notched. These bricks are cut from 2” x 19cm x 19cm baldosa. A third 3cm high brick sits on top of bricks 2 and 3. Cutting a forward slope into the section of the back wall may help the heat to disperse to the back cook rings.



The ceiling sits on top of the horizontal part of the combustion chamber. The front piece lines the chimney. They are cut from 1” x 19cm x 27cm brick.



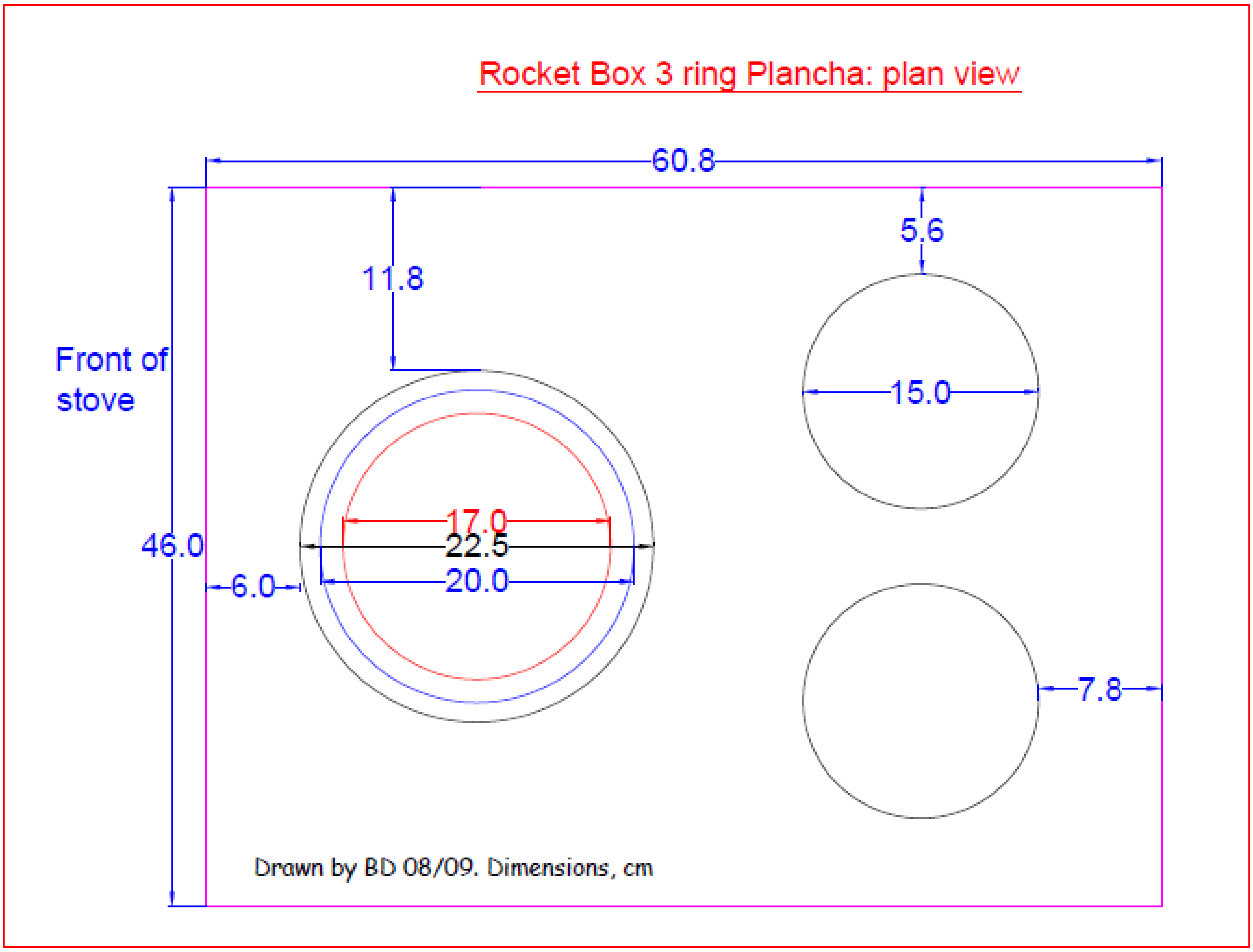
6.2.4 Firewood Support



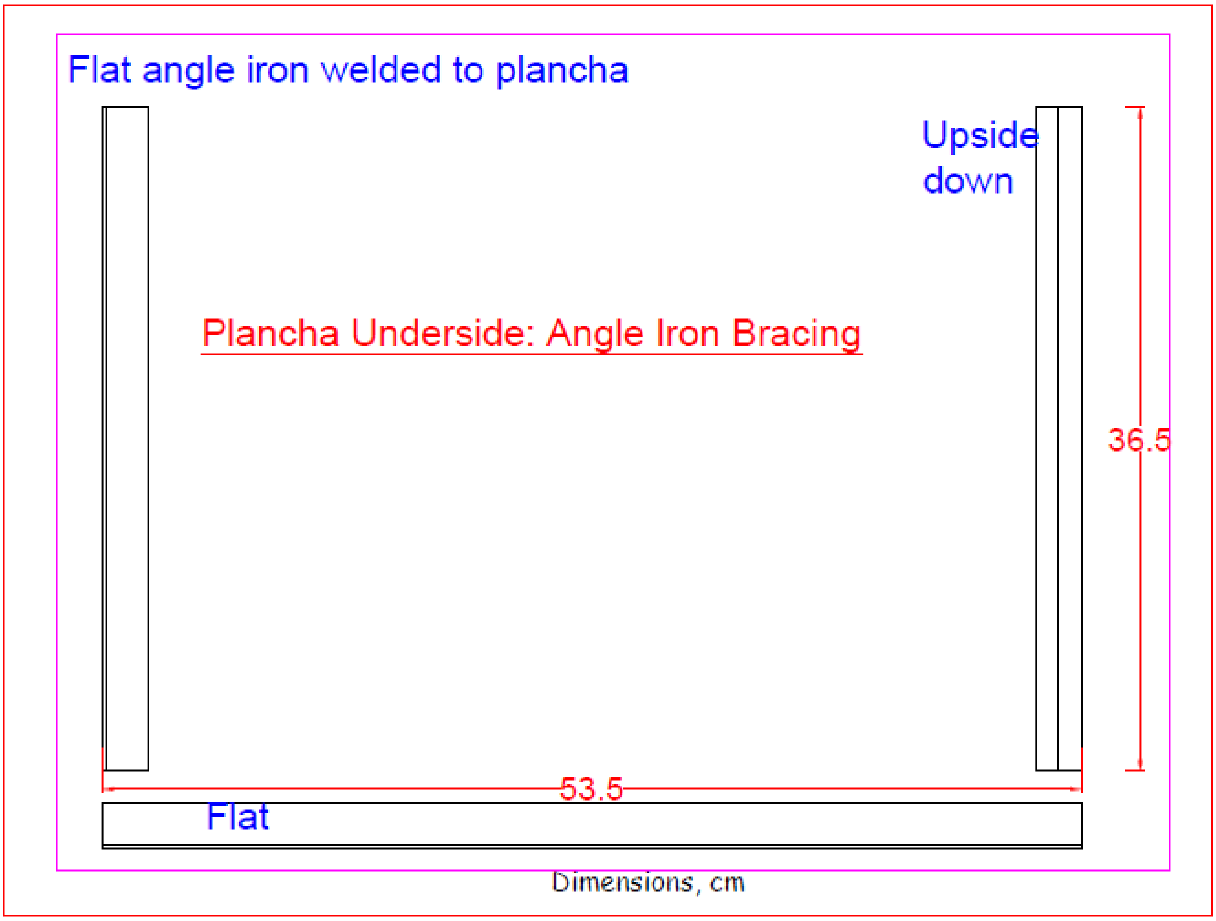
The firewood is held off the floor of the combustion chamber by a grill made by welding 3/8"rebar. The height of the grill is equal to 1/3 of the height of the combustion chamber. This allows sufficient air to pass through to create an effective draft. The innermost part of the grill is open to allow air to flow unobstructed and any hot coals that fall down to continue to feed the fire. In this way air can enter the stove and heat up on the embers before the wood catches fire. Hot air can light the stove with more force. A high temperature flame will completely burn the fuel, reducing smoke (the signal of incomplete combustion.)

6.3 Design: Plancha

The plancha used in this design is a standard 18" x 24" model that can be found commonly in hardware stores. It sometimes has two pot rings, sometimes three. The plancha is 0.5cm thick and is made of sheet steel. The larger pot ring features three individual rings allowing the right size to be removed for a particular pot. Removing the ring allows hot flue gases to scrape against the bottom of the pot, increasing heat transfer.



The plancha comes welded with angle iron braces on the underside, to prevent warping in the heat.

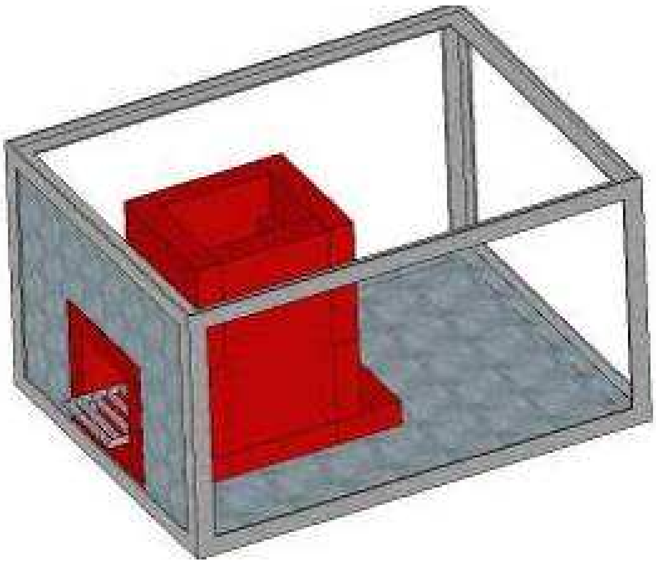


6.3.1 Plancha Sealing

The space between the plancha and the stove body frame is sealed with a thin layer of clay. This provides an extra security for the smoke seal, as well as thermally isolating the body from the heat contained in the plancha.

Kilns, woodstoves, and old furnaces use a twisted high temperature rope as the door seal: information is available at www.pyroglass.com. However AIDG has not been able to locate a material with similar properties in Xela. Potential leads for national supply are given in (8) *Further Study.*

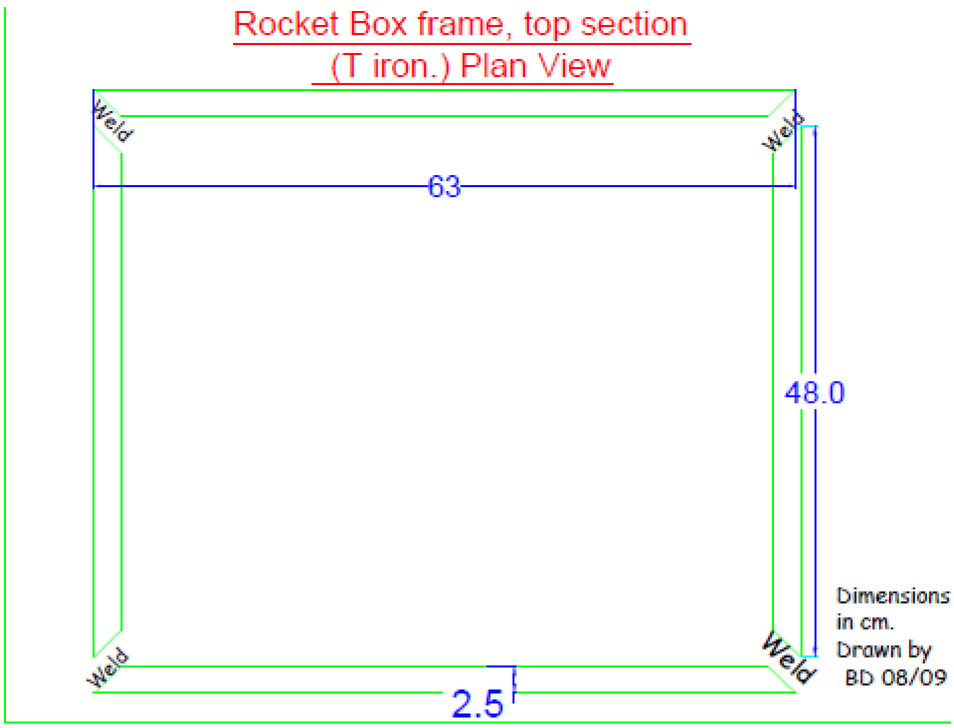
6.4 Stove Body Design



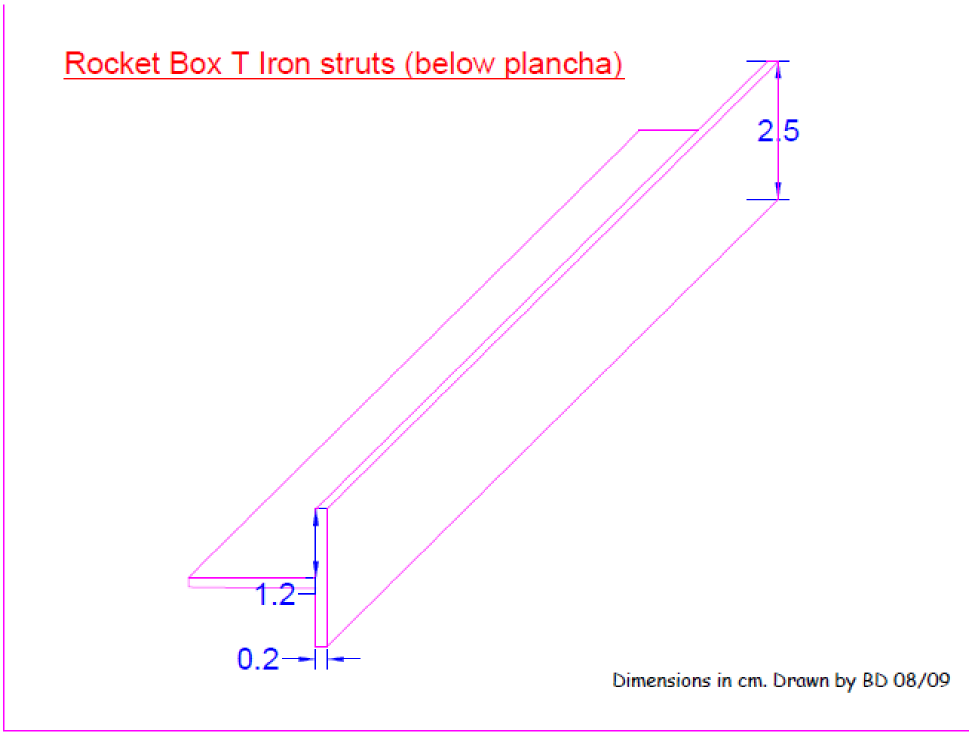
6.4.1 Materials

The box is sheet steel riveted to an angle iron frame. The bulk of the frame is constructed of 1"x 1/8" angle iron, welded together (T iron for the top bracket.) The body is 24 gauge galvanized sheet steel. This is riveted to the frame (4 rivets along the length of the stove; three along the height and width.)

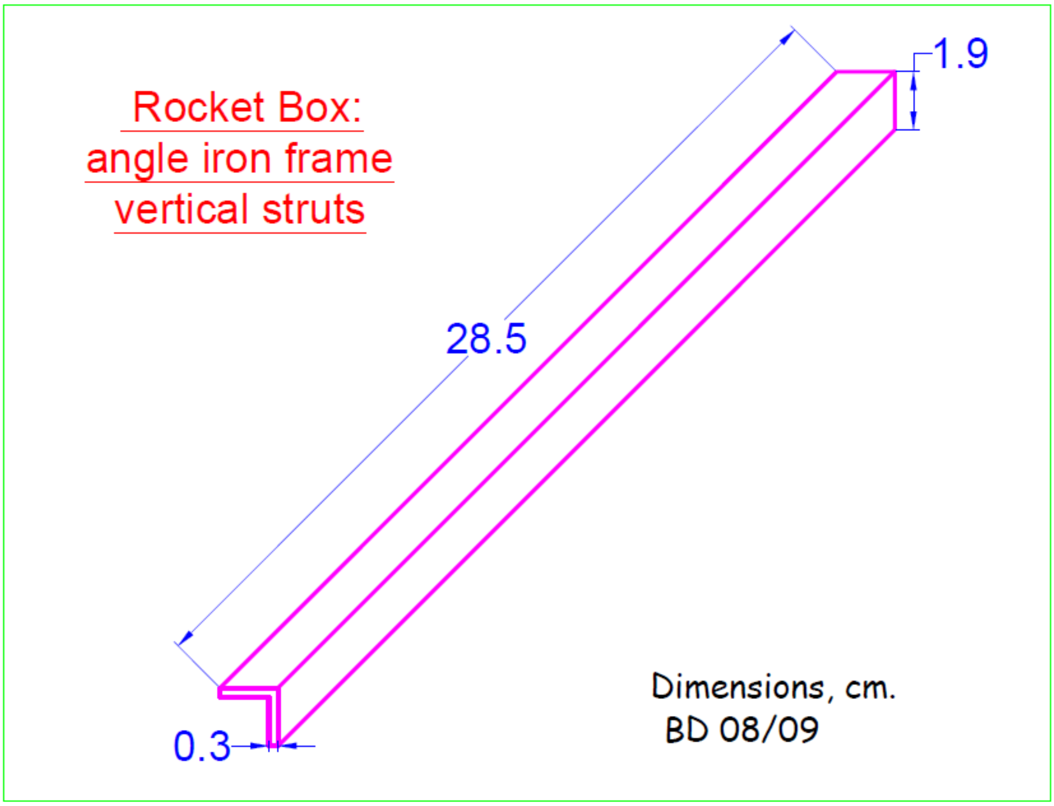
6.4.2 Frame Dimensions



The length and width of the body are determined by the size of the plancha that is being used.

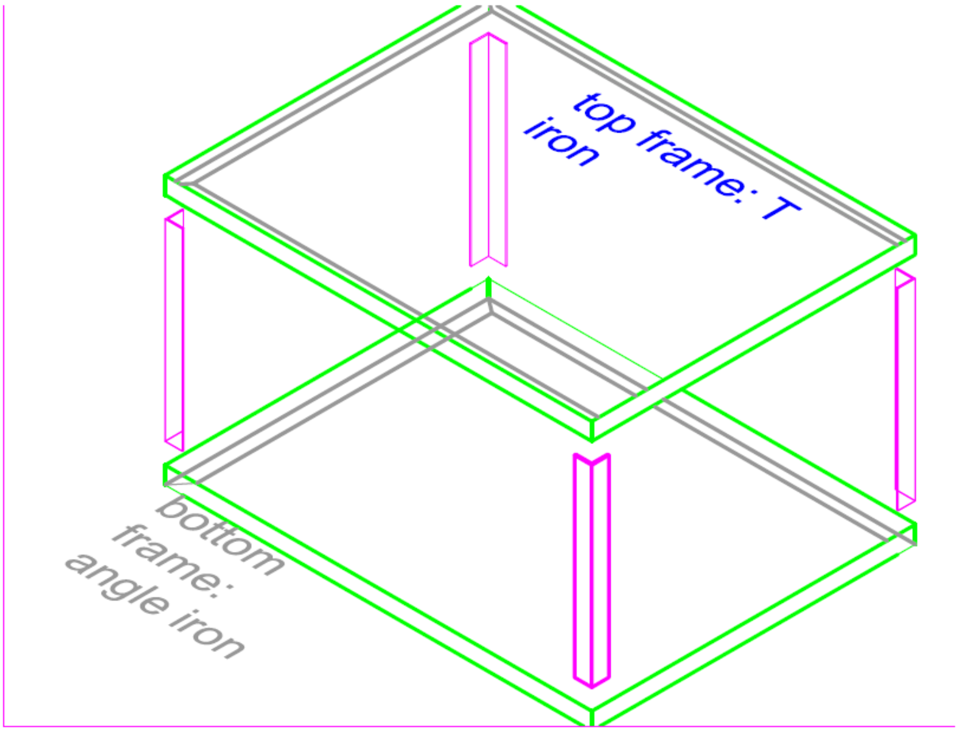


The top bracket, on which the plancha sits, is made of 2.5 cm x 2cm 'T' iron.

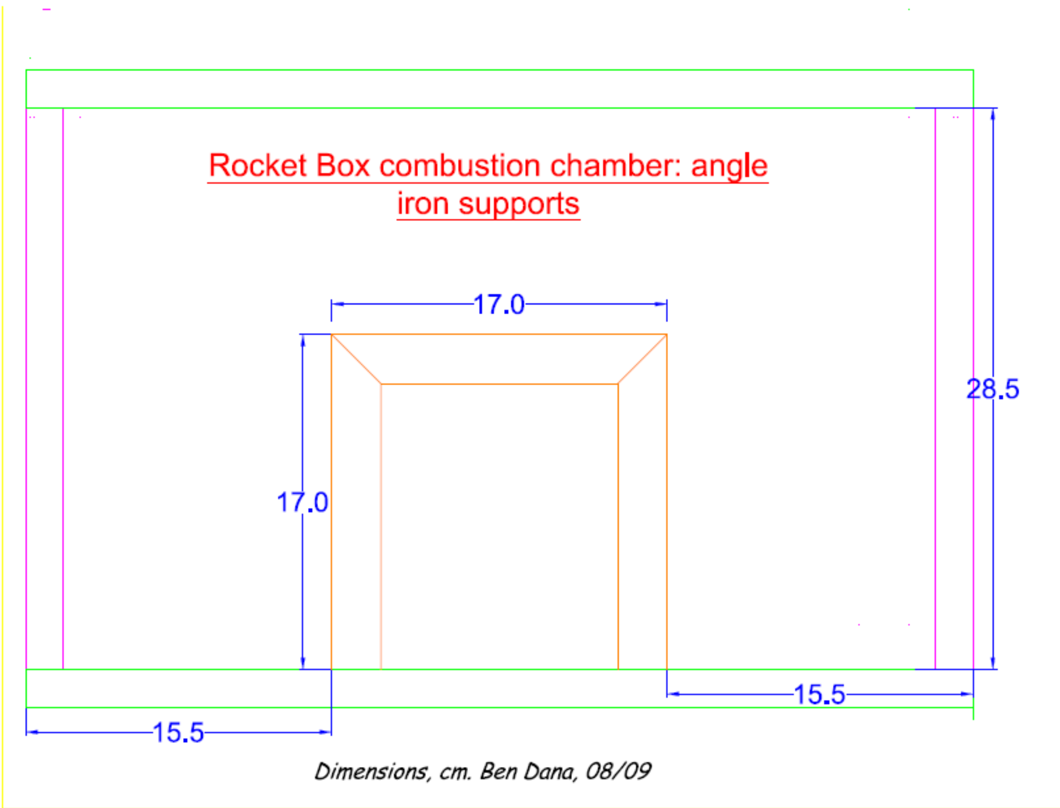


The height of the body is determined by the height of the combustion chamber plus the height needed between the plancha and the insulating material to maintain a constant cross-sectional gas flow area.

Stove Body: Frame 3 D View

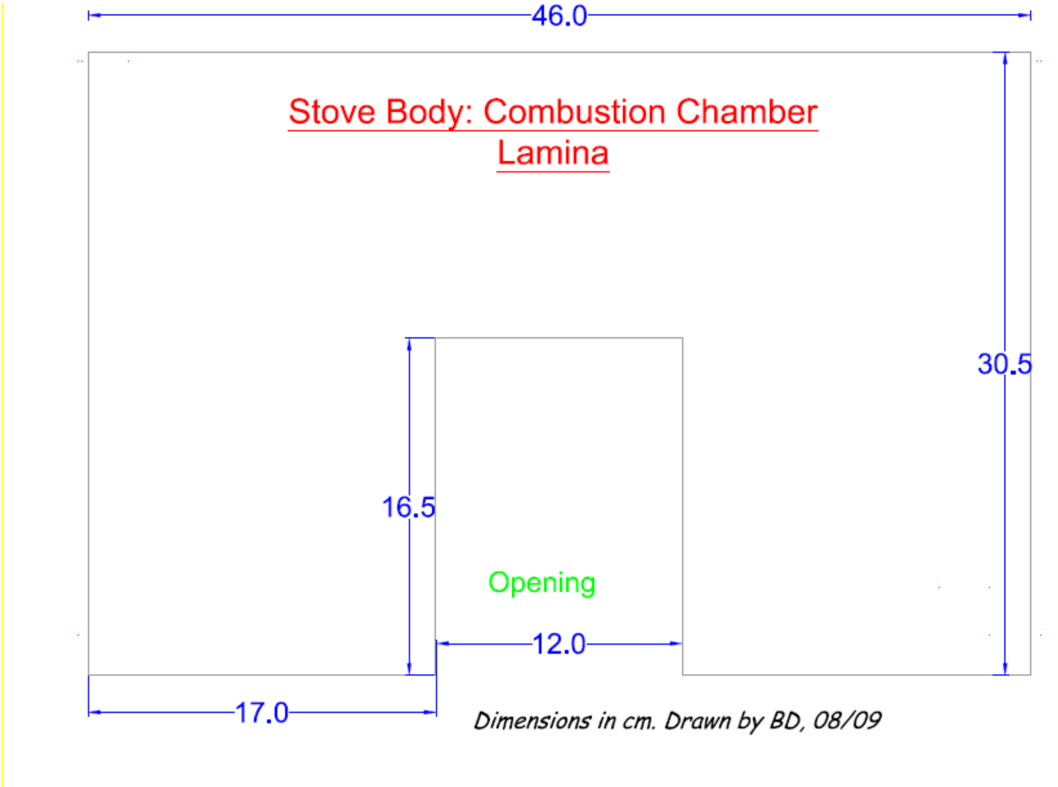


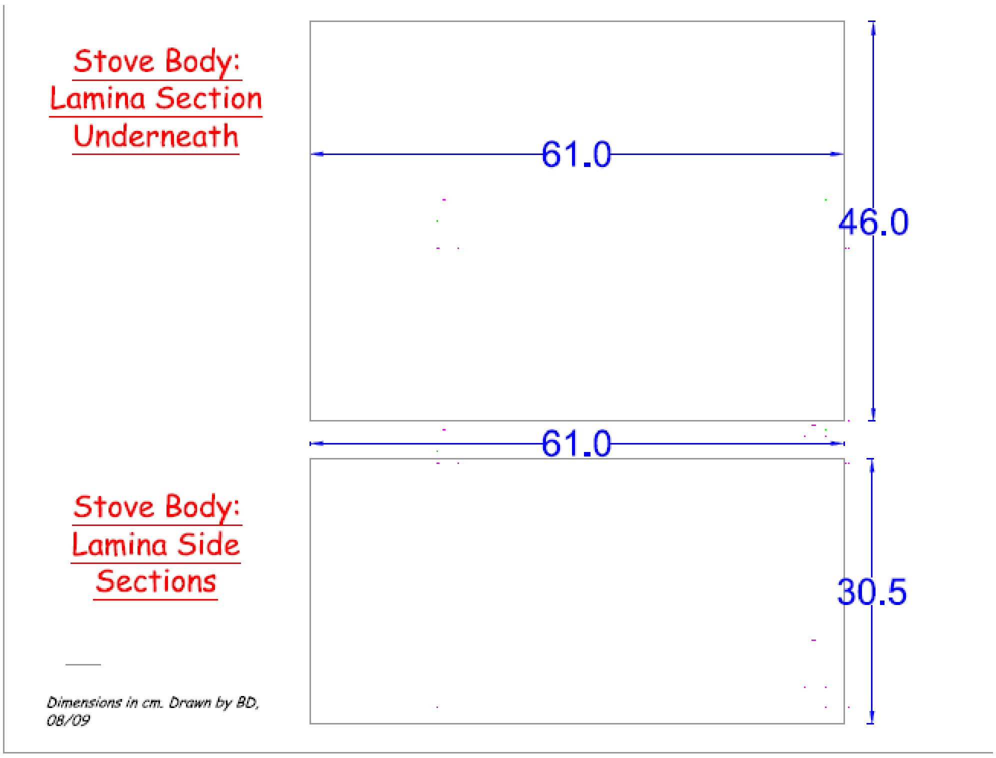
The angle iron that frames the combustion chamber are cut at 45° and welded into the shape shown in *Combustion chamber angle iron frame*. It is sized so that the bricks rest against it. This provides extra support that prevents the bricks from falling inwards.



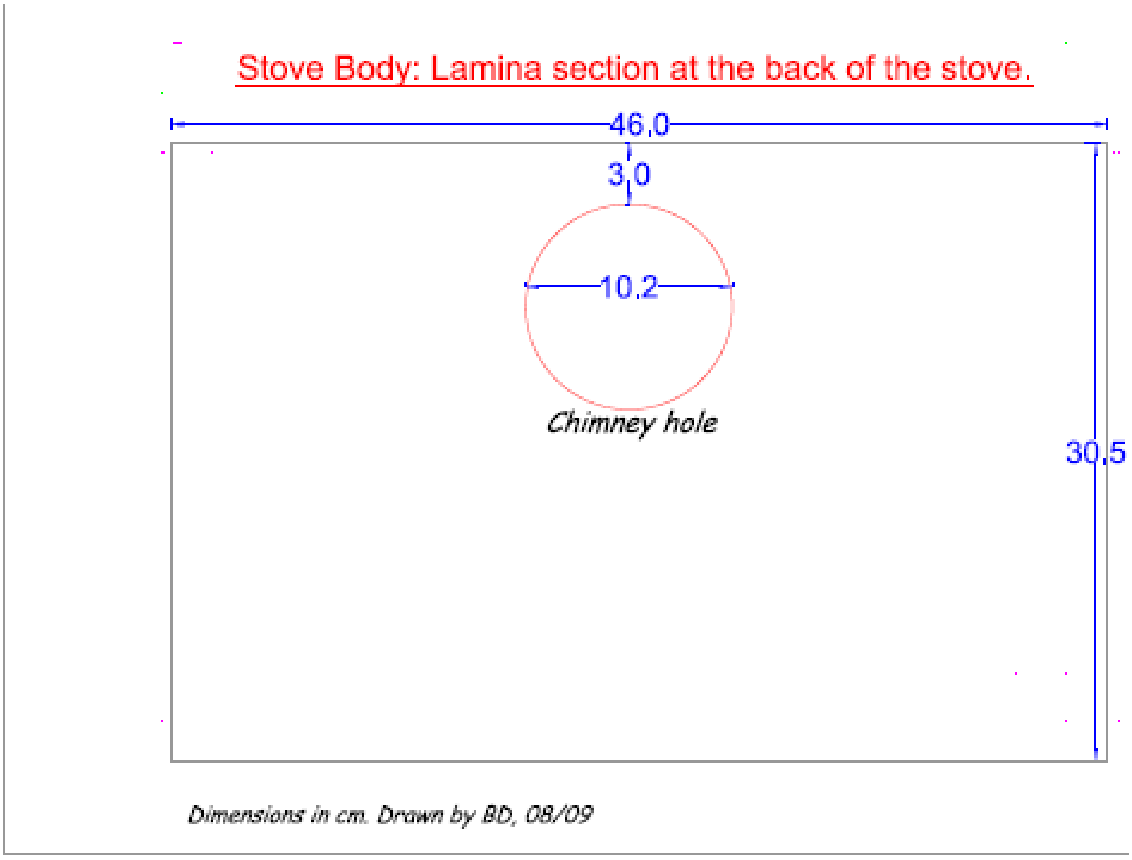
6.4.3 Dimensions: Làminas

The lamina sections are cut to fit snugly inside the angle iron frame. As shown in the drawing *Stove Body Combustion Chamber Lámina*, this section has an opening which aligns with the combustion chamber.



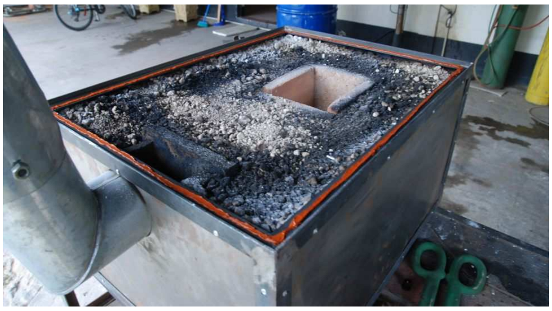


A 10.16cm hole is cut into the section of lámina at the back of the stove for the 4” chimney pipe. The centre of the hole is 8.1cm from the top edge of the lamina.



6.5 Pumice Stone Insulation

Pumice stone is a natural resource in Guatemala and it’s an appropriate material for an improved stove. The pumice stone has a low density and there are air gaps in the stone itself. This air acts as an insulant meaning the heat operates directly on the plancha.



The pumice is sifted; large pieces are placed on the bottom and small pieces on top. This is intended to prevent filtration of smoke and hot gases through the top layer of insulation near the plancha, with more air in between the smaller pieces.

6.6 Chimney Design

The chimney pipes and elbow are also made from lámina - galvinized sheet metal. The lámina section at the back of the stove is left with a hole. This space is fitted with a 4” diameter chimney elbow, which is 17cm long along its outside edge. The elbow is held in place by a lip, hammered flat against the lámina.

Draft is maintained by ensuring space for the chimney on the inside of the lámina. A barrier to the pumice is created with four pieces of baldosa:

Some stove users from the village Nueva Alianza have recommended an elbow which protrudes further from the stove body. This is for extraction to the outside through a hole in the kitchen wall, avoiding the problem of sealing a perforation in the roof; currently this can be a fire hazard if the wall is wooden. Issues of fragility are covered in 7.2.5. Previously Xelateco used 28 gauge lámina for the elbow but new stoves are to be manufactured with 26 gauge.

The stove is supplied with two 92cm x 4” diameter chimney pipes which fit snugly onto the corrugated elbow. It is recommended that both are installed to maximise draft.

7 RB User Feedback from Nueva Alianza

Nueva Alianza is a community of 40 families in Retalhuleu, on the Guatemalan South Coast. Each family has received a Rocket Box Stove in 2009.

AIDG and Xelateco visited the community to investigate opinions on the stove’s performance. The questionnaire used is included in Appendix B. We invited everyone to take part in a Focus Group, in order to discuss the points of investigation. At the beginning of this meeting 20-30 people took part. Of these participants, 14 wrote some answers in their questionnaire, with some giving more information than other. Thirty five families were also visited to hear personal opinions, verify whether the stoves had been modified, and plan chimney improvement work.

7.1 General Results

There were mixed opinions about the Rocket Box. Many people expressed their gratitude for the donation:

- They have noticed that its use has generated considerable fuel savings
- The RB meets their need for cooking tortillas and other kinds of foods
- The stoves heat up well
- People like the mobility of the stove

But there were also criticisms over various issues:

- It was generally felt that the firebox is too small for firewood to fit comfortably.
- It was claimed that the two chimney pipes supplied with the stove were not long enough to take the chimney to the outside.
- Breakage of the chimney elbow coming out of the stove body

The household visits were also a source of important information:

- Almost none of the families had their chimney leaving the house.
- Some families have problems with smoke from the edge of the plancha

- Although the stove heats up properly, it takes longer to get to temperature in comparison with an open fire.
- It appears that the donation project has allowed many families to cook with the RB *as well as* the open fire, rather than replacing one with the other.

Clearly some of the issues raised relate to the stove design. Other problems might have been avoided by managing the donation project differently. The big issue was that the chimneys had not been installed to the outside (AIDG has since resolved this issue.)

7.2 Information Gathered

7.2.1 Current and previous means of cooking.

Most people in the focus group said that they still have their pollo (see 2.2). Four out of five questionnaire respondents said that they cook more with the RB. During the visits in August it was clear that many families still rely on their pollos. This contrasts with the evaluation of other projects by ESMAP, 2004:

(3.84) *Few families continued to use open fires once they acquired a stove. The few who used open fires did so only when they needed to cook large quantities of food that did not fit on the stove. .. Propane stoves, used rarely, were mainly used for preparing food that could be cooked quickly*

7.2.2 Time spent gathering wood each week. Wood savings (10, 13)

During the Focus Group many people said they had to carry wood nearly every day to cook on an open fire. They estimated that this has gone down to twice a week since the donation of the RB.

7.2.3 Cooking with the Rocket Box

7.2.3.1 Heating the front and back cooking rings (23-24)

Seven out of eight respondents replied that the front cooking ring heats up well. But during the meeting some said that: "The small one [the ring at the back] is not for boiling..it's just for keeping the pot warm...The big one is better suited to boiling." If this is generally the case cooking for a large family may be difficult.

7.2.3.2 Size of the combustion chamber (36)

Six out of eight questionnaire respondents recommended making the combustion chamber bigger.

7.2.4 Quality Control

7.2.4.1 Chimney Elbow

Ten families reported that the joint in the chimney elbow which is attached to the stove broke. This was possibly due to rough handling when the delivery was unloaded, or carried to the houses.

7.2.4.2 Modifications made by Users

At least eight of the thirty seven families visited in August had modified their stove. The changes included placing the plancha the wrong way around; removing the combustion chamber tiles and re-building it to make it bigger; and removing the pumice stone insulation.

7.3 Recommended areas for investigation

7.3.1 Rocket Box Design

The results of the Nueva Alianza stove project points to the need to investigate various changes to the present stove design:

- Increasing combustion chamber length to ensure lengths of firewood fits inside it, without reducing combustion chamber efficiency (or adding a lip at the entrance for the wood to sit on.)
- Investigate the temperature of the stove body during firing. Improve the mechanism for preventing over-heating if necessary. The pumice is generally effective, although from the top of the stove to 10-20cm below the plancha becomes very hot. If investigation shows that this is really a problem it may be worth considering a precast concrete body like the ONIL stove.
- Identify supply of stronger chimney elbows to replace breakage rates, or reinforce with welding in the workshop. The new stoves are to be manufactured by Xelateco with 26 gauge lámina elbows. Some users recommended protrusion further from the stove body. for extraction to the outside through a hole in the kitchen wall.
- Add metal surfaces next to the plancha to rest pots on [or offer an alternative model with a bigger plancha.)
- Investigate how to improve back cooking-ring temperature (this may involve a longer combustion chamber.)
- Improvements to plancha sealing

7.3.2 Management of Stove Donation Projects

General observations on the planning and management of stove donation projects are given in Appendix D.

8 Further Study

Several design aspects worthy of research are outlined in 7.3.1.

8.1 Combustion Chamber Height

The height of the chamber tower should be 2 or 3 times that of the height of the entry to the chamber. The combustion chamber mouth is 14cm high by 12cm wide. Therefore the height of the chamber tower should be between 28cm and 42cm to help ensure a good draft and efficient burning. The tower of the existing Xelateco Rocket Box is 28.5cm high. Therefore investigation of a 33cm high combustion chamber would be worthwhile. This would require the stove body height to be increased to around 36.5cm.

8.2 Soot channel

The Doña Justa stove (5.3.5) contains a channel under the chimney to catch the soot, enabling easy cleaning. Incorporating this feature to the RB is worth investigation

8.3 Plancha Sealing

AIDG has not been able to source local supply of specialized products for making an airtight seal between the plancha and stove body that would both contain the smoke and keep the body from heating up. However, the owner of Central Minera hardware, Xela, has contacts with industrial kiln manufacturers in Guate. He might lead to sources of supply elsewhere in Guatemala. High temperature rope is mentioned in 6.3.1. Clay and panela mix could be tested as a traditional alternative to the current clay sealing.

8.4 Position of the Pot rings ('hornillas')

A 3 ring plancha has a 9.5cm gap between the large 'hornilla' above the combustion chamber and the rings at the back of the stove. Using a different plancha with the back rings further towards the front ring may enable them to boil more effectively. However many stove users in Guatemala cook nixtamal in big pots, preventing a second pot from fitting onto an 'hornilla' in this position. The solution may be to offer a choice of RB models: with the existing hornilla positions or a different plancha.

8.5 Pot Skirts

The pot rings on the plancha surround the sides of a pot for around 5mm. It may not be practical to develop the plancha to have pot skirts if these would only fit a predetermined pot size. However, in order to improve heat transfer, it may be possible to investigate removable pot skirts that could be attached to the plancha and removed as needed (4.1).

8.6 Chimney Temperature

The chimney gets very hot close to the stove body, presenting risk of burns. This is also an issue for other stoves. A protective mesh supplied with the stove should be investigated together with other ways of reducing the risk.

8.7 Stove Financing

A market research survey in eastern Guatemala led to this observation:

We also received many inquiries about the possibility of buying the stove under a financing plan. The majority of the people who expressed serious interest (i.e. wanted to commit to buying a stove) also asked about payments. The non-existence of a financing plan was a major obstacle to them

*(*AIDG Internal Research Report: **Stove Trip Report East Guate**.*)*

Conclusion

The Rocket Box is the result of extensive R & D into efficient stoves at AIDG. It's successfully serves the cooking needs for Guatemalan families, reduces fire wood and addresses the health problems of smoke in the house. However further technical development is recommended, especially to improve heating on the back cook rings and make it easier to keep the stove lit in a small fire-box.

Rosalinda and Josefina from aldea La Florida

Appendix (A) Efficiency Tests: Rocket Stove and Mynor Stove

This test report is taken from the *(*AIDG Internal Research Report: **AIDG Standardized Bean Test***.)* The "Mynor" Stove is the name given to the Masonry/ plancha stove promoted by Pop Wuj.No information is given on the date of the test or who carried it out. Neither is it clear that the Rocket Stove tested was exactly the same as the Rocket Box presented in this document, rather than a different kind of Rocket Stove. Note that this test is considerably different to the Shell Foundation Water Boiling Tests presented in 6.1, notably in the use of a pressure cooker with a lid.

AIDG Standardized Bean Test

Equipment:

1. 500g black beans
2. 3 liters of Water (per bean test)
3. Pressure Cooker
4. Scale to measure wood (range 40kg)
5. Firewood
6. Kettle
7. 1 liter of water (per power test)
8. Stoves

Overview:

The AIDG stove bean test is designed to compare the relative efficiencies of stoves, rather than give an absolute value of stove efficiency. This test is designed to compare how much firewood a stove uses to cook a standard pot of beans. The baseline comparison involves an open fire.

In the test, a pot of beans is brought to pressure and boiled for 45 minutes. All wood that remains in the stove upon the completion of the test remains in the stove and is not removed as unused fuel. This mimics a real world situation in which energy into the stove cannot be removed. The same wood, pot and beans should be used in each test so that values correspond between stoves.

Additionally, upon the completion of the bean test, a standard volume of water will be brought to a roaring boiled., The time required to bring each kettle to boil is noted. This data allows us to compare the power output of each stove.

A substantial amount of time was spent before the initiation of this test to become familiar with the common use of wood fired stoves. The stoves were used multiple times before these tests were conducted in order to assure that our during the tests use mimicked a real world application.

Procedure:

- Cut firewood to relative size needed for stove.
- Weigh initial volume of wood ($Wood_1$)
- Light fire in cold stove
- Place pot of beans on stove
- Bring pot to boil
- When pot begins to 'hiss' and escape valve begins to rotate, note time
- Maintain boil for 45 minutes
- When 45 minutes passes, weigh final volume of unused wood ($Wood_2$)
- Δ Wood = $Wood_1$ $Wood_2$
- Once stove is warm, place 1 liter of tap water (room temperature) in tea kettle and measure, time until roaring boil

Efficiency Test Data:

Stove	Wood$_1$ (kilograms)	Wood$_2$ (kilograms)	Δ Wood (kilograms)	ε efficiency (relative to Open Fire)
Open Fire	10	5.5	4.5	1
Mynor	11.5	3	8.5	0.53
Rocket	3.2	0.2	3	1.5

Notes
from Mynor test 1:
Loaded the stove with wood, once it was warm it was never reloaded. Upon the completion of the test a substantial amount of wood remained in the stove, still burning. not enough liquid remained in the beans.
from Mynor test 2:
Stove was loaded with an adequate amount of wood to boil beans. This volume was determined based on previous test. Once the stove was loaded it was reloaded only once.
from Rocket test 1:
Wood to wet to burn in Rocket stove. Wood dried over weekend in sun. Cut into small pieces
from Rocket test 2:
Test ran smoothly.
from Open Fire test:
A fire was arranged between 3 cinderblocks on the roof of the AIDG house. Substantial amounts of smoke, until the fire was just burning coals.

Stove Power Data

Stove	Time to Boil (minutes)
Open Fire	9
Mynor Stove	11
Rocket Stove	11

Conclusions:
A substantial amount of energy is required to bring both the built stoves (Mynor and Rocket) to a working temperature. Each stove is heavy, and there are large volumes of thermal mass which effectively 'rob' heat from the pot. Thus in the standardized bean test the Mynor stove is not as efficient as an open fire, which has relatively little thermal mass (3 cinder blocks) to heat. Presumably once each system is brought to a working temperature, the Mynor would probably be as efficient if not more so than an open fire. Additionally, the efficiency of the Rocket stove relative to the open fire would improve. A day long cooking test in which similar meals were prepared over all the stoves would provide additional insight into stove efficiency. However it is important to note that open fires are not used to fulfill the same needs as traditional plancha stoves. Often a traditional plancha can be used as the same time that food is being cooked to make tortillas, or boil secondary food items/keep things warm.

The comparison between the Mynor and Rocket stove is particularly interesting. The Rocket stove was roughly 65% more efficient than the Mynor stove. The two stoves were equally powerful, requiring the same amount of time to boil 1 liter of water.

This is an important selling point as the rocket stove is often perceived as being less powerful because of the smaller fuel chamber. It is also important to note, that we were completely incapable of cooking on the rocket stove with damp wood. On the contrary, the Mynor, (and open fire) can convert damp wood into thermal energy. Thus in an area where wood is especially damp, the Rocket stove is not appropriate.

Appendix B: Questionnaire (in Spanish)

INSTRUCCIONES:

Lea cada una de las preguntas siguientes y subraye cualquiera de los incisos y conteste las preguntas que no tienen incisos.

1. Que opina del nombre de este estufa: "Rocket Box"?

*Puedes pensar de un nombre mejor?*____
____

2. Cuanto tiempo ha tenido su estufa Rocket Box?

3. Que opina de la presentación de La Estufa Rocket Box?

a) Preciosa b) Algo bonita c)Da Igual d) No es muy bonita e) Muy fea

PORQUE:
____
____

4. Tienen otro sistema para cocinar?

a) Fuego abierto b) estufa de gas c) Otros

*PORQUE*____
____

5 ¿Suele de cocinar mós con su estufa Rocket Box o de otra manera? Porque?

6. Como cocinaba antes de tener una estufa Rocket Box?

7. Como sabe mejor la comida?

a) Cocinando con gas   b) Cocinando con leña

8. Tiene que comprar leña o se van a recoger leña?

9 Si compra, cuanto cuesta el manojo/ tercio/ tarea de leña?

10 Si recoge cada cuanto se hace, y cuanto tiempo le lleva?

11 Cuales aspectos le gusta mas?

- *Tamaño de la plancha*
- *Facilidad de tortear*
- *La reduccion de consumo de leña.*
- *Que no se queme al tocar el cuerpo*
- *Eliminación de humo de la cocina.*
- *Precio*
- *Movilidad*

12 Cuales aspectos no le gusta?

- *Tamaño de la plancha*
- *Facilidad de tortear*
- *Tamaño de la camera de combustion*
- *Quemarse/ no quemarse al al tocar el cuerpo*
- *Eliminación de humo de la cocina.*
- *Precio*
- *Consumo de leña.*

Funciona Bien?

13. Cuanta cantidades de leña (manojos/ tercios/ tareas) tiene que comprar al mes para cocinar con la Estufa Mejorada?

14 Por cuantos personas cocina en cada comida?

15 Ha observado disminución de su gasto de dinero con el uso de la Estufa Mejorado?

Si *Que cantidad ha ahorrado?*

No

16 Su Rocket Box esta en el mismo estado que el día de la entrega?

a) SI *b) NO*

*PORQUE:*____
____

17. Han decidido hacer alguna modificación? Como lo han modificado y porque?

18. Sale humo de alguna parte de la estufa?

19. Ha notado si gasta menos leña con la estufa mejorada a comparación de antes?

a) SI *b) NO*

PORQUE____

____

20 La chimenea sirve para sacar el humo de su casa?

a) Muy De Acuerdo b) De Acuerdo c) Da Igual d) De Contra e) Muy De Contra?

Le Sirve?

21 Ha tenido que modificar su forma de cocinar para aprovechar de la Estufa Rocket Box? Como?

22. Cuanto tiempo tiene que esperar para que la estufa Rocket Box se caliente?

a) Menos de 5 minutos b) 5-10 minutos c) 10-15 minutos d) 15-20 minutos e) más de 20 minutos

23. Se calienta suficiente la hornilla adelante?

a) SI *b) NO*

OPINION:

____

____

24. Se calienta la hornilla de atrás?

a) SI b) NO

OPINION: ____
____

25. Ha notado si el calor sale muy rápido por la chimenea?

a) SI b) NO

OPINION: ____

26. Puede tortear en la Estufa?

a) Es fácil b) Es difícil

27. Si ha tenido problemas a que se deben?: ____
____

28 La plancha de la estufa le parece grande o pequeña?

a) Demasiado grande b) Grande c) Perfecto d) un poco pequeña e) Muy pequeña

PORQUE: ____
____

29. Pueden cocinar dos personas o más a la vez en la Estufa Rocket?

30 La Estufa Mejorada le sirve para cocinar para mucha gente?

31 Se siente incomodo al meter leña de poco en poco en la Estufa Mejorada Rocket Box?

a) SI b) NO

OPINION: ____

32. Que opina del precio de la Estufa Rocket Box? Q 900.00 esta bien?

a) SI b) NO

OPINION: ____

33. Si no → cuanto estará disponible para pagar por la estufa asi misma?

500-600Q ?

600-700Q?

700-800Q?

800Q +?

NUEVOS DISEÑOS DE ESTUFAS ROCKET BOX

34 Que opina de los siguientes ideas para modificaciones?

Una Rocket Box con la Plancha de 36" de largo en vez de 24" de largo:

- a) Mucho mejor b) Un poco mejor c) Da Igual d) Peor
- Pagara Q1200, Q1300, Q1400, Q1500, por ella?

OPINION:

____

____

35 Una Rocket Box solo dos hornillas en vez de tres:

- *a) Mucho mejor b) Un poco mejor c) Da Igual d) Peor*
- *Pagaría Q25, Q50, Q100 más?*

OPINION:

____

____

36 Una Rocket Box con la cámara de combustión más larga para poder meter una leña entera:

a) Mucho mejor b) Un poco mejor c) Da Igual d) Peor

a) Pagaría 900Q por ella b) Pagara por 1300Q por ella

OPINION: ____

→ Le importará si tuviera que gastar hasta 10%/ 25%/ 50% mas leña?

Appendix C: Nueva Alianza survey notes

Appendix C provides more detailed information on the Questionnaire results from stove users in Nueva Alianza. Section 7.2 presents a summary of the most important results.

AC1 Time spent gathering wood each week. Wood savings (10, 13)

All of the nine participants who answered question 19 agreed that the RB saved wood, but there wasn't agreement over how much. The six respondents to question 6 said variously that they gathered wood 4, 8 and 10 times a week; half a 't*area*' saving each month; and 50% saving

AC2 Cooking habits compared to before RB introduction (21)

Three out of five questionnaire respondents replied that they had had to change their way of cooking with the RB. All of the six respondents to question 22 wrote that the RB takes 15-20 minutes to heat up. Out of the nine families visited in June three women said that they only cook with the RB sometimes (as opposed to the 'pollo') because it takes longer. Of the thirty seven families visited in August at least three had never used their stove.

AC2.1 Heating the front and back cooking rings (23-24)

Five out of six respondents said that they prefer a stove with three cooking rings instead of two (35.)

AC2.2 Making tortillas (26-27)

Four out of six respondents said that good tortillas can easily be made on the stove. According to Doña Maria Ramírez either you can make tortillas or cook big pots of food but not both at the same time. "Para tortear si que hay espacio… Pero si tenemos una olla grande y queremos tortear a la vez es muy poco el espacio." Most of the women visited were happy with how the tortillas turn out. One person said that they burn, but this may be because she doesn't sprinkle lime on the plancha.

AC2.3 Size of the plancha (28)

Four of the six respondents thought that the plancha is too small. Two people wrote "a bit small"; two wrote "very small" and one person commented that it's not suitable for big pots. Two respondents wrote that the plancha is big, one of them saying that the size is "perfect", but also that it's not suitable for several pots at once.

Three of the nine families visited commented that the stove is too small. Don Ruperto recommended the addition of metal 'wings' next to the plancha to put pots on: "more space..because on the plancha you can't leave anything because it burns So some 'wings on the side…"

Four people wrote that the stove would be "much better" with a 36" plancha instead of 24". No-one thought that the stove is big enough for two people to cook at once.

AC3 Quality Control

AC3.1 Stove Body

In Doña Mayra's house the stove body is hot to touch. This is still the case 30 minutes after cooking. Mayra worries about her small children burning themselves, so she prefers not to cook with the RB if she is going to have to leave them unsupervised in the house afterwards. In Mayra’s case this could be due to stove modification.

AC3.2Sealing the Plancha

Five of the thirty seven families visited in August report the problem of smoke coming from the edge of the plancha. Another family says that it smokes slightly before the fire gets really hot.

AC4 Affordability (32, 33)

A RB costs 900Q ($112.) During the focus group people didn’t want to give an opinion on the fair price for the stove, saying that they don’t know how much time is involved in manufacture. The four respondents who answered question 33 would pay 500-600Q for the stove. Three of the nine families visited said that 900Q is expensive for the stove. Don Polo said that he would pay 700Q.

Appendix D Management of Stove Donation Projects

NGOs working with improved stoves should carefully plan the management of donation projects. At Nueva Alianza the chimneys were not initially installed to the outside of the house, negating the health benefits of the project.

After the stoves were delivered installation was left to each family; including making a stand and installing the chimney. During our visit it was apparent that people were not confident about how to seal a penetration in the lámina roof around a chimney pipe so that it is water tight.   Wariness about roof perforating the roof was also due to their hope to build more permanent kitchens in the future using the same materials. Such issues should be addressed during other projects of this kind.

- A stove technician should be on site to supervise during chimney installation, and ensure that the smoke will be removed from the house.
- The recipients should receive training from a stove technician on RB use and maintenance. This would help prevent modifications or blockages and other reasons why a stove might not work properly.
- Supervision and care during transport and unloading would help to prevent damage where the stove is fragile e.g. plancha sealing, chimney elbow.

Appendix E Water Boiling Test Results

E.1 Comparative table of average values for the different stoves

	Rocket Box	Modified Rocket Box (longer firebox)	Comparison plancha stove: 'San Mateo Stove'
1. HIGH POWER TEST (COLD START) Time to boil Pot # 1 (2500l)	25min	56 min	63.2 min
Thermal efficiency	17%	12%	5%
Firepower	7115W	5913W	9711W
2. HIGH POWER TEST (HOT START) Time to boil Pot # 1 (2500l)	26min	39 min	38min
Thermal efficiency	21%	16%	9%
Firepower	5499W	7788W	12763
3. LOW POWER (SIMMER) Thermal efficiency	15%	7%	7%
Firepower	5332W	10412W	8712W

E.2 Rocket Box Test Results

1. HIGH POWER TEST (COLD START)	units	Test 1	Test 2	Test 3	Average	St Dev
Time to boil Pot # 1	min	26	29	19	25.0	5.0
Temp-corrected time to boil Pot # 1	min	24	28	24	25.1	2.3
Burning rate	g/min	22	17	27	21.9	4.9
Thermal efficiency	%	22.00%	16.00%	13%	17%	4.73%
Specific fuel consumption	g/liter	144	125	140	136.1	10.2
Temp-corrected specific consumption	g/liter	132	118	169	139.7	26.4
Firepower	watts	7,187	5,471	8,686	7115	1,608.6

2. HIGH POWER TEST (HOT START)	units	Test 1	Test 2	Test 3	Average	St Dev
Time to boil Pot # 1	min	18	24	34	25.6	7.9
Temp-corrected time to boil Pot # 1	min	18	26	34	26.3	8.2
Burning rate	g/min	25	16	10	17.0	7.6
Thermal efficiency	%	22.00%	19.00%	23%	21%	2.13%
Specific fuel consumption	g/liter	124	104	92	106.6	15.9
Temp-corrected specific consumption	g/liter	120	113	93	108.9	14.0
Firepower	watts	8,191	5,083	3,223	5499	2,510.2

3. LOW POWER (SIMMER)	units	Test 1	Test 2	Test 3	Average	St Dev
Burning rate	g/min	17	15	17	16.4	1.0
Thermal efficiency	%	16.00%	16.00%	14%	15%	1.29%
Specific fuel consumption	g/liter	438	383	424	414.9	28.5
Firepower	watts	5,371	4,979	5,647	5332	335.8
Turn down ratio	--	1.34	1.10	1.54	1.33	0.2

E.3 Modified Rocket Box (longer combustion chamber) test results

1. HIGH POWER TEST (COLD START)	units	Test 4	Test 2	Test 3	Average	St Dev
Time to boil Pot # 1	min	63	47	58	56.1	8.5
Temp-corrected time to boil Pot # 1	min	70	50	63	60.6	10.1
Burning rate	g/min	18	22	14	18.2	4.1
Thermal efficiency	%	10%	11.00%	14.00%	11.6%	2.20%
Specific fuel consumption	g/liter	232	198	162	197.0	35.0
Temp-corrected specific consumption	g/liter	255	211	173	213.1	41.2
Firepower	watts	5,775	7,303	4,662	5913.3	1,325.6

2. HIGH POWER TEST (HOT START)	units	Test 4	Test 2	Test 3	Average	St Dev
Time to boil Pot # 1	min	27	52	37	38.6	12.2
Temp-corrected time to boil Pot # 1	min	30	56	40	41.9	13.1
Burning rate	g/min	26	19	27	24.0	4.0
Thermal efficiency	%	19%	15.00%	12.00%	15.5%	3.72%
Specific fuel consumption	g/liter	140	180	181	167.2	23.1
Temp-corrected specific consumption	g/liter	155	196	194	181.5	23.0
Firepower	watts	8,435	6,309	8,620	7787.9	1,283.7

3. LOW POWER (SIMMER)	units	Test 4	Test 2	Test 3	Average	St Dev
Burning rate	g/min	28	33	35	32.0	6.0
Thermal efficiency	%	9%	5.00%	5.00%	6.5%	2.11%
Specific fuel consumption	g/liter	471	825	886	727.4	3,214.6
Firepower	watts	8,988	10,727	11,521	10411.5	1,945.4
Turn down ratio	--	0.64	0.68	0.40	0.6	0.2

E. 4 San Mateo Stove (Comparison Plancha Stove) Test Results

1. HIGH POWER TEST (COLD START)	units	Test 1	Test 2	Test 3	Average	St Dev
Time to boil Pot # 1	min	63	-	-	63.2	-
Temp-corrected time to boil Pot # 1	min	66	-	-	65.8	-
Burning rate	g/min	30	-	-	30.0	-
Thermal efficiency	%	5.00%	0%	0%	5%	0%
Specific fuel consumption	g/liter	358	-	-	357.8	-
Temp-corrected specific consumption	g/liter	373	-	-	372.7	-
Firepower	watts	9,711	-	-	9711	-

2. HIGH POWER TEST (HOT START)	units	Test 1	Test 2	Test 3	Average	St Dev
Time to boil Pot # 1	min	38	-	-	37.9	-
Temp-corrected time to boil Pot # 1	min	39	-	-	39.5	-
Burning rate	g/min	39	-	-	39.0	-
Thermal efficiency	%	9.00%	0%	0%	9%	0%
Specific fuel consumption	g/liter	251	-	-	251.0	-
Temp-corrected specific consumption	g/liter	261	-	-	261.4	-
Firepower	watts	12,763	-	-	12763	-

3. LOW POWER (SIMMER)	units	Test 1	Test 2	Test 3	Average	St Dev
Burning rate	g/min	27	-	-	26.8	-
Thermal efficiency	%	7.00%	0%	0%	7%	0%
Specific fuel consumption	g/liter	516	-	-	516.0	-
Firepower	watts	8712	-	-	8712	-
Turn down ratio	--	1.11	-	-	1.11	-

E.5 Temperature data on back cook rings during water boiling tests

Test	Time (mins)	Pot # 2 (200l) Start temp º C	Pot # 2 (200l) End temp º C	Pot # 3 (200l) Start temp º C	Pot # 3 (200l) End temp º C
		San Mateo Comparison Plancha Stove			
CS # 1	63	18	71	18	86
HS # 1	39	18	86	18	92
		Modified Rocket Box			
CS # 2	47	21	76	22	74
HS # 2	52	21	86	22	90
MOD CS # 3	58	21	74	21	73
HS # 3	37	21	78	21	78
MOD CS # 4	63	23	70	23	70
HS # 4	27	23	72	23	72
		Rocket Box			
RB CS # 1	26	10	45	10	45
HS # 1	18	15	43	15	45
HS # 1	60	15	67	15	65
RB CS # 2	26	13	44	13	39
HS # 2	29	23	48	15	43
HS # 2	70	23	70	23	65
RB CS # 3	19	18	45	18	40
HS # 3	34	23	36	23	46
HS # 3	70	23	63	23	68

CS – Cold Start High Power Test
HS – Hot Start High Power Test

E.5.1 Temp. data on back cook rings – average values from various tests

Test	Time (mins)	Pot # 1 (200l) Start temp º C	Pot # 1 (200l) End temp º C	Pot # 2 (200l) Start temp º C	Pot # 2 (200l) End temp º C
		Comparison Plancha Stove			
Cold Start	63	18	71	18	86
Hot Start	39	18	86	18	92
		Modified Rocket Box			
Cold Start	**56**	**22**	**73**	**22**	**72**
Hot Start	**39**	**22**	**79**	**22**	**80**
		Rocket Box			
Cold Start	**24**	**14**	**45**	**14**	**41**
Hot Start	**27**	**18**	**42**	**18**	**45**
Hot Start after more time	**67**	**18**	**67**	**18**	**67**

These values are given in the graph in 6.1.4

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