CEDESOL Rocket Stove Design Review

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Introduction

CEDESOL is committed to building, distributing and monitoring the use of ecological wood burning stoves. They have developed a low cost, efficient, clean burning stove that is tailored to the peri-urban and rural stove users of Bolivia. Mechanical engineer, Mike Collins worked as a volunteer intern 15 January 2013 to 15 March 2013. This report contains information regarding proposed and completed studies regarding the performance and design of the CEDESOL's rocket stove.

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Rocket Stove Design Intent Report

"Many times a technical person sees it from the perspective of the technology, not the perspective of the user. We were learning, especially from experiences in Africa, how important it is to include the user in the design from the beginning."
David Whitfield, 2013

Design Background

The Birth of CEDESOLs Rocket Stove Program

In 1997 and 1998 CEDESOL's founding director David Whitfield was investigating solar cookers and was participating in international forums and e-lists on the topic of solar cookers, sponsored by solar cookers international. One collaborator, Bruce Stahlburg, completed a range of solar cooker projects in the La Paz area funded by some embassies to Bolivia. On returning to the field, he found that people weren't using the solar cookers, except as storage for shoes or tools.

The uptake of the technology became a fascination of David's: Why was something so easy to use and so beneficial to someone not be used as intended?

Barbara Kerr from SCI (Who along with Roger Bernard is credited with cardboard box cooker and the cook-it) sent David info on the rocket stove and he became connected with Aprovecho Research Institute in the USA. They sent him the book "Capturing Heat". From this book David was able to understand the principles involved in the rocket stove.

Paint Bucket Rocket stove Design

Following capturing heat, CEDESOL built its first rocket stoves, made from 20L paint tins with a 4inch steel elbow manufactured from pipe as the combustion chamber. The space between the combustion chamber and the tin was filled with ash, and with wire grates installed as fuel racks. This design had a pot skirt and was constructed without a chimney.

Multi Pot Stove

CEDESOL's vision was to use a stove to preheat one pot, then put it in the solar cooker or retained heat cooker, then cook the second on the stove. However, they found that in Bolivian culture, most people wanted to be able to cook more than one pot at a time.

The traditional cooking method was having several pots around an open fire. In the highlands they would use a K'Oncha (similar to a three stone fire) and in the eastern departments, they would use two blocks or rows of bricks with metal grates across the fire, which was fed from the side. Theses stoves were sized to match pot size. The vast majority of these are built on the ground and without chimneys of any sort, both causing significant health hazards.

Example of current single pot rocket with chimney

By 2003 and 2004 we were still trying to push single pot stoves, retained heat cooker, use of the solar cooker so that you don't need more than a one pot stove. The German Technical Cooperation Agency (now called GIZ) liked the rocket stoves, and asked if CEDESOL could design a multiple pot stove with a chimney. Following this, CEDESOL developed the two-pot stove in 2005-2006.

Component Description

Sheet steel

Component Description

The main body of the stove is made from folded galvanized sheet metal. The panels are cut to size, holes drilled, and folded and riveted together to form the base and sides of the stove. There are openings in the front and back for the two combustion chambers and the chimney. A male rectangular tube adapter made from folded sheet metal is attached to the chimney outlet. The openings for the combustion chambers are reinforced by another folded sheet that has flaps folded inwards to seal and support the combustion chamber entrance.

Multi pot stove Cedesol model

The body when assembled is 690mm wide, 345mm deep and 290mm tall.

Component Design Intent

CEDESOL wanted people to be able to replicate the stoves in handcrafted ways. The stoves are designed to be built in a simple workshop just using hand brakes and guillotines. Many components used in Bolivian construction and industry are made from galvanized sheet steel (gutters, range hoods, air handling).

The galvanized sheet steel is heat resistant and corrosion resistant and lasts the life of the stove.

The first rocket stoves were metal paint buckets that were painted with heat resistant paint. This solution was interesting as it reused material, but the paint was an additional process that was not cost effective.

Throughout the design, attempts to eliminate metal were made due to the fact that metal in Bolivia is imported and the price of metal is linked to oil price. Thus the height of the stove was reduced to reduce material usage.

Stovetop (Plancha)

Component Description

The top of the stove is 2mm steel plate, cut by plasma cutter. The sides are cut 20mm long and folded down (and corners welded) to make a 18mm high skirt that fits over the sides of the stove body. Two 260mm holes are cut out above the combustion chambers. The circular offcuts are used as stove plates, supported by a ¼ bar which is bent into a circle and welded under the main plate. The stove top and stove plates are reinforced with ¾ inch equal angle section to prevent warping due to heat and a 1x10mm plate formed around the underside of the stove top plate.

Top view of the stovetop

The final stovetop size is 690mm by 345mm producing about 0.24.m^2 of cooking surface.

Component Design Intent

On visiting the HELPS project in Guatemala, it was noticed that the flat steel top was very useful, easy to clean and to use with a range of pot types.

The user can cook on top of the stove, which keeps soot off the pot, but with a loss in efficiency and an increase in cooking time. You can also cook with the pot on the top with the stove plates removed, which is a good compromise, as the pot only gets sooty on the bottom.

Cooking mode is dependent on family size. Big pots are used for bigger families, and therefore require the pot to sit on top. If cooking for a few, they will submerge the pot for faster, more efficient mode.

Experience in the field suggests that most people do not use the plates/lids. Mostly they are found sitting in the corner or amongst the woodpile.

In later designs, the stove was shrunk in width and length to allow the stovetop to be cut and folded to form the shape from one sheet of steel, avoiding extra material to form the edges and extra welding. This preserved most of the surface area of the stovetop but reduced the cost significantly.

Chimney pipes

Component Description

Top and bottom of the chimney pipe

The chimney is formed from 5 pieces all formed from galvanized sheet steel. The first piece is a rectangular 100mm x 80mm sheet metal tube, with a right angle male round tube adapter installed at the rear, pointing upwards. The far end of the rectangular tube is capped with a removable lid. Three pieces of 1m long 150OD (6 inch) round sheet metal tube are attached to the adapter by taper fit, and form the chimney. The final piece is a folded sheet metal shroud, which is attached to the open end to prevent rain from entering the chimney.

Component Design Intent

Adding a chimney adds 30% cost and decreases efficiency so initially it seemed counter intuitive. However, upon considering the health benefits of reducing indoor air pollution, the benefits outweighed the drawbacks

" What's a 30% increase in cost or loss of efficiency worth compared with life and death?"
David Whitfield, 2013

Although there is often no visible smoke from combustion with a rocket stove, there is still significant emission of particulates and gases. Aprovecho now recommend that chimneyless rocket stoves need to be used outside or in a well-ventilated area.

As with the stove bodies, many components used in Bolivian construction and industry are made from galvanized sheet steel (gutters, range hoods, air handling). The galvanized sheet steel is heat resistant and corrosion resistant and lasts the life of the stove.

The chimney design first had a round tube elbow, connected to a round male nipple out the back of the stove. The provider of the round elbows hiked his prices upon increases in orders. Thus the male nipple is now rectangular and joins to a rectangular section sheet metal tube that can be formed with a hand brake. The cap on the back is also included so that it can be removed in order to clean ash or soot that builds up in the chimney. There is a round male nipple pointing up which attaches to the chimney.

The user can chose whether they want the chimney installed inside or outside the house. If they want it outside, they can cut the hole through the wall and fit the rectangular tube through. Most people have access to a hacksaw and can adjust length of the rectangular section depending on the thickness of the wall, and the depth of the eave of the roof. A wire with a round bracket is provided to stabilise the chimney to a rafter or beam.

Sometimes the new rectangular section is not quite long enough to reach past the eave of the roof so the chimney is installed at an angle. Extra effort is made to ensure that the chimney can only be assembled male/female so that rain cannot enter the upside down joint, as water mixing with ash/soot forms an acid that rapidly corrodes the chimney.

The chimney pipes are sometimes formed in workshop but as cylinders they are very voluminous. When a large order of 720 stoves was delivered to Chuquisaca, the chimneys were carried folded and rolled, but without the final seam joint completed. This allowed the C shaped parts to be stacked more efficiently and the seam was completed on site.

Fasteners

Component Description

The stove body is assembled using stainless steel rivets. The additional attachments (internal sleeve, stove top) are attached using regular sheet metal fasteners with Phillips and flat blade screwdriver drives. The flat blade drive is desirable as a knife blade, coin, etc, could be used if a screwdriver is not available in the field.

Component Design Intent

Originally it was desirable to flat pack the whole stove and be assembled using screws onsite. However, due to the accuracy of the folding methods, the screw holes could not be made to line up well enough to ensure there'd be no problems in the field.

Combustion Chamber

Component Description

A refractory brick is placed on the base of the stove, below where the combustion chamber is installed. This supports the weight of the combustion chamber, which consists of 6 refractory bricks assembled and wired together to form the L shaped rocket stove combustion chamber. The inlet of the chamber is placed through the hole in the front of the stove. The opening where fuel is inserted is 120mm wide and 110mm high. The outlet for flames and combustion gases is 120mmx120mm with the sides of the channel cut 40mm shorter than the front and back.

Top view of the combustion chamber

Component Design Intent

After being asked to create a two-pot stove, CEDESOL decided to go ahead with 2 burners. This would overcome the decreased power supplied to the second pot as found in the Guatemalan stove. Each burner can run on full, medium or low, independent of the other. The main concern was to build it so that if one burner was not being used, fire/smoke wouldn't escape through it.

The metal tube elbow used in the paint tin stoves was abandoned as it would only last up to 6 months before burning out, and users would not replace them. CEDESOL also experimented with a thermal brick, that is, a very low thermal mass heat resistant brick. However, Bolivian brick-makers would not build the thermal bricks at almost any price. Another drawback was that they were fragile, and the bricks would break if wood would be pushed in too hard.

Although stove designers have experimented with SS, or 3CR12, CEDESOL have not been able to explore that yet. CEDESOL eventually chose a refractory brick. These could be cast and fired in a range of shapes and sizes by a local brick-maker.

When the height of the stove was reduced to reduce material usage, this also changed the rocket stove configuration (1.5 L:H ratio). Originally, the submerged pot would sit upon a metal rack. However, the flat-topped brick combustion chamber configuration was also changed so that the front and back bricks were higher allowing the gases to flow out the sides and around the pot when placed on top of the bricks. This eliminated the need for the metal pot rack. New moulds for the bricks had to be made.

Over that period CEDESOL decided to eliminate a combustion chamber metal sleeve with a sliding door, which added to the efficiency by restricting airflow, but 80-90% of users didn't use it and the slides had sharp corners and could get hot. The sleeve extended too far and the metal would get hot and warp, causing users to report the stoves as faulty. The combustion chamber bricks were extended past the front of the stove, to reduce heat transfer to the metal front, which ultimately increased the life of the metal.

There is a common misconception that a bigger hole will be useful. However, the important factor is matching the size of the inlet (and combustion gas path) to the fuel usage (air to fuel ratio). Too much air makes it too cold. Regardless the combustion chamber was widened slightly make it a little larger to make it more attractive to the user, and the fuel shelf height was reduced from 2.5cm to 1cm height above the floor allowing them to add more fuel. This provided a slightly larger hole, which satisfied some desire for a larger combustion chamber without deviating from the ideal air to fuel ratio.

Internal Skirt

Component Description

An exhaust gas collector is formed from folded sheet metal and attached to the back wall of the stove, creating and channel for the combustion gases to reach the chimney.

Internal skirt view

Two cylindrical sheet metal inner skirts of 280mm in diameter surrounding the combustion chambers are added, supported by screws attached to the rear collector wall. The top of the skirts are held close to the stove top and are tapered in height so that the gap with the stove top is larger at the front at the opposite side to the chimney.

Component Design Intent

Aprovecho recommends that a skirt around the outside of the pot dramatically increase heat transfer and therefore efficiency. CEDESOL wanted to incorporate this recommendation but as they required a chimney to mitigate indoor air pollution, the external pot skirt would not suit. Thus the internal skirt was used to force the hot combustion gases close to the surface of the stovetop and at a higher velocity. The design also allows for a pot with an outer diameter of 250mm or less to be submerged inside the stove. This leaves an annular gap between the pot and the skirt, forcing even more contact of hot combustion gases with the pot surface. To ensure the gases flow past the front of the pot, and not directly towards the chimney exit, the tapered top of the skirt forces exhaust gases to follow a more circuitous route as close to the stove top as possible, thereby transferring more heat to the stove top or pot.

Insulation

Component Description

Exfoliated Vermiculite insulation is poured into the main body filling the volume around the combustion chambers (not into the chambers or the rear exhaust gas collector).

Specific view of vermiculite

Component Design Intent

CEDESOL considered fibreglass insulation, rock wool, wood Ashes and Pumice for insulation. Aprovecho had recommended natural sources of insulation, like pumice and ash. In Bolivia there is a limited supply of pumice and therefore it was not viable. The advantage of ash is that it can be created anywhere, which was initially appealing to CEDESOL, because it was something that the owner could generate and include in the stove. With some time it was seen that people would buy a stove and not assemble it, blaming the fact that they didn't have any ashes or they couldn't accumulate enough ashes.

In 2010 a company in Bolivia began making vermiculite and CEDESOL was able to purchase it from them. Thus in 2011 they stopped using ash, although they then had to increase the price of the stoves due to the price of the vermiculite. The advantages were that it made stoves lighter and it meant the stoves could be assembled with insulation installed and shipped that way. CEDESOL still recommend that users put some ashes on top of the vermiculite, as over time the vermiculite settles and can be also be drawn up by the draft into the chimney.

Fuel Rack

Component Description

The fuel rack uses construction rod bent and welded to form a grate pattern. The part that extends out of the stove has a plate instead of a grate. The rack is supported by two plates running lengthwise along the outer rods, keeping the rack off the ground.

Component Design Intent

A range of different gauge wire was tested for fire resistance and the 1/8 inch was finally used. Initially a foot was formed at the end of the grate, but this was eliminated, as it tended to get too hot and burn out. Stops were added to the rack so that it could not be pushed too far into the chamber.

Base to support the stove

Component Description

The stove is designed to be placed on an adobe or brick base that the user can build.

Component Design Intent

CEDESOL recommends the base should be built so that the stove is set back somewhat (about a foot), providing a platform to support the fuel shelf and rest fuel wood on keeping it dry, and also to reduce the burn risk to children.

Miscellaneous

Assembly

It is important that assembly is relatively simple, using prefabricated components and predrilled holes. Quality control is performed in the assembly process, as each part could not be assembled if dimensions were incorrect. Each stove is shipped along with the parts to build a chimney.

Aesthetics

The rectangular shape requires multiple seams, but along with the galvanized finish produces a modern looking stove that is pleasing to the owner. Developing a sense of pride and status associated with the stove not only improves the user's commitment to maintenance, but also encourages the user to promote the stove to their neighbours.

Cleaning

CEDESOL recommends that after each use the user remove the fuel shelf and scrape our coals/ashes from combustion chamber and every day they clean stove top with a bit of oil. Once a year, they should remove top and clean soot build up under the stovetop. Each 2-3 months they should clean out soot and ashes from chimney and collector.

Comments and Contact Details

Any comments or questions regarding this report or themes within can be addressed to Mike Collins.

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