Design and Construction of a Full Scale Prototype of a Stove for use by Residents on an Island in Kuna Yala.

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Abstract

Island communities of Panamanians, the Kuna, have been cooking over open-fires inside of bamboo and woven-palm-leaf cooking huts for at least 200 years. Their ancestors are known as the Chibchan Indians of Central America. Addressing respiratory health hazards with a stove device could conserve wood fuel resources while reducing respiratory illness in the female population of this culturally adherent indigenous group. Three semesters of University of Pittsburgh Mechanical Engineering student groups developed an anthropologically considerate stove-smoker design for the island Kuna communities in the Kuna Yala Comarca. The device is made of two 55-gallon steel drums, hardware, and cast iron ventilation piping. The method of study included a series of stages including fieldwork, interviews, design iterations, and prototype fabrication. The stove-smoker serves to reuse construction waste products to make beneficial devices that have the potential to, if accepted among the Kuna, serve as not only a solution to respiratory health problems but also as a potential means of income. Unlike other stoves with an ultimate goal of maximum efficiency, this project explores the concept of tailoring stoves to cultural demands to provide solutions to local problems. The goal of the stove is to improve indoor air quality via smoke transport, while preserving traditional cooking and fire creation methods.

Introduction

Over three million people around the world still use primitive methods of cooking such as cooking over an open fire. Almost four million people die yearly from diseases directly related to the heavy smoke produced by simple fires. In poorly ventilated areas, indoor air pollution can be 100 times higher than acceptable levels. Diseases caused by this include pneumonia, chronic obstructive pulmonary disease, and lung cancer. Women and children are the most affected because they are exposed to the smoke longer from tending the fire which requires a constant presence in smoky atmospheres [1, 2].

Currently, there are many organizations trying to raise awareness about these global problems. The World Health Organization, Global Alliance for Clean Cooking Stove, Aprovecho Research Center and many other organizations are striving towards a cleaner cooking solution that would eliminate the indoor pollution, while reducing the energy and fuel needed to cook a meal. One solution to these problems is to design a “Rocket Stove”, which is an L-shaped cooking stove [3]. The fuel is put into the bottom, and the fire burns, directs the heat to the surface, and is able to cook food, while venting the smoke outdoors as shown in Figure 1.

Figure 1: Drawing of a Rocket Stove

The rocket stove is just one solution to the global problem. As you will see from this paper, we have innovated another solution to the problem, by targeting a specific group of people. Our project is a continuation of the “Kuna Yala Rocket Stove Project”, initiated by Engineers Without Borders to design a stove to improve the cooking conditions for residents of the Kuna Yala islands. The rocket stove idea was originally used, but after analyzing the Kuna Yala Peoples, we added some personalization’s to our version of the stove to increase the chances of use by the native people.

Kuna Yala History

The San Blas Islands are a formation of approximately 365 coral islands located off of the Caribbean seacoast of Panama. Present day land-travel to and from this archipelago involves an arduous journey through dense jungle as facilitated by one eroded, winding and narrow, paved road passable only via SUV or similarly equipped vehicle and only with the provision of financial compensation for Kuna who stop traffic for this purpose in at least one location along the way. In addition to road passage fees, the island Kuna mostly survive on income from the sales of “mola” (a brightly-colored textile made by Kuna women) and from island tourism: rustic island hotel rentals, boat rides, food sales.

Figure 2: Map of the Comarca Kuna Yala

The Kuna people settled in island communities in the San Blas Archipelago (now referred to as part of the Kuna Yala Comarca) around 1800 [1]. Kuna at that time mostly farmed the land-based portion of the Kuna Yala province (shown in Figure 2) for crops. Kuna prospered on the islands and traded with pirates, different families, and explorers.[7]

Panama was established as an independent country in 1903, dividing island populations of Kuna who lived (and some still remain) in what became Columbian and Darien territories. Kuna populations in the newly distinguished Panama were faced with impositions as a result of the colonization including newcomers scouring their land for resources such as gold, rubber, bananas, and sea turtles, suppression of Kuna traditions, and colonial police abuse. A major Kuna rebellion against these impositions in 1925 begot the currently maintained peace treaty between the Kuna and the Panamanian government. The treaty sets aside the "Kuna Reserve 'Comarca de Kuna Yala'" [5] and enforces respect of Kuna traditions and mutually agreed-upon conditions of Kuna self-governance, or autonomy.

The island receives bottled water imported in from mainland Panama, as the only fresh water, In addition, some non-potable water is collected from rainwater or groundwater. Each family on the island has one cooking hut and one living hut. This is because the cooking hut contains an open fire, composed of driftwood arranged in a bicycle spoke pattern as seen in Figure 3.

Figure 3: Current Kuna Fire Style, with cooking pot placed atop the coals.

As seen in the figure, the driftwood is not cut, because the Kuna people do not have access to axes. The fire is arranged so that the people tending the fire, mostly women, can simply push the logs further into the center to keep the coals burning, all day. When the fire needs to be started, trash, normally plastic that has washed ashore, is placed atop of the coals, which are then fanned until a flame has ignited. In addition to the direct heat method using pots over the burning coals, the Kuna also smoke a lot of fish and holistic medicines. One method of smoking is done by hanging the fish or herbs from the top of the hut and letting them hang, while the smoke fills the hut nearly all day. Another method the Kuna use to smoke, is by making a slotted table out of sticks, to be placed above the fire. The fire is then fanned to create an adequate amount of smoke, and this is continued until the fish is done. This method allows for multiple fish to be smoked at one time. This method can be seen in Figure 4, as the Panamanian woman tends the fire.

Figure 4: Woman, dressed in native garb, tending fire to smoke fish, using table made from sticks

As discussed before, the current conditions of the Kuna Yala cooking practices are dangerous. The women breathe the fire smoke in all day, and are at a greater risk of lung cancer or any of the other aforementioned diseases related to the indoor air pollution. Also, the hazard of the hut itself catching on fire is a major concern. Another big issue the Kunas have due to their cooking practices is the lack of space on the island itself. Two huts per family implies twice the space required for each family. Introducing the idea of a single hut per family ideal, half the used land on the island can be conserved.

The intention of our stove is to be fabricated in Panama using mostly materials that are easily accessible there, with little parts to be imported. If the Kuna people accept the stove, this could eventually lead to a “start up business” in Panama, with the Kuna people being the customers. The Kuna themselves do not have the building capabilities so they would not be able to construct the stove. With this is mind, we first came up with a set of functional requirements and designed a stove, which met these requirements. The materials we chose to build the stove had to be dependent on the materials available in Panama as well as compatible with the limited construction equipment available to us, at the University of Pittsburgh and to the final construction location in Panama. We then began fabricating our stove, followed by two tests of the completed stove. From the testing, we found what worked on the stove and what needs improved upon in the future. These topics will be elaborated upon in the following sections of the paper.

Functional Requirements and Design

This unique task brought up many possible designs, but before we could choose which would work best, we had to come up with some project objectives to grade each design against the other. The two basic objectives were to channel smoke away from the cooking hut, and to have a cooking surface hot enough to cook water. From that basic idea, many designs came about. We did some further research into the stoves being built for people in this situation, and found indigenous people are very resistant to changing their ways. So, the next requirement was to utilize the Kuna Yala's current methods of building and maintaining a fire. They have been using the bicycle spoke pattern for many years, and they do not have tools to cut the wood into different sizes, so this requirement had to be included. This design also has to be easily adaptable to different size wood. The area for the fire under the stove had to be adjustable so all logs could fit. We are designing this for a company down in Panama, so we must use materials they have, and fabrication methods they are capable of. Some materials are very expensive local to the project (will be explained in more detail later), so we are very limited with materials. Finally, since this design is going to be shown to the Kuna Yala in May, we must fabricate a functioning model. So in summary, our project objectives are listed here:

- Utilize current methods of building and maintaining fire
- Be easily adaptable for different situations (log size, fire size, etc)
- Use locally available materials and fabrication methods
- Channel smoke away from people cooking

Materials

From the suggestions provided to us from the previous group of students working on this project, and our Engineers without borders contact in Panama, Rick, we decided to base our main design around construction from 55 gallon drums and rebar. The bill of materials for the stove we constructed at the University of Pittsburgh is shown in Table 1, where the parts that could be eliminated by the use of welding or braising as construction methods are shown in gray. As you can see, most of the parts were bought from McMaster Carr, as they are an approved vendor for the University of Pittsburgh, and the parts were accessed easily.

The 55-gallon drums we used from Pitt's chemical waste contractor. These were refurbished drums, with lids, meaning there were no longer traces of whatever was being stored in them originally, and the insides were painted. It took three full size 55-gallon drums to construct one full size stove with a cooking surface and smoking chamber, and one full size stove that only featured the top cooking surface. The drums were used to build the main stove, and cooking chamber, as well as the inner insulation barrier/heat funnel. The scraps left over from the constructions of the stoves should be used as smoke flaps to further channel the smoke up and out of the ducting. We used a high temperature caulking for the construction of our stove to seal in potential areas for the smoke to escape, although welding parts together rather than bolting would eliminate this.

For the smoking chamber we bought an expanded metal sheet to be used as a grate, although we would suggest some sort of welded rebar for construction in Panama. The door required two handles, one hinge, and a steel swinging hook and latch for closure. These parts do not have to be exact matches to what we used, assuming the functions are similar, and could be found at a local hardware store in Panama.

The flexible ducting for the ventilation assembly on the large full size stove design should be rated to at least 200°F to ensure it does not melt. We suggest a simple aluminum flexible duct hose be used for this because they are easily accessible in hardware stores. The smaller stove requires a higher temperature rating, because the fire is placed directly under it. A stainless steel duct pipe would be required for this. To seal the gaps around the ducting, we used a combination of the flue tape and the high temperature caulking. Small pieces of rebar were used to create dampers in the ventilation system.

Table 1: Bill of Materials for Kuna Yala Stove, built in Pittsburgh, items in gray could be eliminated by use of welding or braising as construction methods.

Part of Stove	Vendor	Part #	Part Description	Qty
General Stove	Chemical Waste Contractor, PITT		Refurbished 55-gallon drum with lid.	3
General Stove	McMaster Carr	73335A42	Sealant for Metal Duct, High Temperature, 10.1-Ounce Cartridge.	1
Smoking Chamber	McMaster Carr	9302T89	Expanded Metal Sheet (1008 Carbon Steel), Flattened, .120" Overall Thickness, 2'x 2'	1
Door	McMaster Carr	1967A3	Oval Pull Handle with Threaded Holes, Nylon, Black, 4-3/4" Center to Center	2
Door	McMaster Carr	1798A21	Surface-Mount Hinge, Steel, Dull Black, Removable Pin, 3" High, 2-1/2" Wide	1
Door	McMaster Carr	1727A4	Steel Swinging Hook Latch, Zinc-Plated, 5" Hook L, 7/8" Projection Thread Length, packs of 20	1
Ventilation	McMaster Carr	55335K42	Bend-and-Stay Duct Hose for Air, 4" ID, 26" Compressed Length, 7' Extended Length	2
Ventilation	McMaster Carr	2561K11	Heavy Duty Type 304 Stainless Steel Spiral Duct, 4" Diameter, 2' Length	1
Ventilation	McMaster Carr	7575A33	UL Printed Duct Tape, 2" Wide x 120 Yard Length, Silver Tape with Red Print	1
Ventilation / Legs	Home Depot	0000-274-356	1/2" X 4' Steel Rebar	2
Legs	Home Depot	887480011173	48" X 1/16 " Square Tube	1
Legs	Home Depot	887480074680	Wire Pin Locks	3
Legs	Home Depot	19442146856	3/8" Black Pipe Cap	2
Legs	McMaster Carr	8880T31	Extended-Length Steel U-Bolt, 1/4"-20 Thread, for 7/8" OD, 1/2" Pipe, 435 lb Work Load Limit, pack of 5.	2

Rebar was also used for the legs, these were connected to the sides of the stove with U-Bolts, but these could easily be welded onto the barrel, which would eliminate the need for U-Bolts. The square tubing and wire pin locks are used in making the small stove adjustable, and the pipe end caps are put on the end of the rebar to inhibit the rebar from digging too far into the sand on the large stove.

Designs

Our first design is displayed in Figure 5. This image is an exploded view so that the insides of the barrel can be seen. This design had a skirt around the bottom of the drum, which was designed to keep the fire and the smoke inside the chamber. The outer shell was made from a 55-gallon drum, and there is some metal bent to form a funnel to focus the heat from the fire onto the top surface, where cooking would occur. The smoke would fill the outside of the funnel. There is a drawer on the right of the image, which is where tobacco or fish would be for smoking. The smoke would then leave out the piping to the left.

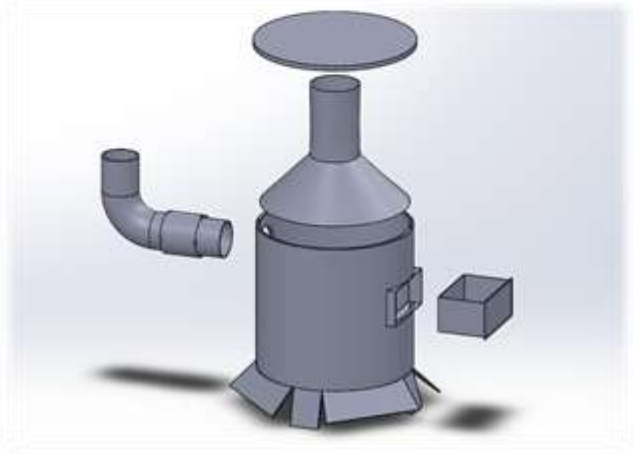


Figure 5: Design idea 1

Our second design is displayed in Figure 6. This idea is made out of sheet metal. This design focused on making a larger smoking chamber, and the ease of construction. Again, there are flaps where the fire would be to keep in the smoke. The fire would heat up the surface directly above it, and the smoke would fill the whole stove. The box on the left would be for the cooking surface, where the box on the right would be for the smoking chamber. Again, there is a drawer where the tobacco or fish would be placed for smoking. Finally, the smoke would be channeled out of the chimney in the back.

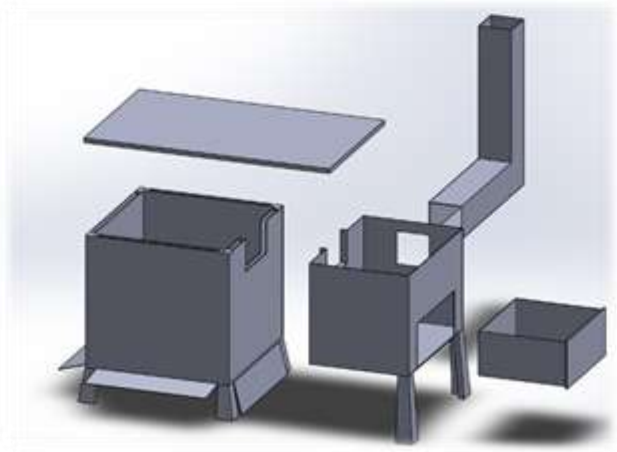


Figure 6: Design idea 2

Our last initial design idea is displayed in Figure 7. This idea focused on simplicity and material availability. The location for the fire is under the half-barrel on the left. There is a hard top on that which acts as the cooking surface. The smoke is then channeled through a pipe to the smoking chamber (the barrel on the right). There is a cut out in the image where a door would be located for smoking food. The smoke would then continue out the chimney to the left. And because both barrels have legs, the height of the fire can be easily adjusted.

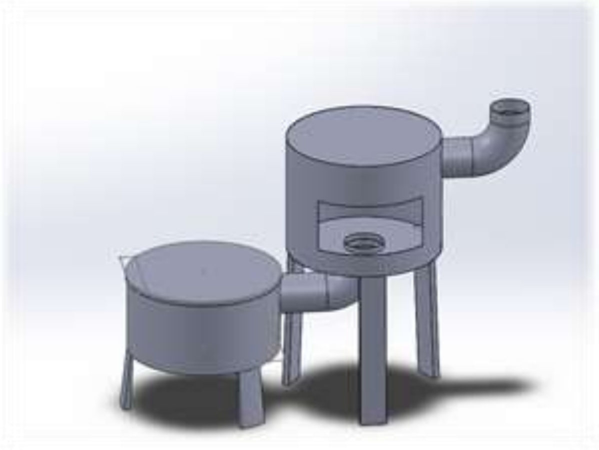


Figure 7: Design idea 3

Each one of these three designs had their downfalls though. For example, design one was very complicated with construction, with many cuts that had to be very accurate and many connections had to be exact. With the fabrication methods currently in use in Panama, this is just not realistic. Also, the piping for the chimney was very expensive. In design two, we underestimated the cost of sheet metal. Since the entire stove was made using sheet metal, this design was instantly disregarded. Design three was closer, but the piping was very heavy in relation to the rest of the design, and the stove was unable to stand on its own. We then kept the good aspects of these three designs to come up with two new designs, one standalone cooking surface, and one cooking surface/smoking chamber combination.

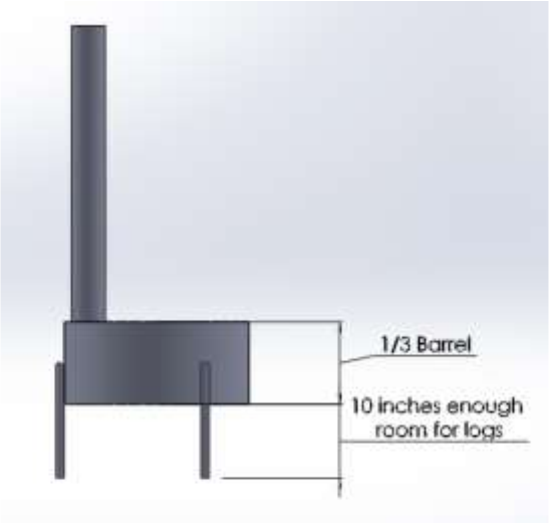


Figure 8: Dimensioned small stove

The final designs are shown in Figures 8 and 9. Figure 8 shows the standalone cooking surface, and Figure 8 displays the cooking surface/smoking chamber combination. Most of the complicated aspects of the first design are thrown out, but some key aspects remain. There is an insulating funnel to channel the heat to the surface in both cooking surfaces, but in both designs, the chimney now comes out of the top. This will help the design stand on its own, while still channeling smoke out of the cooking hut. For the cooking surface/smoking chamber combination, we overlapped two parts of a 55-gallon drum so the smoke can transfer between the two. The cooking surface will still have insulation to focus the heat, and the smoking chamber will still be able to smoke food, with minimal smoke escaping.

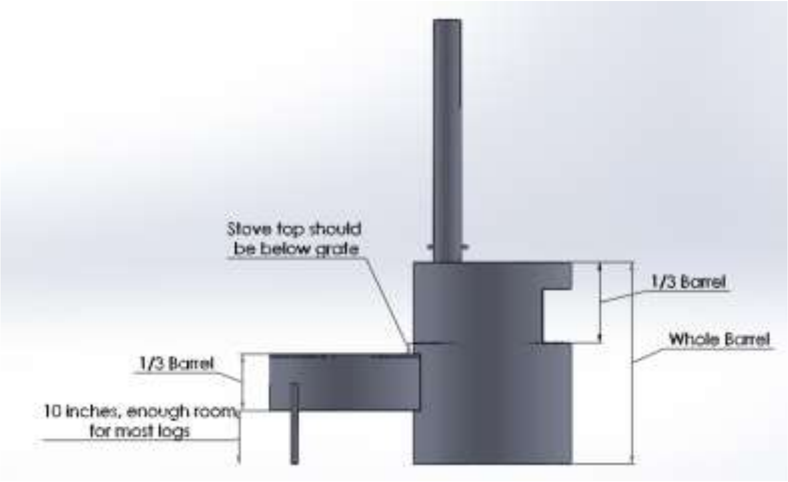


Figure 9: Dimensioned large stove

Fabrication

Fabrication of the stove took place in the University of Pittsburgh's Rapid Prototyping and Reverse Engineering Laboratory. The first and foremost issue that dictated the efficiency of the fabrication process was the method of cutting these barrels into the usable pieces. With the consultation of Thorin Tobiassen, our group decided to purchase a nibbler tool from Harbor Freight Tools.

Advantages of utilizing the nibbler tool resided in the purely mechanical, and cutting speed properties. Other methods considered were sawing, torch cutting, bending into shape, and shear cutting. Due to the shape and the orientation of the barrels, as well as availability, the nibbler proved to be the optimal method. The main disadvantage of the nibbler resides in the powering method. The nibbler used in fabrication of these prototypes was powered by compressed air. Gas, and electrical powered versions exist if this method is chosen in later fabrication attempts. Our group also recommends that a nibbler with max thickness cutting spec of ¼ to 3/8 inch of steel be used in later attempts at this project. In our trial, we used a nibbler with a max steel thickness of 1/8 inch. This proved to be a cumbersome method of cutting the 55 gallon barrel. The rigidity of the barrel degrades as it is cut, which causes variance in thickness due to the elastic deformations of the steel. When the thickness of the barrel approaches the nibbler's max cutting thickness, this causes the nibbler to jam frequently, causing both frustration and delays. Using a higher quality nibbler, with a higher rated max cutting thickness should alleviate this issue, and inevitably keep the man hours required to fabricate these stoves to a minimum. Additionally, a circular disc attached to a high torque Dremel (air powered) or similar tool was necessary and used in creating more precise cuts later in the fabrication process.


Figure 2: Uncut 55-gallon Barrel

Once an adequate cutting method was established, sizes of the final design were considered. Our group found that for the prototype, simple size ratios with a great tolerance would be used. We decided the simple design consisting of only the stovetop and smoke transport system would be approximately 1/3 of a barrel in height. Using the geometry of the manufactured barrels proved effective in deciding sizes. Note Figure 10 to the right. The barrel arrived from the vendor with three concentric rings at different heights on the barrel. Cutting just below the lowest ring was chosen and proved to be an adequate size for the simple stove.

Once the bottom was separated, another cut was made just below the second ring. This material would be used for the insulating ring installed in the simple stove. Figure 11 shows the cutting process and utilization of the nibbler tool. Once the insulating layer was separated from the remaining part of the barrel, the layer was installed using U bolts, which also held the supporting legs to the small stove.

As shown in the Figure 12, the u bolts, two per leg, are placed through both the stove shell and the insulating layer. The supporting legs (3x) are inserted between the u bolts and the shell layers of the stove. The bolts were then tightened down, securing the legs between the two shell layers.

Figure 3: Cutting the second barrel with nibbler Figure 4: Simple stove with insulation

The hole in the top of the cooking surface was cut using a hole-saw drill bit like the one shown in Figure 13 in a batter powered DeWalt drill. Size of this hole depends on the size of ducting used. Our case called for a 4” duct, so our hole was 4” in diameter. The guide hole was initiated via a metal punch, with an impulse delivered by a standard rubber mallet. The guide hole, utilized by the hole-saw’s center drill bit, was expanded with a drill bit with a similar diameter. This step created a uniform hole for the guide bit. This provided ample engagement of the guide bit to steady the hole saw during the cutting process. Importantly, coolant fluid was sprayed on the surface prior to, and at several intermediate points in the drilling process. This provided both an extra method of heat conduction (aside from the metal body of the stove) away from the cutting point, as well as lubrication to prevent over wear on the hole-saw bit. Additionally, the coolant fluid provided a medium for the removed material created by the cutting process to suspend in. This prevents the spraying of hot metal pieces that could harm others. The hole cutout created by this method was saved and used in the construction of the chimney damper, which will be explained later. Slight adjustments to the hole after the drilling process were completed with the nibbler and files of various tooth densities.

Figure 5: Hole Saw Drill Bit. Image courtesy http://tubohotel.com/img/hole-saw-drill-bit-for-metal-i4.jpg

After the legs were attached and the chimney hole was cut, our group members fabricated the support stands that allow for vertical adjustment of the stove. These support stands were built from the 48 square tube. These pieces were cut using a circular saw with an abrasive grinding blade optimal for cutting metal. This method was chosen for time constraints.   Once rough cuts were made, these sections of tubing were cut simultaneously to easily create equal lengths. The square tube could also be cut with a grinding wheel and or a hack saw, if necessary.

Holes were drilled in the square tube. These holes were marked with a permanent marker, indented using a punch and mallet, and drilled with a ¼” drill bit on a drill press. Mounting and drilling on a press ensured that holes on the opposite sides would be in the same position. Wire pin locks were used. The only considerations to make when re attempting this process in the future would be to make sure that these holes are drilled to a diameter allows the pins of the wire pin locks to fit.

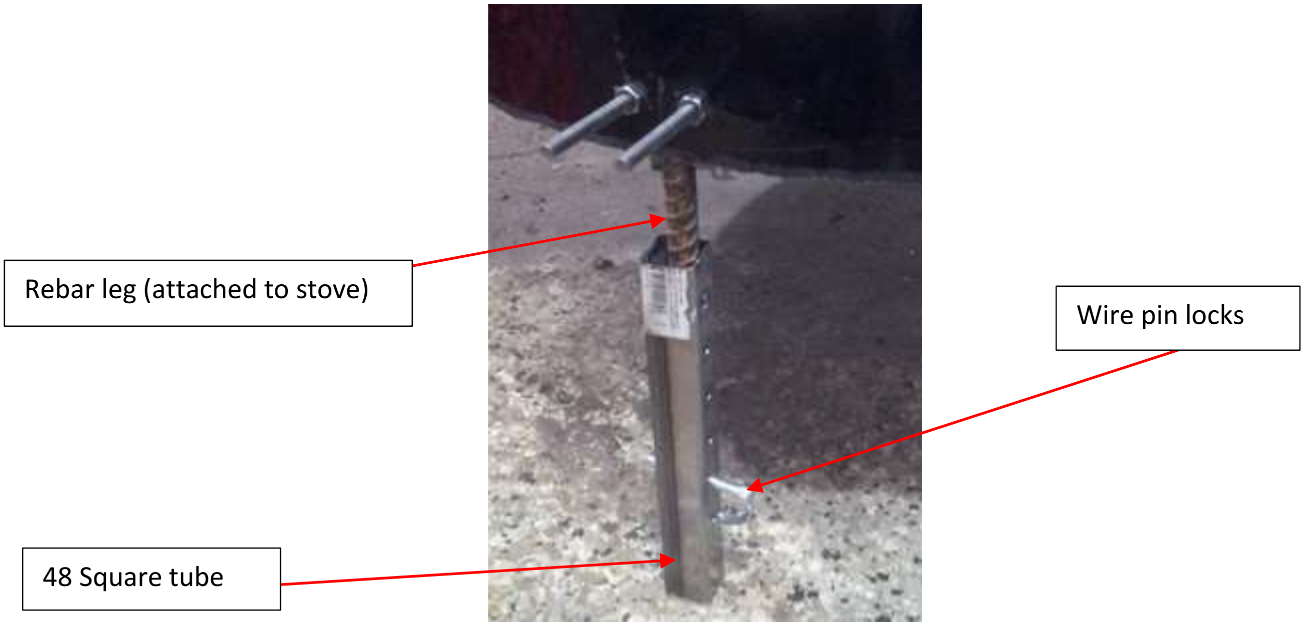


Figure 6: Detail of Leg Assembly; Smaller Stove

As you can see in Figure 14, the legs installed on the small stove fit inside the square tube and rest on the pin. This was simply a concept idea for the purposes of raising and lowering the stove, see later section for conclusions of this method.

The Heavy Duty Type 304 Stainless Steel Spiral Duct was to be placed into the chimney hole. One end of the duct was crushed from all directions in an attempt to narrow the diameter and create a press fit. This allowed for insertion into the stovetop. Several attempts at filing the stove hole and bending the ducting took place before we obtained a snug fit between the duct and stovetop. This mate was sealed with the high temperature caulking. See the results section, but this mate would be much better with a brazing process

Next, the damper was assembled. This utilized the circular cutout from the chimney hole mentioned before, and a 7 inch segment of rebar. The rebar was attached to the circular cutout using a hose clamp, and two holes drilled into the circular cutout. Two holes were drilled into the steel ducting at the same distance from the stove, and the damper was inserted into this point.

Important to note, that a method of securing the damper at intermediate positions should be considered, as this method only allows for an open or closed orientation of the damper.

LARGE STOVE

The large stove was assembled with basically the same technique as the smaller stove. First, sizes were decided based on rough ratios. The stovetop part was decided to be the same size as the smaller stove. The smoking chamber was to be constructed from an entire barrel.

First, the door was cut out of the large barrel. This involved drilling 1" holes in the four designated corners of the access hole. The nibbler was used to make cuts between these holes. Scrap was generated from these cuts, which must be saved. Refer to the recommendation of flaps.

Next, the bottom of the third barrel was cut off in the same manner as the simple stove. This part was to become the cooking surface of this larger stove. The remainder of this third barrel was cut in half, leaving two small rings of metal. The middle ring was used to create our heat funnel insulation. See the figures to follow.

The cooking surface was cut along the side in a straight line, then folded back to reveal the shape shown in Figure 15. This provided the method of smoke transport from the cooking surface to the smoking chamber. Once the bends were created in the cooking surface part, we had the task of creating the heat funnel. We chose to use the nibbler/grinder to create cuts in the ring spanning half of the height, creating a row of flaps. These cuts were made every 6-8 inches. See Figure 16, the flaps were then bent inward, creating a crude cone shape. This was our heat funnel. The funnel was placed in the cooking surface, oriented such that the open end of the ring was towards the smoke transport side. The heat funnel was cut to size at this point.

We decided to rivet the heat funnel to the cooking surface, due to lack of access to welding equipment. The riveting process began from the furthest point from the smoke exchange window. C-Clamps were used to secure pieces in place. A 1/8" hole was drilled through both pieces of metal, between two C-Clamps. The circular grinding wheel was used to remove burrs from the drilling site. A pop-rivet gun was used to secure these rivets. After each rivet was inserted and secured, one clamp was removed and replaced approximately 4 inches adjacent to the clamp that remained. The riveting process was repeated until the heat funnel was secured along one quarter of the circumference of the barrel. At this point, the top bolts for the two supporting legs were installed. Unlike the small stove, these U bolts only penetrated the outer barrel, and not the insulation. These bolts were installed with the apex of the "U" facing outward. The bolts were secured underneath the heat funnel insulating layer. See Figure 24. The lower U bolts were installed after the heat funnel was fully installed. The riveting process continued and proved difficult. After a while, excess of the heat funnel protruded past the bottom edge of the cooking surface, a result of a difficult bend taking place. This excess was trimmed off using the nibbler/grinder. Again, the heat funnel was cut to size.

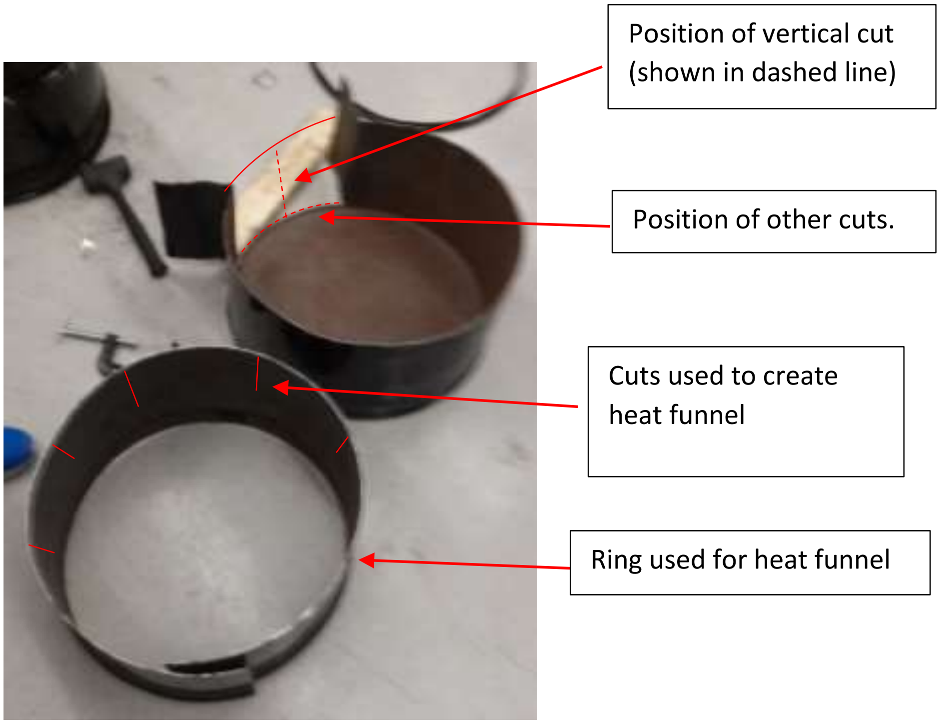


Figure 7: Cooking Surface and Metal Ring

Figure 8: Fabrication of Heat Funnel

Figure 9: Installation of Heat Funnel

Now, fabrication returned to the larger barrel that was to become the smoking chamber. Four holes were drilled and ¼ inch bolts secured by nuts were placed around the top ring of the smoking chamber, just below the access window.

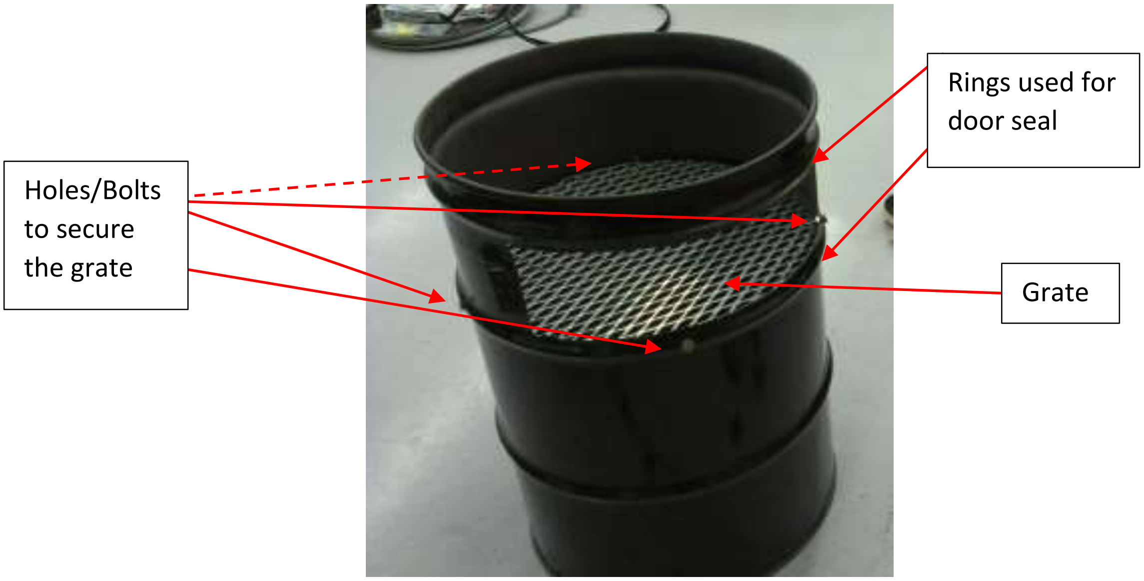


Figure 10: Smoking Chamber Assembly

Figure 11: Grate Support Detail

As shown in Figure 18, the grate rests on the bolts drilled at four equidistant points. Unintentionally, one bolt ended up right below the access door. This required a hole to be drilled into the access door later.

A flexible measuring tape was used to size an appropriate door length. The ultimate goal in the door size was to use the two rings present above and below the access window to help seal the smoke in. Additionally, high temperature rated silicon caulking was used to make a seal. See results section for an evaluation of the effectiveness of this method. Naturally, for the rings present on the outside of the smoking chamber to fit the rings in the door, the door must be cut out of the similar section of the third barrel.

Figure 12: Smoker Access Door Detail

Figure 13: Keyhole Mate Example

Figure 20 shows the detail of the access door with the silicone caulk seal. Additionally, the hole drilled to fit around the grade securing bolt is visible. The two bolts on the opposite side were created for hanging the door on the smoking chamber itself. The door was secured to the smoking chamber with clamps. The holes used to hand the door were drilled simultaneous to assure a perfect mate. A keyhole method was envisioned for this mate. See Figure 21. The idea was to have the protruding bolts installed in the door fit into the keyhole shaped cutout of the smoking chamber. A circular file was used to create the upper portion of the keyhole on the smoking chamber. See the results and conclusions section for an evaluation of this method.

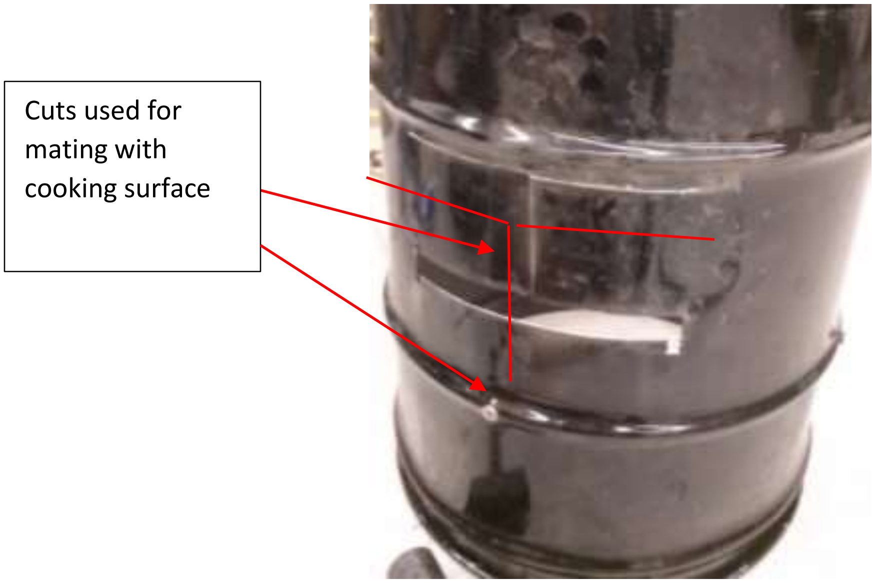


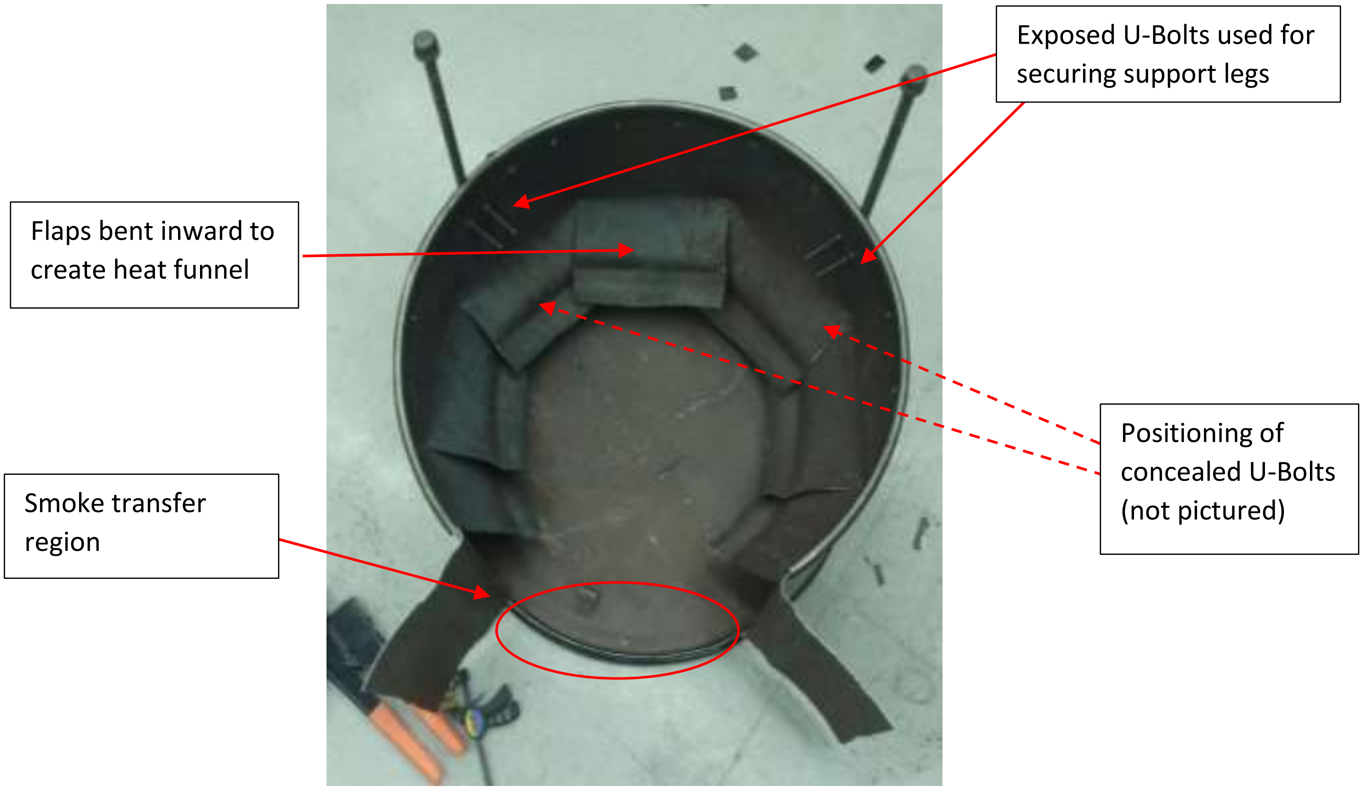
Figure 14: Smoke Window Detail

Figure 22 shows the cuts made in the smoking chamber with a grinder. The grinder was used because these cuts required much more precision than the previous cuts. The top portion was bent out similar to the method used on the cooking surface. These flaps rested on the interior of the cooking surface.

Figure 15: Bolted Mate Detail

The assembled cooking surface was secured to the smoking chamber with a bungee cord to hold it in place while the bolts were installed. Once the two pieces were secured against each other, a drill was used to drill ¼" holes between both barrels. 3/8" bolts and nuts were used to hold the two pieces together. This allowed the two pieces to be mated together. The bungee was removed and the main body of the large stove was assembled.

In the same manner as in the simple stove, a hole was drilled in the top of the smoking chamber for the chimney. This method was exactly the same as the simple stove. A steel spiral duct pipe was not used in this part. Only the bend and stay ducting was used, as temperature's experienced by this chimney would not be as high as the other stove. This mate was sealed with high temperature caulking. A damper was constructed from the scrap created when the chimney hole was cut.



Exposed U-Bolts used for securing support legs

Flaps bent inward to create heat funnel

Positioning of concealed U-Bolts (not pictured)

Smoke transfer region

Figure 16: Underside of Cooking Surface

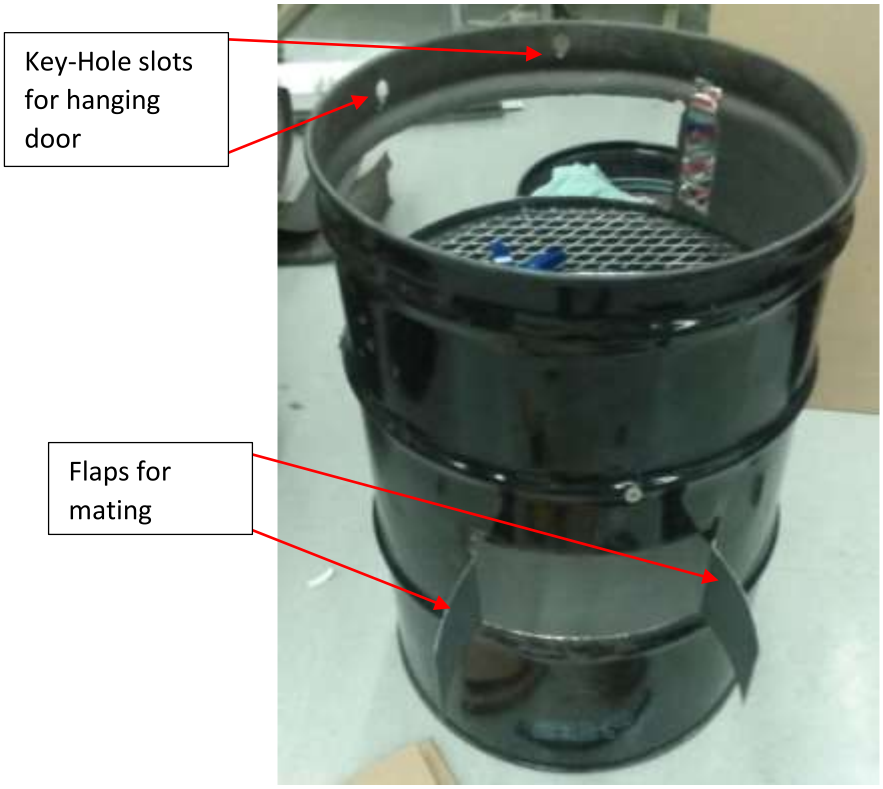


Figure 17: Assembled Smoking Chamber

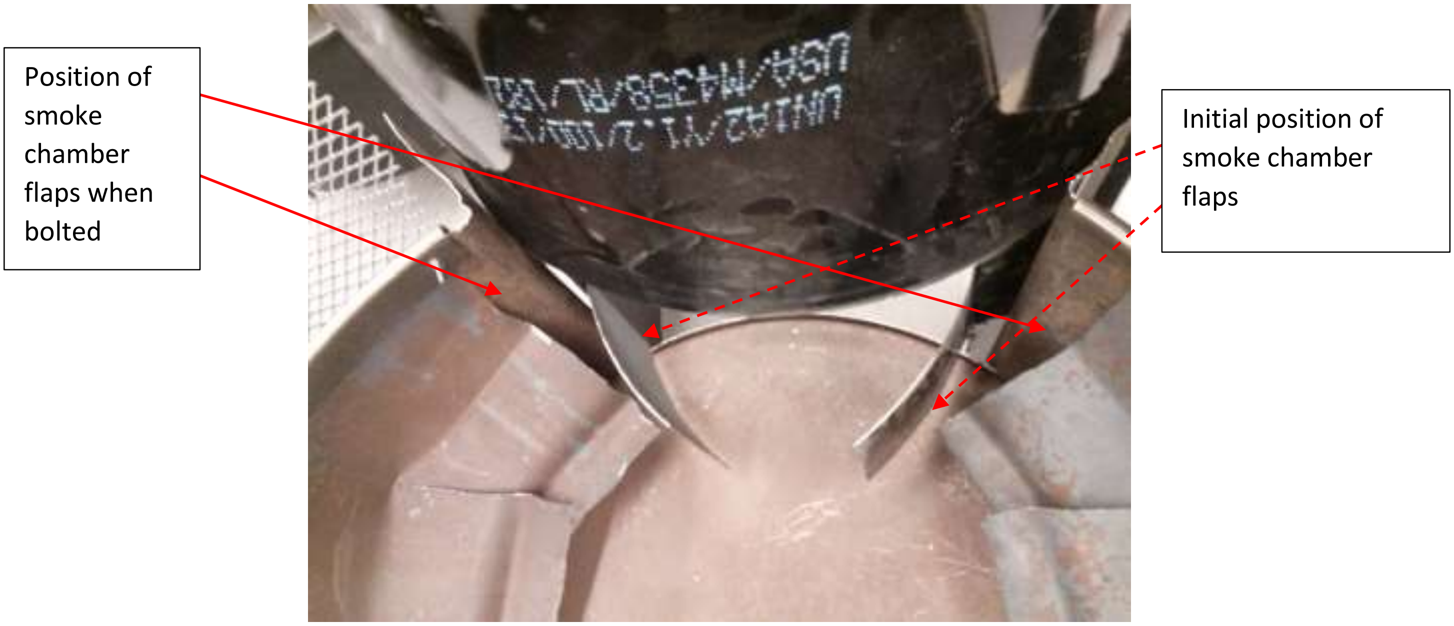


Figure 18: Smoking Chamber - Cooking Surface Mate Detail (Before Bolting)

Figure 19: Smoking Chamber - Cooking Surface Mate (Before Bolting)

Figure 20: Smoke Chamber- Cooking Surface Mate (After Bolting)

Testing and Results

Two tests were conducted on the stoves. An initial test on the shell of the small stove was done to gain an idea of temperatures and smoke generation and removal. A second test was then conducted on the fully assembled small and large stoves, with the aim of measuring temperatures and observing smoke removal. Prior to testing, stoves were burned out in an attempt to remove harmful paint fumes.

During testing, care was taken to ensure that the fire configuration and size was similar to what would be used by the Kuna Yala. Allison McCurdy was consulted, as she had traveled to Panama in the previous semester and had observed Kuna Yala cooking practices. Description of these practices can be found in the Functional Requirements section.

For the initial test, the small stove without the insulation lining was tested. The stove had been fitted with adjustable legs, although these were not used during testing. Additionally, a stove pipe had yet to be attached. As the stove was not yet fully assembled, the primary purpose of the test was to gain an appreciation of the amount of smoke generated and for the surface temperatures achieved. Unfortunately, the day of testing was very windy, leading to a majority of the smoke to leak around the bottom edge of the stove. Therefore, it was difficult to gauge how the stove would act in still, indoor air. However, the decision was made that flaps should be constructed to place around the base of the stove, in order to help channel the smoke.

To help measure cooking surface temperature, a small pot half filled with water was placed on the top of the stove for the duration of the 25 minute test. In the absence of a laser thermometer, temperature estimates of the sides and cooking surface were done by splashing water on them. The cooking surface, although unable to achieve a full boil, quickly evaporated any water poured on it. However, the reached an unacceptable temperature, as they also quickly evaporated the splashed water. The decision was made to create a lining to insulate the inside of the stove, in order to lower the side temperatures and channel more of the heat towards the cooking surface. Additionally, it was decided that the larger stove should also include this lining.

Figure 21: Fire for the first burn test

Figure 22: Water boiling on cooking surface

Figure 23 Boiling from first test

Both stoves were completed for second test. Prior to any measurements or observations, both stove were burned out. The small stove was burned out again, to remove the paint from the recently added insulation. Both the smoking chamber and the cooking surface of the large stove were burned out, by separate fires. While doing this it was important to elevate on side of the smoking chamber to ensure that the fire in smoking chamber received enough oxygen, and became hot enough to burn off the paint. After the paint was judged to have been burned off of the areas that would be exposed to fire, testing of both stoves was started. Images of both stoves during testing are included below. Testing included attempts to boil water on both cooking surfaces, temperature measurements, observations of smoke removal and the smoking chamber. The primary purpose of this round of testing was to establish whether or not the stoves were ready to be used in Panama, and what improvements needed to be made to them.

Figure 24: Large stove during testing

Figure 25: Small stove during testing

For the testing of the small stove, a fire was built and the stove was placed on top of it, using the wooden handles. This was done as the stove was intended to be placed over an already constructed fire, since it is difficult to build a fire underneath the stove. After 25 minutes, water, in a small pot place on the cooking surface, had a temperature of 170 ˚F. The cooking surface temperature was measured at 350 ˚F. As can be seen in Figure X, a majority of the smoke escaped through the stove pipe, with the remainder leaking around the stove bottom.

The large stove was tested simultaneously with the small stove. The large stove could not be picked up and moved as easily as the small stove, therefore the fire had to be constructed beneath the cooking surface. While this method of fire construction was more difficult than the one used in testing the small stove, it was possible and did not detract significantly from the stove's overall utility. Similarly to the small stove, the cooking surface temperature was measured at 350 ˚F. Water, placed in a can, achieved 200 ˚F on the cooking surface. These temperature differences could be attributed to the slightly larger fire size used for the large stove, in addition to the heat funnel and the use of flaps. Inside the smoking chamber, a temperature of 250 ˚F was measured, and upon inspection the volume appeared to be smoke filled. The majority of the smoke traveled out the stove pipe as expected, with leakage occurring from the joint between the barrels and around the smoking chamber door. The smoking door was also difficult to remove from the smoking chamber while the lid was on. A hinge design has since been implemented in the hopes of resolving this issue.

It is important to note that temperatures measured depended largely on fire size and intensity. While Allie was consulted to make sure that our fires were not too big, the addition of new fuel to the fire, in conjunction with fanning would result in raised temperatures. Additionally, neglecting a fire for any period of time would result in reduced temperatures. Lastly, the stove was tested in a climate that is much cooler than that in Panama. Temperature values could be higher in Panama, due to the warmer air.

The major success from the second test was the smoking chamber. From observation made, the entire chamber filled with smoke and the grate temperature was measured at 250 ˚F. This means that the smoking chamber would definitely be suitable for smoking, and may also be able to act as a sort of oven. While not as successful, the cooking surface could also serve a purpose for the Kuna Yala. At a temperature of 350 ˚F, it could be cooked on, so long as it was kept reasonably clean. Additionally, the 200 ˚F, achieved by the pot of water would be warm enough for the Kuna Yala to make their teas and holistic medicines.

Stove Fabrication

In May of 2014, Allison McCurdy and Kevin Laux (Mechanical Engineering graduates of the University of Pittsburgh) travelled back to Panama to fabricate a stove-smoker and install the device in a Kuna cooking hut to gauge receptivity to the prototype. Successful fabrication was performed at the Technical University of Panama (Universidad Tecnológica de Panamá, UTP), where a Civil Engineering staff member, Dr. Alejandro Avendaño, was kind enough to allow two days of use his outdoor construction testing facility.

The prototype was made of 16-gauge 55-gallon steel drums, a small amount of rebar, cast iron ventilation piping, and hardware. It features a stovetop that can be placed over the traditional Kuna fire arrangement, a large smoker barrel, and ample ventilation. A complete Bill of Materials for the stove was created and an instruction manuals detailing preparation of raw stove materials as well as steps for stove fabrication was created. The fabrication methods used during this trip mirror these documents and allowed for real-time insights for improvements to the instruction manuals.

After successfully fabricating the final prototype in two days at UTP, the group brought the stove-smoker to Cangrejo Island in the San Blas. A Kuna woman who presides over a cooking hut proximal to the main docking point on the island allowed us to install the prototype and agreed to assume ownership of the device (see Figure 34.) The group made clear that the stove was built with the Kuna cooking techniques and health interests in mind and that any feedback about stove function or suggested improvements would be greatly appreciated. The Kuna husband of this woman, voiced a desire to fabricate his own stove from two 55-gallon drums he had sitting on the island outside of the cooking hut. The group returned to the prototype trial installation site before leaving the San Blas to gain initial feedback. The Kuna man reported that the smoker portion of the stove was used to make particularly crispy toast.

Figure 34: Kuna stove prototype owner

Conclusion

This project was a successful iteration of the typical design process taught by the University. After consulting various sources, functional requirements for the final design were established. Design stage considerations were carefully planned, adjusted, and ultimately carried into a prototype stage. Prototype testing of our designed stove resulted in real, usable feedback which will be considered in the next design process.

The stove project was a success. This group found ways to communicate with several parties while conducting background knowledge exploration. Our group members worked together to find possible solutions to the smoke inhalation and overcrowding issues plaguing the Kuna Yala, while preserving their current way of life. Our solutions combined into several designs and was ultimately constructed and tested. The stove allows for the smoking of food, while providing simultaneously providing a cooking surface. From the testing results, a list of areas that could be improved upon was made, with suggestions.

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