ENGINEERING CAPSTONE DESIGN SHOWCASE | SPONSOR: EL PORVENIR

ECOLOGICAL COOKSTOVE

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ABSTRACT

Current cooking practices in rural Nicaragua expose families to pollutants which contribute to respiratory health problems. The goal of our team is to design and construct an improved wood burning cookstove within the constraints of Nicaraguan environment and culture. Improvements implemented in the stove will reduce smoke emissions inside the home and reduce deforestation by lowering the amount of fuel required. Our team assembled and tested our stove prototype for efficiency. Our design will be implemented by our team in Nicaragua and written instructions will be provided to a local non-profit on how to construct and maintain the cookstove.

INTRODUCTION

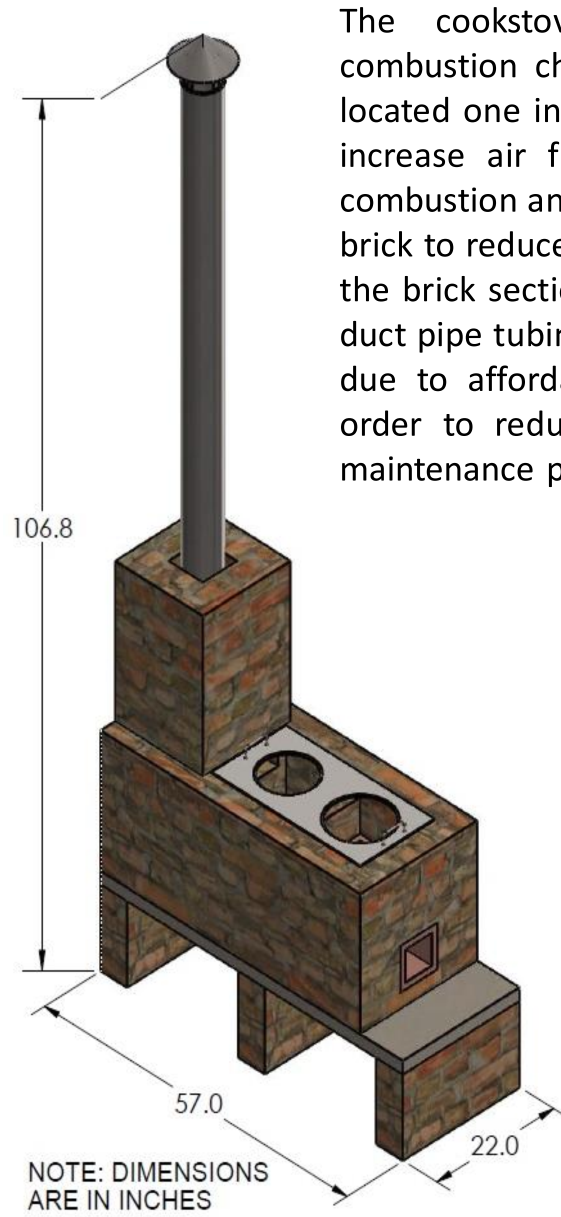
El Porvenir is a non-profit organization that has been actively helping the rural poor in the developing country of Nicaragua since 1990. They began providing an improved cookstove to local families to help move them away from use of the common three stone fire. This cookstove consists of a simple concrete body with an attached chimney and a large hole into which biomass is inserted for burning. Their stove, however, exhibits several issues. Our capstone team plans to provide this non-profit with a better stove design. Their cookstove issues include: chimney corrosion, limiting the lifespan of the stove to two years, significant heat absorption by the stove body, stealing much of the heat that would otherwise be transferred to the pots, and user misuse, where wood can be easily pushed too far back into the stove during the fueling process.

El Porvenir's current cookstove design

OBJECTIVE

- Reduce stove body heat absorption
- Improve combustion efficiency
- Achieve a more complete combustion
  - Introduce a grate to encourage air flow to achieve a higher burning, more complete combustion
- Reduce smoke emissions
- Increase longevity to 5+ years
  - Create a chimney cleaning procedure for corrosion mitigation
- Maintain affordability (less than $300 per stove)
- Guarantee of acceptance into Nicaraguan culture to assure continued use

DESIGN



Dimensioned drawing of stove design

The cookstove includes a rocket elbow style combustion chamber in which a removable grate is located one inch above the bottom of the chamber to increase air flow underneath the fuel, aiding good combustion and draft. The lower chimney is encased by brick to reduce the risk of burn injuries to users. Above the brick section of the chimney is a six inch diameter duct pipe tubing, which is the chosen chimney material due to affordability and availability in Nicaragua. In order to reduce corrosion to the metal, a chimney maintenance procedure will be provided.

Round bottom pot retention is achieved by through-holes in the quarter inch steel cooking surface. Covers can also be installed over the holes to provide a flat surface for cooking tortillas. The insulation material inside the stove body is wood ash. The ash will fully insulate the combustion chamber and provide a clear path for the heat to travel as close as possible to the surfaces to be heated. Soot will accumulate in the chimney exit chamber; therefore, there is a chimney cleanout. This cleanout can be accessed by removing the tin can lid, located on the left side of the stove.



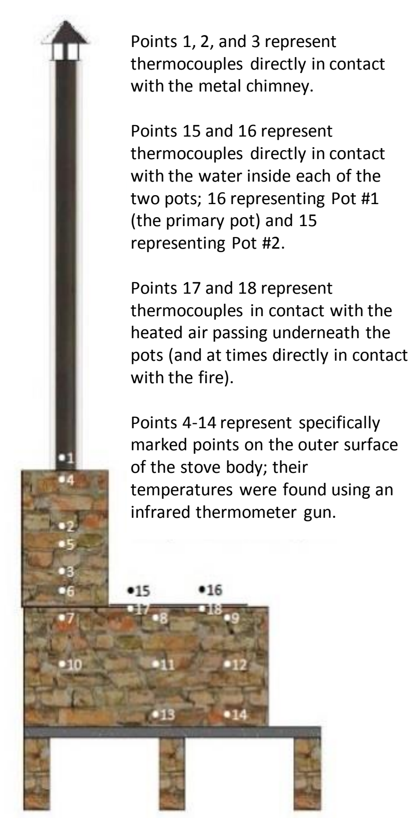


Left: Stove Body
Center top: Steel cooking surface
Center middle: Entrance to chamber showing grate
Center bottom: Round bottom pots in steel cooking surface
Right: Ash insulation of combustion chamber

HYPOTHESIS

The new design will improve combustion chamber efficiency by preventing improper fuel insertion. Using brick instead of concrete and introducing ash insulation will reduce stove body heat absorption, thereby improving thermal efficiency. A chimney cleaning procedure will provide greater corrosion resistance within the Nicaraguan climate. The introduction of a grate will allow air flow for the heating process, resulting in a more complete combustion. Keeping a constant cross sectional flow area throughout the stove will provide a good draft.

METHODS



Temperature distribution points

The Water Boiling Test:

- Cold Start Phase: Start with stove at ambient temperature. Bring 2.5 liters of water from ambient temperature to a boil.
- Hot Start Phase: Start with an already warm stove. Bring 2.5 liters of water to a boil.
- Simmer Phase: Simmer water for 45 minutes at 97 degrees Celsius[2]
- For each test: Record time, wood consumed, and amount of water evaporated

Each test was performed three times in order to ensure accuracy of results[1]

Temperature Collection Test:
Temperature was measured at 18 different points throughout Phase 1 and Phase 2 of the water boiling test, using K-type thermocouples and a Fluke infrared thermometer gun.

RESULTS

Table 1: Temperature Distribution

STOVE TEMPERATURES			
Location on Stove		Maximum Temperature (°F)	Average Temperature (°F)
Combustion Chamber	Under Pot 1	1404	1028
	Under Pot 2	910	662
Stove Body	All Test	119	67
Chimney	Surface (Brick)	126	75
	Pipe (metal)	370	161

Table 2: The Water Boiling Test

BOILING TEST RESULTS					
Data Results		Test 2 (Cookstove)	Test 3 (Cookstove)	Test 1 (Open Fire)	Test 2 (Open Fire)
Time to Boil Pot 1 (min)	Cold Start	14	29	58	23
	Hot Start	14	15	--	--
Thermal Efficiency (%)	Cold Start	15%	14%	9%	9%
	Hot Start	17%	16%	--	--
	Simmering	8%	15%	7%	7%
Dry Wood Consumed (g)	Cold Start	781	1017	1928	1572
	Simmering	1901	2176	3045	3019

CONCLUSIONS

The Ecological Cookstove proved to be a success over the traditional three stone cookstove, commonly used by rural Nicaraguans today. Upon arrival in-country, the El Porvenir stove will be tested and compared to our design.

- Our cookstove design achieved a 39% increase in thermal efficiency, when compared to a three stone open fire, due to the insulation, draft, combustion chamber, and interior dimensions.
- Our cookstove design reduced wood consumption by 41%.
- A cleaner combustion was achieved, as could be noted from the negligible amount of visible smoke exiting the chimney.
- The grate functioned by improving draft, resulting in a more complete combustion

BIBLIOGRAPHY

1 Bryden, M. (2005). *Design principles for wood burning cook stoves.* Washington, DC: U.S. Environmental Protection Agency, Office of Air and Radiation.

2 MacCarty, N., Still, D., & Ogle, D. (2010). Fuel use and emissions performance of fifty cooking stoves in the laboratory and related benchmarks of performance. *Energy for Sustainable Development, 14*(3), 161-171.

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