Aprovecho Research Center
Advanced Studies in Appropriate Technology Laboratory
79093 Highway 99, PO Box 1175
Cottage Grove, Oregon 97424 USA
541-767-0287
www.aprovecho.org

Testing Results of Estufa Finca

By Mike Hatfield, Ryan Thompson, Sam Bentson
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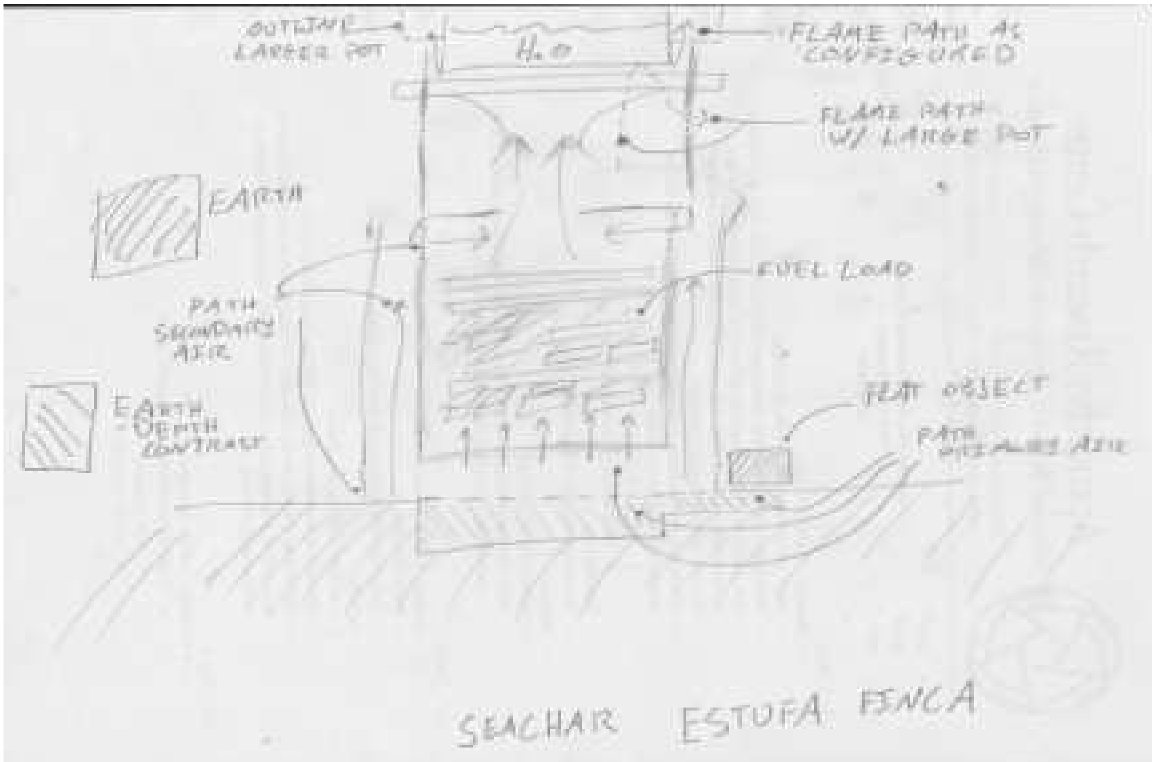
Introduction

The design of the Estufa Finca TLUD (top light up-draft), developed by SeaChar, draws from the work of Dr. Tom Reed, Dr. Paul Anderson, and many others who have applied gasification techniques to low cost cook stove technology. The central idea behind gasification is to separate the gasses from the heated biomass and burn them efficiently in a separate "pyrolysis front". Gasifiers are known to leave behind charcoal that can be removed as a "value added" product. SeaChar promotes this produced charcoal as a soil amendment.

The Estufa Finca Stove

The Estufa Finca consists of a 20-liter can combustion chamber surrounded by shell of galvanized roofing. The shell preheats and channels secondary air into the combustion chamber. It also acts as a heat shield that keeps the combustion chamber hot and the exposed surface of the stove cool. A riser made from a coffee can is attached to the top of the combustion chamber. A stable pot support fits over the riser. An Altoids can attached to the bottom of the stove acts as the primary air control door. The reported results are for this initial design, even though numerous iterations were investigated.

The field design does not include the Altoids can. To provide primary air in the field, where Altoids cans are not readily available, the stove is placed over a pit and an approximately 4" wide channel is made to extend the pit past the radius of the stove. The primary air stream is controlled by partially blocking the channel with a flat object. A sketch is provided below.



Sketch of Estufa Finca showing primary air path for the field model.

The Estufa Finca is versatile at burning biomass. Practically any size, shape, or type of fuel can be burned. This is possible because of the size of the combustion chamber and the primary air control. The combustion chamber is large enough that sticks and twigs can be easily loaded into the stove, as well as small pieces of biomass such as pellets, chips, and shells. Good control of the primary air intake allows the stove to be tuned to burn the many different types of biomass.

Testing Methodology

The stove was tested under the Aprovecho portable emissions collection hood, in which real-time emissions of CO_2, CO, and PM_{TSP} were recorded. The system also measured the flow rate of the diluted exhaust gases, enabling mass-based calculations of the emissions produced during the test.

Emissions Measurement Hood

The Estufa Finca was tested using the UCB Water Boiling Test (WBT). The first phase of the test consists of a high-power analysis in which 5 Liters of water are brought to a boil in an uncovered 7 Liter pot. In the low power phase of the test, 5 Liters of water are simmered at about 3 degrees C below full boiling temperature for 45 minutes. The stove was tested using sticks (approximately 1 cm X 4 cm by 15 cm long) of kiln-dried Douglas fir at 11.2% moisture content (on a wet basis).

Aprovecho has been designing, testing, and helping to disseminate improved stoves for the past 20 years. Over 100 cooking stoves from around the world have been tested in the Aprovecho Laboratory in the last several years using this standard testing protocol. Based on this extensive library of tests, Aprovecho has developed suggested "benchmarks" of stove performance. These benchmarks help to define the performance of a truly "improved" cooking stove. Three key benchmarks have been established for the performance measures of fuel use, production of carbon monoxide (CO), and production of particulate matter (PM).

While benchmarks are a great way to make a global standard for defining improved stoves, inherent generalizations can make the evaluation less pertinent for what we will find when the stove is introduced into the field. For that reason, when applicable, we often site other tested aspects of the stove, that when combined with in-field data, will give another aspect of evaluations. For the Estufa Finca, it is useful to consider the specific emissions per fuel use. This data can be combined with an evaluation of fuel use in the field to project potential emissions reductions of the stove compared to the 3 stone fire.

Results

Fuel Use

The Estufa Finca is a very powerful stove. The average power output during the high power phase of the WBT was recorded as high as 14,000 W, which is equivalent to the power output of a 60 liter institutional stove. A regular household rocket stove is more on the order of 4,000 W. The power output of the Estufa Finca is a little excessive for the 5 liter WBT. As a result, the stove had relatively high fuel consumption for this particular cooking task, and it did not meet the benchmark for fuel use.

Emissions:

The emissions of the Estufa Finca are extremely low. Aprovecho has set clean cookstove benchmarks for emissions at 20 grams of CO and 1500 mg of PM to complete the simulated cooking task of the WBT. While it produced an average of 26 grams of CO in our tests, we found that the Estufa Finca is capable of meeting the CO benchmark (having produced 14.1 and 17.2 g CO in two of the tests). The stove easily exceeded the PM benchmark, producing an average of 573 mg of PM (one third of the benchmark). It is remarkable that such a high power stove is capable of meeting the benchmarks for emissions for a test intended for lower power stoves.

Specific Emissions per Fuel Use:

As noted earlier, the benchmark standards don't always give the best indication of what is going to happen in the field once the stove is used for a particular cooking process. It is useful to evaluate the emissions of the Estufa Finca by considering the specific emissions per fuel use. This data can be combined with an evaluation of fuel use in the field to project potential emissions reductions of the stove compared to the 3 stone fire.

The PEMS gives us the following results for specific emissions per fuel use:

Emission per kg Fuel							
Test #		1	2	3	4	Average	3 Stone Fire*
g CO / kg dry fuel consumed	CO g/kg	10.50	4.78	12.91	4.78	8.24	49.83
g PM / kg dry fuel consumed	PM g/kg	0.23	0.06	0.23	0.21	0.1832	2.1142

*Note: not a three stone fire in Costa Rica.

It should be noted that the scatter around the data points of the tests was large. The coefficients of variation are 49% and 44% for CO and PM, respectively. To gain a reasonable coefficient of variation, more tests will need to be performed.

Now that we have results for emissions per consumption of fuel wood, we can evaluate the possible emissions of this stove versus an open fire once fuel consumption for the two stoves is determined in the field. **If, in the field, the Estufa Finca uses the same amount of fuel as the 3 stone fire, then we can project an 83% reduction in CO emissions and a 91% reduction in PM emissions. If the Estufa Finca uses less fuel than the 3 stone fire in the field, the projected reductions in emissions will be even greater.**

Conclusions and Recommendations:

As mentioned earlier, the Estufa Finca is versatile at burning biomass. Practically any size, shape, or type of fuel can be burned cleanly. The stove also has remarkably low emissions. Tests done under the emissions hood showed that, by adjusting the intake air often during the cooking task, an experienced user can dramatically decrease the stove emissions even further.

Part of SeaChar's purpose is to create a stove that produces charcoal as a by-product. The Estufa Finca had an average charcoal yield of 10% when performing the WBT. The charcoal yield is defined as the mass of charcoal produced compared to the mass of fuel loaded into the stove. However, the stove is capable of producing a much higher charcoal yield. During the WBT, the stove converted wood into charcoal throughout the boiling phase and into the simmer phase of the test. Once all the wood was converted to charcoal, the stove then consumed a considerable amount of that charcoal to complete the simmer phase of the test. If the charcoal was quenched as soon as all the wood was converted, the charcoal yield would be considerably higher.

The high firepower of the stove may make it less applicable to small family sized cooking. For low power applications, we recommend experimenting with a smaller combustion chamber. Also, we recommend continuing to experiment with the design of the stove top and pot supports (optimize channel gaps) in order to maximize the heat transfer to the pot. We look forward to seeing the field performance and future improvements to this great stove.

For further questions about this report, please contact Sam Bentson, Laboratory Manager, at sbentson@aprovecho.org