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Results of Fuel Use and Emissions Testing
Original and Improved Pot Supports
For the CleanCook Alcohol Stove

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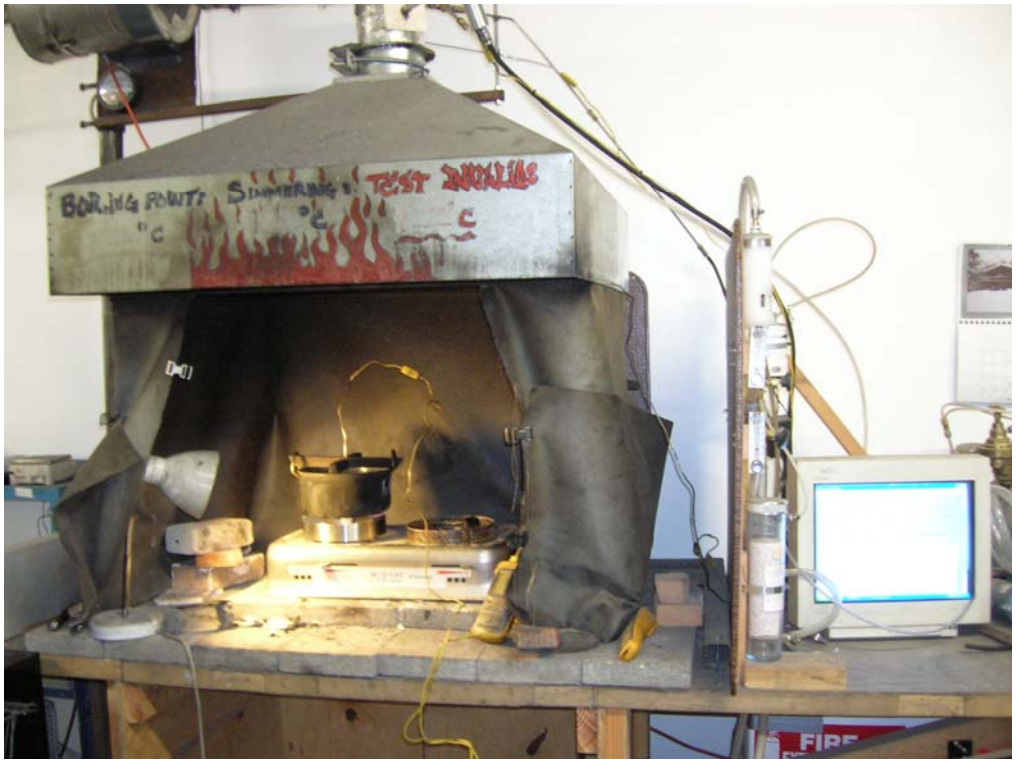
Introduction

The original CleanCook alcohol stove was received from Harry Stokes in 2004. The original stove was tested under the laboratory emissions hood and found to be slightly underpowered and relatively high in emission of CO. As reported by Mr. Stokes in Brazil this October, the Dometic lab had recently identified incomplete combustion and CO production due to the design of the pot supports. The supports were redesigned and sent to the Aprovecho laboratory for testing in December of 2006.



The CleanCook stove was tested under the Aprovecho laboratory Emissions Hood using the Water Boiling Test. The 2003 University of California at Berkeley revised Water Boiling Test protocol was followed using denatured Alcohol for fuel. The fuel was assumed to have a higher heating value of 22,690 kJ/kg. The same fuel canister was used for each test with fresh fuel added to minimize variation due to the condition of the canister. The new standard testing pot for lower powered stoves was used without a lid, holding 2.5 Liters of water.

The goal of the testing procedure was to determine if there was an improvement by comparing the performance of the stove with the old and the new pot supports.

In general, three tests per stove are recommended for statistical validation. The variation between these three tests was within accepted range of variability for cooking stoves. The coefficients of variation (standard deviation divided by average) for Time, Fuel and CO were generally excellent.

Table 2 – Coefficient of Variation of Test Results

	Original Supports	**Improved Supports**
COV Time	2%	4%
COV Fuel	4%	6%
COV CO	24%	5%
COV Firepower	6%	4%

Stove Testing Results

Results of stove testing are presented in the following order:

1. Time to Boil, Fuel Use, and Firepower
2. Discussion of Carbon Monoxide Emission
3. Testing without the Flame Spreader
4. Performance with Standard 5L testing pot
5. Safety Score

1. Time to Boil, Fuel Use, and Firepower

The following chart shows the performance of the CleanCook stove with both the new and old pot supports. Three tests of each were performed.

Chart 1 – Stove Performance

		Old Supports	New Supports	New/Old
Time to Boil	min	21	17	82%
Fuel to Boil	g/L	34	30	89%
Boiling Firepower	Watts	1322	1460	110%
Fuel to Simmer	g/L	46	53	114%
CO to Boil	g/L	1.7	0.6	39%
CO to Simmer	g/L	1.5	1.3	87%

The new pot supports increase the firepower of the stove by 10%. The increased firepower results in an 18% reduction in the time to boil 2.5 liters of water, and 11-13% reduction in fuel use for both boiling and simmering tasks. Because of the reduced CO emissions and reduced fuel use, overall CO emission to complete a boiling task is reduced 61%.

2. Carbon Monoxide Emission

During the test, the average concentrations of CO in the diluted stack of the emissions collection hood was as follows:

Chart 2 – CO Emissions in ppm

CO (ppm)	Old Pot Support	New Pot Support
High Power	100	50
Low Power	25	20

Because the firepower is increased and time to boil is reduced by 18%, the CO emission per task completed is further reduced by a combination of both of these factors.

3. Testing without the Flame Spreader

One additional test was run at high power to determine if the flame spreader was further contributing to CO emission. The new pot support was used on a burner with the flame spreader removed completely. Results showed that the spreader seems to have no effect on either the heat transfer or combustion efficiency of the stove.

Chart 3 – Comparison with and without Flame Spreader using New Pot Support

		Without Spreader	With Spreader
Time to Boil	min	17.6	17.4
Fuel to Boil	g/L	29.3	30.1
Boiling Firepower	Watts	1408	1460
CO to Boil	g/L	0.67	0.65

4. Performance with the 5L Standard Testing Pot

If a stove is able to boil 5 Liters of water in the larger standard testing pot, this larger pot should be used for standardized testing and comparison. Since the stove with new pot supports was able to boil this amount of water, the performance of the CleanCook can be compared to other stoves.

Chart 4 – Standard Performance Measures with the 5L Standard testing pot

Standard Performance Measures		Kerosene	Propane	**CleanCook**	Benchmark	Benchmark Met by CleanCook ?
Fuel to Cook 5L	g	223	140	**317**		
CO to Cook 5L	g	8	1	**5.3**	20	YES
PM to Cook 5L	mg	10	5	**4**	1500	YES
Energy to Cook 5L	kJ	9704	6670	**6766**	15,000	YES
Time to Boil	min	42	23	**32**	-	

Results are presented in comparison to Kerosene and Propane burned in traditional stoves for these fuels. The CleanCook uses less fuel, time, and produces less emissions to complete a cooking task than Kerosene. It does use more time, fuel, and produce more CO than propane, as expected, perhaps due to the un-pressurized burning in the alcohol stove.

The CleanCook now boils 5L in the uncovered standard testing pot in 32 minutes, emitting only 5.3 grams of CO in the process. PM emissions from the stove are negligible, as the 4 mg is likely caused by the match.

This data has been updated in the publication "Comparing Cooking Stoves" which is going to print in the next few months. We are happy to be able to report a stove that successfully boils 5L in the standard testing pot, as the stove with previous pot supports did not.

Proposed Benchmark for Wood-Burning Cook stoves without Chimney

1.) **Fuel use**: Using the International Testing Pot a wood burning stove without a chimney should use less than 850 grams of wood to bring to boil 5 liters of 25 degree C. water and then simmer it for 45 minutes during the UCB revised Water Boiling Test.
2.) **Emissions**: The wood burning stove without a chimney should produce less than 20 grams of Carbon Monoxide to boil 5 liters of 25 degree C. water and then simmer it for 45 minutes during the UCB revised Water Boiling Test.
3.) **Emissions:** The wood burning stove without a chimney should produce less than 1500 milligrams of Particulate Matter (2.5 microns or smaller) to boil 5 liters of 25 degree C. water and then simmer it for 45 minutes during the UCB revised Water Boiling Test.

5. Safety

The stove is well designed for safety. The stove was evaluated by and based on the safety protocol suggested by Nathan Johnson of Iowa State University.

Chart 5 – Safety Score

Test	CleanCook Score out of 4	Name
1	4	Sharp Edges/Points
2	4	Cookstove Tipping
3	4	Containment of Combustion
4	4	Expulsion of Fuel
5	4	Obstructions Near Cooking Surface
6	4	Surface Temperature
7	4	Heat Transfer to Surroundings
8	4	Cookstove Handle Temperature
9	4	Flames/Heat Surrounding Cookpot
10	3	Flames/Heat Exiting Fuel Chamber

Total Un-weighted Safety Score = 39/40

Conclusions and Recommendations

1.) The new pot support successfully increases the combustion efficiency of the stove, both increasing the firepower and decreasing CO emissions.

For further information, please feel free to contact Nordica MacCarty, Aprovecho Laboratory Manager, at nordica.maccarty@gmail.com