INTERNATIONAL CENTRE FOR ENERGY, ENVIRONMENT & DEVELOPMENT

EFFICIENT 100 AND 200 LITRES INSTITUTIONAL WOOD COOKSTOVES

Design

The stove is made with metal/bricks combustion chamber and stainless steel body. A fuel door with air holes is provided together with a tension-bar mild steel fire grate to ensure air inlet from below and optimum firewood burning. A chimney is provided to ensure all the smoke generated is taken out of the kitchen. The pot is a sunken type made of thick stainless steel that ensures durability. The sunken nature of the pot ensures the pot makes maximum contact with the flue gases. The bricks lined inside the stove are topped up with a thin layer of vermiculite mixture, a highly insulating material which ensures the external temperature of the stove remains cool no matter the number of hours of operation. This also insulates the heat thus ensuring that most of the heat generated by the stove is utilized by the pot.

The following materials are used in producing the stove and pot:

- Stove – 0.5 mm stainless steel body, 3mm mild steel top ring, 1.5mm fuel door with air holes, bricks lining, 25mm mild steel fire grate, vermiculite/cement mixture and chimney parts made from 0.5mm galvanized steel.
- Pot – 3mm stainless bottom, 1.5mm stainless body, 3mm aluminium cover and 3mm stainless steel handles.

Benefits of the stove

The stove offers the following benefits:

i. Burns at least 80% less wood when compared to traditional 3-stone and metal tripod stoves thus ensuring 80% wood and cost savings for consumers;
ii. Completely eliminates smoke from the kitchen thus ensuring improved health for users;
iii. Cooks at least 30 minutes faster than traditional 3-stone and metal tripod stoves;
iv. Stove is produced from 100% locally sourced materials thus ensures domestication of production;
v. Reduces deforestation;
vi. At least 1 years guarantee (can last for more than 10 years).
vii. Amortization period is between 6 to 8 months.

PERFORMANCE RESULTS (LABORATORY BASED)

Designed in 2016, the stove was subjected to laboratory tests at the ICEED Clean Energy Development Centre in Afikpo, Ebonyi State on November 2016. The tests were carried out using the latest version of the Water Boiling Test WBT4.2.2 in accordance with the ISO International Working Agreement (IWA). The Water Boiling Test includes three phases - a Cold Start, Hot Start, and Simmer. During the Cold and Hot Start phases, the tester brings the stove to a boil operating the fire at a constant rate. The Simmer phase requires the operator to maintain the water temperature three degrees below boiling temperature, assuring the water does not fall six degrees below boiling temperature.

The test was conducted with 25 litres of water in a 200 litres capacity stainless steel flat bottom pot. The stove is made of stainless steel body with refractory bricks lined on the inside. The walls of the bricks lining is topped with vermiculite/cement mixture to provide added insulation. The fuel used was native wood types, readily available in the vicinity of the testing laboratory with a higher heating value of 17000kJ/kg; moisture content of about 15% and average size of 5.0 x 5.0 x 30.0 cm. The WBT was carried out three (3) times to assure statistical validity.

The stove is the fixed type with a diameter larger than the emissions monitoring hood. Therefore, the emissions system was not used. The test adopted the abridged version where the initial and final weights of fuelwood will be noted, the initial and final weights and temperature of water also noted. In this case, apart from the thermal efficiency which was calculated manually, the time to boil, as well as mass of fuelwood needed to boil the water were reported. Since the emissions reduction is directly proportional to the fuelwood reduction, it will be assumed that stoves that reduce fuelwood use also reduce emissions.

Overview of Reporting Metrics

The International Organization for Standardization (ISO) International Workshop Agreement (IWA) testing and rating system of the IWA was approved in February 2012 at an international workshop held in The Hague, Netherlands. The rating system defines “tiers” of performance in the areas of fuel efficiency, emissions of fine particulate matter (PM 2.5) and carbon monoxide (CO), and safety. Each

area is ranked separately on a scale of Tier 0 – Tier 4, Tier 0 being the baseline or unimproved stove, and Tier 4 being the aspirational goal. Definitions of the Tiers are shown in the table below:

Definition of IWA Tiers	units	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
High Power Thermal Efficiency	%	< 0.15	≥ 0.15	≥ 0.25	≥ 0.35	≥ 0.45
Low Power Specific Consumption	MJ/min/L	> 0.05	≤ 0.05	≤ 0.039	≤ 0.028	≤ 0.017
High Power CO	g/MJd	> 16	≤ 16	≤ 11	≤ 9	≤ 8
Low Power CO	g/min/L	> 0.2	≤ 0.2	≤ 0.13	≤ 0.1	≤ 0.09
High Power PM	mg/MJd	> 979	≤ 979	≤ 386	≤ 168	≤ 41
Low Power PM	mg/min/L	> 8	≤ 8	≤ 4	≤ 2	≤ 1
Indoor Emissions CO	g/min	> 0.97	≤ 0.97	≤ 0.62	≤ 0.49	≤ 0.42
Indoor Emissions PM	mg/min	> 40	≤ 40	≤ 17	≤ 8	≤ 2
Safety	Index	< 45	≥ 45	≥ 75	≥ 88	≥ 95

Fuel Efficiency -- For the fuel efficiency metrics, the high power thermal efficiency is the ratio of the energy absorbed by the water in the pot to the energy released by the fuel consumed during the test. If a Cold Start and Hot Start are both performed they are averaged to find the high power result. For low power, the ISO IWA reports specific fuel consumption as fuel consumed divided by water remaining after the duration of the simmer phase.

Emissions – Emissions measured are carbon monoxide (CO) and particulate matter less than 2.5 µm (PM2.5). Two categories of metrics are reported for each, total emissions and indoor emissions. For high power total emissions, the metrics are based on energy delivered to the cooking pot. For low power total emissions, the metrics are specific to the amount of water remaining and the length of the simmer period. Indoor emissions are displayed in emissions rates - mass of pollutant over time. As earlier stated, the stove was not tested using the LEMS, however, any reduction in wood consumption is directly proportional to reduction in emissions.

Test results

The tables below show the results obtained after testing the stove

Table 1: IWA and Standard Performance Measures

Metrics	Unit	Test 1	Test 2	Test 3	Average
High Power Thermal Efficiency	%	63.3	56.1	50.5	56.6
Low Power Specific Consumption Rate	MJ/min/L	0.023	0.070	0.075	0.056
Fuel to Cook 25L (850/1500)	G	989.1	1726.1	1775.5	1496.9
Energy to Cook 25L (15,000/25,000)	kJ	15,509	27,076	27,840	23,475
Time to Boil (temp-corrected)	Min	51.0	56.1	50.2	52.4
Temp-Corrected Specific Consumption	g/L	132.7	144.6	141.0	139.4
Temp-Corr Specific Energy Consumption	kJ/L	2080.9	2268.0	2211.1	2186.7
Firepower	W	15592	17430	17,393	16,805
Thermal Efficiency	%	63	56	50	56.3
Cooking Power	kW	9.57	9.62	7.94	9.04

Table 2: Stove performance in Tiers

Metrics	Tier			
	Test 1	Test 2	Test 3	Average
High Power Thermal Efficiency	4	4	4	4
Low Power Specific Consumption Rate	3	0	0	1
Thermal Efficiency	4	4	4	4

Summary of results

The thermal efficiency of the stove averaged at **56.6%** for the high power test with coefficient of variability of **12.37%** over the three tests. This result means the stove achieved Tier 4 thermal efficiency rating. The test was carried out using standards developed by Aprovecho Research Centre and adopted by the Global Alliance for Clean Cookstoves. The testing laboratory encourages independent laboratories to carry out tests on the stove where required.

The average value of the Low Power Specific Consumption over the three tests was **0.05** MJ/min/L, which corresponds to Tier 1. The average fuel consumed to cook 5L of water was **1497** g only. The overall performance of the stove is far above average. However the laboratory warns that lab-based results are often times different from field results since tests conducted in the laboratory are done under controlled conditions.

HEAT RETENTION COMPARISON

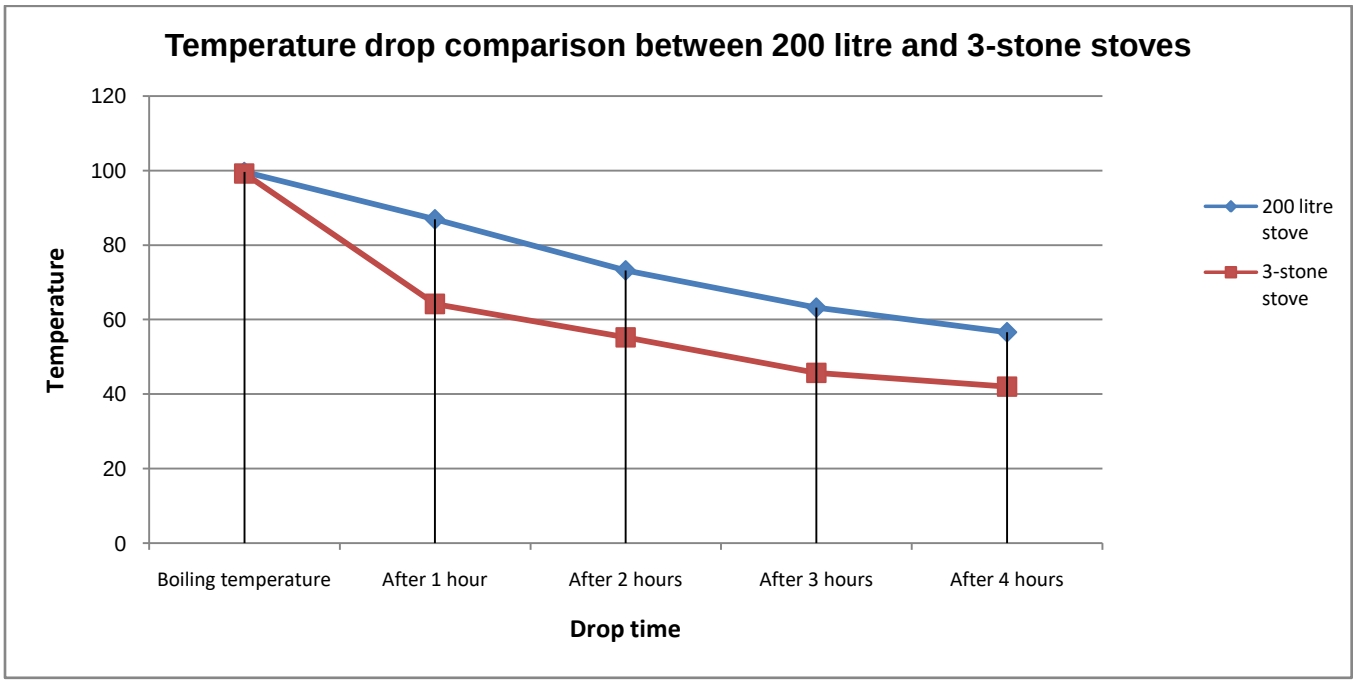
To compare the heat retention properties of the 200 litre stove when compared with traditional firewood stoves, the laboratory carried out tests on the stoves. The tests involved bringing 25 litres of water to boil with the pot covered and thermocouple probe inserted inside the water. After boiling, the time is noted and the firewood and embers removed completely. The temperature of the water is monitored over the next four hours and the readings in the thermocouple noted. In all the tests, the pot remains covered. In addition, the tests were conducted indoors to ensure minimal influence of external conditions on the rate of cooling of the stoves.

Test results

The table below shows the readings obtained from the two stoves:

TIME	TEMPERATURE (200L)	TEMPERATURE (3-STONE)
Boiling temperature	99.6	99.2
After 1 hour	86.9	64.2
After 2 hours	73.2	55.2
After 3 hours	63.2	45.7
After 4 hours	56.6	42.0

This is represented in the chart below



From the table and chart, it is estimated the stove has a heat retention capacity that is about 3 times the capacity of traditional stoves. This implies that the stove can keep cooked food hot or warm for an extended period beyond the capacity of traditional stoves.