CEDESOL
CENTRO DE DESARROLLO EN ENERGÍA SOLAR

Summer 2006 CEDESOL Testing Procedures
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Introduction

Over the course of the next two months, several tests will be conducted in order to find out the thermal efficiency of different rocket stoves. In co-operation with the ETHOS program at University of Dayton and the CEDESOL foundation in Cochabamba, Bolivia, we have been given this opportunity to examine and improve upon efficient ways to use rocket stoves. We used a version of the well-known procedure Water Boiling Test (WBT) which was developed by the Household Energy and Health Program at the Shell Foundation. This test serves as a simple and effective means of comparison between different types of stoves. The goal of these tests is to provide these outputs:

- time to boil
- thermal efficiency
- firepower

Once these values have been found, practical cooking methods will be tested using common foods.

Week 1

During the first week, water boiling tests were performed in order to find the local boiling point and amount of time it takes to bring water to a boil. Several more tests will need to be done in future weeks in order to obtain more accurate results for firepower and thermal efficiency. Due to lack of equipment, accurate results could not be found for all parts of the WBT. The main objective for this past week was to familiarize ourselves with test procedures and possible pitfalls. The local boiling point was found to be between 91-91.5°C. Most tests performed were on the basic CEDESOL rocket stove, and in weeks to come tests will continue to be preformed on these stoves and also the CEDESOL two burner rocket stove. Attached is an appendix of the equations that we will use to form our data once we perform enough tests to substantiate results. We have attached some pictures of our past week's work. We will have updates of our work posted weekly.

This is the setup before starting the WBT. The parameters for this test are 5L of water, start with 2 kg of wood, and check the initial temperature of the water like we are doing above.

The thermometer is to be kept about 5 cm from the bottom of the pot in the center. This position will provide the best temperature reading for the water in the pot.

The water will begin boiling at around 91°C.

A rolling boil will start somewhere between 91-91.5°C. Temperatures have been as high as 91.9°C, which seems to be the highest temperature we can reach at our altitude.

After the water reaches a boil, the unburned wood (above) and charcoal (below) are weighed separately. These weights will be used to determine our power and energy calculations.

The water must also be weighed out in order to see how much evaporated as a result of the boil.

For the simmer test, once the fire is started then the wood is pulled back out and a low flame is kept where only one or two pieces (as seen below) need to be added in order to keep the pot simmering for 45 minutes.

This has been our tests for the past week. We hope to have more accurate results after performing the test more this and next week.

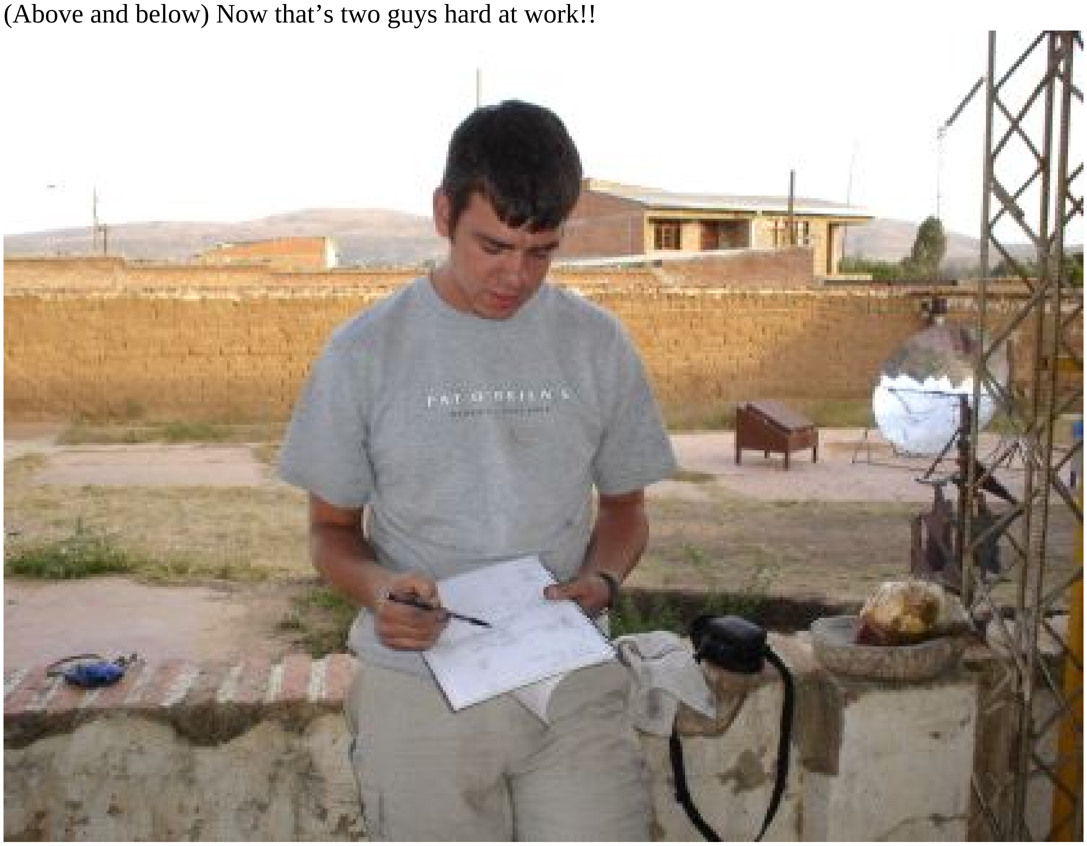
We will also be doing considerable work with **solar cookers**, including participating in different hands on construction workshops directed by **Sobre la Roca**, a Bolivian micro enterprise that receives technical support from CEDESOL.

A second ETHOS team will be in Bolivia for 6 months specifically to work with Sobre la Roca. More about can be found at this web address
http://www.udnews.org/2006/05/graduates_aim_t.html#more

CEDESOL promotes the combined use of rocket type stoves, and various models of solar and retained heat cookers. We will be involved in testing all of these stoves, their fabrication, suggesting improvements at every level and will participate in some of the hands on construction workshops in different parts of Bolivia.

Last year ETHOS took a Sobre la Roca ULOG solar cooker "kit" back to the University of Dayton, assembled it and used it in preparing volunteers for stove work. Here is a picture of that solar cooker.


(Above and below) Now that’s two guys hard at work!!



Notice the 2 solar cookers in the background. One is an ULOG style box cooker and the shinny one is an SK-14 parabolic cooker

In the next couple of weeks we will be testing the two burner rocket stoves (seen above). We will be performing different tests using one burner and some with both burners at the same time. Eventually we will also be performing tests on the industrial cooker (seen at left) that uses a 100 L pot.

Appendix A: Equations used to calculate Firepower and Thermal Efficiency

$$Energy = \frac{100(20) - 2.4(54 + \frac{M}{100})}{100 + \frac{M}{100}}$$

Figure 1.1 Energy in MJ/Kg.
Where M is the Moisture content of the wood fuel, here assumed at 12% (because it is kiln dried pine).

$$\eta = \frac{\Delta T C_p M_w + M_v H_f}{(M_{\alpha i} - M_{\alpha f})Energy_\alpha - (Energy_c (M_c)}$$

Figure 1.2 Efficiency equation for high power tests
Where T is temperature, Cp specific heat capacity of wood (4168 J /Kg°C), Mw is the initial mass of the water, Mv is the mass of water vapor, and Hf is the enthalpy of water (2.33×10^6 MJ/Kg), $M_{\alpha f}$ is mass of unburned wood, $M_{\alpha i}$ is the initial mass of wood, $Energy_\alpha$ is the energy of content of the wood, $Energy_c$ is the energy content of carbon, and M_c is the mass of charcoal generated.

$$\eta = \frac{\Delta T C_p M_w}{(M_{\alpha i} - M_{\alpha f})Energy_\alpha - (Energy_c (M_c)}$$

Figure 1.3 Efficiency equation for low power test

$$P = \frac{\Delta T C_p M_w + M_v H_f}{t}$$

Figure 1.4 Power equation
Where t is time elapsed in seconds

Figure 2 Initial Test Results

Date	Stove	Test	**Efficiency(%)**	**Power(Kw)**	time(min)	$Water_i$(g)	$Water_f$(g)	vapor(g)	$Wood_i$(g)	$Wood_f$(g)	used(g)	Char(g)	$Temp_i$	$Temp_f$
06/5/06	2 burner left	cold	34,70%	1,86	21	5000	4691	309	1000	596	404	26	13,7	91,5
	2 burner right	cold	25,52%	1,49	23,5	5000	4794	206	1000	510	490	30	13,7	91,4
	2 burner both	cold	29,66%	3,34	22,25	10000	9485	515	2000	1106	894	56	13,7	91,45
	left	hot	26,31%	2,05	17	5000	4798	202	600	120	480	34	13,9	91,3
	right	hot	24,99%	1,93	17,5	5000	4828	172	588	96	492	36	13,6	91,3
	both	hot	25,64%	3,98	17,25	10000	9626	374	1188	216	972	70	13,75	91,3
06/6/06	**rocket**	cold	24,39%	1,85	17,5	4500	4312	188	1000	512	488	38	11,7	91,7
		hot	21,43%	2,25	14	5000	4908	92	1112	554	558	54	11,7	91,6

Results will be will be averaged after more tests are made and experience in administering the procedures acquired.