Report

On

The Performance of the Safety Stove Mark IV

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Introduction

The Safety Stove is being developed to burn ethanol gel for cooking in low-income homes. The developer has tested several variants. We tested Mark III recently. Our report showed that it generated somewhat excessive combustion products at the highest power output tested, and that it was somewhat unstable at the low power settings needed to simmer while cooking. The developer revised the design and produced a prototype of Mark IV which he submitted for test on 13 September 2007. It is the purpose of this report to describe the results of the tests.

Test protocol

The test protocol was identical to that employed in testing the Mark III. The stove was lit, operated at full power until it appeared to be stable. A pot containing about 1.5 litres of water placed on it. The water was brought to the boil, and the mass of fuel consumed was measured every minute. Once the water was boiling vigorously, the mass of fuel consumed and the mass of water boiled off as steam was measured every minute for about 10 minutes. The emissions were then measured by replacing the lid of the pot with a hood to divert the steam from the measuring apparatus and collect the combustion products. The stove power was then reduced, the pot lid replaced, and the test repeated at the lower power.

Results

The prototype was slightly imperfect, as the outer part of the burner head did not quite match the inner part, and manual adjustment was difficult. Once adjusted to a high-power setting that had proved stable on the Highveld, the stove settled down, but produced a significantly larger flame than had been observed on the Highveld, and it was apparent that combustion was not quite complete because the edges of the flame were yellow and there was a "burned ethanol" odour. Although it was recognised that the change in altitude was probably responsible for the differing performance, it was decided to proceed with the tests, but to do an additional test with the flame reduced to approach more closely the optimum performance.

The results of the fuel consumption during the boiling test are shown in Figure 1. It took about 14 minutes to boil 1.5 litres of water, but the fuel consumption rose from about 2.8g/min at the outset to about 3.7g/min at the end. The average power output was 1.3kW for a gel with an LHV of 23.55MJ/kg. [1]

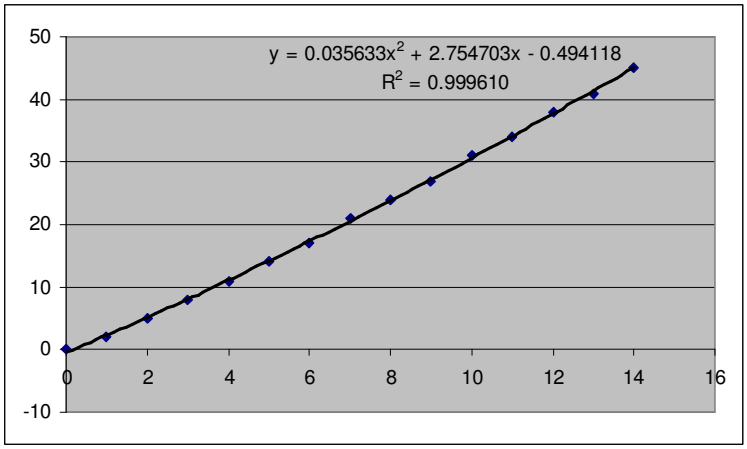

Figure 1. The results of the boiling test

[1] Note that this is somewhat higher than reported in the test of the Mark III. We found an error in our calculation of the LHV which has been corrected. The HHV should be measured in the laboratory.

The results of the efficiency test at high power are shown in Figure 2. The fuel consumption was 3.69g/min, and 21.3g/min of steam were produced. This represents a gross power of 1.45kW, a net power into the pot of 0.800kW, and an efficiency of 55.4%.

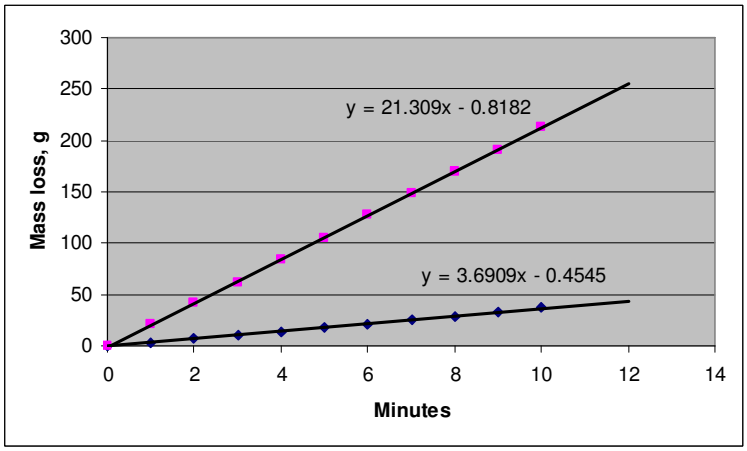

Figure 2. Results of efficiency test at high power

The results of the efficiency test at low power are shown in Figure 3. The stove behaved very stably during this test, which was a marked improvement on Mark III. The fuel consumption was 1.42g/min and the steam produced was 7.94g/min. This is equivalent to a gross power of 0.577kW, a net power of 0.299kW, and an efficiency of 53.7%.

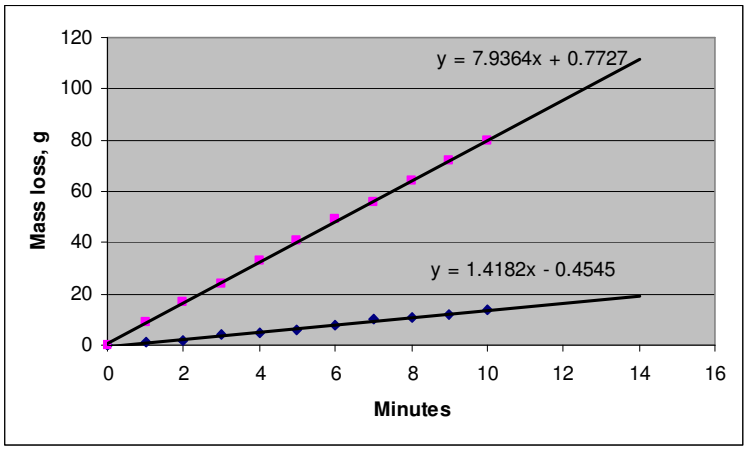

Figure 3. Results of the efficiency test at low power

The results of the repeated test at slightly below peak power are shown in Figure 4. The flame colour was reasonably blue, although there was a hint of yellow indicating slightly incomplete combustion, and a slight "burnt ethanol" smell – but not as noticeable as in the first, higher power, test. 2.92g/min of fuel were used, equivalent to a gross power of 1.145kW, and 17.6g/min of water were released, equivalent to a net power of 0.664kW, or an efficiency of 58%.

The results of the emissions test are given in Table 1. Not surprisingly, at both the high power settings, the CO:CO_2 ratio was above the desired 0.02:1, although it was evident that the emissions of both hydrocarbons and CO were lower in the high-power test than in the highest-power test. At low power, the emissions were entirely satisfactory.

Table 1. Results of emission tests

Component	Highest power	Low power	High power
Hydrocarbons	3.3	0.8	1.2
CO	0.020	0.005	0.013
CO_2	0.53	0.27	0.42
CO:CO_2	0.038	0.017	0.030

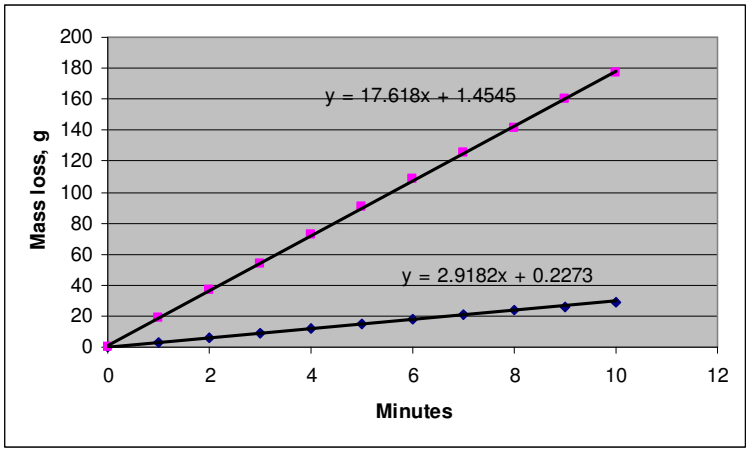

Figure 4. Results of repeat high-power efficiency test

Discussion

The Mark IV represents a significant improvement on the Mark III. In particular, the low power stability and efficiency are excellent, and the 2:1 turndown ratio is most satisfactory. The test work did show a significant effect of atmospheric pressure on the stove performance, and this needs to be taken into account.

In the high-power test, there were only three jets lit, which suggests that making them smaller and increasing their number might allow achievement of the low CO:CO_2 ratio desired. The three jets were reduced in size for the low power test, whereas all six were operational in the highest power test.

The stove operated for over 70 minutes on a single charge, showing that the combination of an efficient stove and a high-ethanol gel can give perfectly acceptable cooking times – in contrast, some of the gel/stove combinations we have tested have had to be refilled before the simplest meal was cooked.

We also noted that, in spite of extensive use, the fuel reservoir showed no signs of corrosion. Again, a number of other gel/stove combinations we have tested have shown significant corrosion of the reservoir after a single test, and the reservoir has proved to have less than a month's lifetime in daily use.