PN-AAX-811 6320206

RENEWABLE ENERGY TECHNOLOGY PROJECT

LABORATORY TESTING REPORT NUMBER 10

TITLE: RESULTS OF KITCHEN PERFORMANCE TESTS ON RET METAL AND EARTHEN STOVES IN NINE HOUSEHOLDS IN THE DISTRICT OF MOKHOTLONG.

AUTHORS: Koranta Matete, David Palasits and Gary Klein.

DATE: 9th January, 1984

LOCATION: MALEFILOANE, LESOTHO.

Acknowledgements

Conducting these kitchen performance tests was the hard word of many individials. Alinah Ramaholi, Puseletso Nthontho, Agnes Adonsti and Koranta Matete interviewed the cooks. In this task they all demonstrated tact and diligence. Maragaret Thomas planned these tests. Judith Gay helped devise the data collection sheets. Howard Geller worked closely with the authors on the statistical procedures used for analyzing the data. Lastly, we must thank the women in whose households the tests were conducted for their cooperation and eagerness to have a new stove in their homes.

Preface

The Lesotho Renewable Energy Technology (RET) Project is part of the Appropriate Technology Section (ATS) of the Ministry of Cooperatives and Rural Development (MINRUDEV). The Project is funded jointly by the Government of Lesotho (GOL) and the United States Agency for International Development (USAID). Technical assistance is being provided by Associates in Rural Development, Inc (ARD), under USAID contract AFR-0206-C-00-1016-00. The RET Project began in April, 1981. The Project has three primary objectives:

* to develop and introduce renewable energy technologies that help rural people conserve scarce fuel.

* to develop and introduce renewable energy technologies that help rural people increase the year-round availability of food.

* to develop and have fully operational an Appropriate Technology Section to carry on this effort beyond the completion of this pilot phase.

This report is part of a series produced by the Project's Research and Development Laboratory to document the research activities that have taken place. Research centers are located at Malefiloane and Mokhotlong in the highlands and at Butha-Buthe and Khubetsoana in the lowlands.

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1. Introduction

One of the goals of the RET Project is to help people in Lesotho to develop fuel-conserving stoves. The Village Energy Survey Report (Gay and Khoboko, Lesotho, November, 1982) was conducted to determine if any help was desired by local women to improve their present methods of cooking and heating their homes. One of the frequently expressed concerns was that it was difficult to keep warm when the door had to be left open to let the smoke escape from the open fire or paola (brazier) that was burning on the hearth. Other problems mentioned were the time spent collecting fuel, the high cost of imported fuels and for many people, the lack of adequate supplies.

With these concerns in mind the Project began to develop two indoor cook-stoves that would also heat the house, remove the smoke and save fuel when compared to traditional practices. In early 1983, it was felt that these stoves were ready to leave the laboratory and be tested by local women in their homes. (Thomas and Burket, Stove Consultancy for Lesotho RET Project, Associates in Rural Development Burlington, Vermont, January, 1983.) This report discusses the results of these user tests.

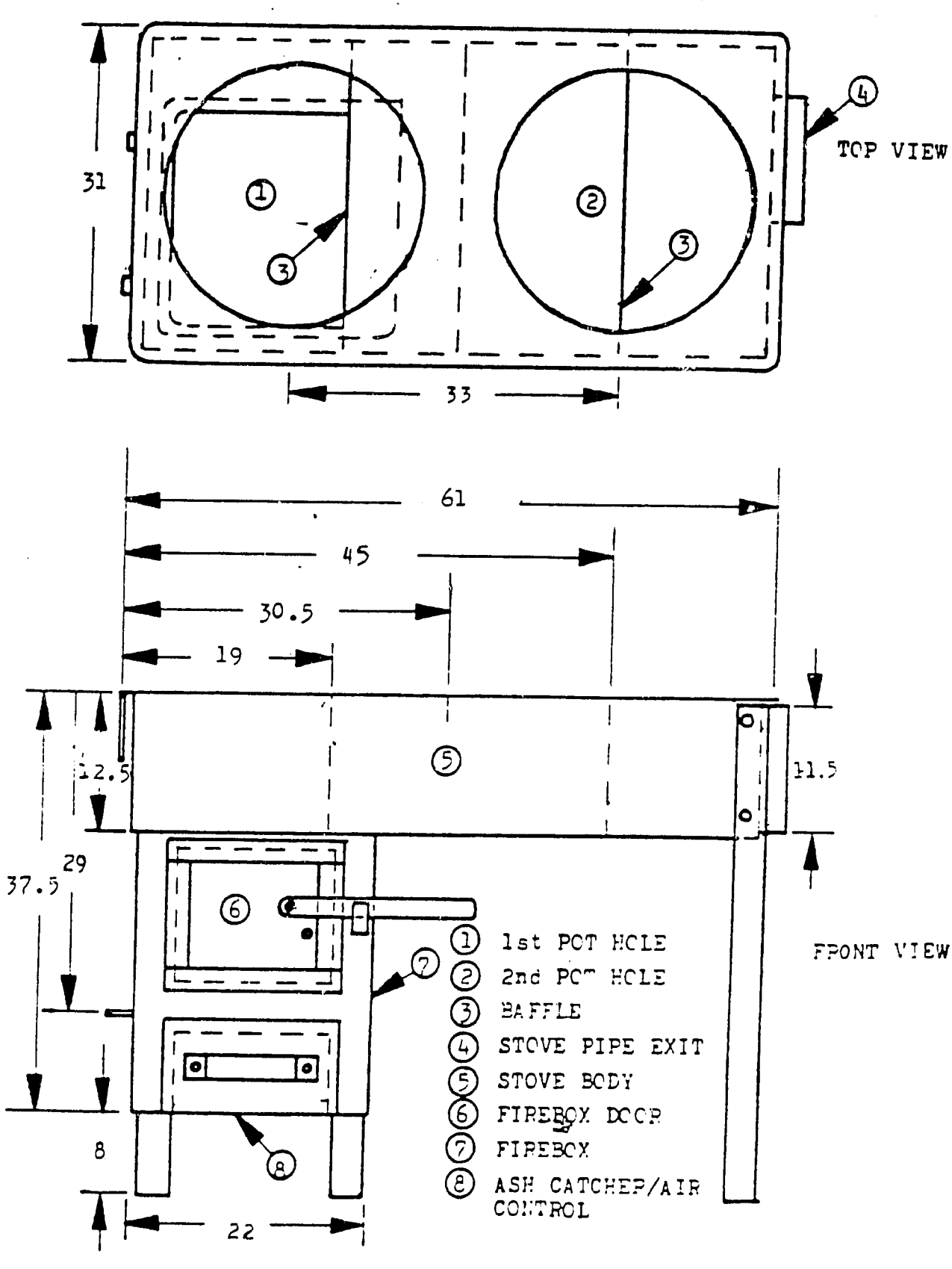
2. Purpose of the Experiment

These tests were conducted to determine if the locally developed earthen and RET metal stoves were more efficient than traditional methods when in daily use. A second objective was to evaluate the acceptability of these designs to the local women.

3. Description of Experimental Apparatus

A. RET Metal Stove (Model 3) These stoves were made from two different guages of steel plate. The heavier gauge (3mm) was used for the firebox and the stove top. The 1.6mm steel was used for the body. Fabrication techniques included the use of oxygen - acetylene cutting, shearing, metal bending and welding. Special features of the stoves were that they could be used with several fuels including dung, shrubs, wood and coal, that both 3-legged cast iron pots and aluminium sauce pans could be used on either of the two pot-holes, and that a chimney could be attached to let smoke directly out of the house. The 5 stoves used for this experiment were made at the Project's workshop in Malefiloane as part of a production training program. More information on the development of this model can be obtained from Thomas and Burket (Ibid.). (See Figure 1).

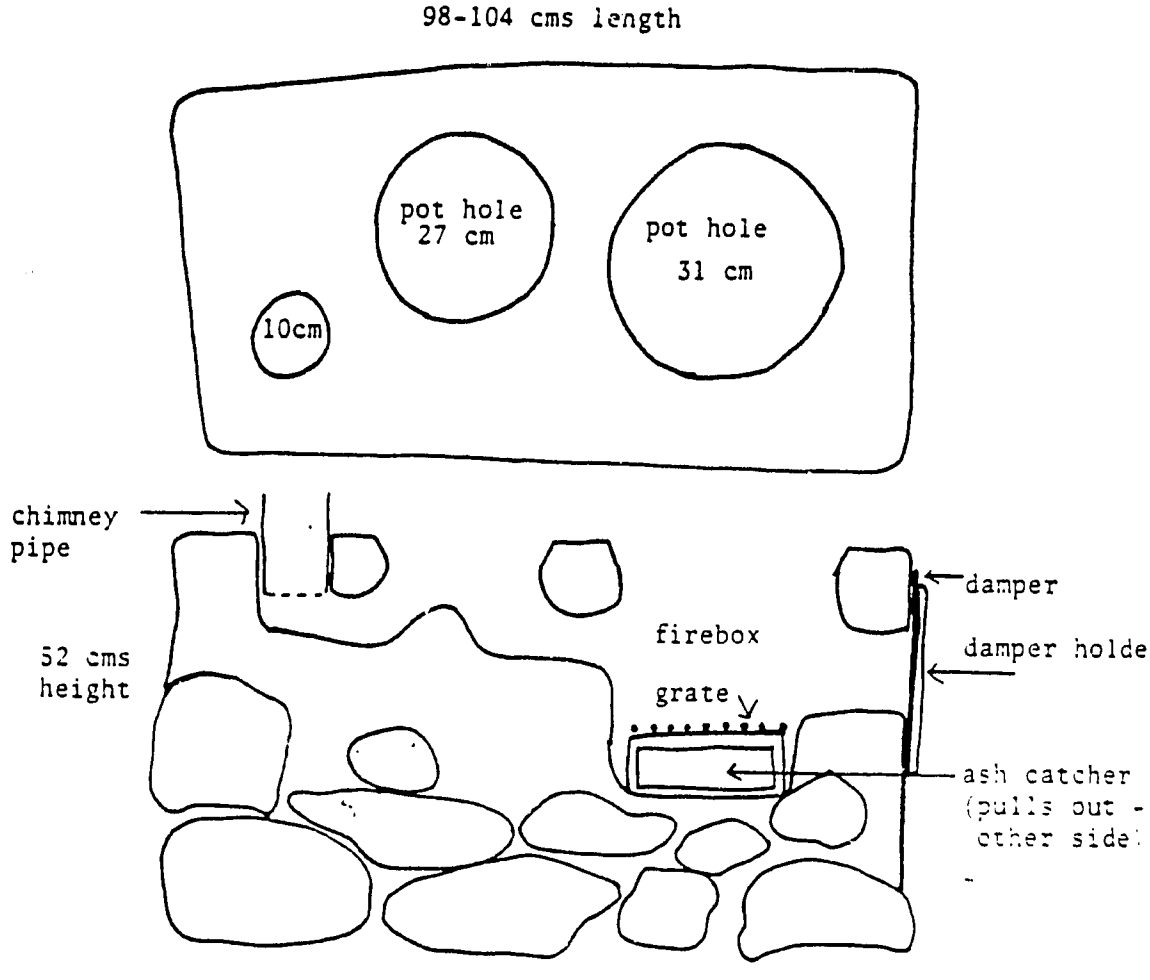
Figure 1 RET Metal Stove Model 3 (Scale 1:5, cm)



B. Earthen Stove (Model 3). These stoves were built by Project staff members together with the women in whose houses they were installed. Each of the 4 stoves was custom-crafted to fit the particular pots that were most often used in that household. All stoves were based on a design that was developed and tested at the laboratory in Malefiloane (Thomas and Burket, Ibid.). Well-mixed sand and clay (otherwise known as Lorena mix), in a ratio of 4:1, was used to make the body of the stove. Built upon a stone base, the mixture was put on in thin layers and pounded down until firm. Ash catchers, grates, dampers, baffles and pot and chimney holes were positioned and formed at appropriate times during the construction of the stoves. Figure 2 contains a diagram of a typical earthen stove.

C. Survey Instruments. Three separate forms were used to collect data for this experiment. The Background Data Sheet utilized questions taken from the Village Energy Survey. The responses were used to compare the innovators with the broader population sampled the previous year. The Daily Fuel Use Record was used to determine the cooking related fuel consumption of each household. Excluded from this study were instances where fuel was used only for space heating, ironing or brewing. The Final Stove User Questionnaire was used to determine the features that each woman liked or disliked about her stove and to get an indication of its overall acceptability as a new household appliance. (See Appendix 1 for sample data sheets).

Figure 2 RET Earthen Stove Model 3 (Scale 1:10, cm)



A Rock Base Mud Stove with Grate and Ash Catcher

4. Experimental Procedure

A. People living near the Project's centres in Malefiloane and Mokhotlong were notified that individuals were desired to participate in the testing of two new stoves. Over a period of several weeks nine households volunteered to cooperate in this experiment.

B. Five households had RET Metal Stoves installed in their homes. Earthen stoves were built in the other four houses. While a serious attempt was made to put the stoves in different villages, it proved to be difficult to find people who wanted earthen stoves. The result was that two of these stoves were built in one village.

Table 1 contains a listing of the location of each stove. While not unreasonable by local standards, the distances to each village posed special problems of timing and coordination.

The stoves in Ntlholohetsane were located only 1.5 kilometers west of Mokhotlong camp and were the easiest to monitor. The sites in Mateanong, Ha Jarose, and Thoteng were each at least a 45 minute walk from the workshop in Malefiloane. The household in Ha Pela was a 1.5 hour journey by horse from Malefiloane and involved crossing the Mokhotlong River. The one in Moeling was even further away, a two-hour horse ride from Malefiloane.

Table 1 LOCATION OF STOVES

HOUSEHOLD	STOVE TYPE	VILLAGE
1	Metal	Mateanong
2	"	Ha Pela
3	"	Ntlholohetsane
4	"	Thoteng
5	"	Moeling
6	Earthen	Matebeleng
7	"	Ntlholohetsane
8	"	Ha Jarose
9	"	Ntlholohetsane

C. Once chosen for participation, an agreement was made between the Project and the household receiving the stove. Its points included:

1. RET Staff were responsible for installing the stove and chimney.

2. RET staff would measure fuel for 14 days. In case mistakes were made, fuel measurements would continue until 14 correct measurements were taken.

3. The user would pay only for the cost of materials if she/he wanted to purchase it at the conclusion of the experiments.

4. If the user did not like the stove, RET would take it out and restore the house to its original condition.

D. Prior to the beginning of the fuel measurements the Background Data Sheet was filled out on each household.

E. The measurements of fuel consumption were made for traditional cooking methods and for the new stove at each house. Each method was measured for seven consecutive days, beginning with the traditional method, which was defined as any other method except the RET Metal or Earthen stoves.

F. The interviewer measured an amount of fuel that the cook thought would be more than enough for the following 24 hours. The next day, the interviewer returned to weigh any remaining fuel and to record information on the amount and type of foods cooked and the number of people fed. This information was recorded on the Daily Fuel Use Record Sheet.

G. Approximately three months after the completion of the fuel measurements the interviewer returned to the household to fill out the Final Stove User Questionnaire. At this time the cook had to decide whether or not to purchase the stove.

5. Results and Conclusions

The first tests began on 18 March and the last one was completed on 19 July, 1983. The tests extended over such a long period of time due to unforeseen problems of scheduling staff, delays in constructing the earthen stoves because of the harvest season, and family problems, such as illness and death in the participating households. Given that the data gathering lasted for 4 months, strict comparisons of fuel use between households is not warranted.

In the mountains, it begins to get quite cold in March and April. Thus, most of the traditional cooking periods could be expected to take place indoors, as in fact most of them were. This allows for better comparisons between the traditional method and the new stove for each household because both fires are used in the well-protected environment of the house.

One problem that the experimenters faced was that due to the harvest season the women were working in the fields almost every day. They were often able to collect only enough fuel for one day - whatever was gathered had to suffice. On many occassions the the total amount measured one day was gone the next. It is realized that this makes the data less valuable than if there had always been surplus fuel at each weighing. However, this highlights another of the difficulties of doing this type of field research.

Another problem was that after the tests were started it became apparent that not all of the cooks were familiar enough with their stove to have it tested. This was true even though RET Project Staff had instructed the cooks in the use of their stoves. It is clear that better information on the operation of each stove needs to accompany its installation and that future kitchen performance tests should not begin until at least three months after the stove is installed.

A final difficulty was that the cook was only allowed to use the traditional method or her new stove, on any given day of the test. However, some earthen stoves did not provide enough heat and they lit a paola for additional heat even though they weren't supposed to on that day. This resulted in repeating a few test days.

For purposes of analysis the households were divided into two groups, those with metal stoves and those with earthen ones. The data on fuel consumption by household are presented in Appendix 2, Tables 5 and 6 respectively. One of the striking details in these Tables is the wide variety of fuels employed by the different cooks.

So that the data could be properly compared, it was decided to base all masses of fuel on a single standard of comparison. Khapane, mapharoa or lisu, all forms of cow dung, were used by all of the cooks and were chosen to be the standard. (Based on tests conducted by the Fuel Research Institute of South Africa, these three fuels have essentially the same energy content, roughly 14 MJ/KG).

Table 2 contains the factors used to derive the equivalent kilograms of fuel per day for each test. These values were then divided by the number of people fed that day to give the equivalent kilograms per person per day used throughout his report.

Table 2 Relative Energy Content of Fuels

Khapane, Mapharoa, Lisu	1.00
Bokuluba	1.12
Sehalahala	1.29
Shrubs (other than Sehalahala)	1.37
Patsi	1.38
Paraffin	3.43

Table 3 presents data on the fuel consumption of five households who received the metal stoves. Table 4 presents similar information on the four households who received earthen stoves. The mean (X), standard deviation (S) and coefficient of variation (COV) have been calculated by household for their traditional and new stove days. The COV is a normalized measure of the variability between different tests. It is found by dividing the standard deviation by the arithmetic mean.

The mean fuel consumption of the traditional and new stoves for each household have been compared using a t-test. The procedure used and a reference t-table are included in Appendix 3. The degrees of freedom (DOF) and the resulting t-values are contained in Tables 3 and 4.

One other comparison is displayed in Tables 3 and 4. All tests for the traditional methods and the new stoves have been combined and the mean and standard deviation found. The t-value was computed from this data so that overall comparisons could be made.

Metal Stoves

Fuel consumption varied substantially from cook to cook. The variations were larger when using the metal stove than when using traditional techniques. This result is not surprising given the newness of the metal stoves. However, it is also clear that fuel conservation is as much a matter of "habit" as it is of having a more efficient stove.

TABLE 3 Comparison of Fuel Consumption Between Traditional Methods and RET Metal Stoves (KG/Person/Day)

Household	Traditional			Metal stoves			t-value	
	X	S	COV	X	S	COV	DoF	t
1	2.39	1.10	0.46	2.64	0.85	0.32	11	0.46
2	1.46	0.48	0.33	1.13	0.55	0.49	12	1.20
3	1.37	0.48	0.35	0.65	0.31	0.47	12	3.33
4	1.40	0.56	0.39	1.16	0.77	0.66	12	0.67
5	2.12	0.74	0.35	1.39	0.46	0.33	10	2.05
COMBINED	1.74	0.80	0.46	1.36	0.88	0.65	65	1.85

With the exception of Household 1, all of the cooks saved fuel when using their new metal stove. However, the savings were significant in only two cases (3 and 5), at the 0.5%and 5% level respectively. A closer examination of household 1 (Appendix 2, Table 5), reveals that sehalahala was used almost exclusively on the days when the metal stove was being tested, in contrast to the mixture of sehalahala and khapane used on the traditional days.

One possible explanation of this problem is that the stove was designed for use with sehalahala and cow dung - the mixture most typically utilized. It is likely that it will not perform as well if sehalahala is used exclusively, as the grate-to-pot distance is rather large, almost 25 cm as opposed to the 10-15cm recommended for wood fuels by Geller, et.al. (Prototype Metal and Mud Burning Cook Stoves for Botswana, Associates in Rural Development, Burlington, Vermont, USA, May, 1983). It should also be noted however, that in household 5, lelingoana,a shrub which burns in a similar fashion to sehalahala was exclusively used on metal stove days. Nonetheless, this cook was able to save significant quantities of fuel with her metal stove.

This raises doubts concerning the explanation given for Household 1's fuel consumption. It probably boils down to a question of cooking habits - Household 1 used more fuel per person per day than any of the other four households.

When the tests for all households are combined, use of the metal stove resulted in fuel savings of 22% compared to traditional methods. This savings is significant at the 5% level. Overall, this would seem to indicate that the widespread use of the RET metal stove would result in a noticeable reduction in fuel consumption and a corresponding decrease in the time spent in its collection, almost 2.5 hours saved per household per week based on the Village Energy Survey Report (op.cit).

It was particularly encouraging that all five cooks purchased their stove after the experiment was over. The Final Stove User Questionnaire elucidated the following advantages of the RET Metal Stove:

1. Cooks any kind of food very well.
2. Saves fuel.
3. Heats the house very well.
4. Uses both 3-legged pots and saucepans.
5. Uses local dung fuel.

While all of the above items were designed into the stove, it is interesting to note that most locally available metal stoves are intended for use with coal, not dung. The RET Metal Stove thus addresses the desire for a modern stove that burns indigenous fuels.

Three disadvantages were mentioned by the cooks:

1. The stove gives heat (with dung) but not as much as when coal is used.

2. The second pot from the firebox is not coming to a boil.

3. Some smoke escapes into the house when the fire is smouldering.

Items 1 and 3 need further investigation to determine if performance can be improved in these respects. Item 2 is of particular concern because the stove was not designed to bring the second pot to a boil. It was intended that the cook should switch positions of the pots when the first one came to a boil. Obviously, this aspect of the stove was not communicated clearly to the cooks. It may also be indicative of the desire for a true "2-burner" stove. Resolution of this question may result in the design of a different stove, perhaps something more similar to the Thaba-Tseka metal stove (Thomas and Burket, op.cit.).

B. Earthen Stoves

As with the metal stoves there was substantial variation in fuel use among the four cooks, Household 8 using aproximately 6 times the fuel of Household 6. This supports the earlier statement that fuel conservation is a "habit", because the difference was irrespective of the stove being used.

TABLE 4 Comparison of Fuel Consumption Between Traditional Methods and Earthen Stoves (KG/Person/Day)

Household	Traditional			Earthen stoves			t-value	
	X	S	COV	X	S	COV	DoF	t
6	0.56	0.1	0.19	0.41	0.06	0.14	12	3.17
7	1.47	0.54	0.37	1.18	0.23	0.20	12	0.51
8	3.00	0.63	0.21	2.78	0.95	0.34	12	0.51
9	1.34	0.47	0.35	1.24	0.36	0.29	11	0.43
COMBINED	1.59	1.01	0.64	1.41	1.02	0.73	53	0.66

All cooks saved fuel when using their new earthen stove. However, the savings were significant only for household 6 (at the 0.5% level). While the combined results of the traditional and earthen stove tests indicate a savings of 11% when using the earthen stove, this savings is insignificant. Thus it is not clear what the fuel savings potential of the widespread use of earthen stoves would be.

All of the cooks decided to purchase their earthen stove. According to the Final Stove User Questionnaire the advantages of the earthen stove were:

1. Cooks any kind of food faster than the tradition method.
2. Saves fuel.
3. Uses local dung fuels.
4. Uses both 3-legged pots and saucepans.
5. The chimney provides a small amount of heat heat to the house.
6. Two pots can be used simultaneously, thus saving time compared to the one-pot-at-a-time traditional paola.

The disadvantages of the earthen stoves were:

1. There was not enough heat.
2. The second pot didn't come to a boil.
3. It was difficult to control the fire.

The fact that the earthen stove users also complained about the second pot not coming to a boil suggests even more strongly that this feature (or lack of it) needs to be investigated further. Two of the cooks had trouble adjusting the fire. One of them complained about burning papa because the fire was so hot under the first pot. Again it seems that the use of the two pot holes was not clearly communicated to the cooks.

The most serious fault of the earthen stoves was that the cooks did not really feel they provided adequate heating in the winter. This same result was found in a separate study by Mahooana and Klein, "Durability of Earthen Stoves When in Use in Peoples' Homes - Preliminary Findings," RET Project, Mokhotlong, Lesotho, 1983.

Coupling the installation of earthen stoves with reducing air infiltration into the home and reducing the thickness of the walls of the stove are two possible solutions to this problem. (See Mahooana and Klein, (Ibid.), for more discussion on this point.)

That the earthen stoves were not perceived of as good heaters was not unforeseen. However, it doesn't bode well for their widespread use in the mountains unless their heating characteristics can be improved. Nonetheless, they may still prove to be an important option elsewhere in Lesotho where the demand for heating isn't so large.

C. Summary

While difficult to administer, this kitchen performance monitoring experiment has given a number of valuable insights into the introduction and performance of new stoves in the mountains of Lesotho. First, stoves should not be tested in this manner until the cooks are completely familiar with their operation. This may take several months and should include written information on stove operation as well as periodic follow-up visits. Once use of the stove becomes widespread, only the written information will be necessary as it is likely that there will be someone else in the village with such a stove.

Second, the ability to heat the house will be an important factor in the widespread adoption of an indoor cookstove. The metal stove seems satisfactory in this respect while, as introduced, the earthen stove is not. Solutions to this problem need to be found for earthen stoves to be recommended for use in the mountains.

Third, the complaint that the second pot does not come to a boil may really be the expression of a desire for a "two-burner" stove. On the other hand, it may be related to the habit of cooking foods at a rolling boil (high flames) instead of at a simmer (low flames), and the solution might be to change cooking habits rather than modifying the stove. In either case listening and responding to this type of concern is fundamental to the success of the interactive design process which is a cornerstone of the Project's approach. This particular problem should be explored in greater detail before either the metal or earthen stoves are widely disseminated.

Fourth, given the large differences between the per person per day fuel consumption of the nine cooks, it is apparent that more attention needs to be paid to changing cooking habits. This kind of change could be coupled with the introduction of a new stove, but it is not essential to do so. However, tying the recommended change in patterns to a new stove may make it easier for the cooks to accept, as it could then be perceived of as "the modern way".

Finally the Background Data Sheets were analyzed to see if the nine households were significantly different from the larger sample interviewed for the Village Energy Survey Report. Wealth, sources of income and level of education were examined. The stove users were similar to the larger population in all three categories. That the innovators were representative of the "average" should be taken into account during future marketing efforts of the stoves.

6. Suggestions for Further Study

In addition to those items mentioned in the body of this report, it is suggested that a similar experiment be done with the same households after they have used their stoves for one year. This would help determine how much more proficient the cooks became in using their stoves. It would also give comparative fuel consumption data that would help to provide better baseline information on this topic for use in energy planning in Lesotho. Data for both years would have to be standardized for differences in temperature.

In such an experiment, efforts should be made to correct the heating problems of the earthen stoves and to reasses this characteristic during the test. If possible, this experiment should also be carried out be in late spring and early summer so that seasonal variations in fuel can be examined.

APPENDIX 1

SAMPLE QUESTIONNAIRES AND DATA SHEETS

BACKGROUND DATA FOR COOKING FUEL USE TESTS

Village	_____
Date	_____
Interviewer	_____
Stove type	_____
Date installed	_____

4.1 Name of household head _____ - _____

4.2 Name of person being interviewed _____

4.3 Number of household possessions used for cooking, heating, lighting etc.

- [ ] iron tripod
- [ ] mpaola (bucket__/ old 20 lt tin__/)
- [ ] paraffin pressure stove
- [ ] paraffin wick stove
- [ ] coal stove
- [ ] gas stove
- [ ] paraffin heater
- [ ] flat iron for pressing clothes
- [ ] radio
- [ ] cassette player
- [ ] iron pots with legs (sizes_____)
- [ ] flat iron pots (sizes _____)
- [ ] kettle
- [ ] saucepans (small__/medium__/large__/)
- [ ] frying pan
- [ ] empty tins (round__/ square__/)
- [ ] big drum for cooking beer
- [ ] hand grinding mill, of iron
- [ ] paraffin lamp (glass__/ [illegible]__
- [ ] flashlight or torch

4.4 For how many people do you cook each day ____?

4.31 Number of domestic animals owned by the household:

TYPE OF ANIMAL	THOSE STAYING HOME ALL YEAR LONG	THOSE AT CATTLE POST DURING SUMMER	TOTAL
cattle			
sheep			
goats			
horses			
donkeys			
pigs			
chickens			
others			

Number of household members: present _____, absent_____, total_____.

Number of

____	rondavels
____	thatched rectangular houses
____	houses with iron roofs
____	cattle kraals

In what kind of house is your new stove? _____

What are the main sources of household income, listed in order of importance?

(1) _____

(2) _____

(3) _____

(4) _____

List all members of your household. Include both those present and those who are absent.

NAMES MARITSO	SEX M/F	RELATION TO HOUSEHOLD HEAD RAMANO	MARITAL STATUS	AGE LILEMO	EDUC LEVEL THUTO	EMPLOYMENT HEREONE OR SCHOOLING	ACTUAL RESIDENCE
1.		He head					
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

FINAL STOVE USER QUESTIONNAIRE

Village _____
Date _____
Interviewer _____
Stove type _____

1. Name of cook _____
2. Does the stove cook well the foods that you normally prepare? Yes_____ No_____
3. If no, which foods do not cook well on the stove, and why?

_____

_____

4. Do you think the stove uses more fuel,___ or less fuel_____than your other method of cooking?
5. What do you like about the way this stove works? (List as many specific points as the owner can think of, but do not suggest answers.)

_____

_____

_____

_____

_____

_____

6. Do you have problems using the stove? Yes _____ No _____
   If yes, what kind of problems? (Check those mentioned, and add others not listed)

   __ Not enough heat
   __ Too much heat
   __ Didn't cook second pot
   __ Pots didn't fit well
   __ Hard to control fire
   __ Hard to add fuel
   __ Didn't burn fuel well
   __ Smoke escaping into the room
   __ Hard to clean out
   __ Difficulties with front door
   __ Difficulties with ash catcher/air control
   __ Difficulties with chimney
   __ People getting burned

   Other _____

   _____

   _____

7. What do your friends say about the stove?

_____

_____

8. Do you know other people who want a stove like this one? Yes_____ No _____

   If yes, please give their names and where they live. (Write on back of page)

9. Do you wish to purchase the stove? Yes_____ No_____
10. If you do not wish to purchase it, why not?_____

_____

PURCHASE MADE: DATE_____ AMOUNT PAID_____ or STOVE REMOVED: DATE _____

DAILY FUEL USE RECORD

circle to show which measurement this is:

traditional	1	2	3	4	5	6	7
new stove	1	2	3	4	5	6	7

Name of village _____
Name of interviewer _____
Name of Cook _____
Date of visit _____

	AMOUNT OF FUEL WEIGHED OUT ON PREVIOUS VISIT	AMOUNT OF FUEL REMAINING IN PILE	AMOUNT OF FUEL USED 1 day ___ 2 days ___
Patsi (shrubs)			
Patsi (willow, poplar)			
Field dung (Khapane / bokoluba)			
Kraal dung (lisu / mapharoa)			
Paraffin (weigh stove)			
Other(s)			

FIRST DAY

Since I was last here what foods did you cook, at what time of day, with what fuel(s), and with what kind of stove? (Use back of page for second day.)

FOOD + TEA WATER

TIME	FOOD OR COOKING WATER	POT SIZE	number of people	FUELS	STOVE	in/outside
Morning						
Midmorning, Midday						
Afternoon						
Night						

From which piles did you take the fuel for cooking? Weighed_____ Unweighed_____

Since I was last here how much water did you heat, for purposes other than cooking with what fuel(s) and in which stove? (Use back of page for second day.)

WASHING WATER

TIME	PURPOSE	AMOUNT	FUELS	STOVE	in/out
Morning					
Midday					
Afternoon					
Night					

From which piles did you take the fuel for water heating? weighed____ Unweighed_

If the woman got fuel for cooking or water heating from anywhere else, the measurements for the day are invalid and you will have to add another day to the observation period.

---SECOND DAY

(USE THIS SIDE IF TWO DAYS OF FUEL ARE TO BE WEIGHED)

Since I was last here what foods did you cook, at what time of day, with what fuel(s), and with what kind of stove? (Use back of page for second day.)

FOOD + TEA WATER

TIME	FOOD OR COOKING WATER	POT SIZE	number of people	FUELS	STOVE	in/outside
Morning						
Mid-morning, Midday						
Afternoon						
Night						

From which piles did you take the fuel for cooking? Weighed_____ Unweighed_____

Since I was last here how much water did you heat, for purposes other than cooking with what fuel(s) and in which stove? (Use back of page for second day.)

WASHING WATER

TIME	PURPOSE	AMOUNT	FUELS	STOVE	in/out
Morning					
Midday					
Afternoon					
Night					

From which piles did you take the fuel for water heating? Weighed____ Unweighed____

Use this space for other comments the people make about the new stove:

4. BAKING IN POLATA

Since I was last here, did you bake bread in a polata? Yes ___ No ___

If yes, how many times? _____

If yes, how did you start the fuel burning? _____

From which pile did you take the fuel? _____

5. FUEL FOR SPACE HEATING ONLY

Since I was last here, did you put fuel in your stove ___ or traditional paola ___ or open fire ___ just to heat or light your house? Yes (indicate which) ___ No ___

For about how long did you heat or light your house? _____

From which pile did you take the fuel? _____

Did you get fuel from anywhere else? Yes ___ No ___, If yes, where?

If the woman took fuel from unweighed piles or from anywhere else, the measurements for the day are invalid and you will have to add another day to the observation period.

6. FUEL FOR HEATING IRON ONLY

Since I was last here did you iron any clothes? Yes ___ No ___

From where did you get the fuel? _____
(Should be from unweighed piles)

7. BREWING (LARGE QUANTITY)

Since I was last here did you brew joala? Yes ___ No ___

From where did you get the fuel? _____
(Should be from unweighed piles)

If the woman took fuel from the weighed piles for ironing or brewing joala, the measurements for the day are invalid and you will have to add another day to the observation period.)

8. How many people have been eating here regularly since I was last here? _____

9. Did you have any guests? How many? _____ and when? _____

10. Describe the weather in this fuel measurement period:

1) Sunny _____ Cloudy _____ Rainy _____

2) No wind ___ Some wind ___ Much wind ___

3) Warm _____ Medium _____ Cold _____

Explain other weather details _____

APPENDIX 2

FUEL CONSUMPTION DATA

Table 5 Fuel Consumption by Household, Traditional vs RET Metal Stove (Equivalent Kg Cowdung/Person/Day)

Household: 1
Village: Mateanong
Test Period: 20/3/ - 14/4/'83

DAY	TRADITIONAL	RET STOVE
1	0.64	*
2	1.35 s	1.87 s
3	3.71 s	2.96 s
4	3.53 s,k	2.96 s
5	2.44 s,k	3.41 s
6	2.80 s,k	3.33 s
7	2.30 s,b,m	1.32 s,b,m

Household: 2
Village: Ha Pela
Test Period: 10/4/-12/5/'83

DAY	TRADITIONAL	RET STOVE
1	1.12 b	0.93 b
2	1.52 s,b	1.12 b
3	1.21 b	0.23 le,b
4	1.13 k	1.12 b
5	1.17 k	0.93 b
6	2.46 b	1.94 s,b
7	1.60 k	1.63 s,b

Household: 3
Village: Nthlolohetsane
Test Period: 18/3 - 19/4/'83

DAY	TRADITIONAL	RET STOVE
1	0.95 s,p,l	0.24 p,s
2	1.21 s,p,l,pa	0.70 s,p,l
3	1.24 s,p,l,pa	0.31 s,l
4	1.18 s,p,l	0.87 s,p,l
5	0.98 s,p,l	1.02 s,p,l
6	2.25 s,p,l,pa	0.91 s,p,l
7	1.81 s,p,l,pa	0.46 s,p,l

Household: 4
Village: Thoteng
Test Period: 18/3 - 13/5/'83

DAY	TRADITIONAL	RET STOVE
1	1.42 s,b	0.75
2	1.79 s.l	1.49 s,l
3	1.15 p,m	0.59 s,l
4	2.44 p,b	1.10 s,l
5	0.86 p.k	2.77 s,l
6	1.37 p,k	0.67 s,l
7	0.86 s,l	0.79 s,l

Household: 5
Village: Moeling
Test Period: 20/3/ - 21/4/'83

DAY	TRADITIONAL	RET STOVE
1	1.59 le,m	0.85 le
2	1.67 s,l	0.83 le
3	1.69 le	1.59 le
4	1.90 le	1.91 le
5	2.34 le,k	1.39 le
6	3.54 le	1.78 le

Notes:
* Test judged invalid due to an abnormal amount of food cooked for sale on that day.

Key:
s - sehalahala, a shrub
k - khapane, cow dung from field
b - bokuluba, horse dung
l - lisu, cow dung from kraal
le- lelingoana, a shrub
m - mapharoa, cow dung patties
p - patsi, firewood
pa- paraffin, kerosene

Table 6 Fuel Consumption By Household, Traditional vs Earthen Stove (Equivalent Kg cowdung/Person/Day)

Household: 6
Village: Matebeleng
Test Period: 5/7/ - 19/7/'83

DAY	TRADITIONAL	EARTHEN
1	0.42 s,k,b	0.37 s,k,b
2	0.67 s,k,b	0.37 s,k,b
3	0.62 s,k,b	0.40 s,k,b
4	0.56 s,k,b	0.45 s,k,b
5	0.66 s,k,b	0.37 s,k,b
6	0.55 s,b,k	0.33 s,b,k
7	0.41 s,b,k	0.51 s,b,k

Household: 7
Village: Nthlolohetsane
Test Period: 10/5/-23/5/'83

DAY	TRADITIONAL	EARTHEN
1	0.94 p	0.87 s,p,l
2	1.96 p,l,su	1.10 li,p
3	2.36 p,l,su	1.00 s,li
4	1.75 p,li	1.19 s,li
5	1.24 p,l	1.25 p,l
6	1.04 p,l	1.61 p,l
7	1.04 le,li	1.31 p

Household: 8
Village: Ha Jarose
Test Period: 20/5/-4/6/'83

DAY	TRADITIONAL	EARTHEN
1	2.49 s,l	2.76 s,l
2	3.19 s,l	0.92 s,m
3	2.41 s,l	3,56 s,l
4	2.27 s,l	3.32 s,l
5	3.51 s,l	3.34 s,l
6	3,19 s,l	3.39 s,l
7	3.96 s,l	2.16 s,m

Household: 9
Village: Nthlolohetsane
Test Period: 12/4/-25/4/'83

DAY	TRADITIONAL	EARTHEN
1	1.49 s,k,pa	1.35 l,p,s
2	2.13 s,m,pa	1.40 p,l
3	1.63 p,k,m,pa	1.65 p,k,l
4	1.13 k,s,pa	1.15 le,b
5	1.36 s,p,k,l	1.28 le,b
6	0.91 le,k,pa	0.58 l,k
7	0.74 s,m,pa	*

Notes:

* Fuel taken from unweighed pile for use in baking in a polata.

Key:

s - sehalahala, a shrub
k - khapane, cow dung from field
b - bokuluba, horse dung

l - lisu, cow dung from kraal
p - patsi, firewood

le - lelingoana
su - sunflower
m - mapharoa, cow dung patties
pa - paraffin, kerosene
li - liqo, maize cobs

APPENDIX 3

"t - TEST" PROCEDURE AND TABLE

APPENDIX 3 "t-test" Procedure and Table

The "t-test" has been used to determine if the mean from one group is significantly greater than the mean from another. The "t-value" was computed according to the formula:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\left[\frac{S_1^2}{n_1} \quad \frac{S_2^2}{n_2}\right]^{1/2}}$$

Where the subscripts 1 and 2 denote the pair of stoves or operating conditions being studied. $\bar{X}$, S, and n are, respectively, the mean, standard deviation and the number of tests for each situation.

Once computed, the "t-value" is compared to values in a "t-table". Table A 3-1 contains an abridged "t-table". The values in the table are listed as a function of the "degree of freedom" and "level of significance". "Degrees of freedom" are calculated by taking the total number of test measurements and subtracting the number of parameters that are being compared. In this report:

$$\text{Degrees of freedom} = n_1 + n_1 - 2$$

The level of significance is the percentage chance that the result indicated by the "t-test" is not true. Thus, the statistical difference between the means from the two groups increases as the indicated level of significance decreases. With the "t-value" and the "degrees of freedom" calculated, one can enter the "t-table" to determine the level of significance. If the computed "t-value" is greater than the number in the table at a certain level of significance, then it can be said that the mean from one group of tests is greater than the mean from the other at that level.

REFERENCE t-TABLE

Degrees of freedom	Level of significance = (%)* 10	5	2.5	1	0.5
1	3.08	6.31	12.70	31.80	63.70
2	1.89	2.92	4.30	6.96	9.92
3	1.64	2.35	3.18	4.54	5.84
4	1.53	2.13	2.78	3.75	4.60
5	1.48	2.01	2.57	3.36	4.03
6	1.44	1.94	2.45	3.14	3.71
7	1.42	1.90	2.36	3.00	3.50
8	1.40	1.86	2.31	2.90	3.36
9	1.38	1.83	2.26	2.82	3.25
10	1.37	1.81	2.23	2.76	3.17
11	1.36	1.80	2.20	2.72	3.11
12	1.36	1.78	2.18	2.68	3.06
13	1.35	1.77	2.16	2.65	3.01
14	1.34	1.76	2.14	2.62	2.98
15	1.34	1.75	2.13	2.60	2.95
16	1.34	1.75	2.12	2.58	2.92
17	1.33	1.74	2.11	2.57	2.90
18	1.33	1.73	2.10	2.55	2.88
19	1.33	1.73	2.09	2.54	2.86
20	1.32	1.72	2.09	2.53	2.84
21	1.32	1.72	2.08	2.52	2.83
22	1.32	1.72	2.07	2.51	2.82
23	1.32	1.71	2.07	2.50	2.81
24	1.32	1.71	2.06	2.49	2.80
25	1.32	1.71	2.06	2.48	2.79
26	1.32	1.70	2.06	2.48	2.78
27	1.31	1.70	2.05	2.47	2.77
28	1.31	1.70	2.05	2.47	2.76
29	1.31	1.70	2.04	2.46	2.76
30	1.31	1.70	2.04	2.46	2.75
∞	1.28	1.64	1.96	2.33	2.58

* This is the one-sided level of significance that is applied when testing whether the mean from one population is greater than the mean from another.