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RESEARCH, DEVELOPMENT AND DISSEMINATION OF COOKING TECHNOLOGIES BY THE LESOTHO RENEWABLE ENERGY TECHNOLOGY PROJECT

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PREFACE

The Lesotho Renewable Energy Technology (RET) project was part of the Appropriate Technology Section (ATS) of the Ministry of Cooperatives and Rural Development (MINCORUDEV). The project was jointly funded by the Government of Lesotho (GOL) and the U. S. Agency for International Development (AID). Technical assistance was provided by Associates in Rural Development, Inc. (ARD) under AID contract number AFR-0206-C-00-1016-00.

The RET project began in April, 1981 and ended March 31, 1984. It had three primary objectives:

- develop and introduce RETs that would help rural people conserve scarce fuel resources;
- develop and introduce RETs that would help rural people increase the year-round availability of food; and
- develop a fully operational ATS that could carry on the RET project's efforts beyond the completion of this pilot phase.

The project's centers of operation were located at Malefiloane and Mokhotlong in the mountains and Butha-Buthe, Khubetsoana and Maseru in the lowlands.

This report is the last in a series written by Mr. Gary Klein, ARD's laboratory supervisor for the RET project's research and development laboratory. These reports were intended to document the research and dissemination activities of the RET project.

I. INTRODUCTION

The three end-uses for energy in the form of heat--cooking, heating water, and keeping people warm--have been grouped together because they are often done simultaneously in Basotho homes. In most homes, cooking is the primary task, followed by either heating water or heating space, depending on the time of day and year. While cooking and water heating create a reasonably constant demand for fuel, space heating requirements vary according to the season and the elevation.

A wide variety of fuels is employed by the homemaker in traditional cooking practice. Rural households use a greater proportion of biomass than urban households, which use more imported fuels such as paraffin, coal, gas and electricity. Assuming access to several fuels, whether indigenous or imported, the cook will choose from among an assortment of stoves. The actual choice is made based on a combination of factors including fuel availability, weather conditions and the task at hand.

This report describes the process undertaken by the RET project to:

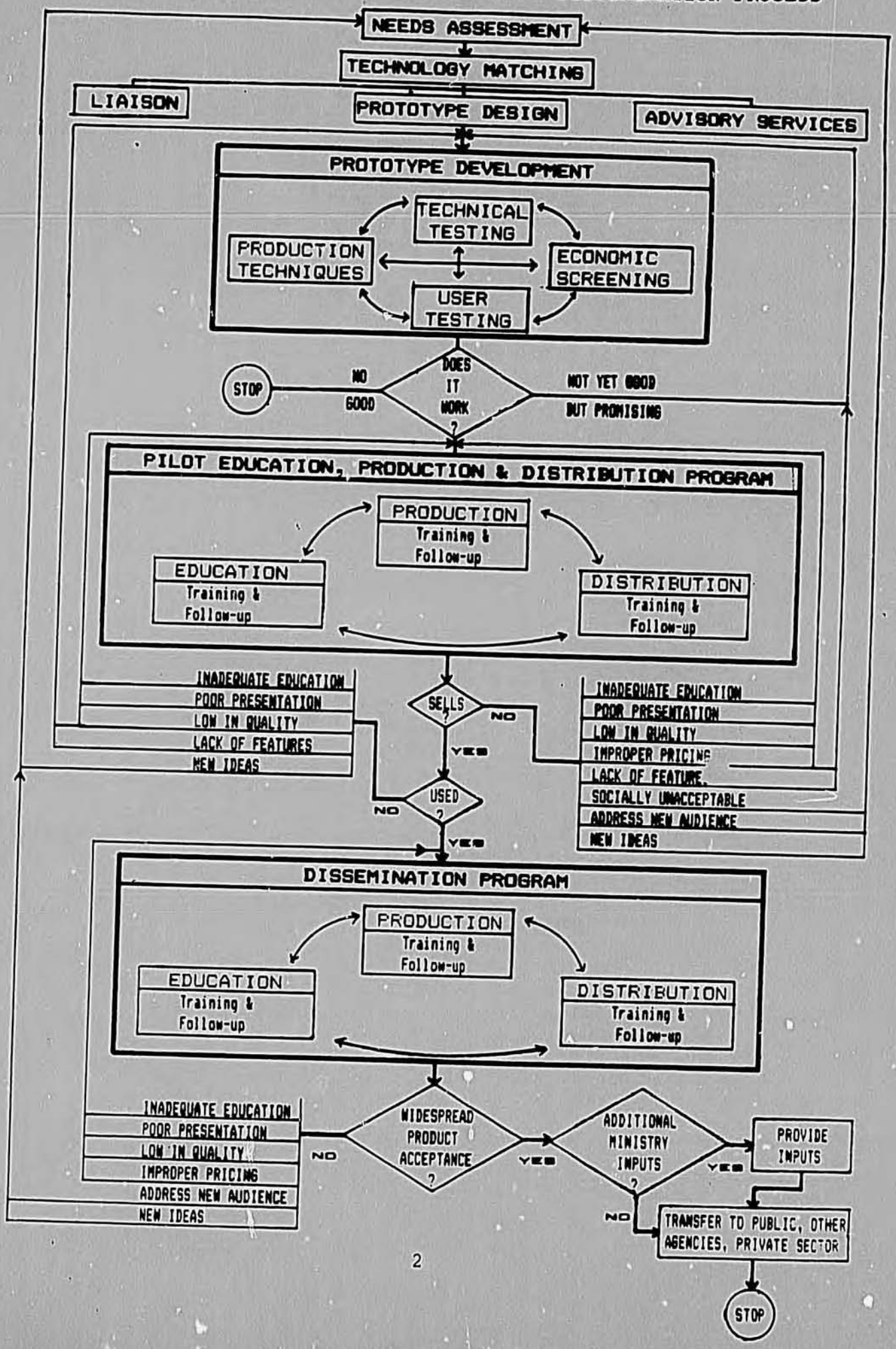
- understand local practices and demands for cooking, water heating and space heating (Needs Assessment);
- match these demands with technologies designed to improve the effective provision of these end-uses (Technology Matching);
- develop prototypes of these technologies and test their technical, productive, economic and social feasibility (Prototype Design and Development);
- initiate and evaluate strategies for the dissemination of the suitable technologies (Pilot Education, Production and Distribution Program); and
- based on the results of these pilot efforts, implement a full-scale program to promote their widespread use (Dissemination Program).

Figure 1 contains a flow chart of this Technology Selection, Development and Dissemination Process. As can be seen, the overall flow is linear. Interaction among component parts has been built into each stage of the process. Furthermore, evaluation and feedback loops have been included to help ensure the development of products truly responsive to locally expressed desires.

Since the RET project was designated a pilot venture, this description of the overall process may be seen as one of its important outputs. This flow chart, evolved during the course of the

Figure 1

TECHNOLOGY SELECTION, DEVELOPMENT AND DISSEMINATION PROCESS



project, is intended to serve as a guide for the future activities of the ATS. It is hoped that it is flexible enough to adapt to changing concerns as the efforts of the ATS mature.

II. NEEDS ASSESSMENT

A preliminary needs assessment was performed in Mokhotlong in December, 1981 - January, 1982. It was focused on cooking, water heating and space heating practices related to indigenous fuels in order to guide preliminary technology selection and to give direction to the work of the project's first stove consultant, Ianto Evans. This effort was documented in RET Technology Selection--Needs Assessment (J.S. Gray, RET Project, MINCORUDEV, January, 1982).

In late fall and early winter, March to May, 1982, a more complete survey was conducted in the District of Mokhotlong, the RET project's first regional field area. One hundred and forty-eight (148) households from six villages were interviewed. These were selected so that diverse environmental, social and economic settings could be examined. In the ensuing paragraphs, data relevant to cooking, water heating and space heating have been drawn from the Village Energy Survey Report (VESR), written by Judith Gay and Mamello Khoboko (Associates in Rural Development, Inc., Burlington, Vermont, November, 1982). Where necessary, observations from elsewhere in Lesotho have been included to provide a more well-rounded picture of the entire country.

A. Fuel

In Lesotho, the verb ho besa means to make fire; the derived noun, libeso, refers to any sort of combustible fuel. Cow dung, horse and donkey dung, shrubs and weeds, crop residues, trees, coal, and paraffin are used to varying degrees throughout Lesotho.

Lisu, mapharoa, and khapane are three types of cow dung. Lisu is dug three or four times a year from the kraals where cattle are kept at night. The rectangular chunks are left to dry on top of the kraal walls and are later stacked near the house, where they are readily available and can be protected from heavy rain.

Occasionally, after periods of heavy rain, very wet dung is formed into flat briquettes or mapharoa. These are dried and stored in a similar fashion to lisu. Khapane is dry cattle droppings gathered from the common land on which cattle graze. Although lisu and mapharoa are preferred fuels, they are only available to those who own cattle (only 60 percent of the households reported on in the VESR). The other 40 percent are required to spend many hours (3 hours per 20 Kg) collecting khapane, which is primarily available during winter and early spring when the cattle are still in the village and neither insects nor summer rain have ruined the droppings.

Horse and donkey dung, bokuluba, is regarded as a less desirable fuel than cow dung. Equine dung is lighter in weight, burns faster, and is a smokier fuel than cow dung. While used in place of khapane by those who own horses (only 49 percent of those surveyed), it is also available to those who own no livestock because it can be collected from the common land where the animals travel or graze.

Shrubs and weeds are referred to generically as patsi or woody fuels. The lowlands and foothills have a wide variety of woody shrubs which are available to the cook. In the alpine environment of Mokhotlong, the choices are limited and the most common and valuable patsi are several species of chrysocoma, locally called sehalahala. Access to the areas where shrubs can be collected is regulated by the chief, as is done with other community resources.

In areas with little or no sehalahala, annual weeds such as lengana (wormwood), letjoi (datura), and lechuchuta (wild marigold), are collected in and between the fields. Basotho custom prevents collecting these annuals until after they have scattered their seeds--evidence of the local recognition of fuel shortages.

Wheat straw, maize stalks and cobs, and sorghum stalks are sometimes used as fuel. However, competing demands for these resources, such as using the straw for thatching roofs, make these fuels of last resort. Maize cobs, commonly used like khapane in the lowlands, are not as widely burned in the mountains because less maize is grown at higher elevations.

The number of trees in Lesotho is extremely limited. This is particularly true in the high mountains of Mokhotlong District. What few trees there are--usually poplar and willow--grow in the valleys next to the streams and rivers. Some families own fuelwood trees and occasionally cut one down or trim branches from several to burn, most often in the wintertime. Stove-length pieces of wood are imported from the Republic of South Africa and are used primarily as kindling by coal-stove owners in the lowlands and by government offices throughout the country for wintertime heating. The Woodlots Project of the Ministry of Agriculture is just beginning to harvest trees from Leribe and Mohale's Hoek, two of the areas, both in the lowlands, where it has concentrated its efforts.

Coal, like most firewood, is imported from South Africa. Less than 10 percent of the households surveyed in the VESR owned a coal stove. It is used primarily by the government, and by individuals in the lowlands and along major roads. In these locations, access to both the fuel and the stoves for which it is intended is considerably better than elsewhere in the country.

Paraffin, or kerosene, was used by over 90 percent of the people surveyed for the VESR. However, as with coal, access to paraffin is dependant upon the road. And the price increases with the distance from major population centers. In the VESR it was shown that an inverse correlation existed between the use of biomass and paraffin. Where the use of dung and shrubs was below average--villages either densely populated and/or along the road--the use of paraffin was above average. The average consumption of 2.2 liters (1.8 kilograms) per week went for lighting and cooking operations where speed and convenience were important, such as preparing tea first thing in the morning.

Table 1 was prepared based on data taken from the VESR. It presents the mean weekly consumption per household of the various types of fuel. It also includes the energy content of the fuel as measured by the Fuel Research Institute of South Africa in Pretoria or taken from standard references. Of particular interest is the column showing the percentage of households using a specific fuel. Paraffin and shrubs were the most widely used fuels. On the other hand, coal, willow and poplar trees, and crop residues were practically non-existent in the weekly fuel mix of the interviewed households.

Table 1. Reported Fuel Use per Week in Autumn

Fuel Type	Mean Amount Used per Household (Kg or l)	Households Using Fuel (%)	Energy Content (MJ/Kg)
Lisu	16.5	55.4	13.8
Mapharoa	3.3	25.0	13.0
Khapane	5.9	31.8	13.1
Bokuluba	6.3	37.2	15.4
Shrubs	23.0	81.8	19.0
Willow and poplar	1.0	7.4	20.0
Crop residues	2.5	10.8	19.8
Paraffin	1.8	92.6	46.4
Coal	1.0	3.4	26.0

Average household size is 6.1.

B. Stoves and Cooking Utensils

Table 2 has been adapted from the VESR. It shows the mean number of stoves and cooking utensils owned per household and the percentage of households owning that item. The items have been ranked according to the latter criterion. The first three stoves are the most common cooking devices in the mountains, as well as throughout Lesotho. The trifoot is made from three pieces of bent iron rod, formed into a triangle and connected at the corners. The trifoot supports a cast-iron (or other) pot 10-15 cm above the ground permitting better combustion than if the pot rested on its three short legs.

Paolas are braziers typically made by punching many holes all around a leaky bucket. The holes provide oxygen to a fire made inside the bucket. In rural areas the fuel is usually dung, while in urban areas, particularly in the lowlands, coal is often burned. The paola is used so that the fire can be transported from outside--where it is started and can emit most of its acrid and unhealthy smoke--to inside the house, where it can provide nearly an hour of cooking and space heating before it needs to be recharged.

Table 2. Ownership of Stoves and Cooking Utensils

Item	Mean Number Per Household	Percent Households Owning Item
Stoves		
Paraffin pressure stove	1.2	79.6
Brazier (paola)	.8	71.6
Iron tripod (trifoot)	.6	48.6
Paraffin heater	.1	11.5
Coal stove	.1	9.5
Paraffin wick stove	.1	8.8
Utensils		
Three-legged cast-iron pot	2.7	95.5
Old tin cans (3.5-5.0 liters)	1.0	85.8
Aluminum tea kettle	1.6	85.8
Aluminum saucepan	3.1	80.4
Flat-bottom iron pot	.6	50.7
Aluminum frying pan	.4	35.1
Half of 200 liter oil drum	.4	27.7

Paraffin pressure stoves are usually referred to by the most common trade name, "Primus." They are used almost exclusively with aluminum saucepans and tea kettles and are prone to malfunctions. The ownership of more than one per household is indicative of this problem of breakdown and the related lack of adequate repair facilities. The paraffin wick stove is also a single-burner cookstove, but does not seem to have the same magnitude of operating problems that plague the pressure stoves. They are gaining in popularity among local cooks, although at the time of the survey few households had one.

Coal stoves and paraffin heaters are almost non-existent in the mountains. This is due primarily to transport costs of the fuel which radically increase the operating costs in remote villages. As was to be expected, most of the households owning and operating these devices were located along the road. Similar patterns prevail throughout Lesotho, with the majority of these stoves concentrated in the lowlands towns.

An outdoor wind protection device, or leifo, is still another type of stove. Although the VESR did not ask about such devices, the project has observed them being used in many, but not all, homes. Sometimes one or two metal sheets are propped up around the fire to protect the pot from the wind. The leifo is most often made of stone and mud and shaped like a cross, with walls 60-100 cm high. Other shapes that have been observed are a "C," a "T" and an "H." (See Figure 2.) The pot is placed so that the leifo protects it from the wind. It is interesting to note that even in windy villages, not all cooks have or use wind protection devices.

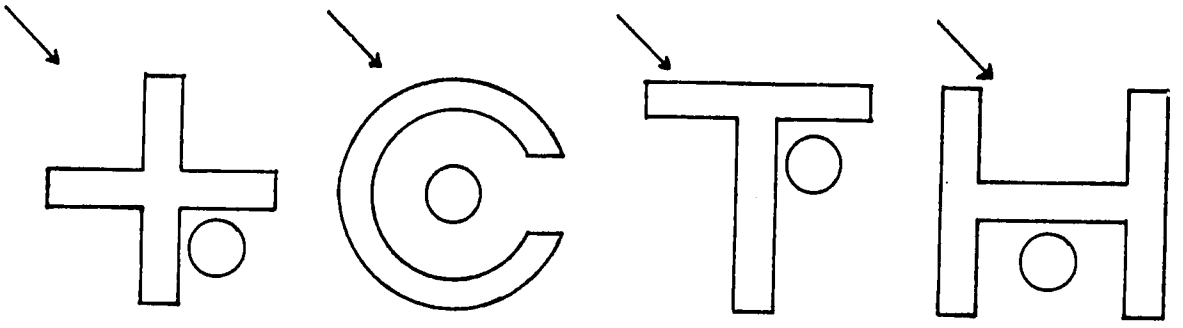


Figure 2

TOP VIEW OF FOUR LEIFO SHAPES

A fairly wide range of cooking utensils was owned by the households that were interviewed. Of particular relevance to the project was the large number of three-legged cast-iron and aluminum pots owned per household. It should be noted that there was a correlation between the use of biomass fuels and ownership of cast-iron pots and between the use of paraffin and aluminum pots.

Table 3. Ranked Order of Ownership of Three-Legged Cast-Iron Pots

Ranking	Pot Size
1	2
2	4
3	3
4	6
5	8
6	1
7	10
8	5
9	14
10	½

Table 3 presents the ranked order of the frequency of ownership of three-legged cast-iron pots as reported in the VESR. The most common sizes are used by the typical family (6.1 people per household surveyed) for cooking foods such as papa, a stiff maize porridge; meroho, leafy green vegetables; and likhobe, boiled grains. The larger pots are typically used for steaming bread and brewing motoho, a sour porridge, or joala, a maize- or sorghum-based beer. The largest pots (up to size 25) are often loaned to other families for the preparation of meat, bread, or beer for feasts. These large pots are also used regularly by primary schools to prepare lunch for the children. While a similar

analysis was not done for aluminum pots, it is probable that the most common sizes are 23, 30 and 35 cm in diameter. Larger aluminum pots are also available and are used for the same purposes as the larger cast-iron pots.

C. Use Patterns

In the mountains during autumn and early winter, 85.3 percent of all reported cooking and 89.2 percent of all water heating operations occurred indoors. Cooking and water heating operations were essentially equally divided between open fires, paolas, and paraffin pressure stoves. The fuels used for both tasks were lisu, shrubs and weeds and paraffin, also in roughly equal percentages when taken over the whole sample. However, as was mentioned earlier, the access to paraffin is unequal and a much greater number of people in the villages near the road used paraffin compared to those living in more remote villages.

At elevations above 2,000 meters, typical of the mountain areas in Lesotho, it is almost never too warm to cook inside. However, since the fuels most people use generate large amounts of noxious smoke, much of the cooking and water heating is done outdoors when the weather is good--such as in the summer and at midday throughout the year. It is probable that in the lowlands (elevations between 1,500 and 1,800 meters), a greater percentage of cooking, particularly in rural areas, is done out of doors. In the urban centers, where dung and shrubs are much less available, there has been a shift to paraffin and coal--both of which are used with indoor stoves.

Over 50 percent of the reported cooking operations were done in the morning. The most commonly cooked food was papa followed by meroho; tea; lesheleshele, a soft porridge-like cream-of-wheat; and bread. With the exception of meroho, these foods require bringing to boil large quantities of water, or, in the case of bread, which is probably steamed, maintaining a couple of liters of water at a boil for over two hours. Table 4, adapted from the VESP, shows the frequency of preparation and percentage of the diet for an autumn day.

It is particularly interesting to note that among the five most frequently prepared foods, there are no meat, dairy or complementary proteins such as peas or beans. Although papa, lesheleshele and bread require fairly large amounts of fuel to cook, this amount is relatively small compared to meat, peas and beans. The problem of providing a balanced, nutritious diet has not gone unnoticed by the women surveyed, many of whom said that they would like to provide their families with such food but did not have the knowledge, food supplies or fuel to do so.

As mentioned earlier, cooking and water heating were done on the same type of stoves using the same fuels. This correspondence is probably due to the fact that the fire used for

cooking, usually the primary operation, is almost always also used for heating water. Water is heated in 3.5-5-liter tins placed alongside the fire or in a pot, tin or kettle placed on the stove just before or after cooking foods.

Table 4. Foods Prepared on an Autumn Day in Mokhotlong District (148 households)

Type of Food	# of Times Prepared in District per Day	Average Percent of Daily Diet in District
Papa (thick maize porridge)	204	32
Meroho (leafy green vegetables)	162	25
Tea	58	9
Lesheleshele (soft porridge)	50	8
Bread (steamed)	43	7
Milk	28	4
Potatoes	15	2
Meat	14	2
Motoho (sour porridge)	12	2
Pumpkin	12	2
Likhobe (boiled grain)	12	2
Peas	4	1
Beans	4	1
Eggs	3	.5
Stamp (maize hominy)	3	.5
Joala (beer)	3	.5
Leftovers	3	.5
Other	8	1
Total	638	100

According to the VESR, water was heated primarily for bathing early in the morning, washing hands and face in the evening, washing dishes after the morning and evening meals, and for bathing infants and new mothers and doing infant laundry at midday. On average, 4.9 liters of water was heated for these purposes twice a day, or roughly 10 liters per household per day. Just over half (58 percent) was heated in the morning. Of the remainder, 29 percent was done in the afternoon, 12 percent at midday and 7 percent at night.

It is particularly significant that almost half of the water heating was not done first thing in the morning. This would belie the commonly stated conclusion that solar water heating is inappropriate in Lesotho because Basotho mainly want water just after waking up. Based on the data, half of the present rural hot water demand could easily be met on clear days with a very simple batch-type solar water heater. This would not require any substantial change in use or preparation patterns and would simultaneously conserve precious fuel for other tasks.

The need for space heating is shown in Table 5, which presents temperature data for the two climatic extremes encountered in Lesotho. Monthly and annual mean, mean maximum and mean minimum air temperatures are presented for Maseru and Oxbow. Maseru is representative of the lowlands and Oxbow is representative of the highest elevations where people live (Klein and Wyatt, Solar Energy Experimentation and Training in the Mountains of Lesotho, Thaba-Tseka Program, Thaba-Tseka, Lesotho, April, 1980).

Table 5. Monthly Mean, Mean Minimum and Mean Maximum Temperatures 1976-1979 (°C)

	Maseru Elevation 1,510M				Oxbow Elevation 2,650M			
	Min	Max	Mean	LT Mean	Min	Max	Mean	LT Mean
Years of Record	4	4	4	21	4	4	4	17
January	14.4	25.8	20.0	21.0	7.1	16.7	11.9	12.1
February	15.0	26.7	20.8	20.4	7.5	17.7	12.6	11.9
March	13.0	25.5	19.3	18.3	6.0	16.1	11.0	10.3
April	9.6	23.2	16.1	14.7	2.4	13.3	7.9	6.7
May	3.4	17.5	10.6	10.3	-2.5	10.2	3.8	3.8
June	0.4	15.7	8.1	6.7	-6.0	8.2	1.0	1.0
July	0.1	16.3	8.1	6.7	-5.9	8.5	1.3	0.9
August	2.9	18.6	10.8	10.1	-0.6	11.2	5.2	3.2
September	6.6	21.2	13.9	13.3	0.8	12.6	6.6	7.2
October	9.2	23.2	16.2	16.0	3.6	13.9	8.8	8.9
November	11.1	26.4	18.7	18.3	5.3	16.3	10.8	10.3
December	14.7	28.5	21.6	20.5	6.4	18.4	12.4	11.5
Annual	8.3	22.4	15.4	14.7	2.0	13.6	7.8	7.3

LT = Long-term

Space heating is generally provided as a by-product of cooking inside on a paola or open fire. However, the smoky fires associated with these non-chimneyed "cookstoves" require large amounts of ventilation--typically an open window or door in addition to the unsealed openings at the top of the walls and in the roof. Consequently, the air that is heated convectively by the fire escapes to the outside and only the radiant energy can be utilized for heating. It is typical to see a family huddled very close to the fire and wrapped in blankets to prevent the minimal heat they receive from escaping out their backs. It is also not uncommon to see one or more children in a family with burn scars acquired from rolling into a still-hot fire, or from blankets that have caught fire.

While open fires and paolas are used for heating thatched-roofed dwellings, they are almost never used in metal-roofed buildings. In these cases, heating, if provided, would be done with a paraffin or coal stove. According to the VESR, households are made up of an average of 2.4 buildings. Ninety-four percent of the households had a thatched rondavel, 16 percent had a thatched rectangular house, and 22 percent had a zinc-roofed rectangular house. The difference between the remote villages and those near the road is most striking for zinc-roofed houses. Over 50 percent of the households near the road had them, compared to much less than one percent in the remote villages.

The relative explosion of zinc-roofed houses in the road towns is probably due to a combination of the availability of time-and-labor-saving building supplies and the lack of traditional building materials in these villages. In the more remote villages, where access to corrugated iron and cement blocks is restricted, a zinc-roofed house is much more of a prestige item. Despite an awareness that an uninsulated zinc-roofed house (the typical situation) can be much more bitterly cold than a thatched-roofed one, almost 40 percent of those surveyed put building such a house at the top of their list of desired home improvements.

Two other factors must be considered with regard to space heating: the number of people sleeping in a building and the size and location of existing windows. Most households in Lesotho have two or more one-room buildings surrounding a courtyard (lelapa). This lelapa has traditionally been set so that the door(s) of the house(s) face the morning winter sun, or somewhere between east and north. One or two very small windows (less than 0.25 m^2 each) are set into the walls of rondavels, usually on either side of the door, so that although the orientation of the windows is acceptable, their size precludes much solar gain. Rectangular thatched- or zinc-roofed houses often have larger windows, which, as long as the house is oriented so that the windows face north and the curtains are open during the day, can contribute to heating the house. Unfortunately, much of this good siting practice has been lost as the peri-urban areas have developed. It must also be noted that in these areas there is a trend for private housing to have several rooms under one roof rather than several one-roomed dwellings.

The large family sizes mean that in the typical household, three or more people sleep in the same room which is an average size of between 12 and 16 square meters. Upon waking up, it is common practice to open windows and doors and air out the house. If the door faces northeast, this brings in the warming rays of the sun along with the desired fresh air. Otherwise, the net effect is to cool the house to the point where a fire is necessary to keep it warm.

A final point concerning space heating is this. Lesotho is blessed with an excellent solar regime for winter heating. Over 250 days a year have at least six hours of clear sunny skies.

Table 6, adapted from Klein and Wyatt (Solar Energy Experimentation and Training in the Mountains of Lesotho, Thaba-Tseka Program, Thaba-Tseka, Lesotho, April, 1980), presents data on sun hours, percent possible sunshine, and horizontal radiation for Maseru and Oxbow. As before, Maseru is representative of the lowlands, and Oxbow of the extreme elevations where people live, particularly along the eastern escarpment. Earlier studies (Klein and Wyatt) found that the middle of the country had radiation levels that were roughly the average between these two extremes.

Table 6. Solar Data for Two Stations in Lesotho

	Maseru			Oxbow		
Month	Sun Hours	Percent Possible Sun	Horizontal Radiation ($MJ/m^2/Day$)	Sun Hours	Percent Possible Sun	Horizontal Radiation ($MJ/m^2/Day$)
January	8.9	65	23.5	6.9	58	21.1
February	8.9	68	19.5	7.0	62	20.3
March	8.1	66	17.3	6.6	63	18.2
April	7.8	69	14.6	6.5	67	15.6
May	8.0	76	12.3	6.9	77	13.4
June	7.8	76	10.9	6.7	81	12.5
July	8.2	79	11.4	7.2	84	13.5
August	8.7	79	13.7	7.8	82	15.8
September	9.0	76	17.0	7.5	74	18.2
October	8.8	69	20.6	7.4	68	20.3
November	9.2	68	22.6	7.5	65	21.6
December	9.8	70	24.5	7.6	64	22.6
Year	8.6	72		7.1	70	

III. TECHNOLOGY MATCHING

Table 7 presents a matrix for matching needs with suitable technical options. There were several underlying factors that were used to select these technologies in addition to those listed in Table 7:

- the need to create local employment,
- the need to reduce recurrent import expenditures,
- the need to increase self reliance,
- the need to improve the ecology, and
- the need to use existing or easily acquired local skills.

This overall context is important because in a different situation the same basic needs could easily have led to other technical choices. The creation of local employment is a particularly crucial consideration given the reduction of employment opportunities in the neighboring Republic of South Africa. Fewer external sources of income also mean that recurrent costs for imported food and fuel need to be reduced. On the other hand, many of the returning miners have skills that could be used in the production of renewable energy technologies. Finally, although it may seem a bit indirect, reducing demand for traditional biomass fuels will contribute to improving the environment by making it possible to recycle organic nutrients, which should reduce erosion and increase agricultural output.

All of the technologies were ranked so that the project could determine its research, development and dissemination priorities. This ranking, based on technical "readiness" and potential for widespread adoption, was done periodically beginning in January, 1982. The order presented in Table 8 was made in October, 1982, and essentially directed the work for the remainder of the project. As can be seen, three of the technologies described in this report were very high on the list, while the other four were near the bottom. Given this priority listing, most of the project's efforts were directed to the first half of the list.

Table 7. Needs-Based Technology Matching Matrix

Assessed Need or Problem	Matching Criteria	Technical Option
A. Local fuels are time consuming to collect and in short supply	1. Save fuel	a. stone paola b. improved metal paola c. earthen stove d. RET Metal Stove e. retained heat cooker
	2. Use a new local energy resource	a. solar water heater b. solar cooker
B. Windy conditions and smoky indigenous fuels	1. Improved combustion and outdoor wind protection	a. stone paola b. improved metal paola
	2. Indoor stoves with smoke removal	a. earthen stove b. RET Metal Stove
C. Certain imported fuels are unavailable (e.g., gas and electricity)	1. Use indigenous fuels	a. stone paola b. improved metal paola c. earthen stove d. RET Metal Stove
	2. Use a new local energy resource	a. solar water heater b. solar cooker
D. Imported fuels are costly	1. Use indigenous fuels	a. stone paola b. improved metal paola c. earthen stove d. RET Metal Stove
	2. Conserve imported fuels	a. Retained heat cooker
	3. Use a new local energy resource	a. solar cooker b. solar water heater
E. Cooks use three-legged pots and saucepans	1. Cookers must accept both types of pots	a. earthen stove b. RET Metal Stove c. retained heat cooker d. solar cooker
F. Cooking operations are primarily boiling and simmering	1. Stoves need to operate near the boiling point	a. stone paola b. improved metal paola c. earthen stove d. RET Metal Stove e. retained heat cooker f. solar cooker

Assessed Need or Problem	Matching Criteria	Technical Option
G. Hot water required in early mornings or late evenings	1. Heat water on stove	a. stone paola b. improved metal paola c. earthen stove d. RET Metal Stove
	2. Capture "waste" heat from cooking fire	a. earthen stove b. RET Metal Stove
H. Hot water required from midday to early evening	1. Heat water on stove	a. stone paola b. improved metal paola c. earthen stove d. RET Metal Stove
	2. Store hot water from earlier cooking task	a. retained heat cooker
	3. Use a new local energy resource	a. solar cooker b. solar water heater
I. Space heating required	1. Indoor/outdoor portable stove	a. improved metal paola
	2. Indoor stove	a. earthen stove b. RET Metal Stove
	3. Reduce demand	a. insulation and weatherstripping
	4. Use a new local energy resource	a. passive solar design

Table 8. Priority Ranking of Technologies

Rank	Technology
1	Stone paola
2	Retained heat cooker
3	RET Metal Stove
4	Food dryers
5	Grow-holes
6	Energy efficient housing
7	Improved metal paolas
8	Earthen stoves
9	Solar water heaters
10	Solar cookers

IV. PROTOTYPE DEVELOPMENT

This section discusses the development of the seven technologies identified during the technology matching process. Technical performance was evaluated at the project's laboratories in Khubetsoana, Butha Buthe and Malefiloane. Since this was often done, particularly in Malefiloane, in conjunction with nearby residents, many of the problems often encountered with social acceptability were avoided as the technologies were modified to suit local preferences. Additional tests were also performed after these laboratory refinements to help determine the widespread suitability of the prototype designs.

Production techniques were always scrutinized with the aim of using local materials and skills wherever possible. When it was necessary to import materials such as steel for metal stoves, local metal workers were employed to fabricate the final product. Economic screening of all technologies was done throughout the development process, beginning as rough approximations and getting more refined as technical, social and production data were acquired and evaluated.

The technical, social and production aspects are addressed technology by technology. The economic analyses of these devices have been grouped together; the result is presented in the following section.

A. Stone Paola

The stone paola, or leifo la majoe, was derived from the traditional leifo, or outdoor fireplace, and the metal paola developed by the Rural Technology Unit (RTU) in Thaba-Tseka. The leifo provided the concept of using stone walls for wind protection, while the Thaba-Tseka paolas provided the shape of the firebox and the relationship of the pot to the paola walls. Figure 3 shows graphically how these two existing devices were combined into the stone paola. Upon seeing one, village women asked, "Why didn't we think of that?"

This outdoor stove is made by making a round stone wall, the diameter dependent upon the size of the pot with which it will be used most frequently. (At one school, part of the Food-for-Work dissemination program, the students labeled their paolas according to the size number written on the three-legged cast-iron pot. Their labeling convention--Size 6, Size 20, etc.--will be used in this report.) The stones are held together with a mud mortar. The inside is plastered with a mixture of sand and clay in a ratio of roughly 4:1, and the outside is smeared with a mixture of dung and soil already commonly used in Basotho homes.

The pot is supported above the ground on three metal rods so that there is space for a grate on which the fire is made and

Table 9. Design Criteria for Seven Technologies

Design Criteria	Stone Paola	Metal Paola	Earthen Stove	Metal Stove	RHC	Solar Oven	Solar Water Heater
Uses indigenous fuels	x	x	x	x			
Saves fuel	x	x	x	x	x	x	x
Improves safety	x	x	x	x	x		
Uses three-legged pots	x	x	x	x	x	x	
Uses saucepans			x	x	x	x	
Requires minimal change in cooking procedure	x	x	x	x			x
Is portable		x		x	x	x	x
Provides supplemental water heating			x	x			
Provides wintertime heating		x	x	x			
Removes smoke from house			x	x			
Can be made mostly from indigenous materials	x		x		x		x
Can be manufactured in Lesotho from imported materials		x		x	x	x	x
Is durable				x	x	x	x
Is easily maintained by owner	x		x		x		x
Bakes						x	

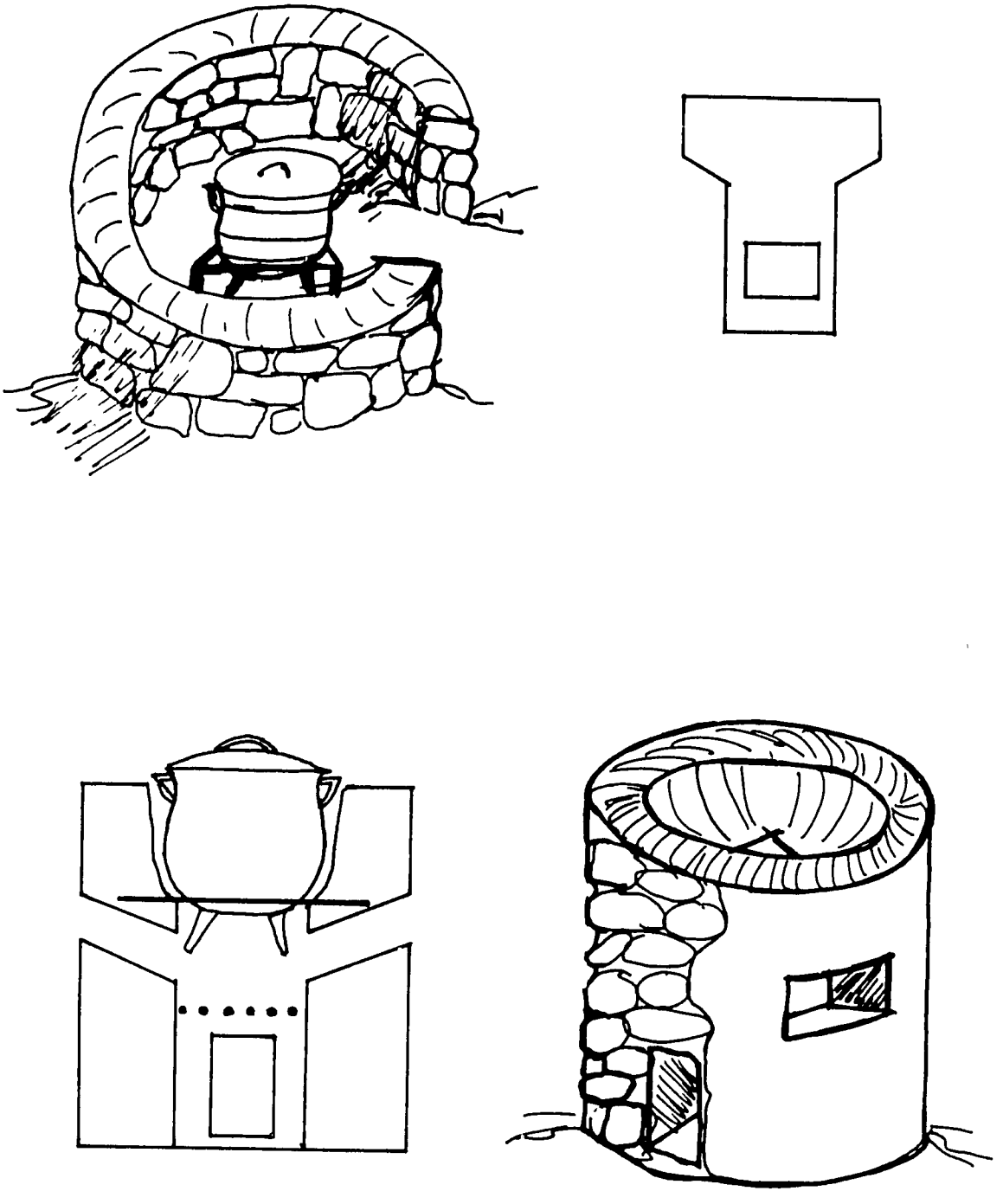


Figure 3

DESIGN OF STONE PAOLA BASED ON
TRADITIONAL LEIFO AND METAL PAOLA

below which the ashes can be collected. The lower holes for removing ashes and the upper holes for adding fuel also serve as inlets for the supply of primary and secondary oxygen to the fire. The gaseous combustion products are only allowed to escape from the firebox by passing close to the pot in a ring 2-3 cm wide formed between the pot and the inner walls of the paola. Locating the pot directly above the fire and in close proximity to the escaping gasses was designed to result in the capture of significantly larger amounts of heat, both radiant and convective, than would be received in the typical open fire.

The stone paola was originally conceived of for primary schools that provide lunch for their students. Most primary schools participate in a School Feeding Program which distributes Food Aid in the form of pulses, maize flour and oil, which must then be prepared. Students often spend school time collecting the fuel used to cook their lunches. Large three-legged cast-iron pots, Size 16 to 25, are used to accommodate the large quantities of food. Although these schools usually have a kitchen containing an indoor fireplace and a chimney, the smoky fuels often drive the cooks outside, where the pots and fires are subject to wind-related heat losses.

The first stone paola was constructed by Mike Savino, a Peace Corps volunteer (PCV), in Ha Mohale, a village east of Malefiloane. The basic design was worked out in consultation with Ianto Evans, a stove consultant to the project, and Gary Klein, Laboratory Supervisor (Status Report on Stove Work, Associates in Rural Development, Burlington, Vermont, March, 1982). Initial tests showed significant fuel savings compared to a protected open fire, and it was decided to perform more rigorous testing and development at the project's workshop in Malefiloane under the direction of stove consultants Margaret Thomas and Glenn Burket. When the local women saw the paola, they immediately requested them for use at their homes. This led to the development of smaller paolas, Sizes 3-8, better suited to a typical cook's needs. Development of large-size paolas continued in Khubetsoana under the direction of the Laboratory Supervisor.

Laboratory technical testing examined potential fuel savings for different tasks, as well as the durability of the sand-and-clay liner. Thomas and Burket (Stove Consultancy for Lesotho RET Project, Associates in Rural Development, Burlington, Vermont, January, 1983) reported that the stone paola showed 46 percent fuel savings, compared to a protected open fire, in controlled cooking tests of lesheleshele. They recommended that the project complete certain controlled cooking tests after they left Lesotho. The number of tests to be performed was modified by Howard Geller (Cook Stove Testing and Development of the Lesotho RET Project, Associates in Rural Development, Burlington, Vermont, May, 1983).

The results of these tests were reported by Gary Klein (Comparison of Stone Paolas and Protected Open Fires--Results of Controlled Cooking Tests, RET Project, Ministry of Cooperatives

and Rural Development, Maseru, Lesotho, February, 1984). Lesheleshele was tested in Size 4 and Size 8 pots; steamed bread in a Size 8 pot; and papa, meroho and water in Size 4, 2 and 3 pots, respectively. Time to bring the first pot to a boil, time to cook the food, temperature rise of the water, and fuel consumption were the parameters that were studied.

Table 10 presents the data from these tests. As can be seen, the stone paola saved over 60 percent of the fuel normally used for cooking lesheleshele in both Size 4 and 8 pots. It saved 47 percent of the fuel when cooking steamed bread; however, when cooking papa, meroho and water, the stone paola consumed 2 percent more fuel than the open fire, although this was a statistically insignificant difference.

While the stone paola saved fuel in the first three tasks, it required more time to do so than the open fire. The differences in bringing the pot to a boil were not significant, but the differences in the time required to cook the food were (60 percent more for lesheleshele and 30 percent more for steamed bread). However, the stone paola was faster than the open fire when cooking papa, meroho and water.

The report concluded that stone paolas were well designed for cooking operations in which the amount of food to be cooked is large (greater than half) compared to the volume of the pot. This includes lesheleshele, steamed bread, peas, beans, motoho and joala. Most of these operations require the boiling of water, and, while somewhat slower than the open fire, the stone paola will save a great deal of fuel. For cooking tasks in which the amount of food is small compared to the pot size, the stone paola will probably not save fuel; but, because the heat is focused more completely on the pot, it will perform the operation more quickly. It was also noted that since primary schools cook large quantities of food in very large pots, stone paolas should prove to be particularly beneficial in saving both fuel and the time school children spend collecting it. They will also protect the children from accidental burns.

The choice of a sand-and-clay mixture for the paola liner was made by consultants Thomas and Burket, based on their work with Lorena stoves. Access to proper sources of sand and clay proved to be difficult in some villages. Also, the women complained about the process of mixing the sand and clay with their hands--a particularly painful task in the cold of winter. Finally, because the technique for applying the liner was new, there have been many instances in which the liner has separated from the wall, particularly above the height of the pot supports where the lining is the thinnest.

The project decided to see if other liners, which were easier to acquire, mix, and apply, might be suitable for the stone paolas. An experiment was conducted comparing three soil-and-dung mixtures,

Table 10. Controlled Cooking Comparisons

Food	Stone Paola	Protected Open Fire
Lesheleshele (Size 4)		
Time to boil (min)	25.0	21.3
Time to cook (min)	15.5	10.0
Fuel used (gms)	2,280	6,058
Lesheleshele (Size 8)		
Time to boil (min)	28.3	27.7
Time to cook (min)	20.7	12.7
Fuel used (gms)	3,358	8,529
Steamed Bread		
Time to cook (min)	93.4	71.3
Fuel used (gms)	3,818	7,156
Papa, Meroho and Water		
Time to boil (min)	15.0	32.0
Time to cook (min)	19.5	28.0
Temperature rise in water (°C)	47.6	27.0
Fuel used (gms)	4,708	4,632

cement, and the normal sand-and-clay liner. In these accelerated aging tests, surface cracking, cracks between the lining and the wall, surface deterioration, and color changes were investigated.

These tests showed that the dung-and-soil mixtures (0.5:1.0, 1.0:1.0, and 2.0:1.0) burned away in the firebox and fell off above the pot supports. The sand-and-clay liner (3-4:1) did very well in the firebox but required better bonding to the walls above the pot supports. Cement proved to be the most durable liner, only exhibiting minimal deterioration in the firebox. From this experiment it can be concluded that if people are prepared to buy the materials (less than one quarter of a packet of cement), they can get a liner which is relatively easy to mix and apply, and which is very durable. On the other hand, if they prefer to use no-cost local materials, the sand-and-clay liner is the best option.

Production techniques were developed along with the early laboratory testing. Thomas and Burket describe the concept that separates the construction of the stone paola into two parts. The first part involves making the bars and grate in a welding shop, and the second involves construction of the walls, incorporating these purchased items, by the homeowner or a Village Technology Specialist (VTS). (See discussion in Section VI.)

User testing of the stone paolas took place during their development in Malefiloane. Women attending the clinic located next to the project's workshop were intimately involved in the design and testing of this and other stoves. (See Thomas and Burket for details.) Given the enthusiastic response of the women, no further field testing of acceptability to this group was undertaken.

Although social suitability didn't seem to be a problem, the project did exert considerable effort to check on the technical quality of the paolas. This was particularly important at schools where stone paolas were built for the large three-legged cast-iron pots. All told, over 100 paolas were examined for technical quality and evidence of durability.

The most common technical faults were the irregular distances between the pot supports and the grate, the space between the pot and the paola walls, and the improper fit of the metal oil tins used for the air, fuel and ash doors. Efforts were made to stress the proper details during future training courses.

The large paolas at schools suffered from the weight of the food-filled pots and from the use of coal. The pots, weighing up to 100 kilograms, bent the pot support rods and caused cracks to form in the walls. These problems were alleviated by specifying larger diameter rods and metal plates in the walls to spread the load over a greater area.

When coal was used, it usually caused the grates to bend and twist and accelerated the bending of the pot supports. The inside

liner also tended to deteriorate quite rapidly compared to those paolas in which only traditional fuels were used. Larger diameter steel rods with additional cross supports were recommended for the grates. Cast-iron grates, intended for use in commercially available coal stoves, have been tried in a number of paolas and seem to be a good solution for these units.

A number of assumptions regarding the stone paola have been made for the economic analysis presented at the end of this section. These are shown in Table 11 and are based on the smaller paolas built at people's homes. The five-year lifetime was chosen because stone paolas seem very similar to the protected hearths already found in Lesotho, many of which have been in use for at least this period of time.

Table 11. Stone Paola--Initial Assumptions

1. Unit Lifetime = 5 years

2. Initial Cost = M14.00

   - Materials--

Bars	M2.50
Grate	M1.50
Dampers	M .45
Cover	M1.50
	M5.95

   - Labor--

Collect materials: 8 hours @ M0.50/hr	M4.00
Construct paola: 8 hours @ M0.50/hr	M4.00
	M8.00

3. Annual Maintenance and Operation Costs
   - Labor to collect fuel is M0.50/hr
   - Used the equivalent of 26 weeks per year
   - Stove paola saves half the fuel consumed by a protected open fire
   - Annual costs = 10.8 x 26 x .5 x .5 = M70.20

4. Non-Annual Repair and Replacement Costs--Present Worth
   - Needs resmearing every two years (4 hours @ M0.50/hr = M2.00)
   - Needs new dampers every two years (@ M.45 today)
   - Non-annual costs--

     d = 6 M2.45 (1.28 + 1.64) = M7.15
     d = 30 M2.45 (.85 + .73) = M3.87

5. Units of Food Cooked per Year = 182.5

Initial material costs are taken from a metalworking shop in Maseru and from the project's workshop in Malefiloane. They include costs for labor, energy, materials, and profits required to fabricate the bars and grates. Labor costs are based on data gathered during the many training courses taught by project staff. The national minimum wage of M0.50 per hour was used to give a monetary value to the time invested in constructing the paola. Table 12 contains similar information for the protected open fire.

Table 12. Open Fire Protected by a Leifo--Initial Assumptions

1. Unit Lifetime = 5 years

2. Initial Cost = M12.00

   - No material costs
   - Labor--

Collect materials: 12 hours @ M0.50/hr	M6.00
Construct leifo: 12 hours @ M0.50/hr	M6.00
	M12.00

3. Annual Maintenance and Operation Costs

   - Labor to collect fuel is M0.50/hr
   - Used the equivalent of 26 weeks per year
   - Annual costs = 10.8 x 26 x .5 = M140.40

4. Non-Annual Repair and Replacement Costs--Present Worth

   - Needs resmearing every two years (6 hours @ M0.50/hr = M3.00)
   - Non-annual costs--

     d = 6 M3.00 (1.28 + 1.64) = M8.76
     d = 30 M3.00 (.85 + .73) = M4.74

5. Units of Food Cooked per Year = 182.5

B. Retained Heat Cooker

The retained heat cooker (RHC) is also known as a hay-box or fireless cooker. It is a proven technology which has been used for at least 100 years in Europe and the United States, although it was most popular in the first quarter of this century. Its popularity was primarily due to the shortage of fuel, particularly during World War I. Other reasons included safety and the convenience of cooking while the family was out working. (Julia Older, Cooking Without Fuel, Yankee Publishing, Inc., Dublin, New Hampshire, 1982.)

The RHC is most suitable for the cooking of foods that would normally be simmered on the stove. It is not intended for fried foods. Many of the foods eaten in Basotho homes are simmered, although papa and meroho, the most common dishes, require little cooking time--quite possibly due to the shortage of fuel. Foods such as meat, peas and beans, which help balance the diet, require longer cooking times and might be eaten more frequently if they didn't require so much fuel to cook (VESR).

The RET project found that there was a type of RHC, known as the Wonderbox, commercially available in southern Africa. It is made and distributed by two organizations based in the Republic of South Africa, Compassion and Women for Peace. Most of their efforts at establishing production as an income-generating activity and at promoting use of the Wonderbox are directed to the non-white urban townships, or bantustans, where the primary cooking fuel is paraffin and the pots are aluminum saucepans.

In Lesotho in 1981, the Food and Nutrition Coordinating Office (FNCO) was distributing the Wonderbox on a small scale. Additional efforts to introduce retained heat cooking were being made by a UNICEF-funded project attached to the Ministry of Agriculture's Nutrition Extension Division, again in a limited fashion.

While most households in Lesotho have aluminum saucepans, paraffin is less available in rural areas than in the towns or along the roads. The RET project felt that to complement the RHC used with saucepans, an RHC should be designed that could be used with the three-legged pots common in rural homes.

The RHC for saucepans has two pillows filled with an insulating material. The commercial Wonderbox uses polystyrene beads, an item not easily found in Lesotho, but which can be ordered from South Africa. Other possible insulation materials include straw, chaff, grass, shredded newspapers, feathers, sawdust and shredded foam. All of these materials are available in Lesotho to a greater or lesser degree depending on where one lives.

The RHC for three-legged pots has an upper pillow only. The bottom two-thirds of the box is filled with grass or straw, which is adjusted to fit the pot being used. (Although many people have expressed concern about the hot pot burning the grass, the pot is only about the temperature of boiling water (100°C) when placed in the RHC, which is much lower than the ignition temperature of grass.)

Technically, the RHC is a device that uses insulation to trap inside the pot the heat contained in the food. When this energy is retained at high enough temperatures for a sufficient period of time, the food will become cooked. The effectiveness of the RHC is dependent upon the quantity of food, the conductivity of the insulation, and the initial temperature of the food.

The mass of food is important since a large mass retains its heat for longer than a small mass does. Thus, it is best to use an RHC with a larger pot than a smaller one. The mass-to-volume ratio is important. Whatever pot size is used should be at least half filled--two-thirds to three-quarters is better. One interesting note is that compared to aluminum saucepans, the small three-legged cast-iron pots (Size 4 and smaller) have a very large mass relative to the mass of food they can contain. This mass, at a temperature very similar to the food, will improve the performance of the RHC by maintaining higher temperatures in the food for a longer period of time.

The conductivity of the insulation and the initial temperature of the food are related concerns. The lower the conductivity (and the greater the resistance) of the insulation, the longer the temperature of the food will remain high enough to cook. Also, the higher the temperature of the food when it is placed in the RHC, the longer it will take until the food drops below cooking temperatures. For an RHC, cooking temperatures range from boiling (100°C at sea level, lower at higher altitudes) down to about 74°C. From this point down to about 60°C, the food will be kept quite hot but not really cooking (Keeping Food Safe To Eat, Home and Garden Bulletin Number 162, USDA, Washington, D.C., 1978).

Reaching and maintaining these temperatures are important to reduce the chances of bacterial poisoning and the spoilage of food. The question of altitude plays a role because it is the primary factor that determines the initial temperature of the food that goes into the RHC. The boiling point of water decreases 0.0111 kilopascals per meter (0.001 inches per foot) of elevation above sea level. Table 13 shows this relationship for sea level and three representative locations in Lesotho.

Table 13. Relationship of Boiling Point and Altitude

Location	Altitude (M)	Pressure (KPA)	Boiling Point (°C)
Sea level	0	101.1	100
Maseru	1,510	84.3	94.8
Mokhotlong	2,160	77.1	92.4
Malefiloane	2,625	72.0	91.0

Lesotho is unique in that the entire country is at elevations above 1,400 meters. Thus, the effectiveness of an RHC is reduced compared to an identical unit operating at sea level. In order to test the effects of the altitude on RHC performance, the project conducted a series of temperature-time tests at its workshop in Malefiloane. These tests compared the drop in temperature over

one hour, of three liters of boiling water in a 23-cm-diameter aluminum pot, placed in five different RHCs. The RHCs consisted of two pillows filled with insulation placed inside a cardboard box. The external surface area of the box was 0.93 square meters. Two RHCs had polystyrene beads for insulation, while the other three used straw or chaff. The conductivity of each RHC was determined based on the temperature drop during the one-hour tests. These values were used to project the time it would take for the temperature of the food in the RHC to fall below cooking temperature

Figure 4 shows the results of this analysis. Since it was found that there was a significant difference between the RHCs insulated with polystyrene beads and those insulated with straw or chaff, the results have been plotted as the average of the two groups. It is important to note that the better insulated RHCs (polystyrene) would have maintained cooking temperatures above 70°C for almost an hour longer than those insulated with straw or chaff. To have equal levels of performance, straw- or chaff-insulated RHCs need to have roughly 1.5 times the thickness of insulation of those with polystyrene beads.

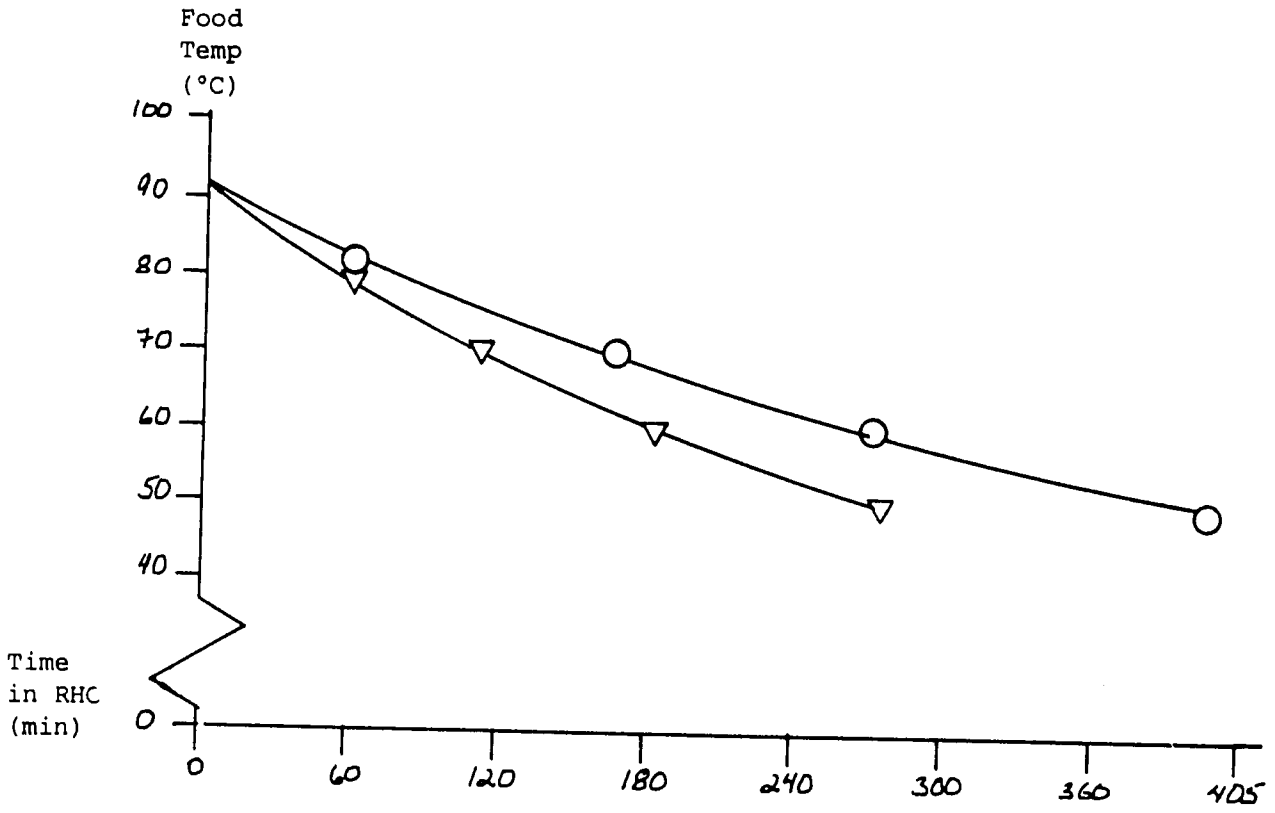


Figure 4

TEMPERATURE DROP COMPARED TO TIME IN AN RHC (ELEVATION 2,625 METERS)

Based on the data in Figure 4, it was possible to determine the length of time the RHC would keep the food above 70°C at other altitudes. Table 14 shows the additional time that food will remain above this temperature in Mokhotlong, Maseru, and at sea level for these two insulating materials. Note the increased time with decreasing altitude and the longer times for the less conductive insulation.

Table 14. Time Adjustment for Lower Elevations

Location	Altitude (meters)	Additional Time To Reach a Given Temp in an RHC Insulated with... Polystyrene (min)	Straw or Chaff (min)
Mokhotlong	2,160	9	6
Maseru	1,510	25	17
Sea level	0	56	38

This information was used as a guideline for the development of recipes for local foods. Other cookbooks for RHCs, written for sea level, show very long retention times in the RHC, many over five hours (Older, Cooking Without Fuel, Yankee Publishing, Inc., Dublin, New Hampshire, 1982; Kirschner, Fireless Cookery, Madrona Publishers, Seattle, Washington, 1981). However, in Lesotho, the commercially available Wonderbox would only keep the food above 70°C for times ranging from 3 hours, 11 minutes for Maseru, down to 2 hours, 45 minutes for Malefiloane. The tested straw or chaff versions have a range of only 2 hours, 10 minutes, and 1 hour, 52 minutes, respectively. While increasing the thickness of the straw or chaff is possible, it makes for a very bulky RHC. Given these parameters, the project devoted its efforts to developing recipes requiring shorter cooking times in the RHC.

These recipes were developed at the project's Khubetsoana workshop, 5 kilometers north of Maseru. Beans, peas, samp, split peas, lentils, rice and stew were the primary foods tested, because of their particular suitability for the RHC. Vegetables such as pumpkin and cabbage were also tried. Special attention was paid to papa and steamed bread because of their prevalence in the local diet. Both boiling times and RHC cooking times were varied during the tests. This was done to determine the minimum boiling times that would give acceptable results within the RHC cooking times established in the previous tests.

With the exception of papa and steamed bread, it was relatively easy to establish cooking times that resulted in "edible" food. It turns out that the "doneness" of these two foods is extremely dependent upon individual taste. A particularly inter-

esting point is that when checking the results in a series of tests in Mokhotlong, steamed bread was found to cook properly in a three-legged pot--not in an aluminum one, thus showing the benefits of additional mass.

Once the recipes were developed, tests were done to determine the fuel savings potential of the RHC. Rice, papa and beans--both simmered and cooked at a rolling boil--were tested on a wick-type paraffin stove. The amount of fuel consumed at various stages of cooking was measured to determine how much fuel would have been saved if an RHC had been used.

Table 15 has been adapted from the test results reported by Klein (Fuel Saving Potential of Cooking with Retained Heat Cookers, RET Project, Maseru, Lesotho, January, 1984). It shows the total fuel consumption, percent savings and amount of fuel saved for the four foods. The savings for beans cooked at a rolling boil are very dramatic. The table also shows that cooking beans normally requires 2-3 times the energy of cooking rice or papa. However, when beans are cooked in an RHC, the fuel requirement drops to the same level as cooking rice or papa entirely on a stove. Using an RHC thus makes it possible for the cook to choose to prepare a more balanced diet without having to use more fuel than presently required for cooking papa--the most common dish.

Table 15. Fuel Savings Potential of an RHC Used with Paraffin*

Food	Total Fuel Used (l)	Percent Savings	Amount Saved (l)
Papa	0.09	30.8	0.03
Rice	0.10	29.8	0.03
Beans (simmer)	0.19	43.3	0.08
Beans (full boil)	0.28	63.3	0.18

*The density of paraffin (kerosene) averages 0.8 Kg/liter.

Production techniques were evaluated in conjunction with the technical testing. The commercially available Wonderbox provided the standard of comparison. It is produced in two patterns--a "diamond" and a "rectangle." Both come with a cardboard box imprinted with the local South African name of the RHC and a picture of it being used. The Wonderbox is most suitable for aluminum

pots up to 30 cm in diameter. They cost M10-11 including postage. The rectangular pattern requires somewhat less sewing and is less wasteful of cloth. The extra "chevron" in the diamond pattern is folded into the pillow during operation, providing a nest for the pot. However, this technically elegant form is not essential to the RHC's operation, and, since the price of the cloth was found to be a limiting factor in the final cost of an RHC, the rectangular pattern was recommended for most economical production.

Since the fabrication of an RHC is a reasonably simple task, the project felt that they could be made by the cook, by a VTS, or by a manufacturing concern. It was also acknowledged that since using an RHC would require a rather significant change in cooking habits, the initial stages of introducing this technology would require a great deal of user education. Therefore, the project chose to develop a recipe booklet and to demonstrate the construction and use of the RHC to multiplier groups such as nutrition extension workers, village health workers, and participants in the Women's Bureau-sponsored Training in Self-Reliance courses. Given the lack of polystyrene beads and the expense of paraffin in rural areas, the potential VTSs have been taught how to use local insulation materials and to make RHCs for both saucepans and three-legged pots.

The economics of an RHC are more complex than it would appear given the dramatic fuel savings exhibited in the project's experiments. The problem is that actual fuel savings depend on the foods cooked in the RHC and on the present cooking practices of the cook. According to the VESR, the typical daily pattern of food consumption includes 42 percent foods with short cooking times, and another 18 percent with long cooking times--all of which are suitable for preparation in an RHC. The first category is expected to exhibit fuel savings similar to rice and papa, while the latter should perform similar to beans.

It is assumed that the fuel savings for the first category is 30 percent, while for the second it is 50 percent. This results in a 21.4 percent daily fuel savings. While the laboratory tests were done only for a particular type of paraffin stove, the economic analysis assumes that there would be similar savings compared to a traditional cooking method as well as for other commercially fueled stoves. Table 16 presents the initial economic assumptions for an RHC used with a protected open fire. Table 17 has equivalent information for an RHC used with a paraffin stove.

C. RET Metal Stove - Model 3

The RET Metal Stove was developed during the second half of 1982 in close cooperation with Basotho women living near the Malefiloane Workshop. The research and development effort was directed by Glenn Burket and Margaret Thomas, stove consultants to the RET project. Subsequent laboratory and field testing was supervised by the project's Laboratory Supervisor.

Table 16. Retained Heat Cooker and Open Fire Protected by Leifo--Initial Assumptions

1. Unit Lifetime = 5 years

2. Initial Cost = M16.00

• Materials--Cloth for 1 pillow	M1.50
• Labor--Collect grass	M .50
Make a "box" inside the house (4 hours @ M0.50/hr)	M2.00
• Leifo--Initial cost	M12.00
Total	M16.00

3. Annual Operation and Maintenance Costs
   - Wash the pillow monthly (3 hours per year @ M0.50/hr)
   - Used the equivalent of 26 weeks per year
   - RHC can cook 42 percent of the daily food, saving 30 percent of the fuel used on the leifo
   - RHC can cook 13.5 percent of the daily food, saving 50 percent of the fuel used on the leifo
   - This gives a combined daily saving of 20 percent compared to using only the leifo
   - Annual costs = (10.8 x 26 x .5 x .8) + (3 x .5) = M113.82

4. Non-Annual Repair and Replacement Costs--Present Worth
   - Replace grass every two years (2 hours @ M0.50/hr = M1.00)
   - Resmear leifo every two years (6 hours @ M0.50/hr = M3.00)
   - Non-annual costs--

     d = 6 M4.00 (1.28 + 1.64) = M11.68
     d = 30 M4.00 (.85 + .73) = M6.32

5. Units of Food Cooked per Year = 182.5

Table 17. Retained Heat Cooker and Paraffin Stove--Initial Assumptions

1. Unit Lifetime--

   RHC = 5 years
   Paraffin stove = 2 years

2. Initial Cost = M25.00

   Commercial RHC = M15.00
   Paraffin stove = M10.00

3. Annual Operation and Maintenance Costs

   - Wash pillows monthly (3 hours per year @ M0.50/hr)
   - RHC and paraffin stove used daily
   - RHC cooks 42 percent of the daily food, saving 30 percent of the fuel used by the paraffin stove
   - RHC cooks 13.5 percent of the daily food, saving 50 percent of the fuel used by the paraffin stove
   - Combined daily savings of 20 percent
   - Paraffin users use at least 3.0 liters per week @ M0.50/liter
   - Annual cost = (3.0 x 0.5 x 52 x .8) + (3 x .5) = M63.90

4. Non-Annual Repair and Replacement Costs--Present Worth

   - Repair paraffin stove in years 1, 3 and 5 @ M1.00

     d = 6 1.13 + 1.45 + 1.86 = M4.40
     d = 30 .92 + .79 + .67 = M2.38

   - Replace paraffin stove in years 2 and 4 @ M10.00

     d = 6 M10.00 (1.28 + 1.64) = M29.20
     d = 30 M10.00 (.85 + .73) = M15.80

   - Non-annual costs--

     d = 6 M33.60
     d = 30 M18.18

5. Units of Food Cooked per Year = 365

Table 18. Paraffin Stove--Initial Assumptions

1. Unit Lifetime = 1.5 years

2. Initial Cost = M10.00

3. Annual Operation and Maintenance Costs

   - Paraffin users use at least 3.0 liters per week @ M0.50/liter
   - Stove is used daily
   - Annual costs = 3.0 x 0.5 x 52 = M78.00

4. Non-Annual Repair and Replacement Costs--Present Worth

   - Replace stove at 1.5, 3.0 and 4.5 years

     d = 6 M10.00 (1.20 + 1.45 + 1.75) = M44.00
     d = 30 M10.00 (.89 + .79 + .70) = M23.80

   - Repair stove in years 1, 2, 4 and 5 @ M1.00

     d = 6 1.13 + 1.28 + 1.64 + 1.86 = M5.91
     d = 30 .92 + .85 + .73 + .67 = M3.17

   - Non-annual costs--

     d = 6 M49.91
     d = 30 M26.97

5. Units of Food Cooked per Year = 365

Two features distinguish this stove from existing commercially available models. First, it is designed primarily for use with traditional bio-mass fuels such as dung, shrubs and agricultural residues. Second, the interior baffle design and removable pot-hole lids enable the stove to accommodate three-legged cast-iron pots as well as flat-bottomed saucepans. Figure 5 contains a detailed drawing of the Model 3 stove. Six stoves can be made from two 1.2 m x 2.4 m steel sheets with less than five percent waste.

The stove was also designed to provide the radiant space heating needed in Lesotho's cold mountain climate. It can burn coal as well as the traditional fuels. A water heater can be added to the side of the stove next to the firebox at no extra cost. Finally, it can be produced in Lesotho with existing metal-working skills, including oxyacetylene cutting, shearing, metal bending and arc welding.

The initial laboratory testing of the RET Metal Stove has been well documented by Thomas and Burket. In comparisons made for cooking papa and meroho, they found that the stove saved roughly 35 percent of the fuel required by the traditional method. Given the added features of house heating and smoke removal, they recommended that the stove be field tested in local homes during the winter of 1983.

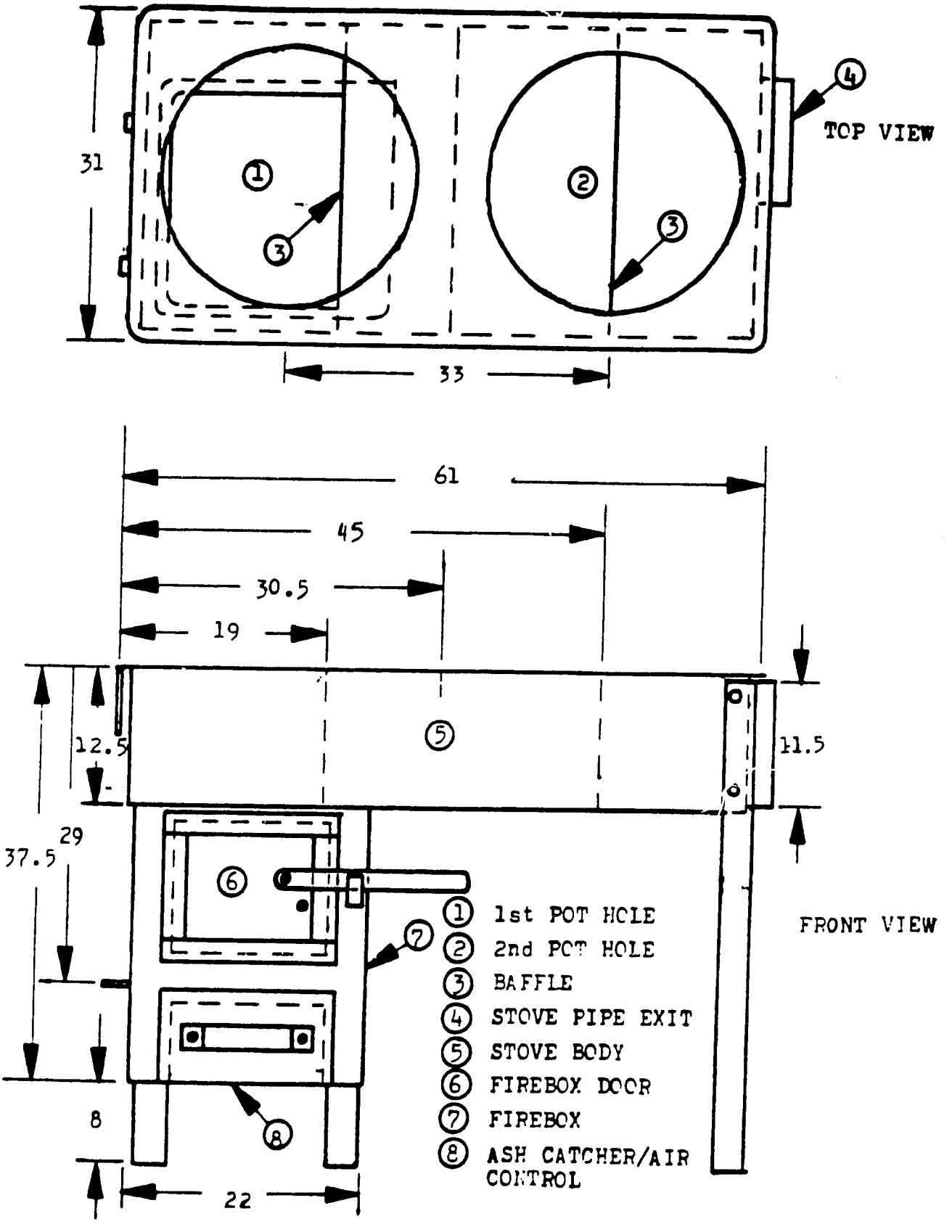
One problem for the field testing and widespread adoption of indoor stoves that was foreseen by project staff was that most houses are roofed with grass or straw. This thatch, which acts primarily to insulate the houses, is known to burn. The few existing chimneys are usually seen sticking through the walls of thatched-roof buildings or piercing through a metal roof. More rarely, stone or cement block chimneys are seen poking up right at the edge of a thatched roof. However, the project felt that, if possible, most of the chimney should be inside the house where it could help provide the needed space heating.

Burket developed a double-stovepipe chimney system designed to protect thatched roofs from burning. The inner stovepipe contains the flue gasses, and is held 25 mm from the walls of the outer stovepipe by spring metal clips. The air space, open at both ends, was designed to prevent the thatch surrounding the outer stovepipe from reaching combustion temperatures--roughly 300°C depending on the moisture content of the thatch. Figure 6 contains diagrams of the chimney systems recommended for combustible and non-combustible roofs.

Following Burket's departure, additional tests were done to determine the performance of the chimney system in the event of a chimney fire. Although the experimenters never actually produced a chimney fire, the double-stovepipe proved itself more than equal to the task of protecting the thatch under excessively high flue temperatures--outer stovepipe 50°C compared to inner stovepipe 280°C (Palasits, McGowan and Klein, Safety Tests of the

Figure 5

MODEL 3 STOVE



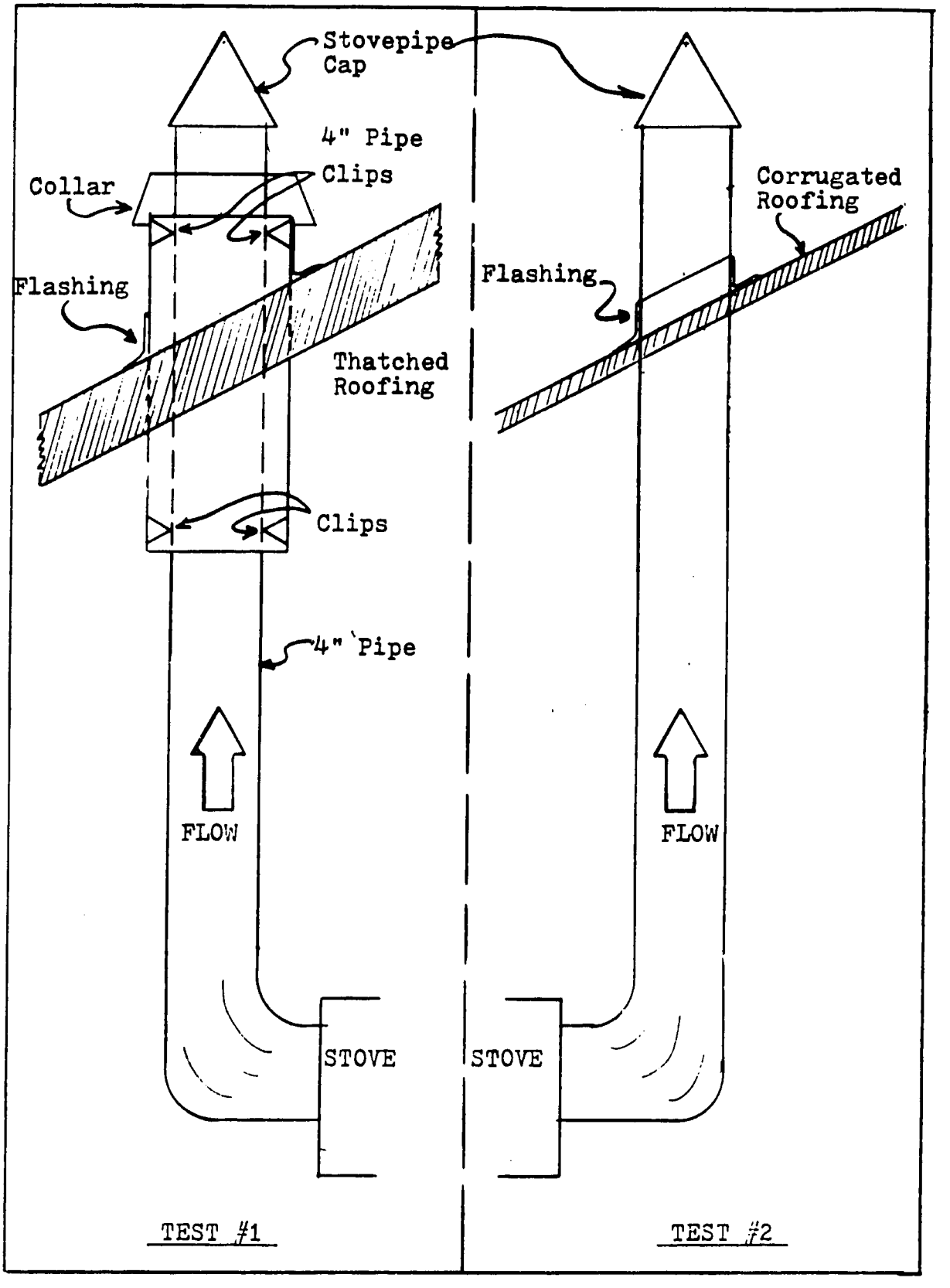


Figure 6

SCHEMATIC DIAGRAMS OF STOVEPIPE/CHIMNEYS

Double-Stovepipe Chimney System Development for Use in Houses with Potentially Combustible Roofs, RET Project, December, 1983).

As designed, the RET Metal Stove had no flue damper. Air flow was to be controlled as it entered the stove by adjusting the ash drawer and fuel-loading door. However, it was recognized that in non-airtight stoves, a properly operated flue damper should improve the performance. A series of tests was conducted at the Khubetsoana laboratory to determine if, in fact, this would occur (Klein, The Effects of a Flue Damper on the Performance of the RET Metal Stove Model 3, RET Project, March, 1984).

Two Model 3 stoves were used for this experiment, one of which was fitted with a flue damper. Table 19 shows the essential results, comparing the fuel consumption, percentage heat used by the pots and the percentage heat radiated by the stoves to the room. As can be seen, the use of the damper marginally reduced fuel consumption but increased the amount of heat entering the pots by 30 percent. (The dampered stove also brought the first pot to boil more quickly than the stove without a damper, which only succeeded in this task in two out of seven attempts.)

Table 19. Effects of Flue Damper on RET Metal Stove

	Without Damper	With Damper
Fuel Consumption (Kg)	4.4	4.2
Percentage Heat Used by Pots	8.0	10.4
Percentage Heat Radiated by Stove	16.0	15.0

However, the radiant heat output was marginally higher in the undampered stove, due primarily to its greater firebox temperatures. The total useful heat output of the stoves was therefore very similar, ranging from 24 to 25.4 percent. It must be noted that the radiant energy was greater than the energy going toward cooking by factors of 2 and 1.5, respectively. This will be particularly useful for space heating during the cold winter months.

It was also found on two occasions that when an inexperienced operator used the dampered stove, performance dropped below that of the undampered stove. Since indoor solid-fuel stoves are practically non-existent in the mountains, knowledge of how to operate a damper correctly is probably also limited. Given the difficulties of teaching the correct use of a flue damper, but recognizing the benefits to be obtained if properly adjusted, it was recommended that dampers be included in the chimney systems

of the RET Metal Stoves. However, the operating instructions should advise people to set the damper wide open while using the stove, until they become thoroughly familiar with their new cooking device. With that background of experience, the cook should be able to learn how best to adjust the damper to improve the stove's ability to perform particular tasks.

It was felt that one more experiment was necessary before releasing the RET Metal Stove for field testing: its durability when used with coal. A series of tests was run at Khubetsoana in May, 1984, to determine if burning coal would result in any immediately noticeable negative changes on the Model 3 stove. The tests involved placing two Size 4 pots full of water (roughly 60 Kg total) on the stove and firing it to maintain firebox temperatures over 350°C for several hours. Observations of dimensional changes due to the large mass and intense heat were the test's parameters (Klein, Durability of the RET Metal Stove Model 3 When Coal Is the Primary Fuel, RET Project, March, 1984).

The experiment determined that there were no immediately noticeable effects of using coal as the primary fuel. Dimensional changes were less than the amount expected based on steel's coefficient of linear expansion. It was found that the most likely problem would be the erosion of the steel in the firebox, in particular, at a point where the smoke path changed direction to pass underneath the pots. The report concluded that if coal was the primary fuel, the stove could be expected to have a shorter lifetime than if dung fuels were used.

The field cooking performance tests planned by Thomas were undertaken in late fall and early winter of 1983. Five households volunteered to participate in an experiment designed to compare the fuel consumption of their traditional stove--a bucket paola or an open fire--with the RET Metal Stove Model 3. Fuel consumption was measured for seven consecutive days for each of the stoves. Following the tests, the cooks were asked about how the stove performed and were given the option of purchasing the stove. All households did.

In their report, Matete, Palasits and Klein (Results of Kitchen Performance Tests on RET Metal and Earthen Stoves in Nine Households in the District of Mokhotlong, RET Project, January, 1984) found that since it was winter, most households used a bucket paola for cooking and space heating. The fuel consumption, averaged over five households, was 1.74 Kg/person/day when using bucket paolas, and only 1.36 Kg/person/day when using the RET Metal Stoves. This savings of 22 percent was statistically significant at the 5 percent level.

While all households felt that the stove heated their houses well, there was a persistent complaint that the second pot didn't boil. It must be noted that the stove was designed to boil the contents of the first pot and keep hot the contents of the second. (Only one of the stoves tested by the project--see Thomas and

Burket--a modified two-pot-hole stove made by the Rural Technology Unit (RTU) in Thaba-Tseka, could boil either of the two pots. However, this stove, with a firebox centered beneath the two pots, was intended for use only with saucepans and thus did not meet one of the design criteria for improved stoves.) Although the cooks were informed of this feature and the subsequent need to switch the position of the pots during cooking, their comments may indicate a desire for a true two-burner stove. This should be investigated further.

Following a few months of use, the RET project examined the chimneys of several stoves. These observations were undertaken in late winter of 1983 to assess the nature of the maintenance performed by the owners and the level of risk if no maintenance had been done. The households interviewed were participating in the kitchen-performance monitoring tests and included owners of both RET Metal and Earthen Stoves (Matete and Klein, Observations on the Maintenance of Recently Acquired Chimney Systems, RET Project, January, 1984).

It was found that the double-stovepipe chimney system was not particularly susceptible to creosote buildup after roughly three months of daily stove use. This was probably due to the combination of relatively short, hot fires, dry fuels, and the interior chimney. The owners had little or no knowledge of proper maintenance techniques even though these had been discussed when the stoves were installed.

One technical problem was discovered during these interviews: back puffing of the stove. This is related to the relative pressure between the inside and the outside of the house. The infiltration rate through thatch roofs, coupled with the open design of the double-stovepipe chimney system, reduces the effective draft up through the flue. Some owners also complained about cold air coming into the house through the air space formed by the stovepipes. The project should develop a closed double-stovepipe system that will address these related problems.

Other observations made on the RET Metal Stove installed at the Watchman's house in Khubetsoana also examined the potential fire hazard of inadequate chimney maintenance. This stove burned coal and was used primarily for heating. Creosote formation was large, necessitating weekly cleaning of the chimney system during the middle of winter. The creosote was probably due to the long, slow burning rate of the coal combined with an inadequate supply of secondary air to burn off the gasses escaping from the coal.

A production and marketing program was begun in January of 1983 so that the Model 3 stove could be test marketed during the winter of that year. Mr. Burket began assessing production methods by training RET staff members to produce the stove. This first "production" run showed that the manufacturing process could be streamlined by using a metal shear instead of an oxy-acetylene torch to cut stove parts (McLean and Klein, Production

and Marketing of the RET Metal Stove Model 3--Preliminary Findings, RET Project, February, 1984).

Given this background, the project approached three local workshops, two in Maseru and one in Thaba-Khupa 20 km east of Maseru, to see if they were prepared to produce the stove for the market test. Even though the purchase of up to 50 stoves had been guaranteed, only the Thaba-Khupa Workshop was interested in the job. They committed themselves to produce 12 stoves by the end of February in return for training of their welders and the jigs used in the manufacturing process.

However, no stoves were delivered until the end of March, when only half the order arrived. The quality of these stoves was adequate in most respects, but unacceptable regarding the location of the smoke baffles and door hinges. The stoves were returned to correct the mistakes, and Thaba-Khupa promised the entire order by the end of April. None arrived until the last week in May.

These delays forced the project to postpone the start of the market test until more stoves could be produced. A production run of six more stoves took place in Malefiloane in early July. The market test was rescheduled to begin in August, which, although not ideal, was still in the middle of the heating season.

The experience of producing the stove in two different locations was very valuable. Table 20 shows the production costs in 1983 at Malefiloane and for a small lowlands workshop similar to Thaba-Khupa. As can be seen, generator costs in Malefiloane are the primary cause of increased costs at that remote site. It is clear that access to an inexpensive source of electricity is important to keeping the final cost of the stove as low as possible. Neither price includes profit.

Table 20. Cost of Production at Two Workshop Locations

	Malefiloane Workshop*		Lowlands Workshop**	
	Cost	Percent	Cost	Percent
Materials	168.85	32.2	142.87	46.4
Generator time (or mains)	225.00	43.0	35.10	11.4
Labor	65.00	12.4	65.00	21.1
Shop time	65.00	12.4	65.00	21.1
Total for 6 stoves	523.85		307.97	
Cost per stove	87.31		51.32	

*Based on data from Malefiloane Workshop.
**Estimated costs assuming 10 percent transport charges on materials and mains electricity at M0.06 per kilowatt hour and a 9-kilowatt demand.

The project must make a decision concerning the production site or sites for the RET Metal Stove. There seems to be a trade-off between lowest production cost and the location of the manufacturing plant. If jobs are desired in rural areas, then it may be necessary to accept a somewhat higher price for the stove. On the other hand, locating the plant in Maseru would make the stove less expensive to the consumer. This dilemma will need to be addressed before a large-scale dissemination program gets underway.

The market test was conducted at two shops, one located in Mokhotlong camp and the other next to the workshop in Malefiloane. It was designed to indicate the acceptability and potential sales of the Model 3 stove. Twelve stoves were placed in the two stores, priced at M78.00 and M75.00 respectively. Both prices excluded the cost of the double-stovepipe chimney system, which was M15.00. The shop in Mokhotlong offered free installation, while the one in Malefiloane charged M5.00 for this service.

When the test was terminated in October, only five of the stoves had been sold, four at Malefiloane where they had been developed, and one in camp. (Immediately following the test, a local school purchased the remaining stoves.) The five purchasers during the test period were interviewed in the VESR. It was found that the purchasers were relatively well off compared to the general population. (In contrast to the "average" sample interviewed in the kitchen-performance tests.)

The owners liked their new stoves, particularly because they burned dung fuels, they used three-legged cast-iron pots as well as saucepans, and they would heat the house during cold weather. On the negative side, the people indicated that it would have been better if the stove, chimney and installation had been sold at one price. Future marketing efforts should remember this point.

This limited market test indicated that there is a place for the RET Metal Stove Model 3. An expanded test should be conducted to verify the results. The test should begin in the fall and run through the entire winter and should be coupled with a complete advertising campaign (posters, radio, demonstrations). The project should evaluate the results three months following the termination of sales.

Table 21 contains the initial economic assumptions for the RET Metal Stove. The most important factors for this stove are its longevity and its initial cost. The longer its useful lifetime, the better chance it has of being a worthwhile investment.

D. Improved Metal Paolas

As mentioned in an earlier section, the metal paola is one of the most common cooking devices in Lesotho. This simple brazier, in use throughout the country, is usually made from an old bucket or an empty 20-liter paraffin tin. The paola is made by punching

Table 21. RET Metal Stove--Initial Assumptions

1. Unit Lifetime = 8 years

2. Initial Cost = M100.00

3. Annual Operation and Maintenance Costs
   - Labor to collect fuel and maintain stove is M0.50
   - Used the equivalent of 26 weeks per year
   - Requires 8 hours annual maintenance
   - Saves 22 percent of the fuel consumed by a traditional paola or an open fire protected by a leifo
   - Annual costs = 10.8 x 26 x .5 x .78 + (8 x .5) = M113.51

4. Non-Annual Repair and Replacement Costs--Present Worth
   - Replace chimney every four years
   - Chimney costs M15.00, installation M5.00
   - Non-annual costs--

     d = 6 M20.00 (1.64 + 2.70) = M74.20
     d = 30 M20.00 (.73 + .53) = M25.20

5. Units of Food Cooked per Year = 182.5

many small holes all around the sides. These enable oxygen to reach the fire made inside the paola. The major advantage of a paola is its portability--during cold or inclement weather, a fire can be started outside and then brought indoors for cooking or heating once the initial smoke has dissipated. Figure 7 contains sketches of these two paolas.

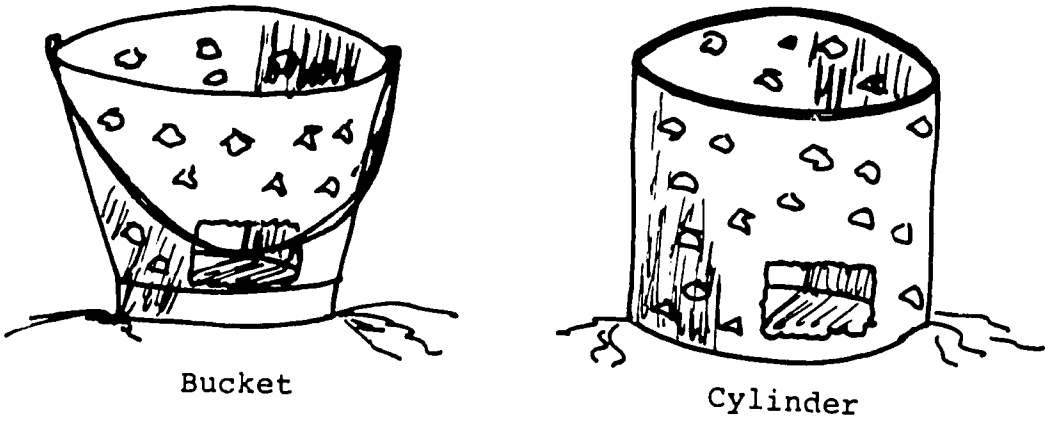


Figure 7

TWO TRADITIONAL PAOLAS

When used for cooking outdoors, the paola is often protected from the wind by a leifo or an old corrugated roofing sheet propped between the wind and the fire. For cooking and heating water, a three-legged pot or flat-bottomed oil tin can be perched on top of the paola, or supported by a single iron rod stuck through the holes in the side or resting on a trifoot set over the top of the paola. In rural areas, paolas most commonly burn dung fuels, while coal is often used in lowland towns.

While the traditional paola is reasonably effective, the firebox is too large for optimal heat transfer to the pot, and when not indoors or otherwise protected, the pot resting on the paola is exposed to the cooling effects of the wind. In 1980-1981, the Rural Technology Unit (RTU) in Thaba-Tseka tested some paolas with integral wind protection collars and smaller fireboxes to see if cooking performance could be improved. The first design was shaped like an hourglass or a cooling tower with a single air-and-fuel door at the base. The pot rested directly above the fire with only a small (1.5-2.0-cm) space for the smoke to escape between the pot and the protective walls of the upper part of the paola. There was no grate. (See Figure 8.)

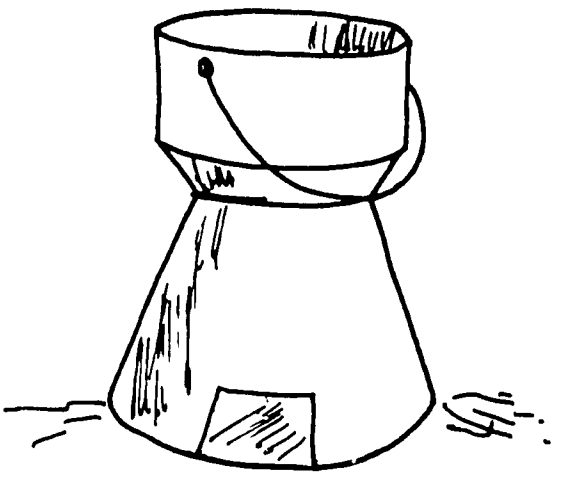


Figure 8

CONICAL PAOLA DESIGNED BY RTU

The unit worked well for cooking, but was found to burn fuel very quickly and proved to be difficult to make. The RTU experimented with other shapes, eventually settling on a version with a square base and a grate. This design wasted fewer materials and was easier for the metalworkers to make. In 1981, the paola for Size 1-3 pots sold for M7.00 in Thaba-Tseka. (See Figure 9.)

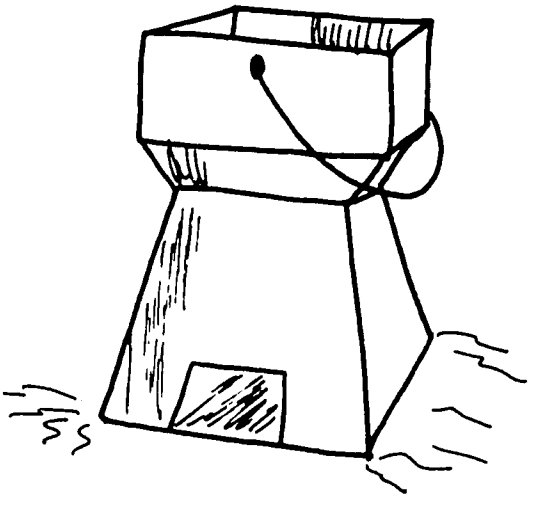


Figure 9

SQUARE PAOLA DESIGNED BY RTU

The RET project felt that the test data from Thaba-Tseka was inadequate and so decided to begin its efforts by testing traditional paolas. This was done to establish a base to which any future developments could be compared. It was recognized that both cooking and heating performance would have to be evaluated. Testing began in 1982, during Thomas and Burket's consultancy.

Three traditional paola shapes were investigated: conical, cylindrical and square. The conical paola was made from a bucket. The cylindrical and square paolas were made from empty paraffin tins with the tops removed. Three configurations of each shape were tested:

1. Holes all around (traditional)

2. Holes one-third of the way up from the paola's base

3. A single large hole near the paola's base

In all, nine paolas were tested. The purpose of these tests was to see which shape and configuration was most efficient when burning dung and shrub fuels. Efficiency, or percentage heat used by the pots, was determined by observing fuel consumption, water temperature and water loss due to evaporation in a series of water boiling tests. These tests simulated a local cooking practice--the preparation of papa followed by the warming of water for washing, using the heat remaining in the fuel. Details of the test procedure may be found in Thelejane and Klein (Simulated Cooking Tests To Determine the Efficiency of Traditional Metal Paolas, RET Project, December, 1983).

Test results showed that the traditional bucket paola had the highest efficiency (11 percent) of any of the nine stoves. Holes-all-around was the most efficient configuration (10 percent) for all three paola shapes. The traditional bucket paola brought the first pot to boil in an average of 17 minutes. These results support the Basotho choice of the bucket paola with holes all around as the most common brazier in Lesotho.

Paolas with integral wind protection collars were tested next. Three firebox shapes were tested: cylindrical, conical and square. (In Figure 10, note the straight sides on the base of the square paola--a modification from the RTU design.) Each paola was fitted with a cowl above the firebox. When in use, the cowl supported the pots directly above the fire and formed a narrow path for the escaping hot gasses. The wind protection collar, attached above the cowl, prevented the wind from removing the gasses until after they had risen above the lid of the pot.

Two other parameters were investigated in these tests in addition to the firebox shape. One was the effect of the inclusion of a grate. The other was the effect of having a fixed or adjustable air inlet. The same cooking simulation was used as for the tests on the traditional paolas.

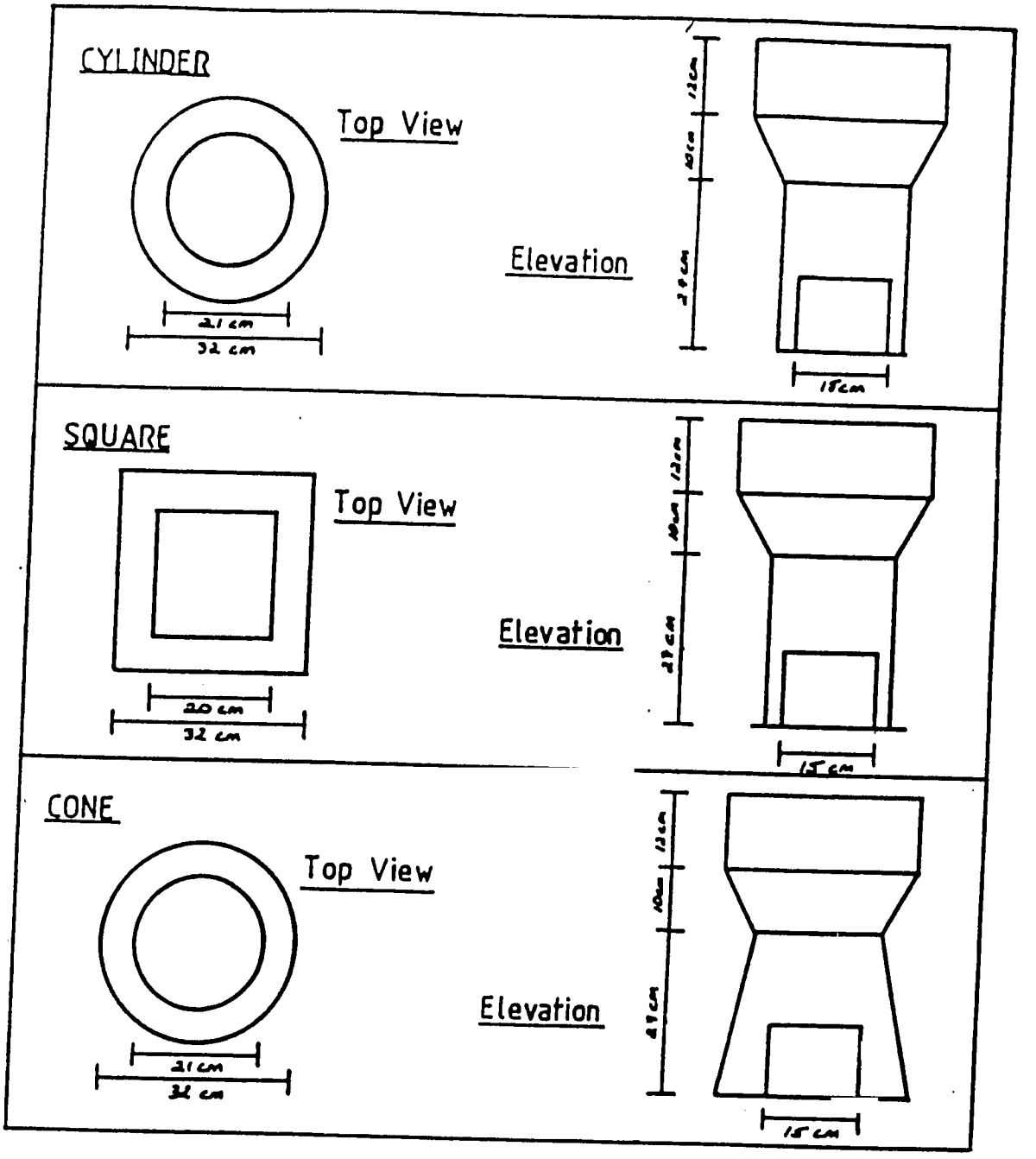


Figure 10

THREE SHAPES OF PAOLAS

These tests showed that the cylindrical firebox with a grate and fixed air inlet was the most efficient paola tested (14.3 percent). This paola brought the first pot to boil in an average of 11 minutes. The addition of a grate resulted in a marginal but insignificant improvement in efficiency over the paola without a grate. However, having a grate resulted in a 15 percent savings (11 minutes compared to 13 minutes) in the time required to boil the water in the first pot--significant at the 1 percent level. Having the option of adjusting the air inlet resulted in an insignificantly lower efficiency than the fixed opening.

It is instructive to compare the average results from the traditional and improved paola tests. Table 22 shows the mean and the standard deviation of the fuel consumption, efficiency, time to boil Pot 1, and temperature rise in Pot 2 for both test series. For all parameters except temperature rise in Pot 2, the improved paolas out-performed the traditional paolas. It is noteworthy that the mean efficiency of the improved paolas was higher than the best performer among the traditional paolas. It is likely, however, that local cooks will place greater value on the average fuel consumption, which was 30 percent lower for the improved paolas. When converted into time, this could mean a savings of over three hours per week in collecting fuel.

Table 22. Comparison of Traditional and Improved Paolas

Parameter	Traditional n=22	Improved n=36
Fuel Consumption (grams)*		
$\bar{x}$	2,844	1,984
s	717	325
Efficiency (percent)		
$\bar{x}$	9.59	11.60
s	1.31	2.23
Time To Boil Pot 1 (min)		
$\bar{x}$	15.45	12.43
s	3.36	4.87
Temperature Rise in Pot 2 (°C)		
$\bar{x}$	37.95	28.42
s	18.29	10.70

*Mass is in equivalent grams of khapane. Fuel indices are lisu = 1.0, khapane = 1.0, sehalahala = 1.29.

Thelejane and Klein (Simulated Cooking Tests To Determine the Efficiency of Traditional Metal Paolas, RET Project, December, 1983) concluded that, although not the best performer, the square paola with a grate and a fixed air inlet should be recommended for production. This was the easiest and the least wasteful to manufacture of the paolas tested, according to the local sheet-metal worker who made the experimental prototypes. One modification of the tested shape was recommended by the authors: rounding off the corners of the wind protection collar. This would make the path for escaping smoke much more like that in the cylindrical paola which was the best performer among the versions tested. The material used for the corner inserts can be taken from what would otherwise be wasted.

A square, improved paola was used to determine the optimal distance between the grate and the bottom of the pot. The same cooking simulation was used as in the previous tests. The performance was compared at 20-, 25-, 30- and 35-cm gaps between the grate and the top of the firebox. Figure 11 shows a sketch of the elongated paola used in this test.

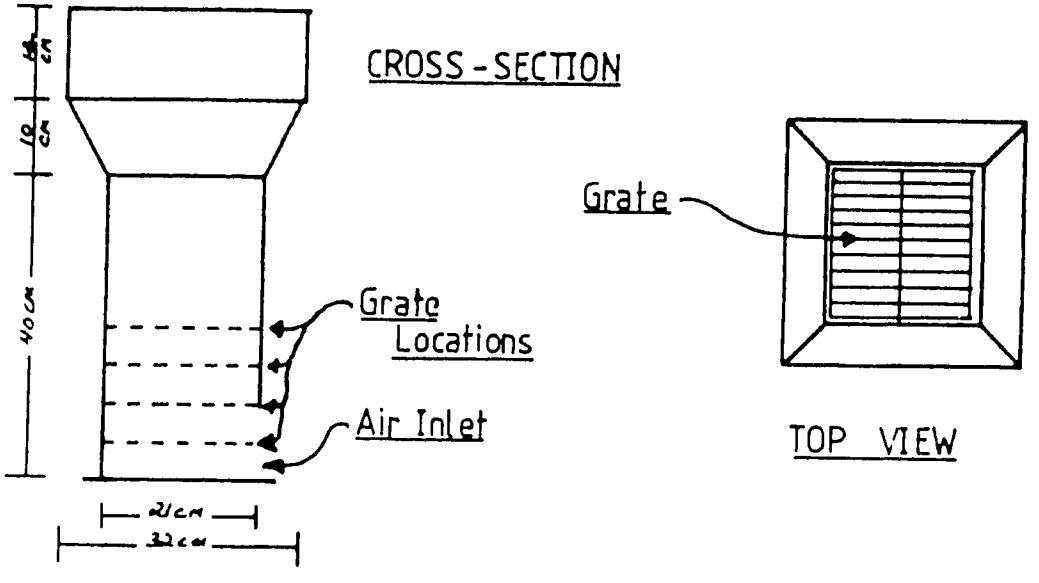


Figure 11

ELONGATED IMPROVED PAOLA

As reported by Thelejane and Klein (Simulated Cooking Tests To Determine the Optimal Spacing Between the Pot and Grate in an Improved Metal Paola, RET Project, December, 1983), a 20-cm gap gave the best performance. This is shown in Table 23, taken from the laboratory report. The 20-cm spacing resulted in the highest efficiency, the lowest time to boil Pot 1, and the highest temperature rise in Pot 2.

Table 23. Results of Grate-to-Pot Separation Tests

Grate-to-Pot Height (cm)	Average Efficiency (%)	Average Time To Boil Pot 1 (min)	Average Temp Rise in Pot 2 (°C)
20	13.3	10	35.0
25	10.6	11	24.3
30	9.8	13	30.0
35	9.5	14	28.3

It should be noted that the efficiency curve had not reached a maximum at this separation distance (20 cm). However, if the spacing was much smaller, the paola would require additional stoking and would thus be less convenient for the cook. While further tests could be run to determine the exact point at which the maximum efficiency occurs, it is felt that 20 cm provides acceptable performance as well as convenience. This separation between the grate and the pot is recommended for production models.

All of the previous tests examined cooking performance. However, one of the major functions of a traditional paola is to provide radiant heating as well as cooking. The RET project felt that this parameter should also be investigated prior to making a decision regarding the dissemination of the "improved" metal paolas.

Nine paolas were chosen for use in these tests. The radiant energy was measured by surrounding three quarters of the firebox of each paola with a ring of water. The water jackets were filled with 20 liters of cold water prior to each test. The temperature rise of the water was used to determine the radiant energy emitted by the paola.

As in previous tests, cooking performance parameters were also measured. The results showed that traditional paolas were better radiant heaters than the "improved" paolas by 67 percent. However, the percent of the total energy absorbed as radiant heat was very small, only 5 percent and 3 percent, respectively, compared to the percentage of heat used for cooking purposes, which was 9.4 percent and 11.8 percent, respectively. The combined cooking and heating performance was virtually identical for the two types of paolas.

Although the percentages of net useful energy were so similar, the "improved" paolas required an average of only 78 percent of the fuel used by the traditional paolas. In addition, they brought the first pot to a boil in an average of only 10.7 minutes, compared to 18.5 minutes for the traditional paola. These findings were in accord with earlier tests.

Production of traditional paolas for urban areas is presently performed by local tinsmiths. Maseru Market has the largest concentration of these skilled artisans of any town in the country. The project estimates that there are fewer than 200 of these independent artisans practicing their trade in Lesotho. It was felt that if the improved paola proved beneficial, it would be a reasonably simple matter to add this product to the existing product lines of these metalworkers.

To test this concept, the project contracted with one of the metalworkers to make the improved paolas used in the experiments. He was supplied with templates to use as cutting patterns, so that the work would go more quickly and to help standardize the final product. The project staff helped him to make one paola of each type and then left him on his own for the rest.

It was found that the metalworker preferred making the square improved paolas. Both the cylindrical and conical paolas had a very difficult joint where the cowl met the top of the firebox. In addition, these two paolas wasted more material than the square shape, which resulted in two complete paolas from one 915-mm x 1830-mm sheet.

The metalworker noted that he was presently getting four traditional cylindrical paolas from the same size sheet. Given the added thought and skill required for the new paolas, he charged the project three times the going price of his regular paolas. This came to M13.50 per paola.

Increased familiarity with the paola should decrease its relative cost to only twice that of the ones presently being sold. Another possibility would be to produce the paolas in a central shop where mass production could reduce the costs somewhat further. The trade-offs between lowest initial cost and widespread production sites still need to be evaluated.

All these considerations effect the economics of the improved paolas. It is clear that there are significant savings of fuel when cooking performance is the primary criterion. There is also some saving of time during the cooking process. However, paolas are very important for winter heating, and the more efficient cookers gave off less than 50 percent of the radiant heat emitted by the traditional paola.

Given these factors, it is likely that, if adopted, the improved paolas would be used for only six months of the year. In the winter, when higher heating rates are desired, people would probably continue to use the traditional paolas. It can be assumed that the fuel consumption would be at most 80 percent of that presently required by the traditional paolas. Tables 24 and 25 contain the initial assumptions used for the improved and traditional paolas in the economic analysis.

Table 24. Improved Metal Paola--Initial Assumptions

1. Unit Lifetime = 2 years

2. Initial Cost = M15.00

   - Materials--

     Sheet metal 0.5 mm M 4.50
     Galvanized wire .50

   - Labor--

     Metalworker
     (5 hours @ M2.00/hr) M10.00

3. Annual Operation and Maintenance Costs

   - Labor to collect fuel is M0.5 per hour
   - Replace grate for M0.50
   - Used the equivalent of 26 weeks per year
   - Saves 20 percent of the fuel consumed by a traditional paola
   - Annual costs = (10.8 x 26 x .5 x .80) + .50 = M112.82

4. Non-Annual Repair and Replacement Costs--Present Worth

   - Replace every two years*
   - Non-annual costs--

     N = 4,5 years
     d = 6 M15.00 (1.28 + 1.64) = M43.80
     d = 30 M15.00 (.85 + .73) = M23.70

     N = 8 years
     d = 6 M15.00 (1.28 + 1.64 + 2.11 + 2.70) = M115.95
     d = 30 M15.00 (.85 + .73 + .62 + .53) = M40.95

5. Units of Food Cooked per Year = 182.5

*When comparing to a traditional paola, ignore these costs.

Table 25. Traditional Paola--Initial Assumptions

1. Unit Lifetime = 2 years

2. Initial Cost = M0.50

3. Annual Operation and Maintenance Costs
   - Labor to collect fuel is M0.50 per hour
   - Used the equivalent of 26 weeks per year
   - Annual costs = 10.8 x 26 x .5 = M140.40

4. Non-Annual Repair and Replacement Costs--Present Worth
   - Needs to be replaced every two years*
   - Non-annual costs--

N = 4,5 years

d = 6 M0.50 (1.28 + 1.64) = M1.46
d = 30 M0.50 (.85 + .73) = M.79

N = 8 years

d = 6 M0.50 (1.28 + 1.64 + 2.11 + 2.70) = M3.86
d = 30 M0.50 (.85 + .73 + .62 + .53) = M1.37

5. Units of Food Cooked per Year = 182.5

*When comparing to improved metal paola, ignore these costs.

E. Earthen Stoves

Earthen stoves are a technology that has been tried in many places around the world. They are made from a mixture of sand and clay, which in Lesotho is usually combined in a ratio of 3-4:1. The stove can be built on the ground or raised on a platform of stones or other material. The mix is typically applied in thin layers which are pounded down until firm. These layers are added to until the stove body has reached the desired height. Pot holes and flue passages are carved out of the resulting block. An ash drawer, grate and dampers can be added, depending on the design of the particular stove.

Prior to the RET project, a number of other groups had introduced earthen stoves. These included Plenty Lesotho, which is a development project located in Quthing District; a UNICEF-funded project in the Food Preservation Unit of the Ministry of Agriculture; and the Rural Technology Unit (RTU) of the Thaba-Tseka Integrated Rural Development Program. The stoves were patterned after the Lorena stove introduced in Guatemala. None of these groups managed to get many earthen stoves into daily use in local homes. Only the RTU tested their stoves prior to dissemination.

The project was able to learn much from these other efforts. They provided a background for the first stove consultant, Ianto Evans, who was in Lesotho during January and February of 1982. Mr. Evans taught project staff how to construct earthen stoves properly and how to adjust the thickness of the walls and the height of the smoke baffles to vary and optimize stove performance. He also helped the project to focus on ways to train earthen-stove builders and methods of disseminating this technology.

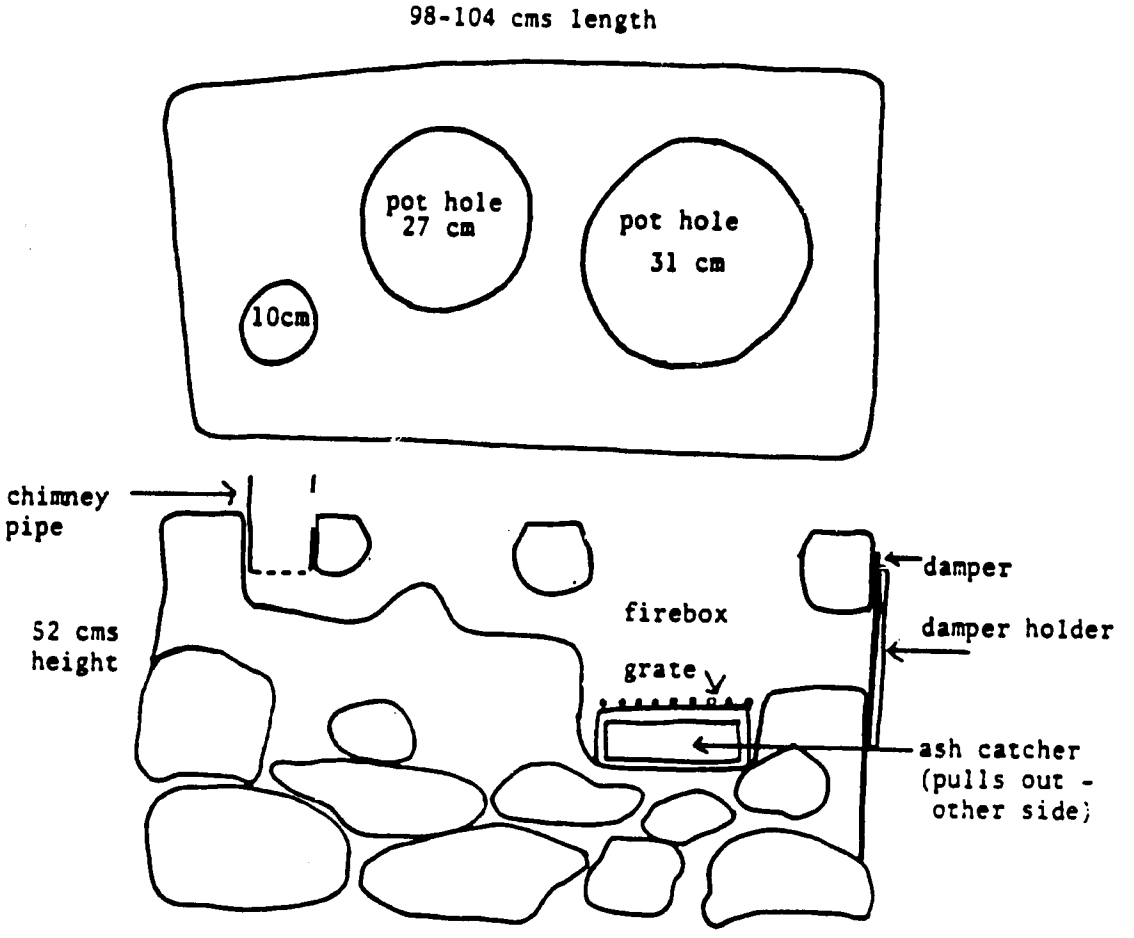
Consultants Margaret Thomas and Glenn Burket arrived in Lesotho in August, 1982, to develop this technology further. Figure 12 contains a diagram of a typical earthen stove. Their work has been well documented in Stove Consultancy for Lesotho RET Project. Briefly, they:

- adapted earlier models to perform better with dung fuels (enlarged the firebox and included a grate);
- measured fuel use during a series of controlled cooking tests to compare performance with other stoves;
- conducted training courses for groups of prospective earthen stove builders in the mountains and in the lowlands; and
- developed procedures for kitchen performance testing of the stoves.

Controlled cooking tests, based on the preparation of papa and meroho and heating water showed that the earthen stoves saved significant quantities of fuel compared to traditional cooking methods. Their preliminary estimates indicated fuel savings of 41-48 percent for the earthen stoves that were tested.

Fuel savings under controlled laboratory conditions are indeed very dramatic, roughly 54 percent. The earthen stove fell between the open fire and the paola in speed of bringing the first pot to a boil. However, it was considerably slower than either traditional method during the actual cooking process. Finally, it raised the temperature of the water in the third pot over 30°C higher than the traditional stoves. This last result may be partially due to the fact that the earthen stove was inside the cooking shed where it was relatively warm, compared to outside, where the other tests took place.

Given the significant fuel savings, Thomas and Burket recommended that the earthen stoves be tested in people's homes. These tests were to examine fuel savings for cooking, space heating capability, and durability and maintenance issues. These kitchen performance tests were conducted in fall and winter of 1983, at the same time as those done with the RET Metal Stove Model 3. Four households participated in the experiment. Although all households saved fuel with their new stoves, the savings were significant in only one case. When the data from all households



A Rock Base Mud Stove with Grate and Ash Catcher

Figure 12

RET EARTHEN STOVE MODEL 3 (SCALE 1:10, CM)

were combined, the earthen stoves saved 11 percent of the fuel consumed by the traditional stoves. However, this amount was statistically insignificant.

The cooks said that they liked their stoves because they found them to be faster than their normal methods (contrary to laboratory test results); they saved fuel; they could be used with local dung fuels and both three-legged pots and aluminum saucepans and with two pots at a time. Although the cooks also noted that the chimney provided a little heat to the house, only one household felt that the heat was adequate for their needs. The cooks expressed two additional problems with their stoves: the second pot didn't boil, and it was difficult to control the fire. The first point was also mentioned by the Metal Stove users and should be investigated further by the RET project.

The issue of durability was assessed by means of a questionnaire administered by project staff members to users of earthen stoves. Cracking, deterioration of the firebox, chipping around the pot holes and damper slots, surface degradation, and durability of the grate, damper, ash drawer and baffle were examined in the four households chosen for this experiment. Two common problems were that the stoves cracked between the damper slot and the front of the stove (see Figure 13), and that the walls of the fireboxes were deteriorating. The first problem was not as serious as the second, which will require reasonably frequent maintenance. With these exceptions, the stoves were well maintained by the cooks and suffered few damages from daily use. The report by Mahooana and Klein (Durability of Earthen Stoves When Installed in People's Homes--Preliminary Findings, RET Project, December, 1983) suggested that the questionnaire be administered at six-month intervals for the next two years, so that a longer-term picture of durability could be obtained.

Mahooana and Klein also found that people were not satisfied with the heating capability of the stoves. They recommended that the project investigate "thin wall" earthen stoves and methods for reducing air infiltration rates in people's homes. If infiltration can be reduced significantly (the scope for which was indicated by Klein and Wyatt), then the lower radiant heating rate of earthen stoves may prove suitable in the mountains. In any event, it was recommended that measures to "tighten up" the house be coupled with the introduction of all indoor stoves which have chimneys to remove the smoke.

Earthen stoves, as designed and tested in Lesotho, need to be handcrafted every time one is desired. While many approaches were explored, the most suitable seemed to be for the cook to assist a trained stove builder in the construction of her stove. This has the advantage that the cook, having learned to make the stove, will be better able to maintain it without needing much assistance. The disadvantage is that widespread dissemination would not be possible unless there were many trained stove builders to assist the cooks. Because of the need to fine-tune the internal

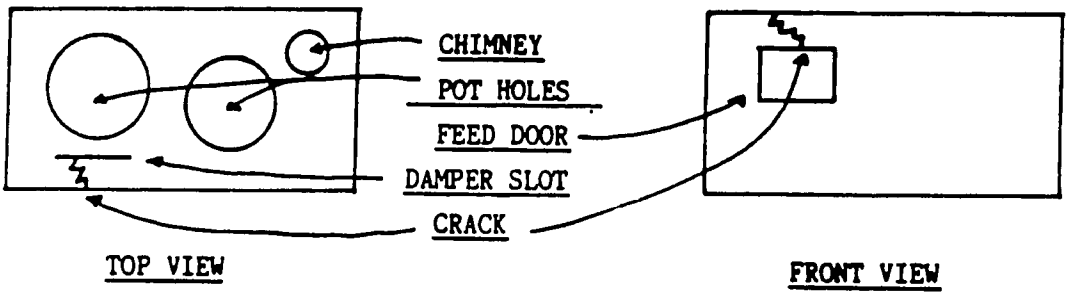


Figure 13

LOCATION OF CRACK ON EARTHEN STOVE

dimensions of the stove, as well as the mix from which the stove is made, training enough skilled artisans would be a time-consuming process.

Thomas and Burket noted that earthen stoves might be better suited to the lowlands where earth is used much more frequently in construction and where heating requirements are lower than in the mountains. Although their laboratory tests showed dramatic fuel savings, these were not borne out in kitchen performance tests. An additional problem was that people were dissatisfied with the heating performance. Finally, long-term maintenance requirements have not yet been determined.

Table 26, the initial economic assumptions for earthen stoves, is presented with these points in mind. The lifespan of the earthen stove is assumed to be five years. This is based upon the results of the short-term durability tests and upon observations of similar earthen structures already used in people's homes. As with the Metal Stove, the earthen stove's initial cost is relatively high. Thus, its lifetime is an important consideration when assessing its economic viability.

F. Solar Water Heaters

Solar water heaters have been in use in Lesotho for many years. The first large-scale installation ($30m^2$) was located at St. Charles Hospital, north of Butha-Buthe, in 1968. The panels operate by thermosyphon action--chosen because of simplicity and the absence of electricity at this remote site. The system was designed to provide sanitary hot water for the entire hospital. This goal has been accomplished with the exception of periods when the panels need maintenance, which has been infrequent in over 15 years of operation.

Given Lesotho's almost ideal solar conditions, one would have expected to see many more solar water heaters than are in evidence today. Several factors seem to have limited their widespread use. These include freezing temperatures on winter nights, initial cost of installation, lack of piped water supplies, and some early bad examples.

As shown in the section on needs assessment, Lesotho has excellent solar radiation, coupled with an extremely variable temperature regime. Daytime temperatures are usually well above freezing, even in the mountains during winter. However, nighttime winter lows are often below freezing throughout the country. Virtually all of the solar water heaters that have been installed have no method of freeze protection. This is not surprising, as it is rarely found in thermosyphon systems which constitute over 95 percent of the installations in the country. As it turns out, it is not necessary to have additional freeze protection in properly designed and insulated collector installations.

Table 26. Earthen Stove--Initial Assumptions

1. Unit Lifetime = 5 years

2. Initial Cost = M40.00

   - Materials--

Chimney	M15.00
Grate	1.50
Ash door	2.00
Baffle	.50
	M19.00

   - Labor--

Collect materials (8 hours @ M0.50/hr)	M 4.00
Make stove (12 hours @ M1.00/hr)	12.00
Fit chimney	5.00
	M21.00

3. Annual Operation and Maintenance Costs
   - Labor to collect fuel and maintain stove is M0.50/hr
   - Requires eight hours maintenance
   - Used for equivalent of 26 weeks per year
   - Saves 11 percent of the fuel used by a traditional paola or an open fire protected by a leifo
   - Annual costs = 10.8 x 26 x .5 x .89 + (8 x .5) = M128.96

4. Non-Annual Repair and Replacement Costs--Present Worth
   - Replace chimney in the fourth year
   - Chimney costs M15.00, installation is M5.00
   - Non-annual costs--

     d = 6 M20.00 (1.64) = M32.80
     d = 30 M20.00 (.73) = M14.60

5. Units of Food Cooked per Year = 182.5

Initial cost has plagued the widespread use of solar water heaters. This is particularly the case in Maseru, where most of those people who could afford commercially available units live. However, most of these individuals live in, or lease out, rental accommodations. They are not looking at long-term costs, something that is necessary in order to realize the benefits of solar water heaters. And, in fact, most of the installations can be found at institutions such as missions, hospitals, clinics, schools, and private homes where the owner is also the user and, thus, is interested in reaping the long-term benefits of the initial investment.

Lack of piped water supplies is an additional impediment to adoption of this technology. Most rural communities get their water from springs, located up to one kilometer from the village. The combined efforts of MINCORUDEV, Helvetas and USAID are slowly resulting in the distribution of both spring-fed and borehole water to public taps dispersed throughout certain villages. Even though this will bring the water closer to the user, most rural homes will not have water inside the house for many years to come.

The situation is better in urban and peri-urban areas. Nonetheless, most households collect their water from a public tap. Only a small and relatively affluent minority have water on their sites or in their homes.

None of the manufacturers of solar water heaters has specifically designed a system for use under these conditions. Some people have modified their units to work from a tap located in their yard. When they want hot water, they put cold water into the heater and take hot water back to the house in a bucket. The needs of this large population without piped water supplies should be considered by the ATS at a later date.

It is unfortunate, but there have been many prominently placed, but technically bad, examples of solar water heaters in Lesotho. One of the earliest activities of the RET project was to examine about 50 installations in Maseru. Most of these units were made by manufacturers in the Republic of South Africa; some were homemade units. Practically all were installed with donor funds and did not adequately account for the water-use patterns of the future inhabitants.

This survey was conducted by Ernest Khabisi, Senior Technical Officer, and Michael Savino, PCV, under the direction of Judith Gay, Field Supervisor. In an unpublished report, they found that most of the units were 100-liter batch heaters made by Shell. Practically all of these heaters were put in by Lesotho Housing Corporation on houses sold to middle-income families. The units were prone to leakage, and most were improperly plumbed. In some cases, much of the heated water was absorbed by the masonry walls in which the pipes were placed before it reached the tap at the sink or bath.

While the VESR found that about half of the daily hot water need in rural areas was at times other than first thing in the morning, no such survey has been carried out for urban centers. In most of the families living in the LHC houses, both husband and wife work and are not home during the day, when the solar heated water is at its hottest. Their comments indicated that the supply of hot water was inadequate and not matched to their desire for hot water early in the morning.

Although installed with good intentions, these solar heaters left a bad impression with LHC and with the general public. This poor image of solar water heaters has spread far beyond Maseru, as

it seems that practically everyone is related to someone living in that housing scheme. Even though there are many more good examples than bad ones, the general attitude is that solar water heating doesn't work.

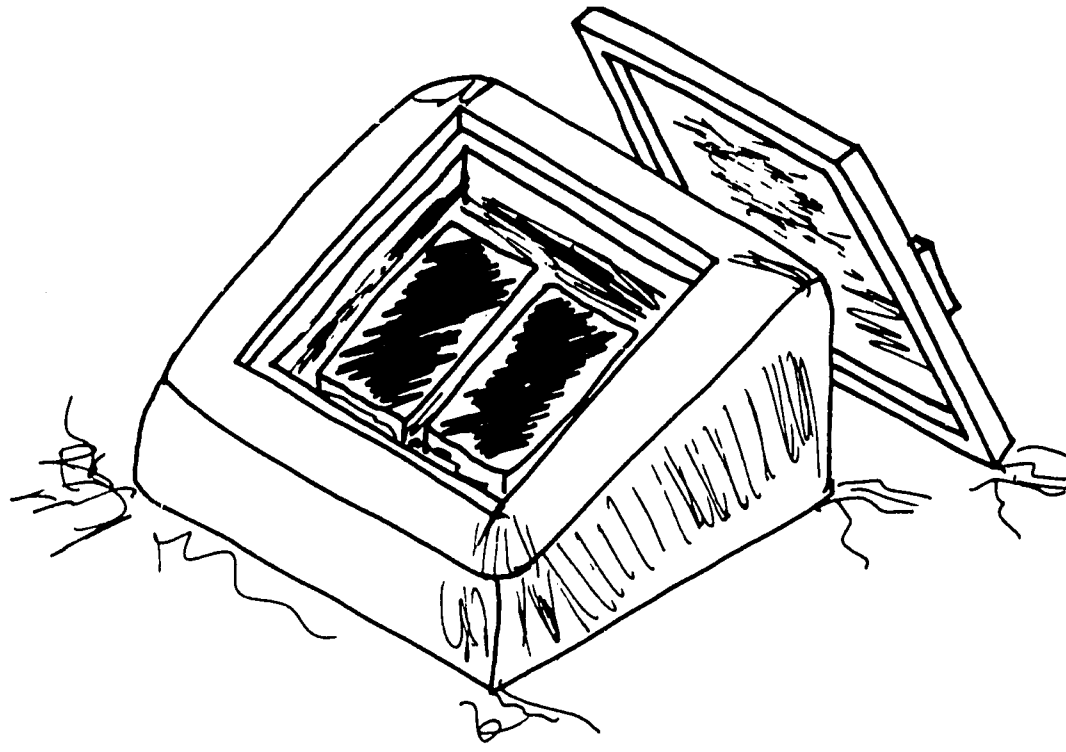
The public perception of solar water heaters was diminished still further by the failure of a small local industry set up to manufacture collectors in Lesotho. Begun in the mid-seventies at BEDCO, an industrial estate in Maseru, the firm produced a small range of batch heaters. They were plagued by poor quality control of an otherwise reasonable design, by the lack of trained installers, and by insufficient marketing of their product. The firm was out of business at the time the RET project began.

Since those early days, the commercially available solar collectors have become better designed, more reliable and increasingly available in Lesotho. It has been recognized that proper installation is essential to get good performance. This applies particularly to orientation and tilt of the collectors, insulation of pipe runs to prevent freezing, and minimization of the length of pipe that can lose heat to the walls en route to its destination.

The RET project decided that it could best help promote the use of commercially available solar water heaters by providing an advisory service to government ministries, private and public institutions, architects and builders, and private individuals who were thinking about installing such devices. To that end, the project contacted manufacturers and distributors, evaluated their products and was able to help these groups and individuals determine the system most suited to their needs. In the past three years, over 25 systems have been recommended, ranging in size from 70 liters (installed at clinics being improved by MINCORUDEV) to 2,000 liters (at the dormitory of a girls' school in Maseru).

A small amount of work has been done to develop and introduce solar water heaters adapted to rural areas of Lesotho. The RTU in Thaba-Tseka developed and tested two 10-liter batch heaters (Klein and Wyatt, Solar Energy Experimentation and Training in the Mountains of Lesotho, Thaba-Tseka, April, 1980). Both units were based on holding the water to be heated in recycled 3.5-5-liter vegetable oil tins. One type was fixed in place and was constructed of stone and mud walls, grass insulation, and a plastic or fiberglass cover. The other was portable, so that the orientation and tilt could be adjusted to suit the time of day and the season. This batch heater was made by nesting two open boxes of sheet metal, filling the space between them with fiberglass insulation, and covering the unit with translucent fiberglass (see Figure 14).

Klein and Wyatt found that these batch heaters were able to raise the temperature 30-40°C above the ambient water temperature in two to four hours, depending on the time of day and year. The portable heater was able to heat more water than the fixed type because it could be oriented to face the sun during the day. Two



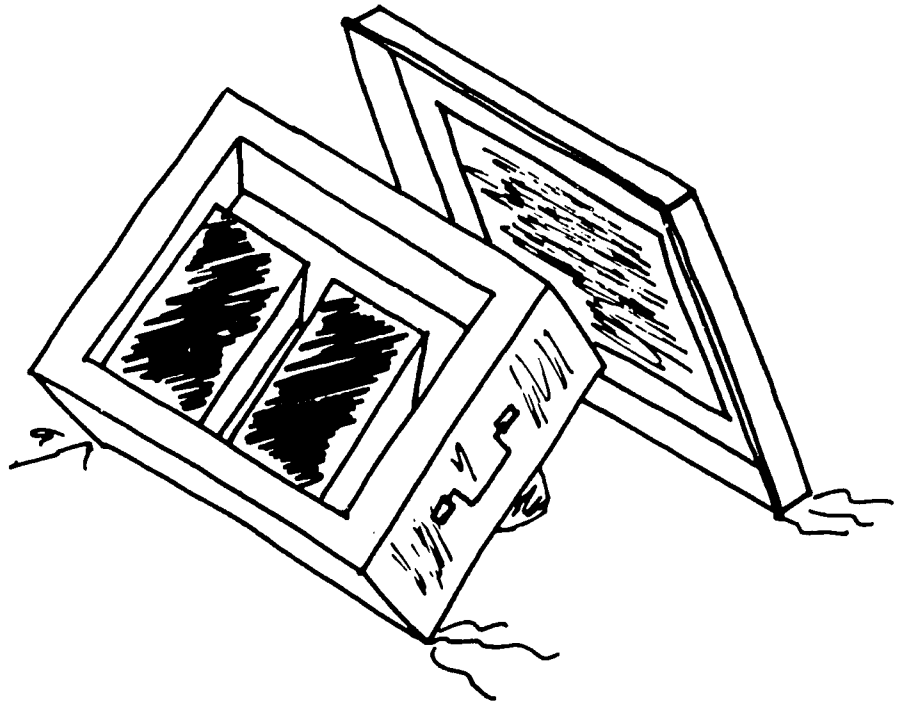


Figure 14

STONE-&-MUD AND PORTABLE SOLAR WATER HEATERS

batches of 10 liters each could be heated on clear winter days, and three in summer by the portable unit. Fixed units heated one and two batches, respectively.

These simple water heaters have been demonstrated by the RET project to many groups. In 1983, the project built another type of fixed unit which used a commonly available wood frame and glass window for the cover and brick for the walls. Again, grass was used for insulation. At the same time, a commercial product was purchased. This 10-liter container was made from rigid black plastic, enclosed within a vinyl membrane which was clear on the front and which held a 0.5-cm-thick layer of polystyrene insulation against the bottom, sides and back of the container. Water was put in through a screw cap and removed from a tap. (See Figure 15.)

Due to time constraints and because performance parameters had been evaluated by the RTU, no laboratory tests were done on these batch heaters. However, the watchmen at Khubetsoana were given the various types used. They preferred the commercial batch heater primarily because it was more convenient to use.

All of these batch heaters can heat at least as much water on clear days as is presently heated in the rural households reported on in the VESR. Their costs range from M12.00 to M55.00. The stone wall unit is the cheapest and the commercial heater the most expensive. Even the commercial unit costs less per installed liter than any of the larger batch or thermosyphon collectors that are presently available in Lesotho (M5.50 per liter compared to M7.50 per liter). A market test should be conducted to determine whether this small batch heater will sell at the present price.

Since no user tests have been done on solar water heaters, it is recommended that the ATS conduct such a study. The four types of batch heaters should be tested in five homes each. Fuel consumption of traditional methods of water heating should be measured in each household so that potential fuel savings can be determined. If possible, these measurements should be made quarterly for one year. The experiment should be divided between the mountains and the lowlands. Durability, maintenance and consumer preference should also be studied. Results should be used to determine the viability of the widespread introduction of simple solar water heaters in rural areas.

G. Solar Cookers

As early as 1882, a missionary in Lesotho reported in the newspaper Leselinyana about a solar cooker being used to make tea. In the more recent past, the ATS (prior to the start of the RET project) and the RTU in Thaba-Tseka experimented with two types of cookers. The ATS worked primarily with a parabolic cooker, and the RTU with a solar oven.

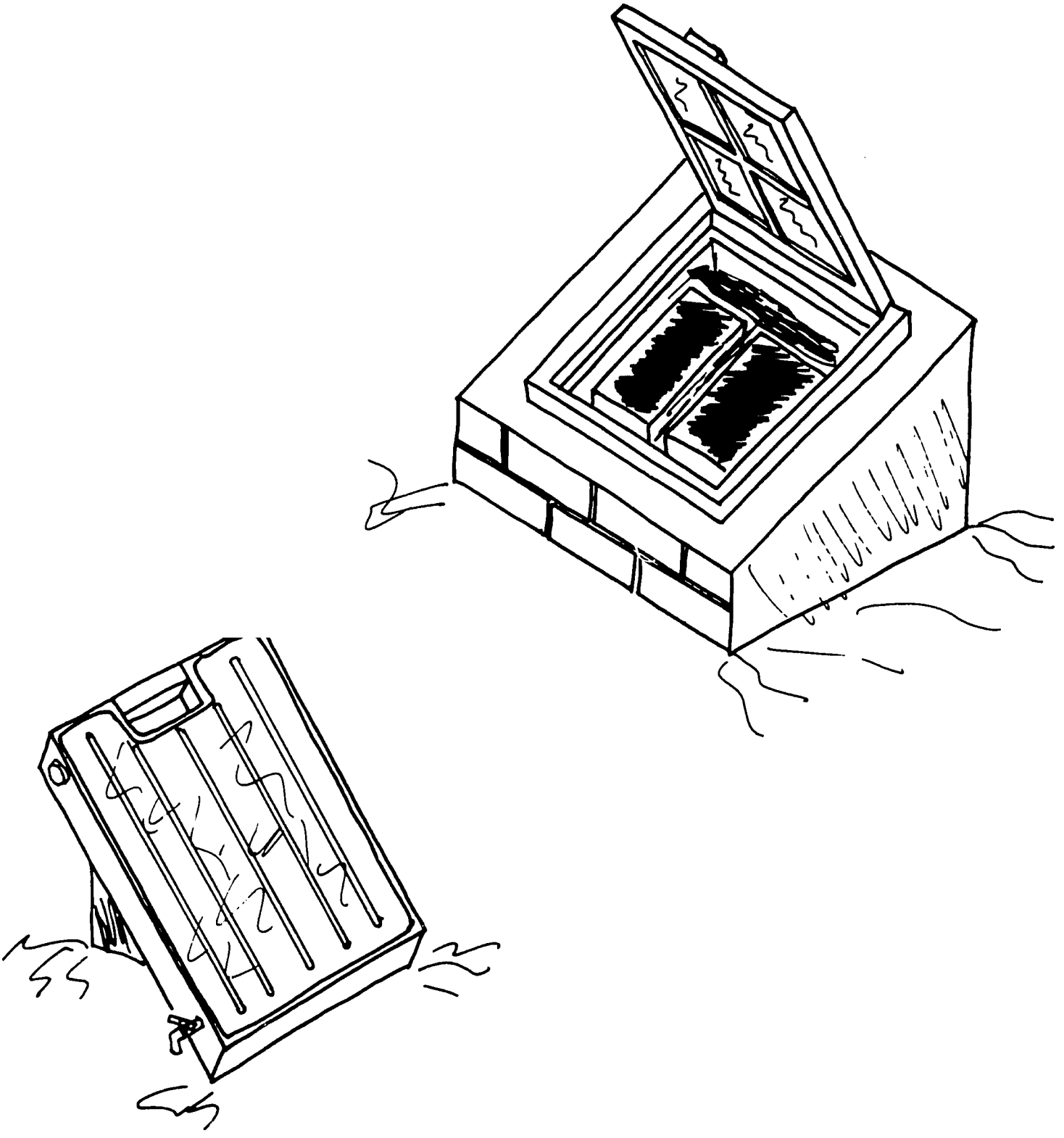


Figure 15

GLASS-COVER-AND-BRICK-WALL AND COMMERCIAL SOLAR WATER HEATERS

In fact, the RTU tested both types of solar cooker to determine their suitability in the mountains. Klein and Wyatt found that the solar ovens performed better than the parabolic cookers. This was due primarily to the cold ambient temperatures and often windy conditions that prevailed in Thaba-Tseka. The RTU's solar oven was designed for use with bread pans, saucepans and three-legged pots. It was built from nesting two open boxes of galvanized sheet metal. The space between the boxes was filled with 75 mm of fiberglass insulation. The glass door was sloped at a 45° angle and was double-glazed. Galvanized steel reflectors increased the collection area to almost 1 m^2. (See Figure 16.)

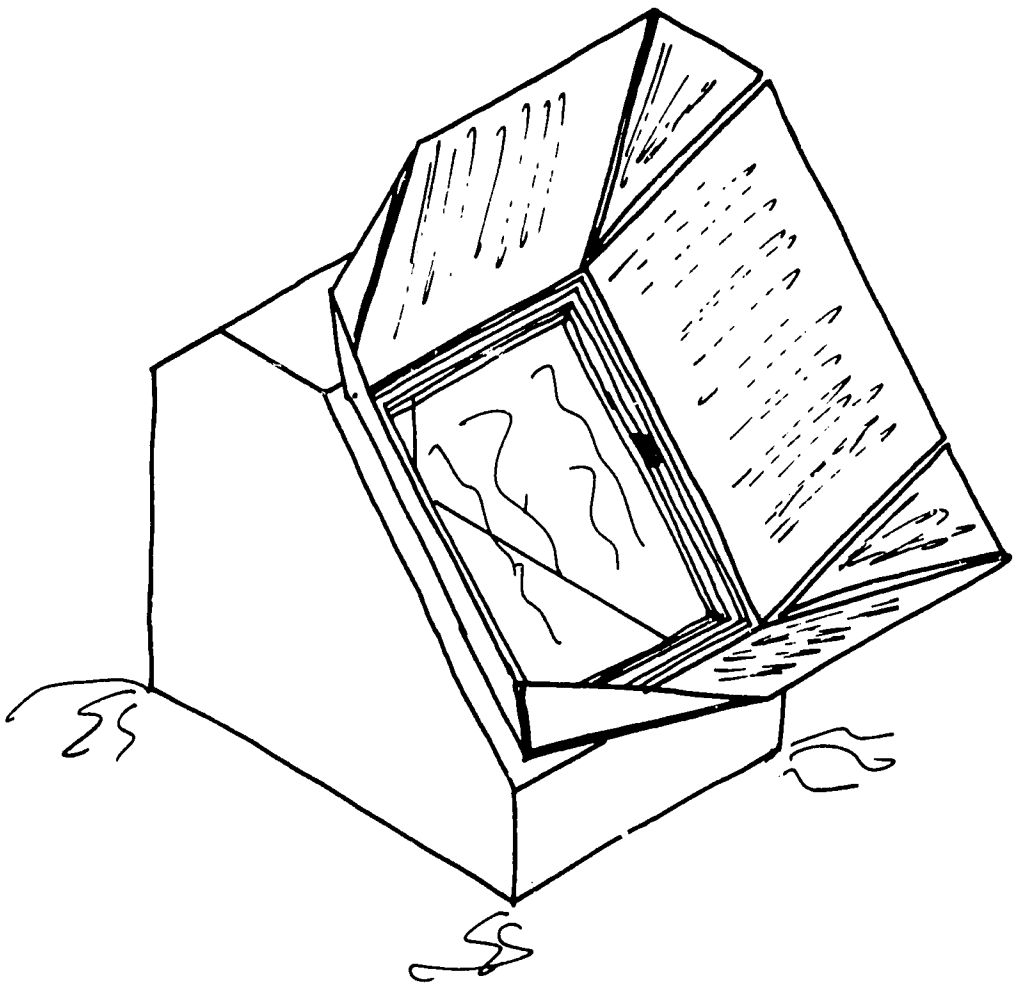


Figure 16

RTU SOLAR OVEN

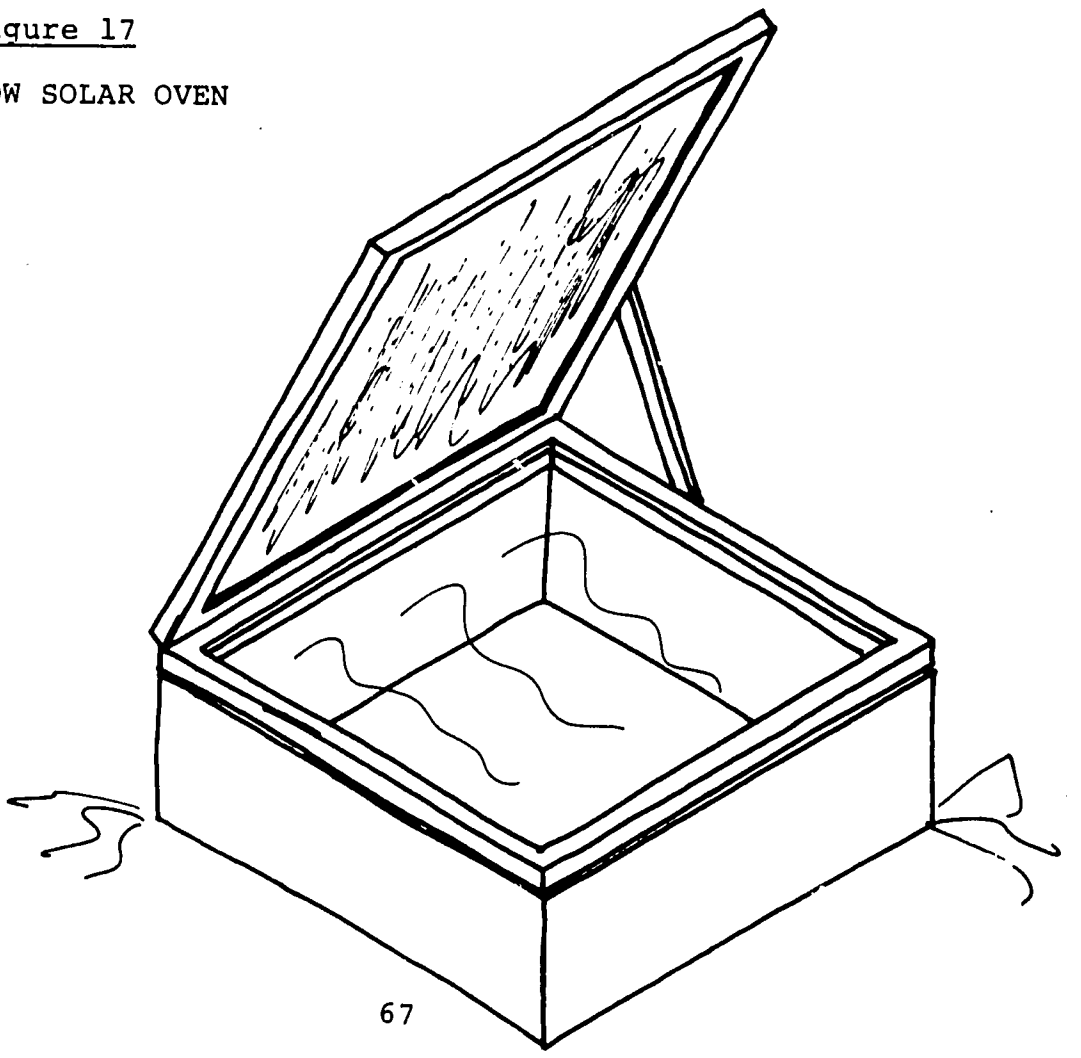
Following the technical tests, a field trial of the solar oven was conducted in a remote village called Lesobeng Ha Mohau. All households were loaned an oven for one year. The RTU staff returned to the village a number of times during the year to check on the experiment. Their evaluation at the end of the year showed that ovens were used primarily for heating water. In general, the ovens were used infrequently, most often when it was both sunny and the women were not working in the fields. Nonetheless, the majority of the people liked their ovens and were prepared to purchase them for M20.00 at the end of the test year.

The RET project showed this oven at many demonstrations in 1981 and 1982. People were intrigued by its ability to bake, bottle fruits, and heat water, as well as prepare many local foods. They commented that the oven was cumbersome and a bit awkward to operate. They were also worried about their food being poisoned or stolen if they left the unlocked oven unattended.

In early 1982, the project was given a solar oven made by an appropriate technology organization in Lucknow, India. This oven was flat and rectangular and designed for use with bread pans or four very small (17-cm diameter) saucepans. Additional radiation was reflected into the oven by a single glass mirror attached to the inside of the wooden lid. The double-glazed glass door was horizontal and hinged to provide access to the oven. (See Figure 17.)

Figure 17

LUCKNOW SOLAR OVEN



Limited testing was conducted by RET staff members in Khubetsoana and Butha-Buthe to compare the performance of these two ovens. While both ovens worked, the Lucknow oven was consistently faster and operated at higher temperatures than the RTU oven. The Lucknow oven was also rated easier to operate and of better appearance than the RTU unit.

From these preliminary tests, the project decided that a Lucknow-type oven should be constructed that was sized for saucepans commonly found in rural homes in Lesotho. The inside should be deeper (roughly 20 cm) so that 1-liter bottling jars as well as standard saucepans could fit inside. It should be designed to accommodate at least two pots 23-30 centimeters in diameter, or 3-4 standard bread pans.

This new unit has not yet been built and tested, as other technologies and needs had higher priority. Since the oven can heat water and increase the variety of prepared foods at no extra fuel cost, the ATS should develop a suitable unit as soon as they can make the time. An additional impetus for this effort is the fact that solar ovens fascinate many Basotho.

Obviously, user testing under actual rural conditions should be done following the development of a technically acceptable unit. Such testing should examine potential fuel savings, durability and maintenance, and consumer appeal. Portability, appearance, and ease and safety of operation will probably be important consumer issues. A "solar oven club" in Nthlolohetsane is ready for units to test. Production techniques and retail cost will also have to be considered. Ideally, the unit will be made in Lesotho and retail for 60-80 Maloti.

V. ECONOMIC ANALYSIS OF COOKING-RELATED TECHNOLOGIES

How does a cook decide which stove to buy? Is the decision based on appearance, expected ease of operation, type of fuel required, initial cost, potential fuel savings, the stove's ability to heat the house in addition to cooking, or some combination of these criteria? The idea behind an economic analysis is to assign values to these criteria so that the different choices available to the cook can be quantitatively evaluated. The more accurate the values assigned to the various criteria, the more closely the analysis will reflect the real world.

Some decision-making criteria are very difficult, if not impossible, to quantify. Appearance and ease of operation are two examples of these so-called subjective criteria. Sometimes these non-quantifiable variables are more important than those that can be quantified when the cook actually decides to purchase a new stove. This analysis does not give numeric values to these subjective criteria. Rather, it attempts to determine if the fuel-saving potential of the cooking-related technologies helps make the adoption of that device an attractive investment for the cook.

The economic analysis uses life-cycle cost methods that take into account all expected future expenses. This makes it possible to compare future costs with today's costs. This is done by determining what would have to be invested today, at the best alternative rate of investment, to have the funds available to meet all expected future expenses. Economists call this procedure discounting costs to their present worth.

To determine the present worth of a series of costs, it is necessary to know the rate of inflation and the discount rate. It is also necessary to know the expected lifetime of the investment. These values are combined into an equation that determines the present worth factor. The present worth factor is calculated differently depending on whether or not the rate of inflation (i) is equal to the discount rate (d). The two equations are:

$$PWF = \frac{1}{(d-i)} \left(1 - \left(\frac{1+i}{1+d} \right)^N \right) \qquad \text{if } i \neq d$$

$$PWF = \frac{N}{(1+i)} \qquad \text{if } i = d$$

where PWF = present worth factor
i = inflation rate
d = discount rate
N = the lifetime of the investment in years

In practice, the present worth factor is multiplied by the value of the first annual payment. The resulting figure is the present worth of that series of payments. To give an example, assume that:

- someone spends M120 per year on paraffin
- the rate of inflation is 15 percent
- the discount rate is 10 percent

We want to know what is the present worth of purchasing this amount of paraffin for five years.

$$PWF = \frac{1}{.10-.15}\left(1 - \left(\frac{1.15}{1.10}\right)^5\right) = 4.98$$

$$PW = 4.98 \times M120 = M597.60$$

Note that this value is not the same as multiplying M120 by five, the number of years during which paraffin was purchased.

It is necessary to know the inflation and discount rates in order to perform this type of an economic analysis. According to the Standard Chartered Review (October, 1983, p.15), the rate of inflation in Lesotho during 1982-1983 was 19.8 percent. For simplicity, a figure of 20 percent has been used in this report. By way of comparison, inflation in surrounding South Africa was just under 15 percent for the same period.

The discount rate is more difficult to determine. This type of analysis assumes that money delivered in the future is worth less than the same amount of money in hand today. And the longer it takes to get this money, the more we "discount" its worth today. The problem here is that the value people assign to the discount rate varies substantially depending on their perception of the future. If the future looks good, the discount rate tends to be lower than if the chances of survival appear to be small.

The discount rate can be chosen based on what is the best alternative investment available to the individual or what is the interest rate on local loans. In Lesotho, most people only have access to roughly 6 percent interest, the amount given by local banks for normal savings accounts. Short-term loans require the payment of 25-30 percent interest. The prime rate of interest, the value used by larger investors, is roughly 14 percent. Discount rates of 6 and 30 percent have been used in this report.

These two discount rates have been chosen to provide some boundaries on the economic analysis. The process is called "bracketing" and is done to define the limits within which the

real world situation is expected to occur. It is also possible to bracket the inflation rate. For example, since the price of paraffin is subsidized, it does not inflate at the same rate as other consumer items. When comparing investments whose costs are related to the price of paraffin, it would be advisable to choose a much smaller rate of inflation. This would help the economic analysis more closely reflect the situation in the real world.

The table comparing the worth of investing in a fuel-conserving stove or continuing to use traditional methods follows a standard format. The ten steps are:

1. Unit Lifetime
2. Initial Capital Cost
3. Annual Operation and Maintenance Costs--First Payment
4. Non-Annual Repair and Replacement Costs--Present Worth
5. Units of Food Cooked per Year
6. Assumed Added Value of One Unit of Cooked Food
7. Gross Annual Benefits
8. Net Annual Benefits
9. Present Worth of Total Investment
10. Added Value of One Unit of Cooked Food Which Makes the Present Worth of the Total Investment Equal to Zero

This procedure for the economic analysis is explained below. Relevant assumptions are stated for each step of the process. Examples are given to help the reader understand how the analysis works. Detailed initial assumptions for each technology have been presented in the preceding section.

1. <u>Unit Lifetime</u>

Some items are more durable than others. That is, they last a longer time before they are no longer usable. In this report, the lifetime for the economic analysis has been taken as the expected lifetime of the most durable investment that is being compared. For example, when comparing a metal stove and a traditional paola, the stove might be expected to last five years and the paola only two. Five years would be used for the lifetime of the analysis.

2. Initial Capital Cost

This amount is the installed cost of the stove being evaluated. For field-fabricated technologies, it includes the cost of necessary parts, the value of the labor to gather local materials, and the value of the labor required to build the unit. For manufactured technologies, the cost includes the purchase price of the item and any labor costs incurred to install the unit. A breakdown of these costs is provided for each technology that was considered.

3. Annual Operation and Maintenance

When comparing stoves using traditional fuels, these costs are based on the time spent to collect the fuel. According to the VESR, this averaged 10.8 hours per week per household. When comparing stoves using purchased fuels, these costs are based on the price of the fuel. Where applicable, maintenance tasks performed by the homeowner have been valued at M0.50 per hour. Labor to collect fuel has also been assigned a value of M0.50 per hour. Potential fuel savings are also used to determine the value of the annual costs for the stoves being compared. For example, a stove that saved 20 percent of the fuel used in a traditional paola would have only 80 percent of the annual operation costs.

4. Non-Annual Repair and Replacement

These costs are for items that need to be repaired or replaced only in certain years during the lifetime used in the economic analysis. An example is the replacement of stovepipe that will last for several years before it is no longer usable. Costs for such items are based on their present value. These values are inflated into the future for the year(s) in which they are needed, and then they are discounted back to the present. Labor for repairs made by the homeowner are valued at M0.50 per hour. The formula used to determine the present worth of these non-annual costs is:

$$PW_N = A^1 \left(\frac{1+i}{1+d}\right)^N$$

where PW_N = the present worth of costs incurred in year N

A^1 = the cost of the items at the beginning of the first time period

i = inflation rate

d = discount rate

N = year in which costs are incurred

For ease of reference, Table 27 is provided, which presents the present worth factor for these non-annual costs. To determine

the present worth of costs incurred in year N, multiply the factors for that year by the amount A^1 taken from the formula on the preceding page. The table is based on the inflation and discount rates used in this report.

Table 27. Present Worth Factor for Non-Annual Costs

Year	d=6% i=20%	i=5%	d=30% i=20%	i=5%
0	1.00	1.00	1.00	1.00
1	1.13	0.99	0.92	0.81
2	1.28	0.98	0.85	0.65
3	1.45	0.97	0.79	0.53
4	1.64	0.96	0.73	0.43
5	1.86	0.95	0.67	0.34
6	2.11	0.94	0.62	0.28
7	2.38	0.94	0.57	0.22
8	2.70	0.93	0.53	0.18
9	3.05	0.92	0.49	0.15
10	3.46	0.91	0.45	0.12

5. Units of Food Cooked per Year

It is assumed that an average family has a certain amount of cooked food every day of the year. This amount is assumed to be constant regardless of the stove being used. Some stoves, such as stone paolas, may not be used daily. An estimate of the percentage of annual use is made for each stove to determine the total number of units of food it will help prepare in a year.

6. Assumed Value of One Unit of Cooked Food

Cooked food is assumed to have a greater value than uncooked food. This "added value," above and beyond the cost of the food, has been assigned an initial value of M1.00.

7. Gross Annual Benefits

This is the number of units of food cooked in a year multiplied by the value of one unit of cooked food. For example, if the stove was used every day, the gross annual benefits would be M365.00.

8. Net Annual Benefits

This amount is determined by subtracting the annual operation and maintenance costs from the gross annual benefits. If the gross

annual benefits were M365, and the annual operating costs were M150, the net annual benefits would be M215.

9. Present Worth of Total Investment

This is the value of the entire investment taking into account the lifetime of the analysis, the value of the net annual benefits, the initial cost of the stove, and the non-annual repair and replacement costs. The formula used to determine this value is:

PW = (PWF x AB) - IC - NAC

where PW = present worth of total investment
PWF = present worth factor at a specific discount and inflation rate
AB = present worth of net annual benefits
IC = initial costs
NAC = present worth of non-annual costs

(The PWF used here is the one used for a series of payments as described in the introduction to this analysis. It is not to be confused with the PWF used to determine the present worth of non-annual costs, which are considered to be one single payment in this analysis.)

To give an example, assuming that the:

- present worth factor is 10,
- net annual benefits are M215,
- initial cost of the stove is M100, and
- present worth of the non-annual costs is M35,

then the present worth of the total investment is:

(10 x M215) - M100 - M35 = M2,015

Given the difficulties encountered in making the assumptions on which this number is based, this amount should only be used to compare the relative value of different possible investments. The investment with the highest value is usually the best choice. The accuracy of this judgment can be checked by eliminating the variable of having arbitrarily assigned a certain value to a unit of cooked food. This procedure is explained on the following page.

10. Added Value of One Unit of Cooked Food Which Makes the Present Worth of the Total Investment Equal to Zero

You might ask why anyone would want an investment to be equal to zero. Typically, they wouldn't; they would want it to have a positive value and, usually, the higher, the better. This part of the analysis asks the question, "What is the minimum value of a unit of cooked food that makes choosing this technology a reasonable investment?" This is done by setting the present worth of the total investment equal to zero. Solving for the added value of a unit of cooked food:

$$AV = \frac{\frac{IC+NAC}{PWF} + AC}{UCF}$$

where AV = added value of one unit of cooked food
IC = initial cost of stove
NAC = present worth of non-annual costs
PWF = present worth factor at a specific discount and inflation rate
AC = annual costs
UCF = units of food cooked per year

To give an example, assuming that the:

- initial cost is M100,
- present worth of the non-annual costs is M35,
- present worth factor is 10,
- annual costs are M150, and
- units of food cooked per year are 365,

then the added value of one unit of cooked food which makes the total investment equal to zero is:

$$\frac{\frac{100+35}{10} + 150}{365} = M0.45$$

This number is to be used when comparing the relative merits of different possible investments. Since we want to spend as little of our time and money as possible to cook our food, the option with the lowest added value is usually the best choice, because it has the best chance of being a good investment.

Table 28 presents the economic analysis of the nine stove technologies considered in this report. It summarizes the initial

Table 28. Economic Analysis of Stove Technologies

	Stone Paola	Open Fire	RHC and Open Fire	Improved Paola	Trad. Paola	Earthen Stove	RET Stove	RHC and Par. Stove	Paraffin Stove
1. Unit Lifetime (yrs)	5	5	5	2	2	5	5	5	1.5
2. Initial Capital Cost (M)	14.00	12.00	16.00	15.00	0.50	40.00	100.00	25.00	10.00
3. Annual Operation/Maintenance Costs--First Payment (M)	70.20	140.40	113.82	112.82	140.40	128.96	113.51	63.90	78.00
4. Non-Annual Repair/Replacement Costs--Present Worth (M)									
d = 6	7.15	8.76	11.68	43.80	1.46	32.80	32.80	33.60	49.91
d = 30	3.87	4.74	6.32	23.70	0.79	14.60	14.60	18.18	26.92
5. Units of Food Cooked per Year	182.50	182.50	182.50	182.50	182.50	182.50	182.50	365.00	365.00
6. Assumed Value of One Unit of Cooked Food (M)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7. Gross Annual Benefits (M)	182.50	182.50	182.50	182.50	182.50	182.50	182.50	365.00	365.00
8. Net Annual Benefits (M)	112.30	42.10	68.68	69.68	42.10	53.54	68.99	301.10	287.00
9. Present Worth of Total Investment (M)									
d = 6	668.23	237.68	393.93	368.94	258.44	255.87	290.71	1789.76	1701.90
d = 30	352.52	112.12	204.20	191.12	138.86	121.99	112.94	949.92	909.62
10. Added Value of One Unit of Cooked Food Which Makes the Present Worth of the Total Investment Equal to Zero (M)									
d = 6	0.40	0.79	0.65	0.67	0.77	0.77	0.74	0.20	0.24
d = 30	0.41	0.80	0.66	0.68	0.77	0.80	0.81	0.21	0.24

assumptions for each technology, based on the detailed information contained in the appendix. Note that the retained heat cooker is included twice in the table, and also that it only occurs in conjunction with another stove. This is because the RHC cannot be used on its own. Some stove must be used to begin the cooking process.

It has been assumed that seven of the stoves are used only for half the year. However, when comparing the RHC and the paraffin stove, daily operation has been assumed. These criteria are based upon the project's observations of existing stove-use patterns,which indicate that people using traditional fuels tend to use open fires and traditional paolas roughly half a year each. Paraffin stove users tend to use their stove practically every day.

The most striking feature of this analysis is how good an investment it is to use a paraffin stove for cooking. It requires less than one-third of the added value to prepare a unit of cooked food than either the open fire or the traditional paola, the stoves most commonly used in rural Lesotho. It is no wonder that many people want to switch to cooking with paraffin. The obvious drawback is that cooking with paraffin requires money with which to purchase the stove and, more important, the fuel. Although apparently more "economical," the fact that cash may not be available (or the fuel accessible) can put this option out of reach for many rural families.

The stone paola is the best of the new stoves that use traditional fuels, preparing food for roughly half the added value of the open fire or traditional paola. The stone paola is followed by the RHC-and-protected-open-fire. This combination is very similar to the improved paola, which is next in line. The remainder of the stoves are grouped fairly close together, further down the list.

While it is possible to conclude from this ranking that the stove that requires the least added value to prepare food is the best choice, the project believes that it is also instructive to compare the performance of various stove groupings. These groupings are based on the design situation that the stove was intended to improve. It seems probable that many people will perceive the value of a new stove in relation to these groups, and it is necessary for extension workers to understand how the new stoves compare case by case.

The first group is the protected open fire. Of the three stoves in this group, the stone paola is the best choice. The RHC-and-protected-open-fire, while much closer to the base case of the protected open fire, is still a better investment.

The second group contains the portable stoves. Even though considerably more expensive to acquire, the savings that accrue from using an improved paola are more than repaid over the lifetime of the investment. It is interesting to note that, from

the standpoint of cooking, the traditional paola is only a slightly better investment than the protected open fire.

The earthen stove and the RET Metal Stove are in the category of fixed-in-place indoor stoves. Because they help heat the house as well as cook, they need to be compared with the traditional paola, which is also used for both of these purposes. At low discount rates, the RET Metal Stove is the best investment among these three stoves, but not by very much. The earthen stove is equivalent to the traditional paola at low discount rates. At high discount rates, neither stove is as good a choice as the paola, due to a combination of their relatively high initial costs and their relatively small energy savings. It is probable that people like the RET Metal Stove for reasons other than its ability to cook. These include its effectiveness as a heater and the fact that the chimney takes smoke directly out of the house. Although it is almost impossible to give accurate "economic value" to these capabilities, it may be that these features are what tips the balance in favor of choosing to purchase such a stove.

The last group contains the intended-for-cooking-only stoves. In this class, the RET project studied the paraffin stove and the RHC. The paraffin stove is designed for indoor use. As can be seen, the RHC-and-paraffin-stove combination is a better investment than just the paraffin stove. The extra cost of purchasing the RHC is paid for just after the end of the first year.

With the exception of the earthen stove, the stoves tested by the project were shown to be worthwhile investments--given the initial assumptions. However, it is quite possible that these initial assumptions were not exactly correct. Perhaps the perceived value of labor is only M0.25 per hour instead of M0.50, or the fuel savings only half as much as measured in project tests. It is possible to see the effect of these changes by varying the appropriate parameters in the analysis. It is best to adjust the parameters so as to "bracket" the various real world possibilities. For example, it is better to examine the effect of halving or doubling the value of labor to collect fuel than to look at a change of only 10 percent. This procedure is called a sensitivity analysis.

Sensitivity analyses have been made for each pair of stoves compared in this report. They have been displayed in graph form so that it is easy to see the effect of varying one or more parameters. The graphs are contained in the appendix. The essential results of these analyses are presented in the following pages.

Group 1 Stoves

Stone Paola Compared to Protected Open Fire. Reducing the value of labor to M0.25 per hour cuts the added value needed to cook a unit of food roughly in half. This is true for both stoves. If the fuel savings is assumed to be only 10 percent, instead of

50 percent, the stone paola is still a better choice than the open fire at either value for labor.

RHC-and-Protected-Open-Fire Compared to Protected Open Fire. Halving the value of labor reduces the added value for both stoves roughly in half. When fuel savings are varied from 40 percent to 10 percent, the RHC-and-open-fire combination is a better choice than the open fire at either labor rate and over the range of the discount rates.

Group 2 Stoves

Improved Paola Compared to Traditional Paola. Two graphs have been used to help analyze this case. As before, halving the value for labor roughly halves the added value for both stoves. However, if labor is only M0.25 per hour, and the fuel savings drop below 10 percent, then the traditional paola becomes a better investment than the improved paola. The initial cost of the improved paola becomes important at low labor values and assuming high discount rates. For example, when labor is M0.25 and the discount rate is 30 percent, if the initial cost goes above M20, the traditional paola becomes a better choice than the improved version.

Group 3 Stoves

Earthen Stove Compared to Traditional Paola. Percent fuel savings are very important when comparing these stoves. When labor is M0.25, stove lifetime between 2 and 5 years, and the discount rate over 10 percent, the earthen stove must save at least 20 percent of the fuel consumed by the traditional paola to be a worthwhile investment. This would not be as critical a variable if the lifetime of the stove could be increased. At low labor rates and small amounts of fuel savings, the initial cost of the stove also becomes important. For example, if the fuel savings are 10 percent and labor is M0.25, then the initial cost of the earthen stove must be below M10 to be a better value than the traditional paola.

RET Metal Stove Compared to Traditional Paola. Two graphs present the relevant data for this analysis. The first one assumes that the Metal Stove will last 8 years. As was to be expected, low labor rates, small amounts of fuel savings, and high discount rates make the Metal Stove economically less attractive than the traditional paola. This situation is made even more critical when initial costs and lifetime of the Metal Stove are considered, as in the second graph. If labor is M0.25 and the discount rate is 30 percent, the lifetime of the stove must be at least 13 years before the Metal Stove is economic at an initial cost of only M60. Higher initial costs require even longer lifetimes or lower discount rates in order for the Metal Stove to be a better choice than the traditional paola. When higher values are assumed for labor, the range of initial costs is more flexible, but the discount rate is still very important.

Group 4 Stoves

RHC-and-Paraffin-Stove Compared to Paraffin Stove. The RHC-and-paraffin-stove combination is a better choice than the paraffin stove even when fuel savings go as low as 10 percent. It gets more worthwhile as the percent fuel savings increases. The graph also shows that as the price of paraffin and the weekly consumption increase, the benefits of using an RHC become still greater.

VI. PILOT EDUCATION, PRODUCTION AND DISTRIBUTION PROGRAM

The original Project Paper proposed that village-level dissemination be carried out by Village Energy Technicians (VETs). These individuals were to be trained in the whole range of project-tested energy technologies and were to become entrepreneurs, selling their skills to villagers. However, in light of experience gained during the first half of the project, the VET concept of an energy "generalist" was felt to be unsuitable for the widespread dissemination of the technologies.

Consultant Erika Morgan suggested a modification of this approach, which she called Village Technology Specialist, or VTS (Disseminating Renewable Energy Devices in Lesotho: A Consultancy Report, Associates in Rural Development, Burlington, Vermont, March, 1983). The VTS concept recognized that it was more realistic to assume that people would "specialize" in only one technology. Morgan proposed a formalized training program, similar to that contained in the original Project Paper. This training program was designed to result in certificates for successful trainees, stating that they were master builders or teachers. The project found this certification procedure to be excessively time consuming for project staff and evolved still another dissemination strategy.

This plan, which is now being implemented, was also developed with the help of Ms. Morgan. It relies on working through "multiplier" groups which consist of people who are members of some organization already engaged in rural development work, and who wish to increase their skills and the range of items that they can introduce to their constituencies. The RET project would train interested multipliers in the construction and use of one or two technologies, and these multipliers would then go back to their villages and transfer the new skills. This approach should help to ensure adequate "back-up" for the newly trained multipliers by placing this responsibility on their organizations' existing support mechanisms. It should also greatly expand the impact of the limited number of RET staff by relatively rapidly increasing the number of village-based trainers.

The project adapted this multiplier approach for what have been termed "field-fabricated" technologies. These technologies are ones which can be built by villagers after a minimal amount of training. Stone paolas, retained heat cookers, earthen stoves, and some simple solar water heaters are the technologies discussed in this report that fall into this category. While they may require the purchase of some specialized materials such as grates, insulation, stovepipe, or windows, all of these items are simple to construct with locally available tools.

Two other production categories are "kit-assembled" and "manufactured." There are no kit-assembled technologies discussed in this report. Manufactured technologies include retained heat

cookers, metal stoves, metal paolas, solar water heaters, and solar ovens. The manufactured technologies must be purchased. They require special skills, tools and materials in their construction, and they are, therefore, most cheaply made by workshops already having the right equipment. The kit-assembled technologies fall between the field-fabricated and manufactured items, requiring simple fabrication skills, but materials that are not yet generally available.

Once a method of production has been established, the education and distribution requirements can be determined. Field-fabricated technologies generally have a different strategy from manufactured technologies. A full discussion of these strategies can be found in another report by Erika Morgan (Dissemination Plan for the Lesotho RET Project, Associates in Rural Development, Burlington, Vermont, March, 1983).

Of the cooking related technologies, only the stone paola and the retained heat cooker are at the dissemination stage. The other technologies are still in the process of being developed to this point. The remainder of this section reviews the project's early efforts to disseminate the stone paola and the retained heat cooker. A more detailed discussion can be found in the Final Report on Social Aspects of the RET Project (Dr. J. Gay, RET Project, MINCORUDEV, March, 1984).

A. Stone Paola

During Thomas and Burket's consultancy, the project found that this stove could be most easily disseminated by training trainers. Both individual villagers and members of multiplier organizations were trained. Village Health Workers, Nutrition Workers and Food-for-Work participants were the primary groups at this early stage.

In conjunction with training trainers, the project began producing bars and grates at its workshops in Khubetsoana and Malefiloane. This production was necessary to meet the needs of the training courses and for the intermittent purchases from the general public. Early production efforts resulted in the fabrication of jigs to standardize and speed up the manufacture of the grates.

A two-page fact sheet was developed at this time for distribution to course participants. This compilation of builder's reminders was written in Sesotho. A complete builder's guide, begun in early 1983, is still in draft form.

The combination of training trainers, project supply of bars and grates, and builder's reminders was generally very effective and well received. Nutrition Workers and Village Health Workers proved to be good groups to work with. Course participants saw a direct link between the new stove and their already defined

extension mission and were enthusiastic about teaching others how to make and use it. In addition, their organizations were able to provide logistic support during training, as well as some backup once they returned to the field.

Individual villagers and Food-for-Work participants were less easy for the project to deal with. All of the individual and some of the FFW participants were interested in the stone paola. However, working with these groups required that excessive amounts of staff time be spent on logistics and backup support since either no organization existed or the one that did was unwilling to provide the necessary assistance.

The project spent many hours evaluating the paolas constructed by the course participants, as well as the overall dissemination procedure. Paolas were usually well constructed, although grate-to-bar distances were rarely the same in any two paolas. One problem, cracking of the walls in large size (18 or greater) paolas, was encountered and addressed by the laboratory. Some innovations, including the horizontal, instead of vertical, placement of the fuel door, were adopted for future units. Perhaps the most valuable result of these pilot efforts was the training of RET project staff in dissemination procedures.

These evaluations were made in March, 1983. Technical changes were incorporated into future designs. The dissemination strategy was modified to focus on those multiplier groups that were prepared to provide training, logistic and follow-up support for their members. Plans were made to get independent workshops to produce the bars and grates. Finally, courses were organized for the final year of the project, so that the stone paola could be widely disseminated throughout the country.

B. Retained Heat Cooker

Initially, the project felt that demonstrating how to use RHCs would be sufficient to result in their adoption. For example, the RHC was often demonstrated as a secondary item at courses intended to teach stone paola construction. They were also shown on several occasions to the 400 women who attended the monthly Mother and Child Health Clinics next door to the project's workshop in Malefiloane.

It was found that demonstrations provided a good forum for discussion about energy use and essential feedback from villagers. However, they did not result in many people adopting the technology. The Malefiloane staff resolved to make the demonstrations more participatory, so that the women would have a better sense of the technology and its benefits.

This approach, where attendees sew and stuff the RHC pillows, bring foods to a boil and cook them in the RHC they have made and eat the food when it is done, proved to be more effective than the

earlier demonstrations. Because of its simplicity, these "mini-courses" were often attached to a longer stone-paola course. Many women were able to take this experience and go home and make their own RHCs.

A two-page fact sheet was developed that explained the construction and use of retained heat cookers. Laboratory tests were run so that a more comprehensive booklet could be written including recipes and fabric cutting patterns. This booklet is in final draft form at this writing.

Much thought has gone into getting ready-made RHCs into the marketplace. One course was held for six women and one man from the peri-urban area of Lithabaneng (near Maseru) who were already using sewing machines and selling the goods they made. This course was well received by the participants, but it is not known if they have begun marketing RHCs.

Given the success of the mini-courses on RHC construction and use, many similar courses were planned for the final year of the project. Village Health Workers, Nutrition Workers and the Women's Bureau were the primary multiplier groups chosen for this effort. Demonstrations and mini-courses were held for other groups when they requested such assistance.

VII. DISSEMINATION PROGRAM

The stone paola and the retained heat cooker are at the dissemination stage of product development. Both are being disseminated as field-fabricated technologies, although the RHC could be either a kit or a manufactured unit. This section briefly discusses and evaluates the activities undertaken by the project which were designed to result in the widespread use of stone paolas. (See Dr. J. Gay, Final Report on Social Aspects of the RET Project, RET Project, MINCORUDEV, March, 1984.)

The project staff gave over 40 stone paola courses during the last year of the project. Almost all were given to multiplier groups, particularly the VHWs, Nutrition Workers, and the Women's Bureau. Just over 100 stone paolas were built during these courses.

The spread of the stone paola has taken place in two ways. First, during the last year, about 10 additional courses were held by members of multiplier groups whose members had been trained by the project. These women organized and taught a course in their villages with only advisory assistance from RET staff members. Another 40 stone paolas were built during these self-directed courses, which were organized primarily by VHW and Nutrition Workers in Mokhotlong. This is indicative of the benefits to be obtained by working with these multiplier groups.

The second spread effort has been the construction of stone paolas after women have participated in a training course. Over 150 such units have been made and are being used throughout Lesotho. Based on responses to a mailed questionnaire, the Women's Bureau course participants would appear to have been the most active builders of stone paolas. Spot checks have been made by project staff on the reported numbers of constructed paolas, and the figures are in reasonable accord. Perhaps more important than the numbers built is the fact that most paolas were built properly, indicating that teaching methods were fairly effective.

A particularly important point was raised by the respondents to the questionnaire: Where could people purchase bars and grates? Women mentioned that their neighbors were "crying" for these items. In the absence of the recommended materials, women were using local substitutes such as fencing standards for the pot supports and galvanized wire or old paraffin stove tops for grates.

It is fortunate that the desire to build stone paolas has not been completely frustrated by the lack of commercially available bars and grates. However, it is likely that if these items were available and reasonably priced, women would buy them so as to have a more durable and "modern" stove. While local innovation should be encouraged, the project should devote more effort to making its recommended bars and grates widely available.

During the spot checks, it was found that the two-page fact sheet was being widely circulated in the villages. In fact, some women had built paolas after only reading the builder's reminders. While most were built reasonably well, there was often quite a wide variation among the paolas in any one village. A slightly expanded fact sheet might be advisable so that more information can be given on critical construction details.

Although not yet in every village, stone paolas have been adopted by many rural women. No media campaign has taken place, primarily due to the lack of staff time to respond to expected course requests and to the inadequate supply of bars and grates. Prior to the start of such a campaign, more trainers from multiplier groups need to be available throughout the country, and the supply of bars and grates needs to be commercialized. If the ATS resolves these two concerns in the next six to eight months, it should be possible to see "a paola in every household" by the end of 1985.

VIII. FUTURE DIRECTIONS

This section recommends what actions the ATS should take concerning the development of the technologies discussed in this report. According to their stage of development, some items require additional prototype development, others need work on dissemination strategies and techniques. Where applicable, timing for particular activities has been suggested.

A. Stone Paolas

This stove is the furthest along of all the technologies developed by the RET project. Nonetheless, it is far from having saturated its potential market. More people need to hear about it; more trainers and builders are required, and a source (or sources) of bars and grates should be established.

Bars and grates should be made available at retail shops throughout the country. Failing this, there should be a producer-distributor in every major town. This spreads out the manufacturing capability but increases problems of quality control. If this option is chosen, the ATS must be prepared to periodically monitor the items produced by these workshops. Another approach would be to manufacture bars and grates at a Maseru-based workshop and distribute them to retail stores. If none of these methods proves feasible, the ATS should then encourage local modifications based on readily available materials such as fence standards and galvanized wire.

The ATS should continue to work closely with multiplier groups so that there are more people trained in stone paola construction throughout the country. The Village Health Workers would appear to be the most promising group to work with, based on the project's experience to date. A special report on the cooperation that has already taken place between the ATS and the VHWs in the Mokhotlong District and elsewhere should be prepared for the people in the Ministry of Health responsible for the VHW program. This could serve as the basis for a well-planned training program of VHWs in each health service sector. These people would then train the others in their sector.

If time allows and interest is there, nutrition workers, home economics students and regional representatives of women's and church groups could be trained in a similar fashion. Alternatively, less effort could be extended by the ATS, and these people could receive only a detailed introduction to the paola so that they could talk about it knowledgeably when they return to their villages. This approach would complement the training of a specific multiplier group by increasing the frequency with which villagers heard about the stone paola from their neighbors.

These production and training activities should precede a well-planned national media campaign. Fact sheets and construction guides must also be available for the trainers to use in advance of the radio programs. Women who have stone paolas should be interviewed to elicit the benefits of stone paola use and the relative ease of construction and maintenance. Suppliers of bars and grates should be announced as should the names of trainers and methods of requesting a course. New ideas should be encouraged from the radio audience and written queries responded to on the air so that everyone can share in the process of adopting this innovative and modern stove.

B. Retained Heat Cookers

The ATS needs to complete and produce the recipe book for use with the RHC. It must then decide if people should be trained, in at least the major towns, to make RHCs. If so, that is the next step prior to mounting a media campaign. The Urban Sanitation Project in the Ministry of the Interior, with its experience of introducing a new type of latrine, can be consulted for advice on how to reach producers in Lesotho's urban centers.

The project has always felt that since the RHC was easy enough to construct, once shown the concept, people could make them themselves. This would certainly seem to be the case based on reports of the respondents to the Women's Bureau Course Questionnaires. Thus, it may not be essential to train RHC producers, although there may be a market for a ready-made RHC in the peri-urban and urban areas.

The media campaign should focus on people who regularly use an RHC. Fuel savings should be stressed. Ease of construction and maintenance, the adaptability to either saucepans or three-legged pots, and the ability to improve nutrition without expending extra fuel are other important points. Radio programs should mention the locations of suppliers of ready-made RHCs.

C. RET Metal Stoves

The results of the limited market test conducted in 1983 suggest that the ATS should plan a much broader and more conclusive test to determine the acceptability of the stove. This conclusion has been supported by consultant Geoff Burrell (Surveying the Marketing/Production Capabilities of Certain Renewable Energy Technologies by Basotho Small/Medium-Scale Enterprises, Technoserve, Inc., Kenya, December, 1983). He recommended that the ATS plan for this program take place in the winter of 1985.

It is likely that the ability of the stove to use traditional fuels and three-legged cooking pots will be appreciated by the cooks. So, too, will be the ability to heat the house in winter and remove smoke throughout the year. However, the stove, as

presently designed, has a rather rough finish. This may prove unacceptable to many Basotho who are generally very sophisticated and appearance-conscious buyers.

Features that should be improved prior to the proposed market test include the quality of the surface finish, the cutting of pot holes and pot support rings, making the pot rings flush with the top of the stove to accommodate larger saucepans, making the ash drawer out of a more durable and presentable material, and relocating the fuel door so that fuel can be added to the fire without having hot coals fall out of the firebox. These should greatly improve the acceptability of the stove.

There are still some technical tests which should be performed. The location and benefits of a secondary oxygen supply should be determined. Two possible locations are underneath the baffle for the first three-legged pot, and from behind a metal firebox liner with openings at the top to allow preheated air to enter the hot gasses above the coals.

Tests should also be performed on an oven. The oven should be thermally isolated from the external walls of the stove. One wall of the firebox should be shared with the oven. There should also be a damper located between the two pot holes to direct hot gasses down to the top of the oven when it is being used.

Still another series of tests should be conducted to improve the performance of the stove with Size 4 pots. The problem seems to be with the baffles which are fixed within the stove. The Size 2 pots sit closest to the baffle, while the Size 4 pots are much farther away. Recent tests conducted in Upper Volta (Dr. Sam Baldwin, "New Directions in Wood Stove Development," Vita News, January, 1984) suggest that the optimal separation between baffle and pot is between 4 and 8 millimeters. They also show that heat transfer is increased when this separation is maintained for as long a distance as possible. One solution is to have baffles that are spring loaded and automatically adjust to the pot placed above them.

Based on the work in Upper Volta, the smoke baffles for saucepans should also be reexamined. Gap width and length of baffle should be investigated. Finally, when the fuel door is relocated to just below the stove top, the grate can be moved closer to the pot. Distances between the stove top and the grate of 12 to 15 centimeters should be tested.

These tests should be done by September, 1984, so that changes can be incorporated into the units intended for marketing in 1985. In the meantime, the ATS dissemination unit should develop an instruction booklet for the stove and a fact sheet on chimney safety and maintenance. The effectiveness of both of these handouts should be evaluated during the market test.

D. Improved Metal Paolas

Results from the research of Dr. Sam Baldwin in Upper Volta suggest that performance of this type of stove could be radically improved. The most important variable is the gap between the paola wall and the pot. This distance should be as small as possible without choking the fire or letting too much smoke escape out the door. Obviously, this basic design must be adjusted to conditions in Lesotho. The air inlets may have to be enlarged because of Lesotho's elevation above sea level. Otherwise, its simplicity is appealing. One important consequence of this design is that for maximum fuel savings each pot should have its own paola. However, the cost of each one is expected to be roughly one-third of the present cost of the improved paolas. If performance is the same or better than the type developed by the project, it will still be a good investment for a cook's three most commonly used pots.

The cylindrical improved paola could be tested to determine the effect of reducing the gap-to-pot distance where the pot rests on the cowl. This should be done if the ATS plans to continue with paolas designed for three pot sizes. A relatively minor change may make a big difference. The same experiment could be done for the easier to produce square paolas by varying the size and shape of the proposed corner inserts.

There would seem to be a market in Lesotho for a more efficient metal paola. The increased cooking efficiency combined with some heating capabilities might be acceptable in the lowlands where heating requirements are lower than in the mountains. The ATS should conduct a series of user tests to determine if this is the case. Such tests should be conducted after the above modifications are evaluated.

Should the user tests prove acceptable, then production methods should be determined. Regionalized production by sheet metal workers is feasible, but quality control problems are increased. Nonetheless, this may be the best approach, given the difficulties of marketing from a central location.

E. Earthen Stoves

The results of the user tests indicate that the earthen stove, as designed, does not save significant amounts of fuel. Neither is it considered an adequate heater during the mountain winters. Both of these problems must be addressed by the ATS before any additional dissemination of this stove takes place.

As outlined earlier in this report, the heating capability can be addressed in several ways. The walls can be made thinner, a metal top can be placed on the clay body (a much greater initial cost), and the houses can be weatherized, or tightened up. This will make the houses less drafty, and the lower heating output of the earthen stove will be perceived to be greater.

The fuel savings in actual use must be measured again. It is quite possible that people were not sufficiently knowledgeable about their stoves during the 1983 tests. Firebox size and distance between the grate and the pot should be examined to make certain they are similar to the units tested by the project. Durability and maintenance should be investigated at the same time as the fuel consumption tests are done.

The ATS should do these experiments at roughly the same time as in 1983. This will make it easier to compare the results of the tests. It would be best to measure a week of earthen stove use and a week of traditional stove use, as in that year's test. However, if people refuse to "give up" their stoves, this should be taken as an indication that they are satisfied with their investment. The ATS should pay particular attention to the cooks' comments and any innovations they may have made. These ideas should be incorporated into future (if any) dissemination activities undertaken by the ATS.

If the 1984 kitchen performance tests show significant fuel savings and acceptable heating characteristics (after tightening up the house), then the ATS can begin promoting earthen stoves in the mountains. If only fuel savings are okay, then earthen stoves could be introduced primarily in the lowlands, where winter heating requirements are lower than in the mountains.

The ATS must remember that quality control of the firebox size and the shape of the smoke passages are extremely important for an efficient stove. Thus, it will probably be necessary to have a small number of highly skilled trainers and stove builders to ensure the construction of high-quality stoves. Some of the Village Health Workers may desire to learn the required skills and, given organizational support, could be quite effective in disseminating this technology.

One last point: The earthen stove should not be thought of as a second-class stove. Assuming it works properly in use, it should be treated by the ATS as an excellent investment for those who wish to own one. People should be encouraged to decorate their stoves, and good examples should be publicized so that other women will want to use one.

F. Solar Water Heaters

Individuals and institutions with properly installed solar water heaters are generally quite pleased with their performance. The ATS should interview these people and groups so that their comments can be used for a media campaign promoting the benefits of solar water heaters. The primary purpose of this effort should be to dispel the existing impression that solar water heaters don't work. The ATS laboratory could assist this dissemination campaign by monitoring some installations during the coming year. These user tests should be highly publicized so that the public knows

about the program. Fuel and money savings should be well documented so that the benefits of solar water heaters can be assessed by all Basotho.

The ATS laboratory should do research to modify the commercially available 70-100-liter thermosyphon, or batch-type, water heaters for use in areas without piped water supplies. One strategy would be to involve the manufacturers of such units in this development effort as the need for such a product exists throughout southern Africa. The ATS could provide the manufacturers with relevant data showing the market potential for such equipment. Another approach would be to develop a prototype in the ATS laboratory at Khubetsoana, after which the manufacturers should be called in to see the proposed product. It is estimated that the added retail cost of such a modification is less than M50.00.

The ATS should address two technical groups in the coming years. The first of these are the plumbers, the people who might install solar water heaters. At this time, there is only one reliable installer in Lesotho. This situation could be remedied by the ATS offering training courses in proper installation techniques to local plumbing firms and students at the various technical schools including LTI, Leloaleng and LTS.

The other group is made up of the government and private architects and engineers. They can help develop local building standards that will ensure that properly installed solar water heaters will be used on all future buildings. Of particular concern are those buildings built by government or donors in which the running costs must be borne by the GOL at some later date.

Fact sheets should be developed to increase the public awareness of solar water heating. A fact sheet is needed on commercial systems, including typical applications, expected benefits, and initial costs. Another should be produced on simple solar water heaters intended for use in rural villages. A third, on proper installation techniques, could be prepared for the proposed training courses for plumbers and for use in the adopted building standards.

G. Solar Ovens

A great deal of laboratory testing needs to be done on this device. The ATS should first develop a prototype based on the Lucknow oven that is designed for use with saucepans commonly used in Lesotho. Perhaps the oven should hold only two larger pots instead of four, as used in the Lucknow oven. Reflectors made of mirrors, stainless steel, polished aluminum, and polished (with Brasso) galvanized sheet metal should be tested on the new design.

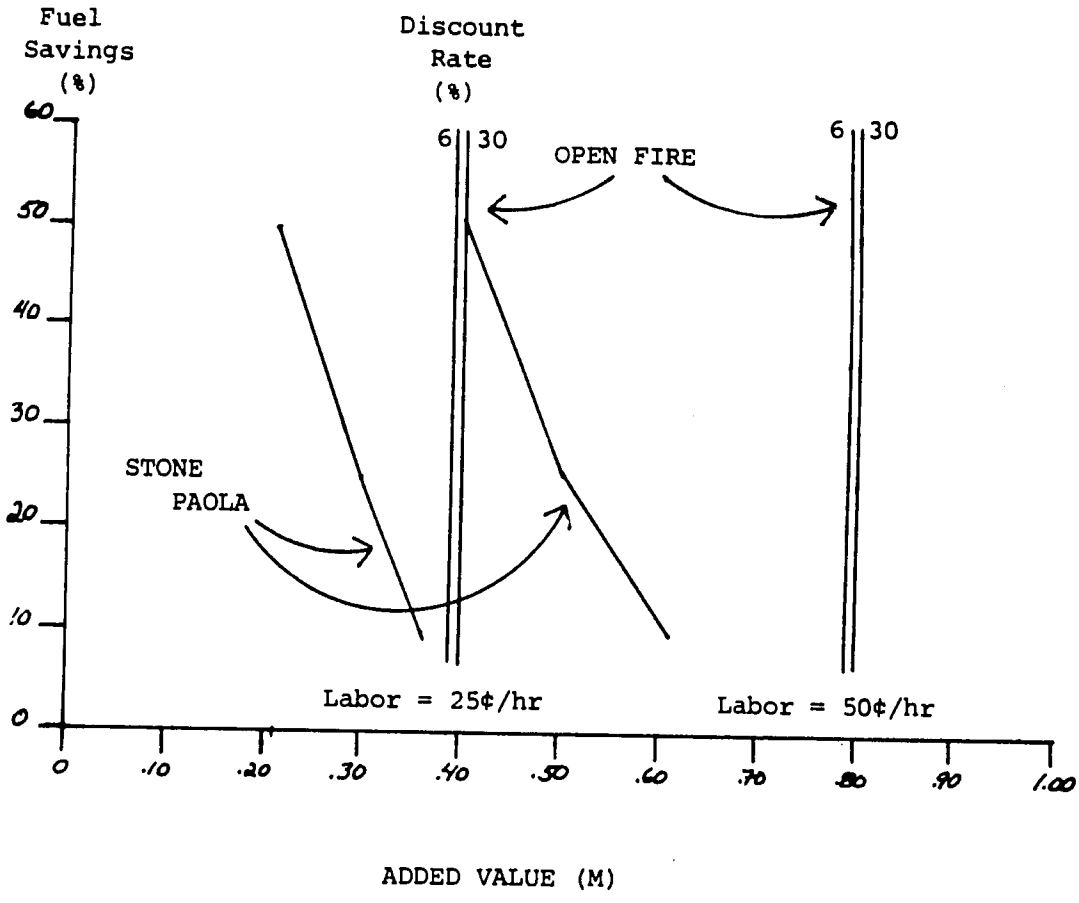
User testing should wait for the results of the technical tests and the economic screening. The ATS should schedule its

research on this device during the next 12 months because it may prove to be an excellent water heater as well as being able to prepare food. These two functions should appeal to the intended rural audience, who will be able to do two things with their new investment.

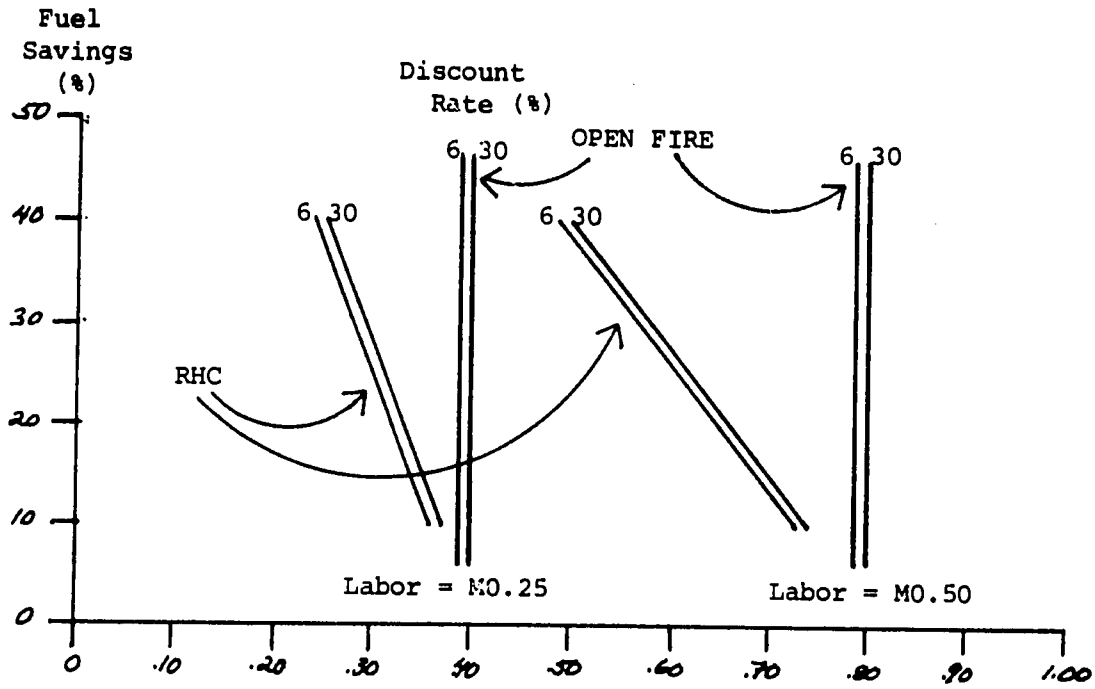
While it is recommended that the ATS continue to develop the solar oven, it should be prepared for its efforts to be unsuccessful. Solar cooking has yet to be widely adopted anywhere in the world, even though it has been promoted by many organizations. Stressing the features of water heating, bottling fruits, and baking, rather than the daily preparation of food should greatly improve its acceptability.

APPENDIX A

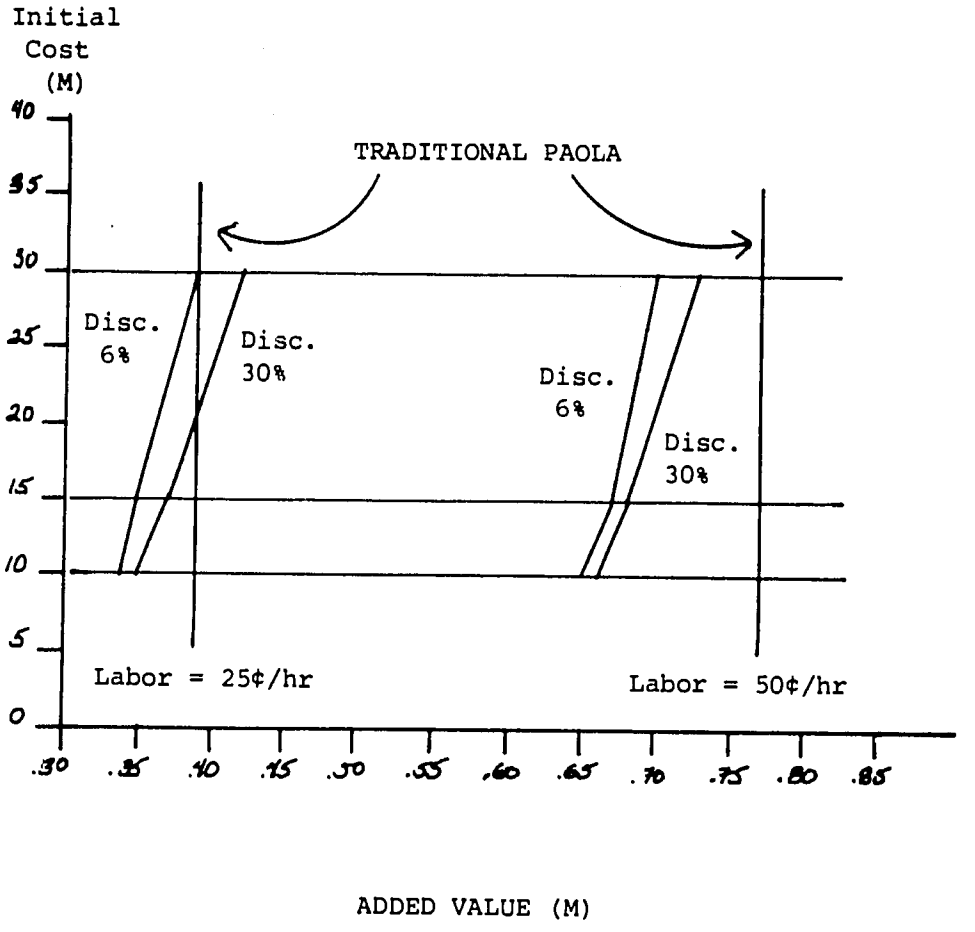
Sensitivity Analysis of Stove Economics



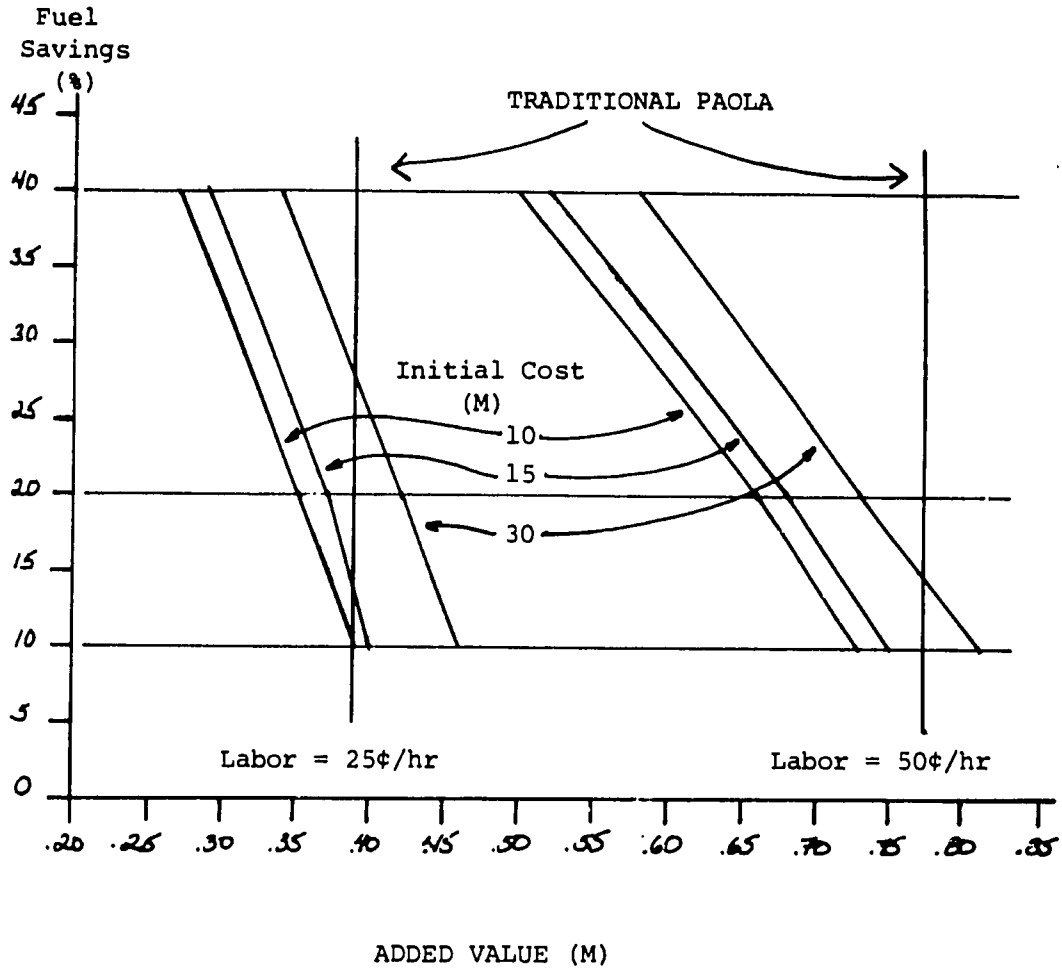
STONE PAOLA COMPARED TO PROTECTED OPEN FIRE



RHC & PROTECTED OPEN FIRE COMPARED TO PROTECTED OPEN FIRE

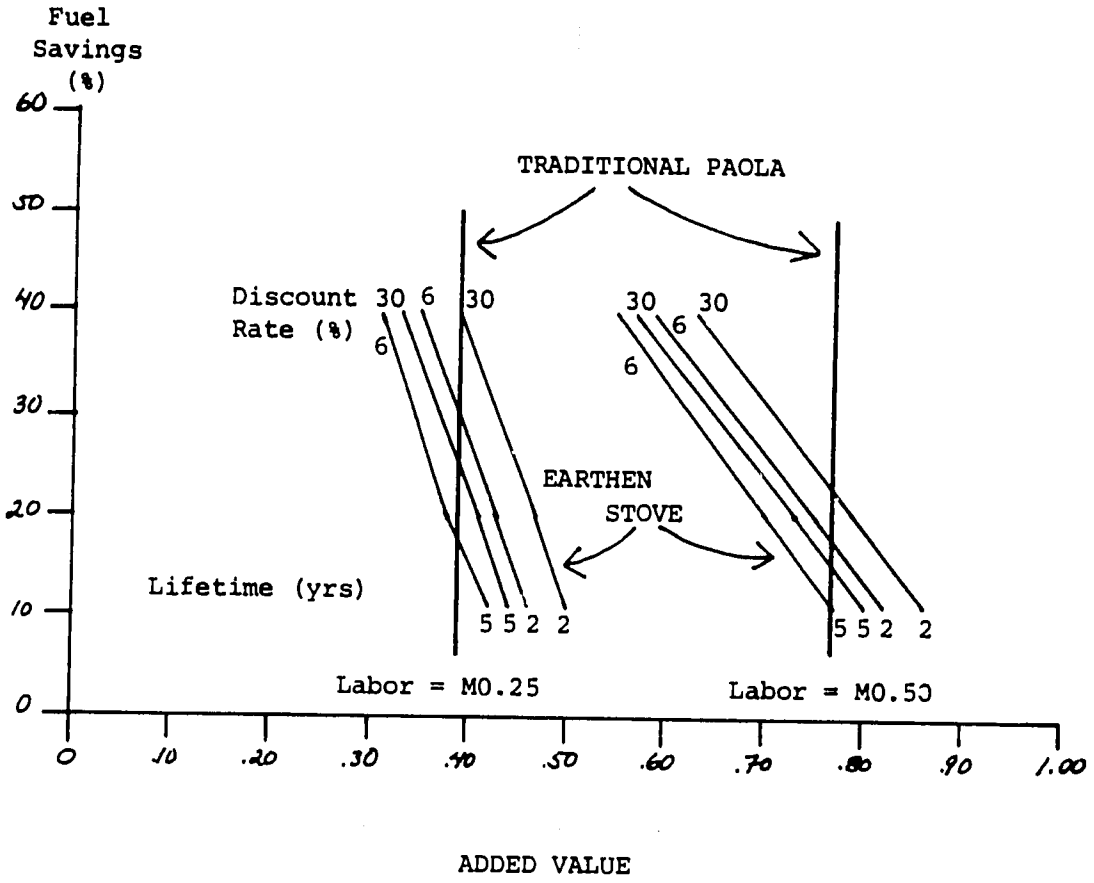


IMPROVED PAOLA COMPARED TO TRADITIONAL PAOLA

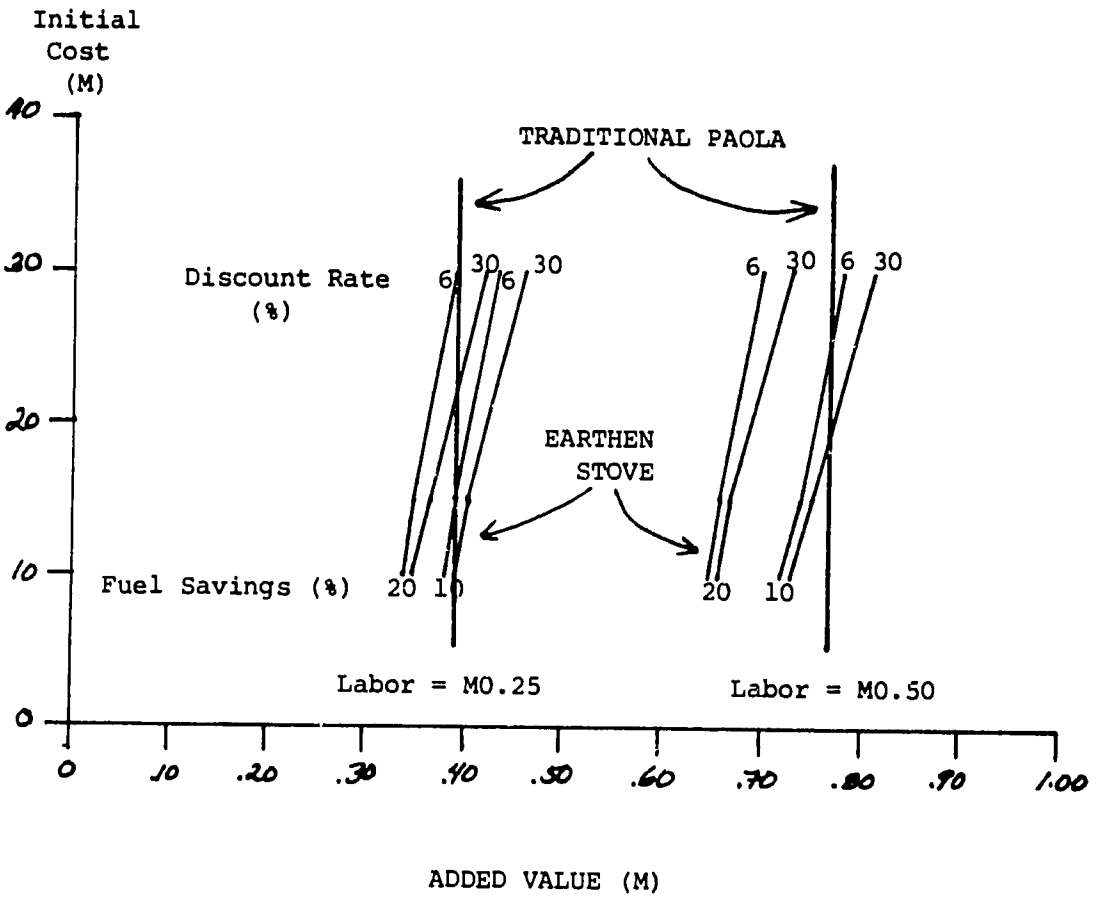


IMPROVED PAOLA COMPARED TO TRADITIONAL PAOLA

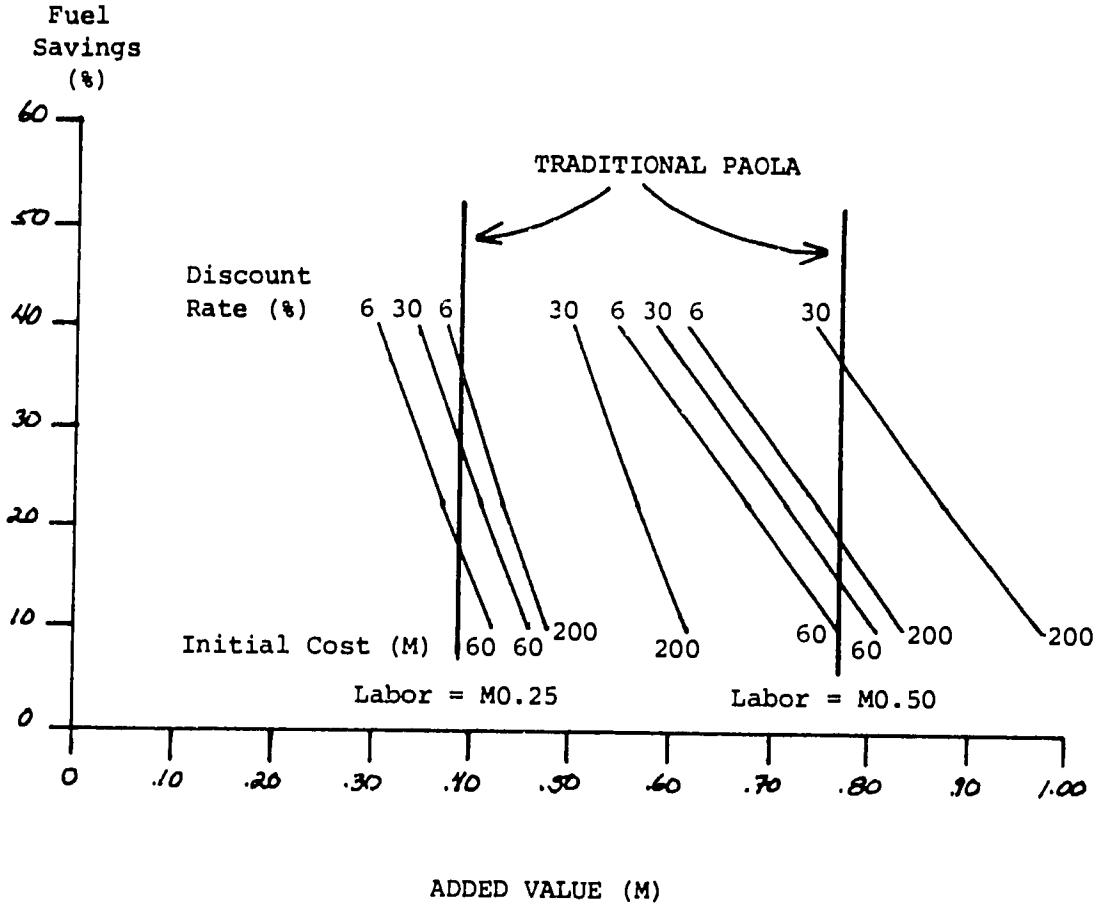
Discount Rate = 30%



EARTHEN STOVE COMPARED TO TRADITIONAL PAOLA

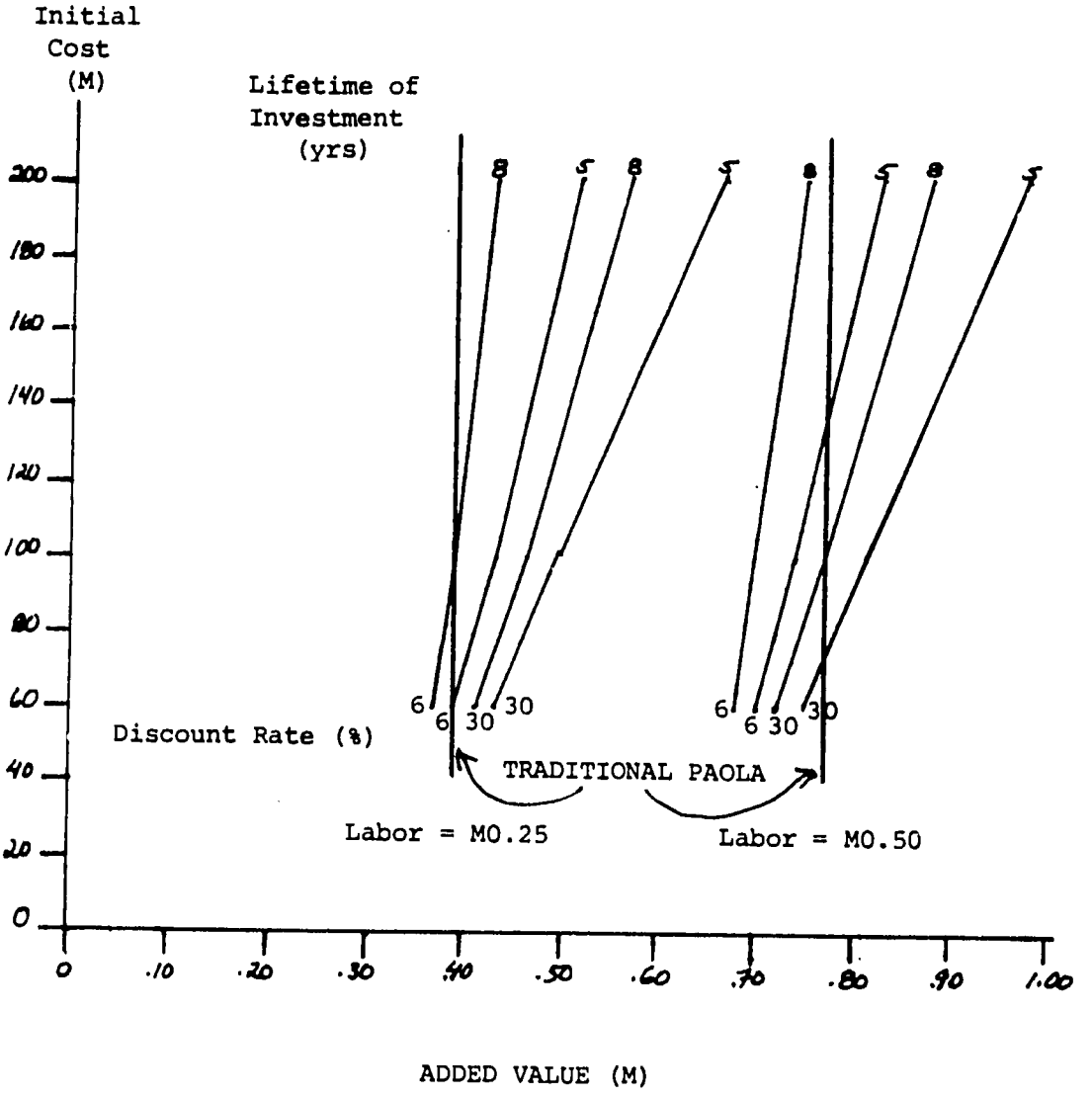


EARTHEN STOVE COMPARED TO TRADITIONAL PAOLA

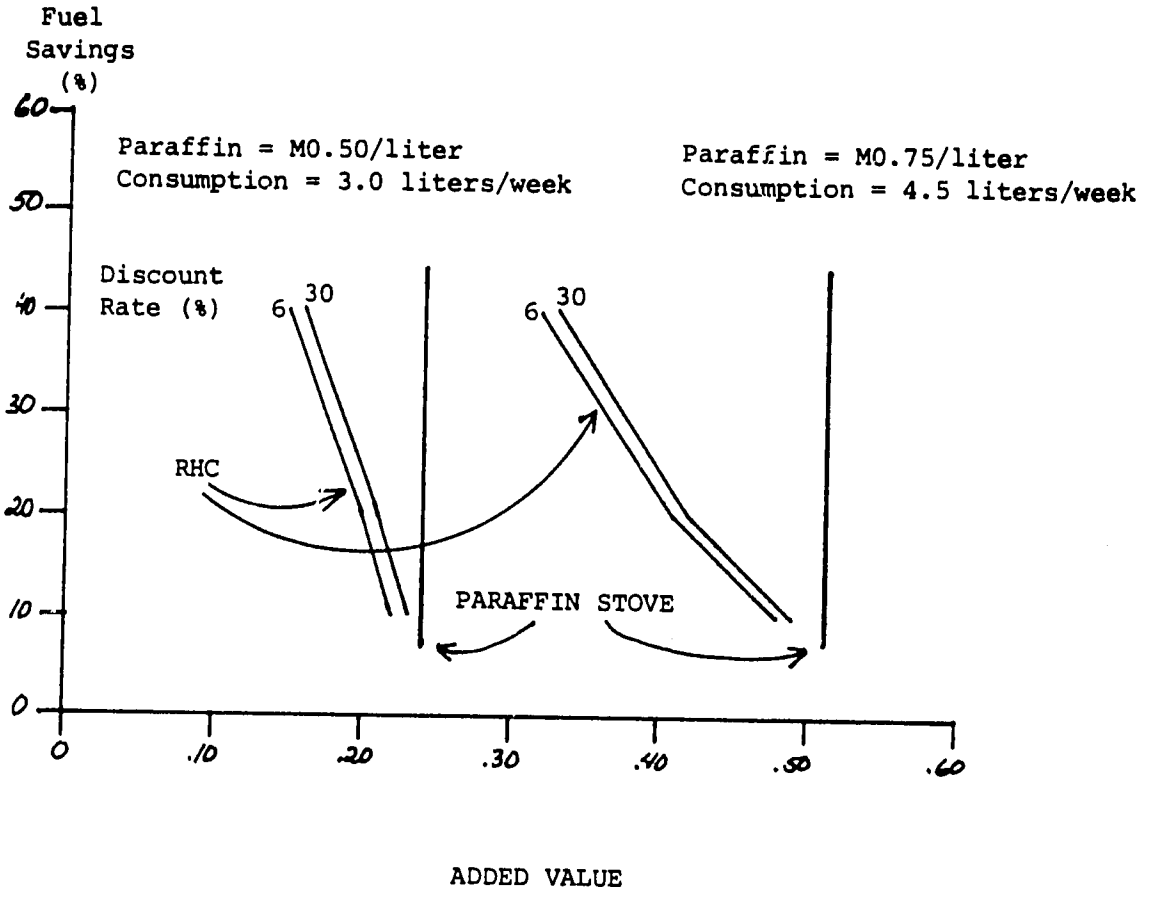


RET METAL STOVE COMPARED TO TRADITIONAL PAOLA

8-Yr Lifetime



RET METAL STOVE COMPARED TO TRADITIONAL PAOLA



RHC & PARAFFIN STOVE COMPARED TO PARAFFIN STOVE

APPENDIX B

THE TECHNOLOGY SELECTION AND DEVELOPMENT PROCESS

The RET Project has attempted to derive a process for developing a technology from the perceptionof a need through to its widespread (and appropriate) use. It is broader in scope than that contained in the Project Paper (chart No. 5) and hopefully it is more complete as well as useful. We have been trying to accurately define this process since we began the Project and this paper should be considered a draft, intended for comments, criticism and revision.

The process is graphically represented in Chart 1, attached to this narrative. This report will examine and describe each stage in turn. While the process has a major linear component, there are clear avenues of feedback so that technologies can be modified and new ideas introduced.

The RET Project did a preliminary needs assessment and technology matching in December 1981 - January 1982. This has been documented in a short paper entitled RET TECHNOLOGY SELECTION - NEEDS ASSESSMENT. The Village Energy Survey had not yet been done and we felt that more specific direction had to be given to our efforts. At this stage, the determination of needs was based upon our in-country experience, observations, early data collection and discussions with villagers and officials. We were able to identify cooking, growing food, energy efficieny in industry and institutions, water pumping, and availability and procurement of fuel as priorities. Of these, water pumping and fuel availability were being dealt with by other institutions and energy efficiecy in industry and institutions was decided to be outside of our Project's immediate concern. This left cooking and growing food throughout the year as primary needs for the Project to address.

The technologies chosen for these tasks included insulated cookers, improved paolas, more efficient stoves, solar ovens and parabolic cookers, and freestanding and attached growholes. These choices were based on technical criteria including conservation potential, use of renewable resources, use of indigenous or locally available materials for their construction and their being relatively proven technologies. Additional technical criteria included expected ease of construction and maintenance and expected performance. Social criteria included likelihood of user acceptance and the definition of various user groups, if any could be determined. Economic criteria included whether or not the item could be made at a reasonable price and if so, would the price be worth the benefits it could supply to the user or to the society at large.

Beginning in May, 1982 the RET Project undertook a full scale needs assessment and a subsequent technology matching exercise. The needs assessment process is fully explained in the Village Energy Survey Report, Gay, July - October 1982. In July, 1982, a consultant, Fred March, prepared a paper on the economic feasibility of several technologies as detailed in The Economics of Improved Energy Technology in Lesotho, March, July 1982. The analyses contained in these reports as well as in Social Feasibility of Renewable Energy Technologies by Khoboko, September, 1982, have been combined with a report by Klein, Technology Development: Status as of October 1982 to provide the present matching technologies with needs.

The priority technologies of October are not the same as those of January, although the modifications necessary in our activities have not been that great. The priorities now include cooking, water heating and space heating and increasing the year-round availability of foods through food storage and improved and increased production. (See Techonology Development: Status as of October 1982 for more details.) Based on the stated needs, we have found it necessary to expand our efforts to encompass the above areas. Since they were included as secondary or tertiary needs at an earlier stage we have only had to plan in their development into our future activities. (See the plan from Mokhotlong District for October 1982 to January 1983 as an example.

Having made this needs-technology match it is then necessary to determine the level of effort our Project should put into each area. For example, some technologies will require extensive research and modification. (e.g. more efficient stoves or paolas). Other technologies will require little research but perhaps redesign for local conditions and practices and are virtually ready for dissemination. (e.g. growholes, food driers and passive solar design). Still others will be dealt with in an advisory capacity (e.g. photovoltaic charging systems). Final category would be liaison with other agencies. (e.g. improved tree and vegetable species). While all categories of effort need to include user tests, the development of dissemination strategies and evaluations, only the first two, primary research and model redesign require the complete process beginning with Prototype Design and running through to widespread production and dissemination. This process is explained below.

The stage of prototype design includes laboratory testing and further economic screening. Metal stoves, earthen stoves, metal paolas, small greenhouses and some food driers are at this stage in their development at this time. The criteria for passing out of this stage are based on adequate performance, expected features of durability and ease of maintenance, and the costs of making the device. If any of these criteria are not suitably met the product can be redesigned and retested or it can be thrown out of the process. This might occur, if, for example, fuel use was twice as great as before or the cost of the item was much too great to achieve the desired performance.

Completion of this stage leads to user testing. This should be as extensive as possible and accurately monitored so that realistic evaluations can be made. Stone paolas, some greenhouses and some food driers are at this stage. The criteria for passing this stage are based on whether or not the device meets the user's needs, technically, economically and socially (health, safety, convenience). If technical performance is inadequate (will this stove really heat me in winter?) the device must be rethought and development should return to product design. If socially unacceptable, the problem may be referred to design, or back to needs assessment (if we were meeting the wrong need) or to new user tests (if the original group chosen was in fact inappropriate- e.g. dung burning stoves for lowland towns). If the unit is a complete failure it can also be thrown out at this stage and with few exceptions none should be rejected until they have been tested by the intended users.

Furthermore, in case we still haven't found a "proper" group of users, the RET Project should maintain the final form of the device as a unit for dissemination purposes. The right to decide on a technology belongs primarily to the users not a priori to the Project. Rather, the Project should provide good quality choices and let the market decide.

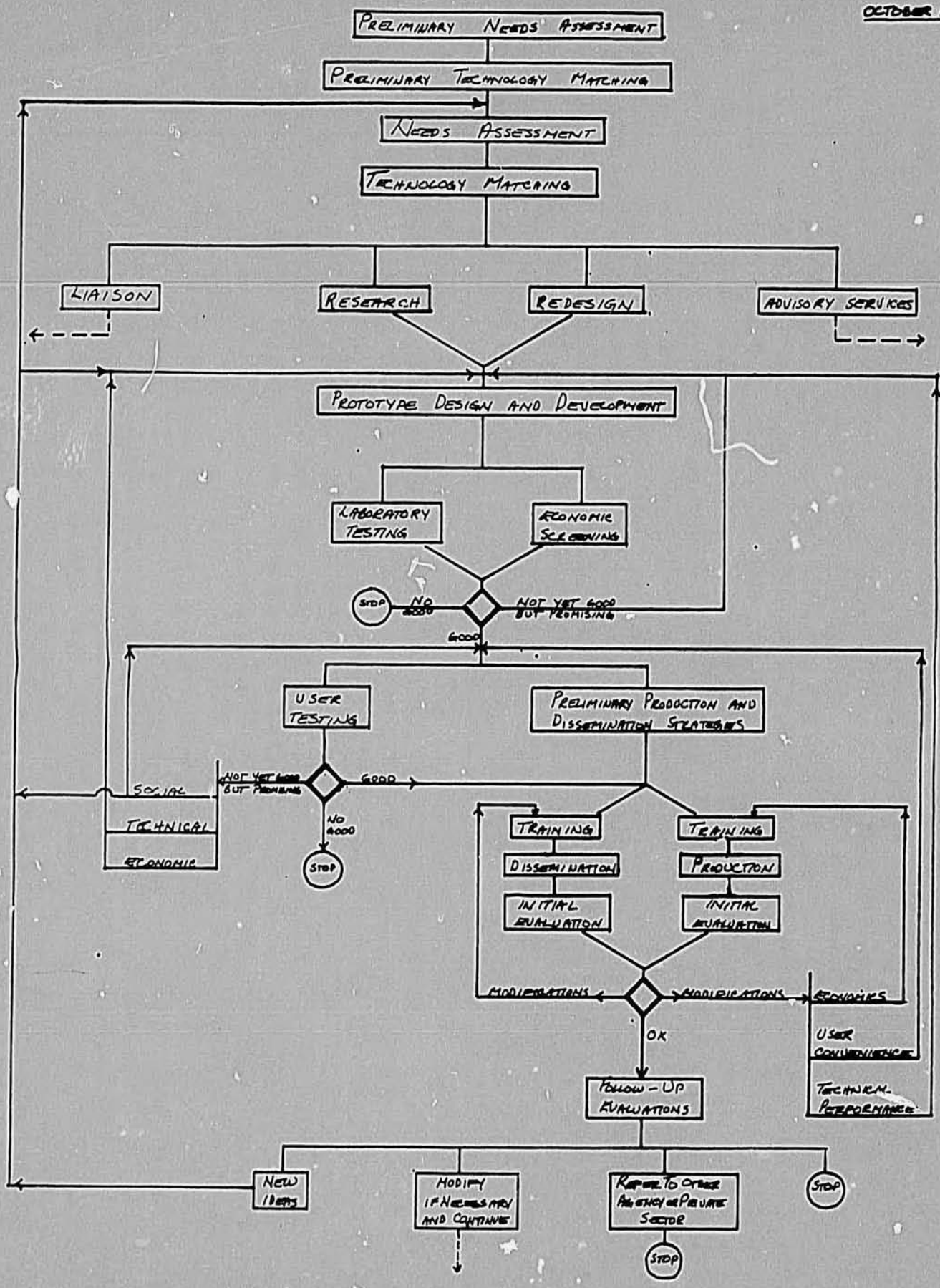
A unit that leaves this stage then needs to be produced and disseminated. The Project feels that preliminary production and dissemination strategies should begin when the unit reaches user testing. Should the unit be perceived of as "good" then full scale production and dissemination can begin in a timely fashion. This effort requires that methods of production (one-by-one to mass), location of production (village, workshop, factory), training needs (VETs, upgrading skills, adding new items to extension work), the possibilities of subsidies, and to whom will the device be disseminated and how, be examined and preferred strategies and alternatives drawn up. Some of this information can be elicited from the users, but many other opinions and factors will be included in the overall strategy chosen.

After production and dissemination have been underway for a short period (let's say 3 months), an initial evaluation should take place. This evaluation could say that modifications are needed in either or both production or dissemination strategies. On the dissemination side, if changes are necessary a new strategy could be developed or chosen. On the production side, technical performance, user convenience and safety, and economics all need to be evaluated. Any of them could send the unit further back in the process. Perhaps production strategies need to be modified (economics based on a too expensive item of changes in demand) of simple but non-performance related features that need adjustment (user testing of these is necessary) or perhaps an item needs to be added (or subtracted) from the devices repertoire (an oven or water heater is desired on a stove, requiring prototype design, etc).

If the device is doing well at this stage then the process should continue and a second evaluation scheduled. At this point, if further modifications are needed and everything else seems promising, make the changes and continue. If things need to be changed but can't be done by RET, RET should find others to help. If no one is willing or able to do so, then the technology should be dropped from the RET Project's repertoire.

As some parts of the process have still not been tried, we don't know how well this flow path will describe our eventual activities. It is, however, flexible and subject to change. And, as it will be documented, we will be able to review how we in fact did proceed from one stage to the next.

Gary Klein
Laboratory Supervisor
October, 1982

TECHNOLOGY SELECTION AND DEVELOPMENT PROCESS

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