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COMPARING CHARCOAL AND WOOD-BURNING COOKSTOVES

IN THE CARIBBEAN

by

Jeffrey L. Wartluft

MONTSERRAT FUELWOOD/CHARCOAL/COOKSTOVE PROJECT

A cooperative effort by the

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--Jeffrey L. Wartluft
Project Manager

1. INTRODUCTION

In English-speaking countries of the Caribbean, liquid petroleum gases (lpg) are the most common cooking fuels. With the exception of Trinidad, lpg is imported and so is expensive for families as well as a drain on a country's treasury. Lpg supply to these countries is uncertain too. It depends on seasonal demand and shipping and refinery schedules. The occasional long lines at the lpg dealers bear witness to this problem. Families who can afford to, have purchased two lpg cylinders to get around delivery uncertainties. Someday in the future there will be no affordable lpg--it is not renewable.

For most islands there is an alternative cooking fuel which is local, renewable, and viable right now. In fact, families have cooked with it for centuries, and still do. This fuel is wood from forests. However, this valuable resource is renewable only if used wisely. Such use involves many activities--measuring supplies and demands of different products, and satisfying these demands over the long term by efficient utilization of the forest

and, if necessary, prudent plantations of suitable tree species.

The Government of Montserrat had the foresight to initiate a project that would guide the country in managing its forest resource, particularly for fuel. In this effort they enlisted help from the Caribbean Development Bank (CDB), Volunteers In Technical Assistance (VITA), and the United States Agency for International Development (USAID). The Montserrat Fuelwood/Charcoal/Cookstove Project, begun in 1982, is studying 20 fast-growing tree species in experimental plantations, assessing the fuel supply from natural forests, finding efficient ways to convert wood to charcoal, and finding efficient ways to cook with both charcoal and wood. This paper reports on the results of the cookstove portion of the Montserrat project. Because cooking methods and cookstoves are similar enough throughout most of the Caribbean, the results of the Montserrat work are likely applicable across the region.

The 1980 Commonwealth Caribbean Population Census stated that 40 percent of the people in Montserrat cooked with traditional wood and charcoal fuels (GOM, 1980). This surprisingly high estimate prompted the initiation of the project out of concern for the future of Montserrat's forest resource. Our own estimates of traditional fuel use were:

Use Fuel Percent of Population

full time charcoal 20
occasional charcoal 60

full time wood 5
occasional wood 40

Meals cooked with charcoal customarily used cookstoves called coal pots (Appendix I). There were several models using various materials, but with very similar designs and sizes (Figure 2).

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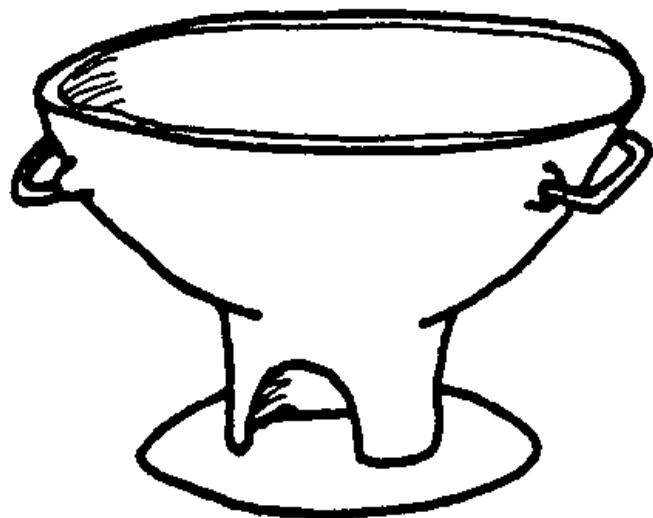


Figure 2. Traditional
Coal Pot--Caribbean

In fact, the Caribbean coal pot design was similar to many charcoal cookstove designs in Asia and Africa. Cookstoves like these have been shown in laboratory tests to have efficiencies (amount

of heat absorbed by the water/amount of heat available in the fuel x 100) around 30 percent (de Silva, 1981; Singer, 1961; and Tata, 1980). Little is known about the efficiency of these stoves in actual use.

When wood is used as a cooking fuel, it is usually burned in a three-stone fireplace (Figure 1 and Appendix I). The literature

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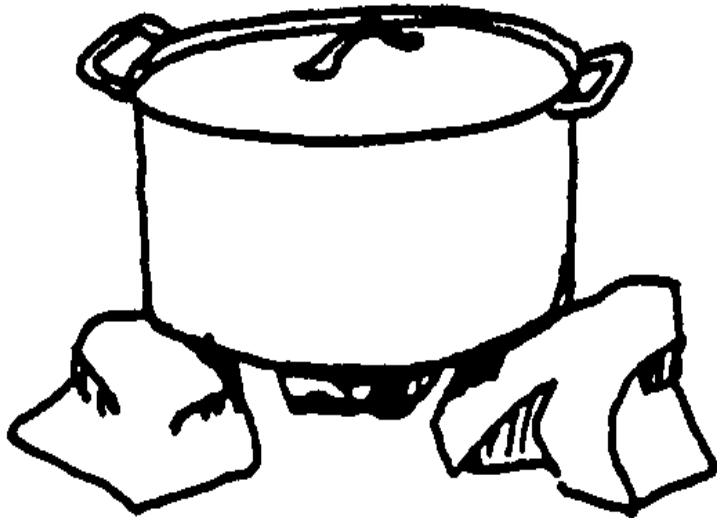


Figure 1. Three-Stone
Fireplace--Universal

has been harsh in its evaluation of three-stone fireplace efficiency, leading one to believe it is in the order of five to 10

percent. Recent laboratory and field testing, however, has shown a higher percentage of efficiency, around 17 (Yameogo et al., 1983).

For certain cookstove models to "catch on" we felt they should be efficient, economical, and acceptable. So we tested cooking techniques to measure these three criteria. Twenty-six cookstove models including the current standards were compared. Interpretation of the data suggested that the smaller cookstoves were more efficient and economical, but at a cost in time to bring food to cooking temperatures. Positive air control was important for efficiency but difficult to achieve in inexpensive stoves. Kitchen performance field testing was valuable in determining efficiency, economics, and fuel demand, but definitive data would require a large input of time and effort.

2. THE PROJECT

The objectives of the Montserrat Fuelwood/Charcoal/Cookstove Project were to:

1. Substitute local renewable cooking fuel from the forest for imported liquid fuels,
2. Use the forest resource wisely, and
3. Create local industry and employment.

Specifically for the cookstove portion of the project, all three

objectives would be enhanced by identifying and testing techniques for efficiently using charcoal and wood fuel for cooking.

STOVE SELECTION

In order to know if any improvements were made, we had to know the performance of the stoves currently in use. So we selected four models of coal pots--cast iron, cast aluminum, clay, and the converted steel auto wheel--and the only cookstove used with wood fuel, the three-stone fireplace (Figures 1 and 2). In Montserrat, wood fuel is also used in massive stone ovens for baking, but ovens were not tested.

Trial cookstove designs expected to be improvements over the standard cookstoves were chosen according to strict criteria. They had to be:

1. simple to build and use,
2. made locally with local materials,
3. inexpensive,
4. appealing in looks, and
5. formerly tried and reported in the literature.

The only locally available materials in quantity were sand,

stone, and clay. From the start, "mud" stoves were not considered due to the strong local feeling that their use would be a step backward in progress. Even though clay coal pots were not in much favor because they broke so easily, attractive double-walled models were made for both charcoal and for wood fuel.

A limited number of metal recyclable components were also available locally. Our trial designs incorporated used oil drums, five-gallon buckets, steel pipe, paint cans, and tin cans. All other materials, galvanized sheet metal, wire mesh, one quarter inch rod, and cement used in trial stoves were imported.

The large variety in design and size of pots used for cooking in Montserrat made decisions on stove dimensions difficult. Improved stove features called for shielding and insulating around the pots. So a stove designed for a 10-inch diameter pot would be too small for a 12-inch pot, and allow unnecessary heat loss when cooking with an eight-inch pot. Most trial designs were dimensioned for 10-12-inch pots. Coal pots and three-stone fireplaces were very flexible in accommodating various pot sizes, even frying pans.

Chimneys were not considered very important in our trial designs. Other stove programs have found chimneys to be a mixed blessing (Foley and Moss, 1983). And Montserrattians were not fond of the idea of holes in their roofs. Cooking with wood was generally done outside. Even though much charcoal was used inside, Montserrattian homes were always well ventilated to get the cooling effects of constant breezes. Smoke and carbon monoxide have not

caused problems. Only the two-hole cement wood-burning trial cookstoves had chimneys.

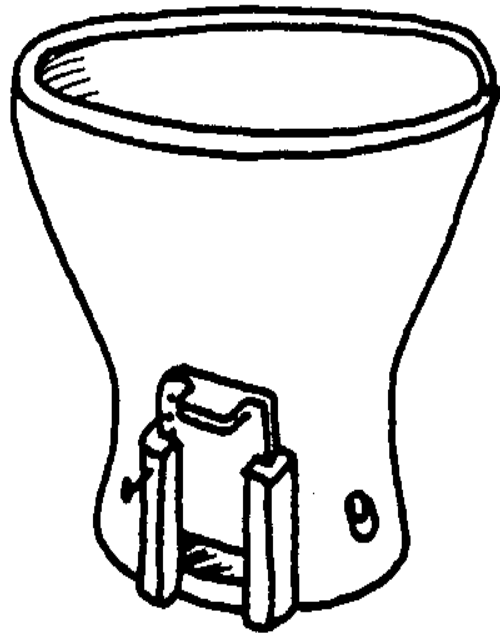
Even though there was interest in ovens and grills based on traditional fuels, the project did not have sufficient time to design and test these. There were several types of charcoal "Charlie Man" ovens in use. One design employed a used oil drum, inside of which was placed a coal pot for heat. It had a hinged door for access, and two steel mesh shelves for baking. For added heat, charcoal was burned on the top. These drums were not insulated. A better design was the wooden box with hinged door, tin lining inside, and shelves. This oven was heated by placing a coal pot with burning charcoal inside. Both ovens were easy to build and required no welding tools or special skills.

Trial Charcoal Cookstoves

The simplest design selected for testing was a coal pot modification, a sheet metal pot ring. The ring fit over the top of a standard coal pot and had a hole cut in it to match the pot diameter (Appendix I). This was an attempt at keeping the heat closer to the pot to enhance heat transfer into the pot.

The double skin (DS) fired clay charcoal stove mentioned earlier provided a wind screen, preheated secondary air, an insulated firebox, and draft control (Figure 3; Appendix I; and Joseph and

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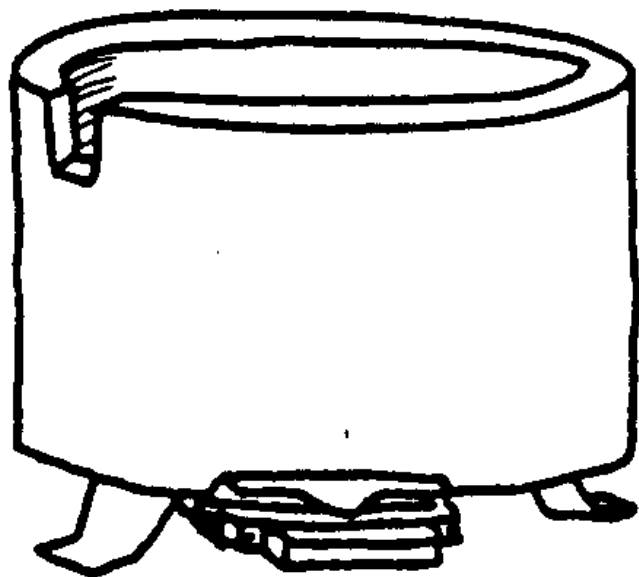


**Figure 3. Clay Double-Skinned--
Africa (Modified)**

Trussell, 1981). This sophisticated design originated in Africa. For use in Montserrat, the design was slightly modified and was beautifully executed by potter Joseph Howson.

Another design of African origin, the Umeme, was selected. The Umeme was made with galvanized sheet metal and several types of insulation--air, soil, and cement. It featured a wind screen, tapered firebox, ash drawer, and draft control (Figure 4; Appendix

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**Figure 4. Umeme--Africa
(Modified)**

I; and Hassrick, 1982). Craftsmen fabricating trial cookstoves for the project were encouraged to add their own creativity to their work. Three tinsmiths, James Sweeney, Cecil Roach, and John Harris, were enlisted to build the Umeme. Using the same drawings, each came up with quite different looking versions.

Only one stove selected was manufactured outside Montserrat. The Z Ztove, mass produced in California, USA, was a sophisticated design made with sheet metal and ceramic fiber insulation. It was tested because of the possibility of mass producing them in Montserrat for the Caribbean market. Features of the Z Ztove included preheated secondary air, firebox insulation, and positive

separate controls for primary and secondary air (Figure 5

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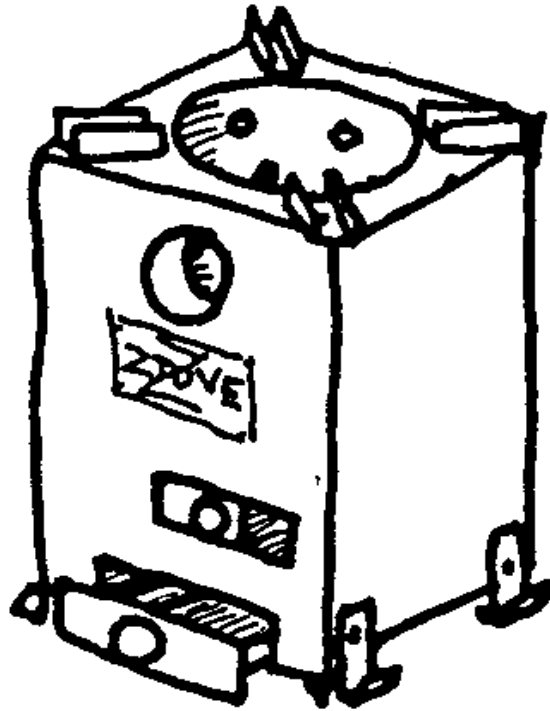


Figure 5. Z Ztove--USA

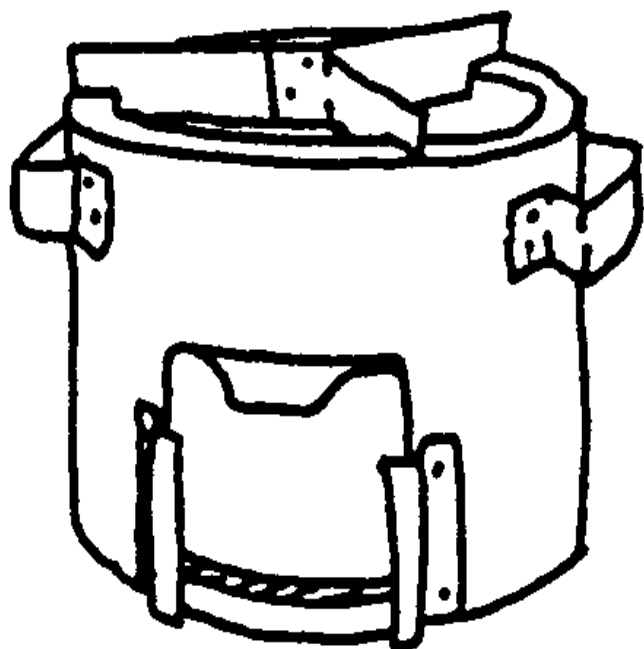
and Appendix I).

As stove testing progressed, modifications and new trial designs were born as a result of user feedback and our own efforts to improve stove performance or acceptance. For instance, the Z Z Corporation made several two-burner and larger burner Z Ztoves at

our request.

Two models that would be inexpensive and easy to construct in the home were tried. The Advanced Charcoal (AC) Stove used a juice tin inside of a paint can, with cement insulation between the cans (Figure 6 and Appendix I). It was conceived by Joseph

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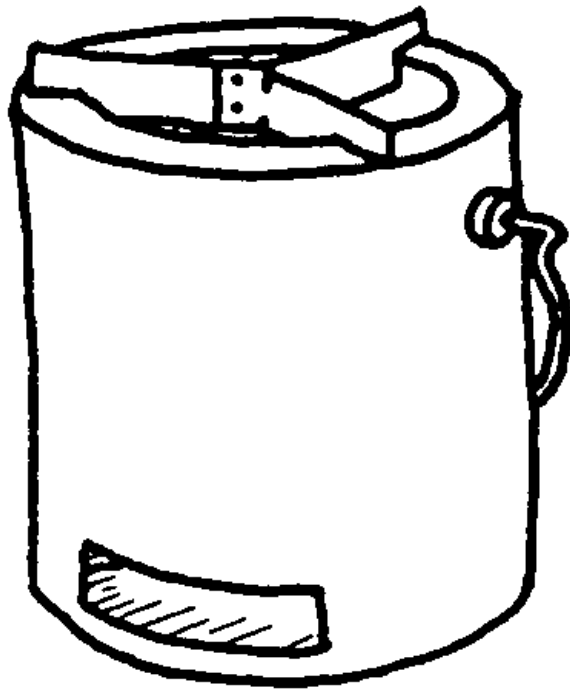
**Figure 6. Advanced Charcoal
(AC)--Montserrat**

Daniel, the Energy Officer in Montserrat. The AC stove was

tested in three sizes, and with and without a combustion air preheater and draft control.

The idea for the two-can stove design was sparked by a simplified copy of the Z Ztove built by Montserratian stove tester James Bradshaw. In this simple design a motor oil can was placed inside a paint can (Figure 7 and Appendix I). The design allowed

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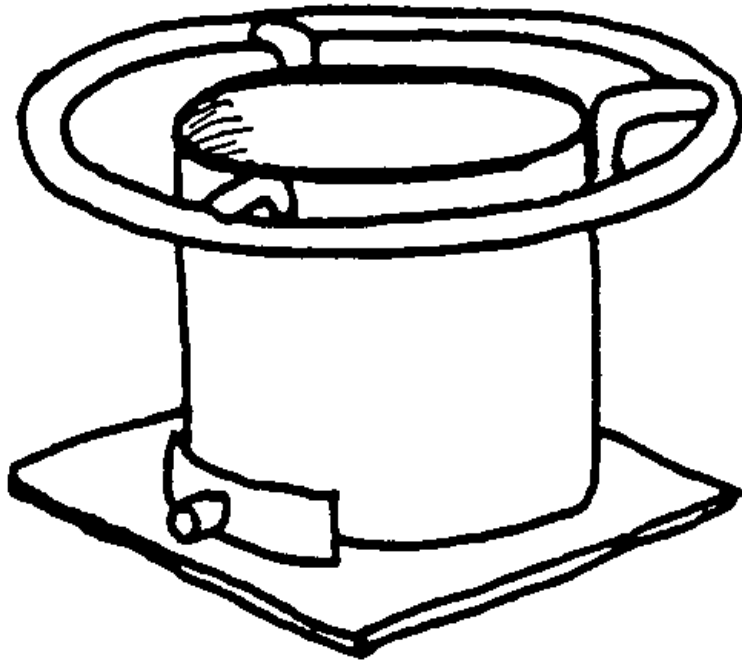


**Figure 7. Two-can Stove--
Montserrat**

both primary and secondary air to reach the burning charcoal.

In an effort to overcome the lack of durability of the Z Ztove and two-can stove, the project team designed an attractive Satellite stove (Figure 8 and Appendix I). Materials used included

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**Figure 8. Satellite Stove--
Montserrat**

six-inch diameter steel pipe, steel plate, and steel reinforcing rod. The Satellite stove had an ash drawer and draft control. Tests were run with clay and cement liners.

Trial Wood-burning Cookstoves

The African double-skinned fired clay stove was selected for testing. It had provision for primary and secondary combustion air (Figure 9 and Appendix I).

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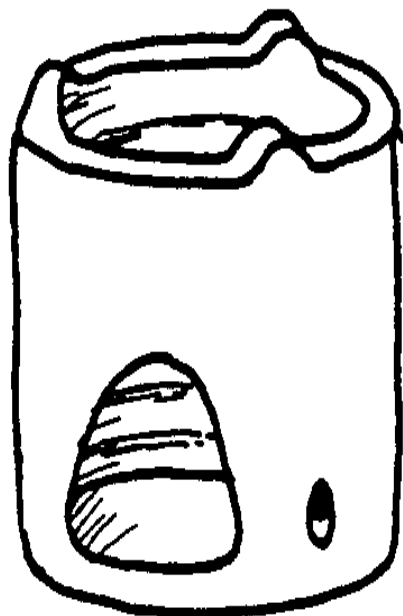


Figure 9. Clay Double-Skinned
Wood-Burning Stove--Africa (Modified)

A simple stove was made from a used five-gallon resin bucket and some 1/4-inch rod. The bucket served as the firebox and pot wind screen. The large fuel opening in both the clay and bucket stoves allowed sticks of any length to be used with the stove, but did not allow for combustion air control.

Two reinforced cement cookstoves were built for trial with wood

fuel. Each was built by different masons, incorporating some individual creativity. One built by Tony Carty and Charles White had thicker walls, a grate, and a removable firebox door. The other, built by Joseph Sweeney and David Lake, had thinner walls, a hinged firebox door, and a weight-saving hollow under the sloping firebox floor (Figure 10). Each had two holes for pots

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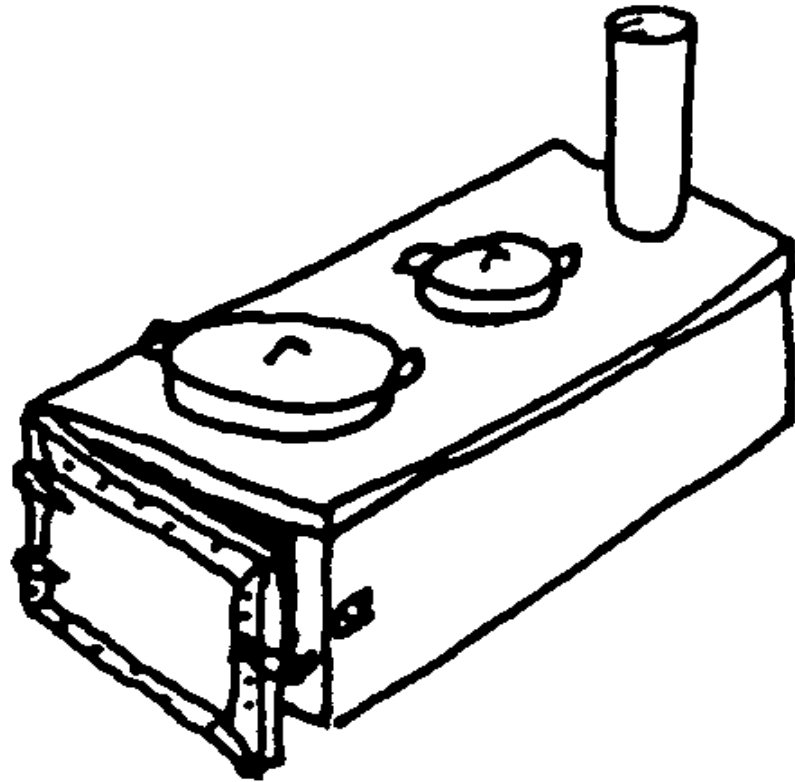


Figure 10. Cement Wood-Burning Stove--Montserrat

and a short four-inch diameter chimney. They were built to be portable for demonstration purposes (Appendix I).

EFFICIENCY TESTS

Two different tests for efficiency were performed with trial cookstoves: the water boiling test (WBT), and the kitchen performance test (KPT). Provisional international standards for

these tests were developed during a meeting of experts at VITA headquarters (VITA, 1982). We followed these standard procedures with a few modifications.

The WBT measured the amount of heat used in raising water temperature and evaporating water in a ratio over the amount of heat used from the fuel. Results were reported as percent heat utilized (PHU). We also reported the time required for a standard quantity of water to boil, and the amount of fuel that would fit in the firebox.

Equipment used in the WBT included:

- * two 11-inch diameter aluminum pots with flat bottoms and lids,
- * two eight-inch diameter aluminum pots with flat bottoms and lids,
- * balance accurate to 1/10 gram with a capacity of 6,250 grams,
- * four rubber stoppers with single holes,
- * four mercury thermometers reading to 250 [degrees] F (two spares),
- * electric oven with accurate temperature control to 220 [degrees] F,

- * small tongs,
- * heavy leather gloves,
- * clock reading to the nearest minute,
- * Zip fire fuel pellets (for standardized kindling), and
- * magic markers.

The detailed procedure is presented in Appendixes II and III.

The second test measured the relative efficiency of the stove and operator together. The KPT was performed by many different Montserratian families. Participating families were selected to represent different economic levels and geographic areas. In order to have reliable results, we needed many families to participate due to the added variability of different stove operators, cooking styles, food prepared, and eating habits. Since our time was limited, we field tested stoves with as many families as we could accommodate in our schedule. Only charcoal stoves were tested in the KPT.

We loaned a trial stove to each family and gave them a 10-pound bag of charcoal with instructions to keep track of the number of meals cooked on that stove with that bag of charcoal--no more or less. We also asked them to keep track of the number of people who ate those meals, their ages and sex. Each family was given a KPT data sheet to help them record data (Appendix IV). When we

returned in two to four weeks we reviewed the data sheet with them. We asked for their likes and dislikes about the stove, if they used it for heat needs other than daily meals, and checked to make sure they did not use the fuel in different stoves, they used all the fuel, and no fuel in addition to what was in the bag. At that point we offered to let them repeat the KPT with a different model stove. Once a family had tested two or more trial stoves, we asked them to repeat the KPT with their standard coal pot. When we returned for the last results, we gave them a bag of charcoal in appreciation for their cooperation. The charcoal was from our kiln trials in the other segment of our Montserrat project.

Results of the KPT were expressed as the number of standard adult equivalent meals (SAEM) prepared per 10 pounds of charcoal. SAEM were figured according to a widely used League of Nations formula which uses the following values.

Sex and Age Standard Adult Equivalent Meal

Child, 0-14 years 0.5

Female, over 14 years 0.8

Male, 15-59 years 1.0

Male, over 59 years 0.8

Since there were a number of stoves with different Montserratian

families under test simultaneously, and the stoves were switched around among families, we used a stove location sheet for each stove (Appendix V). By keeping these up to date, we knew where each stove was and when it was time to visit each family.

ECONOMICS

Economic comparisons of stoves were figured on the cost to use each type of stove per SAEM. We maintained records on the:

1. material and labor costs of building the stoves,
2. maintenance costs, and
3. fuel costs.

To arrive at the investment or depreciation cost, we estimated stove life and divided the original cost of the stove by the expected SAEM over its life. Maintenance costs included any replacement of parts over the life of the stove. Again these costs were divided by the expected SAEM over its life. Fuel costs were based on EC\$5 per 10 pounds of charcoal divided by the average SAEM per 10 pounds of charcoal from all families testing a particular stove. To get the total cost to use each stove model, the three costs per SAEM were added. Each trial stove model's cost of operation was compared to the average cost of operating all standard coal pots over one year. This showed the savings or losses of trial stove operation compared to the conventional cooking methods. Since we only ran KPT on charcoal stoves, no economic comparisons were made for wood-burning stoves.

ACCEPTABILITY

It was very difficult to quantify the acceptability of any given stove model, so all comparisons made about stove acceptability were subjective. Notes were kept on the comments that people made about each stove model. Most information was collected from families participating in the KPT. During each visit with a family, they were specifically asked what they liked and disliked about the stove (Appendix IV). When participants were reluctant to answer the general questions, more specific questions were asked about stove size, materials, looks, and operating features.

Feedback from families testing stoves was valuable in guiding our attempts to modify stove features for greater acceptance.

3. RESULTS AND DISCUSSION

The limited duration of this project did not allow definitive answers to the question of which cooking technique among those tested was the best in terms of efficiency, economics, and acceptability. However, the tests did allow us to establish some baseline data on traditional cooking practices and to pick out some general indications for improving them.

EFFICIENCY

There were several differences between the two tests for efficiency. With WBT we intended to screen stove models and features in order to select two or three of the best for the important KPT

field testing. WBT results were not indicative of expected fuel savings of cookstoves in actual use because they did not measure: the operator variable. So to get a measure of the efficiency of stoves and operators together, we ran the KPT.

We found the KPT results particularly useful. Besides (1) comparing the efficiency of different stove models in actual use, we (2) applied the results in our economic comparison of stoves, (3) used feedback for gauging acceptance of different stove models, and were able to (4) estimate the demand for fuel from the forest, which could then be matched with forest inventory data to see if tree plantations were-necessary to satisfy demand without depleting the resource.

WBTs were easier to conduct than KPTs. WBTs only involved our project team, while KPTs involved many people and required travel and visit time. In two months time, 160 WBTs were performed, an average of four per day. In approximately six months time, 55 families participated in the KPT, with 37 usable responses collected. Many families did not fully understand our purpose--or pretended not to understand in order to keep the trial stoves for longer periods of time. We made up to four visits to the same family to get a single response. In order to speed up data collection, we enlisted the help of teachers and agriculture extension agents. This effort, too, brought variable results.

Due to the greater variability of KPT results, more tests were needed than in WBT for the same degree of predictability. Unfortunately, the more useful information required a much greater

effort.

Interestingly, the cheapest and simplest cookstove, the two-can, had the highest average WBT efficiency, 34 PHU (Table 1). Other cookstoves that rated above 30 PHU in this comparison were the small AC with preheater and air control and the cast aluminum coal pot, each with 32 PHU, and the five-gallon bucket woodburning stove at 31 PHU. The poorest performers were the cement wood-burning stoves, the Satellites, and the Umemes, all with less than 20 PHU.

Among the traditional coal pots, the cast aluminum averaged 10 percentage points better than the clay, cast iron, or steel. All tested coal pots had similar shapes and sizes. Since clay was the best insulator of the materials tested, we expected it to perform better than the metals, which were all good conductors of heat. One possible explanation for aluminum's superiority was that its relatively high emissivity or ability to reflect heat back into the fire overcame its ability to conduct heat away from the fire. Indeed, some cookstove researchers have lined fireboxes with shiny metals to improve stove efficiency. Perhaps if the firebox walls of the cast aluminum coal pot were polished, it would be an even better stove.

We got conflicting results testing firebox insulation. The Umeme stove worked best with cement, next best with soil, and poorest with air insulation. The Satellite did best with clay, next best with cement, and poorest with no insulation. On the other hand, the two-can stove was more efficient without a clay liner, and

Table 1. Cookstove Efficiency Test Results**Water Boiling Test [a] Kitchen Performance**

Time No. Meals

Fuel to PHU of per SAEM

charge boil coef. re- lb coef.

(lbs) (min) PHU of spon- coal of

Cookstove & features [b] [c] (%) var. ses (SAEM) var.

Charcoal Cookstoves

| | | | | | | | |
|---------------------|------|----|----|-----|---|-----|-----|
| Clay coal pot | 1.27 | 22 | 21 | .57 | - | - | - |
| Cast iron coal pot | 1.29 | 21 | 22 | .27 | 2 | 2.5 | .04 |
| Cast alum. coal pot | 1.16 | 22 | 32 | .40 | 2 | 3.7 | .11 |
| Wheel coal pot | 1.46 | 24 | 22 | .24 | 1 | 1.0 | - |
| " /pot ring | 1.32 | 25 | 22 | .14 | 2 | 5.4 | .28 |
| Umeme/cement insul. | 1.40 | 22 | 20 | .28 | 6 | 2.8 | .30 |
| " /soil insul. | 1.11 | 22 | 16 | .24 | 6 | 4.0 | .37 |
| " /air insul. | 1.27 | 29 | 14 | .09 | - | - | - |
| Small AC | .57 | 34 | 21 | .22 | 4 | 5.7 | .57 |
| " /preheater | .32 | 38 | 25 | .11 | 1 | 6.2 | - |
| Medium AC | .57 | 27 | 25 | .26 | - | - | - |
| Large AC | .79 | 24 | 24 | .15 | - | - | - |
| " /preheater | .66 | 22 | 25 | .16 | - | - | - |
| Z Ztove | .42 | 24 | 27 | .45 | 5 | 4.7 | .80 |
| " /double burner | .48 | 26 | 25 | .14 | 6 | 5.6 | .66 |
| " /large burner | 1.26 | 20 | 22 | .10 | - | - | - |
| Two can | .28 | 27 | 34 | .28 | 1 | 3.3 | - |

" /clay liner .34 29 26 .27 - - -
 Satellite 1.36 29 11 .43 - - -
 " /cement liner .91 29 16 .27 1 2.0 -
 Table 1 - Continued

Water Boiling Test [a] Kitchen Performance

Time No. Meals

Fuel to PHU of per SAEM

charge boil coef. re- lb coef.

(lbs) (min) PHU of spon- coal of

Cookstove & features [b] [c] (%) var. ses (SAEM) var.

" /clay/preheat. .72 23 24 .14 - - -

Short satellite/cement .63 26 22 .25 - - -

Wood-burning Cookstoves

3-stone fireplace 27 .43 - - -

5-gallon bucket 31 .45 - - -

Cement/grate [d] 10 14 .94 - - -

" /sloping floor [e] 10 12 .59 - - -

[a] Averages based on at least five tests.

[b] To convert to kilograms, multiply by .454.

[c] Amount boiled was 2 kg. Does not include first five minutes from the time of lighting.

[d] Based on four tests, PHU total of two pots.

[e] Based on three tests, PHU total of two pots.

the non-insulated five-gallon bucket wood-burning stove was more efficient than the cement walled wood-burning stoves. In the case of the two-can stove, the air that was insulating the firebox was heated, then moved beneficially into the fire as preheated secondary combustion air. The insulating air in the Umeme was dead air. Once heated, it then transferred the heat to the outer shell of the stove from where it escaped into the air.

In the five-gallon bucket stove, increased efficiency was probably due more to the fact that in the simmer stage the fuel was retracted from the firebox for heat control. In the Umeme, Satellite, and cement wood-burning stoves, heat was not as effectively lowered by closing the not-so-positive air controls, loose fitting ash drawers and doors. Therefore, more heat than needed was used up. So if positive air control or ability to manipulate fuel are features of a cookstove, insulation is not as important. For instance, the three-stone fireplace did not have insulation or even a wind shield; but with manipulation of the fuel, its PHU was a respectable 27.

Recent African stove testing programs pointed out that thin-walled

metal cookstoves were more efficient than massive cookstoves for cooking durations less than 100 minutes. Only when cooking times were longer, say for restaurants or institutions, or at high altitudes, would massive stoves lose less heat through conduction (Baldwin, 1984).

Combustion air preheaters seemed to improve efficiency. In both the small and large AC stoves and the Z Ztove (the double burner Z Ztove did not have preheated secondary air) where this feature was tested, the preheaters added one to four PHU to the stove's efficiency.

Even though grates were not tested for charcoal cookstoves, it was obvious in the smaller models that the maximum air possible was necessary. In small stoves without secondary combustion air, ash build-up tended to close off the holes in grates. For this reason all of the smaller charcoal cookstoves were provided with grates of 1/4-inch wire mesh. One of the two cement wood-burning models had an iron bar grate. Its efficiency was two PHU greater than the model without a grate.

Control of combustion air was important to stove efficiency. With good air control fuel consumption was lowered to the amount needed for simmering, once the pot was boiling. In the AC stove, a slide control over the draft opening increased the stove's performance by seven PHU. The Z Ztoves all had positive air controls and good PHUs.

The variability of test results seemed high considering the tests

were controlled to minimize variation. PHU coefficients of variation ranged from 10 to 94 percent. Wood-burning cookstoves had much more variation than charcoal cookstoves. Wood was a more variable fuel than charcoal in size, shape, and moisture content. Wood fires were trickier to control. Charcoal cookstove results with high variation included the clay coal pot, Z Ztove, Satellite, and cast aluminum coal pot. There was no obvious common trait to explain their higher variability. A certain amount of variation was certainly due to the stove testers. Three of us from the project team did the testing. I suspect from observation that some of the variation in performance not specific to any one stove model but more likely to affect smaller stoves, was due to the random arrangement of fuel and how it affected air flow through the fuel. The same stove operated in exactly the same manner would sometimes fire up quickly and lively and other times barely perk along.

It took anywhere from 20 to 38 minutes to boil two kilograms of water with charcoal. This did not include the first five minutes after lighting the fire and allowing it to catch. Among charcoal cookstoves the ability to boil faster belonged to those with larger fireboxes (Table 1). The small AC stove with the next to smallest amount of fuel charge required the longest times to boil. The five-minute waiting period before putting on the pot to boil was arbitrary. Some additional testing determined that a charcoal fire needed about 10 minutes to be fully lit, after which boiling times averaged around 15 minutes. The fastest individual boiling time with charcoal was on the Z Ztove with 12 minutes to fully light, and nine minutes to boil. By contrast,

the same amount of water was boiled in the same pot on an lpg cookstove in six to 14 minutes, depending on burner size.

The manufacturer of the Z Ztove also made a multi-fuel backpacking stove that was supercharged with a C cell battery and small fan. Charcoal was fully lit in it after just one minute. In about two minutes some of the charcoal was white hot, indicating temperatures near 2800 [degrees] F. And flames from the stove made it look like a gas stove. The project team built a bellows to supercharge trial stoves. It worked well, but required a cook's attention. Besides, a traditional piece of cardboard for fanning, although not as effective, was much cheaper.

In actual use the AC stoves were the most efficient according to KPT (Table 1). They cooked an average 5.8 SAEM per pound of charcoal. Next were the Z Ztoves with 5.2 SAEM per pound of charcoal, and then the coal pots with 3.5 SAEM per pound of charcoal. The Umeme stoves averaged 3.4 SAEM per pound of charcoal, no better than the standard coal pots. Since there were few test responses, we grouped these stove types for comparison. These tests suggested that the smaller the stove, the more efficiently it worked under actual conditions.

Since the two-can and Satellite charcoal cookstoves were models developed late in the project, only one KPT response was available for each. Dissemination of these results is to take place during the second year of the project. The KPTs will be ongoing in conjunction with dissemination.

No tests were made of the clay DS stoves as they broke after a few uses.

A comparison of the results of the WBT and KPT showed that WBT results could not be used to predict fuel savings of cookstoves under actual use. For example, the WBT results for coal pots as a group were in the mid range, but under KPT were clearly inferior.

Though the KPT results indicated that a 49 to 66 percent fuel savings would be possible by using AC stoves or Z Ztoves rather than coal pots, these estimates were based on few data. And "improved" stove use would also hinge on their economics and their acceptance.

ECONOMICS

A comparison of the economics of using cookstoves showed that the AC stoves were cheapest, followed by the Z Ztoves (Table 2). The Umeme stoves were more costly to use than the coal pots. Since the economic calculations were based on KPT results, insufficient data were available to compare the two-can, Satellite, and all wood-burning cookstoves. In fact, we grouped the data by stove type for this comparison because there were few KPT responses.

Fuel cost emerged as a more influential cost than investment or maintenance costs. The stoves with smaller fireboxes and less fuel consumption per meal, the AC and Z Ztoves, would save about EC\$100 and EC\$25 respectively per year compared with the use of

traditional coal pots. The use of Umeme stoves would actually cost about EC\$65 more than using coal pots.

Theoretically, with improvements in cooking practices brought about by public education campaigns, cooking could become more efficient and economical than our estimates of present day practices. With this in mind, the Energy Officer in Montserrat issued a kitchen calendar with tips on fuel conservation such as using lids on cooking pots, using smaller amounts of water when cooking vegetables, using pressure cookers, etc.

It is important to realize that our economic comparisons ignored the capacity of a particular stove to cook for different sized families. A small cookstove could not adequately cook a large pot of food. Of course a large family could use several small cookstoves and experience the same savings, as long as large pots were not used for cooking. However, cooking in large pots is common in the Caribbean. The fact that smaller cookstoves were shown to be more efficient and economical does not guarantee that they would be acceptable to users.

Table 2. Economic Comparison of Charcoal Cookstove Use

Coal Z

Item pots Umeme Ztove AC

Purchase cost (EC\$) 44 180 83[a] 30

Estimated stove life (years) 7 3 2 4

Maintenance cost over life
of stove (EC\$) 15 9 30 8

Stove/operator efficiency
(SAEM/pound charcoal) 3.5 3.4 5.2 5.8

KPT responses (no.) 7 12 11 5

Fuel cost (EC\$/SAEM) [b] 0.143 0.147 0.096 0.086

Investment cost (EC\$/SAEM) [c] 0.003 0.032 0.022 0.004

Maintenance cost (EC\$/SAEM) [c] 0.001 0.002 0.016 0.001

Total cost (EC\$/SAEM) 0.147 0.181 0.134 0.091

Savings [loss] compared to
coal pots (EC\$/year) [c] - [64.53] 24.67 106.29

[a] Purchase cost as imported.

[b] Fuel cost, EC\$.50 per pound.

[c] Average family of three cooks 5.2 SAEM per day or
1898 SAEM per year.

ACCEPTABILITY

Inasmuch as people's opinions on any single subject vary tremendously, there was no one trial cookstove model that was universally acceptable. A range of cookstove models would have to be available to satisfy all people's desires and cooking needs.

To begin with, there was no perceived need among the users of coal pots and three-stone fireplaces for improving upon traditional cooking systems. The government felt the need to protect its valuable forest resource by introducing more efficient cooking methods.

So there was a need to develop a consciousness in the people about cooking fuel efficiency. Therefore, very few comments were made about a cookstove's efficiency, the major reason for the project's existence. Most concerns were expressed about cookstove appearance, how well they worked, how they fit the cooking needs, how durable they were, what the working features were, their cost, and their efficiency, in roughly that order of importance to potential users.

The most excited feedback we received was based on a trial stove's looks. Older users seemed to prefer the Umeme, perhaps because they were more like coal pots than other trial cookstoves. Younger folks seemed to like the smaller, more modern looking stoves. The most coveted design was the Z Ztove, with its manufactured look.

People liked the way the smaller stoves worked, but the stoves did not always fit their needs. Cooking capacity generally was

lacking. Comments such as these led us to enlarge several cookstove models. At our request, the Z Ztove manufacturer sent us modifications of the Z Ztove that were double burners and single but larger burners. We had local tinsmiths make two larger sizes of AC stoves. The larger models were well received.

Cookstove durability was a concern. Clay coal pots were not favored due to their fragility. We found that expensive sheet metal lining around fireboxes lasted only one to three months. The Umeme, Z Ztoves, AC stoves, and two-can stoves had these liners. It was of little concern in the Umeme and AC stoves with their cement insulation. Once the tin burned out the cement became the firebox wall. The tin merely acted as a form for the cement. But the firebox lining had to be replaced periodically in the other stoves. The Z Ztove had easily replaceable liners, and the two-can stove used easily replaced motor oil cans. But the Umeme with soil insulation required shaping sheet metal into a cone for relining. Concern was registered for the durability of wire mesh grates, but these were inexpensive and easily replaced.

Of the working features of cookstoves, the most appreciated was the ash drawer for ease in emptying the ashes. The ash drawers also doubled as air control, but there seemed to be little esteem for its value in conserving fuel.

The fact that much food was cooked in frying pans led to our modified wind shield with slot for frying pan handle on the Umeme stoves. That made them more acceptable.

The large Umemes with cement or soil insulation were very heavy. Montserratians moved their coal pots around--to light them outside, bring them inside for cooking, and back outside for emptying ashes. We tried reducing the weight of cement insulated models by incorporating charcoal fines into the cement mix. We never really overcame that objection to the Umeme.

Another objection to the Umeme stoves was the lack of air getting to the fire. The only combustion air in Umemes was that which was pulled up to replace the hot air rising out of the stove. Coal pots were designed such that when the "arch" (draft opening) was faced into the breeze, the air going into the arch was all forced up into the fire. Breezes simply passed under the Umeme.

For many families the cost of a cookstove was not important. Nevertheless a segment of the stove testers complained about not being able to afford a new cookstove. For these people we developed the AC and two-can charcoal stoves, and introduced the five-gallon bucket wood-burning stove. Each of these models was inexpensive and easy enough for most families to make in their own home. However, the two charcoal stoves were small and had a homemade look, which detracted from their acceptance. And because wood fuel use was associated with families in the lowest economic group, any wood-burning cookstove had to overcome that debasement to be acceptable.

If we had to rank cookstoves according to their overall acceptability, they would roughly follow in order of descending acceptance:

1. coal pots for their familiarity,
2. Satellite stove for its good looks and durability,
3. Z Ztove for its good looks and working ability,
4. Umeme stove for its similarity to coal pots and ash drawer,
5. AC stove for its simplicity and low cost,
6. two-can stove for its simplicity and low cost,
7. five-gallon bucket stove for its simplicity and low cost,
8. the cement wood-burning stoves, and
9. the clay cookstoves.

As time goes by this ranking could change. People will become more aware of the value of improved stove efficiency as lpg becomes more expensive and competition for wood and charcoal becomes more keen.

Cooking with wood and charcoal was dirtier and slower than cooking with lpg. In an effort to help clean up the handling of charcoal, the project introduced the use of inexpensive ice tongs and scoops cut from discarded plastic bleach bottles. For faster

starting of charcoal fires, a tin juice can with top and bottom removed, and side air holes punched around the bottom was promoted. With one sheet of crumpled newspaper in the bottom and charcoal in the top of the upright cylinder, a fast fire was assured for even the novice fire builder (providing the charcoal was dry).

It was hoped that all of these efforts at improving cookstoves and cooking systems would help elevate the status of using wood and charcoal fuels, and assure a perpetual supply of these local renewable resources.

4. CONCLUSIONS AND RECOMMENDATIONS

Test results and user comments led us to the following conclusions:

1. Smaller charcoal cookstoves were more efficient and economical than traditional coal pots, but required more cooking time and often were not suitable to the cooking needs of Montserratian families.

2. Positive air control was difficult to achieve in cookstoves, but improved their efficiency.

3. Insulating the firebox was most useful in cookstoves without air control or the ability to retract the fuel.

4. Grates in smaller charcoal cookstoves needed maximum air holes.

5. The cast aluminum coal pot was superior to other coal pots in efficiency.

6. Kitchen performance testing (KPT) of cookstoves yielded information for many important uses, but required a large input of time and effort.

7. The operator variable in cooking system efficiency is so great that more impact on fuel conservation might be possible through public education (people improvement) than through stove improvement.

And finally, we concluded that a number of suggestions for further work are in order:

1. Continue kitchen performance testing of stove models to obtain solid baseline data on the number of standardized meals prepared by each oven dry pound of fuel.

2. Participate in public education efforts to conserve cooking fuels.

3. To overcome problems in production and quality control, develop systems to mass produce inexpensive cookstoves.

4. Develop a small battery-powered fan unit with variable speeds to hook to small cookstoves for supercharging combustion air.

5. Develop a more durable firebox and top for the Z Ztove.

6. Polish the firebox walls of the aluminum coal pot and retest for efficiency.

APPENDIX I

COOKSTOVE DESIGNS

FCCA

MONTSERRAT

FUELWOOD * CHARCOAL * COOKSTOVE PROJECT

Name and origin of stove TRADITIONAL COAL POT-CARRIBEAN

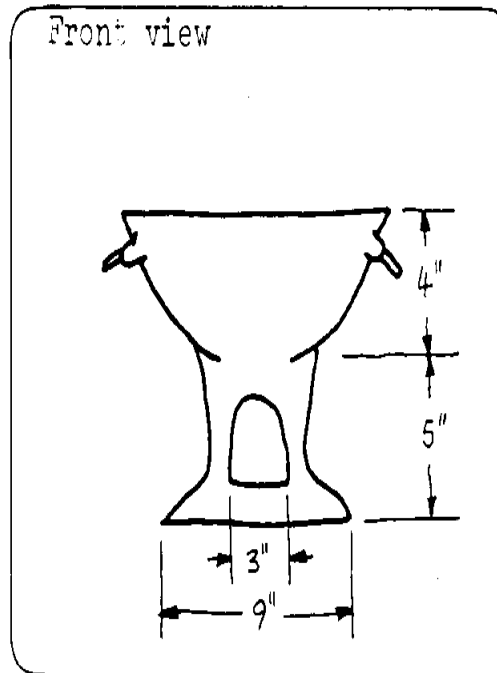
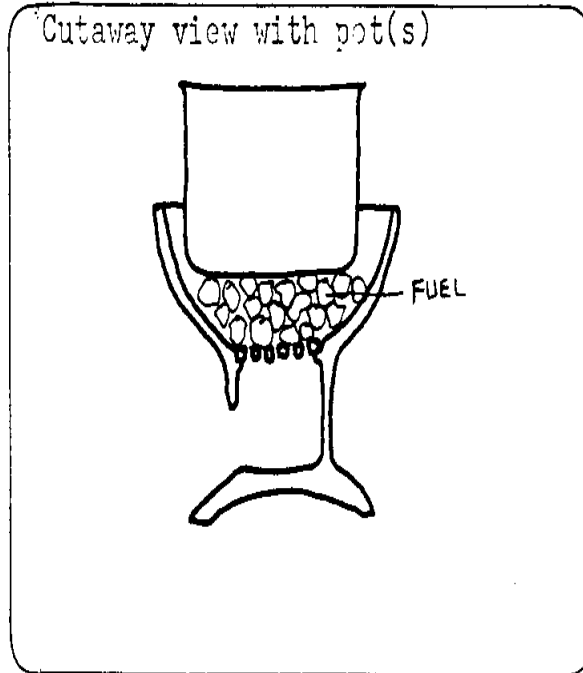
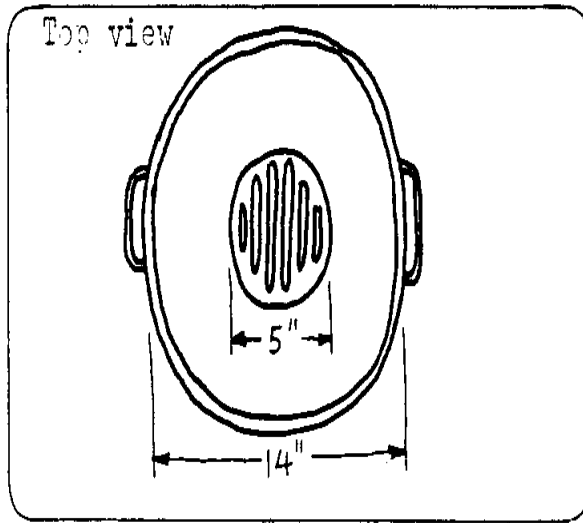
Name of stove builder(s) VARIOUS

Construction date 1982 Materials used CAST ALUMINUM,

CAST IRON, CLAY, OR CEMENT WITH WIRE ROD AND DRUM STEEL.

<FIGURE A>

48ap01.gif (600x600)



Details of stove construction GRATE IS CAST SEPARATELY. CLAY

COAL POTS CLAY GRATES, WHILE CEMENT COAL POTS USE OIL DRUM

STEEL WITH PUNCHED HOLES.

FCCA

MONTSERRAT

FUELWOOD * CHARCOAL * COOKSTOVE PROJECT

Name and origin of stove CLAY DOUBLE-SKINNED - AFRICA (MODIFIED)

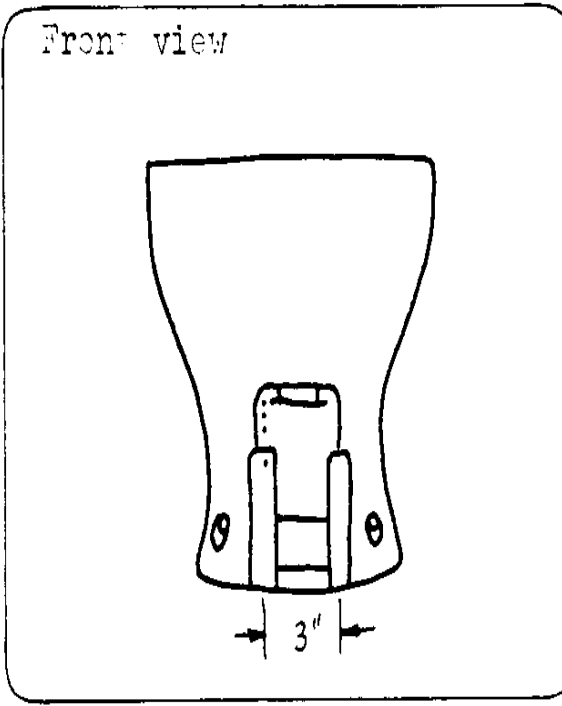
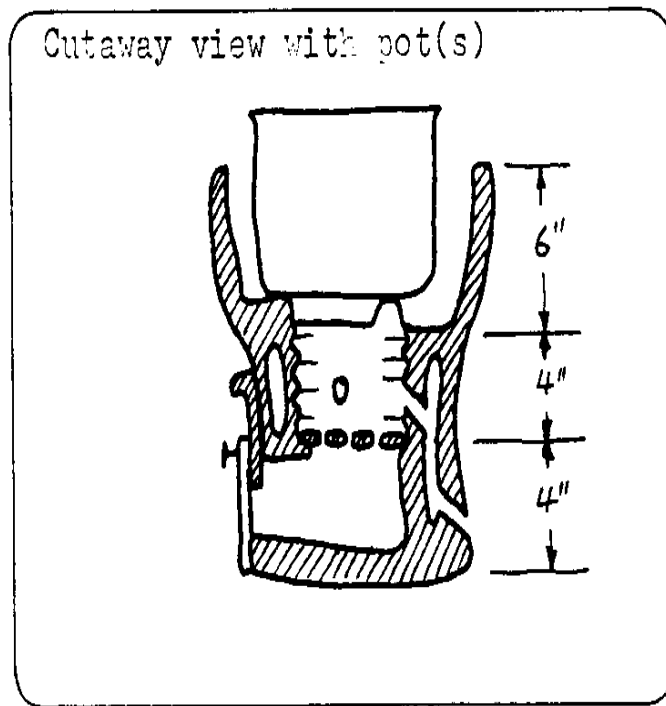
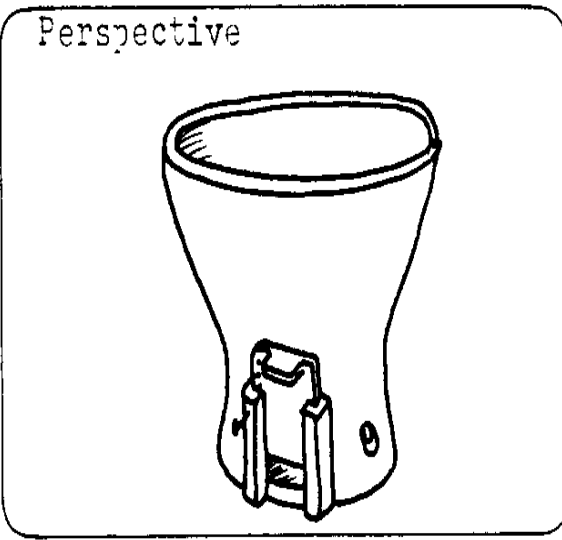
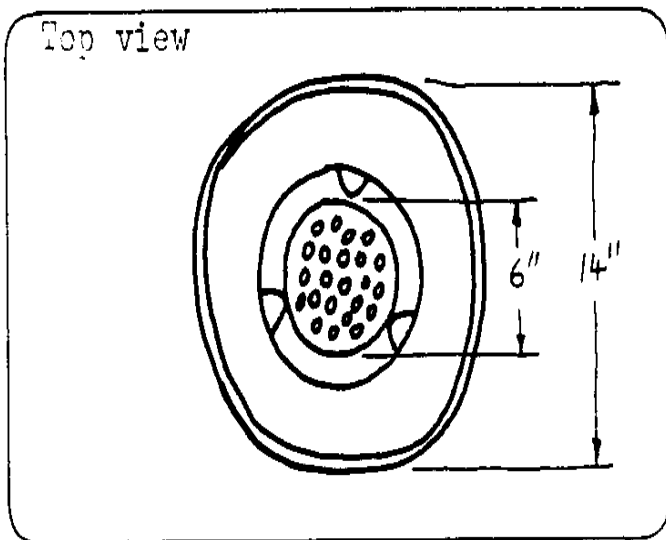
Name of stove builder(s) Joseph Howson

Construction date 2/83 Materials used CLAY MIXTURE WITH

WHITE VOLCANIC POWDER AND ONE NAIL.

<FIGURE B>

48ap02.gif (600x600)



Details of stove construction INSIDE AND OUTSIDE CYLINDERS WERE

TURNED SEPARATELY, JOINED, CURED, AND FIRED AT 900-1100 [degrees] C. SECONDARY AIR HOLES WERE 12-IN. DIAM. AND SLANTED UPWARD TOWARD THE INSIDE. WALLS OF FIREBOX WERE ROUGH TO PROMOTE MIXING OF GASES AND AIR. DRAFT DOOR ADJUSTABLE WITH NAIL.

FCCA

MONTSERRAT

FUELWOOD * CHARCOAL * COOKSTOVE PROJECT

Name and origin of stove UMEME - AFRICA (MODIFIED)

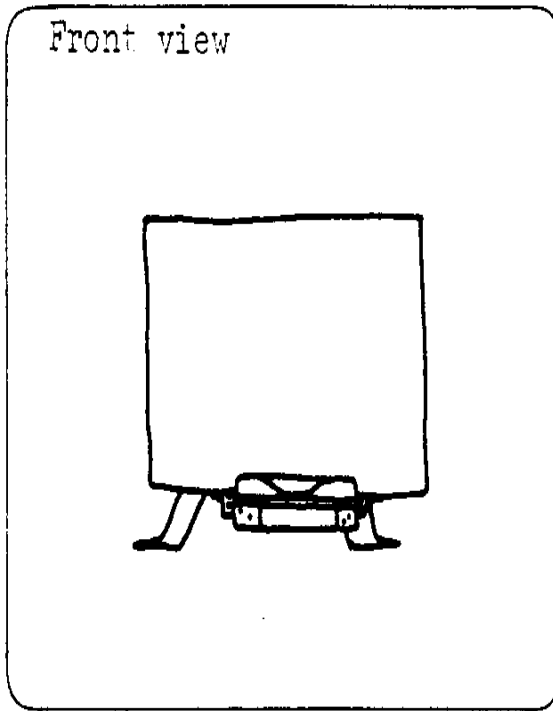
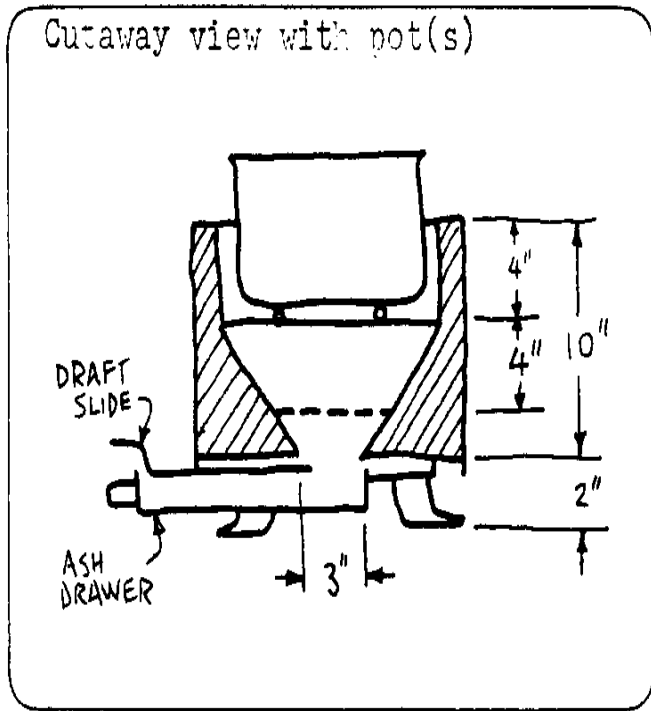
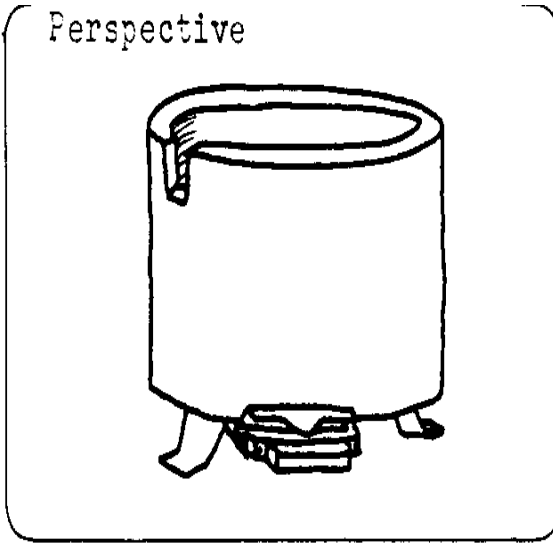
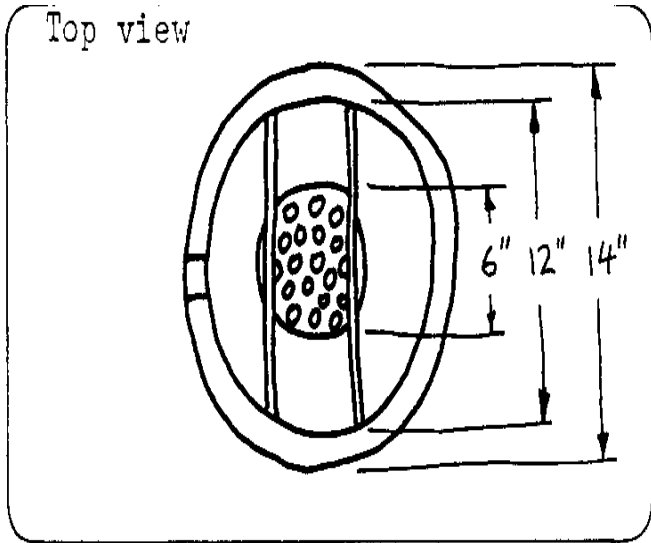
Name of stove builder(s) John Harris, James Sweeney, Cecil Roach

Construction date 2/83 Materials used SHEET METAL WITH

CEMENT, AIR, OR SOIL INSULATION, NAILS, 1/4-INCH ROD, AND DRUM STEEL

<FIGURE C>

48ap03.gif (600x600)



Details of stove construction NAIL RIVETS FASTENED THE ASH DRAWER,

DRAFT SLIDE AND DRAWER RAIL TO THE BOTTOM, AND THREE LEGS

TO THE BOTTOM. CHARCOAL FINES WERE MIXED WITH CEMENT TO LESSEN
THE WEIGHT. POT SUPPORT RODS EXTENDED INTO THE CEMENT. NOTCH IN
WIND SCREEN WAS FOR FRYING PAN HANDLE.

FCCA

MONTSERRAT

FUELWOOD * CHARCOAL * COOKSTOVE PROJECT

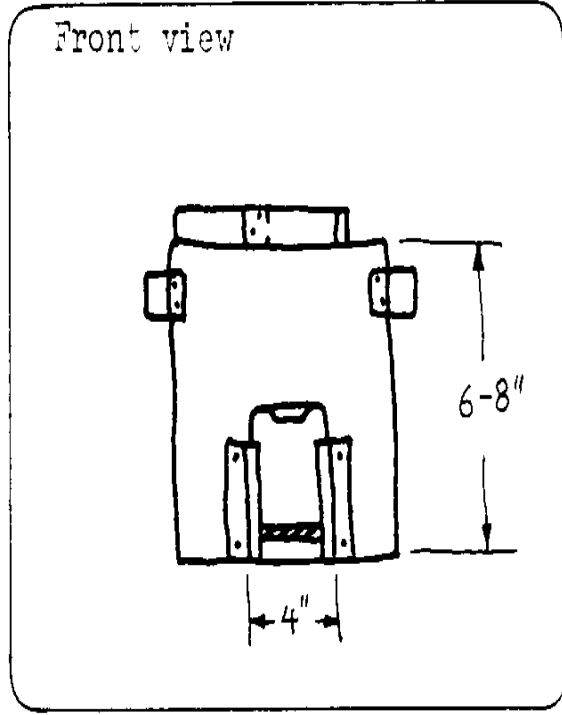
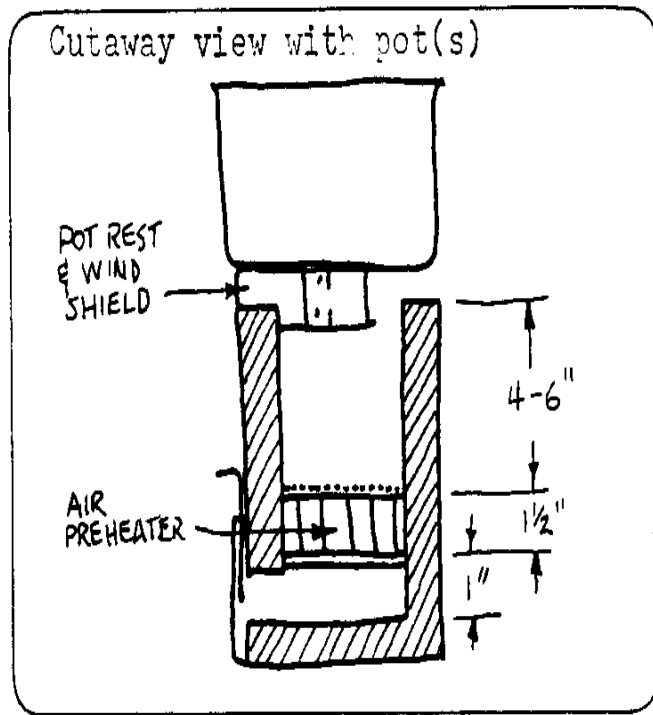
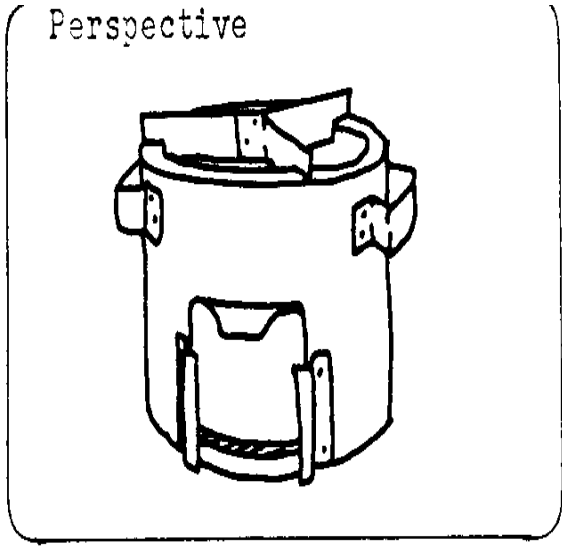
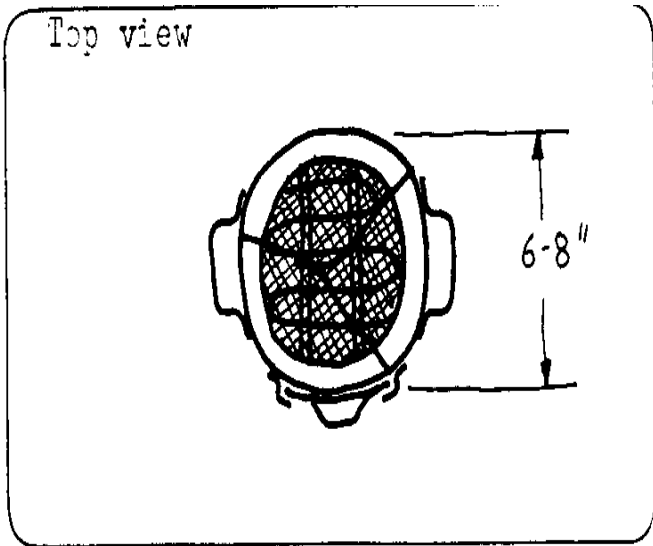
Name and origin of stove ADVANCED CHARCOAL (AC) - MONTSERRAT

Name of stove builder(s) JOHN HARRIS, JAMES DYER

Construction date 4/83 Materials used VARIOUS CANS, NAILS,
DRUM STEEL, 1/4-INCH AND 1-INCH WIRE MESH, 1/4-INCH ROD, AND CEMENT

<FIGURE D>

48ap04.gif (600x600)



Details of stove construction CEMENT INSULATION WAS REINFORCED

BY 1-INCH MESH WIRE. POT REST/WIND SHIELD AND HANDLES MADE WITH
DRUM STEEL, FASTENED WITH NAIL RIVETS. DRAFT DOOR AND AIR PREHEATER
MADE WITH TIN. 1/4-INCH ROD SUPPORTS AIR PREHEATER WHICH
SUPPORTS 1/4-INCH MESH GRATE.

FCCA

MONTSERRAT

FUELWOOD * CHARCOAL * COOKSTOVE PROJECT

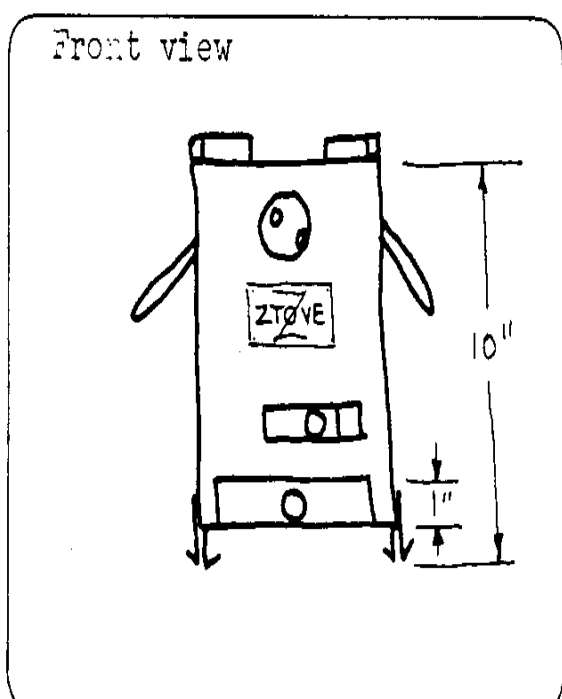
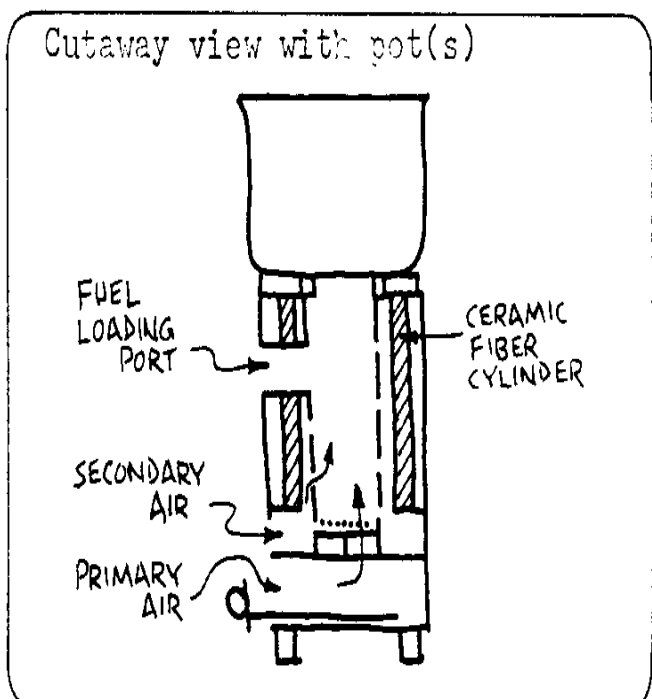
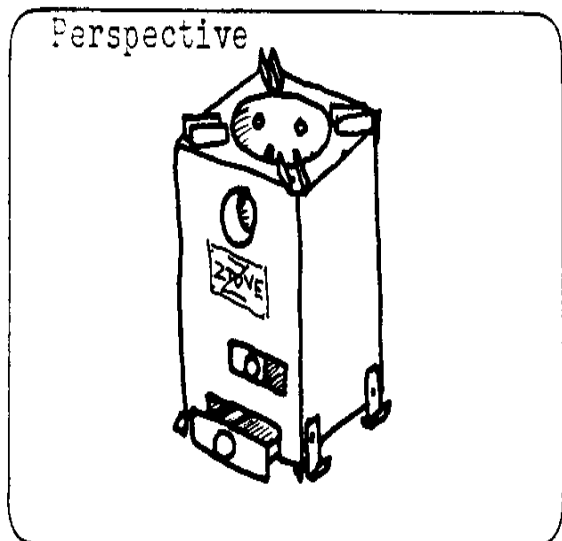
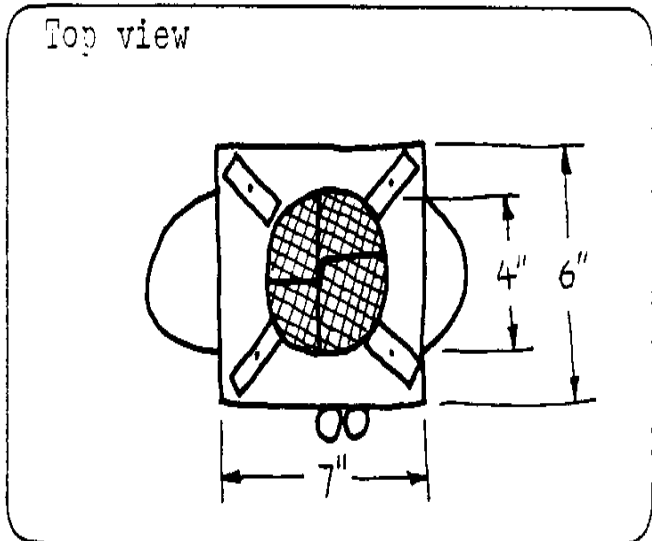
Name and origin of stove Z ZTOVE - U.S.A.

Name of stove builder(s) ZZ CORPORATION

Construction date 2/83 Materials used SHEET METAL,
POP RIVETS, 1/4-INCH WIRE MESH, AND CERAMIC FIBER.

<FIGURE E>

48ap05.gif (600x600)



Details of stove construction THE Z ZTOVE IS MASS PRODUCED

FROM PRE-CUT SHEET METAL PARTS. THEY ARE BENT IN PRESSES, GANG
DRILLED, AND POP RIVETED. THE INNER BURNER BOWL IS REPLACEABLE
AFTER IT BURNS OUT.

FCCA

MONTSEERRAT

FUELWOOD * CHARCOAL * COOKSTOVE PROJECT

Name and origin of stove TWO CAN STOVE - MONTSEERRAT

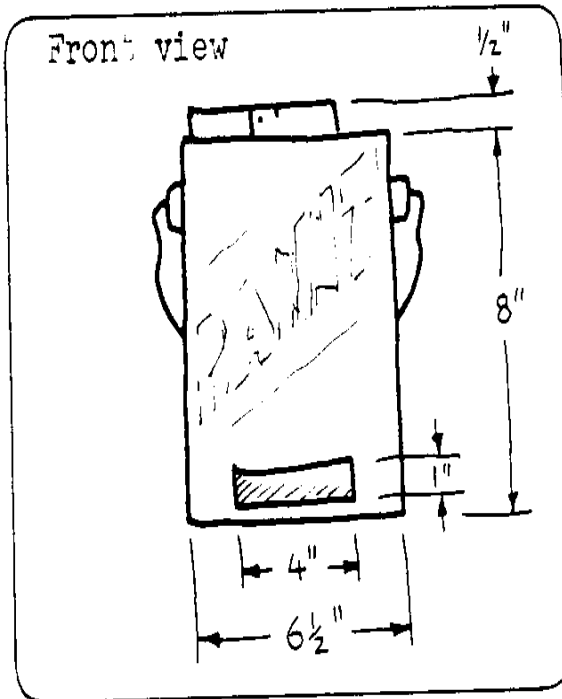
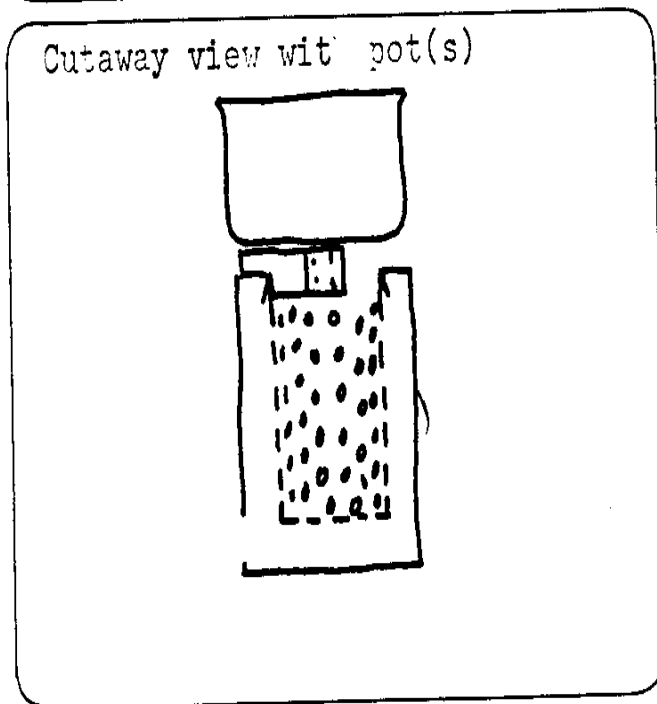
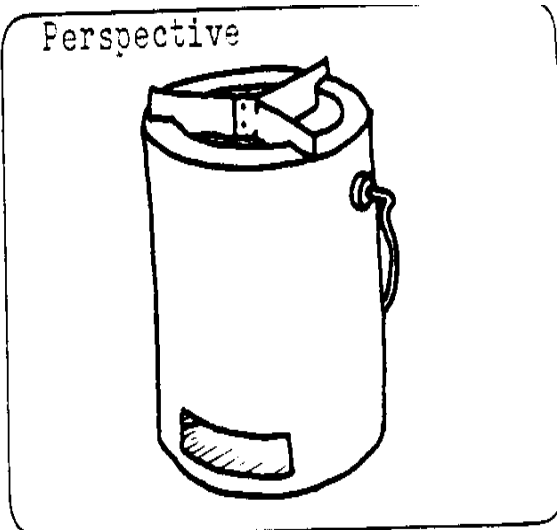
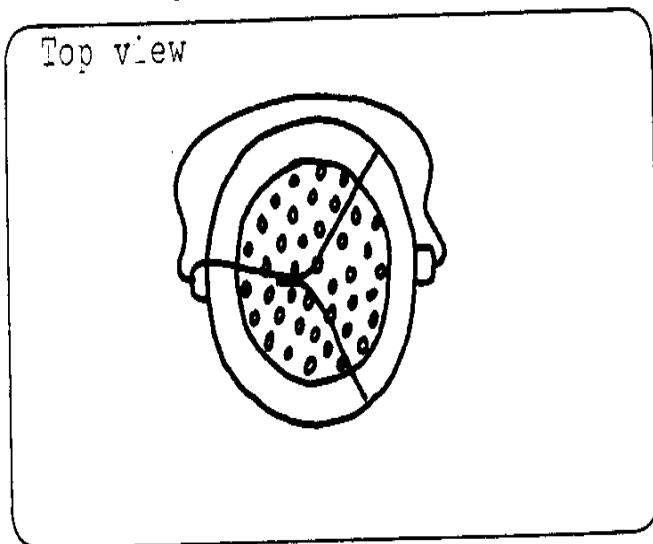
Name of stove builder(s) ANYONE

Construction date 7/83 Materials used PAINT CAN, MOTOR

OIL CAN, DRUM STEEL, AND NAILS.

<FIGURE F>

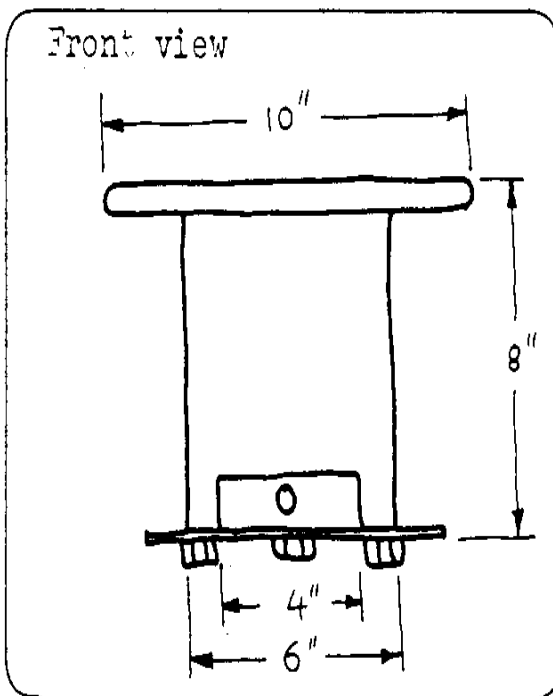
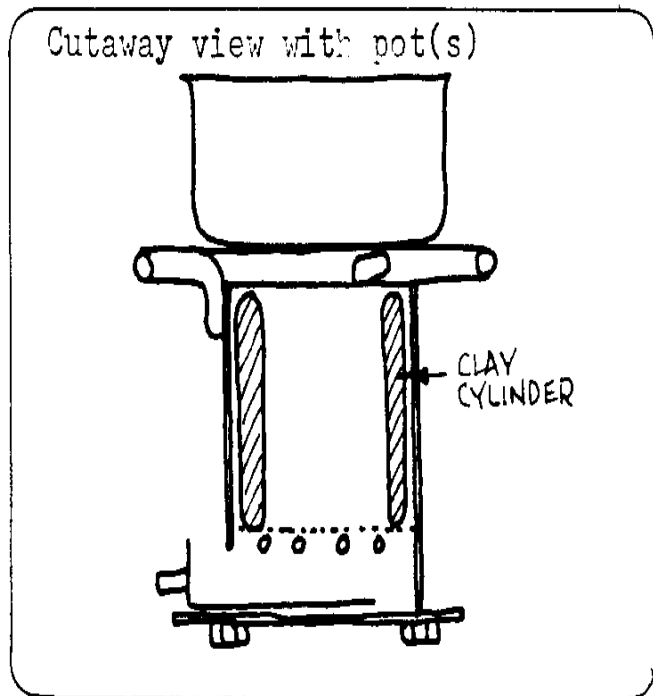
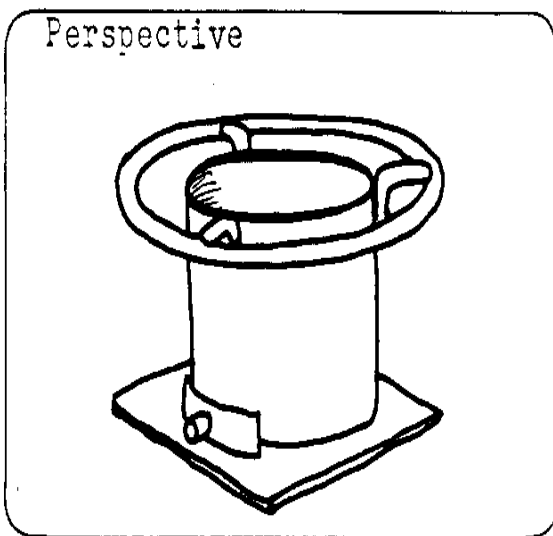
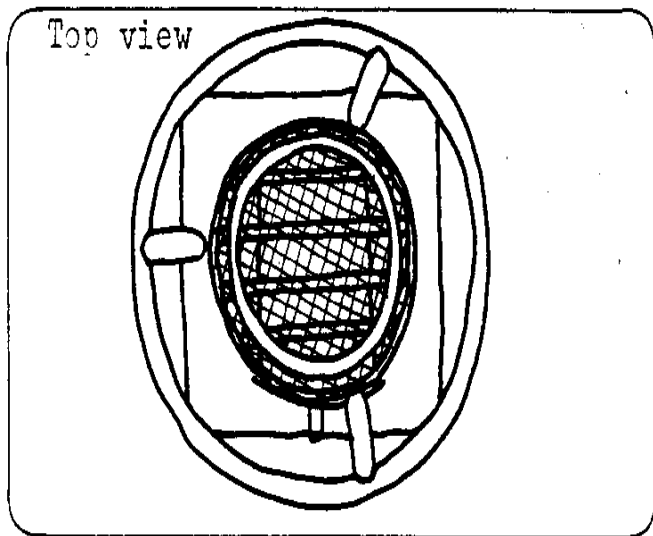
48ap06.gif (600x600)



Details of stove construction FIRST PUNCH MOTOR OIL CAN FULL OF HOLES,

THEN REMOVE ITS TOP, CUT PAINT CAN LID RADIALY LEAVING SHORT TABS UNTIL
THE MOTOR OIL CAN FITS DOWN IN IT AND IS SUPPORTED BY ITS FLARED TOP
EDGE. PLACE LID WITH MOTOR OIL CAN ON PAINT CAN. THEN CUT OPENING
FOR DRAFT AND MAKE POT REST WITH DRUM STEEL AND NAIL RIVETS.
FCCA

MONTSEERRAT**FUELWOOD * CHARCOAL * COOKSTOVE PROJECT****Name and origin of stove SATELLITE STOVE - MONTSEERRAT****Name of stove builder(s) SYLVESTER MEADE****Construction date 9/83 Materials used SIX-INCH STEEL PIPE****1/8-INCH STEEL PLATE, 1/2-INCH REBAR, 1/4 INCH ROD, SHEET METAL, 1/4-INCH WIRE
MESH****<FIGURE G>****48ap07.gif (600x600)**



Details of stove construction PIECES WERE WELDED TOGETHER,

ASH DRAWER WAS FASHIONED FROM SHEET METAL. A CLAY CYLINDER
AND CEMENT WERE TRIED AS INSULATION.

FCCA

MONTSERRAT

FUELWOOD * CHARCOAL * COOKSTOVE PROJECT

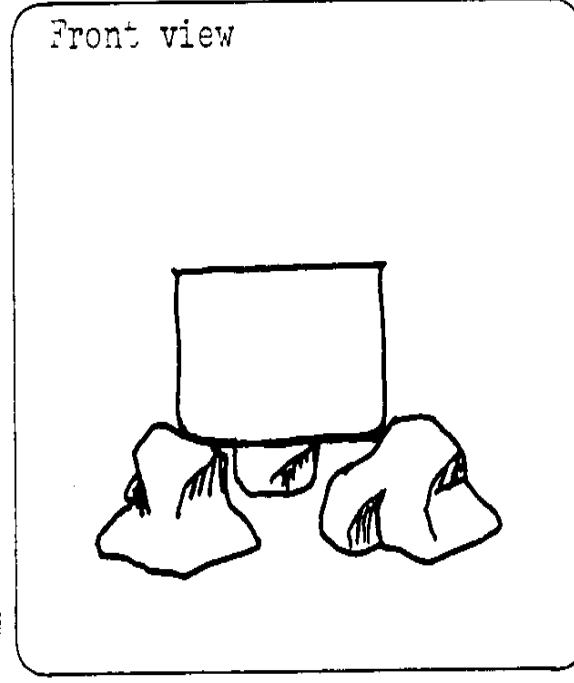
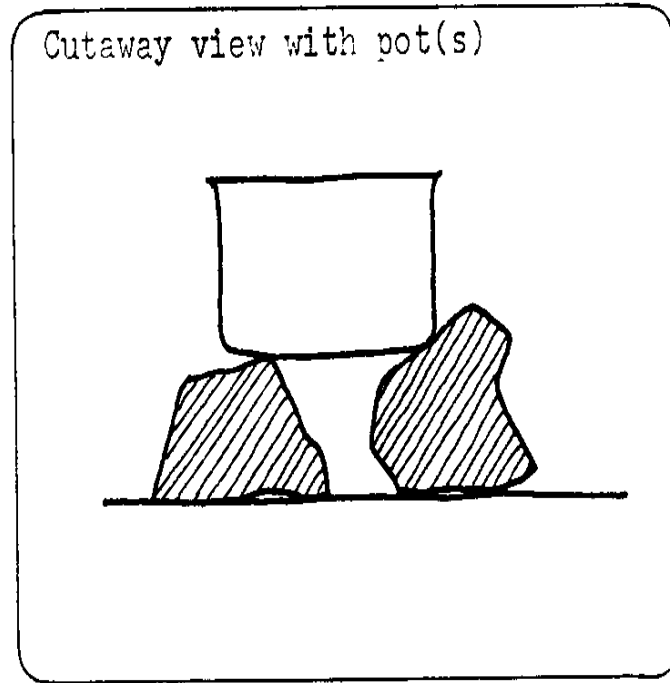
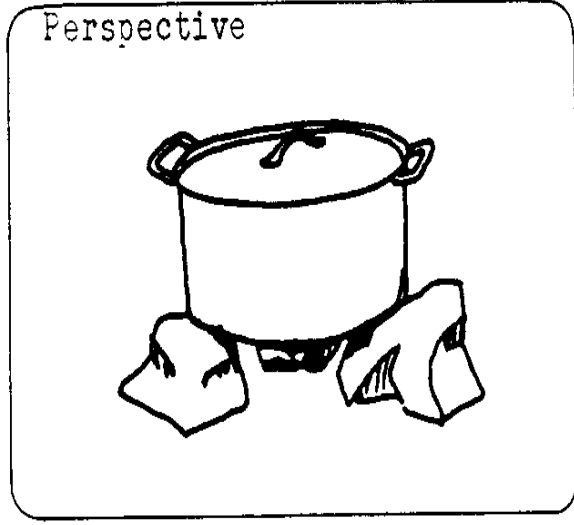
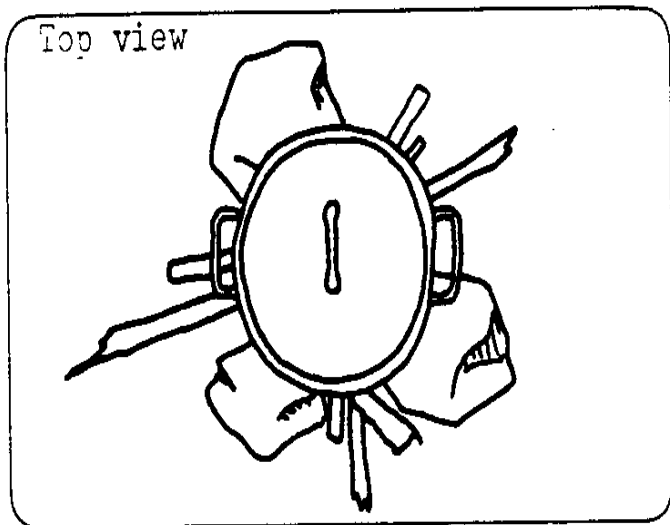
Name and origin of stove THREE-STONE FIREPLACE - UNIVERSAL

Name of stove builder(s) ANYONE

Construction date 9/83 Materials used THREE STONES

<FIGURE H>

48ap08.gif (600x600)



Details of stove construction PLACE THREE STONES SO THEY

SUPPORT THE POT ABOVE THE GROUND AND LEVEL.

FCCA

MONTSERRAT

FUELWOOD * CHARCOAL * COOKSTOVE PROJECT

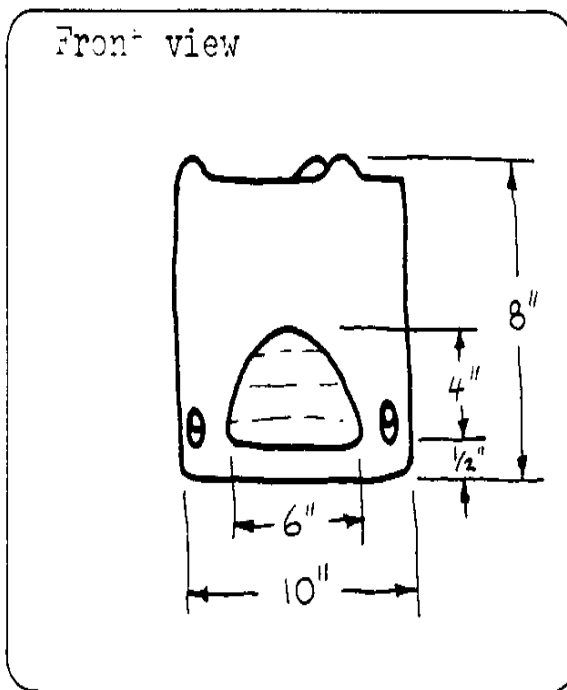
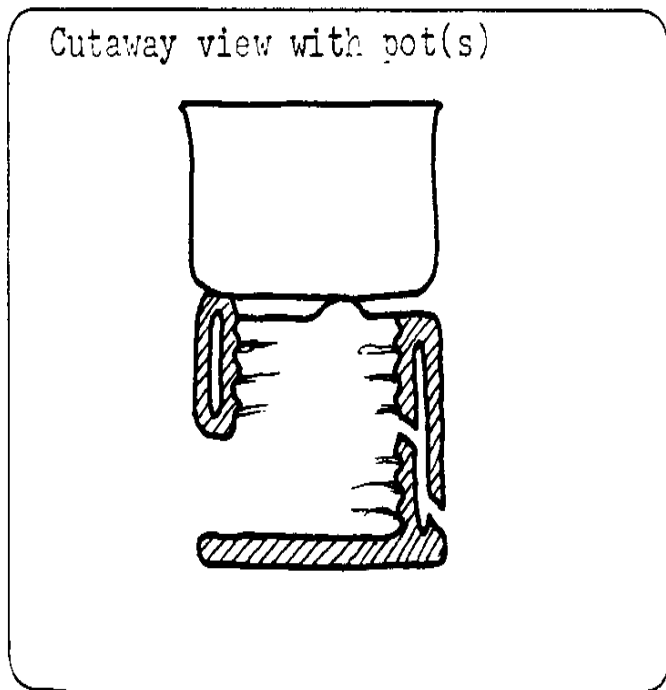
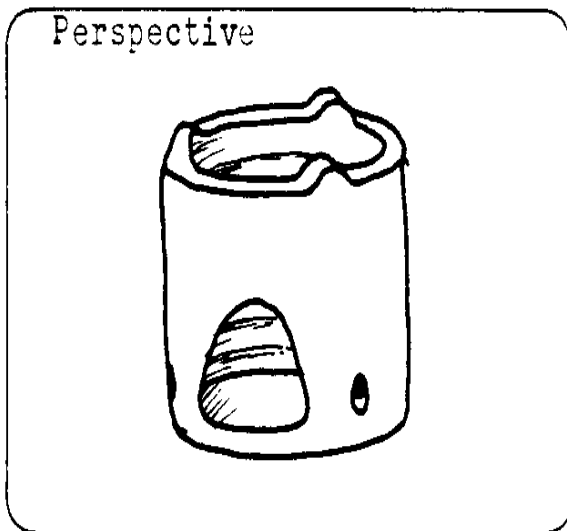
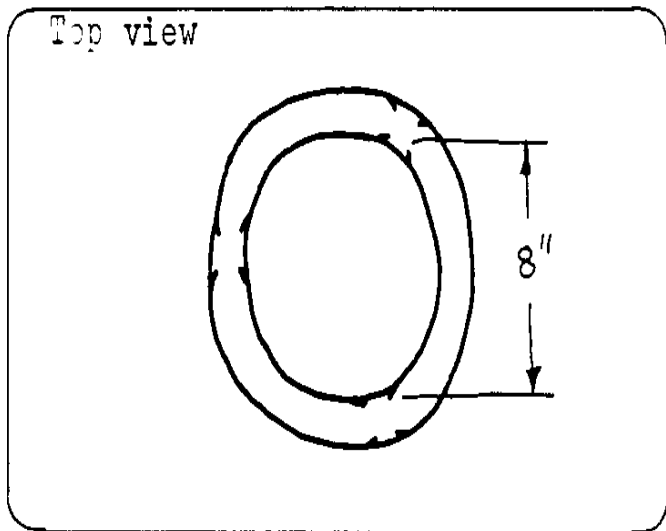
Name and origin of stove CLAY DOUBLE-SKINNED WOOD-BURNING STOVE-AFRICA (MONFIED)

Name of stove builder(s) Joseph Howson

Construction date 2/83 Materials used

<FIGURE I>

48ap09.gif (600x600)



Details of stove construction INSIDE AND OUTSIDE CYLINDERS WERE

TURNED SEPARATELY, JOINED, CURED, AND FIRED AT 900-1100 [degrees]. SECONDARY AIR HOLES WERE 1/2-INCH DIAM. AND SLANTED UPWARD TOWARD THE INSIDE. WALLS OF FIREBOX WERE ROUGH TO PROMOTE MIXING OF GASES AND AIR.

FCCA

MONTserrat

FUELWOOD * CHARCOAL * COOKSTOVE PROJECT

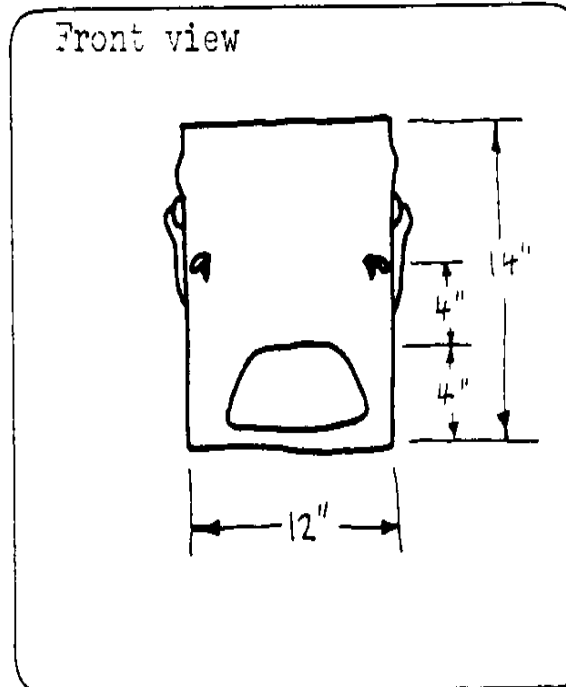
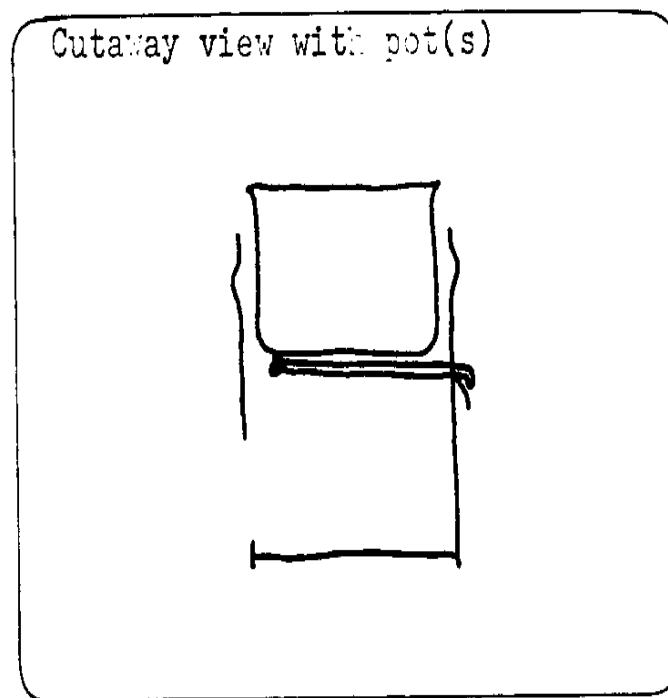
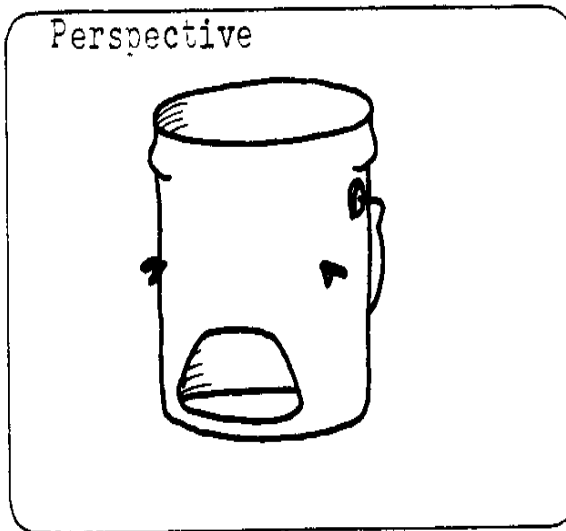
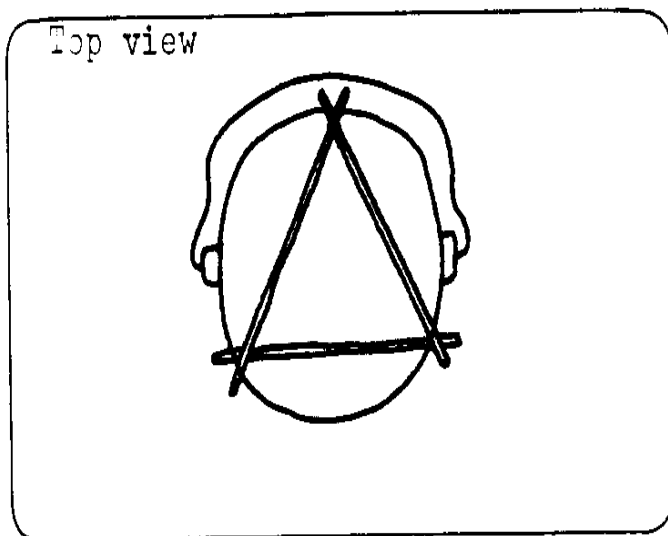
Name and origin of stove FIVE-GALLON BUCKET WOOD-BURNING STOVE-AFRICA

Name of stove builder(s) ANYONE

Construction date 8/83 Materials used FIVE-GALLON BUCKET AND 1/4-INCH ROD.

<FIGURE J>

48ap10.gif (600x600)



Details of stove construction SIMPLY PUNCH THREE EQUIDISTANT

HOLES AROUND THE CIRCUMFERENCE, INSERT 11-INCH LONG RODS AND
BEND ROD ENDS. THEN CUT OUT THE DRAFT OPENING.

FCCA

MONTSERRAT

FUELWOOD * CHARCOAL * COOKSTOVE PROJECT

Name and origin of stove CEMENT WOOD-BURNING STOVE-MONTSERRAT

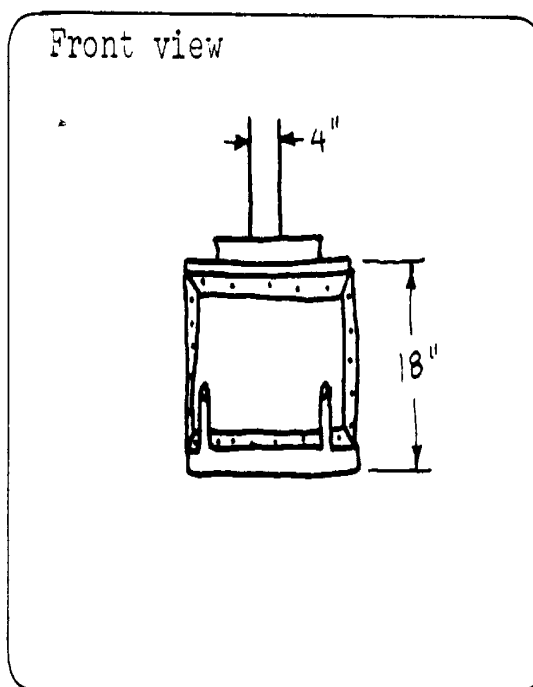
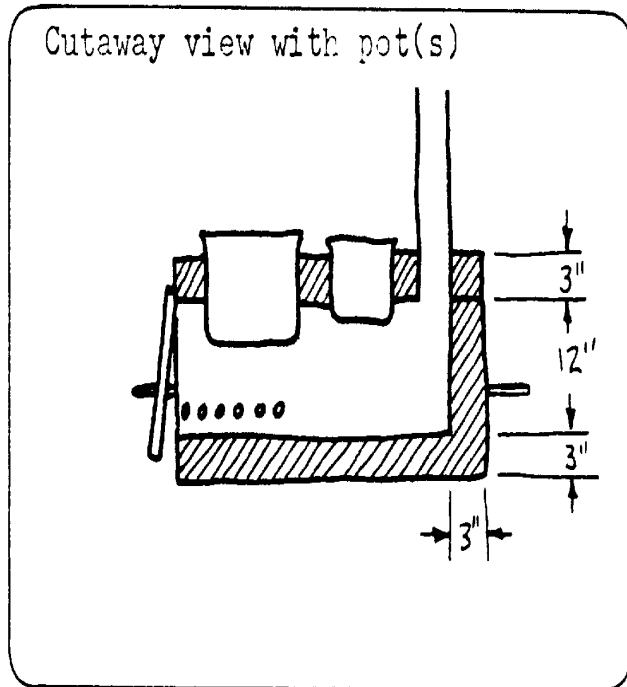
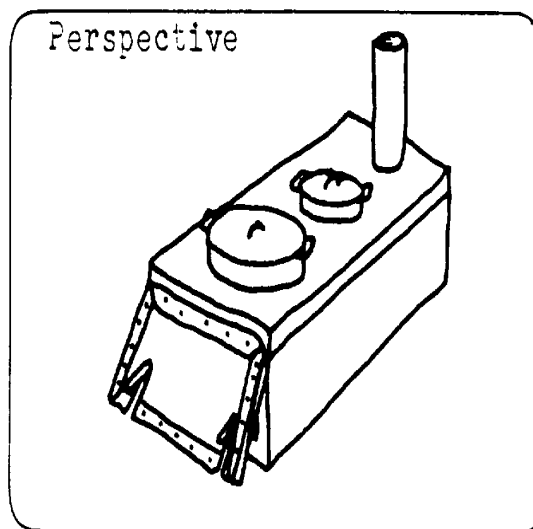
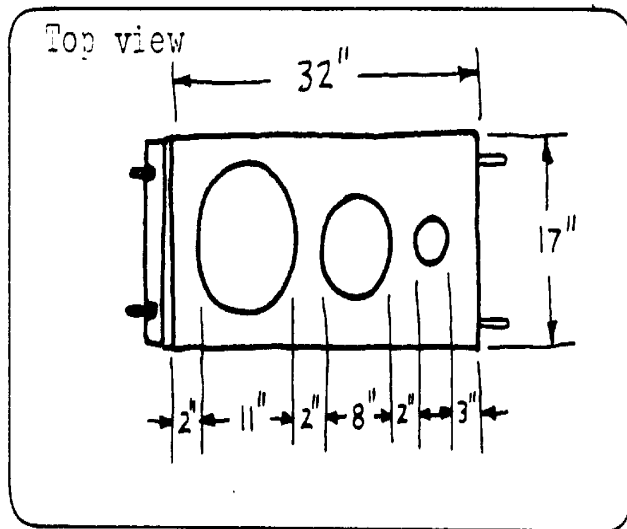
Name of stove builder(s) TONY CARTY AND CHARLES WHITE

Construction date 4/83 Materials used CEMENT, 1/2-INCH

REBAR, REINFORCING MESH, WOOD, SHEET METAL, AND NAILS.

<FIGURE K>

48p11.gif (600x600)



Details of stove construction THE TOP SLAB IS POURED AROUND THE

ACTUAL POTS. POTS ARE REMOVED AND POT HOLES SMOOTHED WHEN CEMENT IS PARTIALLY CURED. DOOR IS WOOD-LINED WITH TIN INSIDE. GRATE IS MADE OF REGARS. AND REBAR HANDLES ALLOW FOR PORTABILITY. REINFORCING MESH IS INSIDE CEMENT.

FCCA

MONTSEERRAT

FUELWOOD * CHARCOAL * COOKSTOVE PROJECT

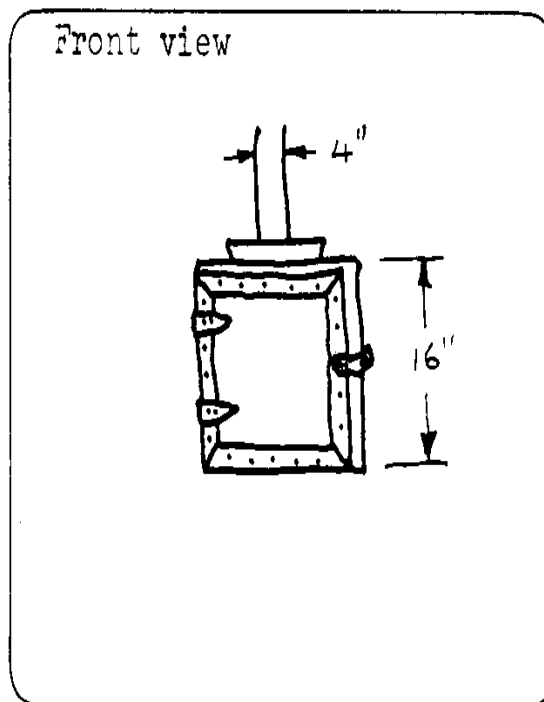
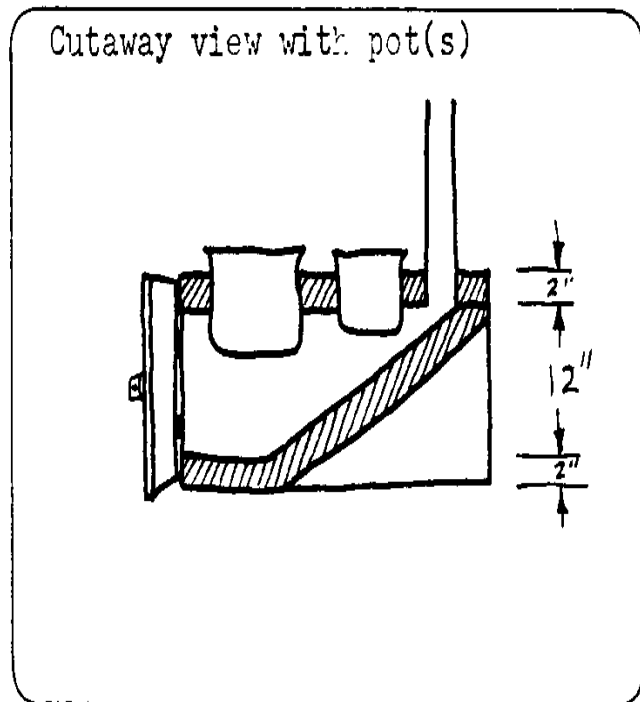
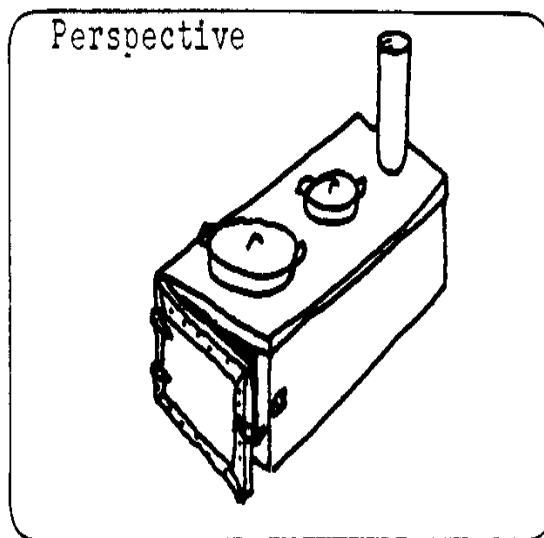
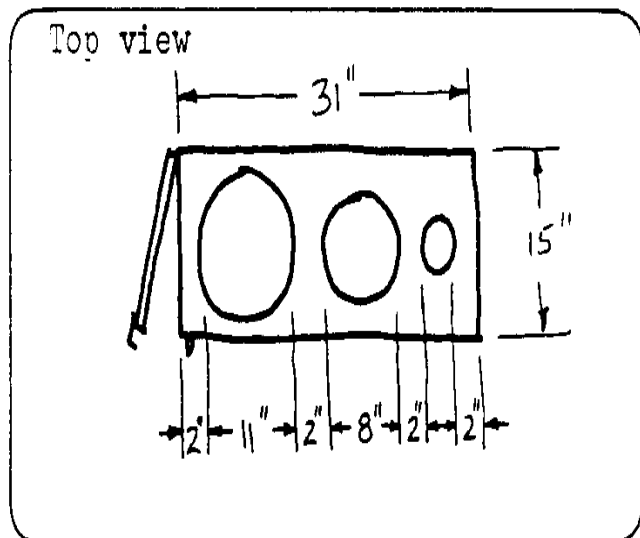
Name and origin of stove CEMENT WOOD-BURNING STOVE-MONTSEERRAT

Name of stove builder(s) Joseph Sweeney and David Lake

Construction date 9/83 Materials used CEMENT, CHICKEN WIRE, WOOD, SHEET METAL, HINGES, AND NAILS.

<FIGURE L>

48ap12.gif (600x600)



Details of stove construction THE TOP SLAB IS POURED AROUND THE

ACTUAL POTS. POTS ARE REMOVED AND POT HOLES SMOOTHED WHEN CEMENT IS PARTIALLY CURED. THE HINGED DOOR IS WOOD LINED WITH TIN ON THE INSIDE. THE CHIMNEY IS SHEET METAL. CHICKEN WIRE IS USED TO REINFORCE THE CEMENT.

APPENDIX II

WATER BOILING TEST PROCEDURES

In order to compare different designs of stoves, all variables other than stove design that might affect efficiency such as fuelwood species, moisture content, size, and amount; operator and operating sequence and schedule; weather (mainly wind); and pot design, size, material, and contents were held as consistent as possible.

The testing was conducted according to the following procedures:

1. We sampled the fuel to determine moisture content (MC). For charcoal we disregarded MC unless it had been wetted. The MC samples were at least 100 grams and were chosen to be representative of the fuel being used. They were cut just before the WBT. We weighed the samples immediately to the nearest 1/10 gram and recorded the weight. We identified each sample by marking a number directly on it with a magic

marker. The samples were put in an oven at 215 [degrees] F for at least 24 hours (until they lost no more weight) and reweighed. The oven dry weights were recorded. Then MC was calculated on the green weight basis by the formula:

percent MC = (green weight - oven dry weight/green weight) x 100.

2. We weighed the fuel put in the stove and recorded the weight in pounds.

3. We weighed an 11-inch diameter flat bottomed aluminum pot without the lid. The weight was recorded. Then we added two kilograms (four pounds, six ounces) of water at ambient temperature and recorded the weight. The lid was fitted with a stopper through which a mercury thermometer was placed. The lid was put on the pot and the thermometer adjusted to be about one inch from the bottom of the pot. For two-pot stoves we used an 11-inch and an eight-inch diameter pot of the same design.

4. We used two Zip fire fuel pellets for kindling, lit them and recorded the time. We added the fuel.

5. After allowing five minutes for the fire to get started, we put the pot(s) on. The fire was maintained for maximum heat until the water was boiling.

6. At each five-minute interval, the time and temperature of

each pot were recorded. When the thermometer reached 212 [degrees] F the time was recorded. For two-pot stoves only the first pot directly over the fire was used for this determination.

7. After the water boiled, the stove was adjusted to simulate simmering, to provide just enough heat to keep the water lightly boiling for 30 minutes. In charcoal stoves this was done by closing draft controls or loosely blocking draft openings on stoves without draft controls. In the cement wood-burning cookstoves the doors were closed. And in the three-stone fireplace and five-gallon bucket, we pulled the wood pieces outward to slow down the fire.

8. During the test we recorded miscellaneous observations such as the amount of flame or smoke, how hot the stove was to touch, etc.

9. At the end of the 30 minutes of simmering we did the following in rapid sequence:

- recorded the water temperature,
- weighed and recorded in pounds the amount of water remaining, and
- weighed and recorded in pounds the amount of unburned fuel. When wood was the fuel, we separated the wood and charcoal before weighing.

10. Calculations were made on the following:

WE - Amount of water evaporated (pounds) = initial weight of pot and water minus the final weight of pot and water.

CT - Change in water temperature ([degrees] F) = highest water temperature minus the beginning water temperature.

CB - Weight of charcoal burned (pounds) = initial fuel weight minus the weight of the unburned remainder.

DW - Weight of oven-dry wood burned (pounds) = [initial weight of wood put in stove times 1 - MC in decimal form] minus the weight of wood and charcoal unburned.

FM - Weight of moisture in fuel (pounds) = initial weight of fuel put in stove times MC in decimal form.

EF - Stove efficiency (PHU) = [CT x original weight of water in pounds] + [WE x 1,050] / [DW x 8,500 - FM X 1,2001 - [pounds of charcoal remaining x 12,500] x 100.

where:

- 1,050 was the latent heat of water in Btu per pound at room temperature,

- 8,500 was the heat value of oven dry wood in Btu per pound,

- 1,200 was the heat needed to drive moisture out of wood fuel in Btu per pound of water,
- 12,500 was the heat value of oven dry charcoal in Btu per pound,
- for charcoal stoves the denominator was simply CB x 12,500, and
- DW and FM were considered accurate for our use since there was little unburned fuel.

SSC - Standard Specific Consumption = DW/WE.

APPENDIX III

WATER BOILING TEST DATA SHEET

DATE: _____ STOVE TYPE: _____
OPERATOR(S): _____ MODIFICATIONS: _____
TEST NUMBER: _____ FUEL: _____

MOISTURE CONTENT SAMPLES:

Identification Fresh weight Oven-dry weight MC (Green basis)

FUEL WEIGHT AT START: _____ POT WEIGHT: _____

INITIAL WEIGHT OF POT & WATER: _____ INITIAL WATER TEMP: _____

ELAPSED WATER FUEL WEIGHT
TIME TIME TEMPERATURE ADDED COMMENTS

| | | | | |
|----|-------|-------|-------|-------|
| 0 | _____ | _____ | _____ | _____ |
| 5 | _____ | _____ | _____ | _____ |
| 10 | _____ | _____ | _____ | _____ |
| 15 | _____ | _____ | _____ | _____ |
| 20 | _____ | _____ | _____ | _____ |
| 25 | _____ | _____ | _____ | _____ |
| 30 | _____ | _____ | _____ | _____ |
| 35 | _____ | _____ | _____ | _____ |
| 60 | _____ | _____ | _____ | _____ |

FINAL WEIGHT OF POT AND WATER: _____
WEIGHT OF WOOD REMAINING: _____
WEIGHT OF CHARCOAL REMAINING: _____

APPENDIX IV**KITCHEN PERFORMANCE TEST DATA SHEET**

STOVE TYPE: _____ FAMILY NAME: _____

LOCATION: _____

NUMBER OF PEOPLE FED: _____ STANDARD ADULT EQUIVALENTS:

children 0 - 14 years _____ x 0.5 =

women over 14 years _____ x 0.8 =

men aged 15 - 59 years _____ x 1.0 =

men over 59 years _____ x 0.8 =

NUMBER OF MEALS COOKED: OTHER USES:

breakfast _____ ironing _____

lunch _____ baking _____

dinner _____ others _____

other cooking _____

WAS THERE ANY LEFTOVER CHARCOAL IN THE STOVE? _____

WHAT DID YOU DO WITH IT?

WOULD YOU USE MORE _____ OR LESS _____ FUEL FOR SIMILAR MEALS IN THE CONVENTIONAL COAL POT?

GENERAL COMMENTS:

APPENDIX V

COOKSTOVE LOCATION SHEET

STOVE MODEL: _____ FEATURES: _____

DATE DATE

START FINISH ADDRESS USER COMMENTS

APPENDIX VI

CONVERSION FACTORS

1 pound = 0.454 kilograms

1 kilogram = 2.2 pounds

1 Btu = 0.252 kilocalories

1 kilocalorie = 3.968 Btus

1 Btu/pound = 2.32 Joules/gram

[degree] C = [degree] F - 32/1.8

[degree] F = (1.8 x [degree] C) + 32

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