FIELD EVALUATION OF WOOD STOVES
(with special reference to West Africa)

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PREFACE

Very little testing has been associated with wood cookstove development efforts so far. To my knowledge, there are no instances where statistically significant measurements of wood savings have been reported. This lack of interest in testin has many unfortunate consequences. It is difficult to judge the fuel efficiency of the so-called "improved" models. Preliminary data indicate instances where the "improved" stoves used more wood than traditional methods. Without statistically meaningful tests of stove energy consumption, it is impossible to design stoves to minimize wood use. Thus, none of the stoves being promoted today have been optimized. One may speculate on reasons why there is so little testing. Perhaps designers have felt that it is tedious and requires too much skill, specialized equipment, and time. It is quite possible that statistical design and empiricism were not part of the designers' consciousness.

The stove testing methodology described in this report is an attempt to alter the prevailing negative attitude towards testing. I hope to convince prospective stove designers and builders that field-based testing is neither difficult nor particularly time consuming. Often, a spring balance to weigh wood is all that is necessary. To those unfamiliar with statistical design of experiments, guidelines for conducting the tests are spelled out in detail. Data reduction, though not spelled out in this report, is not difficult either. However, with VITA's help, I will try to analyze data collected along the lines suggested in this report. These data are of great interest to me personally and essential to VITA's role in disseminating appropriate technology.

Efficiency in wood use is not the only criterion in evaluating a stove's performance or comparing it with another. Other factors: for example, durability, ease of use, and adaptability to various cooking situations must also be considered. For this purpose, one must conduct a number of surveys of potential users, in some cases long after stove installation. There is no sense in designing and building efficient stoves if people cannot or will not use them, or if they fall apart three weeks later and cannot be easily fixed. Followup to stove introduction--fuel consumption measurement, user training, etc.--is another much-neglected area. An approach to stove introduction and testing forms a major part of this report with the hope that prospective stove promoters will include followup as a necessary part of their program.

SECTION I

STOVE TESTING METHODOLOGIES -- COOKING TRIALS

The purpose of cooking trials is to determine the relative fuel used for cooking in two stoves or fires. The first of the two following tests (the Kaya test) is intended to produce a statistically significant measure of relative fuel use by using a sufficiently large number of families and cooking sessions in the study. The second test (the Bamako test) is intended to be a quick way to determine the effect of changes in stove design parameters or cooking practices. A third test is the traditional flue gas analysis test, which is not described here (1,2).

A. Relative Fuel Use in Two Stoves (Kaya test)

Five families are selected according to the "Criteria for Selecting Households," Appendix A. Stoves are installed so that each household has the two types of stoves that are to be compared. The investigator conducts a brief interview with the principal cook in the household. (See Appendix B, "Preliminary Survey Questionnaire.") The test is conducted over a week (7 consecutive days) during which the two stoves are used according to the schedule below, and the weight of wood used to cook each meal is recorded.

Cooking Schedule:

Day 1	midday meal:	Stove A
	evening meal:	Stove B
Day 2	midday meal:	Stove B
	evening meal:	Stove A
Day 3	midday meal:	Stove A
	evening meal:	Stove B, etc.

Test Procedure:

Sufficient wood is weighed and set aside for each cooking session. The wood remaining after the cooking is over is set aside by the cook to be weighed by the investigator upon his/her return. Visits should be timed to be sufficiently before and after each cooking session to weigh the correct amount of wood. It is suggested that cooking times be observed for a couple of days prior to the commencement of the test, in order to set up a satisfactory visiting schedule. During a morning visit, one may weigh the wood remaining from the night before as well as the wood set aside for the midday meal. A mid-afternoon visit would be necessary to weigh the wood remaining from the midday meal and the wood

for optimal design parameters based on wood use data will be of great significance since virtually no such optimization is currently practiced by designers of wood stoves*.

The Bamako test may also be used to evaluate changes in cooking practices, e.g., which burner is used for the rice and which for the sauce. However, cooking practices for the reference stove must remain unchanged.

Weaknesses of the Bamako Test

(1) Optimal values relate only to a stove of a particular dimension. So, in principle, separate and tedious optimization must be performed for each design parameter in all sizes of stoves. However, after some tests, the range of design parameters should narrow substantially and the relationship of the optimal values to the stove and pot dimensions may emerge.

(2) The test is based on weighing wood and does not take into account variations in calorific value or moisture content. However, the alternate-cooking arrangement should reduce errors due to this variability.

(3) The main drawback of optimizing each parameter separately is that one obtains local optima for each parameter individually. These individual optimal values together may not constitute a global optimum since many of the parameters are inter-related. However, one could use the ensemble of local optima as a starting point and vary the sets of parameters to other sets of values and try to arrive at global optima. Here, again, the first tests will provide clues to reduce the effort of optimization.

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* Optimization is carried out with respect to water heating trials in some laboratories, but whether these optimum parameters hold for various cooking situations has yet to be demonstrated.

A. Proposed Timetable of Activities

	Village 1	Village 2
Week 1	• Preliminary Survey	
	• One week wood consumption measurement	
Week 2	• Install stoves	
Week 3	• Train users	
Week 4	↑ (at least three week interval)	• Preliminary survey
		• One week wood consumption measurement
Week 5		• Install stoves
Week 6		• Train users
Week 7	• Kaya test	↕ (at least three week interval)
Week 8	--	
Week 9		• Kaya Test
Week 10	• One week wood consumption measurement	
	• User survey I (acceptance)	
Week 11		• One week wood consumption measurement
		• User survey I (acceptance)
Week 30+	• User survey II (durability, etc.)	• User Survey II (durability, etc.)
Week 60+	• User survey III	• User Survey III (durability, etc.).
	• One week wood consumption	• One week wood consumption

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TABLE B

Household No.	Household Size
H5	13
H2	12
H9	11
H1	10
H10	10
H7	9
H3	8
H8	7
H4	6
H6	4

They are paired as indicated by the horizontal lines above.

For each pair, a random assignment is made one to Group A and one to Group B. The most simple procedure would be to toss a coin: if the outcome is heads, the first household of the pair (in this case H5) falls into Group A and the other household (H2) falls into Group B; if tails, H5 falls into Group B and H2 falls into Group A. By tossing a coin 5 times all 10 households are assigned into two groups (Table C).

in wood use of the households that are equipped with new stoves, the effect of the stove alone on wood consumption can be more accurately determined. In order for the analysis to be valid, the control group must be identical in every way possible to the other -- "experimental" -- group. That is why we use the same criteria for selecting all 10 households. For instance, all are asked if they are willing to cook alternate meals on the new stoves even though some do not get new stoves during the test. The reason for randomly assigning them to either group is to avoid additional bias in putting households into one group vs. the other.

There may be some difficulty arising from the fact that half the households agreeing to participate in the study receive no stove. This may be resolved at the outset by setting it up as a gamble to prospective participants. Alternatively one can install stoves in the control groups after a delay -- so that all the relevant data is taken before the control group get stoves. In the timetable above this would be after week 10 for Village 1 and week 11 for Village 2.

2. Preliminary Survey *

The survey should provide relevant information about the household and its cooking practices. Fuel consumption and energy related questions are used to determine changes in the users' fuel consumption and other activities.

Questions concerning cooking practices and foods prepared may shed light on the type of "improved" stove that should be introduced and how it can be popularized. (For example, we have seen cases of "improved" stoves not being used because they were not placed in the household compound according to local custom.) These questions might include: Where does one cook? Why does one cook there? Who cooks? What does one cook on?

The survey also includes an inventory of local technologies that may aid in the development of a more structurally efficient stove. A study of local pottery making would provide useful data. Questions could include: Are there traditional devices using combustible materials (stoves, smokers, ovens, etc.)? How are these devices built and how are they used? Who builds

* Written largely by Andre Longmire

	Household	Weight of Wood (kg)								
		Start of Week		Successive Weighings				End of Week		Wood Use
		Day Time	weight					Day Time	weight	
GROUP A	H5	Sat. 1PM	35 kg	15 kg	10 kg	25 kg		Sat., 2:30 PM	10 kg	75 k
	H1									
	H7									
	H3									
	H4									
GROUP B	H2									
	H9									
	H10									
	H8									
	H6									

6. Kaya Test

The purpose of this test is to compare the fuel used in new and traditional stoves by the households equipped with new stoves. The test is described in Section IA as "Relative Fuel Use in Two Stoves (the Kaya test)." Because households alternate between the two stoves during the same week-long period, they act as their own "control" group; wood used by the 5 households that did not get the improved stoves need not be monitored.

7. User Survey I

The purpose of this survey is to determine the stove's efficiency and what the cooks think of their new stoves,what sorts of problems they have encountered, whether they have any suggestions on improvements, etc. Efficiency is determined from a "one-week wood consumption measurement." This will offer opportunities to visit each household several times, and to observe cooking in progress and to complete the rest of the survey. Additional questions might be:

- Are they using the new stove? If not, why not? (they may not give the correct answer, out of politeness).
- Are they following the instructions developed for maximum efficiency? If they are doing things differently, there is probably a good reason. What could it be?)

A great deal of sleuthing is necessary to find out people really think about the stoves, but may be too polite to say. Circumstances evidence may be crucial. Lessons learned are applicable to future design modifications as well as to an understanding of stove usage.

No stove should even be built if there is not going to be follow up. It is not worth the effort. Furthermore, local stove technicians must understand the reasoning behind the questions,so that villagers will also understand why questions are being asked.

Longmire has designed and pre-tested a questionnaire which (with minor modifications) is presented in Appendix D. This questionnaire does not include the one-week wood consumption measurement discussed earlier.

8. User Survey II

One of the most important (and rarely included) aspects of stove introduction is long-term followup. Are people continuing to use the stoves after 6 months? Has the novelty worn off or are they making even more use of it now that they have figured out how it works? Have any problems developed? Is the flue clean or is it blocked? Are dampers intact? Are there cracks or structural defects in the stove body? Have they done any repairs themselves?

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SECTION III

SURVEY PROSPECTS

Arrangements were made in Upper Volta to carry out the Kaya test to compare wood consumption rates of the "brousse" stove, developed by Hooper and Lavell, against a traditional 3-stone stove. For this purpose 5 "brousse" stoves were to be built at 5 households and wood use monitored as required by the Kaya test. Lavell (Kaya) agreed to be responsible for this operation, and for comparing the performance of Hooper's concrete stove with traditional cooking. Preliminary tests at Kaya indicated an approximately 40% wood savings (see "Status of Wood Stove Development in Upper Volta".) (4)

Longmire (Mali) intends to carry out more tests including both the Kaya test and the Bamako test for optimizing stove design and operation. In addition, he is conducting a variety of user surveys for sociological as well as wood consumption data. (See Appendices B and D. Appendix E gives Longmire's suggestions for user training.)

The Kaya test, the Bamako test, and the surveys designed by Longmire and the author are available to other organizations who are working on wood stove development in West Africa.

Surveys and testing methodologies developed and presented here are generally not very time-consuming. Most can be done by one person in a week. Perhaps many people will be encouraged to carry out these surveys, and throw a great deal of light into the murky waters of stove development.

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APPENDIX A

CRITERIA FOR SELECTING HOUSEHOLDS

Ask the following questions of the principal cook of the household. The preferred answers are circled below. If the household does not give all the preferred answers, exclude the household.

1. Are they willing to cook alternate meals on the two stoves to be compared and have their wood weighed? (Yes) No

   (Note that for meals other than the midday and evening meals they are free to use any stove they wish.)

2. Are there between 3 and 16 people (inclusive) in the household? (Yes) No

3. How many people cook regularly in this household? One, more than one

   (If it is not possible to find enough househods that have only one regular cook, include household that have two regular cooks. Note below the relationship of the two cooks to the head of household;

   cook 1:
   cook 2:

4. Do they cook primarily with wood? (Yes) No

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If an interior stove put all its smoke outside, would they mind cooking inside most of the time? Yes/No

Comments:

_____

_____

_____

In the cold season do they cook inside to keep warm? Yes/No

Describe stoves below, listing them by frequency of use.

Stove No. 1 (used most often)

Type: Three stone/2 hole without flue/2 hole with flue

other (specify) _____

Age of stove:

Location: inside/outside/under a shelter/other _____

Months of use _____

Frequency of use: daily/3 to 5 times a week/ 1 or 2 times a week/other _____

Which meals are prepared on it: _____

Types of pots most frequently used (metal, clay, etc.) _____*

Which pot sizes fit this stove best: _____, _____, _____, _____*

Stove No. 2 (used next most frequently)

Type: Three stone/2 hole without flue/2 hole with flue

Other (specify) _____

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* Questions are adapted to Upper Volta, where cooks use mostly aluminum or clay cooking pots, and pot sizes are indicated by a more or less standard pot number.

How long does it take for each trip? _____

Do they store their wood dry? _____

If yes, how long? _____

3) Local materials and technology

Are there locally made stoves, ovens or other cooking or brewing devices?

Yes/No

If yes, describe how they are used and how often; how they are made and by whom _____

_____

_____

_____

What do the local people use for mortar for their granaries and houses? Traditionally what is the best mortar? Describe _____

_____

_____

_____

Is there someone in the village who makes pottery? Yes/No. If yes, describe the type of pottery; how it is made; what materials are used.

_____

_____

_____

Are there stone-cutters in the area? Yes/No

What is the local process for drying vegetables and fish?

_____

_____

Stove A: ** _____ Pot sizes: Pot type(s):

Stove B: _____ Pot sizes: Pot type(s):

Principal cook(P.C.) _____ (relationship to head of household)

***For numbers in the table headers below refer to notes below table

Date of cooking (circle if market day	Meal cooked M/E (1)	Cook (2)	Stove used (A/B) (3)	Weight of wood Before cooking (kg)	Weight of wood After cooking (kg)	Number of people eating meal	Leftovers saved for later meal (yes/no)	Comments on type of wood
			A					
			B					
			B					
			A					
			A					
			B					
			B					
			A					
			A					
			B					
			B					
			A					
			A					
			B					

(1) M: mid-day meal; E: evening meal; specify M or E

(2) Enter P.C. if meal was cooked by principal cook. Otherwise enter relationship of cook to head.

(3) Ifs a different stove is used than indicated on schedule, please note it.

(4) Specify if wood is wet or dry, large pieces or twigs. Enter additional comments on reverse along with relevant date ane time.

APPENDIX C

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What don't they like about the stove?

_____

Any suggestions to improve the stove?

_____

Do they use the stove to heat water? Yes/No

Note any signs of deterioration:* _____

Note any physical changes made by the family (alterations, repairs, etc.)*

_____

If the stove was altered or repaired who did it? * _____

Has the stove been reproduced by others in the village? (specify)* _____

_____

Have others asked for a stove*? _____

Would villagers be willing to pay for the stove or pay for a stove which is more resistant and/or more efficient?

_____

* Some of these questions are more appropriate for user surveys II and III conducted some time after the installation.

Users may notice at times that the stove is not performing as well as before. There can be several reasons for this: the chimney may be blocked with excess residue; the firebox may have excess ash and coals; or the cook may be using green wood. An excess of black, thick smoke may indicate visibly that the stove is not performing well. In this event, the user should be given instructions to correct misuse: the chimney or firebox may need to be cleaned out; or, she should let green wood dry before using.

For mud stoves exposed to the weather, users should try to protect their stove from rains by placing mats over it or by constructing a hangar. In cases where the mud stove is damaged by rain, the user can repair the surface of the stove, letting it dry out sufficiently before using it again. Cooks should be encouraged to repair their own stoves.