PN AAR 315
ISN-36916

TESTING THE EFFICIENCY OF WOOD-BURNING COOKSTOVES

Provisional International Standards

From proceedings of a meeting of experts at:

Volunteers in Technical Assistance (VITA)
1815 North Lynn Street, Suite 200,
Arlington, Virginia 22209-2079 USA

December 1982

ARLINGTON MEETING PARTICIPANTS

Dr. Samuel Baldwin, Permanent Interstate Committee for Drought Control in the Sahel (CILSS)/VITA, Upper Volta

Prof. Guido de Lepeleire, Katholieke Universiteit Leuven (Louvain), Belgium

Dr. Dhammika de Silva, Ceylon Institute for Scientific and Industrial Research (CISIR), Sri Lanka

Dr. Gautam S. Dutt, Center for Energy and Environmental Studies, Princeton University, USA

Mr. Howard Geller, American Council for an Energy-Efficient Economy, USA

Dr. C.L. Gupta, Tata Energy Research Institute (TERI) Field Research Unit, India

Mr. Hamata Ag Hantataye, Laboratoire d'Energie Solaire, Mali

Mr. Stephen Joseph, Intermediate Technology Development Group, United Kingdom

Ms. Karen Kennedy, Aprovecho Institute, USA

Prof. K. Krishna Prasad, University of Technology, Eindhoven, The Netherlands

Ing. Marco August Recinos, Central American Research Institute for Energy (ICAITI), Guatemala

Mr. Sylvain Strasfogel, Association BOIS DE FEU, France

Dr. Timothy S. Wood, VITA, USA

CONTENTS

Introduction..... 1

Water Boiling Test..... 5
- Equipment..... 5
- Procedure..... 6
- Procedural Notes..... 7
- Data and Calculation Form..... 11
- Test Series Reporting Form..... 13

Controlled Cooking Test..... 15
- Equipment..... 15
- Procedure..... 15
- Procedural Notes..... 17
- Data and Calculation Form..... 18
- Test Series Reporting Form..... 19

Kitchen Performance Test..... 23
- Equipment..... 23
- Procedure..... 23
- Procedural Notes..... 24
- Data and Calculation Form..... 28
- Test Series Reporting Form..... 29

Technical Notes..... 31

Glossary..... 39

Abbreviations..... 41

APPENDIX:..... 43
- I. Concepts of Efficiency..... 45
- II. Interpreting Test Results..... 53
- III. Quantities, Scale Effects, and Other Influencing Parameters. 63
- IV. Participants at Arlington meeting..... 65
- V. Participants at Louvain "Woodstoves Seminar"..... 67
- VI. Participants at Marseille meeting..... 71
- VII. Other Reviewers..... 75

INTRODUCTION

These proposed international standards for testing the efficiency of woodburning cookstoves result from efforts of a group of stove experts who met at VITA in Arlington, Virginia, in December 1982. Thirteen experts from ten countries attended the week-long meeting, and agreed on three basic tests and reporting procedures. By imposing a rigorous scientific standard in stove testing, the experts hope to communicate credible test results that will ensure not only technical performance but also the socioeconomic and commercial viability of stoves.

This document includes step by step procedures for each of the standardized tests, followed by Procedural Notes that give specific suggestions for conducting the tests. The sample data and reporting forms included for each tests are designed to simplify the recording of essential information. For easy reference, Technical Notes giving background information relevant to all three tests are printed on colored paper. A glossary and list of abbreviations are followed by a section discussing concepts of efficiency used in testing stoves; a short course in the statistical analysis of testing data; and the effects of quantities, scale, and other influencing parameters.

The expert group recognizes that some of the procedures described here differ significantly from what has been recommended in the past. The main difference is in the concept of efficiency used. These standards are based on a broader description and justification of efficiency than Percentage of Heat Utilized (PHU). They interpret evaporation as a measure of energy wasted, not energy used (see Appendix I, Concepts of Efficiency). It is not the group's intention to demand that these standards be adopted. Rather, it is hoped that stove testers will use the provisional standards, watch for flaws in them, and share their experience in using them so that they can be revised as necessary. The purpose of developing standards for testing is to help technicians get the most reliable results from their tests, to consider sources of error, and to interpret test results reliably. These standards do not preclude the use of existing ways of testing; however, the group thinks that the new standards can yield more reliable, comparable results. These provisional standards are being circulated for review and comment among participants of the meetings at Arlington, Louvain, and Marseille (see below), and to other interested technicians recommended by participants. A complete list of meeting participants and other reviewers is in the Appendix.

Following this process, a finalized document will be prepared and disseminated to stove testers worldwide. The standardized tests will be presented to the U.S. National Bureau of Standards for their review and, hopefully, eventual acceptance.

Problems surrounding woodstove design and testing have gained increasing attention over the past five years or more. Many individuals and groups have become involved, circulating papers and meeting occasionally to discuss problems. At the "Seventh Woodstove Seminar" held at Louvain, Belgium, 4 - 5 March 1982, it was agreed that a systematic effort should be undertaken to reach as wide a consensus as possible on field testing of woodstoves. Too many approaches to testing were being used, it was felt, resulting in misunderstanding and hindering comparison of results.

An informal international working group of Louvain participants and others on developing a standard for field testing of woodstoves met in Marseille 12 - 14 May 1982. This group agreed that there was an urgent need for an internationally acceptable standard. It noted that field testing had been done in many places by many different people, some of whom have published on the subject and made suggestions for standards. None of the published suggestions was used as a basis for discussion. Rather, the group brainstormed from comments received following the Louvain meeting and from new ideas, keeping the earlier suggestions in mind.

The general consensus of the Marseille meeting was that:

- A worldwide standard should be simple and limited. A standard will be more acceptable if it imposes strict rules only where necessary, but includes recommendations where possible.

- A distinction should be made between testing done for local use only (for stove users and others) and testing where the results are intended to be transmitted to other places.

- The standard should represent a compromise between the widest possible range of applications, and the closest possible fit with actual cooking practices.

- It would be useful for the standard to classify the many different parameters that influence stove performance.

The Marseille group decided that evaluation concepts and reporting specifications could be fixed in the standard test procedure, and that food, fuels, and pots could be specified in local standards. While the stove itself cannot be standardized, a detailed description of the stove is needed with the test report. It was thought that an international standard might recommend a way to do this. Discussions resulted in a set of "instructions" for the draft of a proposed standard. The Marseille group draft was circulated among participants, who then provided comments. The resulting second draft, among others, was discussed at the meeting held at VITA 6 - 10 December 1982.

It is hoped that the document presented here, once revised to address reviewers' comments, will be widely accepted and used by stove testers around the world. The widespread use of standardized testing procedures will permit the comparison of stove designs on a more systematic basis, and foster wider sharing of the results of research and development efforts. This will benefit stove designers and users, and ultimately all who depend on the world's forest resources.

This document was compiled from notes and recordings of the meeting in Arlington by Dr. Timothy Wood, with supplemental material from Prof. Guido de Lepeleire, Dr. Gautam S. Dutt, and Howard Geller. Editing was done by Kristine Stroad Ament, with typesetting by Juleann Fallgatter. The meeting of experts was made possible by the support of the U.S. Agency for International Development (USAID), the Government of the Netherlands, and IBM/Europe.

WATER BOILING TEST

Water Boiling Tests (WBT) are short, simple simulations of standard cooking procedures. They measure the fuel consumed and time required for simulated cooking. They are used for a quick comparison of the performance of different stoves or the performance of the same stove under different operating conditions to quantify an expected stove performance. WBTs are done by stove designers, research people, and field workers.

Water Boiling Tests use water to simulate food; the standard quantity is two-thirds the full pan capacity.

The test includes "high power" and "low power" phases. The high power phase involves heating the standard quantity of water from the ambient temperature to boiling as rapidly as possible, and keeping it boiling at the same high power for 15 minutes (see Technical Note 2). The low power phase follows. The power is reduced to the lowest level needed to keep the water within 2°C of boiling over a one-hour period.

WBT should be repeated at least four times, and the results summarized statistically (see Appendix II). Test results are expressed in terms of wood consumption and time required. Correction factors are used to reflect the known influence of some non-standard parameters.

<u>Equipment</u>

- Stove
- Pots with lids
- A balance accurate to 10 grams with a recommended capacity of 5 kg (Technical Note 5)
- Locally dominant wood species, air dried (Technical Notes 3, 9), preferably 2 to 3 cm diameter
- Water, within 2°C of ambient temperature
- Timing device
- Mercury or digital thermometer for measuring temperatures up to 105°C (Technical Note 7)
- Device to measure/estimate the moisture content of wood (Technical Note 4)
- Equipment for removing and weighing hot coals (see Procedural Note 1)
- Forms for recording data and calculations

Previous Page Blank

Procedure

1. Note and record the test conditions. Prepare a drawing of the pots and stove to be tested. Include all relevant stove dimensions and show how the pots fit into the stove (Technical Note 8). Note climatic conditions (Technical Note 1).

2. Take a quantity of wood not more than twice the estimated needed amount, weigh it, and record the weight on the data reporting sheet.

3. Weigh the pots with their lids, and record the weight. Fill each pot with water to 2/3 capacity, replace the lids, and record the new weight.

4. Put a thermometer in each pot so that it is fixed in the center, about 1 cm from the bottom (Procedural Note 1). Record water temperatures and confirm that they vary no more than 2°C from ambient.

5. After a final check of preparations, light the fire as in Technical Note 10. Record the exact starting time. Throughout the following "high power" phase of the test, control the fire with the means commonly used locally to bring the first pot to a boil as rapidly as possible.

6. Regularly record the following on the Data and Calculation Reporting Form:

   - the water temperature in each pot;
   - the weight of any wood added to the fire;
   - any action taken to control the fire (dampers, blowing, etc.); and
   - the fire reaction (smoke, etc.).

7. Record the time at which the water in the first pot comes to a brisk boil. Move the lid if necessary to prevent the pot from boiling over. Continue to maintain the fire at the same high power level.

8. Exactly 15 minutes after boiling begins, rapidly do the following:

   - Note the time.

- Remove all wood from the stove, knock off any charcoal, and weigh it together with the unused wood from the previously weighed supply.
- Weigh all charcoal separately (Procedural Note 2).
- Record the water temperature from each pot.
- Weigh each pot, including water and lid.
- Return charcoal, burning wood, and pots to the stove to begin the "low power" phase of the test.

With practice a single tester can complete this step within 2 to 4 minutes and move on to Step 9 without introducing significant error to the data. If, however, this interruption is judged too difficult or disruptive, an alternate procedure is suggested in Procedural Note 3.

9. For the next 60 minutes maintain the fire at a level just sufficient to keep the water in the first pot within 2°C of boiling. Use the least amount of wood possible, and avoid vigorous boiling. Continue to monitor all conditions in Step 6. If the temperature of the water in the first pot drops more than 5° below boiling, the test must be considered invalid.

10. Recover, weigh, and record separately the charcoal and all wood.

11. Weigh and record the water remaining in each pot.

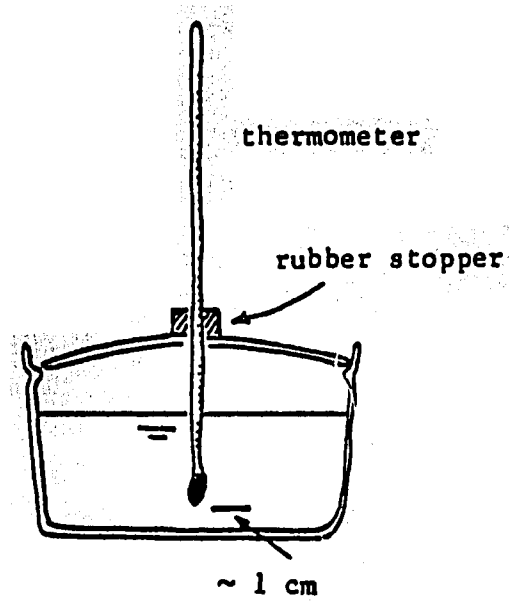
12. Calculate the amount of wood consumed, the amount of water remaining, the specific time, the Standard Specific Consumption (SSC), the Consumption Ratio for two or three pot stoves, and the minimum and maximum power levels.

13. Interpret test results (see Procedural Note 4), and fill out a Test Series Reporting Form.

Procedural Notes

1. Temperature gradients may occur in the water when it is not boiling. A representative point to check the average temperature seems to be in the center of the pot about 1 cm above the bottom. It is a good practice to have one thermometer or temperature probe in each pot. One arrangement is to have a series of special lids with a

support in the center to keep the thermometer in place at a suitable level (Figure 1).



2. Recovering and weighing hot coals from a stove can be simplified by using a removable metal ash tray on the floor of the combustion chamber (Figure 2). Often the ash tray with its contents can be weighed together as a unit, and the weight of the empty tray subtracted later. It is not necessary to separate charcoal and ashes, since ash weight is usually insignificant. Wire tongs (Figure 3) may be used to pick up hot pieces of charcoal. Heat-resistant, insulated gloves are also handy.

3. "High power" and "low power" tests may be conducted separately. The fire is extinguished at the end of Step 8, and the stove is allowed to cool for at least six hours. The low power test is then conducted in exactly the same way, except the fire is reduced the moment the first pot comes to a boil. The test continues with minimum fuel consumption, keeping the water in the first pot within 2°C of boiling.

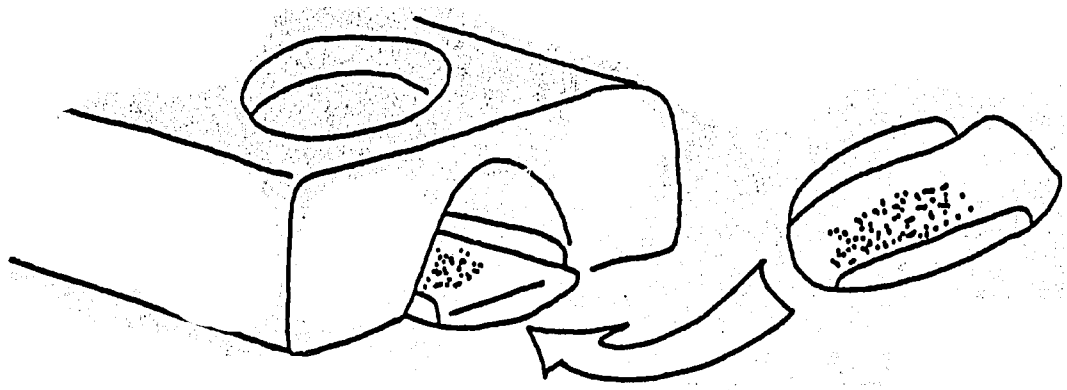


Figure 2
Ash tray for removing and weighing coals

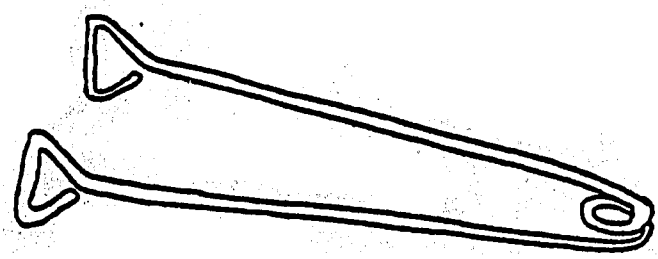


Figure 3
Wire tongs for picking up coals

The test is ended 60 minutes after boiling, and all measurements are recorded. The weight of the fuel used during the high power phase is subtracted from the total amount used in the low power phase. A separate or modified data sheet is needed for recording test results. Final calculations remain unchanged.

4. It is important to know how to interpret the results of the WBT, and to remember that a low standard specific consumption indicates a high efficiency. As efficiency declines, SSC rises. It is possible to use WBT results to judge the suitability of a stove for various cooking tasks. For example, for high power cooking (rapid frying and boiling), a stove with the greatest high power efficiency might be best; for simmering, however, the best stove might be the one that shows low SSC for both high and low power. (See also Appendix I which explains concepts of efficiency. Appendix II covers interpretation of test results in some detail; Appendix III addresses effects of scale and other influencing parameters.)

WATER BOILING TEST
DATA AND CALCULATION FORM*

Test Number_____ Location _____

Date_____ Air temp. ____°C. Wind_____ Rel. humidity_____%

Stove_____ Stove condition _____

Tester_____ Remarks_____

BASIC TEST DATA	INITIAL MEASUREMENT	END OF HIGH POWER PHASE	END OF LOW POWER PHASE
Wood moisture content	a)_____		
Weight of wood	b)_____kg	j)_____kg	u)_____kg
Weight of charcoal		k)_____kg	v)_____kg
Weight of Pot #1 with lid and water	c)_____kg	m)_____kg	w)_____kg
Weight of Pot #2 with lid and water	d)_____kg	n)_____kg	y)_____kg
Weight of Pot #3 with lid and water	e)_____kg	p)_____kg	z)_____kg
Water temperature, Pot #1	f)_____°C	q)_____°C	aa)_____°C
Water temperature, Pot #2	g)_____°C	r)_____°C	bb)_____°C
Water temperature, Pot #3	h)_____°C	s)_____°C	cc)_____°C
Time	i)_____	t)_____	dd)_____

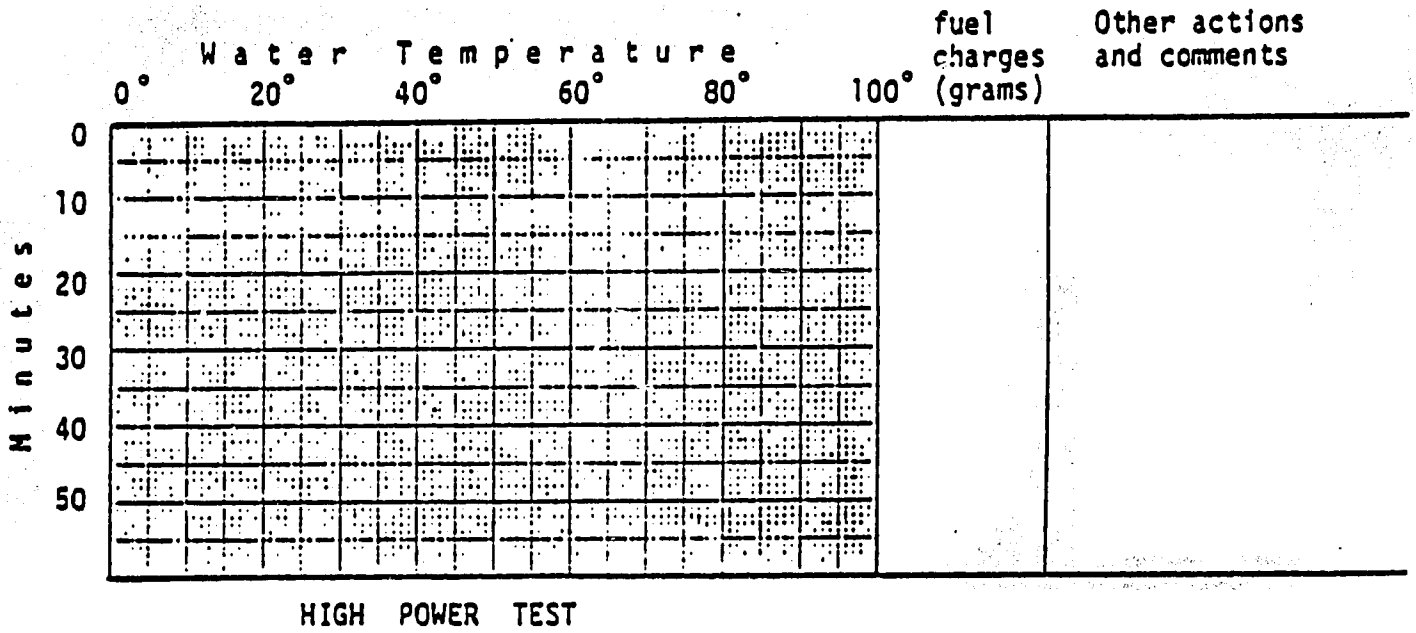
(Use the graph outline on reverse side to record changes in water temperature)

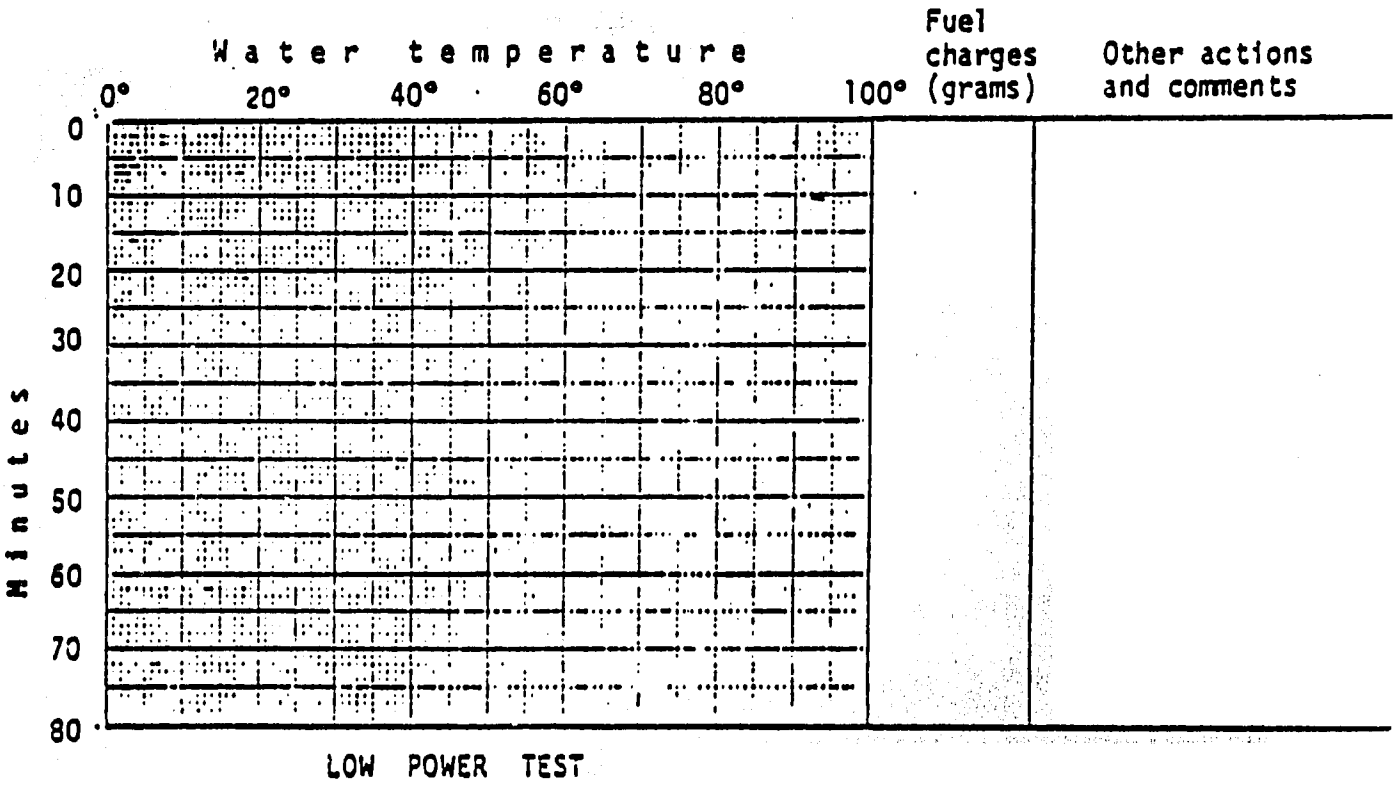
CALCULATIONS	HIGH POWER PHASE	LOW POWER PHASE
Wood consumed	A) b - j = _____kg	J) j - u = _____kg
Charcoal remaining	B) k = _____kg	K) v - k = _____kg
Equivalent dry wood consumed	C) A(1-a) - 1.5 B = ____kg	L) J(1-a) - 1.5 K = ____kg
Water vaporized, Pot #1	D) c - m = _____kg	M) m - w = _____kg
Water vaporized, Pot #2	E) d - n = _____kg	N) r - bb = _____kg
Water vaporized, Pot #3	F) e - p = _____kg	P) s - cc = _____kg
Consumption ratio	G) D/(D+E+F) = _____	Q) M/(M+N+P) = _____
Std. specific consumption	H) C/D = _____	R) L/M = _____
Duration of test	I) t - i = _____	S) dd - t = _____

* This is an example of a form to be completed every time a test is run.

WBT Data and Calculation Form, continued

TIME/TEMPERATURE PLOTS





WATER BOILING TEST

TEST SERIES REPORTING FORM*

Organization conducting tests _____

Address _____

Name of stove tested _____ Name of tester _____

Test numbers being reported: _____ - _____ Testing period _____ (months) _____ (year)

CLIMATIC CONDITIONS

	MAXIMUM	MINIMUM	MEAN
Air temperature			
Relative humidity			
Wind conditions			

FUELWOOD

SPECIES (Botanic name)	APPROX. % TOTAL (by weight)	MOISTURE CONTENT	MEAN LENGTH	MEAN DIAMETER

Calculated overall fuelwood moisture content: _____.

Method of determining moisture content: _____

Fuelwood cost per kg: _____ / estimated collection time OR _____ local currency = $ _____ US dollars

MEASURING DEVICES

INSTRUMENT	RANGE	SCALE LENGTH	TYPE, MANUFACTURER
Balance #1	kg	cm	
Balance #2	g.	cm	
Thermometer	°C	cm	
R.H. indicator	%	cm	
Anemometer	m/s	cm	
Other:		cm	

	MEAN	STANDARD DEVIATION	COEFF. OF VARIATION	STANDARD ERROR	95% CONFIDENCE INTERVAL
Consumption ratio					
Std. specific consumption					
Duration of tests					

Total number of tests reported: _____

* This is an example of a form used to summarize and report results from a series of tests of a single stove.

Name and origin of stove _____

_____

Name of stove builder(s) _____

Construction date _____ Materials used _____

_____

Stove location and condition _____

_____

TOP VIEW	PERSPECTIVE

CUTAWAY VIEW WITH POTS	FRONT VIEW

POTS	POT #1	POT #2	POT #3
Weight (empty)	kg	kg	kg
Maximum capacity	l	l	l
Diameter at rim	cm	cm	cm
Composition			

Details of stove construction _____

_____

_____

_____

_____

CONTROLLED COOKING TEST

The Controlled Cooking Test (CCT) is intended as an intermediate step between the Water Boiling Test and the Kitchen Performance Test. The primary objectives of the CCT are:

- To compare the fuel consumed and the time spent in cooking a meal on different stoves; and
- To determine whether a stove can effectively cook the range of meals normally prepared in the area where it is to be introduced.

The Controlled Cooking Test may also be used:

- To compare different cooking practices on the same stove;
- To give a cook the opportunity to learn how to use the stove; and
- To follow the Water Boiling Test in subjecting a stove to more realistic, but controlled, conditions.

The CCT is normally conducted in a laboratory or field demonstration center by trained stove testers, extension workers, or potential users. The cook, preferably a woman, should be experienced in traditional cooking techniques.

Equipment

- A homogeneous mix of fuelwood as it is normally available locally, sufficient for at least 20 tests (see Technical Note 9).
- A selected type and amount of food sufficient for 20 tests.
- Weighing instrument accurate to 10 grams, with a recommended capacity of 5 to 10 kg, depending on the amount of food prepared in each test (Technical Note 5).
- Timing device.
- The same pots, lids, and other cooking utensils are used throughout the test.
- Forms for recording data and calculations.

Procedure

1. Establish a test design that accurately reflects local cooking practices (Procedural Note 1).

2. Remove any charcoal and ash from the stove to be tested. The stove should not be warm from a previous fire.

3. Record climatic conditions (Technical Note 1).

4. Take a quantity of wood not more than twice the estimated amount needed. Weigh it and record the weight on the Data and Calculation Form.

5. Weigh the pots with their lids and record the weight.

6. Assemble and prepare the food to be cooked.

7. Light the fire and record the time (Technical Note 10)

8. Perform the defined cooking task (Procedural Note 1).

9. When the cooking task is completed, record the time (Procedural Note 2).

10. Weigh separately the remaining wood and charcoal (Procedural Note 3).

11. Weigh the food in its pots, including any lids.

12. Record comments from the cook on any problems encountered during the test, including qualitative differences between the tested stove and other stoves.

13. Repeat the same test at least five times for each type of meal cooked.

14. Repeat all the CCTs again, this time using a different stove or traditional cooking system for comparison.

15. For each test calculate total test time and Specific Fuel Consumption. For each set of similar tests, calculate the standard deviation of results. Record these on the Test Series Reporting Form. Carry out a t-test to compare statistically the two types of stoves tested. (See Appendix II, Interpreting Test Results).

16. Write a test report for each test using, if desired, the sample Data and Calculation Form on the following page. Include a description of:

    - stoves and pans used in the test (Technical Note 8);
    - standard meal used in the test; and
    - standard procedure used to cook the meal.

Procedural Notes

1. The CCT design is tailored to specific local cooking practices. It is therefore important to specify the following conditions:

   - Pot types and sizes.
   - Fuelwood types and sizes.
   - One or two standard meals commonly prepared in the region. Where several types of meals are prepared, select no more than two for the test, one requiring long cooking time and the other short.
   - Exact cooking tasks and sequences required to cook the standard meal. For example: "Bring the first pot to a boil; switch the first and second pots; bring the second pot to a boil; reduce the fire by breaking off charred ends of fuel; remove the first pot and simmer the second until the food is cooked."

   Establishing the test design may be done in either of two ways: by conducting a thorough survey of local cooking practices to collect the needed information; or, by having a team of three to five experienced local cooks define the one or two standard meals and the specific way they should be prepared and cooked for the test (see Appendix III, Quantities, Scale Effects, and Other Influencing Parameters).

2. It is important to consider the criteria by which food will be considered "done," since this determines the time at which the tests will be finished. It is best to determine the time objectively, such as "The skins come off the beans," or "The porridge loses all traces of graininess." However, even if the criteria used are very subjective ("The sauce tastes right"), they should still be mentioned in the test design. Whatever the criteria used, the cook must be encouraged to be very consistent in judgement.

3. Recovering and weighing hot coals from a stove can be simplified by using a removable metal ash tray on the floor of the combustion chamber (Figure 2, page 5). Often the ash tray with its contents can be weighed together as a unit, and the weight of the empty tray subtracted later. It is not necessary to separate charcoal and ashes, since ash weight is usually insignificant. Wire tongs (Figure 3, page 5) may be used to pick up hot pieces of charcoal. Heat-resistant, insulated gloves are also handy.

CONTROLLED COOKING TEST
DATA AND CALCULATION FORM*

Test Number _____ Location _____

Date _____ Air temp. _____°C Wind _____ Rel. humidity _____

Stove _____ Stove condition _____

Cook _____ Remarks _____

BASIC TEST DATA.	INITIAL MEASUREMENTS	FINAL MEASUREMENTS
Weight of wood	(A)_____kg	(G)_____kg
Weight of charcoal		(H)_____kg
Wt of Pot 1 (empty)	(B)_____kg	(I)_____kg (with cooked food)
Wt of Pot 2 (empty)	(C)_____kg	(J)_____kg (with cooked food)
Wt of Pot 3 (empty)	(D)_____kg	(K)_____kg (with cooked food)
Time	(E)_____	(L)_____
Wood moisture content	(F)_____	

CALCULATIONS.		
(M) Weight of wood used	A-G =	
(N) Equivalent dry wood used	M(1-F)-1.5 H =	_____kg
(P) Weight food cooked, Pot 1	I-B =	_____kg
(Q) Weight food cooked, Pot 2	J-C =	_____kg
(R) Weight food cooked, Pot 3	K-D =	_____kg
(S) Total weight food cooked	P+Q+R =	_____kg
(T) Specific consumption	S/N =	_____
(U) Total testing time	L-E =	_____

Cook's comments about stove performance, ease of use, etc.:

_____

_____

_____

_____

_____

* This is an example of a form to be completed every time a test is run.

CONTROLLED COOKING TEST
TEST SERIES REPORTING FORM*

Organization conducting tests _____

Address _____

Names of stoves compared: 1) _____ and 2) _____

Test numbers being reported: _____

Testing period _____ (months) (year) Name of test supervisor _____

CLIMATE

	MAXIMUM	MINIMUM	MEAN
Air temperature	°C	°C	°C
Relative humidity	%	%	%
Wind conditions	m/s	m/s	m/s

FUELWOOD

SPECIES (Botanic name)	APPROX % TOTAL (by weight)	MOISTURE CONTENT	MEAN LENGTH	MEAN DIAMETER

Calculated overall fuelwood moisture content _____.

Method of determining moisture content _____

Fuelwood cost per kg: _____ (estimated collection time) OR _____ (local currency) = $ _____ (US dollars)

MEASURING DEVICES

INSTRUMENT	RANGE	SCALE LENGTH	TYPE, MANUFACTURER
Balance #1	kg	cm	
Balance #2	kg	cm	
Thermometer	°C	cm	
R.H. indicator	%	cm	
Anemometer	m/s	cm	
Other		cm	

		MEAN	STANDARD DEVIATION	COEFF. OF VARIATION	STANDARD ERROR	95% CONFIDENCE INTERVAL
STOVE #1	Equiv. dry wood consumed per test	kg				
	Total weight food cooked per test	kg				
	Calculated specific consumption					
	Duration of test	hrs				
	Total number of tests:					
STOVE #2	Equiv. dry wood consumed per test	kg				
	Total weight food cooked per test	kg				
	Calculated specific consumption					
	Duration of test	hrs				
	Total number of tests:					

t-Value = _____ at ____% level of significance and _____ degrees of freedom.

* This is an example of a form used to summarize and report results from a series of tests of two stoves being compared.

(CONTINUED...)

CCT Series Reporting Form, continued

Description of Standard Meal. _____

_____

_____

Defined procedures for cooking the meal. _____

_____

_____

_____

_____

_____

Summary of cook's comments, Stove #1. _____

_____

_____

_____

_____

_____

_____

Summary of cook's comments, Stove #2. _____

_____

_____

_____

_____

_____

_____

CCT Series Reporting Form, continued

Name and origin of stove _____

_____

Name of stove builder(s) _____

Construction date _____. Materials used _____

_____

Stove location and condition _____

_____

TOP VIEW	PERSPECTIVE

CUTAWAY VIEW WITH POTS	FRONT VIEW

POTS	POT #1	POT #2	POT #3
Weight (empty)	kg	kg	kg
Maximum capacity	l	l	l
Diameter at rim	cm	cm	cm
Composition			

Details of stove construction _____

_____

_____

_____

_____

KITCHEN PERFORMANCE TEST

The Kitchen Performance Test (KPT) measures the relative rate of fuelwood consumed by two stoves as they are used in the normal household environment. It is a prolonged test conducted with the willing cooperation of individual families. Compared to the previously described tests, the results of the KPT can provide the most reliable indication of stove performance under actual household conditions. However, because of the large effort involved, it is normally conducted only after the more controlled tests have been completed.

The primary objectives of the KPT are:

- To study the impact of a new stove on overall household energy use (Procedural Note 1); and
- To demonstrate to potential users the fuel-saving quality of a new stove in the household, and to suggest correct operating practices.

Variations of the Kitchen Performance Test may also be used in conjunction with a stove dissemination program (Procedural Note 2) or as part of a survey of household energy use (Procedural Note 3).

Kitchen Performance Tests should be carried out by an investigator who is trained to follow instructions, is motivated to do so, and has certain basic numerical skills. Extension workers, school teachers, or high school students are well suited for the task. It is important that the person be well motivated in order to obtain reliable and useful data.

Equipment

- Balance for weighing fuelwood
- Forms for recording data and calculations
- Pots, etc., to be supplied by household

Procedure

1. Select households to participate in the test (Procedural Note 4). Explain to family members the purpose of the test, and arrange to measure their fuelwood each day. Encourage the family to use only a single stove throughout the test.

Previous Page Blank

2. Gather any needed information about each participating household. For example: determine the sex and age of each person served meals, and use this information to calculate the number of standard adult persons served (Procedural Note 5); ask about the approximate cost of the fuelwood used, in terms of either money spent or time needed to collect it; and collect any other information that may help interpret the final data (Procedural Note 6).

3. Define an inventory area for fuel consumption measurement. Any fuel entering or leaving this area must be accounted for (Procedural Note 7). Weigh all wood and other fuels in the inventory area. Estimate or measure the moisture content of the wood (Technical Note 4).

4. Define the testing period of seven consecutive days. If it is not possible to measure for seven days, measure for at least five days. Stop and start at the same hour each day (Procedural Note 8).

5. Visit the household at least daily, if possible, without being intrusive. Weigh wood remaining in the inventory area, and add to it if necessary. Inquire about the number of people being served each day, and confirm that the stove is operating properly.

6. Compile the results at the end of eight days. Calculate specific daily consumption for each household, and then the mean and standard deviation. Compare the results with those from households using other stoves (see Appendix II, Interpreting Test Results, and III, Quantities, Scale Effects, and Other Influencing Parameters).

7. Inform participating families of the results, and thank them for their cooperation.

Procedural Notes

1. The introduction of a new stove may alter the amount and type of cooking done in the household. For example, the result may be a substantial improvement in the well-being of the family, but make little change in overall fuel use. Or it may be that a fire enclosed within the stove provides so little light that it becomes necessary to use a kerosene lamp.

2. A survey of cooking practices to determine current local cooking procedures, foods cooked and eaten, types of stoves used, etc., is a

useful starting point for the development and dissemination of improved cook stoves. The survey may be accompanied in a number of households by a measurement of all the fuel used for cooking, such as is involved in the Kitchen Performance Test.

Later, new stoves can be built in these same households, and another KPT may be carried out after the households have had an opportunity to get acquainted with the new stoves. At that time the KPT may be accompanied by a user survey to determine how well the stoves are being received, with later surveys to evaluate other parameters such as stove durability. Later KPTs may be performed to evaluate whether the fuel savings have remained the same and if other factors have had a positive or negative influence on the stove's long term acceptability.

3. It may be tempting to use the results of the KPT to estimate the fuel saving potential of a new stove before it is widely accepted and used. For this purpose, however, the test would have to be greatly expanded to include:

   - many more households, carefully selected to be representative of the regional population;
   - a period of time that includes all major seasons;
   - a study of stove deterioration rates and repair records; and
   - an economic analysis demonstrating the economic attractiveness of the stove to both the user and the producer.

4. For meaningful results:

   - Households should be selected from approximately the same economic level. This will reduce variation and permit more reliable interpretation of the results.
   - Participating families should use fuelwood for at least 90% of their household cooking needs.
   - A minimum of five participating households is essential. Depending on the expected difference in fuel use between the two stoves tested, a larger number of households may be necessary (see Table I on the following page).

TABLE I

Minimum number of households necessary in the KPT relative to expected differences in fuel use

Expected percent difference in fuel use	Minimum number of households*
10	54
20	14
30	7
40	5

* Corresponds to COV = 0.4; 10% level of significance (See Appendix II)

5. For purposes of this test, the "standard adult" will be defined according to a simplified version of the widely used League of Nations formula as shown in Table III. (Guidelines for Woodfuel Surveys, for F.A.O. by Keith Openshaw).

TABLE II

"Standard adult" defined in terms of sex and age

Sex and age	Fraction of standard adult
Child, 0-14 years	0.5
Female, over 14 years	0.8
Male, 15-59 years	1.0
Male, over 59 years	0.8

6. Other information gathered for each family may include:

- the number and types of any other stoves used regularly (for making tea, heating water, cooking manioc, etc.);
- the major activity of the head of the household (a possible indication of family economic level);

- easily observable indicators of social or economic status;
- uses made of fuelwood other than for cooking food; and
- tribal or cultural affiliation.

7. It is recommended that no more fuel be in the inventory area than is likely to be consumed during the one-week test period. If much more fuel is stored than will be used, define a smaller inventory area from which all fuel for the test is taken. Stress to household members that only wood from the small area be used during the test, and that if more wood is needed, the investigator be present when it is added to the pile. The number of visits the investigator must make to the household to weigh the wood will depend on the size and adequacy of the initial inventory.

8. The recommended seven consecutive day test period recognizes that many family activities are conducted according to a weekly routine. Seven days is the shortest time likely to include market days, work days, and any weekly religious observances in their proper proportion.

   It often happens that the person conducting the test is unwilling to work on the day of weekly religious observance. In such a case, advance provision should be made for a substitute on that day, if possible.

   Note that a seven day test usually requires <u>eight</u> days of measurement (see Data and Calculation Reporting Form on the following page). Similarly, if only a five day test is planned, measurements will be taken for six days.

9. Different types and sizes of wood used by different households may introduce unwanted variation to test results. To avoid this, the tester may consider providing uniform fuelwood to be used for the duration of the test. It is important, however, that this practice not encourage the household to use significantly more or less wood than it would normally.

KITCHEN PERFORMANCE TEST

DATA AND CALCULATION FORM*

Household No. _____ Family Name _____

Location _____

HOUSEHOLD

	NUMBER		STANDARD ADULT EQUIVALENTS	OTHER HOUSEHOLD INFORMATION
Children 0-14 years	_____	x 0.5 =	_____	_____
Women over 14 years	_____	x 0.8 =	_____	_____
Men aged 15-59 yrs.	_____	x 1.0 =	_____	_____
Men over 59 years	_____	x 0.8 =	_____	_____
(A) TOTAL ADULT EQUIVALENTS:			_____	_____

FUELWOOD

SPECIES (Botanic name)	APPROX. % TOTAL (by weight)	MEAN LENGTH	MEAN DIAMETER
_____	_____	_____cm	_____cm
_____	_____	_____cm	_____cm
_____	_____	_____cm	_____cm

Condition of fuelwood: (dry / damp / wet / green) _____

Fuelwood cost per kg: _____ OR _____ = $ _____

estimated collection time — local currency — US dollars

ALTERNATE FUELS/STOVES

	DESCRIPTION	FUNCTION
Other fuels in use:	_____	_____
	_____	_____
Other stoves in use:	_____	_____
	_____	_____

	TOTAL WOOD REMAINING IN INVENTORY AREA	WOOD ADDED TO INVENTORY AREA	COMMENTS
Day 0	(None) kg	_____kg	_____
Day 1	_____kg	_____kg	_____
Day 2	_____kg	_____kg	_____
Day 3	_____kg	_____kg	_____
Day 4	_____kg	_____kg	_____
Day 5	_____kg	_____kg	_____
Day 6	_____kg	_____kg	_____
Day 7	(B) _____kg	(None) kg	_____

(C) TOTAL WOOD ADDED TO INVENTORY: _____kg

(D) TOTAL WOOD CONSUMED: C-B = _____kg

(E) TEST DURATION: _____days

SPECIFIC DAILY CONSUMPTION: D/A/E = _____

* This is an example of a form to be used for each participating household.

KITCHEN PERFORMANCE TEST
TEST SERIES REPORTING FORM*

Organization conducting tests _____
Address _____
Names of stoves compared: (1) _____ (2) _____
Testing location _____
Testing period _____ Name of test supervisor _____
(months) (year)

		STANDARD ADULT EQUIVALENTS	SPECIFIC DAILY CONSUMPTION	FUELWOOD COST / KG
STOVE #1	ARITHMETIC MEAN:	_____	_____	_____
	STANDARD DEVIATION:	_____	_____	_____
	COEFFICIENT OF VARIATION:	_____	_____	_____
	STANDARD ERROR	_____	_____	_____
	95% CONFIDENCE INTERVAL:	_____	_____	_____
		(TOTAL NUMBER OF TESTS _____)		
STOVE #2	ARITHMETIC MEAN	_____	_____	_____
	STANDARD DEVIATION:	_____	_____	_____
	COEFFICIENT OF VARIATION:	_____	_____	_____
	STANDARD ERROR:	_____	_____	_____
	95% CONFIDENCE INTERVAL:	_____	_____	_____
		(TOTAL NUMBER OF TESTS _____)		

Specific Daily Consumption: t-Value = _____ at _____% level of confidence and _____ degrees of freedom.

(Attach a full description of both stove models tested)

* This is an example of a form used to summarize and report results from a series of tests of two stoves being compared.

TECHNICAL NOTES

1. Climatic conditions

Among the climatic data to be reported during stove testing, the most important are: air temperature, wind conditions, and relative humidity.

- Air temperature affects the rate of heat loss from stove and pots. It also establishes initial water temperature in the Water Boiling Test. Ideally, air temperature measurements should be taken before and after each test so that a mean value can be estimated.

- Wind conditions affect the stove's draft and can have considerable influence on stove performance. Ideally, stove testing should be done only when conditions are calm. Where this is not possible a windbreak should be erected around the stove to reduce air movement.

  A hand-held anemometer is useful for measuring wind speed. However, precise measurements are probably unnecessary, and a simple description of wind conditions may be satisfactory.

- Relative humidity provides one indication of the moisture content of air dried firewood (see Technical Note 3). It is a simple and useful condition to measure during stove testing. For this purpose, a small sling psychrometer, a hair hygrometer, or a similar instrument is satisfactory. Recalibrate a hygrometer frequently by wrapping it in a wet cloth, leaving it for five minutes, and adjusting it to 100% RH.

2. Atmospheric pressure and temperature

The normal boiling temperature of water depends on the local atmospheric pressure and thus on weather conditions and, mainly, on the altitude above sea level (H). At an altitude (H) the normal boiling point can be computed from

$$T_b = (100 - H/300)^\circ C$$

when H is expressed in meters (One foot equals 0.305 meters). The normal boiling point is 100°C at sea level, for example, and 95°C at 1500 m altitude.

Previous Page Blank

With a given ambient air temperature T_o, the net (minimum) heat needed to bring water to a boil and to maintain simmering is proportional with the temperature difference $\Delta T = T_b - T_o$, and so is probably the fuel consumed for cooking.

This can be taken into account by using a temperature factor when computing the food or water processed W" from weighed quantities W'

$$W'' = W'(T_b - T_o)/100$$

where 100°C is considered as a reference temperature difference.

Note that cooking times increase with reduced boiling temperatures at high altitude. The cooking time is doubled for a temperature decrease of 5 to 10°C, depending on the kind of food. This may influence Kitchen Performance Test results, but not Water Boiling Tests.

3. Humidity and moisture

The relative humidity of air RH controls the equilibrium moisture content X of "air dried" fuelwood, which in fact is moist. The wood species and the temperature have some influence too, but a useful first approximation is given by:

$$\frac{\text{water mass}}{\text{mass of dry wood}} = X \approx 0.2\ RH^*$$

For example, in saturated air (RH = 1), 1.0 kg of dry wood will contain about 0.2 kg of water (possibly more). At a lower RH = 0.6, the moisture content X drops to about 0.12. Of course, RH and X can be expressed as percentages as well.

Obviously the specific heating value, H_x, of moist wood is lower than the heating value of dry wood H_o. It can be shown that for moderate moisture contents ($X \leq 0.2$)

$$H_x \simeq H_o(1 - X) \approx H_o(1 - 1.1\ X')$$

*The moisture content may be expressed with reference to the dry wood quantity as done above or, alternatively, with reference to the moist wood quantity as well:

$$X' = \frac{\text{water mass}}{\text{mass of moist wood}}$$

As a consequence, a larger quantity of moist wood M_x is needed for a given job than of dry wood M_o. This can be accounted for by computing an equivalent dry wood consumption from a measured moist wood quantity.

$$\text{(equiv. dry wood) } M_o = (1 - X) \cdot M_x \text{ (moist wood)}$$

4. Moisture measurements

The moisture content (X) of air-dried firewood can be estimated from the humidity RH (See Technical Note 1) ($X = 0.2$ RH).

The most direct and precise procedure is to make a double weighing of a moist or air-dried sample: first as it is, and then after drying it in an oven (at 110°C for 24 hours or more, depending on the sample size). With M_x (moist weight) and M_o (dry weight):

$$X = (M_x - M_o)/M_o \quad \text{or} \quad X' = (M_x - M_o)/M_x$$

In fieldwork the first weighing is done at the test site (M_x). The second weighing can be done afterwards in a lab.

Alternatively, the wood moisture X can be measured with a battery operated tester which uses the electric resistance of the sample as an indication of its moisture content. The results will depend slightly on the species of the wood and on the quality of the instrument used.

5. Weight (mass)

Weighing can be done with any good balance. For field testing, direct reading instruments are preferable, as no adjustments of weights are needed. Spring balances do a good job if they have a long reading scale and thus good resolution, and if they are used within 20 to 100% of the full capacity. Spring balances should occasionally be checked with calibrated weights (1 liter of water has 1 kg of weight, etc.) A set of balances with different full-scale capacities should be used, for example, 1, 5, and 15 kg. Compare them with each other: they should give the same reading for the same load.

The weighing basket used with a balance should be as light as possible, since precision is lost when the difference between two weighings is relatively small.

6. Volume

Volumes can be measured with graduated bottles. One can also use commercial bottles with known volumes (1/4, 1/3, 3/4, 1/1 liter). A balance can do the job, too, as 1 liter of water weighs 1 kg.

7. Temperature

Mercury thermometers are, in general, precise but breakable. The glass can break, and the liquid column can separate as well. Spare glass thermometers should be kept on hand. Metallic thermometers are more resistant but need periodic calibration, for example, by comparison with a good quality glass thermometer. Rechargeable battery-operated thermistors and thermocouples have proven very useful in field work, although models with digital readouts that are indistinct in direct sunlight should be avoided. In any case, look for instruments with a long scale, as they give better resolution and precision.

Before using a thermometer for stove testing, check it in visibly boiling water and look for a possible difference between the reading and the normal boiling point for that altitude:

$$\text{Actual boiling point} = \frac{100 \text{ altitude (meters)}}{300}$$

For Water Boiling Tests, simmering means that the water temperature is kept no lower than 5°C below the actual boiling temperature. If water temperature does drop below this point, the test should be discontinued.

8. Pot and stove description

The tests concern a pot and stove combination, where the inside dimensions are the most important, and outside dimensions are less important. Therefore:

- Give a complete pot description (size, shape, weight, capacity, material, etc.).
- Give a functional stove description (inside dimensions, total weight, wall thickness, etc.). Make sketches showing top view, front view, cutaway side view with placement of pots, etc. (see Figure 4).

- Be sure to report how well the pots fit into the stove. Often the net inside dimensions of the combustion chamber and the flue gas ducts cannot be measured directly. They can be calculated from readily accessible data, for example, by subtracting pot height from the combined distance from the top of the pot to the top of the stove and the bottom of the pot to the bottom of the flue gas duct or combustion chamber (W = X + Y - Z, in the figure).

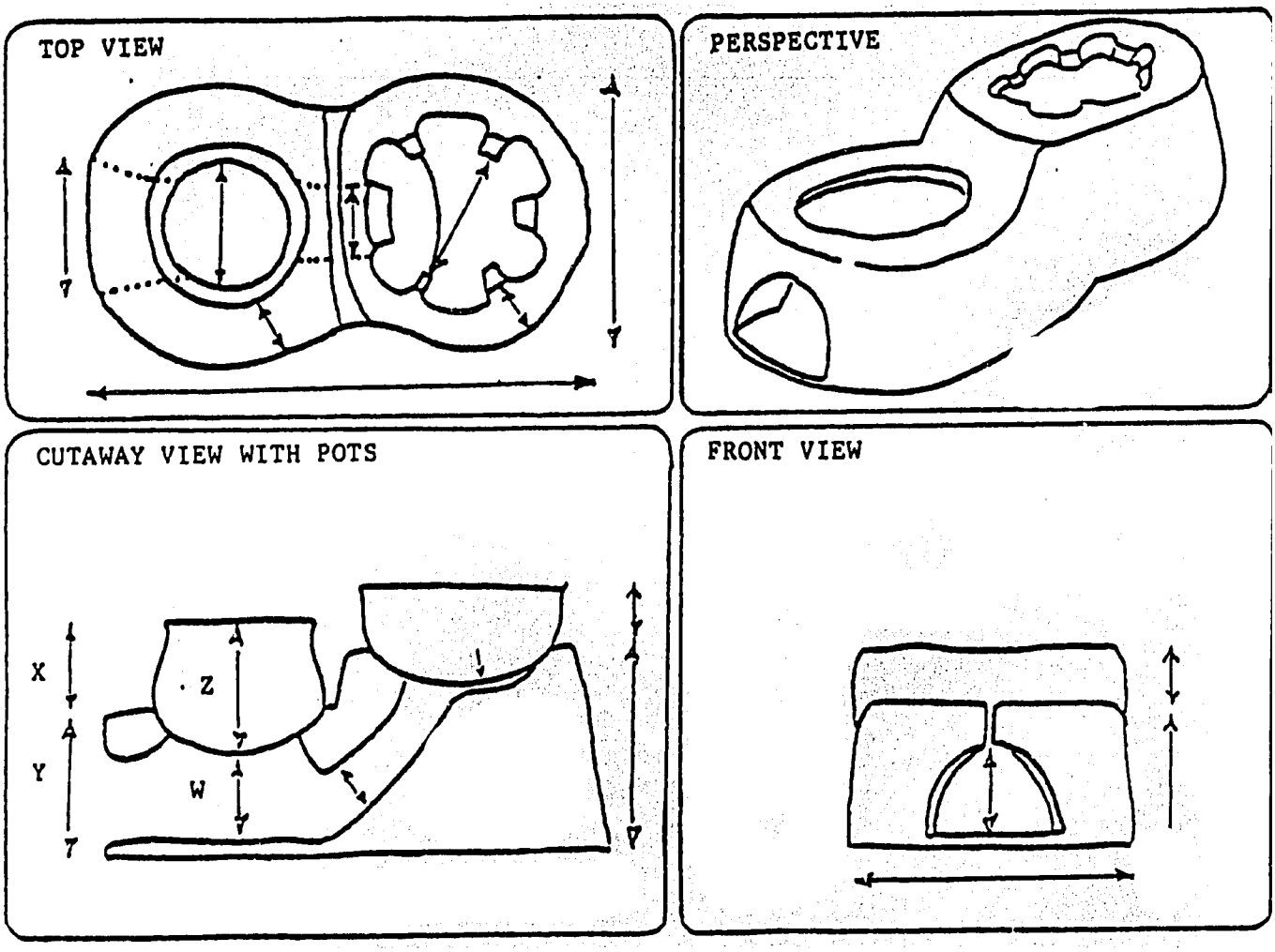


Figure 4
Stove views for descriptive sketch in test report

It is difficult to report how a pot fits in a pot hole. Of course, the pot hole should be described as clearly as possible. Measure the thickness of the stove top. Measure the diameter of the pot hole from both inside and outside the stove.

Lengths are easily measured. If you do not have a tape measure at hand, remember that standard ISO-A4 paper is 297 x 210 mm; you might use paper with 5 mm squares from your notebook. A man's hand span is about 20 cm. The diameter of a spheroid pot can be derived from the circumference L as measured, for example, with a string:

Diameter = L/3.14

For measuring hard-to-reach internal dimensions of a stove, a pair of thin sticks may be useful. Grasp the sticks in one hand by the ends and insert them into the stove. Spread the tips apart until they span the distance to be measured. Maintain this "V" shape while removing the sticks, and measure the distance between the tips with any conventional device (see Figure 5).

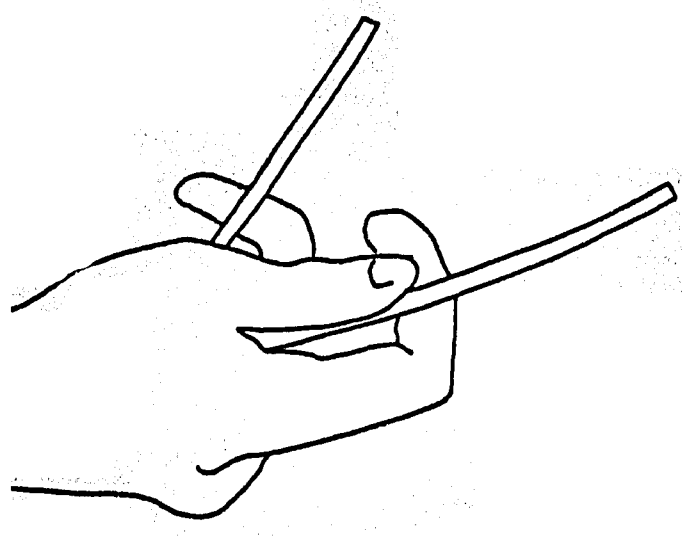


Figure 5

9. Fuelwood variation

Different types, sizes, and conditions of fuelwood are a potential source of great variation in all the tests presented here. The following precautions can help minimize this variation:

- Use only wood that has been thoroughly air dried. For sticks 3 to 4 cm in diameter drying time may be 3 to 8 months, depending on tem-

perature, relative humidity, degree of protection from rain and mists, amount of air circulating through the wood pile, and wood species. Air dried wood is generally light weight and brittle. Hot water and steam should not escape from the wood as it is burned.

- Wood may be cut in a uniform size (3 x 3 cm, for example) and only this wood used for stove testing. While this gives uniformity, it is often difficult to ignite and maintain a fire without smaller or tapered pieces.

  Alternatively, if a series of tests is planned, prepare in advance a stack of fuelwood to be used for each test. Stacks should be as similar as possible in terms of wood type and size. They should then be bound tightly to prevent loss of any pieces. Sealing each wood stack in a large plastic bag will protect the wood from outside moisture.

- Protect fuelwood from boring insects.

10. Ignition

For Water Boiling Tests and Controlled Cooking Tests it is important to light the fire in the way it is normally done in the household or area. This may be done, for example, using kerosene as the ignition material. Three pieces of wood can be dipped vertically into kerosene (about 8 cm deep) for about five seconds, and the excess kerosene tapped off. The kerosene-dipped wood should contain about 10 grams of kerosene (check it by weighing the wood before and after dipping). Or, a measured amount of kerosene (less than 10 grams) may simply be poured over the wood. The test's starting time coincides with the lighting of the kerosene-soaked wood pieces. If desired, the kerosene used may be considered as consumed fuel (1 gram of kerosene is equivalent to about 2 grams of wood), however, the energy involved is so small that it may be safely ignored in the calculations.

GLOSSARY

COEFFICIENT OF VARIATION (COV): Normalized measure of variability, independent from the units of the quantity being measured. See Appendix II.

CONSUMPTION RATIO: An expression sometimes used in the WBT to describe the amount of water evaporated from the first pot relative to the water evaporated from all the pots on the stove; calculated by CR $= W_1/W_1 + W_2 + W_3 + \ldots + W_n$, where W is the amount of water evaporated.

CONTROLLED COOKING TEST (CCT): An intermediate laboratory test to compare fuel and time used to prepare a meal on different stoves, and to determine the range of meals a stove can accommodate in a given area. See page 15.

DEGREES OF FREEDOM: The number of test measurements minus the number of parameters that have been estimated on the measurements. See Appendix II.

HIGH POWER: Maximum stove power. WBT high power phase brings the water to boiling as rapidly as possible, and then maintains boiling at the same heat level for 15 minutes. See page 5.

KEROSENE: Petroleum-based fuel, known as "paraffin" in British English.

KITCHEN PERFORMANCE TEST (KPT): A field test to measure fuel consumption in a normal household situation. See page 23.

LOW POWER: Minimum stove power. WBT low power phase requires the fire to be maintained at the lowest level necessary to simmer water for one hour. See page 5.

PARTIAL EFFICIENCIES: Fractions of the overall efficiency of a system. For a cookstove these might include combustion efficiency, heat transfer efficiency, pot efficiency, and control efficiency. See Appendix I.

PERCENTAGE OF HEAT UTILIZED (PHU): A commonly used expression to describe stove performance, calculated by measuring energy gain in all pots (increase in temperature + evaporation losses), divided by calculated heat input from wood or charcoal. See Appendix I.

SPECIFIC CONSUMPTION (SC): Fuel consumed divided by a measure of the work performed. See Appendix I.

SPECIFIC DAILY CONSUMPTION (SDC): An expression used in the KPT to describe the amount of fuelwood (in kg) used for cooking per person served per day. See the KPT Data and Calculation Form on page 28.

SPECIFIC FUEL CONSUMPTION (SFC): An expression of the total amount of food cooked in the CCT, divided by the total amount of wood used to cook it. See the CCT Data and Calculation Form on page 18.

STANDARD ADULT EQUIVALENT: A standard way to define and compare the number of people in a family group. See Table II, page 26.

STANDARD DEVIATION: A statistic used as a means of dispersion in a distribution, indicating the amount of variability within a series of measurements. See Appendix II.

STANDARD SPECIFIC CONSUMPTION (SSC): An expression used in the WBT to describe the equivalent dry wood consumed relative to the amount of water vaporized from the first pot on the stove. See the WBT Data and Calculation Form on page 11.

t-TEST: Used to determine whether a test parameter is significantly different for different stoves. See Appendix II.

WATER BOILING TEST (WBT): A simple laboratory test to measure the fuel and time necessary to cook a simulated meal. See page 5.

ABBREVIATIONS

C	Centigrade
CCT	Controlled Cooking Test
cm	centimeter
COV	coefficient of variation
ISO	International Standards Organization
kg	kilogram
KPT	Kitchen Performance Test
kW	kilowatt
m/s	meters per second
PHU	Percentage of Heat Utilized
RH	relative humidity
SC	Specific Consumption
SDC	Specific Day Consumption
SFC	Specific Fuel Consumption
SSC	Specific Standard Consumption
t_b	time to boil
WBT	Water Boiling Test

APPENDIX

I. Concepts of Efficiency

II. Interpreting Test Results

III. Quantities, Scale Effects, and Other Influencing Parameters

IV. Participants at Arlington Meeting

V. Participants at Louvain "Woodstoves Seminar"

VI. Participants at Marseille Meeting

VII. Other Reviewers

Previous Page Blank

APPENDIX I

Concepts of Efficiency

There are many different ways of looking at stove performance and of measuring stove efficiency. A widely used method compares the energy that goes into the stove with the energy that comes out, to determine Percentage of Heat Utilized (PHU). A broader concept of efficiency accounts for energy losses in evaporation. Once food or water reaches the boiling point, it does not absorb more heat; only excess heat is produced. A stove that is regulated to maintain the temperature for boiling without creating excess heat is, in that respect, more efficient. This section will review some different ways of measuring efficiency.

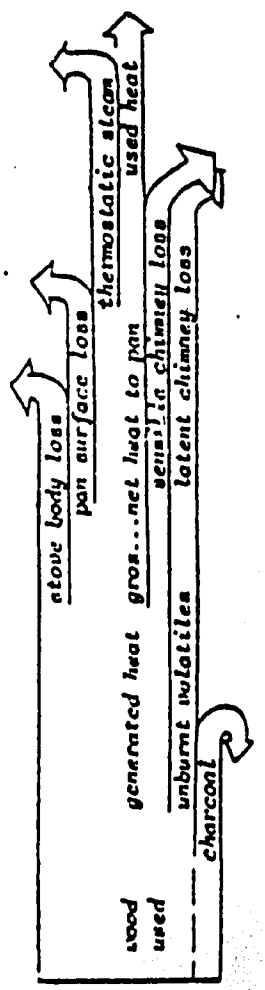


Figure 6

Figure 6 is an energy flow diagram for a wood-burning cook stove. Useful heat is absorbed in the food, but heat losses are associated with:

- incomplete combustion of wood
- heat loss from the stove body to the environment
- heat loss from the pot surfaces (including lids)
- heat loss through the chimney
- thermostatic steam escaping from the pot due to excessive stove power.

2. Partial efficiencies

Different partial efficiencies can be suggested, for example:

- combustion efficiency

$$\eta_c = \frac{\text{heat generated by combustion}}{\text{heat consumed by fuelwood}}$$

- heat transfer efficiency

$$\eta_t = \frac{\text{gross heat input to the pan}}{\text{heat generated}}$$

- pot efficiency

$$\eta_p = \frac{\text{net heat input to pot}}{\text{gross heat input}} = \frac{\text{gross heat - surface losses}}{\text{gross heat input}}$$

- control efficiency

$$\eta_r = \frac{\text{heat absorbed by the food}}{\text{net heat input to the pot}}$$

These efficiencies can be associated with stoves operated in predictable or well defined ways, such as at a single power level, or in defined cooking patterns.

3. Overall efficiency

An "overall stove efficiency" is often used. It is a product of the first three partial efficiencies described above

$$\eta' = \frac{\text{net heat input to pot}}{\text{heat consumed by fuelwood}} = \eta_c \cdot \eta_t \cdot \eta_p$$

A cooking efficiency can be defined as:

$$\eta = \frac{\text{heat absorbed by the food}}{\text{heat consumed by fuelwood}}$$

This final efficiency level accounts for all the heat losses. It is the overall stove efficiency multiplied by control efficiency:

$$\eta = \eta_c \cdot \eta_t \cdot \eta_p \cdot \eta_r = \eta' \cdot \eta_r$$

4. Specific consumption

Alternatively, stove performance can be expressed by specific consumption figures instead of efficiencies. For example at the cooking efficiency level

$$SC = \frac{\text{mass of consumed fuelwood}}{\text{mass of cooked food}}$$

There is a link with the cooking efficiency, as

$$\eta = \frac{\text{heat absorbed in cooked food}}{\text{heat consumed by fuelwood}}$$

$$\eta = \frac{(\text{mass of cooked food}) \cdot c \cdot \Delta t}{(\text{mass of consumed wood}) \times \text{heating value}}$$

Thus: $\eta = \frac{1}{SC} \cdot \frac{c \cdot \Delta t}{\text{heating value}}$

when c represents the specific heat of the food, and Δt the temperature change (from ambient temperature to boiling temperature).

$$SC = \frac{1}{\eta} \cdot \frac{c \cdot \Delta t}{\text{heating value}}$$

5. Expected general tendencies and correlations

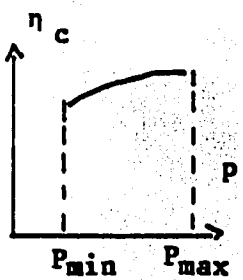


Figure 7

The combustion efficiency might be relatively high at high stove power output (Figure 7). However, in general, a woodstove has a limited power range $P_{max} - P_{min}$ or flexibility P_{max}/P_{min}. Below the power level P_{min}, stable combustion cannot be maintained and thus the combustion efficiency disappears.

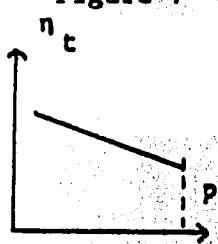


Figure 8

The heat transfer efficiency is expected to increase slightly when the stove power is reduced (Figure 8). This is a well known tendency in any heat exchanger.

The pot efficiency can be written as

$$\eta_p = (1 - \text{pot loss/gross heat input})$$

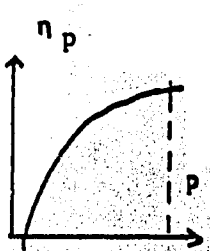


Figure 9

With a given pot temperature, pot losses are expected to be constant; therefore, pot efficiency will decrease when the power is reduced (Figure 9). It goes down to zero when the gross heat input to the pot equals the pot losses.

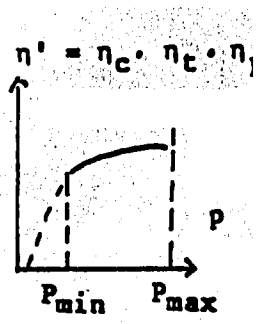


Figure 10

Finally, the control efficiency is close to one as long as the water is not boiling. It drops too close to zero when steam is generated, as little heat is further absorbed in the food (except when food is cooked in large pieces) (Figure 10).

From the preceding it can be seen that overall stove efficiency is zero when the pot is maintained at simmering, without producing steam. If the stove cannot operate at this low power level, the cooking efficiency, not the stove efficiency, is zero.

6. Efficiencies in Water Boiling Tests

The overall stove efficiency can be measured in Water Boiling Tests by heating the stove at high power, or by heating it at a controlled power level where steam generation simulates absorbed heat. A power-efficiency plot can be drawn, with power limits $P_{min} - P_{max}$.

Cooking efficiency can be measured in a similar way. Note that in this case the steam generation is a loss. At simmering power levels the cooking efficiency is close to zero. The cooking efficiency concept therefore has been applied to a cycle that includes both the heating up period and simmering. In this case, however, the cooking efficiency drops as simmering times increase.

A better approach to this problem is to switch to specific consumption concepts:

$$SC = \frac{1}{\eta} \quad \frac{c \cdot \Delta t}{H.V.} = \frac{\Delta t}{\eta} \cdot \frac{c}{H.V.}$$

When the efficiency goes to zero during simmering, the SC figure will not go to infinity (which is meaningless). The reason for this is that the temperature change t is also zero.

For practical reasons a Water Boiling Test report should give not only the specific consumption, but the power limits and evaporation as well. This will make it easier to predict cooking test results from simple Water Boiling Tests.

Cooking efficiencies can more realistically be checked in Controlled Cooking Tests. Again, the concept should be applied to the entire cooking cycle. However, in Controlled Cooking Tests, the specific consumption concept is widely preferred.

Table III summarizes WBT data, and shows how data from WBT can be used to judge stove performance in actual cooking tests. At the top of the table are the WBT data from two different stove models. Below that the WBT data are applied to two imaginary cooking situations. In the first test, 4 kg of food is heated to boiling, and then simmered for 90 minutes. The second test is the same except that the food is simmered only 15 minutes.

The quantity of food cooked is expressed as

$$W' = 4 \text{ kg}$$

The expected water evaporation W_e is computed from the evaporation rate in the WBT, and the duration of the cooking test. The initial food and water used is

$$W' + W_e = W$$

The time to boil is expected to be roughly proportional to the initial food and water

$$(\text{time to boil})_{\text{cooking}} = (\text{time to boil})_{\text{WBT}} \times \frac{\text{initial food and water (CCT)}}{\text{initial water (WBT)}}$$

- The expected wood consumption is the sum of
  - wood to boil: P_{max} x time to boil
  - wood to simmer: P_{min} x simmer time

- The expected specific consumption derives from

$$SC = \frac{\text{wood to boil + wood to simmer}}{\text{water vaporized, pot \#1}}$$

The above approach gives an estimate--not a guarantee. Wood consumption might be higher than shown due to limited dynamic flexibility, poor stove control, or other reasons.

TABLE III

Using WBT Results to Calculate Expected Stove Performance in a CCT

	Stove 1	Stove 2
WBT data:		
Power P (kW)	2 - 4 kW	1 - 4 kW
	0.4 - 0.8 kg/h	0.2 - 0.8 kg/h
Flexibility (P_{max} - P_{min})	2 kw	4 kw
Initial water W	5 kg	5 kg
Water left W'	4.05 kg	4.68 kg
Evaporation W_e	0.95 kg/h	0.32 kg/h
Time to boil t_b	20 min	30 min
SSC_1	0.055	0.080
SSC_2	0.167	0.127
$\eta' = \eta_c \eta_t \eta_p$	~ 0.3...0.3	~ 0.2...0.2
Cooking Test 1 (4 kg x 90 min simmer)		
cooked food W'	4 kg	4 kg
evap. water W_e	0.95 x 90/60 = 1.43 kg	.32 x 90/60 = 0.48 kg
initial food and water W	5.43 kg	4.48 kg
time to boil t_b	5.43/5kg x 20min=22min	4.48/5 x 30 = 27 min
wood: to heat	22/60 x 0.80 = 0.294	27/60 x 0.80 = 0.360 k
to simmer	90/60 x 0.80/2 =	90/60 x 0.80/4 = 0.300 kg
	0.600/0.894 kg	0.660 kg
specific consumption	0.224	0.165
Cooking Test 2 (4 kg x 15 min simmer)		
cooked food W'	4 kg	4 kg
evap. water W_e	.95 x 15/60 = 0.236 kg	.32 x 15/60 = 0.08 kg
initial food and water W	4.236 kg	4.08 kg
time to boil t_b	4.236/5 x 20 = 17 min	4.08/5 x 30 = 24.5 min
wood: to heat	17/60 x 0.8 = 0.225 kg	24.5/60 x 0.80 = 0.327 kg
to simmer	5/60 x 0.8/2 =	15/60 x 0.84 =
	0.100/0.325 kg	0.050 kg/0.372 kg
specific consumption	SC = 0.081	SC = 0.094

Previous Page Blank

APPENDIX II

Interpreting Test Results

A series of Water Boiling Tests, Controlled Cooking Tests, or Kitchen Performance Tests yields many measurements of the same parameters. In order to get the most information and insight from these tests, it is useful to make a few relatively simple statistical calculations.

The first calculation to make from a number of tests of specific fuel consumption, standard specific consumption, etc., is the average or arithmetic mean. The arithmetic mean of n values of the parameter X is given by:

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i = \frac{1}{n} (X_i + X_2 + X_3 + \ldots + X_n) \qquad (1)$$

The second important statistical calculation is the standard deviation, which characterizes the variability between different tests of the same parameter. Standard deviation S is given by:

$$S = \left[\frac{1}{n-1} \sum_{i=1}^{n} (X_i - \bar{X})^2 \right]^{1/2} \qquad (2)$$

The standard deviation divided by the mean yields a parameter known as the coefficient of variation (COV). COV is a normalized measure of variability that is independent of the units of the quantity being measured.

$$COV = S/\bar{X} \qquad (3)$$

Calculation of the mean, standard deviation and COV should be applied to individual series of tests where SSC, specific day consumption (SDC), percentage of heat utilized, etc., are being determined, as well as in cooking or kitchen tests where the difference in fuel consumption or SDC between two different stoves or operating conditions is being studied. In the latter case, the test parameter is first averaged for each household/cook (if multiple tests are conducted with each cook) and then averaged between households/cooks to determine overall average usage or savings. The mean value of a quantity can be estimated more precisely as more measurements of the quantity are

made. The standard error of the calculated mean is the precision with which we make this estimate.

$$\text{Standard error} = \frac{S}{\sqrt{n}} \qquad (4)$$

where n is the number of measurements and S is the standard deviation. There is a 95% probability that the true mean is within $\pm \frac{2s}{\sqrt{n}}$ of the estimated mean (see example below). The variability can be evaluated both within households and among households.

The table below shows the results from a set of Kitchen Performance Tests comparing an open fire and cookstoves designed by a Peace Corps volunteer in Kaya, Upper Volta (Hooper, 1980). The tests, performance on a meal basis, were carried out by Peace Corps volunteers (Schroeder, 1981). Fuel consumption per meal was evaluated in six households, with a total of 9-13 tests conducted per house.

TABLE IV

Kitchen Performance Monitoring Data from a Set of Tests on Open Fires and "Kaya" Stoves

Household	Household size	Average wood use per meal (kg)*		Fuel savings with Kaya stove relative to open fire	
		open fire	Kaya stove	(kg/meal)	%
1	12	3.72 (5)	3.00 (4)	0.72	19
2	6	3.69 (7)	2.84 (5)	0.85	23
3	8	2.58 (6)	1.88 (6)	0.70	27
4	14	4.45 (4)	3.05 (6)	1.40	31
5	6	3.82 (6)	2.13 (7)	1.69	44
6	10	3.10 (4)	2.42 (6)	0.68	22
Average		3.56 (32)	2.55 (34)	1.01	28

* The numbers in parentheses refer to the number of meals over which the fuel consumption has been averaged.

The test results within each household for a particular stove are first averaged as shown in the table. Then, averaging over households is carried out in order to compute overall average fuel savings. In

this example, the average savings is 1.01 kg/meal, or 28% of the average fuel consumption with the open fire.

A high degree of variability between tests (say, COV values of about 30% or more) indicate that there are one or more uncontrolled factors in the series of tests that strongly influence the results. High levels of variability can be expected among households in KPTs but should not occur in highly controlled laboratory tests.

The mean and standard deviation can be used to calculate confidence intervals. Assuming that the results from a series of calculations of the same parameter are normally distributed, the 95% confidence interval is given by:

$$\text{95\% Confidence Interval} = \bar{X} \pm 2S \qquad (5)$$

This means that measurements of the parameter have a 95% probability of falling between X - 2S and X + 2S.

The comparison of fuel consumption, SSC, efficiency, etc., between two different stoves or different operating conditions is a common testing objective. The "t-test" is used to determine whether the test parameter is significantly different for the different stoves or operating conditions, and the significance of any difference. In order to perform the t-test, the mean and standard deviation for each group of tests must be calculated. Then, the t-value can be computed from:

$$t = \frac{X_1 - X_2}{\left[\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right]^{1/2}} \qquad (6)$$

where the subscripts 1 and 2 denote each stove or operating condition. **X**, **S**, and **n** are the mean, standard deviation, and the number of tests, respectively, for each situation.

The computed t-value is compared to values in a t-table to determine if the mean from one group is significantly greater than the mean from the other. An abridged t-table is shown on the following page. The values in the table are listed as a function of the "degrees of freedom" and level of significance. Degrees of freedom is simply the number of test measurements minus the number of parameters what have

TABLE V

T-Table

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

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

been estimated based on the measurements. In this case,

$$\textbf{Degrees of freedom} = n_1 + n_2 - 2$$

The level of significance is the percentage chance that the result indicated by the t-test is not true. Therefore, the statistical difference between the means from the two groups increases as the indicated level of significance decreases.

The t-table is used by comparing the calculated t-value to the numbers in the table at the appropriate degrees of freedom. It can be said that the mean from one group of tests is greater than the mean from the other at a certain level of significance if the computed t-value is greater than the number in the table at that level.

The t-test can be illustrated using the KPT data presented on page 5x. For the open fire tests applied to the household averages, $\mathbf{X_1}$ = 3.56, $\mathbf{S_1}$ = 0.644, and $\mathbf{n_1}$ = 6. For the "Kaya stove," $\mathbf{X_2}$ = 2.55, $\mathbf{S_2}$ = 0.485 and $\mathbf{n_2}$ = 6. The resulting t value using **equation** 6 is 3.07. Also, there are 6 + 6 - 2 = 10 degrees of freedom since the means for each group are estimated. Based on the entries in the t-table at 10 degrees of freedom, the t value is greater than the number at the 1% significance level (2.76) but less than the number at the 0.5% level (3.17). Thus, there is less than a 1% probability that the fuel savings occurred by chance. In addition, from **equation 11**, the 99% confidence interval for the difference in specific consumption is 1.01 ± (2.76 x 0.108 x 3.055) = 1.01 ± 0.91 kg/meal. This means that there is a 99% probability of savings between 0.10 and 1.92 kg/meal. This is consistent with the 95% confidence interval calculated for the Kaya stoves discussed earlier.

The t-test can also be used to check how various uncontrolled factors in cooking or kitchen tests affect or relate to fuel economy. This is done by dividing the test population into two groups, according to the factor of interest. The division can be along socioeconomic lines (for example, high/low income, large/small family size) or based on a factor related to cooking (for example, pot type). If a significant relationship is observed between fuel economy and factors related to cooking, it would be desirable to study the factor more systematically using Water Boiling Tests. Ultimately, it may be possible to reduce fuel consumption by encouraging practices that correlate with higher fuel economy (and vice versa for inefficient practices).

Sample Size Selection

Statistical analysis of test results can also be very helpful for choosing an appropriate sample size (that is, the number of tests to conduct). It is possible to select a sample size for comparative testing based on the anticipated difference in means, variability, and the level of significance desired. As an alternative, a relatively small number of tests can be conducted with each stove or operating condition--say, about five each. Then the level of significance of the difference in means is computed, and more tests can be conducted if a sufficient level of significance has not been obtained in the first round of tests (assuming the initial tests give encouraging results).

The level of significance (α) with which the means of two samples of data can be distinguished depends on the number of measurements (sample size), the standard deviation of the measurements, and the difference between the sample means. If **a** equals an overall standard deviation for the two samples (the denominator in **equation 6**) divided by the mean for all tests,

$$a = \left[\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right]^{1/2} \Big/ \bar{X} \tag{7}$$

where, $\bar{X} = (\bar{X}_1 + X_2)/2$ (8)

and if **d** is the difference between the means of the two samples divided by the mean for all tests,

$$d = (\bar{X}_1 - \bar{X}_2)/\bar{X} \tag{9}$$

then the number of measurements in each sample (sample size) **n** is given by:

$$n > 2[(t_d^\alpha)a/d]^2 \tag{10}$$

where t_k^α is the t value corresponding to a significance level of α and **k** degrees of freedom. For comparative tests in which the means from each sample are derived, $k = n_1 + n_2 - 2$. **Equation 10** is somewhat difficult to evaluate since t_k^α is a function of k and hence n. However, the t-table shows that for n greater than about 8, $t \cong 2.1$ for a

2.5% level of significance, t ≅ 1.7 for a 5% level of significance, and t ≅ 1.3 for a 10% level of significance. For n less than 8, **equation 10** can be solved iteratively.

The following tables of required sample sizes have been computed for two specific values of **a**. The tables show, as expected, that the number of tests required increases as the desired level of significance decreases, as the percentage difference in means decreases, and as the coefficient of variation factor (a) increases. Since the level of significance is the probability that the savings is being observed by chance and will not occur on a larger scale--that is, in the population as a whole--a lower level of significance means the observed savings is more likely to occur in the real world. For cookstoves, a 5% level of significance gives good confidence in the savings and a 10% significance level is still reasonable.

TABLE VI

Minimum Sample Sizes for Various Percent Difference in Means and Levels of Significance

1) (a) = 0.40

Percent difference in means (d x 100)	Level of significance 10%	5%	2.5%
10	54	92	128
20	14	23	32
30	7	11	14
40	5	7	9
50	3	5	7

2) (a) = 0.25

Percent difference in means (d x 100)	Level of significance 10%	5%	2.5%
10	21	36	55
20	6	9	14
30	4	5	7
40	3	4	5
50	2	3	4

The preceding tables show that if the percentage difference in means is 30% or more, less than about 10 tests can be conducted with each stove or operating condition at the 5% level of significance and 7 tests or less at the 10% level. However, if the percentage difference in means is only 10%, 20 tests or more are required. As previously noted, limiting the variability between tests through careful, controlled testing will lower a, and thereby reduce the number of tests needed for statistically significant results.

Confidence Interval for t-tests

The confidence interval for the difference in means of two samples (that is, the average savings) at the α level of significance is given by:

$$(\bar{X}_1 - \bar{X}_2) \pm (t_k^{\alpha} a\bar{X}) \qquad (11)$$

This means that the actual savings has a $(100 - \alpha)$% chance of falling in the range of $[X_1 - X_2 - t_k^{\alpha} a\bar{X}]$ to $[\bar{X}_1 - \bar{X}_2 + t_k^{\alpha} a\bar{X}]$

STATISTICAL ANALYSIS OF TEST RESULTS

A. Type of test (circle):
WBT CCT KPT other _____
Primary test parameter (circle):
SSC PHU SFC SDC other _____
specify unit _____
Secondary test parameter, if applicable (circle):
SSC PHU SFC SDC other _____
specify unit _____

B. Stove type or cooking situation 1*
Describe _____

Test #	Date	Results for primary test parameter	Results for secondary test parameter
Number of tests (n_1)			
Mean value for test parameter (X_1)			
Standard deviation for test parameter (S_1)			
Coefficient of variation (COV_1)			
Standard error ($S_1/\sqrt{N_1}$)			
95% Confidence interval ($X_1 \pm 2S_1$)			

Other comments or calculations _____

* Use the traditional or baseline stove as type 1 and the new stove as type 2, if these categories are applicable.

C. Stove type or cooking situation 2: _____

Test #	Date	Results for primary test parameter	Results for secondary test parameter

Number of tests (n_2)		
Mean value for test parameter ($\bar{X}_2$)		
Standard deviation for test parameter (S_2)		
Coefficient of variation (COV_2)		
Standard error ($S_2/\sqrt{N_2}$)		
95% Confidence interval ($\bar{X}_2 \pm 2S_2$)		
Other comments or calculations		

D. Comparison of results:

Difference in means ($\bar{X}_1 - \bar{X}_2$)		
Percentage savings ($(\bar{X}_1 - \bar{X}_2)/X_1$)		
t statistic $(\bar{X}_1 - \bar{X}_2)\left[\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right]^{1/2}$		
Degrees of freedom ($n_1 + n_2 - 2$)		
Level of significance (smallest α in the t-table for which t statistic is greater than value in the t-table)		

APPENDIX III

Quantities, Scale Effects, and Other Influencing Parameters

The net heat quantity theoretically needed for food processing is proportional to the food or water quantity, or indirectly to the family size. Therefore the concept of specific consumption is used, that is, a consumption per kg (WBT) or per capita (KPT).

However, other scale effects disturb the picture. For example, it is expected that the specific consumption of fuelwood will be higher in a smaller family.

It can be shown that--with geometrically similar pots and comparable fire temperatures and heat flux densities--the time and fuel needed for cooking change with the pot size.

- Time to boil: increases with pot diameter (or cubic root of capacity)
- Heat losses when heating up: same for any pot size
- Heat losses when simmering: inversely proportional to the pot diameter (or cubic root of capacity).

The first scale effect on the time needed can be taken into account by a "specific" time **ST**, derived from the time t_b as measured. Considering 25 cm (about 10") as a reference pan diameter:

$$ST = \frac{\text{time to boil x maximum diameter pan 1 (cm)}}{25}$$

The scale effects involved in fuel consumption can hardly be included as they are different for high- and low-power operation. They should simply be kept in mind when interpreting test results. For example, an 8-liter pan, when compared with a 1-liter pan, will need twice the amount of time to come to the boiling point, but half the specific consumption of wood for simmering.

Many other parameters can influence the fuelwood consumption, often unpredictably. Cooking equipment itself is not responsible for stove performance. The performance depends on the skill, attention, and style of the user, and cannot be standardized or expressed in a "correction factor." It is therefore important to report background data as completely as possible.

APPENDIX IV

Participants at Arlington Meeting

Dr. Samuel Baldwin
CILSS/VITA
B.P. 3826
Ouagadougou, Upper Volta

Prof. dr. ir. G. de Lepeleire
Laboratorium voor Koeltechnik
en Klimaatregeling
Katholieke Universiteit
Leuven Celestijnenlaan 300
3030 Heverlee, Belgium

Dr. Dhammika de Silva
Wood and Cellulose Section
Ceylon Institute for
Scientific and Industrial
Research
P.O. Box 787
363 Bauddhaloka Mawatha
Colombo 7, Sri Lanka

Dr. Gautam S. Dutt
Center for Energy and
Environmental Studies
Princeton, NJ 08544 USA

Mr. Howard Geller
American Council for an
Energy-Efficient Economy
1101 Connecticut Ave., N.W.
Washington, DC 20036 USA

Dr. C.L. Gupta
TERI Field Research Unit
c/o Sri Aurobindo Ashram
Pondicherry 605002 India

Mr. Hamata Ag Hantafaye
Laboratoire d'Energie Solaire
B.P. 134
Bamako, Mali

Mr. Stephen Joseph
Intermediate Technology Development
Group
9 King Street
London WC2E 8HN
United Kingdom

Ms. Karen Kennedy
Aprovecho Institute
442 Monroe Street
Eugene, Oregon 97402 USA

Prof. dr. K. Krishna Prasad
University of Technology, W&S
P.O. Box 513
5600 MB Eindhoven, The Netherlands

Ing. Marco Augusto Recinos
Proyecto Lena
ICAITI
Apartado Postal 1552
Avenida la Reforma 4-47, Zona 10
Guatemala, Guatemala, C.A.

Mr. Sylvain Strasfogel
Association Bois de Feu/GRET
73, Avenue Corot
13013 Marseille, France

Dr. Timothy S. Wood
VITA
1815 North Lynn Street
Suite 200
Arlington, Virginia 22209 USA

Previous Page Blank

Observers at Arlington meeting

Mr. Stephen Klein
Energy Policy Advisor
AID/PPC Room 3887
Agency for International Development
Washington, DC 20523 USA

Mr. Fernando Manibog
Energy Department
Room D-435
World Bank
1818 H Street, N.W.
Washington, DC 20433 USA

Mr. Robert Morgan
(VITA Corporation Member)
Science Policy Fellow
The Brookings Institution
1775 Massachusetts Avenue, N.W.
Washington, DC 20036 USA

APPENDIX V

Participants at Louvain "Woodstoves Seminar"

- Michel Christiaens
- G. de Lepeleire
  Laboratorium voor Koeltechniek en Klimaatregeling
  Katholieke Universiteit Leuven (Louvain)
  Celestijnenlaan 300A
  B-3030 Heverlee, Belgium
  Tel.: 016-23.49.31

- Beatrix Westhoff
- Franz Zinner
  Sozietat für Enwicklungsplanung (SFE)
  Friedrichstrasse 38
  D-6000 Frankfurt am Main 1, West Germany

- Van der Spek Alexander
- P. Bussman
- K. Krishna Prasad
- Vermeer Nord-Jan
- C. Nieuwelt
- M. O. Sielcken
- P. Verhaart
- P. Visser
- P.T. Smulders
- S.F. Laperre
- N. Eossche
  Technische Hogeschool Eindhoven (THE)
  Postbus 513
  5600 MB Eindhoven, The Netherlands
  Tel: 47.38.30/47.21.47

- D.L.M. Baay
- Eric Ferguson
- W.F. Sulilatu
  TON/MT
  Postbus 342
  7300 AH Apeldoorn, The Netherlands

- Robert Celaire
  GRET/GERES, 34 rue Dumont d'Urville, 75116 Paris France
  Tel: 502.10.10
  Centre St. Jerôme
  13397 Marseille Cedex 13, France
  Tel: 98.90.10, ext 367, code 264

- P. Dunn
  Department of Mechanical Engineering
  University of Reading
  Whiteknights
  Reading RG6 2AH, United Kingdom

- H.E. Huynink
  Populierendreef 257
  2272 RE Voorburg
  The Netherlands

- Yvonne Shanahan
- Stephen Joseph
  ITDG Power Unit
  A.R.S. Shinfield
  University of Reading
  Whiteknights
  Reading RG6 2AH, United Kingdom

- Waclaw L. Micuta
  Bellerive Foundation
  5, rue du Vidollet
  CH-1202 Geneva, Switzerland
  Telex: 427993, tel: (22)33.74.22

- Rainer Geppert
- Cornelia Sepp
  GTZ GmbH
  Deutsche Gesellschaft für Technische Zusammenarbeit
  Postfach 5180
  Dag-Hammerskjöldweg 1
  D-6236 Eschborn 1, West Germany

- Peter Pluschke
  GATE (German Appropriate Technology Exchange)
  Postfach 5180
  D-6236 Eschborn 1, West Germany

- Günter Salzmann
  Friedrichstrasse 38
  D-6000 Frankfurt/Main

- Ianto Evans
  Aprovecho Institute
  442 Monroe Street
  Eugene, Oregon 97402 USA
  Tel: 503/683-2776

- Robert Chomé
- Anne Spirlet
- Michel Taymans
  Agence Internationale du Développement Rural (AIDR)
  Handelsstraat 20
  B-1040 Brussels, Belgium

- Alice Guidicelli
  CEE-Développement/Energie
  Berlament 995
  B-1049 Brussels, Belgium
  Tel: 02/735.00.40, ext. 3771

- J.A. Boer
  Ministry Foreign Affairs
  Muzensstraat 30
  The Hague, The Netherlands

- Dr. Timothy Wood
  VITA
  1815 North Lynn Street, Suite 200
  Arlington, Virginia 22209-2079 USA
  Tel: (703) 276-1800

- Bernard Kauffmann
  GRDPR
  145, rue St. Dominique
  75007 Paris, France
  Tel: 705.16.29

- Louis Vroonen
  ABGS (Ministry of Developing Countries)
  Maraveldplein 5
  1050 Brussels, Belgium

- Sylvain Strasfogel
  Association Bois de Feu/GRET
  73, avenue Corot
  13013 Marseille, France
  Tel: (91) 70.92.93

- J.B. Roggeman
  Club du Sahel
  13-15 Chausée de la Muette
  75016 Paris, France

- Vera Van Eenoo
  Zeeptstraat 50
  B-2850 Keerbergen, Belgium

- Donaat Cosaert
- Chris Avondts
  ATOL
  Plijde Inkomststrzat 9
  B-3000 Louvain, Belgium

- Luc Vandaele
  Werkgroep Zachte Technologie
  St. Janshuis
  Celestijnenlaan
  B-3030 Heverlee, Belgium

- Joseph Melotte
  Zandheuvel 1, Appt. 123
  B-8401 Bredene, Belgium

APPENDIX VI

Participants at Marseille meeting, 12 - 14 May 1982

Beatrix Westhoff
Sozietat fur Enwicklungsplanung (SFE)
Friedrichstrasse 38,
6000 Frankfort, West Germany

Elisabeth Gern
Karen Kennedy
Aprovecho Institute
442 Monroe St.
Eugene, Oregon 97402 USA

Ralph Royer
Church World Service
B.P. 11624
Niamey, Niger

Michel Taymans
Agence Internationale du Développement Rural (AIDR)
20, rue du Commerce
B-1040 Brussells, Belgium

Beauchesne Patrick
CTFT
45 bis Bd. Belle Gabrielle
94130 Nogeret/Marne, France

Annette Legris
FIEF
5, av. Porte Braucion
75015 Paris, France

Patrick Hauser
Etudiant
16, rue des Samfoins
77380 Combe la Ville, France

Bernard Kauffmann
GRDRP
145, rue St. Dominique
75007 Paris, France

Pedro Costez
ICADA-Choqui
Apartado postal 159
Quetzaltenango, Guatemala, C.A.

Roberto Cáceres
ICAITI
Apartado Postal 1552
Avenida la Reforma 4-47, Zona 10
Guatemala, Guatemala, C.A.

Malcolm Lillywhite
D.T.I.
Box 2043
Evergreen, Colorado 80439 USA

Philippe Simonis
G.T.Z.
Postfach 5180
Dag-Hammerskjöldweg
Eschborn 1, West Germany

Yvonne Shanahan
Stephen Joseph
ITDG
A.R.S. Shinfield
University of Reading
Whiteknights
Reading RG6 2AH, United Kingdom

Sylvain Strasfogel
Association Bois de Feu/GRET
73, avenue Corot
13013 Marseille, France

G. de Lepeleire
Katholieke Universiteit Leuven
Waversebaan 178
B-3030 Heverlee, Belgium

Woodstove Group
Technische Hogeschool Eindhoven (THE)
Postbus 513
5600 MB Eindhoven, The Netherlands

Mr. W.J. Weerakoon
T.D.A.U.
University of Zambia
P.O. Box 32379
Lusaka, Zambia

Mme. Seck
CERER
B.P. 476
Dakar, Senegal

E. Ferguson
van Dormaalstraat 15
Eindhoven, The Netherlands

Alice Guidicelle
200, rue de la Loi
B-1049 Brussels, Belgium

Cherif Zaouch
ITTA
Sidi-Bau-Ali
4040 Tunisie

L. Van Daele
ATOL
Holsbeeksesteenweg 117
B-3200 Keseel-Lo, Belgium

FEISEAP
Faculty of Engineering
Chulalongkorn University
Bangkok 5, Thailand

Tata Research Institute
Bombay House
24, Homi Mody Street
Bombay 400023, India

APPENDIX VII

Other Reviewers

The following list was compiled from suggestions made by Arlington meeting participants.

Dr. J.E.M. Arnold
FLCD
United Nations Food and Agriculture Organisation (FAO)
Vie delle Terme di Caracalla
Rome 100, Italy

John Ashworth
Associates in Rural Development
362 Main Street
Burlington, Vermont 05401

Ken Darrow
Volunteers in Asia
Box 4543
Stanford, California 94305

Dr. Lamine Kaba
Roghane Research Centre
P.O. Box 561
Conakry, Guinea

Prof. Kumar
Chemical Engineering Dept.
Indian Institute of Science
Bangalore 560012 India

Prof. Igbal Mahmud
Chemical Engineering Department
Bangladesh Univ. of Eng. and Tech.
Dacca 2, Bangladesh

Dr. Pablo Mulas del Pozo, Director
Div. Fuentas de Energia
Instituto de Investigaciones Electricas
Cuernavaca, Morelos, Mexico

Dr. Mark J. Mwandosya
University of Dar Es Salaam
Dept. of Electrical Engineering
P.O. Box 35131
Dar Es Salaam, Tanzania

Keith Openshaw
c/o Ministry of Energy
P.O. Box 30582
Nairobi, Kenya

Previous Page Blank

Organización Latinoamericana de Energía (OLADE)
Casilla 119A
Quito, Ecuador

Lic. Ana Maria Palomo
CEMAT
Apartado Postal 1160
Guatemala, Guatemala, C.A.

Sr. Hugo Pineda
Centro Choqui
Apartado Postal 159
Quetzaltenango, Guatemala

C.V.S. Ratnam
Adviser on S&T Policy
ESCAP Regional Centre
P.O. Box 115
Bangalore 560 052, India

Prof. Amulya Reddy
Indian Institute of Science
Bangalore 560 012, India

E. Griffin Shay
BOSTID Room JH-213
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, DC 20418

Asif Sheikh
Energy/Development International
1110 Vermont Avenue, N.W.
Washington, DC 20005

William Stewart
Sarvodaya Institute
Palletalawinna
Katugastota
Kandy, Sri Lanka