ACTIVITIES ACCOMPLISHMENTS, AND RECOMMENDATIONS

A REPORT FOR THE SOMALIA NATIONAL WOODSTOVE PROGRAM

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VITA/UNICEF

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1) INTRODUCTION

This report covers the consultant's activities and observations during his visit from Dec. 30, 1984 to March 6, 1985. The goal of this visit was to give assistance to the staff of the VITA/ Somalia National Woodstove Program. This program is now in its third year of existence, and has developed two stoves which are ready to be put into production and disseminated. The focus of this work was on assisting in the successful production of these stoves.

The consultant was also given the mission of assisting VITA in establishing working relationship with the UNICEF sponsored CARE Forestry project in the Northwest Region of Somalia.

Throughout the visit to Somalia the VITA staff worked hand in hand with the consultant. The results and recommendations which follow should not be attributed to the consultant alone, as they were all arrived at through a cooperative effort.

2) ACTIVITIES AND ACCOMPLISHMENTS

Testing

The results of all lab and field tests conducted to date were reviewed. The consultant was requested to first evaluate the test results obtained, and then train the staff in the areas which were found to be lacking. Please refer to Appendix One for a summary of this work which was submitted during the term of this work.

Soapstone Stove Design.

The development of the Soapstone stove design was reviewed with the staff. The major issues with the present design had to do with producibility and quality control. Three aspects of the stove present particular problems in this regard: 1) the grate, 2) the draft control, and 3) the size of the soapstone block needed to make the stove.

Upon arrival, the VITA staff had concluded that soapstone was a poor material for a grate, as it tended to crack after a short period of use. They had turned to the use of a thin sheetmetal grate, made by a local metalsmith. The grate holes were poorly distributed, as well as being too few. Efficiency tests showed no detectable difference in the performance between a stove with a soapstone grate, and that with a metal grate. The production cost was 40 shillings per metal grate with a life expectancy of less than 12 months. Since the stove is expected to last for at least five years, this was seen as an unacceptable design.

After discussions, it was decided to design a cast iron grate, which could be produced at any of the three local foundries. Such a grate should last for at least five years, and will cost under 80 shillings. It was also felt that the cast grate would be recognized as a quality item by customers. The consultant designed a grate, and met with managers of local foundries. Bids for the work have been between 50 and 80 shillings per piece in quantities of 1,000. Quality control should not be a major problem, as all of the shops being considered are experienced in these operations. As a precaution, the consultant has developed a brief list of tolerances.

Minimum Tolerances For Cast Iron Grate

Thickness- 1cm, +-0.2cm

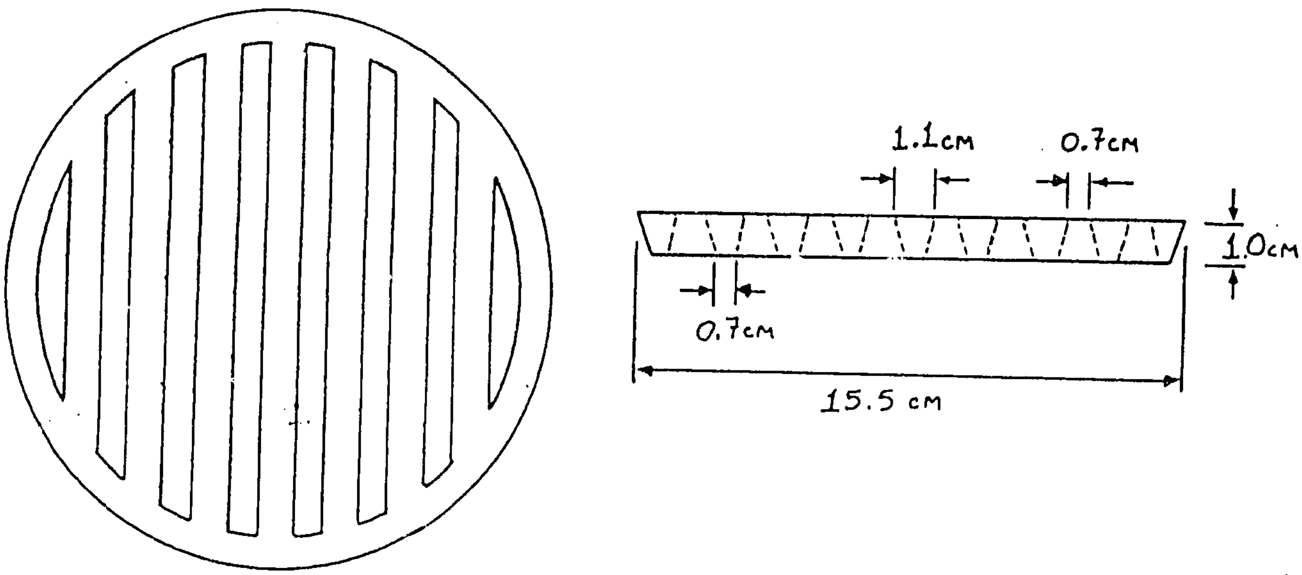
Diameter- 15.5cm, +-0.2cm (including any remaining flashing)

Width of top of grate cross bars- 1.1cm, +-0.2cm

Width of bottom of brate cross bars- 0.7cm, +-0.2cm

Space between cross bars- 0.7cm, +-0.2cm

Maximum thickness of outer ring- 1.1cm



Top View   Cross Section

Figure 1, Cast iron grate

The second design aspect considered was the overall size of soapstone block required to make the improved stove. VITA had been told that it would be impossible to produce the stove in large quantities in the size requested. In successive production runs, the stoves became narrower to the point that virtually no pots would sit into the stove.

It was the consultant's belief that the efficiency would not be significantly reduced if the top part of the stove was omitted. Through a series of eight controled tests, this concept was verified (see table 1 and figure 2). In this way, pots of all sizes sit at the same level on the stove. By taking this portion of the stove off, it reduces the overall dimensions of the stove considerably. The marketing implications of this alteration are yet to be determined: many people found the larger size of the improved stove to be attractive. In fact, leaving the stove in its full size was not a possibility due to the dramatic production problems.

Test #	with or without Top	Water loss Loss (ml, +-40)	Charcoal Used (gr, +-20)	PHU (%, +-3)	GSC +-0.02
1	without	910	370	27	0.18
2	without	980	330	33	0.16
3	with	980	320	32	0.15
4	with	890	330	31	0.16
5	without	750	300	34	0.13
6	without	740	290	30	0.13
7	with	895	340	30	0.16
8	with	725	310	29	0.14
OVERALL AVERAGE		876	324	30	0.15
WITH TOP AVERAGE	WITH	853	325	30	0.15
WITHOUT TOP AVERAGE	WITHOUT	900	323	31	0.15

Table 1: Results of test of stove with and without top section.

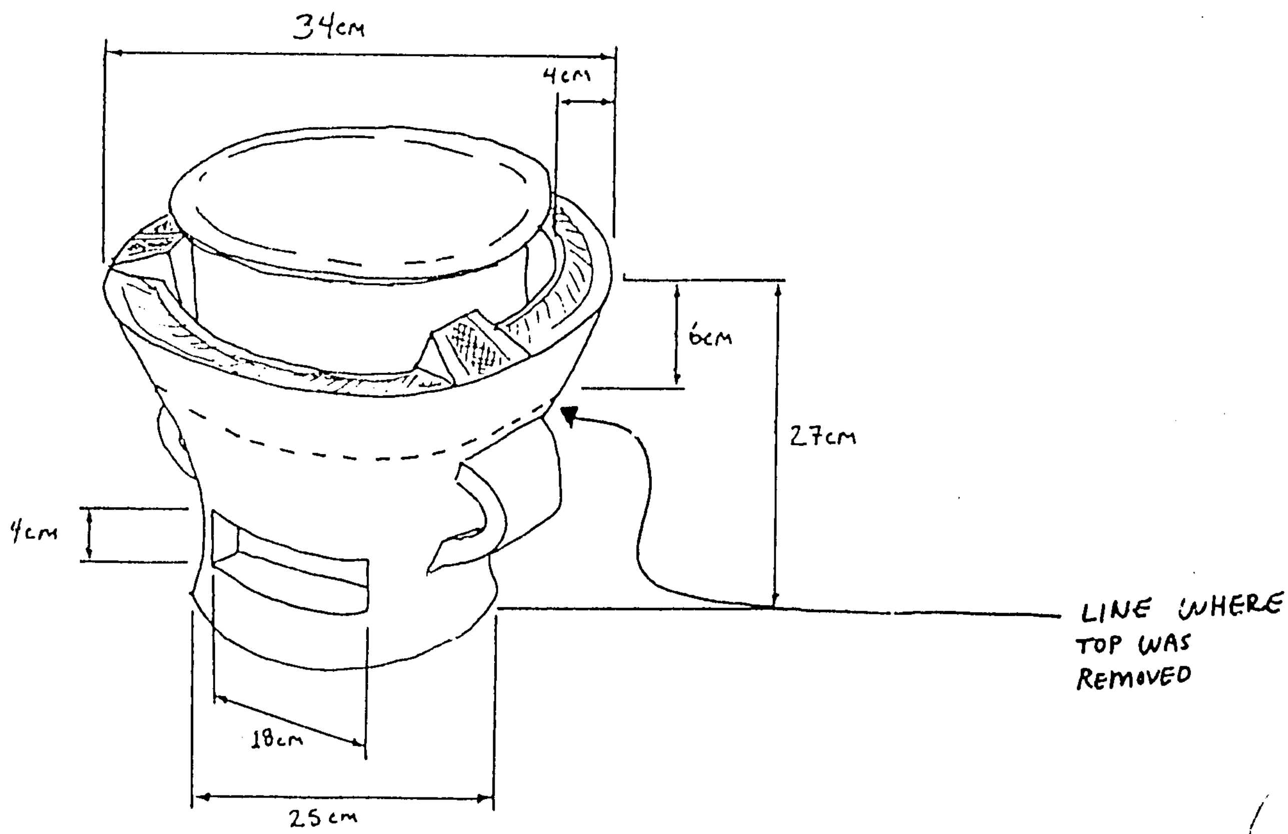


Figure 2: Test configuration with and without top section.

The third problem addressed by the consultant was the production of a high quality draft control. The draft control which has been employed to date has been difficult to produce, and has a very short working life (approx. 6 months). Although there was not time to test other options, several ideas were generated, which are presented here.

Soapstone door with copper insert. This door is a simple modification of the present draft control. To install this door, first the piece of soapstone is cut to the desired size. The door is put in place, and a long nail (should be made from 3 mm wire) is pounded into the base of the stove until it just hits the door. The door is removed, and at the location of the nail, a hole is drilled. A section of 3 mm inside diameter copper water pipe is inserted to act as a bearing with the nail. One small washer is used to support the pipe, once the door is installed.

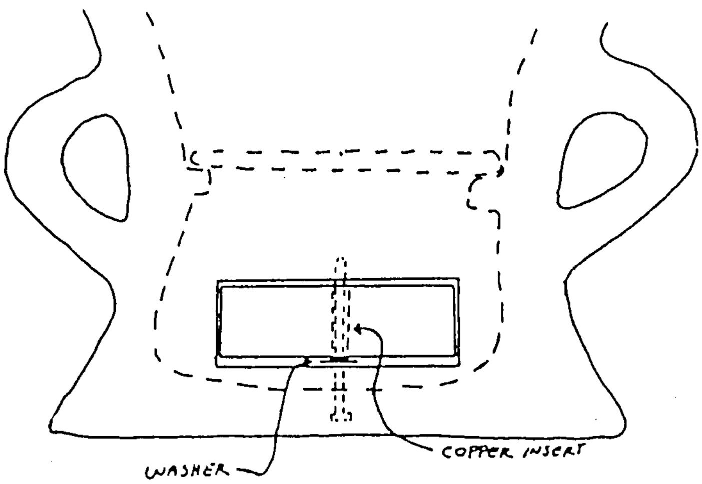


Figure Three: Soapstone door with copper insert.

Leather Door. In this case, the door is simply made from a piece of full grain leather, as shown. This door would be durable, and easy to construct, and could be reinforced around its mountings with extra leather, or metal washers.

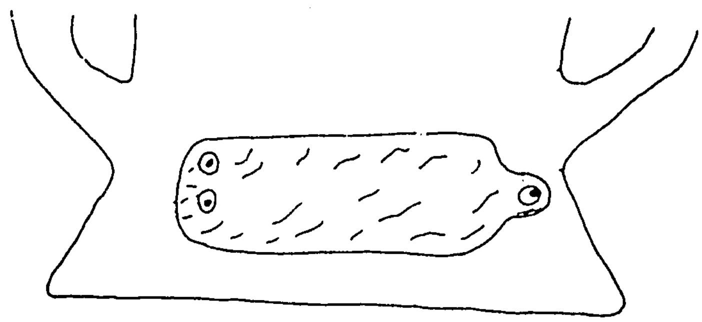


Figure 4: Leather door.

Soapstone door with metal hinges. The success of this approach lies in the strength which nails have in soapstone.

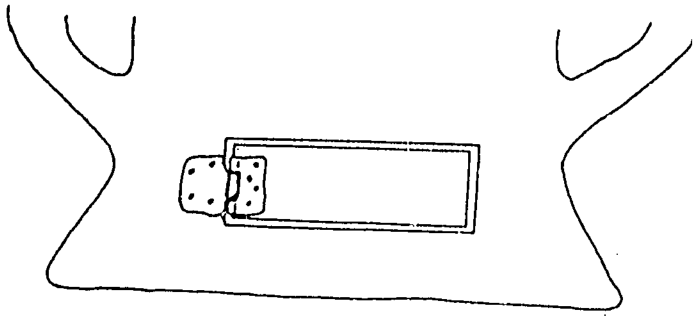


Figure 5: Soapstone door with metal hinge

Two part sheet metal door. This door could be made in large numbers, then bent to fit the particular stove. It could also be used to standardise the door size, which has varied considerably on the stoves built to date.

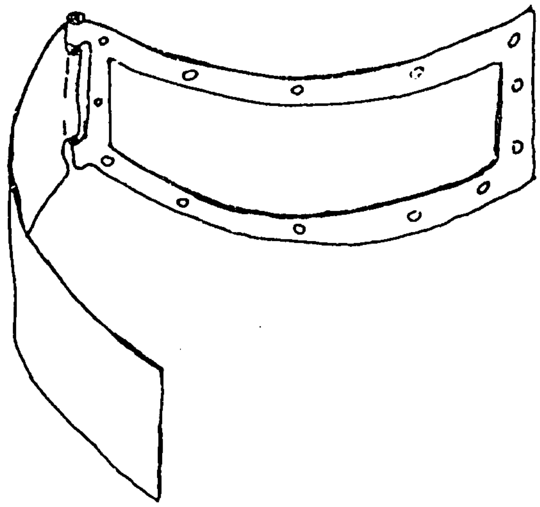


Figure 6: two part sheetmetal door.

The results of testing in the lab indicate that the draft control is essential to preserving improved performance. **This problem should be taken as a top priority.**

The consultant also worked with the staff in developing quality control guidelines for the production of the improved stove. This problem was dramatically exibited when a first shipment of twenty one stoves was brought to the Mogadishu office during the consultants visit. Of these stoves, no less than 19 required reworking before they were acceptable for use in a field test. The consultant attended to these changes. The following items were noted to be frequently beyond the limits of acceptablity.

ROUNDED BOTTOMS: 9 stoves had severly rounded bottoms, which made them unstable.

SMALL AIR INLET UNDER GRATE: 19 stoves had inlets less than 12cm in diameter. This opening should be at least 13 cm to allow air to come in complete contact with the coal bed.

SHALLOW FIREBOX: 1 stove had a firebox under 10cm deep, which is unacceptable.

POOR AIR CONTROL: 3 draft controls were totally jammed, and only 2 were seen to be of good quality.

Such problems must be taken care of by the Soapstone Cooperative for this stove to have a chance at long term dissemination. It is VITA's responsibility to let these problems be known to the Cooperative, and assist in resolving them.

The topic of marketing the improved soapstone stoves was also considered at some length with the staff. The following ideas were agreed to:

1) The grates should be transported to El Bur to be sold as a unit with the stove to wholesalers. In the long term, it was thought that the logistics of transport should be carried out by the Soapstone Cooperative. As an incentive to the cooperative, and as a partial price support for the stove, the first 2,000-4,000 grates should be paid for by VITA.

2) As an incentive to the wholesalers to carry the stoves to market, they should be be given a sales guarantee. If they are unable to sell the stoves on the market, VITA guarantees that they will buy the stoves for the EL BUR wholesale price. In this way, there is not incentive to the wholesalers to carry the stove just to sell to VITA, but they are assured that they will not be a total loss if the market cannot accept the stoves. This technique leaves an easy path for VITA to take to get out of the marketing of stoves once the new product catches on.

3) If further price subsidies are required, they are to be phased in, to assure VITA that the subsidies are at the minimum required level. This minimizes the shock to the market when subsidies are terminated. Options include partial payment of the price of the stove at El Bur, free advertisement, etc.

The overall concensus of the discussions was that VITA should keep their involvement in the marketing as small as possible, utilizing traditional market forces as much as possible. It was agreed that this was the most effective way to assure long term dissemination of the stoves.

Training

This VITA project has been particularly successful in staff development. In light of these successes, and responding to the immediate needs of the project, several areas of training were undertaken. The most apparent needs were in comprehension of numerical values, and documentation in the form of drawings. The lecture notes from two sessions can be found in appendix 3 .

UNDERSTANDING CALCULATED QUANTITIES. Both in field and lab tests the staff must use the data collected to calculate standard comparative quantities. Using the calculation of Gross Specific Consumption as an example, we discussed how to discern the significance of a number obtained through such a calculation. The concept of dominant variables and misleading results were investigated using actual VITA test data.

UNCERTAINTY. Concepts of aggregate uncertainty from calculation, and uncertainty of groups of data were discussed. Examples from VITA tests were used as the basis of the lectures. Techniques for determining the uncertainty of individual calculated quantities and standard deviation of average values were introduced. Each of the staff recieved copies of the lecture notes contained in Appendix 3.

BASIC DRAWING SKILLS. Conducted three classes covering basic drawing as applied to the subject of cookstoves. The classes were co-instructed with consultant Childers. Homework assignments were completed by all participants, and marked improvements were noted.

The concepts introduced in these sessions were reinforced in actual use where ever possible.

3) RECOMMENDATIONS

1) Concentrate efforts on marketing the improved soapstone stove in the Northwest region.

The stoves presently used are of very low efficiency, where as in the south, the soapstone stoves which are used for coooking are of high efficiency.

Deforestation is much more severe in this area, and the production methods of charcoal are much less efficient. The impact of a fuel saving stove would be much greater.

2) Have Mohamed Hassen visit the UNICEF/CARE cookstove project at least once every two months, as was generally agreed. Provide technical support by way of occasional lab testing in Mogadishu, and design verification in the Northwest. (see Appendix 5).

3) Have a VITA intern come to Mogadishu to assist the staff in documenting the evolution of the project. This would be a very valuable learning experience for the staff, and would facilitate the sharing of the lessons of the work done here with other stove projects. In particular:

Ceramic Stove Design Evolution. Cookstove programs around the world are turning to ceramic stoves as an inexpensive, locally made solution. Unlike metal stoves, there have been few successful ceramic stove projects, and information is sorely needed. The process of documenting the progress to date, and next steps to be taken, would also be a valuable motivational tool.

Experiments in mass marketing of stoves. This is another important development in improved cookstove dissemination. This information would be a timely addition to the field of improved cookstoves.

Project Managment: A success story. This project was an exceptional case of quality management on the part of Hank Cauley. A brief review of the techniques used would be useful for others who find themselves with difficulties of managment.

4) PROGRAM EVALUATION

Staff

The staff involved with this project is without a doubt the most competent observed during the consultant's work in Africa. Beyond particular skills, the members have effectively worked together to build a whole which is far more than the sum of its parts. The experience and development for all of the members of the staff is certainly one of the primary products of this project, no matter how many thousand stoves are finally produced.

Hank Cauley- Applied creative and effective managerial skills which were central to the success of the project. Over-extended in duties and responsibilities, which held the progress of the project back to some degree.

Mohamed Qabile- Provides a good balance of moderation to the project. His thorough attention to issues is helpful. Will become more effective as his understanding of the project increases.

James McCormick- An enthusiastic, goal oriented facilitator. Excellent in working with the Somali staff, and bueracracy. Development of technical issues of the stove project will increase his ability to monitor the project. Marketing intuitions are a timely addition to the project, and are of great assistance.

Mohamed Hassan Nur- Acutely aware of the technical and logistical aspects of the project. Very effective at keeping the full scope of the project in mind, which is critical at this time. The scope of his assignment is too large for one person to handle. Will need to delegate tasks to other staff, and take a more managerial role, particularly until McCormick and Qabile are able to accept this responsibility.

Dahir Ahmed Kolonbi- Completely dedicated to the success of the project and a very good team worker. It is clear that Dahir has developed greatly in this position. Dahir fits the role of technical assistant to Mohamed Hassan well, and in this capacity is invaluable. Emphisis should be put on Dahir's ability to evaluate and recomend ideas based on his observations. More careful note taking by Dahir, and greater investment of responsibility by Mohamed Hassen would facilitate this.

Jinah- Jinah is capable of directing his own activities with minimal input. He grasps the import of his assignments, and fulfills his duties completely up to the required level. It is unfortunate that he is leaving the staff, as his contribution has been most valuable.

Mohamed Ali Noor- Mohamed is an intelligent, experienced field worker. The task assigned to Mohamed is very large, and in actual fact, outside of his area of expertise. Even so, his accomplishments are quite impressive, particularly his kiln building activities in Belet Huen. Focus, patience, and attention to detail will be required of Mohamed in the coming months.

Abdirahman- Abdirahman's experience, and ability in facilitating the finnacial aspects of the project are the hidden reinforcement for all of the activities of the staff. Many times over he showed his ability to single-handedly resolve complex and crucial matters. His competence has freed Jim and Qabile to attend to the countless non-finacial details which arise in alarming number daily.

Program

The approach taken by the VITA staff was most ambitious. They have undertaken to develop a set of stove designs, production sites, and marketing channels over the whole of Southern Somalia. The process has been deliberate and methodical. Overall the consultant was very impressed with the strides taken by the team.

The inherent difficulty of this task is the interelated nature of each separate element. The design must fit the cooking habits, the producers' abilities, and the traditional marketing patterns, to say nothing of being efficient. In the consultant's opinion this type of project must be tackled as a whole, working on all fronts at once. From our observations attention to the production problems was delayed in deference to the "completion" of the lab testing. In actual fact, the designs have been, and will be, substantially modified through the production phase of the work.

The lab testing efforts were by no means wasted, as they provided excellent training for the staff on cookstove design. The laboratory tests were carried out with insight, and thoroughness, which has increased the utility of the results several fold.

The planned activities for the remainder of this year are well conceived. With the staff, resources, and a sturdy foundation in hand, the consultant believes that this project will live up to all goals and expectations held for it.

APPENDIX 1.

Memorandum

DATE: Jan. 18, 1985

RE: Evaluation of VITA/Somalia Stove Testing

TO: Project Director: Hank Cauley
Co-director: Mohamed Noor Dabile
Technical Director: Mohamed Hassan
Research Assistant: Dahir A. Kolonbi
UNICEF Director of Technical Support: Phil Hassrick

FROM: UNICEF Consultant: John Selker

Summary of Observations

1) **Overall quality of measurements is very high.** Having worked for one year on water boiling tests, the technical staff has refined their methodology to effectively obtain reliable, repeatable results in each test. There is excellent understanding of significant testing procedures.

2) **Qualitative evaluation from testing is employed in developing stove designs.** Test results are understood sufficiently to apply the results in design decisions.

3) **Understanding of calculated quantities needs attention.** The staff's comand of the testing procedures stems primarily from VITA's provisional testing standards. Intuitive grasp on the rational for the tests, and calculated quantities (e.g. PHU, GSC) should be developed. The staff is keenly aware of this situation.

4) **Controled Cooking and Field Test inputs are needed.** In light of upcoming mass production, the results of these tests are urgently needed for practical verification of the laboratory results.

5) **Testing documentation needs additions.** Particularly good quality drawings, and written qualitative evaluation of the unit under test.

Actions to be taken by UNICEF consultant Selker to aid testing program

1) Discuss, explain implications of the tested and calculated quantities. Focus on:

UNCERTAINTY. Review concept of uncertainty in measurements, explain calculation of uncertainty in calculated quantities, introduce concept of uncertainty in averages of experimental data (e.g. standard deviation).

REVIEW PRIMARY CONCEPTS. Focus on the concepts of gross specific consumption (GSC), and percentage of heat utilized (PHU). Review implications of these ideas in the context of stove evaluation. Discuss significance to this stove project.

2) FIELD TESTING. Work with Mohammedd Hassan and Mohammed Ali Jinah in the design of upcoming controled cooking and field tests. Create field testing plan, and time line to be followed in February in the Lower Shabelle Region.

3) DOCUMENTATION. Conduct basic drawing seminars to improve documentation, and dissemination materials. Concentrate on proportion and perspective in drawings.

4) CONTROLED COOKING. Design and conduct tests with the staff in the laboratory, and in controled cooking conditions. Emphasise goal-oriented testing strategy (as opposed to spectrum testing of all stove models).

5) TECHNICAL REVIEW. Summarize conclusions of tests to date in report/article form. Submit copy to ITDG for publication in journal Boiling Point, use as testing justification of production design.

Review of Tests Done to Date

1) The traditional soapstone charcoal stoves of Somalia are unusually efficient.

In particular, the traditional Soapstone charcoal burning stoves have higher efficiency than improved cookstoves in most other countries, as well as being very safe. The primary problem with the traditional stove is incovenience, since the stove needs constant ventilation for high power use (achieved by waiving a hand fan).

2) The improved soapstone stove gives improvement in convenience of operation, and superior high power efficiency.

The stove design is quite good, having gone through a systematic evolution of designs. The present design has exceptional efficiency in both high and low power operation, is easy to use, and is a very safe stove (outside surface temperatures rarely go above 85 C, and stability is excellent). High power efficiency is 40% higher than the traditional soapstone stove, with low power operation being very similar to the traditional stove.

I concur with the staff's conclusion that the improved soapstone stove should be disseminated in to complement the present use of traditional soapstone stoves, and thus reducing consumption among people who are employing more wasteful methods of cooking (eg. the North Western region among users of very inefficient metal stoves).

3) The traditional ceramic stoves are effective heaters, but are difficult to control, thus leading to high fuel consumption.

In the laboratory tests we have seen that the Percentage of Heat Utilized in the traditional ceramic stoves is very similar to that of the improved stoves. With the improved stoves, however, it is easy to build a small fire, as is needed for most cooking operations. This fact has been noted in laboratory tests by a 44% improvement in low power gross specific consumption (a good indicator of simmering efficiency), and a 17% reduction in overall fuel consumption. While these results are suggestive, they will be convincing only after the completion of field testing. Preliminary field tests showed dramatic fuel savings, however the stove design has been changed substantially since those tests were completed, thus more field tests are vital to the project at this point.

4) Improved ceramic stove design shows good efficiency, but must be field tested.

Wood stoves are particularly subject to variation between laboratory and field results. This project has experienced several unexpected negative reactions to the new design, which they have accommodated. With this stove in particular, the field tests yet to be completed will be the key indicators of potential fuel savings. Laboratory tests do show evidence of improved efficiency (see 3), which are noteworthy.

APPENDIX 2.

FIELD TESTING

Goals

The most important question to answer first is, What do we want to find out in this field test? Some possibilities are:

- acceptability of stove design (do we want feedback in order to modify the design?)

- durability of stove (and where its weakest point is, so that the stove can be strengthened there)

- fuel use with new stove design as compared to traditional stove

- attitude of stove users regarding fuel efficiency and other factors.

Of course, you will have many small goals. The point of listing your goals is to make sure that your field test is focused to answering your most pressing questions. At different stages of your program, you will have very different needs: in the early stages of a stove program you will be making broad decissions in design changes, while later you will be refining details of design, looking at marketing, and establishing actual fuel saving.

Survey Design

The next questions to ask is how do we get this information? People tend to tell you what they think you want to hear. The kitchen is a very intimate part of people's lives, you must be very careful when you go into the kitchen to gather information. Another difficulty is that the mere fact of your presence is going to change what goes on; you cannot gather information without affecting it.

Because field testing is closely tied with the cooking habits, and culture you are in, there are no "rules" which will tell you what questions to ask, or exact method to follow. You will have to follow your own observations, designing, and altering the test to suit the people you are dealing with. At the end of each field test, you should meet with the field staff to discuss how the test went, and what suggestions they have for future tests. This is very valuable information, that no book, or expert can give you.

In the early trial stages, the field test designers should spend enough informal time in kitchens so that there are very few surprises in gathering information on paper. This may well take several visits of just talking, and listening. After each visit notes should be taken on any pertainate comments; often these comments hold as much information as the later numbers that you will gather will. The formal information gathering will serve to quantify the impressions gathered informally and give a realistic view of fuel savings.

How questions are phrased has a big effect on the answers given. For example, suppose you notice in informal observations that the cook has to go to alot of trouble to keep the stove lit in the first 10 minutes she is using the stove. If the questionnaire asks, "Is it easy to light the stove?" that person may well answer "Yes." Maybe she doesn't consider the time spent keeping the fire going as part of lighting, or she is polite and wants to please you, or she feels that she does not know very well how to light the stove yet. The question could be asked several different ways: "Once you light the stove, how long is it before you can leave the stove unattended and the fire will stay lit?" (remember that not every housewife wears a watch.) "Do you have trouble keeping the fire going once you have lit the stove?"

Finally, have as many people look over your strategy as possible. A field test is a people oriented thing, and different people will have different reactions to your questions.

Control Groups

In the case of improved stoves, we judge the new stove in relation to the traditional method of cooking, and there by see how much of an improvement the stove really is. The role of a "control group" is to provide you a basis for comparison. The control group is just the same as your test group, except that they are cooking in a traditional way.

The key here is that you are trying to test the change in fuel consumption changing only the stove which is being used. We call this testing for "one variable". It is important that you have the same family size, economic level, and traditional cooking method in both your test group and control group, so that you really are just testing the change in fuel consumed as a result of the new stove, rather than some difference in the life style of your two groups.

How to know how big of a sample to take

The bigger your sample is, the more accurate and complete your information will be. Typically testers use at least 10 families for each the test group, and the control group, which makes for a total group of 20 families. If you are testing more than one stove, you need not have another control group, as the one control may be used for both (assuming that the stoves use the same fuel type).

APPENDIX 3

What is Uncertainty?

Say we are selling oranges and we want to know what fraction of our stock we have remaining at the end of the day. We start the day with 50 Kg, and sell 20 Kg. The problem that we have is that our scale is only accurate to plus or minus 10 Kg. How much fruit do we have remaining?

Well, if we were not concerned with uncertainty, we would simply divide the stock remaining at the end of the day by the stock wew had at the begining of the day, and have the fraction of the stock which remained:

30 Kg/50 Kg = .6 .

This can also be written as a percentage:

.6 x 100% = 60% .

The question now is how sure are we that we have 60% remaining? Any number that is obtained by a measurement has some amount of uncertainty. For instance if you measure the length of a pencil with a ruler, you can only be as accurate as your eyes can see, and as the ruler was made. In this example, the scale was only accurate to plus or minus 10 Kg. We would write the fraction as:

$$\frac{30\ \text{kg}\ (+-\ 10\ \text{kg})}{50\ \text{kg}\ (+-\ 10\ \text{kg})}$$

To find out what our uncertainty is, let's look at the two worst cases:

the lowest our fraction could be would be if the scale measured 10 Kg high in the morning, and 10 Kg low in the evening.

$$\frac{20\ \text{kg}}{60\ \text{kg}} = .33$$

the highest our fraction could be would be if the scale measured 10 Kg low in the morning, and 10 Kg high in the evening.

$$\frac{40\ \text{kg}}{40\ \text{kg}} = 1.0$$

So the lowest that the fraction of oranges remaining could be is .33 , and the highest that the fraction could be is 1.0. This means that it is possible that we didn't sell any oranges at all, but just that the scale made it look like we did! If all we sell is oranges, that can be pretty dissapointing. Maybe it's time for a new scale!

Now let's look at another way to calculate the uncertainty of this measurement. There is a rule (which was figured out by people who make uncertainty thier business) that when you are dividing or multiplying uncertain numbers, the uncertainty will be equal to the sum of the fractional uncertainties. This is more clear when we consider the uncertainties as percentages of the measurement. For instance, 10 Kg is 20% of 50 Kg, and is 33% of 30 Kg. . Thus, using the rule that I just told you, we would simply add the percentage uncertainties. 20% + 33% = 53% . I will round his number to 50% to maintain what we call one significant digit, which I will talk about a little later. We can compare the result from this method with the result from our worst case calculation above.

50% of .6 is .3, so our worst case towards the high end would be .9, and the worst case on the low end would be .3.

You can see that these numbers are slightly different than those obtained from the worst case method, however the fact is that both of these methods are being used to get an idea of the uncertainty in the calculated quantity. Notice that both of these methods give us close to the same value for the uncertainty, and this is all that we can ask for from uncertainty calculations. You have to get used to the uncomfortable feeling of not knowing exactly, which is how the real world works, and thus, how the laboratory, or field measurements work.

Now let's look at another calculation we might need to do if we were selling oranges. Let's figure out how many kilos of stock we have remaining. To find this we just subtract:

50 kg - 20 kg = 30 kg .

But how sure are we that this answer is correct? Again, let's start by looking at the worst cases:

least possible fruit remaining: most possible fruit remaining:

40 kg - 30 kg = 10 kg 60 kg - 10 kg = 50 kg

So it would be more realistic to write that we have:

30 kg (+- 20 kg) of fruit remaining.

The rule for uncertainties in addition or subtraction is that uncertainties are added. Thus, our fruit sales person should write:

50 kg (+- 10 kg) - 20 kg (+- 10 kg) = 30 kg (+- 20 kg)

In many cases you will have a long calculation that will involve many steps of addition, subtraction, multiplication, and division. Often different values will have different uncertainties, since they were measured using different scales, or were arrived at from previous calculation. In this type of situation we simply use the two rules and calculate the uncertainties as we go, in the same steps as we calculate the answer to the calculation. As an example, let's look at one of the calculations used in stove testing. Using the actual data from a test on a "Shabelle 2" wood stove, done on September 3, 1984, let's see what the uncertainty is on the value obtained for the stoves Gross Specific Consumption (GSC).

We see from the notes on testing, that the GSC is calculated from the following formula:

GSC = Gross fuel consuption (Effective Dry Weight of fuel)
Weight of Water Remaining

to get the uncertairty, we must start with the actual numbers from the laboratory measurements. Starting with the numerator of the above fraction, we recall that the Gross Fuel Consumption (GFC) was actually calculated by subtracting the weight of fuel remaining at the end of the test from the fuel weighed at the beginning of the test. This subtraction will be done just as in the case of the fruit merchant, with uncertainties being added. Then this weight was multiplied by the ratio of dry weight of wood to wet weight of wood, to get the effective dry weight. This ratio was also the result of calculation on measured quantities, so it will have an uncertainty that must be calculated, and taken into acount. So let's start by calculating the numerator of the above equation.

GFC = (Weight of wood initially (WWI) - Weight of wood finally (WWF)) X

(Dry Weight / Wet Weight).

From looking closely at the scales in the laboratory, we can say that the uncertainty of these measurements is about plus or minus 10 grams. We will do this calculation one step at a time using the numbers from the lab, first:

WWI - WWF = 1790gr (+- 10gr) - 380gr (+-10gr) = 1410gr (+- 20gr)

Now, going on to the ratio of dry weight to wet weight, we see that there were no numbers written down for the weight of wood wet, and weight of wood dry. In this case we will have to guess that the wood sample started off as 1.00 kg, and ended up as 890 gr (I get this from the number in the test results that there was an 11% water content. We need to always start with the actual measured quantities, the 11% was calculated from the weight before baking, and the weight after baking). So the ratio of dry to wet is:

Ratio of dry to wet = dry weight / wet weight

= 890gr (+- 10gr) / 1000gr (+- 10gr).

To get the uncertainty here, we add the fractional (or percentage) uncertainties:

890gr (+- 10gr) = 890gr +- 1.1%

1000gr (+- 10gr) = 1000gr +- 1%, so

890gr +-1.1% / 1000gr +- 1% = .89 +- 2.1% .

Finally, we can multiply the two calculated values. To multiply, we will need the percentage uncertianty on the wood used:

1410gr (+- 20gr) = 1410gr +- 1.4% .

now multiplying we get:

(1410gr +-1.4%) X (.89 +- 2.1%) = 1250gr +- 3.5% .

When I actually calculated this on my calculater, it read out:

1254.9 .

I rounded this number off to 1250 using the rules of rounding, which I will talk about later. The reason I rounded it off is complicated, and we will talk about this later too, however the basic reason can be seen easily. The uncertainty is 3.5%, which could also be written as +- 44gr. This is the range that the actual dry weight is in. Due to our scales, we don't know exactly where in that range the actual dry weight is. It is somewhere between 1210gr, and 1299gr, and it really could be anywhere in that wide range. With such a wide range, it is missleading to specify the weight to 1/10th of a gram, because it makes it look like we know exactly what the dry weight is, when we don't. Maybe another example will make this more clear: imagine that you and your friend were to meet a third friend at a certain tree in the town market, at around two o-clock. The friend who you are with is very concerned about when and where you go to the market. You look at your watch and notice that you have ten minutes until the time you were suposed to meet, so you start walking to the market. When you get to the tree, your friend gets right up the tree, and asks you to do the same. He says "Look, we were suposed to meet at this tree, if you stand out there we won't be at the meeting place!". Being more sensable you insist that when you were told to meet "at the tree", that that ment that you were to meet close to he tree, and that exactly where you stood was just a matter of what was easiest, or most convenient. This was the uncertainty of your friends responce to where you should meet. When two o-clock came around, your friend who was up agaist the tree became very worried "Look, it is now more than ten seconds after he was suposed to show up, and he is still not here! Should we leave?". "Of course not!" "He said that he would be here at 2:00, but on his watch it still might be 1:59, I'm sure that he ment that he would be here within a few minutes of 2:00." In this example we see that every number has an uncertainy, even though it is often not stated. It is usually understood by the way the number is presented. If your friend had said that he wanted to meet at 1:53 on the north side of the tree, you would have known that he needed to be right on time, so he indicated a more precise time and place.

In just the same way, we write numbers down in accordance to their uncertainty. The acurracy of the number written down should never be much more than that of the uncertainty of that number. So if we have the number

1254.9 +- 44

we know, even with out knowing what the number stands for, that it should be written:

1250 +- 40

because the number can be no more accurate than it's uncertainty. This is a tricky concept, and it requires quite a bit of thinking to make it make sense, but it is important. Understanding uncertainty is the first step in understanding the information that you obtain from the field, or lab.

Let's get back to our calculation! We left off having calculated the numerator of the fraction that will give us the stoves GSC. Now, from the lab data, we know that the weight of water remaining was 2340gr (+-10gr),which can be written as 2340 +- .4% . We simply divide the numerator by the dinominator, adding the percentage uncertainties:

GSC = 1250 gr +- 3.5% / 2340 +- .4%

= .536 +- 3.9% .

this can also be written:

= .536 +- .021 .

depending if you want to know the uncertainty as a percentage, or as a number.

SIGNIFICANT DIGITS

There is another way to look at uncertainty, which gives us further insights to understanding numbers. This is the idea of significant digits. Let's look at this concept one word at a time. First, let's look at the word digit. A digit is just a number between 0 and 9. For example the number 234 has three digits: 2, 3, and 4. The number 2340000 has seven digits, the number .0000000234 has ten digits, and the number 00.0000000234 has twelve digits.

Now on to the idea of significant digits. The word significant means important, or note worthy. In the case of numbers we say that a digit is SIGNIFICANT if we know that it is correct, or in not uncertain. In the GSC we just calculated, .536 +- .021, we really only have one significant digit, since he 3 or the six are in the range of te uncertainty. In fact it would be best if we rounded this number to .54 +- .2. We say that a digit is significant if it is not uncertain (we are sure that it is right). Thinking back to the story about two friends meeting another friend, we recall that they were to meet at 2:00pm. In this case, we would guess that this number has one significant digit, the two. We know that he did not mean three o-clock, and we know he did not mean one o-clock, thus the two is a significant digit, in that we know that it is correct. The two zeros, however, are not significant, since he only said around two o-clock, he could come at 2:05, or even 2:15, thus we are not sure that those two zeros are correct, or certain. If he had said that he would meet you at two o-clock sharp, then we could say that he would be there within a minute of two, and thus those two digits would be significant, and it would have been a "three significant digit number". One quick way to ceck if your uncertainty is ok is to look at all of the numbers in your calculation, and find the one with the lowest number of significant digits. Your final answer will never have more significant digits than that number.

Looking at the example of calculating the GSC of the Shabelle 2 stove, we see that the original uncertainty was plus or minus 10grams. In this case, we know that the 1 of the ten is a significant digit: we looked carefully at the scale, and saw that it was always within ten grams, it was certainly never off close to 20 grams, and it was commonly off more than 5 grams. But the "0" is not significant. Sometimes it was off by seven grams, and maybe once in a while it was even off by 12 grams, so the zero is not accurate, or we could say that we are not sure of the zero. Most often uncertainties are only of one significant digit (since they are by nature uncertain). Just above I said that the number of significant digits in a calculated quantity is never greater than the number of significant digits in the least accurate number of the calculation. Thus our final uncertainty should be of no more than one significant digit. We must, then, round 3.9% off to 4%, which is the closest number with one significant digit. So we should write the final answer as:

1250gr +- 40gr

so that the answer is written to agree with the uncertainty (as we disscussed earlier)

This might look like we are loosing valuable information, but infact, nothing could be farther from the truth. We are just getting rid of misleading information. Perhaps one final example will make this a little more clear.

Suppose you are talking with a friend at breakfast about when you will meet in the afternoon. You figure out your day in your head to see what would be a good time. It is now 8:03 am. You need to get you hair cut (which will take about 25 minutes), get some petrol (20 minutes), go to the market (45 minutes), and work in the office for about three hours (you need to write a few letters, and talk to your boss). If we add up all of these times, we get 270 minutes, or four and one half hours. If you ignored the uncertainty of each step, you might tell your friend that you would meet at 12:33 pm. When he heard this, he would figure that you really ment that you would be there at 12:33, and that he had better get there right on time. In fact, you had only guessed at each of these times, and if traffic was heavy, or you had to wait at the barber, all of your errands could take even an hour longer than you had thought. Each of your guesses were only plus or minus 15 to 20 minutes. Even if you had been absolutely sure that the barber would only take 25 minutes, because other factors were more uncertain, the final time would be more uncertain. To figure out about when you would meet for lunch, you look at your least certain time: how long will you be at the office, could be up to four hours. Better leave an hour and a half extra, just in case. Try to meet at two o-clock for lunch. Now if you are five minutes early or late, your friend won't be offended. So we see that the uncertainty of a calculation can be no more accurate than the least accurate number in hat calculation.

From the example above, you can see that the final certainty of a calculation can never be greater than the least significant value known. You must look at your least significant numbers to find out about what your uncertainty will be. Of course, the same is true of numbers you arrive at in the lab, in field tests, or numbers you use in your daily life.

ROUNDING NUMBERS

The last thing that I would like to discuss is rounding numbers off. There are certain rules for rounding which should be followed.

1) If the number you are rounding is between 1 and 4 you round it down.

2) If the number you are rounding is between 6 and 9 you round it up.

3) If the number is 5, round to make the next digit even.

Examples:

Round these numbers off to the nearest ten.

Original number	Rounded number	Reason
21.5	20	We round the 1 down to zero, by rule 1).
4356.654	4360	We round the six up to ten, by rule 2).
30	30	The number is already rounded to the nearest ten.
455	460	round the 5 up to make the six even
445	440	round the 5 down to make the four even

APPENDIX 3

John Selker
1/85

WORKING WITH GROUPS OF DATA- Uncertainty in Average Values

After taking many measurements, in the field or in the lab, we like to put the information that we have gathered into a form that is easy to understand. For instance, instead of presenting a table of all of the data collected, we often just present the average values of our measurements. In this way we can show what the overall results are, without having to look at all of the individual measurements. When we present such an average we also must give an idea of how much uncertainty there is in that average.

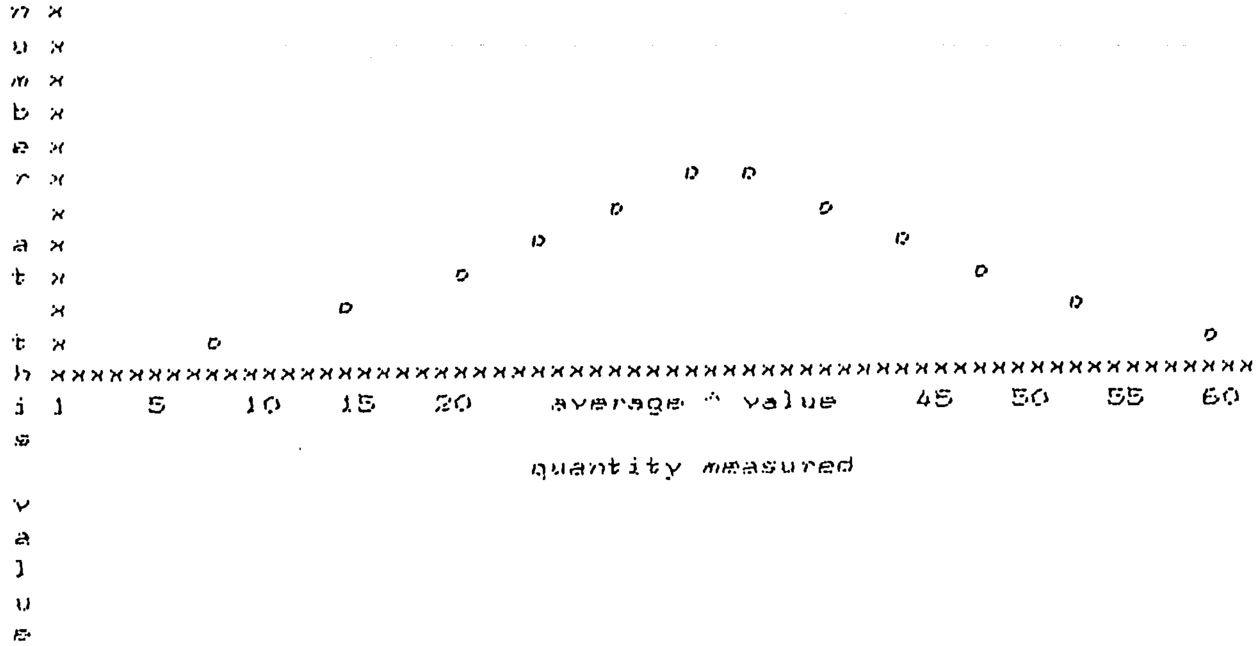
This applies particularly to data of the kind obtained from stove tests, in both the laboratory, and the field. In most cases, each stove is tested five or more times under nearly identical circumstances in order to determine the stove's average performance. However, in every case, the tests have some what different uncertainty. Sometimes the data is all very close to the same value, and other times, the numbers are spread widely. In either case, we must put an uncertainty, or range, on the average, to give the reader an idea of how likely it is that if the stove is used at some later time that its performance will actually be that indicated by the average. This uncertainty also tells the reader something about the stoves consistency: if a stove always tests out the same, it is likely that the stove will also be more consistant in the field.

The uncertainty of averages are expressed as "standard deviations". Before we get on to defining standard deviation itself, we shall look at some more basic concepts of the notion of uncertainty in average numbers.

NORMAL DISTRIBUTION

Let's look at this idea one word at a time. First NORMAL. By normal we mean common, typical, or standard. A person is normal if he or she has ideas that most other people have, dresses the way other people do, talks like other people do, etc. DISTRIBUTION means "how things are spread". "The distribution of rain" is another way to say "how the rain is spread".

When we say normal distribution, we are refering to a particular mathematical model of how measurements are typically spread in the real world. This model has been developed by looking at the way data typically spreads in many different situations, and seeing that there is a common pattern to most sets of data, or a NORMAL pattern of DISTRIBUTION. REMEMBER: THIS IS ONLY A MODEL of how measurements will spread in the real world. In fact, you will never find this distribution, but you will see distributions which come very close. The pattern looks something like this:



The chances are that the graph shown here is a little confusing. Let me say in words, what this graph says in lines and numbers.

In a typical set of measurements of some quantity, you will find that most of your measurements will be close to the average, and that the further you go from the average, the fewer of your measurements will be found.

The curve shown above is also known as a "bell curve" (due to its shape, which looks some what like a bell), or "Guassian Distribution", or just the normal curve. Mathematically, it is stated:

$$F(x) = \frac{N}{2\pi} e^{-A(x^2 - \bar{x}^2)/2}$$

where,

N = number of measurements taken,

A = related to peakedness of the curve (A is large for sharply peaked data).

$\bar{X}$ = Average of data

X = Value of the measurement

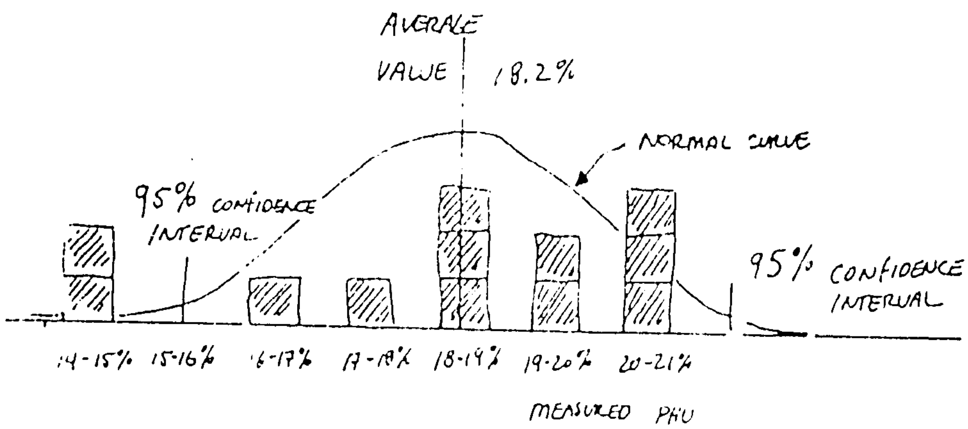
F(X) = Height of the normal curve at any measuremment X.

The main thing to understand here is the general idea; don't worry if you don't understand the mathematics. The main idea here is that the normal distribution gives us an idea of what our actual distribution of data would look like if we had taken many measurements.

Let's look at an example of a stove test to see what this all means. Remember that YOU will never have to go through this calculation, we are just doing this so you have a better feel for where all of this stuff comes from. For this example, we will use the test data from the experimental Soapstone wood burning stove, taken in December of 1983. We will only concern ourselves with the stove's overall PHU for the sake of this example.

overall PHU's measured: 20.8, 19.0, 19.4, 14.4, 18.1, 18.9, 20.5, 18.5, 17.5, 20.3, 14.7, 16.6.

We will plot these numbers on what is called a "histogram". A histogram is a graph that plots the number of tests (or measurements), against the range those tests were in. In this example, for instance, we will plot the number of tests falling into each 1% PHU range (how many tests had PHU's between 14% and 15%, between 15% and 16%, etc.).



Histogram of test data from Soapstone wood stove, Dec. 1983.

You can see that this test data doesn't look much like the "normal distribution" I have drawn over it. That is fine, the normal distribution represents what the graph would look like if we have taken many measurements. We can use the normal distribution curve to guess how what the chances are that future tests will fall into any particular range. All we do is measure the area under the curve in that range, and divide it by the total area under the curve. This measurement is not something that you do normally, but it does work.

STANDARD DEVIATION

Before getting into WHY the standard deviation is what it is, I will tell you HOW to calculate the standard deviation, and WHAT it means in practical terms.

How to calculate the STANDARD DEVIATION of an average.

If you have N pieces of data labled a, b, c, ... , x, y, z, which have an average of AVE, their standard deviation is written:

$$\text{Standard deviation} = \sqrt{\frac{(a - AVE)^2 + (b - AVE)^2 + \ldots + (z - Ave)^2}{N}}$$

This definition holds true no matter how many (or few) pieces of data you have. As you can tell from the formula, it can take a while to calculate this, particularly if you don't have a calculator with square roots.

As an example, let's calculate the standard deviation of the stove testing data listed above, using this formula.

The first step is to calculate the data's average.

AVE = sum of measurements/ number of measurements

sum of measurements = 20.8 + 19.0 + 19.4 + 14.4 + 18.1 + 18.9 + 20.5 + 18.5 + 17.5 + 20.3 + 14.7 + 16.6

= 218.7

The number of measurements = 12.

AVE = 18.2 .

The next step is to find the sum of the squares (SOS):

$$SOS = (20.8-18.2)^2 + (19.0-18.2)^2 + (19.4-18.2)^2 + (14.4-18.2)^2 + (18.1-18.2)^2 + (18.9-18.2)^2 + (20.5-18.2)^2 + (18.5-18.2)^2 + (17.5-18.2)^2 + (20.3-18.2)^2 + (14.7-18.2)^2 + (16.6-18.2)^2$$

= 84.0 .

Next we devide this by 12 (the nunber of data):

SOS/ N = 84.0 / 12 = 7.00 .

Now, we just take the square root, to find the standard deviation:

$$\text{Standard deviation} = \sqrt{7.00} = 2.65$$

We would write this as

PHU ave. = 18.2 (s.d. 2.7)

From this example, you can see that calculating the standard deviation of an average is not difficult. It is useful to go through this same calculation on your own to make sure you understand each step.

We use standard deviations to calculate what are called "confidence intervals". A confidence interval is a range about the average you have calculated, and is much like an uncertainty. A confidence interval gives us a range, and tells us what the chances are that any future tests will fall in that range. For instance a 95% confidence interval tells us that 95% of all future tests should fall within the range of uncertainty. Below I have listed various confidence intervals for averages, which can be calculated from the standard deviation. As you can see from the list, to calculate the 95% confidence interval for some average, all you do is multiply the standard deviation of the average by two, and use that as the range on the average. The idea, then, is that 19 out of the next twenty tests you run should fall within the 95% confidence interval.

Confidence	Range
99%	+- 2.6 x standard deviation (s.d.)
95%	+- 2 x s.d.
90%	+- 1.7 x s.d.
85%	+- 1.5 x s.d
75%	+- 1.2 x s.d.
68%	+- 1 x s.d.

So, going back to our example, say that we want to state the uncertainty such that we are 90% sure that all other measurements will be found in the range of the uncertainty. We would write:

Ave PHU = 18.2 +- 1.7 x 2.7

Ave PHU (90% confidence interval) = 18.2 +- 3.6 .

Using the table shown above, you can select the confidence interval that suits your tests. Repeating, a confidence interval of 90% tells us that there is a 90% chance that any further test will fall in that range. REMEMBER: this is all a way of getting an **idea** of the uncertainty on a set of measurements. If you take ten measurements in the future, there is no guarantee that nine of them will be in the 90% interval. This is an "educated guess", no more. The more tests you have done, the more certain you can be of your standard deviation.

Most people use the 95% confidence interval (twice the standard deviation) as the basic measure of uncertainty. This is both because it is easy to calculate, and because 95% confidence is seen to cover all but the most exceptional cases. Because of its wide use, I would recommend listing the 95% confidence interval in any reports to be read outside of the staff of your project. It is also quite acceptable to simply list the standard deviation, and let the reader use this at face value.

Other quantities may be calculated from the standard deviation, the most common being the variance of an average. To my way of thinking, further statistical calculations do not give further insight to the stoves performance. We must realize that these calculations are most appropriate where the number of tests is over thirty. Although in field testing situations the number of tests can get this high, the standard deviation gives us the most important information on the reliablitiy of the test results.

APPENDIX 4

Recommended Scope of Work for Max Kinyenjui.

The present focus of the Nation Woodstove Program is on production. Fortunately, this is also Mr. Kenyanjui's strength. We recomend that Max should focus on several key production problems. In decending order of importance these are:

1) The draft control on the soapstone stove.

2) Cracking of the ceramic stoves, particularly around pot rests.

3) Quality contol aspects of production of soapstone stove, as mentioned in this report.

4) The building of very simple kiln, as he has done at his own production site.

If time allows, it would be useful for Mr. Kinyanjui to visit the CARE forestry project in Hargeisa. This activity is not crucial. If this trip is taken, we recommend that Mr. Kinyanjui also focus on production issues, with particular focus on adapting the designs they are presently using to the metalsmiths available.

Round these numbers off to the nearest .01.

234.5678	234.57	We round the seven in the thousanths place up.
234 indicate	234.00	We add the zeros to that we are rounding to the nearest .01.