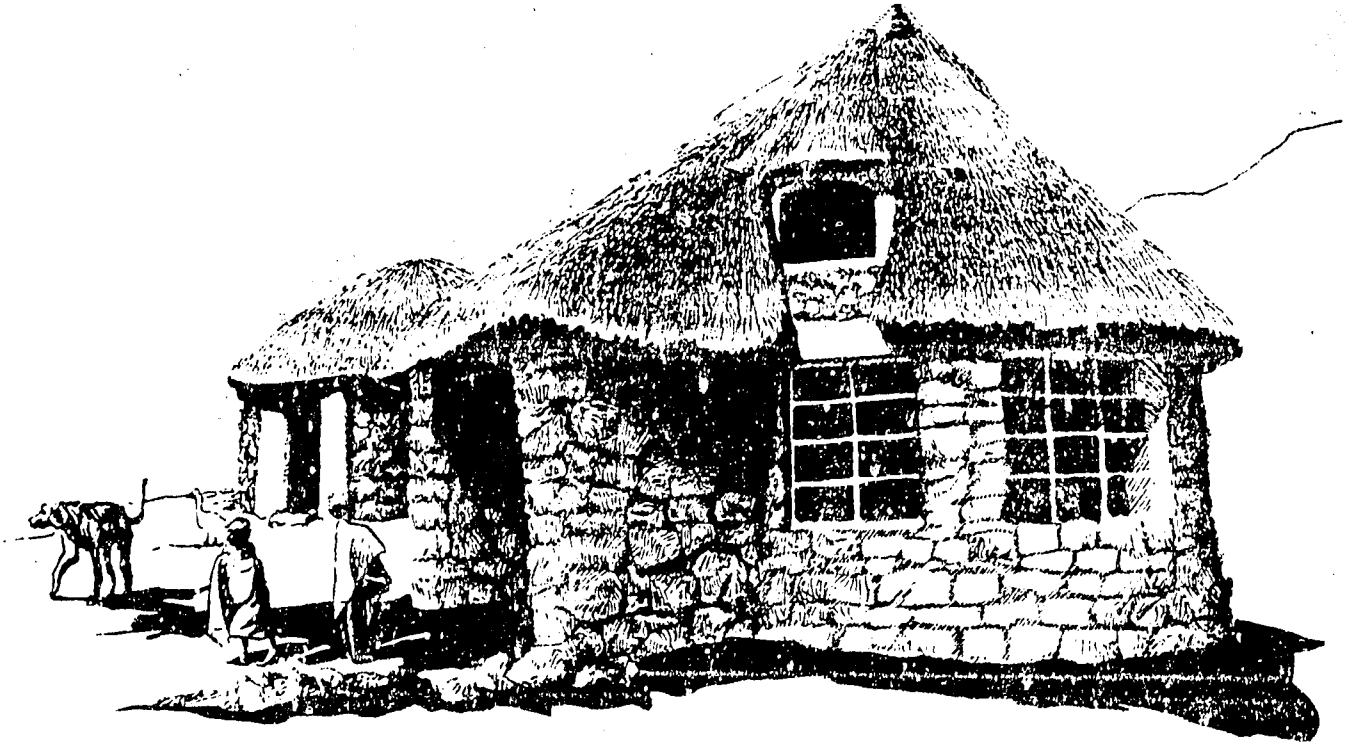
PN-AAX-818 6320206

MOLLO O KAE?



(WHERE IS THE FIRE?)

SOLAR ENERGY EXPERIMENTATION AND TRAINING in the MOUNTAINS of LESOTHO

PHASE 111

September, 1979 - December, 1980

Final Report

by

Gary Klein

A study conducted Under the Auspices of the Rural Technology Unit, Thaba Tseka, Lesotho, with Financial Assistance from Appropriated Technology International

Disclaimer

The opinions, facts and data presented in this report are solely the responsibility of the author. They do not necessarily reflect the opinions of Appropriate Technology International or of the Thaba Tseka Integrated Rural Development Program. Any inquiries concerning the contents of this report or concerning the proprietary use of the concepts and techniques presented should be addressed to the author:

C/O Rural Technology Unit
T.T.I.R.D.P.
P.O. Box 1027
Maseru, Lesotho

Dedicated to the children of Lesotho, and perhaps to their children and even <u>their</u> children for it is they who will have to live with the future we have begun to create.

Acknowledgements

The author wishes to thank Appropriate Technology International and the Thaba Tseka Integrated Rural Development Program for their support of this project. Special appreciation is extended to the staff of the Rural Technology Unit who participated in this venture and without whose help we would not have been able to accomplish what we did. In particular, I wish to thank ORLA HANSEN, RTU Coordinator, for design and construction of the free-standing cold frame Prototype I, JOHN KENNEDY, RTU Advisor, 1979, for the design and construction of the B-House cold frame, ALAN WYATT, ATI Consultant, for his innovative and industrious contributions to the solar oven, the solar electric system and the solar still, MICHAEL SAVINO, US Peace Corps, for the final solar oven design, NATHAN HINE, US Peace Corps, for designing a folding reflector system for the solar ovens, FRANK WEYER, RTU Advisor, for developing the improved paola Prototype 3, for constructing the large solar oven and for further innovation on the other solar ovens, to SANDY HILGENDORF for the artistic renderings of the various technologies, to M. MASAKOANE for the technical drawings and to RANDY WEEKES for printing the photographs, which were taken by the author. Special thanks must be given to MASWATI NKOME, Village Technology Section Head, RTU, TEBELLO KALOLI, TEBOHO MOKHOMO, MOOKHO MAFITOE, HALIEO MALIBENG and LEUNA LECHESA for their unfailing efforts to construct, test, and disseminate the concepts and tools contained in this report. Finally, the typists and the printers must not be forgotten, for it is their combined labours which made this report a reality.

TABLE OF CONTENTS

			Pages
Chapter	1	Introduction	1
Chapter	2	Climate in Thaba Tseka	2/1 - 2/2
		Tables 2-1 to 2-2	2/3 - 2/4
		Figures 2-1 to 2-3	2/5 - 2/7
Chapter	3	Solar Water Heaters	3/1 - 3/6
		Tables 3-1 to 3-3	3/7 - 3/8
		Figures 3-1 to 3-3	3/9 - 3/11
Chapter	4	Food Dehydrators	4/1 - 4/8
		Tables 4-1 to 4-2	4/9 - 4/10
		Figures 4-1 to 4-12	4/11- 4/22
Chapter	5	Solar Electric System	5/1 - 5/4
		Tables 5-1 to 5-2	5/5 - 5/6
		Figures 5-1 to 5-3	5/7 - 5/9
Chapter	6	Cooking	6/1 - 6/11
		Figures 6-1 to 6-5	6/12- 6/16
Chapter	7	Solar Distillation	7/1 - 7/5
		Table 7-1	7/6
		Figure 7-1	7/7
Chapter	8	Climate - Wise Buildings Design	8/1 - 8/7
		Tables 8-1 to 8-17	8/8 - 8/21
		Figures 8-1 to 8-15	8/22- 8/36
Chapter	9	Greenhouses and Cold Frames	9/1 - 9/11
		Tables 9-1 to 9-4	9/12- 9/15
		Figures 9-1 to 9-19	9/16- 9/34
Chapter	10	Extension and Marketing	10/1 - 10/4
Chapter	11	Training	11/1 - 11/7
Chapter	12	Conclusion	12/1 - 12/2
Appendices:			
	1.	Instrumentation	A1/1 - A1/3
		Tables A1-1 to A1-4	A1/4 - A1/7
		Figure A1-1	A1/8
	2.	A Preliminary Examination of the Introduction of Solar Water Heaters in the District of Thaba Tseka	A2/1 - A2/37
	3.	Rural Technology Unit Report Format	A3/1 - A3/3
	4.	Corrections to Interim Report	A4/1

CHAPTER 1 Introduction

The following work was carried out from September,1979 through December, 1980 in the Rural Technology Unit (RTU) of the Thaba Tseka Integrated Rural Development Program (TTIRDP), Thaba Tseka, Lesotho. This report encompasses the activities discussed in Solar Energy Experimentation and Training in the Mountains of Lesotho Phase 111, September,1979 to April 1980, by Gary Klein and Alan Wyatt, which will hereafter be referred to as the interim report. Financial assistance for this report was provided by Appropriate Technology International (ATI) of Washington, D.C.,USA and TTIRDP.

The original goals of the project were to examine village energy demands and to identify techniques of utilizing solar energy that would meet these requirements and to train a local staff to identify, build, test, and explain the resulting devices to people in the District. Based on the results of the first seven months of work, it was felt that cooking represented the largest demand for fuel and that both conservation techniques and solar technologies had to be explored in greater detail. In addition, the existing prototypes needed to undergo wintertime evaluation and the extension effort needed to be developed.

This document reports on the new research areas and on the results from just over one year's effort in the other activities. These topics include climate, water heating, food dehydration, solar electric systems, cooking solar distillation, climate-wise building design, greenhouses and cold frames, extension and marketing, and training. Rather than repeat many technical tables, relevant sections of the interim report have been referred to in the following chapters. Please note that Appendix 4 contains corrections to the interim report.

Happy reading!

CHAPTER 2 CLIMATE IN THABA TSEKA DISTRICT

This chapter will analyze the weather data available for 1980 and compare it to the long term records. This is done primarily to evaluate the effect of weather patterns in a specific year on the various devices we modelled in the interim report. Some new data will be presented where we acquired new equipment to aid in our investigations. Topics include temperature and solar radiation.

Temperature

Temperature and degree day information are necessary for predicting heating and cooling loads of buildings. Temperature data is also used for determining the efficiency of various solar collectors. In the interim report, it was decided to use data from the Paray Mission weather station for the long-term temperatures. We have continued to do so here.

Figure 2-1 compares the mean minimum, maximum and average temperatures from the Paray station for six months in 1980. The pattern compares well with the long-term information that is available. Table 2-1 and Figure 2-2 compare the 1980 mean with the long-term mean. As can be seen, the differences are slight. Because of this, the long-term Paray data will continue to be used for the general calculations in the remainder of this report. When particular situations are examined, the 1980 data will be used.

Solar Radiation

Data on insolation, or the amount of radiation, is very important for evaluating the design of devices utilizing solar energy. In the interim report, it was decided that the mean of the long-term monthly values from Maseru and Oxbow would serve as reasonable approximation for horizontal surface totals. From these values, monthly mean daily surface totals for north facing tilted surfaces were derived.

In late June,1980, an integrating pyranometer was installed at the R.T.U.

The Unit was purchased from Australia and is being used to establish an accurate radiation record for the Thaba Tseka area. It contains its own battery and a six digit counter. Specifications are included in Appendix 1. For purposes of this report, SI units have been converted to BTU/SQ.ft.

Table 2-2 compares the actually measured radiation with the previously derived figures from July to November,1980. A graphic representation is contained in Figure 2-3. The standard deviation and the percent deviation of the measured radiation were calculated for these months. The percent difference between the measured and derived radiation was also calculated.

As can be seen, the standard deviation was very large for August and September. These months were in fact quite variable, with periods of sunny weather followed by periods that were cloudy. By comparison, however, the difference between the measured and derived readings is small. Since these differences are small and because the data is available for only part of one year, for general purposes, the derived figures should still be used. When specific periods of time are examined in this report radiation totals from 1980 will be used. It is recommended that daily readings continue so that long-term results can be obtained.

Conclusion

The previously developed temperature and solar radiation data should continue to be used when making long-term predictions. When analysis of specific periods within particular years is desired, the measured information for that period should be used. The pyranometer that was purchased performs well and is recommended to others if similar quality is desired.

Table 2-1. Comparison of Long Term and 1980 Mean Temperatures for Selected Months, Paray Mission

	Long Term Mean (°C)	1980 Mean (°C)	σ_n	Difference (LT-1980) (°C)	Percent Difference (%)
January	16.4				
February	16.4	16.5	2	-1	6
March	15.0	15.5	2	-.5	3
April	11.8	11.5	3	.3	2
May	8.0	9.5	3	-1.5	19
June	5.2	5	2	.2	4
July	5.6	5	2	.6	4
August	8.3	8.5	3	-.2	2
September	11.3	11	3	.3	3
October	13.2	14	3	-.8	6
November	15.6				
December	17.9				

Table 2-2. Comaprison of Measured and Derived Radiation on a Horizontal Surface

	Derived Radiation on a Horizontal Surface (BTU/ft² /Day	Measured Radiation on a Horizontal Surface (BTU/ft² /Day	σ_n	Percent Deviation	Percent Difference
January	1960				
February	1760				
March	1560				
April	1330				
May	1130				
June	1030				
July	1090	1140	100	9	5
August	1300	1310	300	23	1
September	1550	1420	490	34	-8
October	1800	2020	90	4	12
November	1940				
December	2080				

FIGURE 2-1

COMPARISON OF MINIMUM, AVERAGE, AND MAXIMUM TEMPERATURES FOR SELECTED MONTHS IN 1980, PARAY MISSION

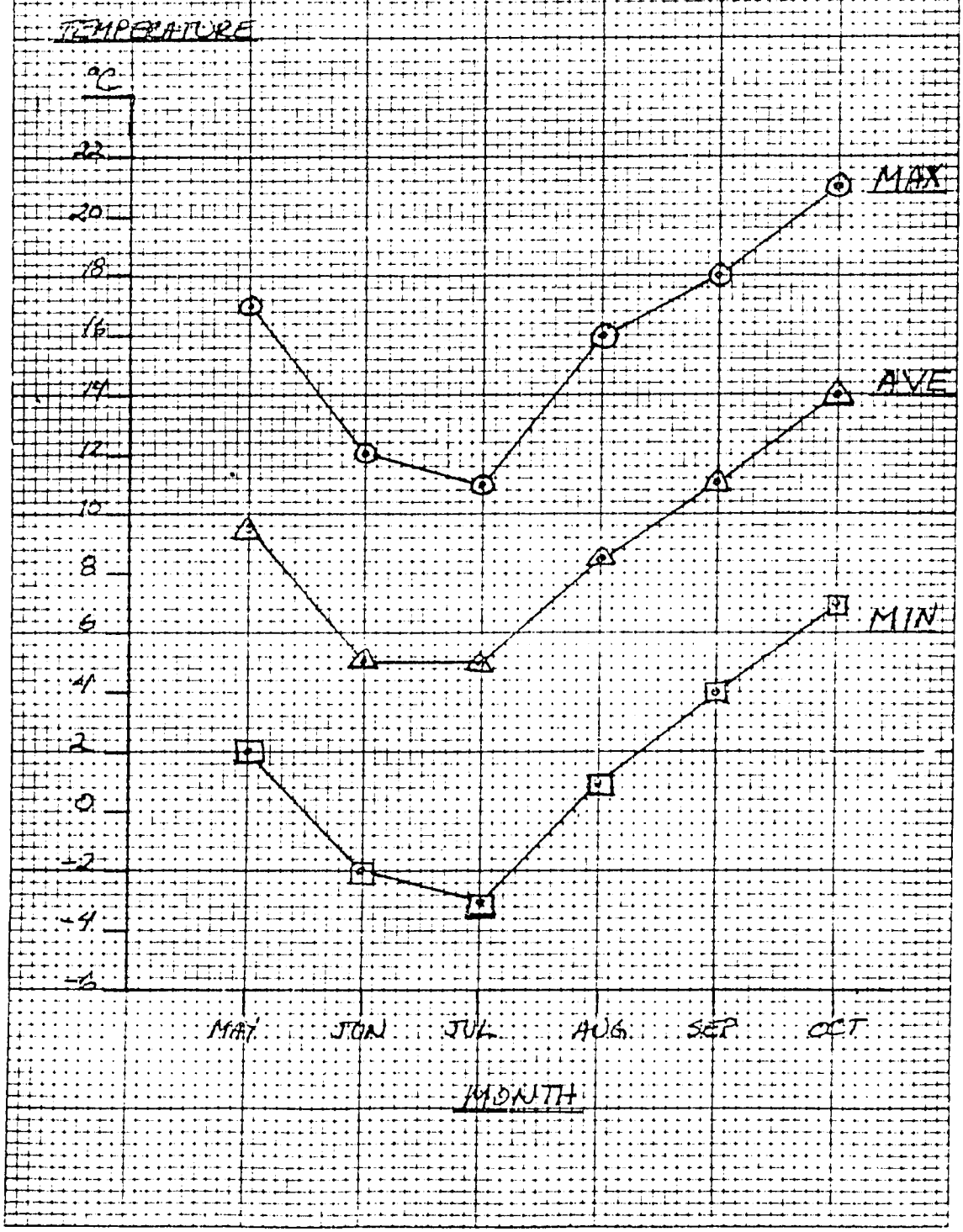
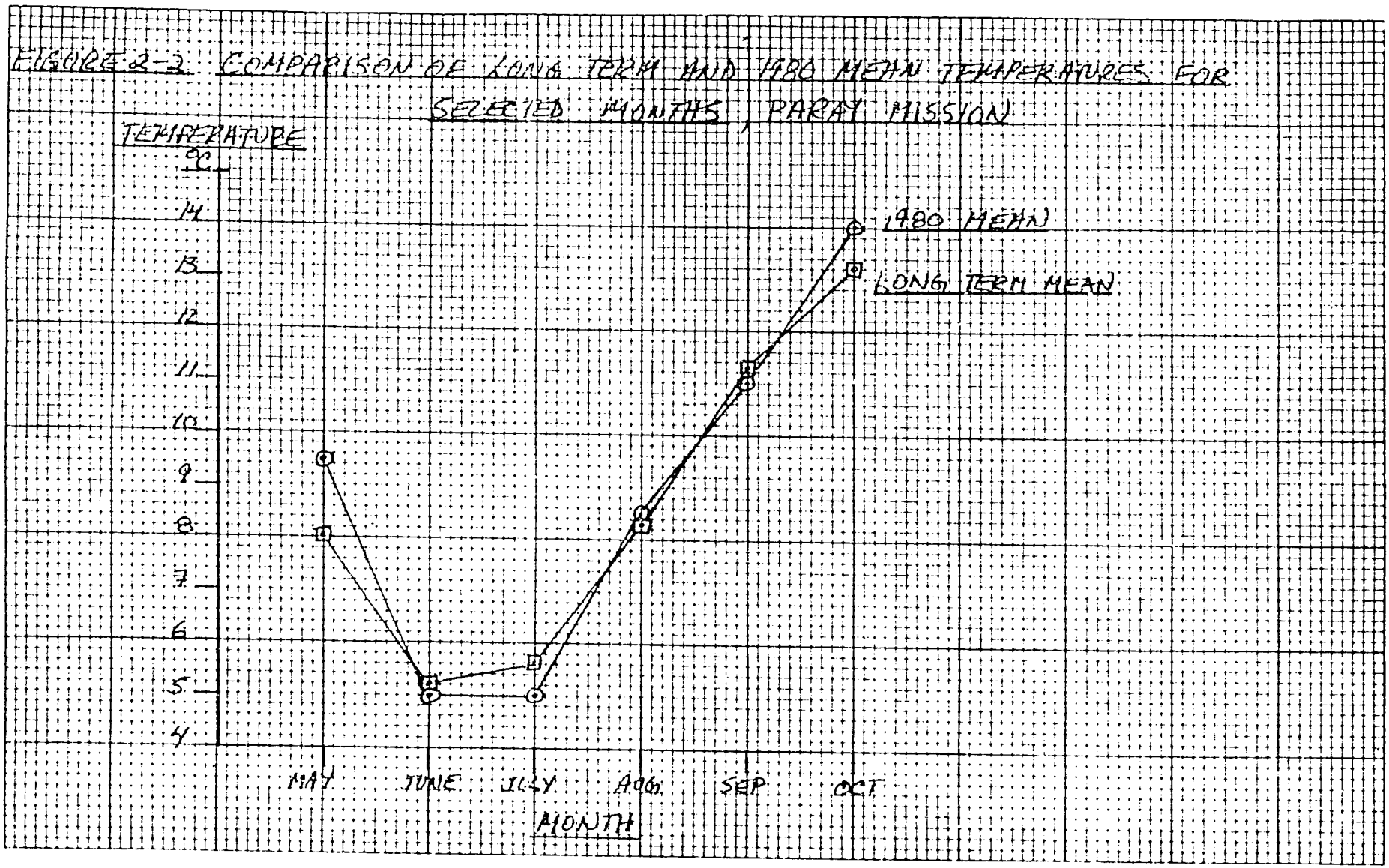


FIGURE 2-2 COMPARISON OF LONG TERM AND 1980 MEAN TEMPERATURES FOR SELECTED MONTHS, PARAY MISSION



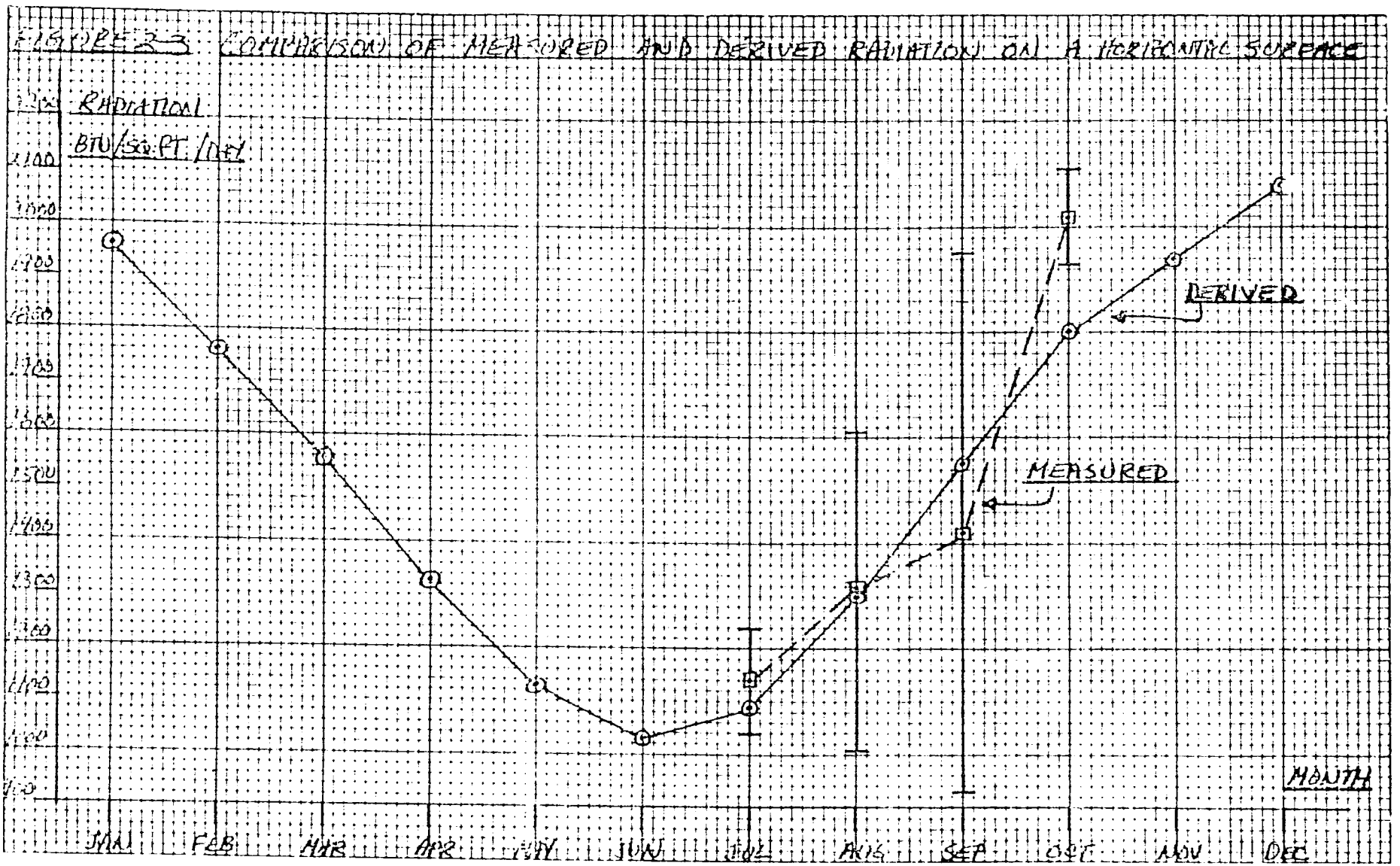


FIGURE 23 COMPARISON OF MEASURED AND DERIVED RADIATION ON A HORIZONTAL SURFACE
RADIATION
BTU/SQ.FT./DAY
DERIVED
MEASURED
MONTH
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

CHAPTER 3 SOLAR WATER HEATERS

Since April 1980, only two basic types of solar water heaters have been tested, and marketed. Both of these are batch units, one with stone and mud walls, the other with an insulation-filled sheet metal skinned enclosure. A single sheet of fiberglass allows light to enter the box and heat the tins. Technical drawings and initial test results are contained in the interim report. This report will describe the efforts to create "production" models, the development of a standardized test procedure and the evaluation of the prototype following one year of testing.

DESCRIPTION OF PROTOTYPES

Mud and Stone Wall

The stone wall and mud mortar water heaters were the type most frequently sold in villages in the district. Over twenty have been built and operating for periods up to one year. In addition to continuing the test programs, attempts were made to optimize the use of expensive materials and to standardize the construction methods so that high quality units could be produced with the minimum of cost and effort. Figure 3-1 shows the final design.

The first element that needed attention was the cover, This is the most expensive part of the heater, costing M11.00 per square meter just for the fiberglass sheet. Based on sheet sizes and compared to tin sizes, it was felt that a reasonable size would be 600mm x 600mm for the cover. This allows for simple construction at tilts from 30° to 45° without necessitating any changes in materials or construction practice. It is possible to reduce the size to 450mm x 600mm for the 30° tilt models. Costs for the fiberglass run M3.96 and M2.97 for the two sizes.

It was also necessary to make the wood frame simple and durable. Wood planks have been supplied in 38mm x 38mm x 3.6 meter lengths. This allows cutting to size with almost no waste. Joints are made so that one piece laps over

the other. Much time has been saved where it used to be spent ripping the planks to size.

To make a cover, all that is now required is to cut the boards to length, mark and cut the joints, nail the boards together, and attach the fiberglass sheet. The entire process takes less than one hour for someone with a minimum amount of training in carpentry. The cost for the wood is M0.40/meter or M0.96 or M0.84 for the two sizes respectively.

Once the cover is made, it is then time to make the walls. The ground is levelled and then dug down about 100mm. Going down reduces the final size of the walls, thereby also reducing wind resistance and heat loss. The rectangular hole should be no bigger than 250mm x 450mm for the 30° tilt unit and 300mm x 450mm for the 45° tilt model. The walls should be built up about 150mm wide right from the edge of this hole. The long axis of the hole should be oriented east- west and the high back wall of the heater should be on the south. This results in the cover facing north. While exact orientation is not necessary, it is best if a compass is used when siting the device. The cover should rest in the middle of the walls and should be surrounded by mud built up as high as the thickness of the cover. (See Figure 3-1C.) To complete the unit, thatch grass is cut and put in the box. For a good stonemason, construction time of the walls takes two hours if stones and water are at the site. Cost for labor is figured at M2.00 per unit. Total costs run about M7.00 -M8.00 for the water heater.

Sheet Metal Sides

Figure 3-2 contains photographs of this model. It is shown with two used Food Aid oil tins painted black. However, to make it more versatile, the interior has been designed to hold two five liter tins. Details of the catch and handle are shown in Figures 3-2C and D respectively.

Production of these units has proven to be a problem. The difficulty has been finding a skilled local person to build them. When the sheet metal worker in Majakaneng left, we decided to hire and train someone to build these units. Training was provided in Thaba Tseka and was not very extensive. The woman hired is now reasonably capable of making water heaters and ovens, but will need much more work before she is a skilled metal artisan.

To simplify construction procedures, cutting templates were made for the inside and outside boxes. This reduced measurement error as well as time. The templates also contain marks which show where to bend the sheet metal. A great deal of time is still spent on making the frame for the fiberglass glazing. The most efficient use of materials requires that two pieces of metal be spliced together. While the necessary tools are available, the skills and patience to do this correctly are not. In a reasonable production mode, it should be possible to make two to three units per day. Present costs of a completed unit are M15.00 including materials and labor.

Test Procedures and Results

A test yard and test schedule have been developed so that standardized observations of water heater performance can be made. Ten mud and stone water heaters have been built. This exercise enabled us to train people in making these devices as well as providing us with the desired test units. Five orientations, east, northeast, north, northwest and west, and two tilts, 30° and 45° can be examined simultaneously. In addition to the mud and stone units, six sheet metal water heaters are used to test various additional orientations. Based on the results of the initial tests it was felt that furthur tests of sheet metal versus mud and stone models were unnecessary. Rather, orientation and tilt were of primary concern and the sheet metal units should be used to take advantage of their major design feature, their portability.

Table 3-1 displays the test schedule. Two days of testing are necessary to examine most of the important possibilities. Stationary tests, to determine the value of a particular orientation and tilt throughout the year are the major components of the Day 1 procedure. The second day examines the effect of switching the tins from one orientation in the morning to another in the afternoon. Tilt is fixed while the orientation is changed. Both days have tests of changing the water at noon in the north facing water heaters and of tracking the sun from morning to afternoon. A final feature is that north at two tilts is also tested on both days.

The idea was to perform each test two days per week. A minimum of one day per week per test was expected. This would allow for following the performance of the collectors throughout the year so that the best determina-

tion of angle and tilt could be made for this climate. It would also enable us to determine if two batches of water could be heated daily in a stationary collector, and how substantial the benefits of owning a portable unit might be.

It proved to be very difficult to institute and maintain this schedule. Data acquisition was done by hand using both glass bulb and dial thermometers. Due to the large number of tins and the relatively slow response of the thermometers, it often took up to 30 minutes to take each set of readings. Four or five readings were taken each day at two hour intervals so this became a rather time consuming task.

The results are generally what would be expected. Of the stationary units, north at 30° provided the best overall results; however, north at 45° performed better during the winter months. Two batches of water per day are possible, even during the winter. In summer it might be possible to heat three batches per day in the north-facing unit. The portable unit that tracks the sun is most valuable for allowing one to use the early morning and late afternoon sun, which a north-facing stationary unit misses. This results in slightly higher overall temperatures per batch and should make it possible for three batches per day in winter and four in summer.

A batch is defined as two tins heated each to an average temperature of 30°C to 40°C above initial water temperature. In winter, this means 35°C to 45°C final temperatures. In summer, temperatures up to 60°C are possible. The period from 1200 to 1400 hours is excellent for putting energy into the water, particularly if the water has been changed at noon. If this has been done, a 20°C average increase in temperature will generally result.

Evaluation

The sheet metal units are more durable and versatile than the mud and stone wall water heaters. These units could be improved if cement was used instead of mud for the mortar. The additional cost is a minimal M1.00 to M2.00 per unit and would mean that virtually no maintenance of the walls would be required during its useful life. In a survey conducted in the Linakeng area

(Appendix 2) after six months, the mud and stone walls on three of the four units purchased needed to be rebuilt. All owners wanted cement mortar to be used when this was done. As mentioned in the interim report, rusting of the tins was a problem. In an attempt to reduce this, sheet metal primer paint has been applied to the inside of the tins. While rusting has been reduced, a smell from the paint has taken its place. Because of this, it is recommended that the water not be used for cooking purposes, only for washing. It is necessary to find a more stable paint to be used for this coating .

The Food Aid oil tins, while very inexpensive, are somewhat inconvenient to use. This is due to the very small and easily breakable plastic opening that allows water to go in and out of the cans. The five-liter oil tins have a relatively wide screw cap and a handle but are more difficult and expensive to acquire. It has not been possible to secure a supply of these tins in over six months of searching.

Perhaps the most important evaluations have come from the people who are actually using the heaters in the villages in the District. The owners used the heaters on most good days except for one who left hers covered most of the winter. One woman used her heater to finish cooking samp(hulled maize) on a fairly regular basis. It is probable that both the sun and the insulative qualities of the heater contributed to the success of this innovative effort.

Table 3-2, taken from this survey, compares the benefits and disbenefits derived by the purchasers of the water heaters. All mentioned fuel or cost savings as benefits of using the water heaters. Only one was concerned that it took a long time for the water to get warm. The general impression obtained by survey teams was that people were pleased with their purchase. The survey also revealed that someone from almost every household in the two villages where the devices are located had either seen one of the heaters or had been told about them by one of the owners. The diffusion of the idea has been quite complete, although not very wide-spread beyond the two villages. More details concerning this are contained in Chapter 10.

Conclusions and Recommendations

The solar water heaters tested and marketed in the District have met with a generally favorable response. The demand for portable units is less than that for the stationary ones, probably because of initial costs. It would seem that demand for water heaters will not be all that great. This is due to the fact that cooking is a much greater priority. Marketing a cooker that also heated water would be a better idea.

Test results have been very difficult to obtain. The findings have been basically what we expected. It is recommended that the stationary units be placed due north or slightly off to the northeast if water is desired roughly once per day. Some owners prefer water earlier or later and the direction can be adjusted accordingly. The tilt should be 40°- 45° if hot water is desired during the winter. If lower water temperatures can be tolerated at this time, then 30° will be best for year-round performance. Many of these decisions necessary for the stationary units are eliminated if a portable unit is purchased.

It has been possible to train several people, both at the Program and out in villages to build the mud and stone units. While it is hoped that these villagers will begin constructing these heaters on their own, this has not yet occurred. It is probably still too soon for this to happen. The production of the sheet metal heaters requires more training and consequently it is likely that fewer people will take up this trade. Training should be given to at least one member of the permanent R.T.U. workshop staff. In addition, it would be advisable to include a sheet metal working course in the trade center curriculum. The people trained here should be from diverse parts of the District so that their skills can best serve the people when they return to their homes. Part of this training should include "mass" production or other time-saving and quality-improving techniques.

Table 3-1. Water Heating Test Schedule

Day 1

Orientation	Tilt	
East	30°	45°
Northeast	30°	45°
North	30°	45°
Northwest	30°	45°
West	30°	45°
North - Change water at noon	30°	45°
Track Sun		

Day 2

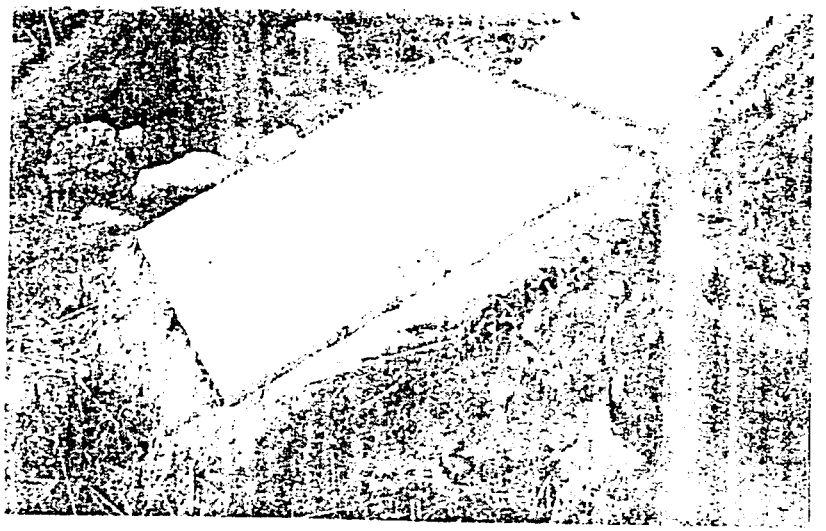
Orientation		Tilt	
AM	PM		
East	West	30°	45°
East	Northwest	30°	45°
Northeast	Northwest	30°	45°
Northeast	West	30°	45°
North	North	30°	45°
North - Change water at noon		30°	45°
Track Sun			

Table 3-2

Derived Benefits and disbenefits as Stated By the Purchasers

Derived Benefits	Percent	Derived Disbenefits	Percent
1. Less fuel used for cooking	50	1. It takes a long time to heat water	25
2. Knowledge that the sun can work as fuel	25	2. Not working on cloudy days	25
3. Reduced money spent on paraffin	50	3. Trouble of having to keep frames indoors at night	25
4. Saved time devoted to collecting fuel	25	4. Expenses on repairing walls	25
5. Hot water for washing	50		

N.B. Some people mentioned more that one benefit.



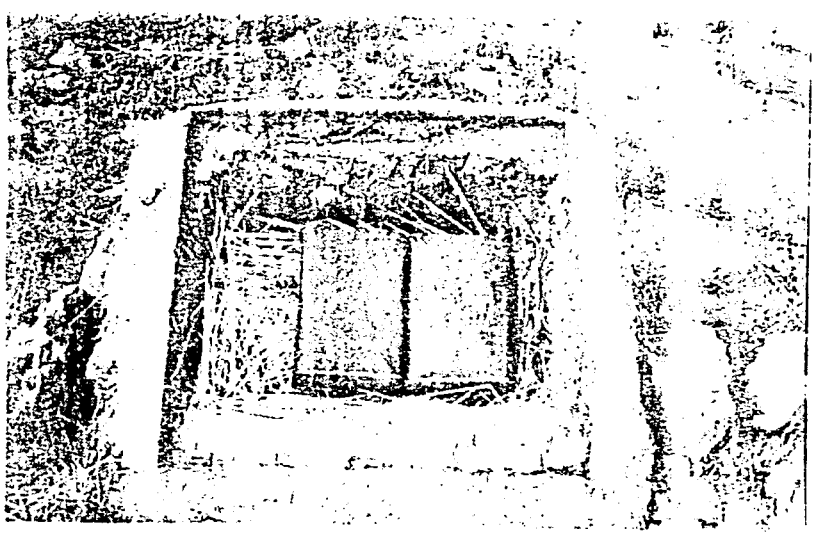


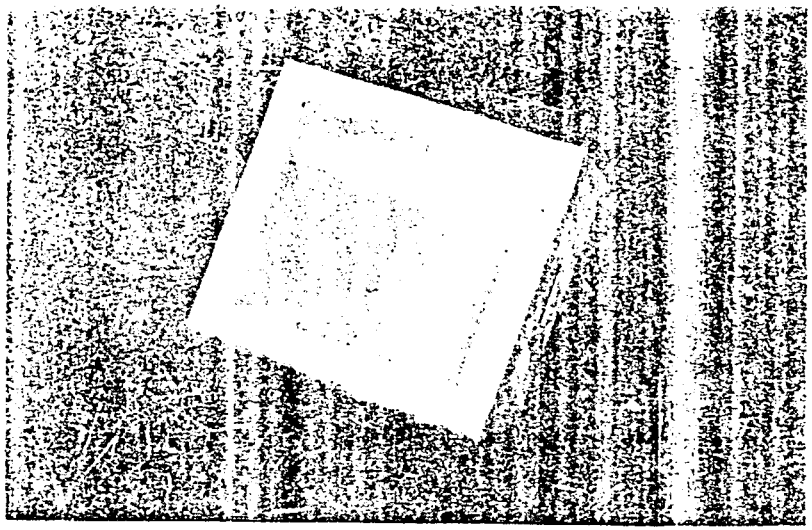
Figure 3-1 Mud and Stone Wall Solar Water Heaters

A. (Upper left) 30° tilt

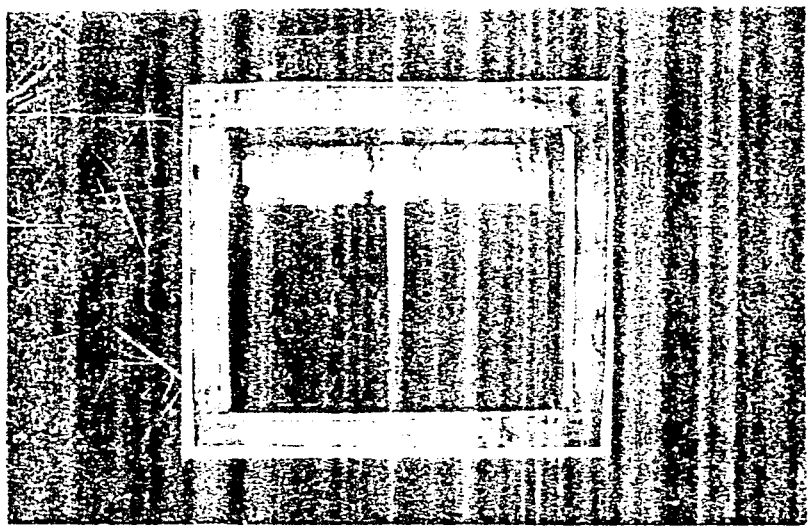
B. (Upper right) 45° tilt

C. (Lower left) Cover removed showing tins and thatch grass insulation

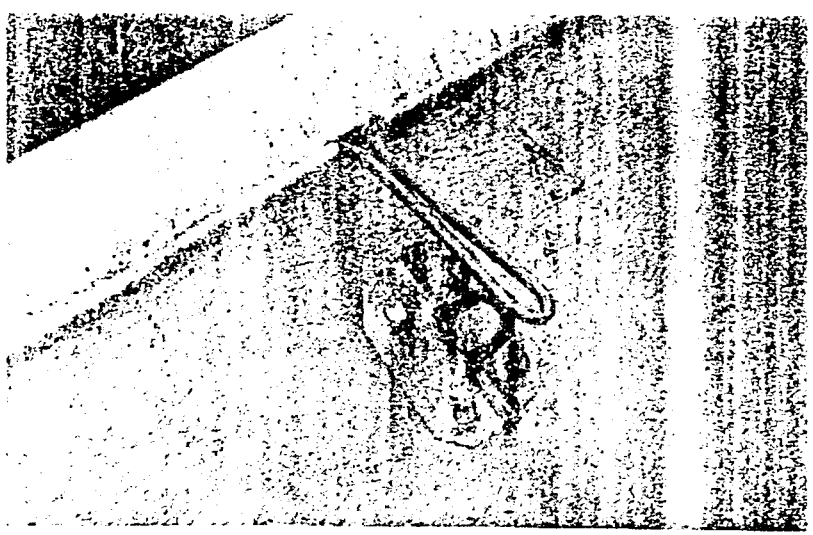
Figure 3-2



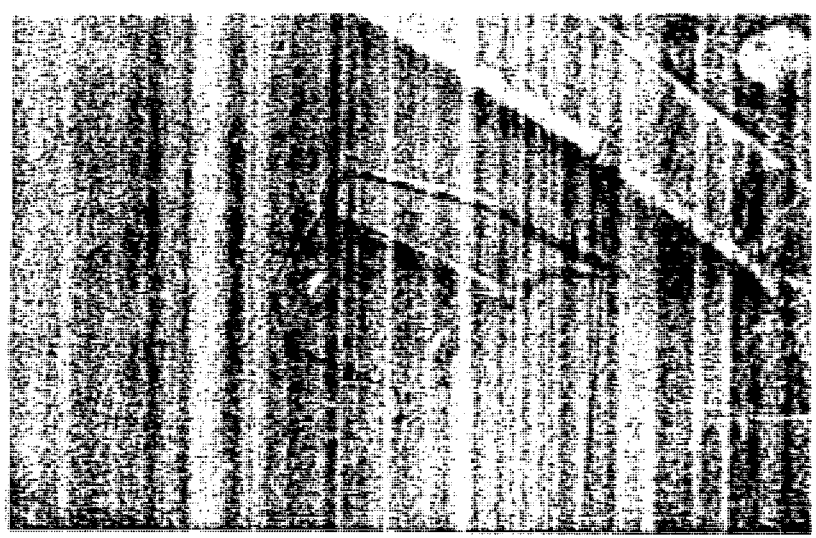
A. Sheet Metal Solar Water Heater



B. Covered Removed Showing Tins



C. Latch Detail



D. Handle Detail

CHAPTER 4 FOOD DEHYDRATION

Storage of food beyond the growing season is one of the problems facing people in the District. This study focuses on the methods of employing the sun as the energy source for this method of food preservation. Five different types of dehydrators have been tested. This chapter will explain the various dehydrators and the results of tests carried out over the past year. Early investigations are explained in the interim report.

Methods Of Food Dehydration And Experimental Prototypes

Three types of dehydration were investigated; sun or natural drying, combined convection and direct radiation and convection only. Sun drying is usually done on a flat surface out in the open. This method is subject to contamination by air-borne particles, to animals and insects, and to the vagaries of the weather. The designs of the other dehydrators attempt to address some of these problems.

Three units were built that combine direct radiation and convection. Figures 4-1, 4-3 and 4-5 contain sketches while Figures 4-2, 4-4 and 4-7C contain a sketch and photographs of this device.

The stone wall food dehydrator (M&S) is a very simple unit, usually built of stones and mud mortar. The cover, a fiberglass sheet, dimensions 900mm x 600mm, is attached to a wood frame, constructed of 38mm square planks. The drying tray is somewhat smaller, 750mm x 450mm, and is made of metal or fiberglass screen or galvanized sand sieve (3/16" mesh) attached to a wood frame of the same size lumber as the cover. Screened vent holes are located above and below the tray in the stone walls so that the pattern of air flow is up through the food and out the top of the box. The unit employs direct radiation and convection. (See Figures 4-1 and 4-2.)

The cost of the unit is approximately M10.00 for materials and M4.00 for labor. This yields a cost per unit drying area of M41.50/m^2. Costs could be reduced by making the cover out of greenhouse grade plastic sheet, but this would need to be replaced annually.

While this unit performs reasonably well, two basic problems have been

experienced. The first is that the mud mortar washes away during periods of heavy rain. This can be remedied by using cement mortar which slightly increases the cost (now M42.40/m^2) but will result in a much more durable dryer. The second problem is that the cover often gets blown off when it is very windy. The cover is relatively light and the wind can easily blow into the box through the relatively large and protected vent holes. The vent holes could be provided with a cover or blocked up with a suitably-sized rock or brick. Another option would be to attach wire loops to the cover and hook these to heavy rocks placed on either side of the unit. This method worked well for the solar water heaters and is recommended in this case.

The second dehydrator using direct radiation and convection that was tested was supplied by the Ministry of Rural Development (MINRUDEV). The unit is made of galvanized sheet metal riveted to a welded angle iron frame and painted flat black inside and out. The 900mm x 600mm fiberglass cover is attached to its hinged angle iron frame with silicone caulk. The screened tray is similar to the one described in the previous unit but is slightly larger, 800mm x 500mm. Unscreened vent holes have been provided by punching out round holes in the bottom and in the back side of the device. A metal slide allows for adjustment of the size of the upper vent holes. Total cost of the dryer is M50.00, yielding a cost per unit drying area of M125.00/m^2, substantially higher than the stone wall unit. The angle of tilt of the cover of both units is 20°. For test purposes both units were faced north. (See Figures 4-3, 4-4C and 4-7C.)

The solar chimney (SC) food dehydrator is a substantially larger unit than either of the previous examples. It, too, operates on the principles of direct radiation and convection. The roof, bottom and access doors are made of galvanized sheet metal. The east, west and north sides are fiberglass sheets. The entire structure has been bolted together; angle iron providing the necessary structural support. In addition to the energy that penetrates the fiberglass walls, a small collector, tilted at 45°, provides preheated air to the food drying in the trays. This simple air collector is made of sheet metal sides, a fiberglass cover and a piece of corrugated roof sheet placed inside such that air passes along both sides of the sheet perpendicular to the direction of the corrugations. Vent holes are screened and are located

across the bottom of the collector and above the access doors at the back of the dryer. (See Figures 4-4A and B, 4-5.)

This unit contains seven drying trays, although it should be possible to put in more, perhaps as many as 12, without substantially effecting its performance. Each tray is 600mm x 880mm giving a total drying area of $3.7m^3$. The unit cost, M115.00 in materials and M80.00 in labor for a total cost of M195.00. The cost per unit drying area is $M52.70/m^2$.

This prototype had a few minor problems. The first was that it fell over during construction and once during a severe wind storm. This caused the frame to go out of square and made it difficult for the doors to close properly. Obviously such a top-heavy device needs to be stabilized. Concrete blocks attached to the two windward legs worked in this situation. The doors actually did not close well for another reason; the hinges were welded to the frame such that the doors tended to spring open. This meant that it was difficult to control the air flow because air could come in or escape wherever it found a crack around the door. This situation allowed for the entry of more air-borne contaminants than was desirable. It prevented interior temperatures from ever getting very warm and it reduced the effective draft that could have been achieved by virtue of the height differential between the top and bottom vents.

Another problem is that the roof is corrugated and opaque. The corrugated roof makes it difficult to seal the edges and again reduces the ability to control air flow through the device. The opaque material prevents sunlight from entering the box when the sun is high in the sky. This makes the dehydrator less useful during the summer months. It is recommended that future units have clear, flat roofs if this configuration is maintained. Another option would be to place the entire unit at some angle, say 45°. The trays would be placed level to the ground and access be provided by a side door. This idea should be compared with the performance of the present unit.

A final problem with this unit was the direction of the top vent. Because of the location of the dryer in a valley, the wind was often directed right at the opening which meant that the air flow was in the direction opposite to what was intended. While this problem would occur depending primarily

on the location of the device in a particular microclimate, it was felt that an omni-directional vent should be provided on future units so that they could be used without modification throughout the District.

The last dehydrator works on convection only. This unit is modelled after a design by Solar Survival, a company in New Hampshire, U.S.A. The original plans use a 55-gallon oil drum to provide lateral structural support and a collector surface. Since used oil drums are not as common in the mountains of Lesotho as they are in the United States, it was decided to modify the design to use a piece of galvanized sheet metal painted flat black instead of the oil drum. Lateral support is provided by an angle iron frame to which the collector surface is attached. The drying rack supports are part of this framework. Vent holes are screened and are located on either end of the dryer and underneath on the east side of the unit. (Left hand side in Figures 4-6, 4-7A, B.)

Operation of the unit is somewhat more involved than the other units. When the sun strikes the dehydrator the metal surface absorbs the energy and causes the air on either side of it to warm up. The air inside the dryer, where the food is located, expands and escapes out the vent holes at either end of the box. This results in a slight vacuum which in turn draws air in the lower vent, through the passage between the sheet metal and the fiberglass sheet, and into the dehydrator below the drying racks. This pre-heated air rises through the food and out the upper vents, taking moisture with it. The temperatures in this unit were generally warmer than in the other dehydrators.

Six trays were provided for this unit of 480mm x 1150mm each. Total drying area is $3.3m^2$. The cost of this unit is M90.00 for materials and M80.00 for labor. The cost per unit drying area is $M51.50/m^2$.

Testing has revealed a number of problems with this prototype. The first is that the trays were made too large. On many occasions it has been difficult, and in one case, impossible, to remove some of the trays. They both were too thick and too wide. The obvious solution is to make future trays slightly smaller in width and, given the spacing of these racks, 25mm thick.

Another problem is that the air passage is constricted as it enters the unit beneath the food. Solar Survival design had a smooth, easily accessible and large opening at this point. In contrast, this prototype has a sharp bend and an opening smaller than the previous passageway. Future units should be made so that this opening is more like the Solar Survival model. An associated problem is that the top vents are smaller in area than the inlet vent. Future units should have the top and bottom openings equal in area.

After several months of operation, the access door fell off its hinges. These were not put on as well as they might have been, the screws pulling out of the chipboard surface. It is recommended that the hinges be bolted rather than screwed onto future driers of this type as the chipboard is inherently very weak.

This prototype was made with one layer of fiberglass glazing rather than the two shown in the Solar Survival design. Although provision was made for a second, outer layer, only one was put on to see how well the unit performed. It is probable that two are needed because of the high temperatures that are developed in the passage between the glazing and the galvanized metal sheet. With the second layer, performance should improve because heat loss along this surface should be significantly reduced and warmer air with the potential to absorb more moisture will reach the food. The effect of this still needs to be investigated. If put on, this extra sheet will add M20.00 to the overall cost. (Cost per unit drying area will increase to M57.60.)

One final note, this dehydrator was designed around the size of the sheet of fiberglass intended to be used as the outside cover. The sheets in stock at the time were 1.2 meters x 1.8 meters. While this results in a good size unit, it would be advisable to try a design based on a 1.2 meter x 2.4 meter glazing layer. This would make it possible, without substantially increasing cost, to accommodate an additional one or two racks and still make the desired modifications to the functioning of the dehydrator.

Test Results

During our early investigations, several types of food were dried. Due to cost and availability, most foods were dropped from the list and cabbage used as the test product. It was hoped that enough data would be required to enable a thorough assessment of year-round performance of the various drying methods but it was not possible to do this. It is recommended that this be attempted during the coming year.

Figure 4-8 compares the drying rate of mutton in three dehydrators during a period in August. The solar radiation was average for that month. The daytime temperatures ranged from 6°C to 18°C. Nighttime temperatures never dropped below freezing. While the Minrudev Unit did somewhat better than the other two models, it still took nine days for the weight remaining to drop below 20%. The Minrudev and mud and stone units had approximately the same rate of weight loss on most days, slightly greater than the Solar Survival design.

Figure 4-9 compares the rate of drying of cabbage by sun drying and in the two small units. Again, the Minrudev unit did slightly better than the mud and stone wall drier. Both units performed better than the open-air method. The experiment was ended after eight days. This period would have been reduced if the long weekend had not intervened during which time the food was brought inside. It is interesting to note that with the exception of the first day, the drying rate in the open air method was essentially the same as in the other units.

Figure 4-10 compares the drying rate of cabbage in the Minrudev drier during three different periods. As should be expected, the drying rate was faster in October than for either period in September. It is interesting to note that in October, moisture loss was recorded during the period from 1600 to 0800 hours whereas it generally did not occur in September. It can also be observed that the drying rate slows down significantly when the moisture content drops below 30%. Finally, the food was considered dry one day sooner during the October test.

Figure 4-11 examines the same periods but concerns the operation of the mud and stone wall unit. This drier did not perform as well in October as did the Minrudev model. In fact, an extra day should have been used to bring the weight remaining below 20%. The patterns for the other two periods are essentially the same as in the Minrudev unit.

Figure 4-12 compares the drying rate of cabbage in four dehydrators in early September,1980. At the end of the test period, five days, the food in the Minrudev unit had reached the lowest percent weight remaining. Next in order were the mud and stone, the solar chimney, and the Solar Survival units. On most days, except the first, the drying rates were almost exactly the same in all units. However, as shown in Table 4-1, while the percent weight loss per hour was essentially the same on each day, the solar chimney and Solar Survival units were filled with much more food than the smaller units. In fact, the SSD had twice the weight at the beginning while the solar chimney had seven times the weight. As can be seen, the fact that a much larger quantity can be dried as well in the same amount of time makes the initially larger investment a sound one.

Table 4-2 examines the percent weight loss per unit of solar radiation for each day of the test period. The rate is essentially the same for all units on any given day. However, substantially less weight is removed (approximately 50%) per unit of radiation as each day goes by. This points to the fact that it is harder te remove moisture as the material gets drier. Cloudy, calm days at the end of a drying period would probably result in poor performance by all of the units.

Conclusions and Recommendations

All units have performed reasonably well, although the SSD design has not done as well as expected. This is probably due to the lack of the second layer of glazing and to the problems discussed concerning the air passage and vent sizing. Its performance should improve if these modifications are made. The most cost-effective design is the solar chimney, if ten trays are used (M37.90/m°). This is probably of value to farmers who wish to dry large quantities of produce. In several tests approximately 1.5kg or

one head of cabbage was cut and put on each shelf in this unit compared with only one head in the small dryers.

With the exception of a few larger farmers, not much interest has been expressed in food dehydrators. Extension and marketing efforts in this area should be directed to this particular segment of the population rather than to everyone in the District. Technical modification and future testing should focus on improving the devices desired by this group of people.

Table 4-1. Weight Loss Per Hour and Percent Weight Loss Per Hour for Four Dehydrators, September 1-5, 1980

Day	Number of Hours	Weight Loss Per Hour(g/hr.)				Percent Weight Loss Per Hour			
		SSD	SC	M	M&S	SSD	SC	M	M&S
1	5.5	80.0	321.8	58.2	67.3	3.4	4.0	4.9	5.8
2	8.0	96.2	296.2	41.2	41.2	3.5	3.6	3.6	3.5
3	8.0	52.5	178.8	28.8	20.0	2.2	2.1	2.4	1.9
4	8.0	32.5	96.9	8.8	10.0	1.4	1.2	0.8	0.9
5	8.0	11.2	50.6	8.8	3.8	0.5	0.5	0.8	0.5

Table 4-2. Percent Weight Loss per Pyranometer Count for Four Dehydrators, September 1-5, 1980

	Pyranometer			Percent Weight Loss Per Count			
Day	Counts	BTU/ft^2	Counts/hr	SSD	SC	M	M&S
1	238	754	43.3	.08	.09	.11	.13
2	443	1404	55.4	.06	.06	.06	.06
3	493	1563	61.6	.04	.03	.04	.03
4	428	1357	53.5	.02	.02	.01	.02
5	461	1461	57.6	.01	.01	.01	.01

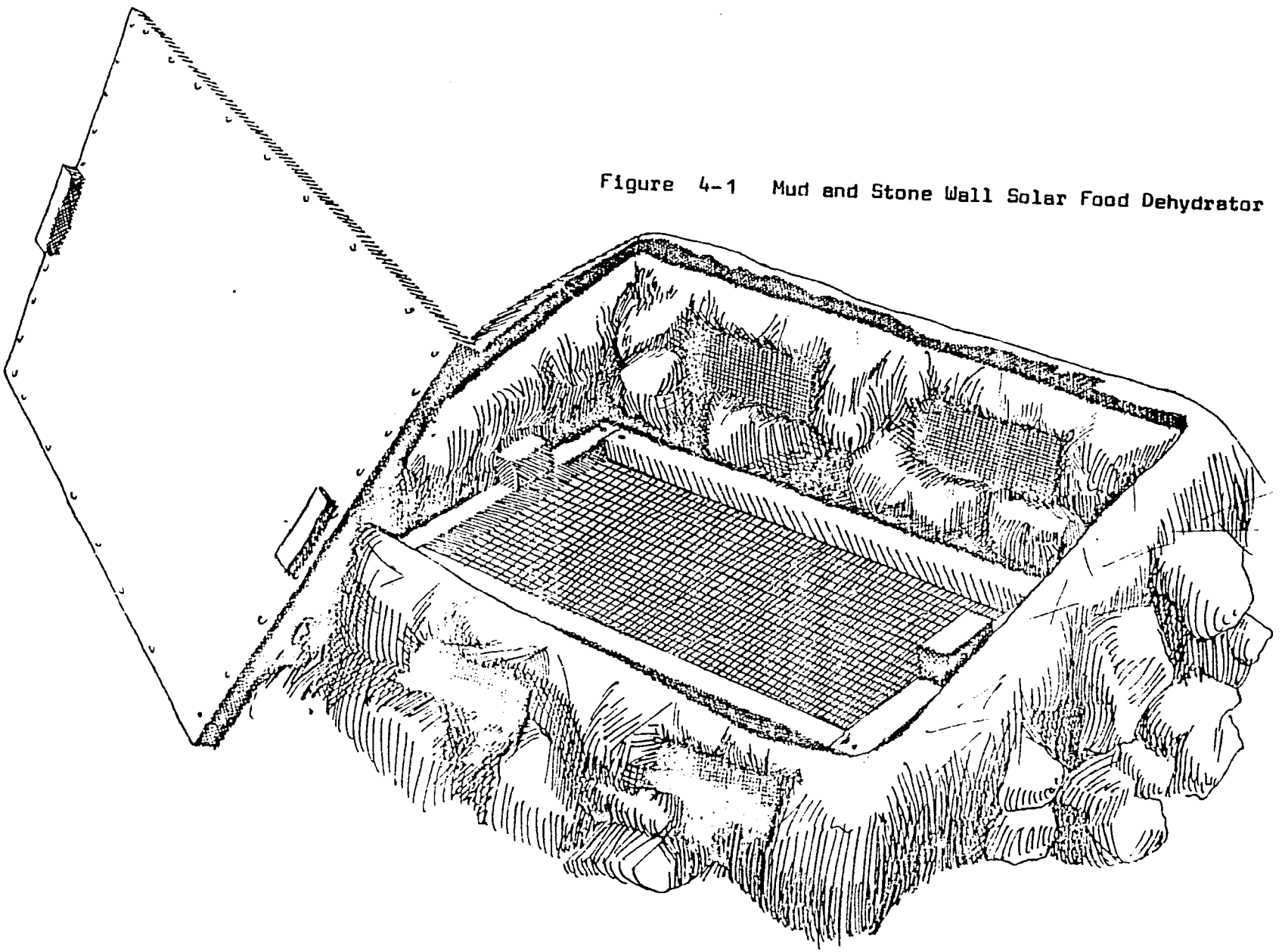
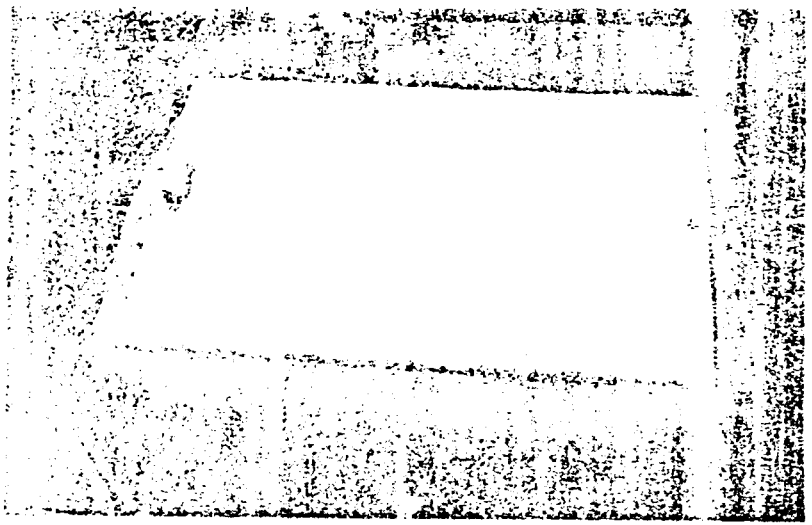


Figure 4-1 Mud and Stone Wall Solar Food Dehydrator



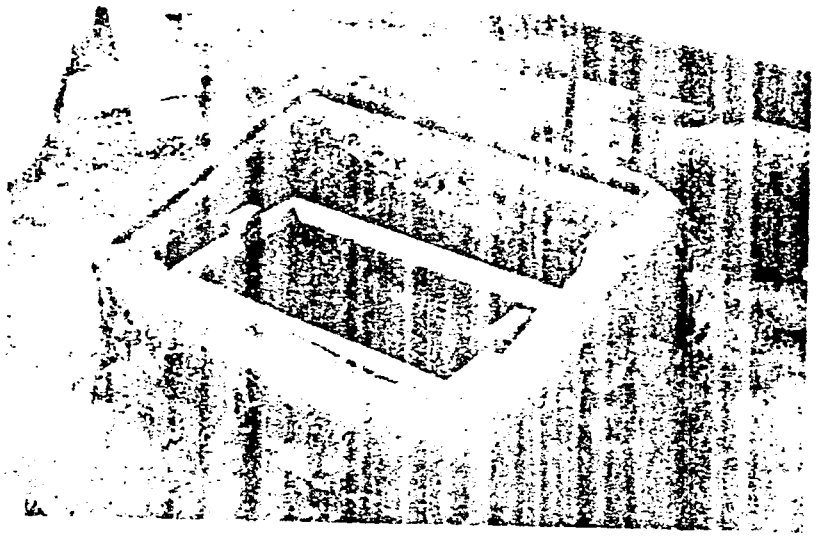


Figure 4-2 Mud and Stone Wall Solar Food Dehydrator

A. (Upper left) North view

B. (Upper right) Cover removed showing tray

C. (Lower left) West view showing tilt

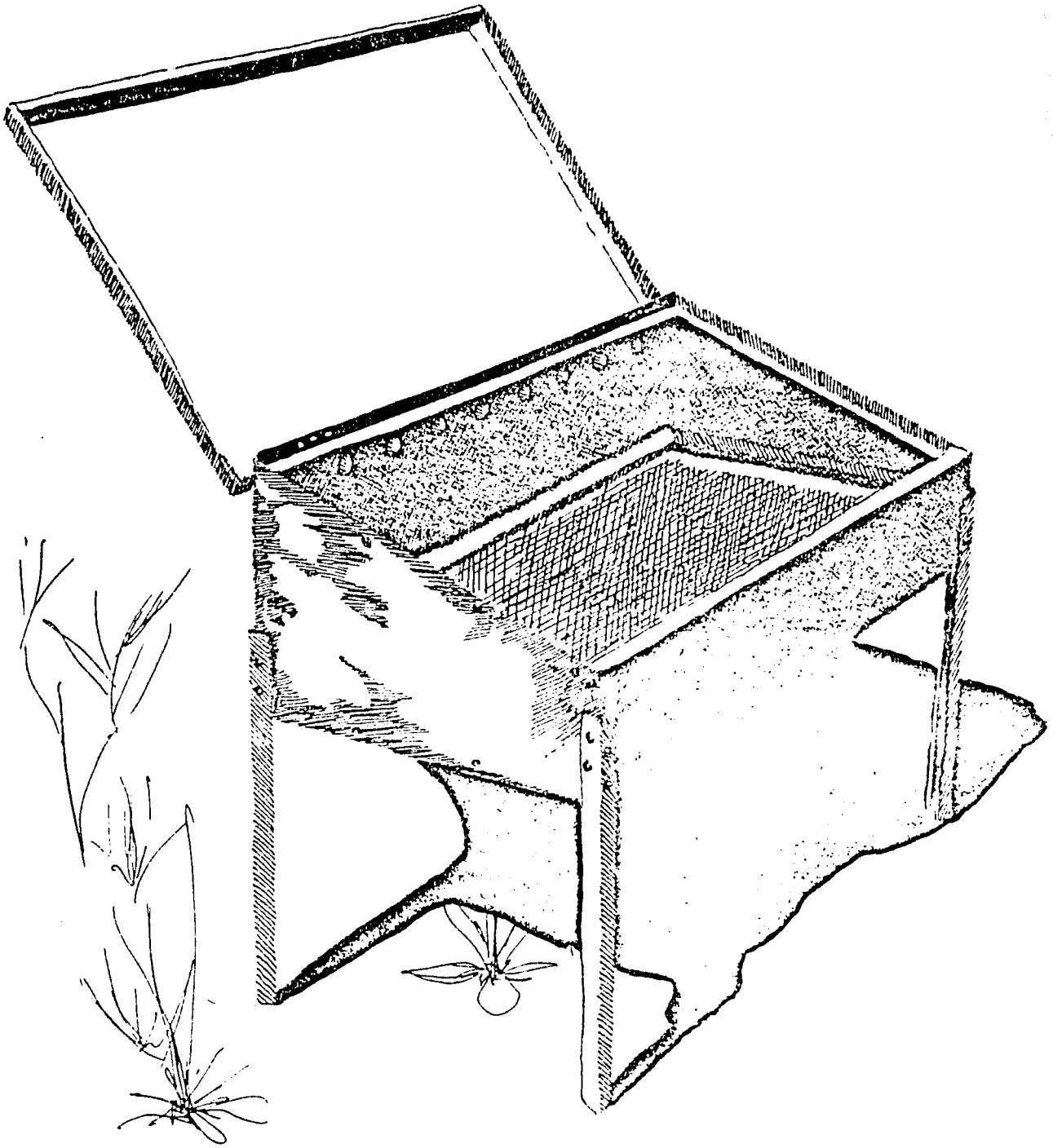
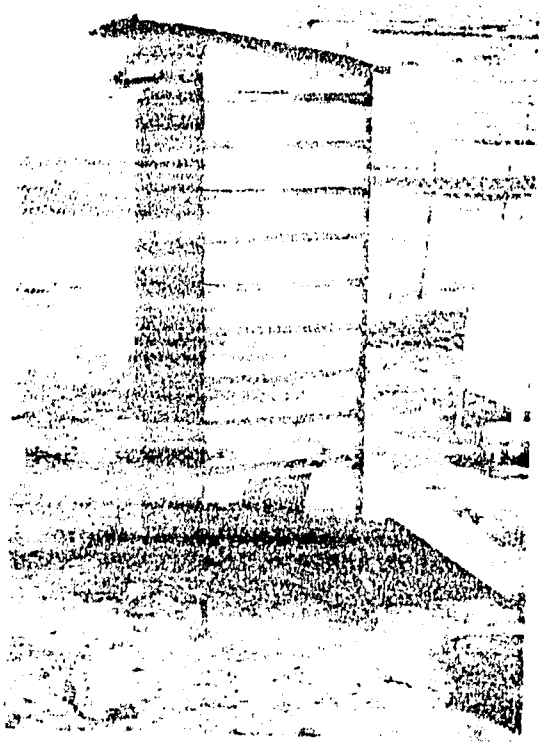
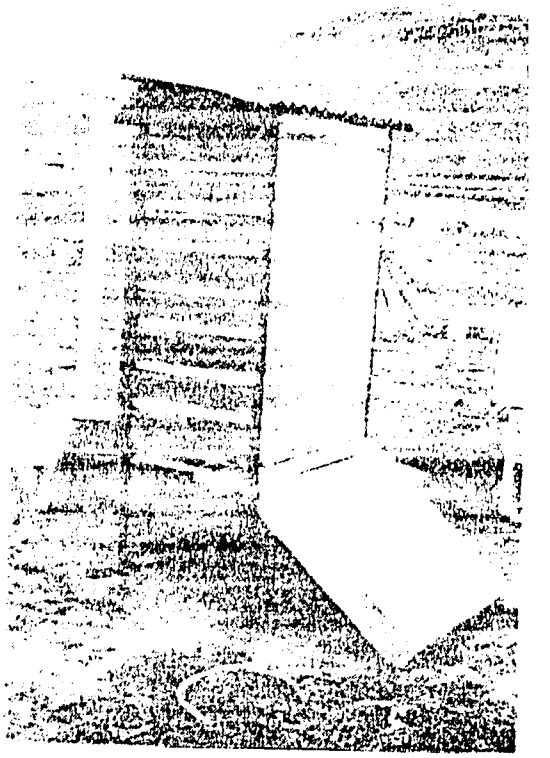


Figure 4-3 Sheet Metal Solar Food Dehydrator -Minrudev Prototype





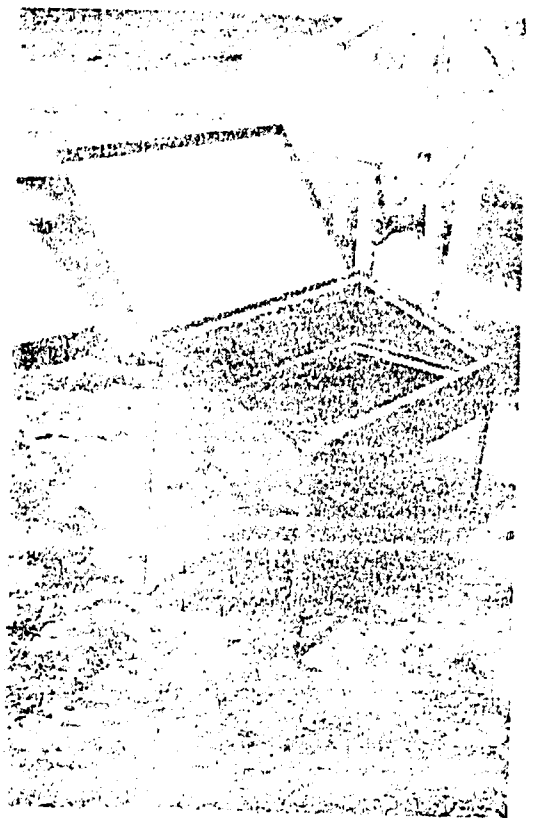


Figure 4-4 Solar Food Dehydrators

A. (Upper left) Solar Chimney-Southeast view

B. (Upper right) Solar Chimney Northeast view

C. (Lower left) Minrudev Prototype-Northeast view, cover open

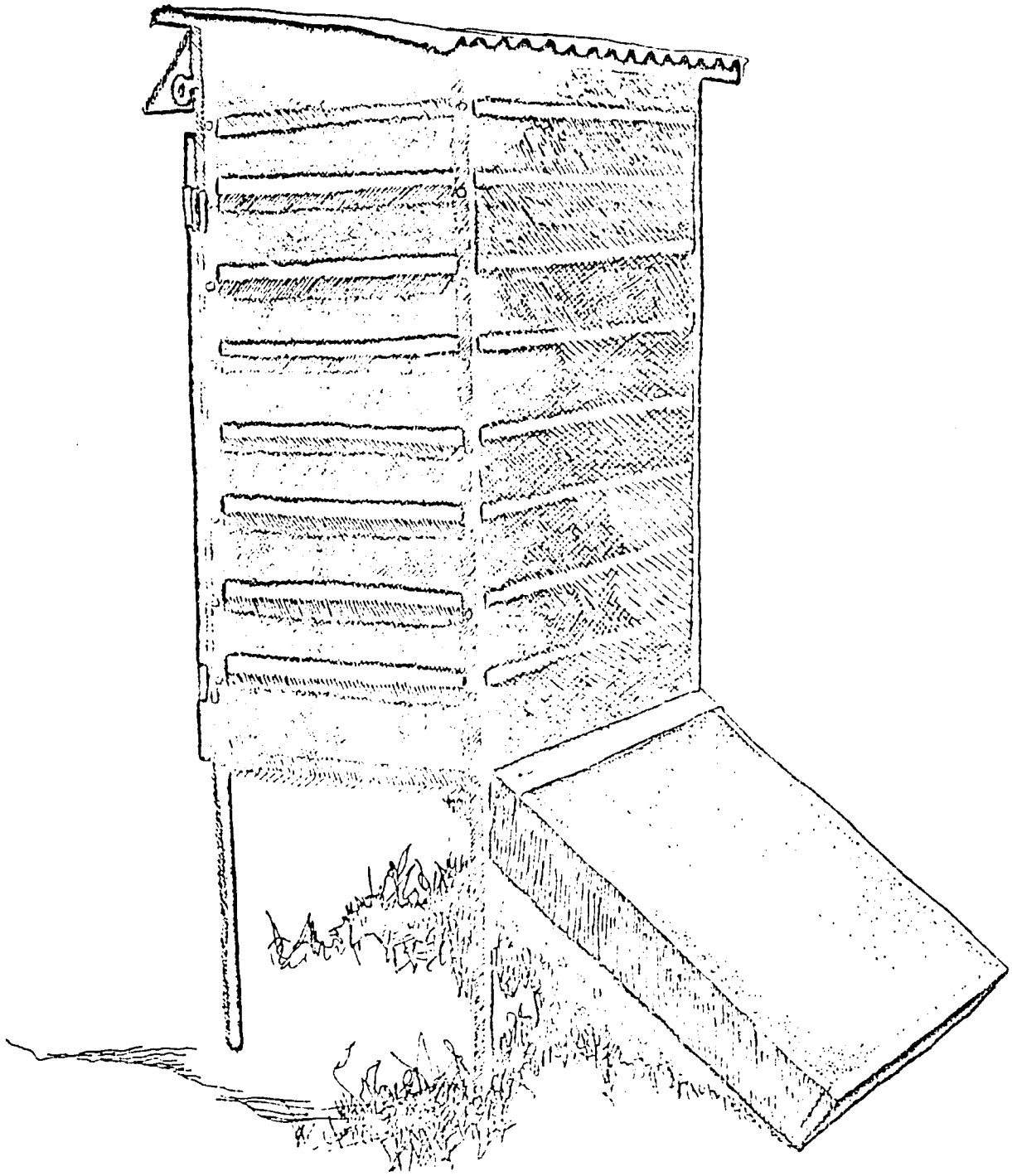


Figure 4-5 Solar Chimney Food Dehydrator

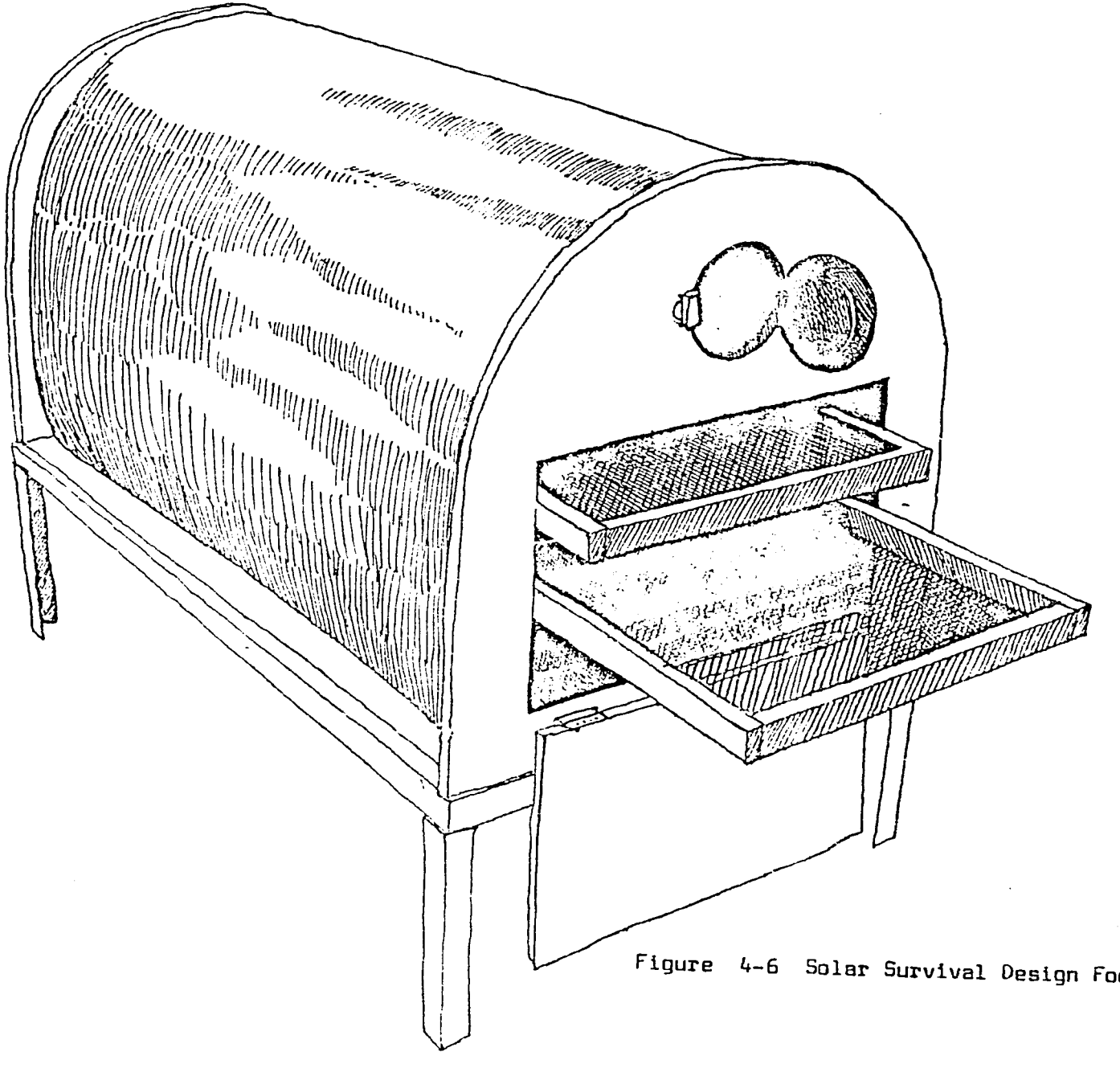
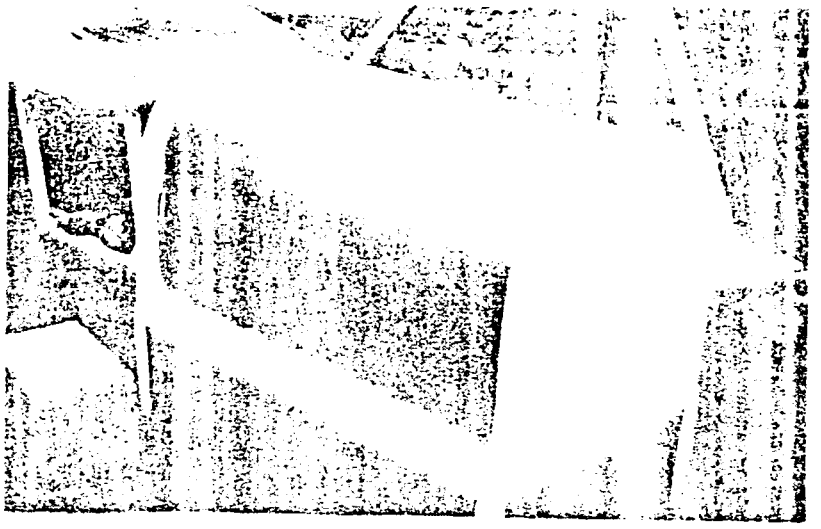
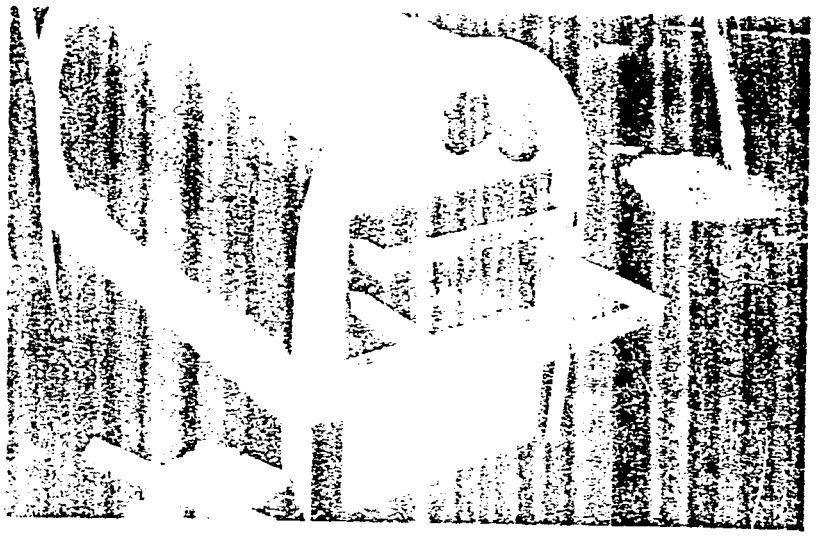


Figure 4-6 Solar Survival Design Food Dehydrator





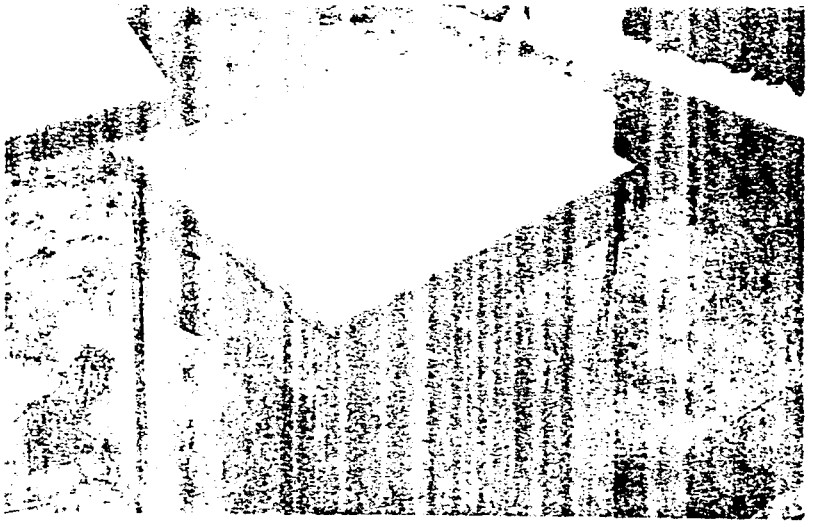


Figure 4-7 Solar Food Dehydrators

A. (Upper left) Solar Survival Design- Northeast view

B. (Upper right) Solar Survival Design- Northeast view, door and vent open

C. Minrudev Prototype- Northeast view, cover closed

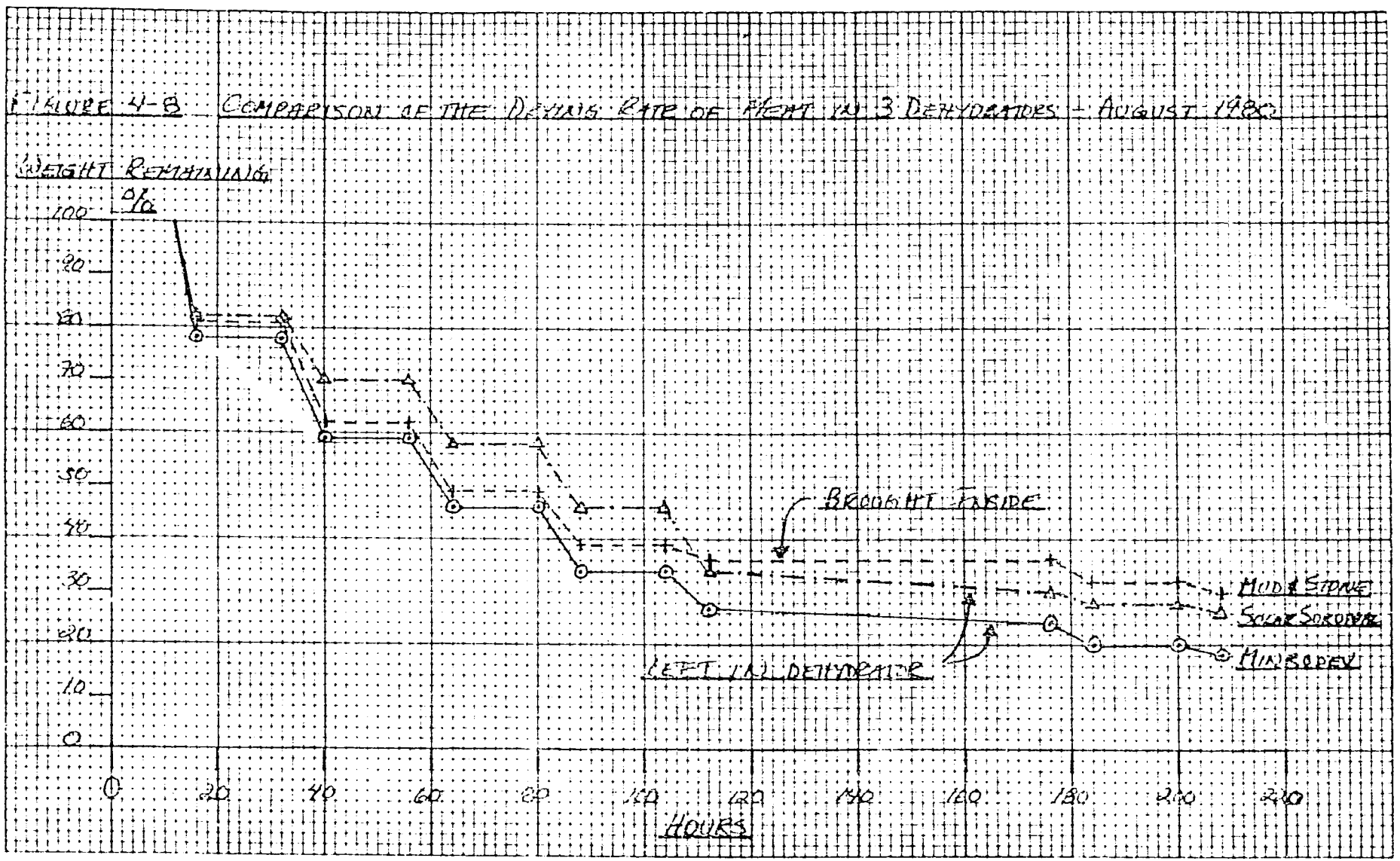


FIGURE 4-8 COMPARISON OF THE DRYING RATE OF FRUIT IN 3 DEHYDRATORS - AUGUST 1980

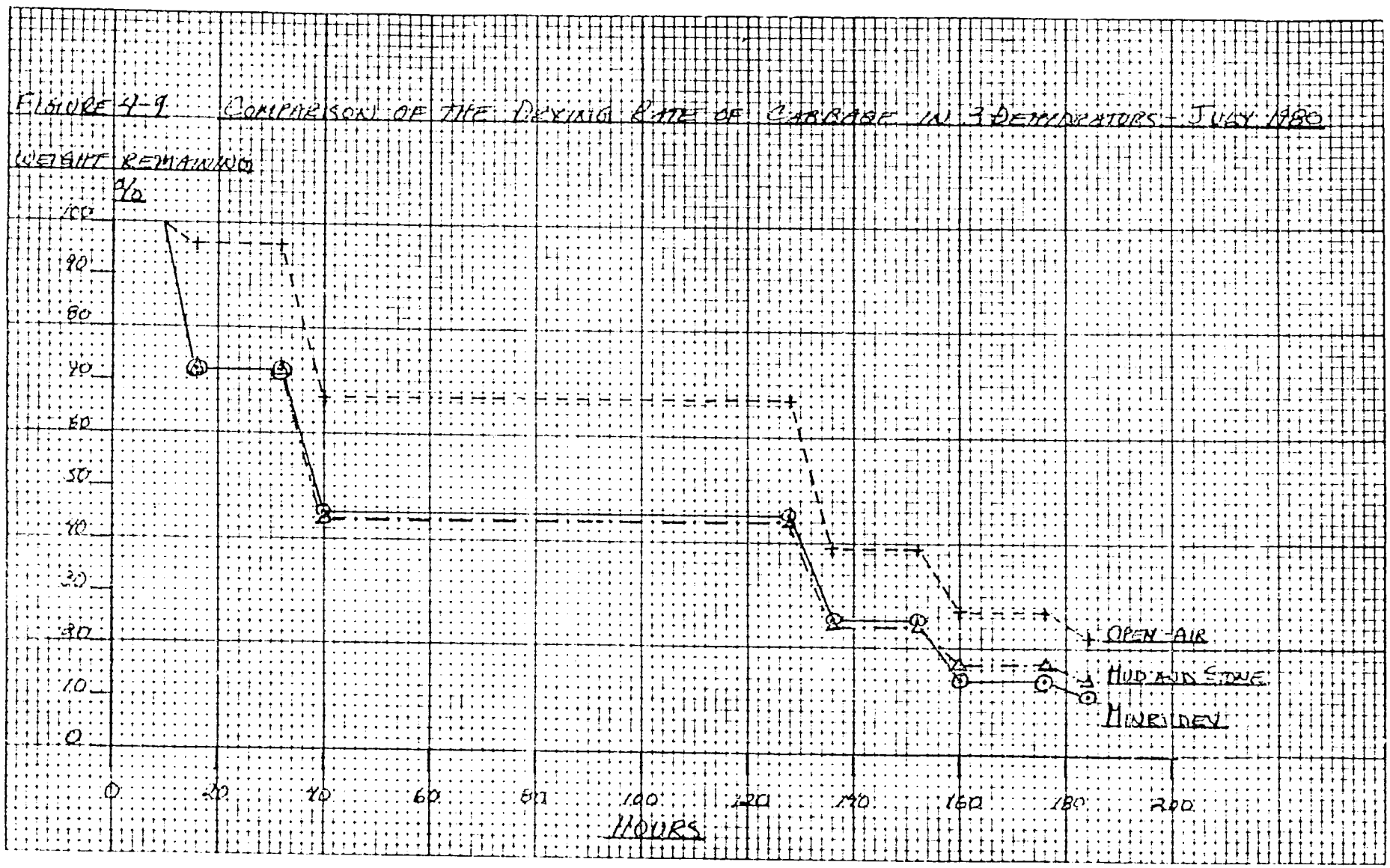


FIGURE 4-9 COMPARISON OF THE DRYING RATE OF CARRAGE IN 3 DEMONSTRATORS - JULY 1980

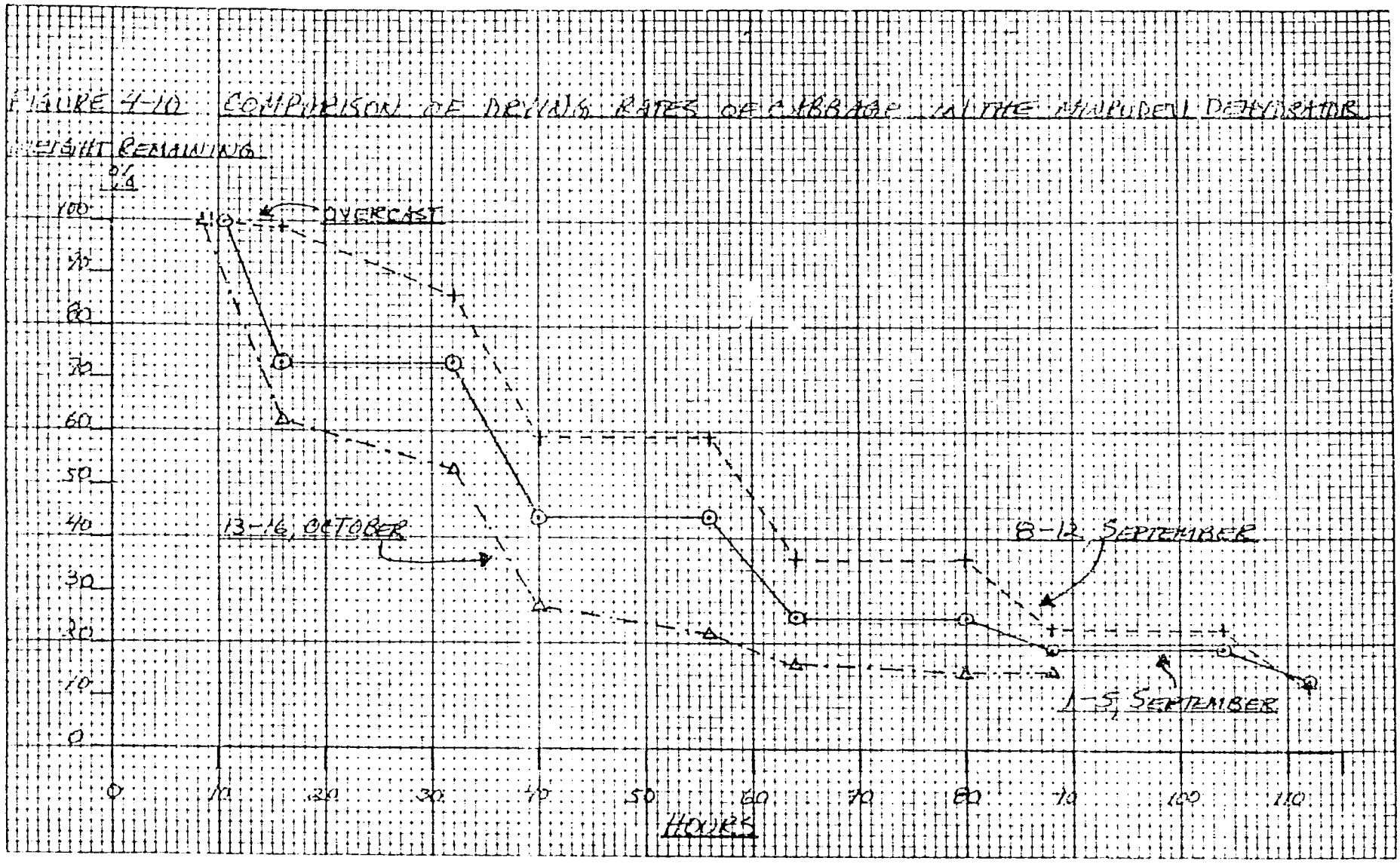


FIGURE 4-10 COMPARISON OF DRYING RATES OF CABBAGE IN THE MAUPUDEN DEHYDRATOR

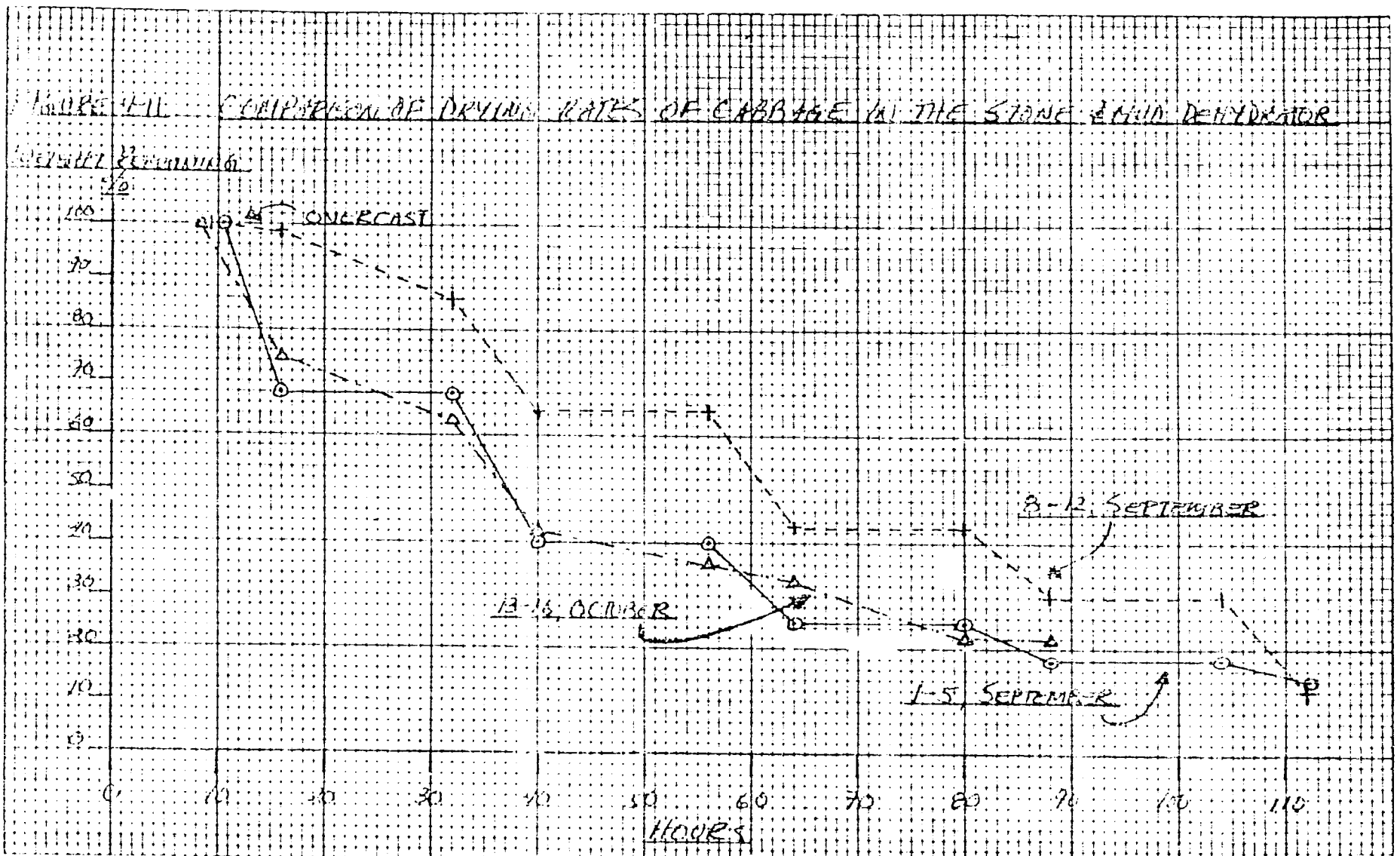
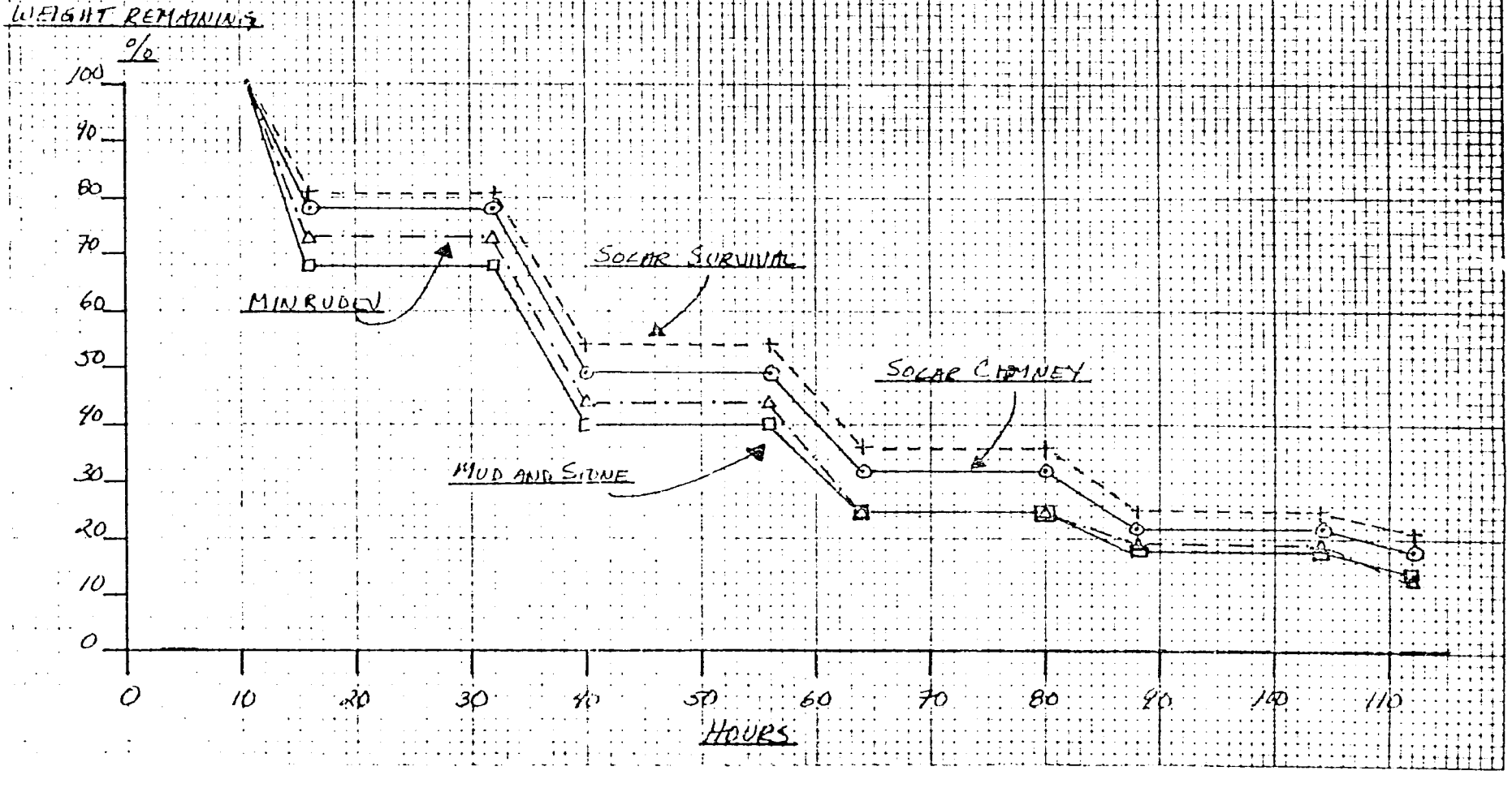


FIGURE 4-11 COMPARISON OF DRYING RATES OF CABBAGE IN THE STONE ENERGY DEHYDRATOR
OVERCAST
8-12 SEPTEMBER
13-16 OCTOBER
1-5 SEPTEMBER
HOURS
0
10
20
30
40
50
60
70
80
90
100
110

FIGURE 4-12 COMPARISON OF DRYING RATES OF CABBAGE IN 4 DEHYDRATORS - SEPTEMBER 1980



CHAPTER 5 SOLAR ELECTRIC SYSTEM

In April,1980, a field installation of a solar electric system was made at Linakeng Clinic. The two photovoltaic panels were attached to an engle frame which in turn was bolted to a gum pole and wood-plank stand which raised the whole assembly about 2.0 meters off the ground. The panels face true north. Power is fed underground to a control panel and battery box inside the clinic. From there, power is distributed through conduit to the two-way radio and to ceiling-mounted 12 VDC flourescent lamps. More details on installation and initial test results can be found in the interim report.

The batteries initially used were two dissimilar automotive batteries that had been in use at the clinic. Blocking diodes were used to prevent cycling between the two batteries which could be caused by uneven charging in the two batteries. Two 90 amp-hour, 12 volt truck batteries (Chloride No.670) were installed in late August. While probably unnecessary, the blocking diodes were left in the system.

Two watt-hour meters were installed in May,1980 to measure energy input to the batteries from the solar cells and to measure lighting energy used. The third watt-hour meter had to be returned to the manufacturer because the wrong unit was supplied. Of the two meters installed, only the one measuring energy input ever worked. This unit was out-of-order for portions of July and August and finally stopped working in October. The unit sent to the U.S.A. for replacement returned in late November and was installed in December. The exact problem with these meters has yet to be determined. However, at one inspection, it was noticed that the counter sometimes moved forward an extra digit or one-half digit in the tens or hundreds place on the dial. Sometimes this occurred so that the thousands digit would move even though the total accumulated on the counter only read 500. Although we realized that this problem could occur at any time, we decided that the counter should be reset at the end of any day when the reading was greater than 450. Whether it was the result of this procedure or due to chance, the meter worked for an additional forty-five days without a breakdown.

While problems have been experienced with the data-gathering equipment, there have been none with the photovoltaic cells. These have been supplying power to the batteries on a regular and reliable basis. The only breakdowns that have occurred have been elsewhere in the system.

On several occasions, the radio did not work on cold, winter mornings. This was probably due to the fact that the radio and batteries are both located in a room which at the time had no door and old windows that closed poorly. This could very likely result in "hard-starting". A further complication was that the batteries were both relatively old. In any case, the problem was cleared up by noon and the radio was working fine. To prevent this problem in the future, it is recommended that the batteries and the radio be located in a place where they are not subject to such severe temperature extremes.

The second major complaint was that on certain occasions, there was not enough energy in the batteries. Upon investigation, it was discovered that this situation occurred after the lights had been heavily used the previous night and usually after a period of very inclement weather. One particular case was when someone in the village died and all of the lights were on in the clinic the entire night. In the morning, there was not enough energy to run the radio and the petrol generator had to be turned on. This problem has not occurred since the new batteries were installed, but neither do we think that much energy has been required in the same manner since that instance. One solution would be to increase the capacity of the system, but this does not seem warranted because in most cases the energy provided has been quite adequate. It seems that until a substantially larger energy demand is experienced, it will be the responsibility of the clinic staff to be conservative of their use of lights, even on emergency occasions, or be prepared to use the petrol generator if communications are required first thing the following day.

On one occasion, the wire fuse between the battery and the radio blew out. This occurred shortly after the radio was properly wired to the battery through the protective fuse. Since the fuse was only 2 amps and the current draw of the radio during transmission is 10 amps, it is not surprising that the fuse blew. The wire was replaced with a larger one, so that under normal usage , the fuse would remain intact.

More recently, we were told that the batteries had drained down for no apparent reason. When checked, it was found that this was due to a poor connection that occured when the broken watt-hour meter was removed. Once this was fixed, the system seemed to be working fine once again.

The final problem has to do with dust accumulation on the solar panels. On most inspections, it has been necessary to wipe off the panels so that they were once again free of dust. The only real solution to this problem is for the clinic staff to inspect the panels weekly and clean them as needed.

Subjectively, the system has performed very well. The intention had been to monitor the system fairly exactly and thereby see how well demand and supply were matched. Because of equipment failure, it was not possible to do this. Only energy input was monitored, and that only for a period of four months.

Table 5-1 compares the mean daily watt-hour meter and pyranometer readings for these four months. Two separate totals, 0800-1600 and 0800-0800 hours are shown as are the standard deviations of the readings for these periods. With the exception of September, the mean daily watt-hour output is relatively constant. This is to be expected because the tilt of the panels was adjusted to follow the seasons. It was 60° in winter and moved to 45° at the end of August. The lower readings in September are probably due to the fact the solar radiation was lower than anticipated during that month. Note also that the standard deviation is substantially larger in August and September. This corresponds to increased variability in the solar insolation resource during these months. (See Chapter 2 for more details.)

This information is supported and displayed on a daily basis in Figures 5-1, 5-2 and 5-3. These graphs compare daily pyranometer and watt-hour meter readings for July, August and September. Data presented are for the 0800-0800 totals. As before, the variability of the readings increases for each month. A closer examination reveals that in general, the trend in pyranometer readings is closely followed by the watt-hour recordings. This is particularly noticeable when the weather is relatively overcast compared to the surrounding days. Exact relationships should not be attempted because the pyra-

nometer is located in Thaba Tseka while the solar electric system is in Linakeng, about 30 kilometers away. It is obvious that the weather in both locations will not always be the same. (To convert pyranometer readings into BTU/ft^2 multiply the numbers given by 3.17.)

Table 5-2 compares predicted and measured mean daily watt-hour readings for the four test months. The predicted values are based on the equation

Energy Output = .15 x Incident Radiation

(watt-hr/day) (BTU/ft^2/day)

where the incident radiation varies depending on the month and the angle of tilt of the panels. Percent differences are all less than 10% so it is felt that the panels are performing up to their expectations.

Conclusions and Recommendations

The performance of the solar electric system at the Linakeng Clinic has proven to be quite successful. The staff at the clinic have found the unit to be reliable with the few noted exceptions. Measured output is close enough to predicted values that sizing future installations should be fairly simple and accurate. Based on the performance of the energy monitoring equipment, it would be advisable to find more reliable meters for future work.

Since the present two-battery system has been able to keep up with the average demands of the clinic, the District Medical Officer has been advised to include this type of system in the other clinics around the District. It will only be necessary to go to larger systems if the demand is substantially greater than that experienced in this situation. Obviously, long-term performance should be watched and an accurate record of repairs and difficulties encountered should be kept. At this stage, it would seem that the system should prove to be reliable for many years to come.

Table 5-1. Comparison of Mean Daily Watt-Hour Meter and Pyranometer Readings for Four Months, in 1980

Month	Watt-Hour Meter Readings 0800-1600	Watt-Hour Meter Readings 0800-0800	Pyranometer Readings 0800-1600	Pyranometer Readings 0800-0800
June	213	247		
σ_n	30	33		
July	216	255	343	355
σ_n	36	36	31	32
August	220	246	369	403
σ_n	48	65	96	93
September	187	222	402	437
σ_n	84	85	153	156

Table 5-2. Comparison of Predicted and Measured Mean Daily Watt-Hour Readings

Month[1]	Watt-Hours Predicted	Watt-Hours Measured	Difference M-P	Percent Difference
June	260	247	-13	5
July	272	255	-17	7
August	256	246	-10	4
September	235	222	-13	6

1. Predicted watt-hours for June are based on derived insolation values presented in Table 2-14 of the interim report. Values for July through September are based on actual insolation figures obtained in Thaba Tseka in 1980.

FIGURE 5-1 COMPARISON OF DAILY INSOLATION AND WATT-HOUR METER READINGS FOR JULY 1980

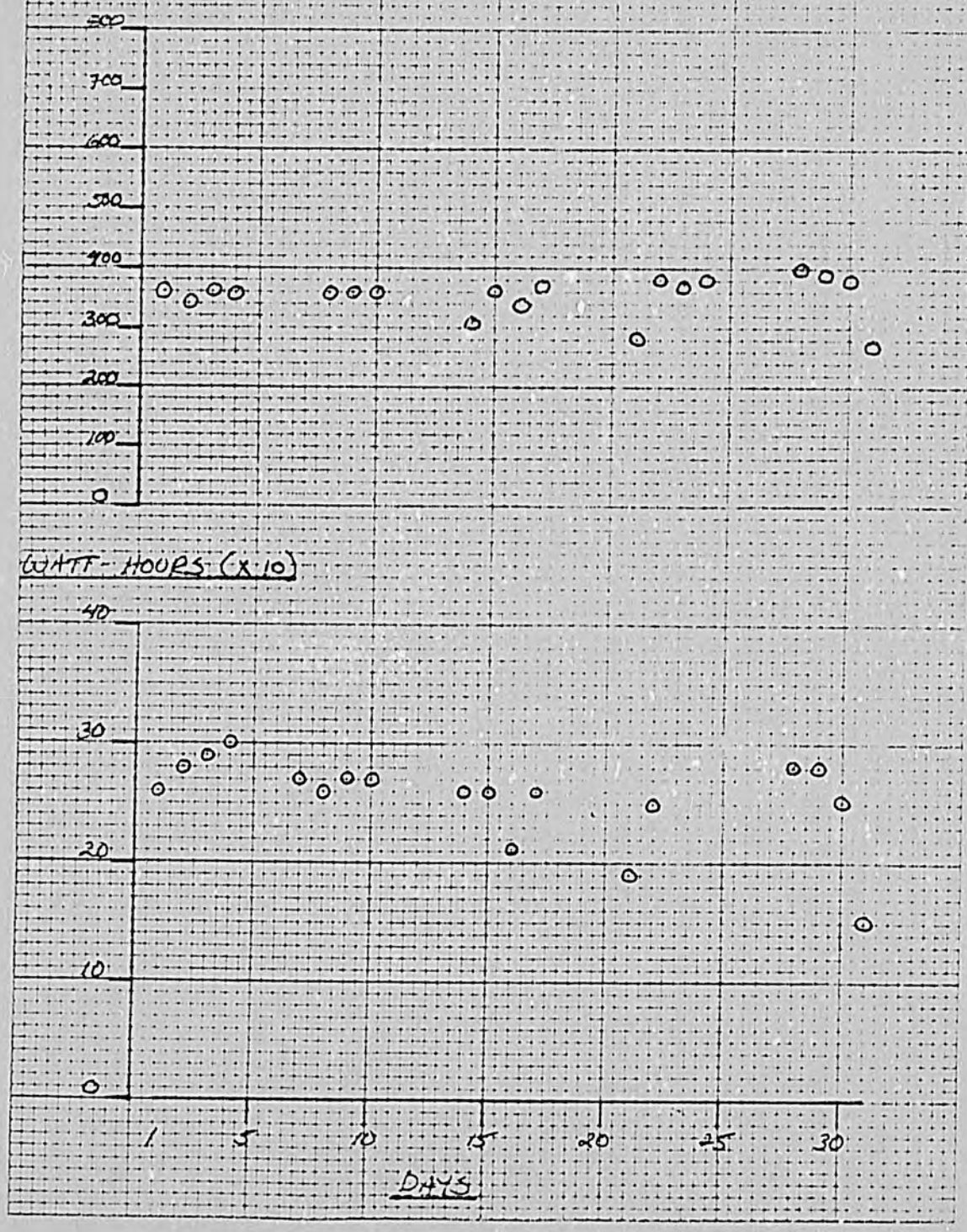


FIGURE 5-2 COMPARISON OF DAILY INSOLATION AND WATT-HOUR METER READINGS FOR AUGUST 1980

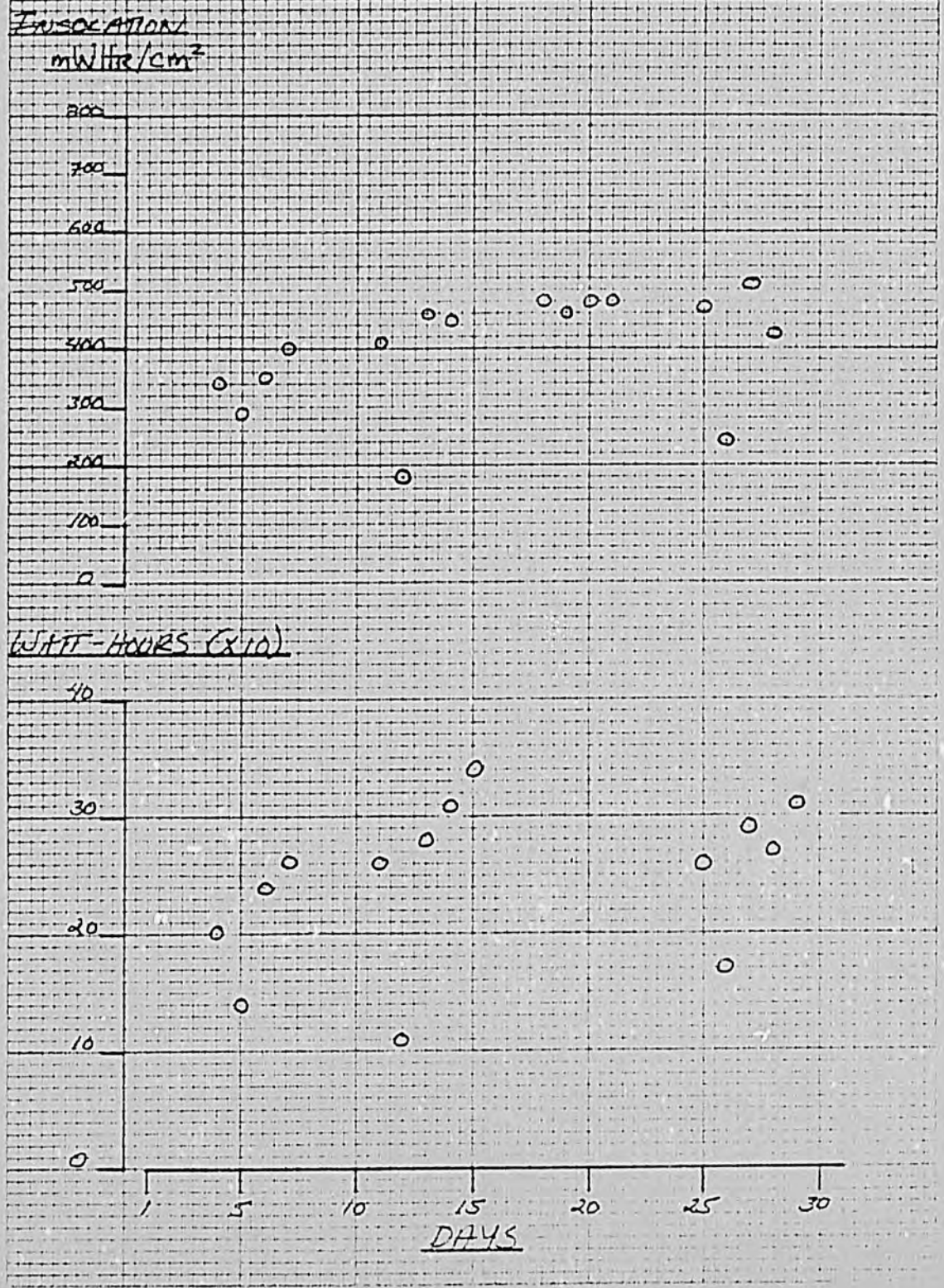
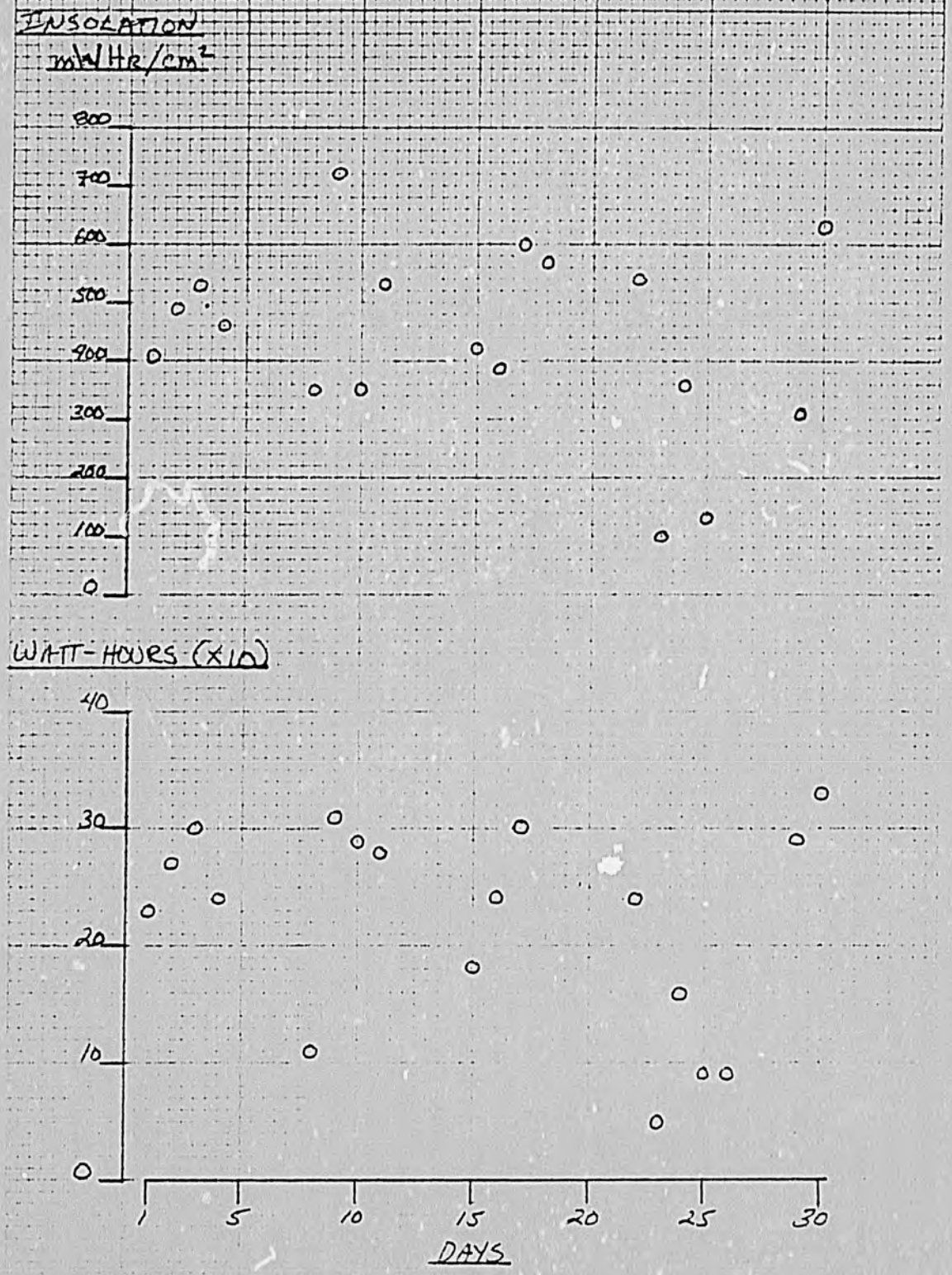


FIGURE 5-3 COMPARISON OF DAILY INSOLATION AND WATT-HOUR METER READINGS FOR SEPTEMBER 1980



CHAPTER 6 COOKING

Based on surveys done during the first part of the year. It was determined that cooking was the primary purpose for which fuel is used in the home. We felt it was necessary to concentrate more of our efforts on this problem and about one quarter of our time was spent on this task in the second half of the year. Open fires, paolas, mud stoves, and solar ovens were investigated. This chapter presents the prototype we tested, initial results and evaluations of these units. Much more work is needed.

Prototypes and Cooking Methods

Local cooking methods rely on the use of open fires and paolas (brazier type cookers). Occasionally, people use a clay oven to bake bread, although we have not yet seen this in Thaba Tseka District. The fuels used are lisu-kraal dung, khapane-cow dung from the fields, shrubs, cheche, sehalahala, lengana, etc., and usually in wintertime, if available, willow or poplar trees. Fires are made either inside or outside depending on the time of the day and the weather. Windbreaks are used by some and are made of stone walls built into a cross, a 'T' or a circle or are just pieces of sheet metal propped up as needed to protect the pots.

We decided to look both at methods of increasing the efficiency of traditional fuels and at their replacement. In the area of efficiency, paolas and mud stoves were considered. Solar ovens were examined for their potential of replacing or supplementing existing supplies. Increasing efficiency and replacing the need for traditional fuels should result in conserving these scarce resources. However, the outcome might be that there will be no net decrease in consumption. Instead used patterns might change, and by at least one measure, the "standard of living" would increase. It is much too soon to tell.

Mud Stoves

The idea behind a mud stove is to use one fire to cook several pots simultaneously, without having to purchase an expensive store-bought stove. Other features include smoke removal from inside the house, storage of heat in the walls of the stove for use during cold winter nights and more efficient use of the fuel that is used. In order to see how well this technology would

be accepted by people in this District, three prototypes were built at the R.T.U. and two in peoples' homes in the nearby village of Pontseng.

Figure 6-1 contains photographs of the three units at the R.T.U. Figure 6-1A is the first mud stove we built. A wooden form 1 meter square by 500mm high was placed on top of a previously constructed stone and mud base. Sand and clay were mixed together in a ratio of 2:1 and 50mm long pieces of thatch were added to help act as a binder. Water was combined until a rather wet cement mixture was obtained. This was then poured into the mold until a height of 400mm was reached. The stove was left to dry for a week after which the holes, damper slots and smoke passages were carved out. Since no round flue pipe was available, a 75mm square piece of galvanized down pipe one meter long was used as the chimney.

Figure 6-1B shows the second prototype. Instead of using a mold, this stove was built up with layers of a not-so-wet mix. The mason was able to complete the upper portion of the stove in less than a day. The mixture used the same clay, only this time the ratio of sand to clay was 1:3. The smoke path follows a counterclockwise loop and the only damper has a side slot. The pot holes are recessed into the surface of the stove.

Figures 6-1C and D are of the third prototype. In this case the slump method was also used and the smoke passage, damper slot and pot holes are the same as in the previous design. The clay-to-sand ratio is also the same but in this case a different clay was used, red instead of black.

All units have been left outside during the rainy season without any coverings. They have held up quite well although the second prototype shows the greatest signs of wear; surface cracking is noticeable in the third stove although not in the others. The fire chamber in the first unit changed from black to red after several firings. The damper slots have become worn as have the pot holes. This is probably due in part to the relatively coarse sand used in the mix. Since this sand is what is typically available, it would be advisable to pass the sand through a 1/8" mesh sieve for future units. The fire chamber in this unit has continued to pit and wear away since the stove was completed. It is likely that silt in the clay, coarse sand and the sharp points of the sehalahala are contributing to this situation.

Smoke is a problem with all of the stoves. It comes out around the sides of all the pots, and through the top damper slots. On many occasions the chimney does not draw well and the flames and smoke come out the feed hole. The height of the chimneys relative to their surroundings and the wind pattern in that particular location are probably the cause of this last problem. The smoke escaping around the pots is probably due to inadequate draft and to the fact that the pots do not sit completely smooth all the way around the holes. Even though effort has been put into fixing this, some of the difficulty lies with the cast iron pots which have a bump in their surface right where they sit on the stove; recessing the pots protects them from the winds but has not really solved the smoke problem. The probable solution to the smoke dilemma will be to increase the height and diameters of the chimneys. Other options include fixing the cast-iron pots permanently into the stove,or using the easier-to-seal aluminum pots. In spite of the difficulties we have encountered, cast-iron pots have been used throughout our experiments because these are most commonly found in peoples' homes and because aluminum pots are used primarily on a paraffin burner, not on an open fire.

Papa, steam bread, rice, cabbage and meat have all been cooked successfully on the mud stoves. Most of the testing has been done on the first prototype which has two relatively short smoke paths. The second two holes both cook considerably slower than the hole over the fire. Food always has to be brought to the first hole to finish cooking.

The mud stove usually was compared to an open-fire without a windbreak during the tests. Water evaporation and cooking tests were performed. Amount of fuel used and time taken to complete the process were the primary measures in the cooking tests. When evaporating water, the fuel used was kept constant while water loss and time were measured.

If only one pot was used, on the hole above the fire, the mud stove took 1-1.2 times the time to cook the same food as on the open fire. In these cases fuel consumption also ranged from 1-1.2 times that of the open fire. Since the first prototype did not have a water container permanently in the smoke path, the additional energy probably went into heating up the stove walls. This would be valuable if the unit was inside a house and the heat was needed.

When more than one pot was placed on the stove and only one on the open fire, the mud stove took from 1-1.3 times the time to cook the food as the open fire. The pot on the fire hole generally took the same time or evaporated the same amount of water as the pot on the open fire. While the time ratios are similar to the first case, the fuel consumption ratios are considerably different, ranging from .74 to 1.5. However, in these cases the quantity of food cooked on the stove was 1.8 times that cooked on the open fire so actual fuel consumption per unit of food cooked was 0.41 to 0.83. This translates into a 20% to 60% savings in fuel.

Water evaporation tests show similar results. Three pots were placed on the stove and one on the open fire. The pot on the fire hole evaporated about the same amount of water as the one on the open fire. However, because there were two more pots to absorb energy, 1.7 to 1.8 times the amount of water was actually evaporated. It is interesting to note that when three pots were placed over the same open fire, only about 60% of the water could be evaporated compared to the mud stove.

There was a noticeable difference between the hot and cold mud stove. This experiment involved evaporating water from three pots when the stove was still cold from the night before. Shortly afterwards, about 3/4 hour, the same test was repeated. The time decreased and the amount of water evaporated increased. The increase on the hole over the fire was 1.5 times while on the back holes it was as much as 3 times the amount during the first test.

Paolas

In Lesotho, paolas are used to cook almost exactly the same foods as on an open fire. Their major value is that they make the fire "portable". This is particularly important when dung is used as the fuel. After the initial smoky stage, the dung coals. It can then be taken inside and used for both cooking and heating without the occupants having to suffer quite so much from the smoke.

Three types of paolas were investigated, a regular paola, a 3--hole unit and a unit that is similar in design to a cooling tower. Figure 6-2A contains photographs of these three items. The regular paola is usually made from a

a discarded paraffin tin. Many small holes are punched around the sides; a slightly larger hole is put in which is used when tending or lighting the fire. A wire handle is provided and some method of holding the pot up off the fire is usually included.

The second prototype has three larger holes provided around the base. No small holes have been punched around the sides. Both this and the regular paola are about 30cm in diameter and 30cm high.

The third prototype is made from galvanized sheet metal which has been formed into two truncated cones. The top cone has been inverted and has been provided with small ridges, presently one centimeter high, to support the pots up off the surface of the cone. This allows the smoke to exist around the sides of the pot. The top of the upper cone has been fitted with a wind shield to help protect the pot from losing too much heat when it is windy. One small hole has been provided for tending the fire. This paola is designed to take a size 3/4 up to a size 3 cast-iron three-foot pot. A size 1 is shown in the figure. See Figures 6-2B,C, and D for more details.

The reason for developing the last model was to help eliminate some of the problems apparent in the other two designs. The regular paola has two basic difficulties; no real control of the airflow and, depending on the size of the pot, a high probability that the flames and smoke will not hit the pot as they rise out of the paola. The fire tends to glow, not flame, a situation which is good for home heating which results in slower cooking. The three-hole prototype at least directs the airflow; but it still does not control the smoke and flame path around the pot.

The last design both directs the airflow up through the fuel and forces the flames and smoke to pass close by the pot as they leave the paola. This is because the hole over which the pot rests is smaller than the pot and in order to escape, all air must go in that direction. The concentrating effect is quite substantial. In one comparative test with the regular paola the new unit cooked rice in 15 minutes using .79 kg of fuel while the regular paola took 25 minutes and required 1.3kg of fuel. This represents a 60% savings in fuel consumption. In a water evaporation test, with the fuel held constant, the new paola required 85% of the time and evaporated off 1.9 times the water compared to the regular paola. Approximately the same

comparisons would be true of the 3-hole design since it and the regular paola performed similarly in their comparative tests.

The new paola design is capable of producing and sustaining a flame throughout the cooking process. This is not typical of normal dung or lisu fires whether in the open or in a paola. Another feature is that the new design produces almost no smoke if the fuel is dry. This combination allows for quicker cooking inside or out and less smoky conditions when the paola is brought inside. A possible disadvantage of the design is that it does not give off heat for a long period of time as do the paolas in which the fuel coals.

Some modifications are already apparent. First, because of the high temperatures caused by the concentration of the flames, it is likely that the galvanized sheet metal will burn out fairly quickly. While not expensive to replace (the material cost of the entire poala is only M1.50) we feel it would be better to have a more durable design. If the idea takes-off, it might be worthwhile to consider a cast-iron model, particularly for the base, which should prevent burning out for 10 years or so. Other possibilities include heavier gauge sheet metal or even steel plate 1/8" to 1/4" thick. It would probably be advisable to have a hexagonal or octagonal base and flat sides rather than a conical shape to facilitate the manufacturing process if heavier materials are used.

Another possible modification is to put a door over the fire tending hole that allows for control of the incoming air. This should help slow the fire down. The effect of this will have to be monitored but might prove beneficial for situations where space heating is desired as much as cooking heat, such as on a cold winter night.

It also seems that the ridges that support the pot above the upper cone are larger than they need to be. For a start, they should be reduced to .5cm high. If a flat-sided design is tried, they may not be needed at all as the pots could rest on the flat sides of the upper "cone". The smoke would pass through the vees formed where the sides meet.

Still another option is to either insulate or to add thermal mass such as

cement or sand to the outer walls of the fire chamber. The insulation would probably result in more heat to the cooking pot. The additional mass would make the paola more difficult to move around but would serve to store the heat that presently radiates out the side walls. This may solve some of the problem of the quicker cooking times on cold winter nights; heat is released around the pot during cooking while the mass stores up heat for when the fire has gone out.

While technical modifications need to be made, it is also important to work with local village women to examine their reactions to these new energy-conserving cooking designs, both mud stoves and paolas. Village tests of the mud stoves began in late November but results have not yet been received. The paola was also developed at about the same time and has yet to be demonstrated to many people. However, the women who come to the R.T.U. are very impressed.

The mud stoves represent only one attempt to bring stoves into the home that reduce fuel use and take out the smoke. Much more work has to go into reducing the amount of smoke that escapes into the house around the pots. If this can not be accomplished well enough in mud to the satisfication of the local women, it may be necessary to go to alternative and probably more costly designs.

Finally, more effort must go into including local women into the design process of the cooking devices. The R.T.U. should set up a stove development unit that works with women in one or two villages for a concentrated period of time. The object of the discussions would be to examine more closely performances and attitudes towards fuels and cooking practices. The women should be encouraged to help develop designs that would better meet their desires. A particularly good reference printed in October,1980 is "Helping People in Poor Countries Develop Fuel-Saving Cookstoves", a manual from GATE, c/o Deitsche Gesellschaft für Technische Zusammenarbeit (GTZ), Gm BH, Posttach 5180, D-6236 Eschborn 1, Federal Republic of Germany.

Solar Ovens

Our experimentation began in April 1980 with the design described in detail

in the interim report. This design had fixed reflectors which were attached to the cover. When access to the inside was desired, the entire hinged assembly had to be moved. This proved to be quite awkward. A number of modifications were proposed and this report will explain the ones that we tried.

Figure 6-3 contains photographs of the next model investigated. The objective of this design was to reduce cost, and to increase the ease of construction and operation. To this end, the amount of wood in the oven was reduced, the corner reflective flaps were removed and the remaining reflective flaps were hinged and placed so that the door could be opened without having to move the reflectors. The door remains in the front but is now of two layers of glass so that cooking food can be inspected without opening the door. The reflectors can be folded down for easy transport and storage of the oven.

Because of the modifications made for this design, it costs M35.00 to produce. This includes M15.00-labor and M20.00- materials. Templates have been made for the sheet metal parts which decreases measuring time and increases standardization so that other parts can be precut and the whole unit simply put together. The only real problem in construction are the slanted pieces of wood that make up the top and bottom edges of the frame that separates the inner and outer boxes. (See Figure 6-3C.) It was not possible to get these precut to the correct size so each one had to be made separately.

The next prototype was a much larger unit. The internal floor area is roughly four times that of the initial model ($.35m^2$ versus $.09m^2$). This unit has a rear access door that uses strips of sheepskin for the weatherstripping. The walls are the same thickness as before, 75mm, and are also filled with fiberglass insulation. The four reflector flaps are each $.25m^2$ and held apart and at the correct angles by lengths of wire. Figure 6-4 contains photographs of this oven. The oven was recently sold for M45.00. It had been optimized for a glass size of $.25m^2$ and materials totaled M30.00.

The final prototype combined features of both designs. The front surface was widened and lengthened to best utilize the glass that had been precut to a size of 340mm x 590mm, originally intended for use on the first oven described. The shape is similar to the second prototype but the back has been truncated to facilitate cleaning the oven. This results in a floor

area roughly double that of the first oven, .17m^2 versus .09m^2. The change in design removes the need for difficult carpentry and has brought labor costs down slightly. Materials are slightly more expensive. The result is that the unit is being sold for M35.00 (Figure 6-5 shows construction details).

The idea of a front door is still a good one, particularly because of transportation difficulties within the District. Breakage of glass can be a problem, but in very rough terrain the door can be removed and carried separately. Front access only becomes a problem when the unit increases in size, as in the second prototype. The wood for the door frame is supplied with the two necessary grooves already rabbeted out. This makes the installation of the present glass quite simple. Silicone caulk is used to prevent heat loss and to allow for expansion. A flat piece of leather screwed onto the frame acts as a handle.

The reflectors have caused some difficulties. The first design for the movable flaps relied on bending over the sheet metal to provide structural strength. This turned out not to be good, so 3mm wire was wrapped into the edge where the hinges were attached. Upon examination of the work done at the market in Maseru, it was decided that 4mm wire should be wrapped around all four sides of the reflector to provide the desired stiffness. The heavier gauge wire should also be used for the stiffness between the reflectors. A modification is now being tried which includes hinged corner flaps which increase the reflective area but will still allow for the easy fold-up-for-storage feature of the present design.

The latest design has proved to be very popular. Six ovens completed in early December were sold within a week. It seems that people liked the combination of size, style and price.

Performance tests of the solar ovens continue throughout the year since the first one was built. Papa, cabbage, meat, rice, and bread have all been cooked successfully. Compared to cooking with other fuels, cooking in a solar oven is much more time-consuming, often two or three times as long as other methods. It must be remembered, however, that very little baking is presently done by villagers, although baked bread is a desired food. Since the solar oven offers an opportunity to increase the variety of foods

that can be cooked, it could become a useful item in many homes.

The oven cooked well even in the wintertime when days are relatively cold. The sun is still quite strong and the 45° tilt of the glass presents a good surface for energy to enter the oven. It was found on one particular occasion that white bread rolls put in to bake at 0830 continued to rise instead of bake and about 1/5 of the dough spilled out into the oven. The bread began to bake at about 1000 and was done by 1330. The next day the experiment was repeated except that the oven was allowed to warm up until 1000 when the dough was put in. It began to bake right away and was done by 1300. Since both days were similar in temperature, wind and sunshine, this points to the fact that the sun is not very strong early on winter mornings. The oven requires greater warm-up time before it is ready to cook. By contrast, in mid- December between 0800 and 0900, the oven temperature rose from 20°C to 120°C, and this in an oven that had not yet had its interior painted black.

Because of production difficulties it was not possible to make accurate comparison tests of the three models. However, observation of the units suggests that cooking times are similar for all three units, although the larger oven is a little slower than the smaller ones. This is because its capacity per surface area of glazing is slightly larger, and because its heat loss rate is greater than the other designs. This points to the need to increase insulation as the ovens become larger.

The solar ovens seem to be a desired item but the exact market is not yet clear. They require a certain amount of patience to use if for no other reason than they take longer to cook and, of course, they do not work when it is overcast. A good production system for these ovens has been devised which allows for the quick manufacture ofadurable and easy-to-maintain device. The potential fuel savings is quite large if many people use one of these ovens.

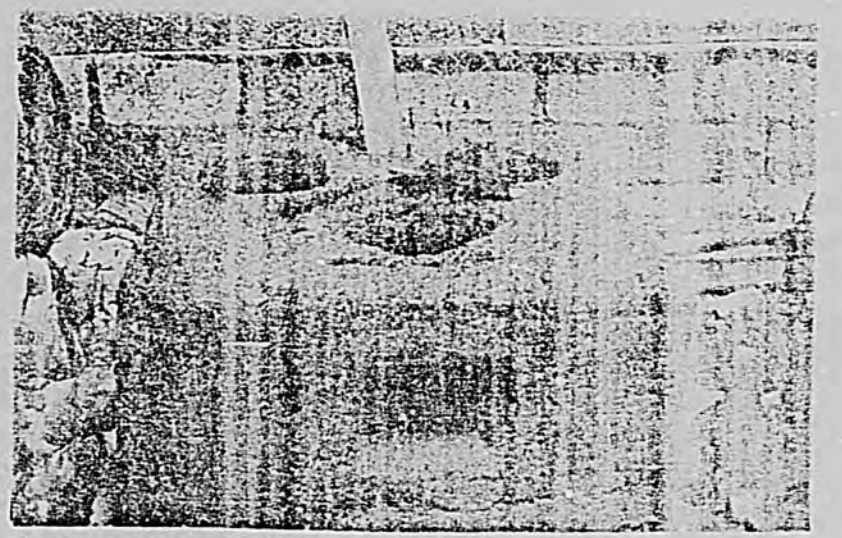
Conclusion and Recommendations

Several attempts have been made to develop energy-conserving and supplement devices that can be used for cooking. Much more work needs to be done

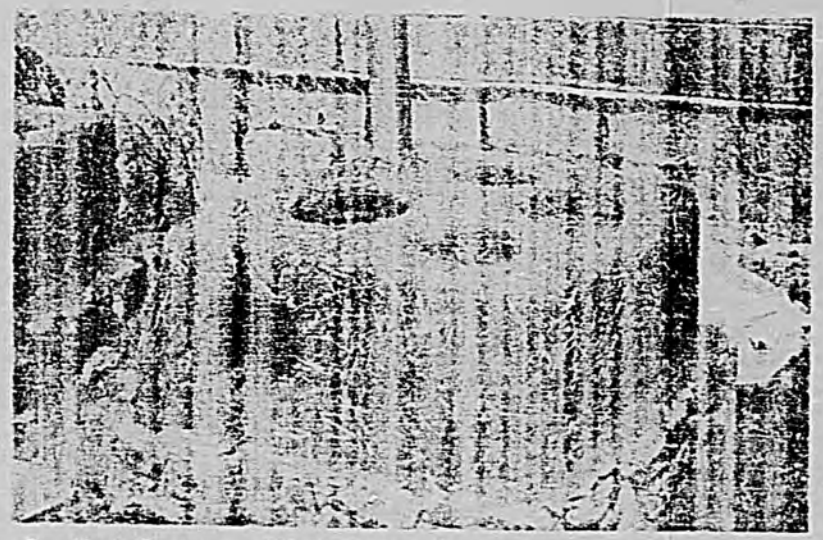
to improve the performance of the mud stoves, although when more than one pot is used, they are somewhat more efficient than an open fire. The paola design needs to be tested further and the recommended modifications made. The solar oven that has been developed works well but this should in no way limit future experimentation and testing of new design.

All of these devices need to be used by village women so that their reactions can be ascertained. It is equally important to work with these people to develop new designs and modifications on existing ones so that cooking needs and desires are best met; this will probably mean that concentrated periods of time should be spent working with one or two villages in the entire process of needs identification and assessment, design, product development, testing, modification and evaluation. This should be done so that the R.T.U. staff gains a better understanding of what people want when it comes to cooking. In the meantime, marketing of proven designs should continue elsewhere in the District.

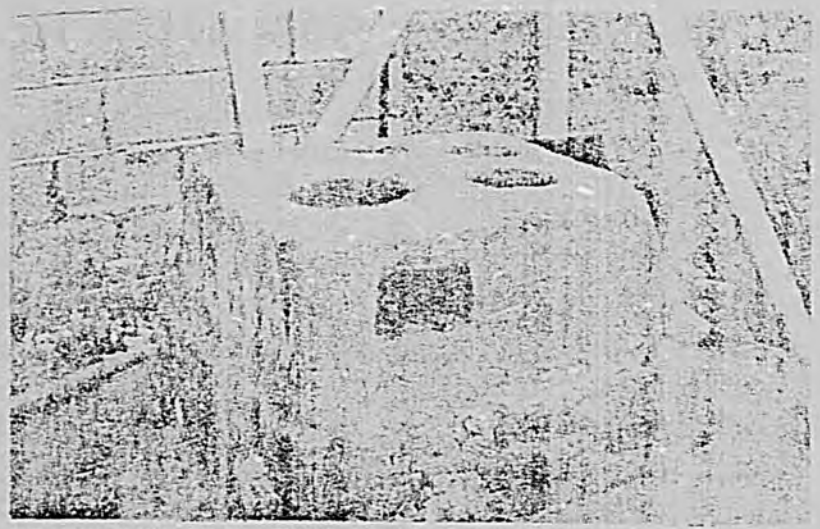
Figure 6-1



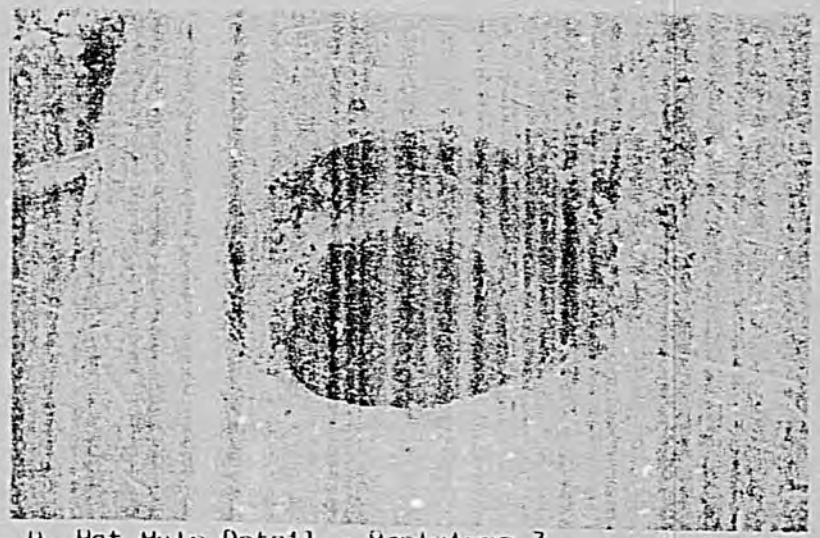
A. Mud Stove - Prototype 1



B. Mud Stove - Prototype 2



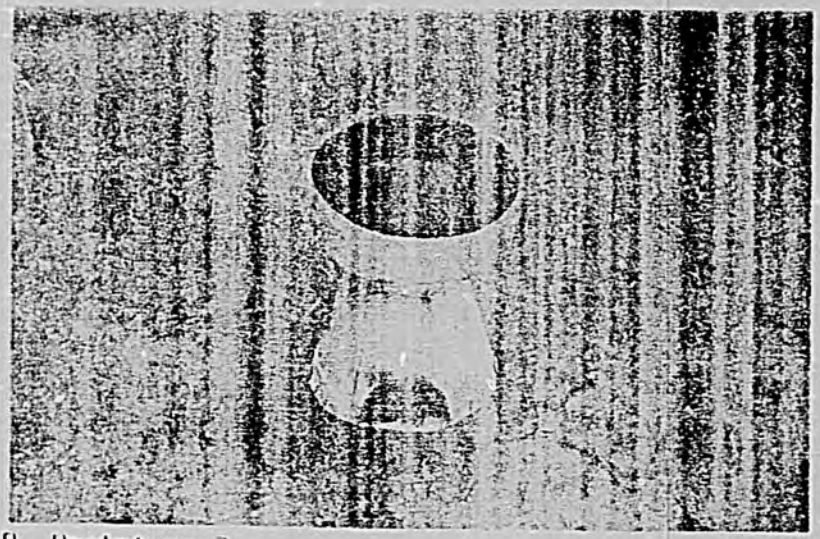
C. Mud Stove - Prototype 3



D. Pot Hole Detail - Prototype 3

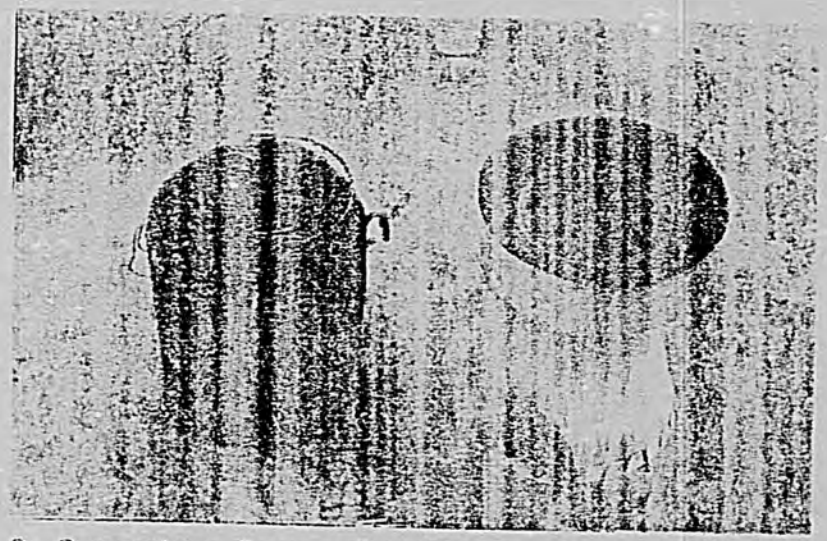
Figure 6-2

A. Three Paolus



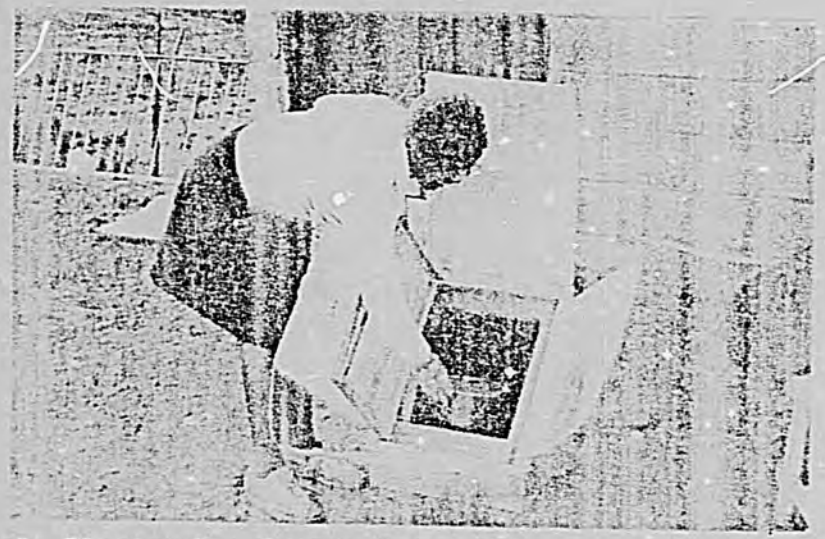
B. Prototype 3

C. Comparison Test - Starting Fire

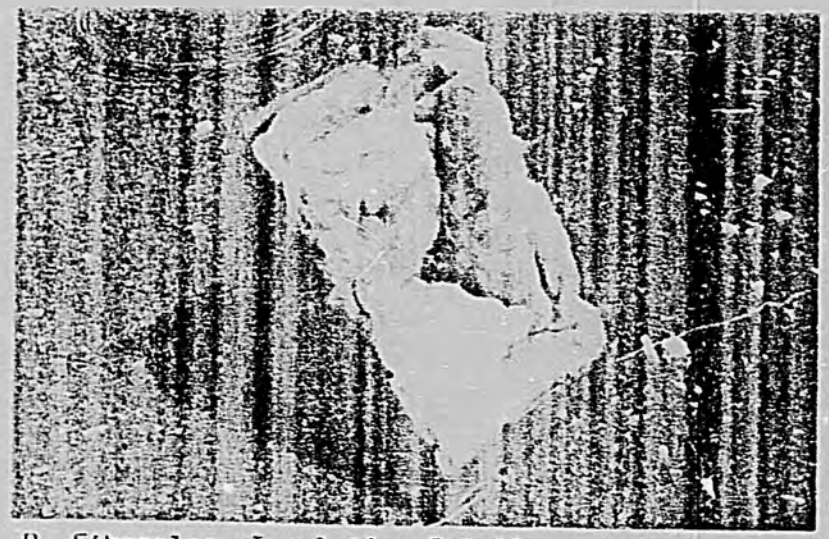


D. Comparison Test - Pot Placement

Figure 6-3

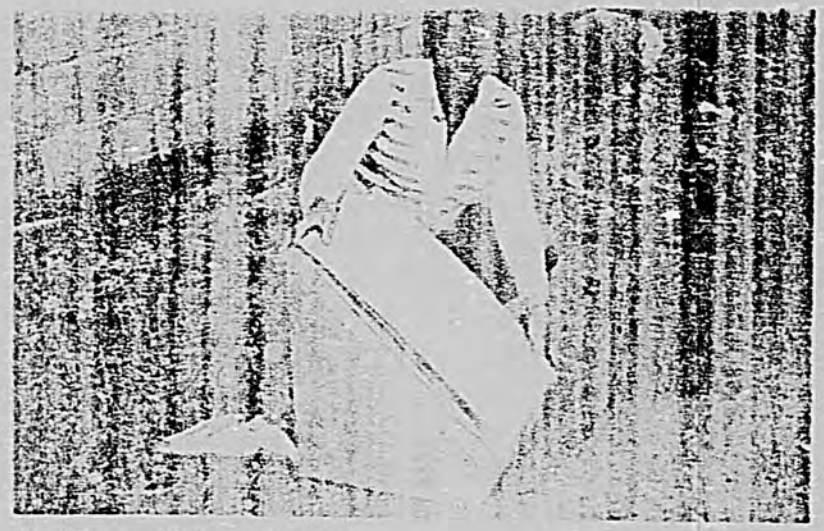


A. Placing Pot Inside Solar Oven



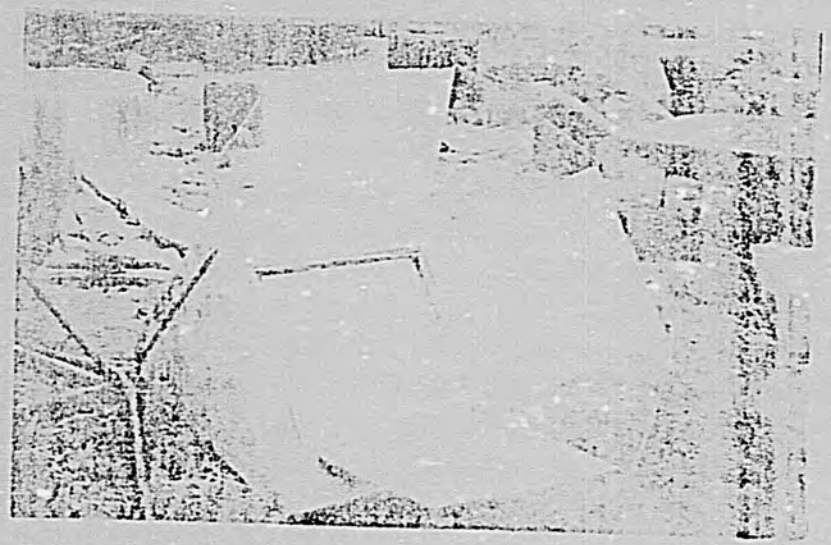
B. Fiberglass Insulation Detail

C. Placement of Inner Box

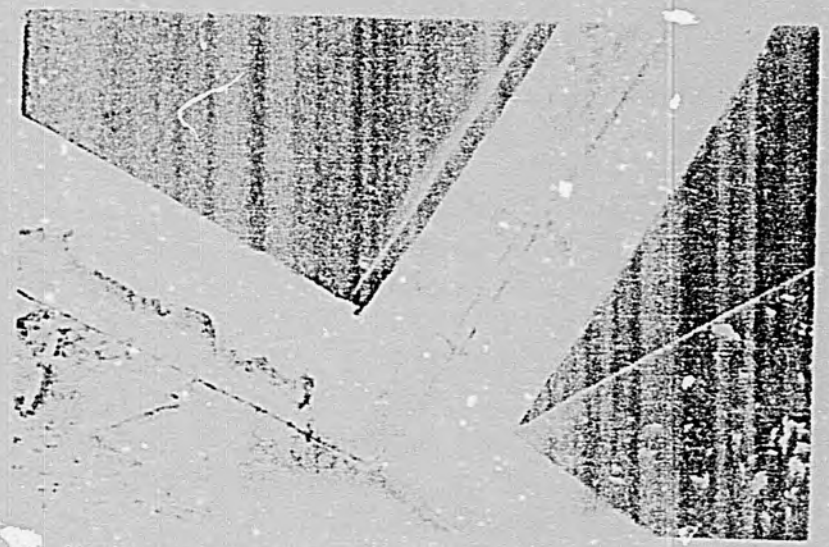


D. Flaps Folded Down

Figure 6-4

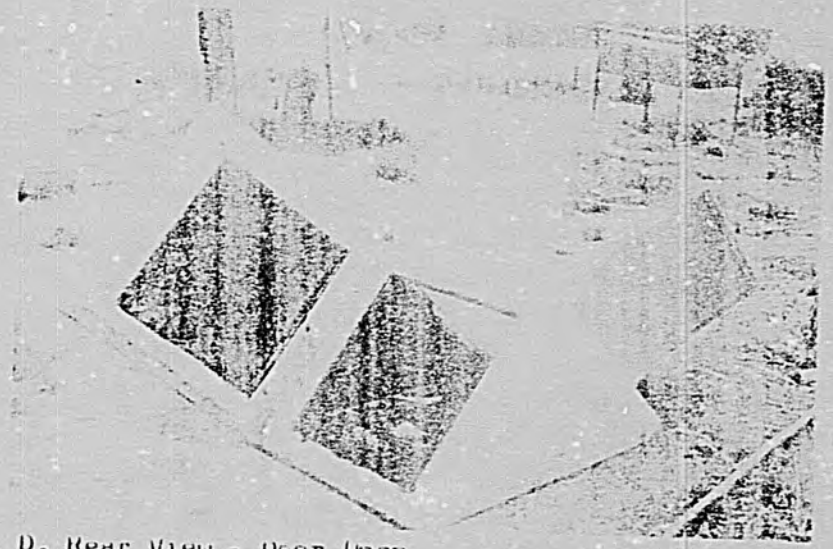


A. Large Solar Oven

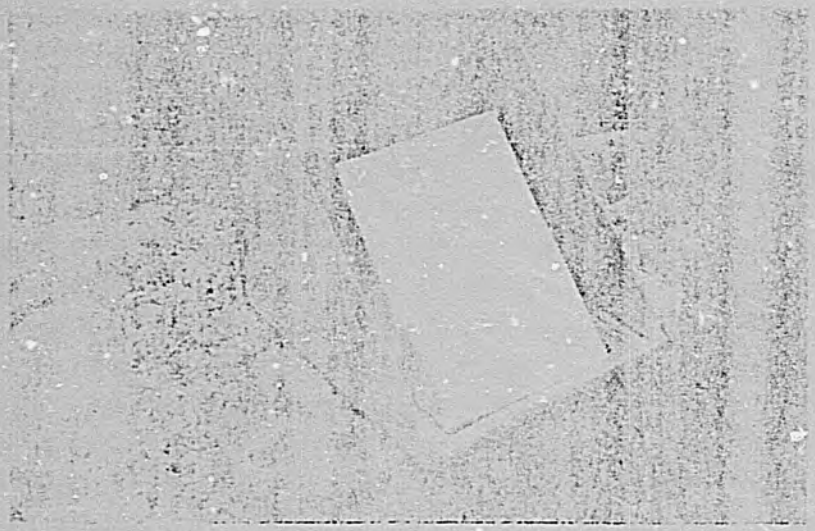


B. Weatherstripping and Hinge Detail

C. Reflective Flap Spreader Detail



D. Rear View - Door Open



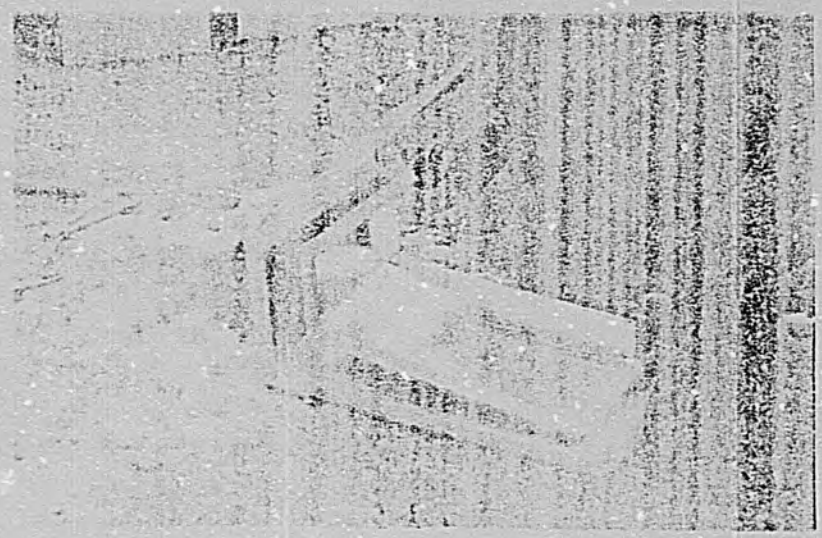


Figure 6-5 Solar Oven

A. (Upper left) Inner and outer skins

B. (Upper right) Central section of sheet metal skins

C. (Lower left) Templates for side pieces of metal skins

CHAPTER 7 SOLAR DISTILLATION

The prototype solar still that was completed in February, 1980, has been operating almost continuously since that time. Production has been monitored twice each day along with visual observations of other performance factors. The stored distilled water has frequently been required by the mechanical workshop for the use in the vehicles it services. So far, demand has not exceeded available supply.

Test Results

Table 7-1 compares production from 0800 to 1600 hours with full day output. Production is shown in a standardized quantity, liters/m^2/day, based on the water pan area, which in this case is .48m^2. The standard deviation and the percent standard deviation are also displayed. The percent standard deviation varies much less for the full day production figures than for the daytime output. While the exact reasons for this are unclear, it is probably due partially to the fact that not all of the water distilled for the day has made it into the primary storage container by the 1600 reading. Additionally, since total production is strongly influenced by daytime weather conditions, it is to be expected that these figures would be more variable.

Figure 7-1 is a graphical representation of Table 7-1. Production in liters/day is shown in additional to the standardized values. The output pattern is generally what one would expect, low in winter and increasing to a summertime peak. Based on the rough predictions contained in the interim report, winter production was expected to be about 0.4 to 0.5 liters/m^2/day. The actual output for June was 0.6 liters/m^2/day, slightly higher than the predicted values. Since the predictions were only rough estimates, this figure is certainly within reason.

Evaluation of Prototype

Other factors were monitored in addition to daily output. In particular, the unit was observed to see how the various materials withstood exposure to the elements, both inside and outside the still. As explained in greater detail in the interim report, the unit was constructed with 3mm glass (cover),

16mm chipboard (sides, door, and bottom), 0.5mm galvanized sheet metal (water pan), silicone caulk (to seal joints) and paint (both inside and outside). A 10-liter plastic container was used for the primary storage container. The following conditions were observed over the last year:

1. Rusting of metal water pan
2. Salt deposits on pan
3. Swelling of chipboard
4. Deterioration of foam weather-stripping
5. Cracking of plastic container
6. Difficulties in measurement of production
7. Access door falling off.

The metal water pan showed a significant bloom of rust that had to be removed in late August. The rust had appeared through the primer and finish coats of paint, both of which were brushed on. Neither paint was rated for use in extreme environments such as the high temperature and humidity conditions that might be found in a still. Both coats of paint were removed and the pan was scraped and rubbed clean. It was then repainted with a high temperature black spray paint. No primer coat was used. No rust has shown in the three months since this operation was performed.

Despite this, salt deposits seem to be occurring after this modification, whereas they were not apparent before. The appearance of salt is one obvious consequence of the distillation process although it is unclear why it was not in evidence before the paint layer was modified. It is probably due to the thinner paint layer and to the fact that the water pan has run dry on a couple of occasions, which did not happen before the change. The salt, which makes the water pan surface appear mottled, does not seem to have substantially affected production, so no attempt has been made to remove it. Obviously, this situation should be monitored and if it becomes significantly more pronounced, the surface should again be scraped clean and repainted, this time with a thicker coat of spray paint.

The chipboard, made of sawdust and glue, while structurally strong, does not hold up very well in a wet environment. It seems to absorb moisture

much like a sponge, and having done so, it expands, generally increasing its thickness. While this has not caused any structural weakness, it has resulted in dimensional changes at several joints and subsequently the appearance of a couple of leaks. Moisture comes from both inside the box and from periods of rain. In the future, stills should not be constructed of chipboard but rather of more water-resistant materials such as fiberglass or concrete.

Foam weatherstripping was used to properly seal the access door to the back of the frame. This weathered badly over a period of about four months and had to be replaced in mid-winter. Sections had to be replaced four months later when the door was rehinged. Since this type of weatherstripping normally lasts about a year in its typical application around windows and doors, it is clear that it has been exposed to harsher conditions than it was designed for. It is recommended that future stills utilize a better, although probably more costly stripping and at the same time design the unit to provide greater protection for the weatherstripping that is installed.

The ten-liter plastic container that serves as primary storage for the distilled water cracked after nine months of use. Only the top surface of the container had become so brittle that it cracked; the rest was still resilient. Since the entire jug has been exposed to the elements, it seems that the problem is due primarily to the effect of ultraviolet radiation, which is stronger when the sun is higher in the sky, striking the top of the jug. As a temporary measure, the top of the jug was patched with tape until the container could be replaced. It is clear that in order to increase the longevity of this part of the system it is necessary to find a more durable container and/or to provide it protection from the harmful effects of the sun's radiation.

Another problem encountered with this primary storage container was the difficulty of accurately measuring output. The first method tried was to mark the container with a magic marker at 0.5 and 1.0 liter divisions. These marks soon washed off and were replaced by pieces of tape, one edge of which corresponded to the previous one-liter markings. Interpolating between marks proved to be difficult for the trainees, particularly in winter when daily output was only 0.1 or 0.2 liters/day. In the future, it

would be advisable to use a premarked container. However, since these have been difficult to obtain, another system of marking that is both durable and has greater accuracy will have to be devised.

Just recently, the access door fell off its hinges. This happened during a storm when it was windy. On examination, it was found that the major cause of the problem had to do with the location of the screws on the door. These were set into the edge of the chipboard, most likely because of the ease of installation which this surface afforded. Due to the poor weathering characteristics of the chipboard, and the weight of the door, the screws eventually worked loose and the door fell off. The hinges have been relocated so that they are properly attached to the door, the screws going across the grain.

Conclusion and Recommendations

The results from nine months of testing and evaluation indicate that a solar still performs reasonably well in this environment. While a large demand for locally produced distilled water has not yet presented itself, the area hospitals and clinics are still importing the quantities that they use. It is recommended that two other units be built and tested utilizing more durable materials such as concrete and fiberglass. One of these could be built at the local hospital thereby providing both production results and an in-situ test, which would help examine the reliability of supply and problems of maintenance for a local institution.

On a more technical level, the problems experienced with the prototype should be accounted for in future units. Testing and observation should continue and another unit should be built at the R.T.U. Based on observations difficult to quantify, future units should have at least as much insulation surrounding the water pan and evaporation chamber as does the prototype. It would probably be desireable to go so far as to provide an U-value of about 0.15 in the walls and base of the unit. This would prevent condensation on the walls and force more to occur on the relatively colder glass.

Given the basis of nine months of data it would also be valuable to test the effect of both an insulated and an uninsulated reflector for use primarily in the winter months when production is low. While an insulated reflector will probably reduce the amount of frost and ice found in the still on cold winter mornings, it will be much more costly than a simple

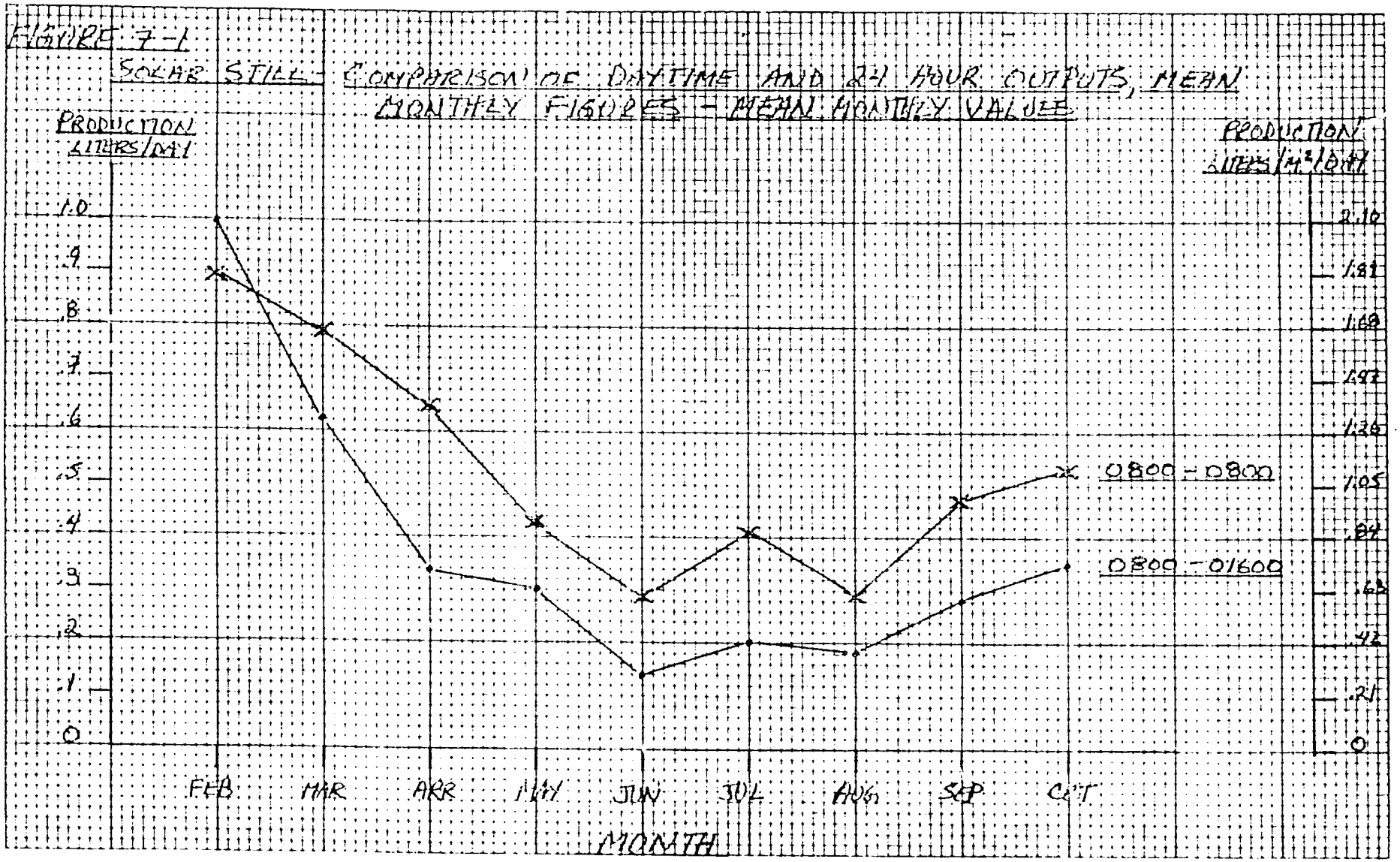
reflector which will provide the same benefit during the day. In any case, both of these options should be compared with the cost of constructing a larger still that would meet the desired demand.

Table 7-1. Solar Still - Comparison of Daytime and 24 Hour Output (liters/m^2/Day)

Month	Daytime			24 Hour		
	L/m^2/Day	σ_n	$\frac{\sigma_n}{L/m^2/Day}$	L/m^2/Day	σ_n	$\frac{\sigma_n}{L/m^2/Day}$
February	2.1	0	0	1.9	1.0	.5
March	1.3	.5	.4	1.7	.6	.4
April	.7	.4	.6	1.4	.6	.4
May	.6	.6	1.0	.9	.5	.6
June	.3	.2	.7	.6	.3	.5
July	.4	.2	.5	.9	.5	.6
August	.4	.1	.2	.6	.2	.3
September	.6	.4	.7	1.0	.5	.5
October	.7	.4	.6	1.1	.4	.4

FIGURE 7-1

SOLAR STILL - COMPARISON OF DAYTIME AND 24 HOUR OUTPUTS, MEAN MONTHLY FIGURES - MEAN MONTHLY VALUES



CHAPTER 8 CLIMATE-WISE BUILDING DESIGN

This chapter focuses on the heating and cooling of buildings in the District of Thaba Tseka. The goal of this work is to develop an approach to design that integrates building into the climatic conditions prevalent in this region. The interim report outlines the basic concepts behind this procedure. In addition, it should be referred to for explanations of traditional housing design and of the method used to calculate the thermal performance of buildings. In this report, a pair of rondavels and a pair of townsite houses will be compared and the analytical method evaluated. Weather data for 1980 are used in the calculations wherever it is available.

Description of Buildings and Test Procedure

The solar rondavel, described in detail in the interim report, has been lived in since January,1980. In March, a thermograph was installed to measure daily temperature fluctuations. With the exception of heat from people and from either a paraffin or gas cooking burner, the only source of heat to the building has been the sun. The thermograph was located about one meter above the floor near the south wall of the building, never in direct sun. Due to its location, it probably records temperature fluctuations that are somewhat smaller than what actually occurs. Because the peaks are not as great, the daily averages are slightly reduced. Based on observations of a maximum-minimum thermometer located near the peak of the roof at a height of 4 meters from the floor, the actual depression is only about 1°C (1.8°F). Figure 8-1 is a drawing of this house.

The rondavel that was instrumented stands about 20 meters from the solar rondavel in Mohlakeng. The two buildings are approximately the same size. This rondavel has one small window and door which faces to the northeast. The building is used only for sleeping by the man of the house when he is at home. The thermal model has been adjusted accordingly. A thermograph was placed in this rondavel in August. Testing continued through October.

The E-house with the attached greenhouse was completed in July. A thermo-

graph was installed in August and operated through October. With the exception of two evenings in July, it was not necessary to supply any additional heat to the house beyond that which came from people and appliances. Mid-day temperatures were always quite comfortable and the interior of the house was significantly brighter than similar units without greenhouses. The greenhouse was not used for growing plants until late August, when seedlings for the garden were started. A few that were in containers close to the ground and to the glazing were killed off. All others did very well. It is anticipated that the greenhouse will be farmed much more intensively during the coming year. Figures 8-2 and 8-3 contain a drawing and photographs of the house.

A standard E-house was also instrumented from August through October. This unit required several hours of auxiliary heat each night in order to bring the temperatures up to the level desired by the occupants. Both a paraffin heater and an electric heater were used. This house is located about twenty meters away from E-house with the attached greenhouse. Figures 8-4 and 8-5 contain technical drawings of this building.

Thermal Performance Results

Table 8-1 contains the monthly degree-days calculated for 1980. Based on a comparison with the temperature data contained in Chapter 2, these figures are not substantially different than the long-term results, with all months except May less than 10% off. The 1980 degree-days are used to calculate the monthly heat loss of the buildings being examined.

Table 8-2 displays the adjustment of solar heat gain based on the percent difference between the 1980 measured and long-term derived figures calculated in Chapter 2. The adjustment is made by multiplying the percent change for each month times the relavant values contained in Appendix 17 of the interim report. These adjusted values have been used in the heat gain calculations contained in this chapter.

Comparisons of the mean minimum, maximum, and average temperatures inside the four buildings are contained in Tables 8-3 and 8-4. Table 8-4 includes maximums that occured in the E-house due to auxiliary heating, while the data for the E-house in Table 8-3 does not. The average inside and

outside temperatures are compared in Table 8-5, again for all four buildings. This data is displayed graphically in Figure 8-6. The E-house with attached greenhouse does significantly better than the other units. In August and September, the sleeping rondavel has the same average temperature as does the outside air.

The actual temperature variations are also interesting. In the two rondavels, the maximums tend to be similar but the solar rondavel has higher minimums. The result is that the solar rondavel has a more stable temperature pattern fluctuating around a higher average. In the two E-houses, the minimum tends to be similar while the unit with the attached greenhouse experiences higher maximums. Although the temperature fluctuations are greater, the overall effect is to create a generally more comfortable environment. In this case, this is due both to the higher temperatures and to the higher relative humidity. These relationships are graphically displayed in Figures 8-7 and 8-8.

Table 8-6 compares the times at which the minimums and maximums occur in the four buildings. This information was obtained by examining the weekly thermograph charts. These times, combined with the temperatures in Table 8-5, make it possible to develop Figures 8-9 through 8-12 which show the [illegible] daily temperature fluctuations by month for each of the houses.

Analysis of these figures supports earlier statements. The solar rondavel follows the trend of the mean outside temperature but remains well above it until September. September was cooler and highly variable. Solar month [illegible] mean maximum is compressed relative to the other months. The minimum temperature occurs at 1000 and, with the exception of June, the maximum occurs at 1700.

The sleeping rondavel also follows the trend of the outside temperature, however, the minimum and maximum straddle this temperature. This makes it [illegible] to assume that this house is more temperature [illegible] than the solar rondavel when outside temperatures are [illegible] or below.

It should be pointed out, however, that since the main source of solar energy input in the solar rondavel is through the windows, as the sun gets higher in the sky less energy actually enters the building. This effect

Best Available Document

becomes very noticeable beginning in September and points to the need for windows that extend up from the floor and/or reducing the size of the roof overhang on the north side of the building.

The E-house has been plotted so that the temperature rise due to the input of auxiliary heat can be seen. This information was taken from the thermograph charts which showed a distinctive secondary peak that occurred in the evening around eight o'clock. Based on conversations with the occupants, it appears that the October auxiliary input is primarily due to cooking. It is likely that the same temperature gains can be attributed to this source during the other months, the remainder being the auxiliary heat inputs.

The temperature fluctuations are most marked in the E-house with the attached greenhouse. As with the solar rondavel, the September maximum is depressed. By October, it became necessary to use some ventilation on most days. If this had not been the case, the maximum would probably have been over 25°C.

It is now necessary to compare the 1980 performance against what the thermal model predicted would occur. Tables have been prepared showing heat balance, percent solar contribution, and predicted average indoor temperatures on a monthly basis. These are Tables 8-7 through 8-14. An inspection of the data shows that the sun contributes roughly six times the energy to the solar rondavel as compared to the sleeping rondavel. The E-house with attached greenhouse has an even greater proportion of its heat provided by the sun when compared to the E-house. In fact, according to the model, there should be a surplus of heat in all of the months examined. The model also shows that the solar rondavel should be warmer than the sleeping rondavel. The same relationship holds true for the E-house with greenhouse compared to the E-house, although the difference is more pronounced. The experience this year shows that these predictions are indeed the case.

Table 8-15 compares the predicted and measured average indoor temperatures for the two rondavels. Temperatures are shown in both Fahrenheit and Centigrade. The percent differences are very slight, and are generally negative. This means that the actual temperature was below the predicted value. Figure 8-14 disolays this graphically.

Table 8-16 compares the two E-houses. The percent difference for the E-house with the attached greenhouse is large, ranging from 13% to 20%. Also of note is the fact that the measured temperatures were greater than the predicted values in the E-house. The large, negative differences in the E-house with greenhouse are probably due to the fact that whenever the temperature reached 25°C the occupant began to ventilate the greenhouse. This served to prevent inside temperatures from reaching the peak they might otherwise have attained. An additional explanation is that one of the vents in the west wall was left open most of the time so the cats could go in and out. Neither of these phenomena were accounted for in the model.

The fact that the measured temperatures in the E-house were greater than the predicted values, albeit by a small amount, is intriguing. By examining days in these months during which the occupants were not at home it was possible to see how the "pure" house fluctuated. Although there were very few of these days, the result is that without occupants, or the auxiliary heat inputs they required, the measured values would be reduced by 3°C. This is sufficient to account for the skewing of the anticipated relationship. Of course it is also possible that the building is better insulated than assumed or that heat gains through the opaque wall surface are greater than accounted for in the model. Figure 8-15 displays this graphically.

Table 8-17 compares the predicted and measured increase in temperature above the outside average temperatures for each of the buildings by month. If the explanations just given are, in fact, true, the thermal model is reasonably accurate.

Conclusion and Recommendations

Based on several months of tests on two different building types, it appears that the analytical model used to predict the thermal performance of buildings is sound. It must be understood that the method relies heavily on an accurate assessment of the building heat loss and gain parameters by the person doing the calculations. Values for materials typically used in construction in Lesotho were presented in the interim report and should be used in future calculations. It must also be remembered that when predicting the thermal performance of not-yet-buildings, the actual construction may result in a significant variation of the thermal parameters from that intended in the design. This will probably be most noticeable in infiltra-

tion rates although it will also show up if insulation is left out of places where it was intended to be installed. Further variations from the estimation procedure will occur because of the occupants. Remember, what actually happens and not what the designer intended, is correct!

After living in the rondavel for nine months, several design recommendations are apparent. The first is that during construction, one must be sure that the thatch grass is tightly packed when laid on the roof. This will reduce the infiltration of cold air into the house through the thatch, something which is particularly noticeable on windy days.

The second is that the windows need to be enlarged if they are to be used as the heat source for the building. They should run from close to the floor to just below the lintel and the overhang should be such that the north windows become completely shaded at noon in November, December and January. The rough window openings should be about 35% to 40% of the wall area and should be placed on the northern half of the building. The entryway should be placed more toward the southeast so that little or no shading occurs on the east window in the mornings. Double glazing is preferred.

The final recommendation is that shutters should be designed to fit the windows prior to construction. If they are installed during the building process, the result will probably be a tight-fitting, useful insulating device. Coupled with the double glazing, heat loss will be substantially reduced and comfort levels raised.

When attaching a greenhouse to an existing building or when building one into the design, a choice of materials becomes very important. Due to the large temperature fluctuations, a great deal of expansion and contraction occurs in the building materials. This needs to be accounted for in the design so that the structure is not unduly stressed.

Ventilation is also very important. It is necessary to prevent the greenhouse from overheating. While utilization of the prevailing winds can be beneficial, the basic design should not rely on them. In this climate, an area

equivalent to at least one-sixth of the floor area of the greenhouse should be vents. An even distribution of high and low openings is best.

The airflow between the house and the greenhouse is also very important. In the experience of the occupant, opening two windows and the door on the adjoining wall was often sufficient to adequately distribute the heat. This was true even though two windows were remounted so that they had side hinges. A small fan, perhaps solar-powered, would help, but would add to the initial cost.

During this past heating season no additional thermal mass was added to the greenhouse. Twenty-liter water storage containers were ordered but did not arrive until October. They should be installed and performance monitored. The effect should be to decrease daytime extremes and to increase nighttime greenhouse temperatures. While more heat will be stored in the greenhouse, it is possible that the temperatures inside the house may be reduced. This will also have to be checked as will the effect on plant growth.

In conclusion, it needs to be stated that new buildings should be designed so that they are well integrated into the climatic conditions prevalent in the District. The basic principles have been outlined and the necessary data base has been established. Using the developed thermal performance model as a tool, designs can be made that should work well. All that is required is to recommend practices. Given the proposed expansion of facilities and services throughout the District, there will be many opportunities to do so.

Table 8-1. Calculation of Monthly Degree Days Based on 1980 Monthly Mean Temperatures

	1980 Mean Monthly Temperature °C	°F	(65-°F)	Days Per Month	Monthly Degree Days
January				31	
February	16.5	61.7	3.3	29	96
March	15.5	59.9	5.1	31	158
April	11.5	52.7	12.3	30	369
May	9.5	49.1	15.9	31	493
June	5.0	41.0	24.0	30	720
July	5.0	41.0	24.0	31	744
August	8.5	47.3	17.7	31	549
September	11.0	51.8	13.2	30	396
October	14.0	57.2	7.8	31	242
November				30	
December				31	

Table 8-2 Adjustment of Solar Heat Gain through Vertical Single and Double Glazing at Various Orientations Based on 1980 Data, Daily Totals, (BTU/ft^2)

	North		E/W		NE/NW	
	Single	Double	Single	Double	Single	Double
July	1430	1310	570	500	1070	980
August	1110	1010	640	580	960	870
September	740	650	680	620	810	740
October	550	460	920	830	860	770

Adjustment of Solar Heat Gain through North Facing Single and Double Glazing at 15° and 60° Tilts Based on 1980 Data, Daily Totals, (BTU/ft^2)

	15° Tilt		60° Tilt	
	Single	Double	Single	Double
July	1310	1200	1720	1590
August	1350	1230	1520	1390
September	1400	1280	1280	1170
October	1840	1680	1320	1190

Adjustment of Solar Heat Gain on North Facing Vertical Surfaces Based on 1980 Data, Daily Totals, (BTU/ft^2)

July	1550
August	1360
September	1030
October	930

Table 8-3. Comparison of the Mean Minimum, Maximum and Average Temperatures, °C

	Solar Rondavel			Sleeping Rondavel		
	MIN	MAX	AVE	MIN	MAX	AVE
May	12	15	13.5			
June	8	12	10			
July	8	12	10			
August	10	13	11.5	6	12	9
September	11	13	12	9	13	11
October	14	17	15.5	11	17	14

	E- House[1]			E-House with Attached Greenhouse		
	MIN	MAX	AVE	MIN	MAX	AVE
August	13	17	15	13	23	18
September	14	18	16	15	22	18.5
October	16	20	18	16	24	20

1. Does not include maximums due to auxiliary heating.

Table 8-4. E-House - Typical Daily Temperature Fluctuations for Selected Months, Includes Maximum Due to Auxiliary Heating

	Minimum (°C)	Daytime Peak (°C)	Afternoon Minimum (°C)	Evening Maximum (°C)
August	13	17	16	19
September	14	18	18	20
October	16	20	20	21

Table 8-5. Comparison of Average Inside and Outside Temperature for Four Buildings for Selected Months in 1980

	Average Outside Temp (°C)	Solar Rondavel		Sleeping Rondavel		E-House		E-House with Attached Greenhouse	
		Inside (°C)	Diff. (°C)	Inside (°C)	Diff. (°C)	Inside (°C)	Diff. (°C)	Inside (°C)	Diff. (°C)
May	9.5	13.5	4						
June	5	10	5						
July	5	10	5						
August	8.5	11.5	3	9	.5	15	6.5	18	9.5
September	11	12	1	11	0	16	5	18.5	7.5
October	14	15.5	1.5	14	0	18	4	20	6

Table 8-6. Comparison of Times at which the Minimums and Maximums Occur for Selected Months

	Solar Rondavel		Sleeping Rondavel		E-House with Greenhouse		E-House			
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	Day Peak	Afternoon MIN	Evening MAX
May	0700	1500								
June	0700	1400								
July	0700	1500								
August	0700	1500	0600	1500	0800	1500	0800	1500	1700	2000
September	0700	1500	0700	1600	0800	1500	0800	1600	1800	2100
October	0700	1500	0600	1500	0700	1400	0700	1500	1800	2000

ble 8-7. Mohlakeng Solar Rondavel - Heat Balance and Percent Solar Contribution

Month[1]	Heat Loss ($X10^6$ BTU)	Window Heat Gain ($X10^6$ BTU)	Wall Heat Gain ($X10^6$ BTU)	People and Appliance Heat Gain ($X10^6$ BTU)	Heat Balance ($X10^6$ BTU)	Percent Solar Contribution (%)
May	3.42	1.37	.19	.29	-1.57	46
June	5.01	1.38	.19	.28	-3.16	31
July	5.18	1.42	.20	.29	-3.27	31
August	3.81	1.15	.18	.29	-2.19	35
September	2.75	.82	.13	.28	-1.52	34
October	1.68	.74	.11	.29	- .54	51

1. May and June have been adjusted for changes due to temperature only. July, August, September and October have been adjusted for both temperature and solar radiation.

Table 8-8. Mohlakeng Solar Rondavel - Prediction of Average Indoor Temperatures

Month[1]	Daily Window Heat Gain (BTU)	Daily Wall Heat Gain (BTU)	Daily Heat Gain from People and Appliances (BTU)	Total Daily Heat Gain (BTU)	Daily Heat Loss (BTU/°F)	Daily Change in Temperature (°F)	Mean Daily Temperature (°F)	Predicted Average Indoor Temperature (°F)
May	44330	6010	9400	59740	6938	6.6	49.1	57.7
June	45970	6490	9400	61860	6953	8.9	41.0	49.9
July	45750	6560	9400	61710	6958	8.9	41.0	49.9
August	37210	5770	9400	52380	6946	7.5	47.3	54.8
September	27340	4210	9400	40950	6935	5.9	51.8	57.7
October	23800	3540	9400	36740	6936	5.3	57.2	62.5

1. May and June have been adjusted for changes due to temperature only. July, August, September and October have been adjusted for both temperature and solar radiation.

Table 8-9. Mohlakeng Sleeping Rondavel - Heat Balance and Percent Solar Contribution

Month	Heat Loss ($X\ 10^6$ BTU)	Window Heat Gain ($X\ 10^6$ BTU)	Wall Heat Gain ($X\ 10^6$ BTU)	People and Appliance Heat Gain ($X\ 10^6$ BTU)	Heat Balance ($X\ 10^6$ BTU)	Percent Solar Contribution (%)
August	4.17	–	.26	.14	-3.77	6
September	3.01	–	.18	.13	-2.70	6
October	1.85	–	.14	.14	-1.57	8

Table 8-10. Mohlakeng Rondavel - Predicted Average Indoor Temperature

Month	Daily Window Heat Gain (BTU)	Daily Wall Heat Gain (BTU)	Daily Heat Gain from People and Appliances (BTU)	Total Daily Heat Gain (BTU)	Daily Heat Loss (BTU/°F)	Daily Change in Temperature (°F)	Mean Daily Temperature (°F)	Predicted Average Indoor Temperature (°F)
August	–	8556	4400	12956	7592	1.7	47.3	49.0
September	–	5957	4400	10357	7598	1.4	51.8	53.2
October	–	4390	4400	8790	7653	1.1	57.2	58.3

Table 8-11. E- House - Heat Balance and Percent Solar Contribution

Month	Heat Loss ($X\ 10^6$ BTU)	Window Heat Gain ($X\ 10^6$ BTU)	Wall Heat Gain ($X\ 10^6$ BTU)	People and Appliance Heat Gain ($X\ 10^6$ BTU)	Heat Balance ($X\ 10^6$ BTU)	Percent Solar Contribution (%)
August	4.36	.42	.14	.63	-3.17	13
September	3.15	.06	.09	.61	-2.39	5
October	1.96	–	.03	.63	-1.30	2

Table 8-12. E-House - Predicted Average Indoor Temperature

Month	Daily Window Heat Gain (BTU)	Daily Wall Heat Gain (BTU)	Daily Heat Gain from People and Appliances (BTU)	Total Daily Heat Gain (BTU)	Daily Heat Loss (BTU/°F)	Daily Change in Temperature (°F)	Mean Daily Temperature (°F)	Predicted Average Indoor Temperature (°F)
August	13671	4660	20398	38729	7940	4.9	47.3	52.2
September	2026	3080	20398	25510	7955	3.2	51.8	55.0
October	–	986	20398	21384	8098	2.6	57.2	59.8

Table 8-13. E- House with Single Glazed Greenhouse - Heat Balance and Percent Solar Contribution

Month	Heat Loss ($X\ 10^6$ BTU)	Window Heat Gain ($X\ 10^6$ BTU)	Wall Heat Gain ($X\ 10^6$ BTU)	People and Appliance Heat Gain ($X\ 10^6$ BTU)	Heat Balance ($X\ 10^6$ BTU)	Percent Solar Contribution (%)
August	6.60	9.39	—	.63	3.42	> 100
September	4.76	8.56	—	.61	4.41	> 100
October	2.91	9.72	—	.63	7.44	> 100

Table 8-14. E- House with Single Glazed Greenhouse - Predicted Average Indoor Temperature

Month	Daily Window Heat Gain (BTU)	Daily Wall Heat Gain (BTU)	Daily Heat Gain from People and Appliances (BTU)	Total Daily Heat Gain (BTU)	Daily Heat Loss (BTU/°F)	Daily Change in Temperature (°F)	Mean Daily Temperature (°F)	Predicted Average Indoor Temperature (°F)
August	303,000	—	20398	323,398	12024	26.9	47.3	74.2
September	276,000	—	20398	296,398	12024	24.6	51.8	76.4
October	313,600	—	20398	333,998	12024	27.8	57.2	85.0

Table 8-15. Comparison of Predicted and Measured Average Indoor Temperatures for Two Rondavels by Month

Month[1]	Solar Rondavel				Sleeping Rondavel			
	Predicted (°F/°C)	Measured (°F/°C)	Difference M-P (°F/°C)	Percent Difference (%)	Predicted (°F/°C)	Measured (°F/°C)	Difference M-P (°F/°C)	Percent Difference (%)
May	57.7 / 14.3	56.3 / 13.5	-1.4 / -.8	-2				
June	49.9 / 9.9	50.0 / 10	.1 / .1	.2				
July	49.9 / 9.9	50.0 / 10	.1 / .1	.2				
August	54.8 / 12.7	52.7 / 11.5	-2.1 / -1.2	-4	49.0 / 9.4	48.2 / 9	-.8 / -.4	-2
September	57.7 / 14.3	53.6 / 12.0	-4.1 / -2.3	-7	53.2 / 11.8	51.8 / 11	-1.4 / -.8	-3
October	62.5 / 16.9	59.9 / 15.5	-2.6 / -1.4	-4	58.3 / 14.6	57.2 / 14	-1.1 / -.6	-2

1. The predicted average indoor temperatures for May and June have only been adjusted for changes due to temperature. July, August, September, and October have been adjusted for both temperature and solar radiation.

Table 8-16. Comparison of Predicted and Measured Average Indoor Temperatures for Two E-Houses by Month

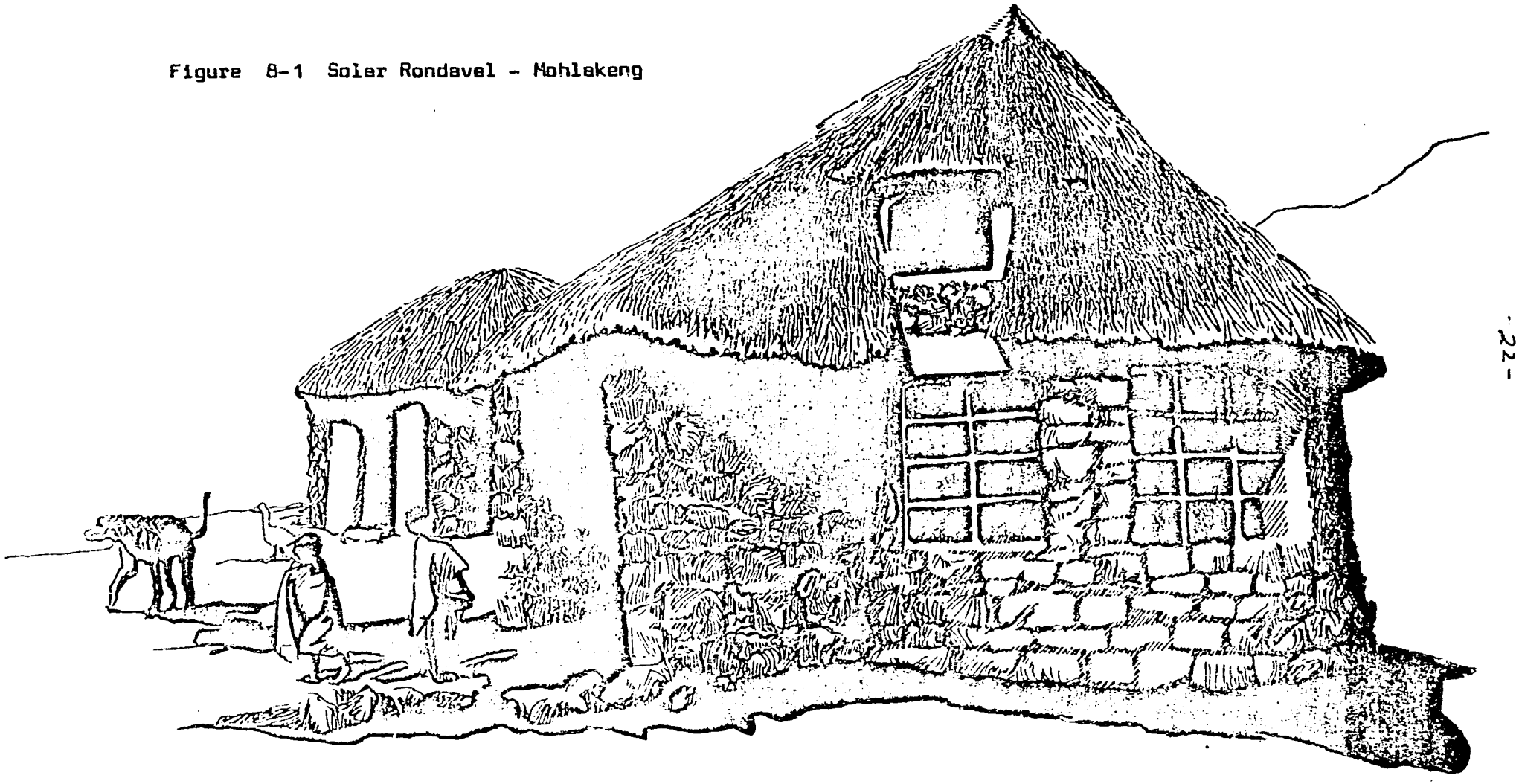
	E- House with Greenhouse				E-House[1]			
	Predicted (°F/°C)	Measured (°F/°C)	Difference M-P (°F/°C)	Percent Difference (%)	Predicted (°F/°C)	Measured (°F/°C)	Difference M-P (°F/°C)	Percent Difference (%)
August	74.2 / 23.4	64.4 / 18	-9.8 / -5.4	-13	52.2 / 11.2	59.0 / 15	6.8 / 3.8	13
September	76.4 / 24.6	65.3 / 18.5	-11.1 / -6.2	-14	55.0 / 12.8	60.8 / 16	5.8 / 3.2	10
October	85.0 / 29.4	68.0 / 20	-17.0 / -9.4	-20	59.8 / 15.4	64.4 / 18	4.6 / 2.6	8

1. Does not include increase due to auxiliary heating.

Table 8-17. Comparison of Predicted and Actual Increase in Temperature above the Mean Outside Average Temperature by Month

	Solar Rondavel		Sleeping Rondavel		E-House		E-House with Attached Greenhouse	
	Predicted (°F)	Actual (°F)	Predicted (°F)	Actual (°F)	Predicted (°F)	Actual (°F)	Predicted (°F)	Actual (°F)
May	8.6	7.2						
June	8.9	9						
July	8.9	9						
August	7.5	5.4	1.7	.9	4.9	11.7	26.9	17.1
September	5.9	1.8	1.4	0	3.2	9	24.6	13.5
October	5.3	2.7	1.4	0	2.6	7.2	27.8	10.8

Figure 8-1 Solar Rondavel - Mohlakeng



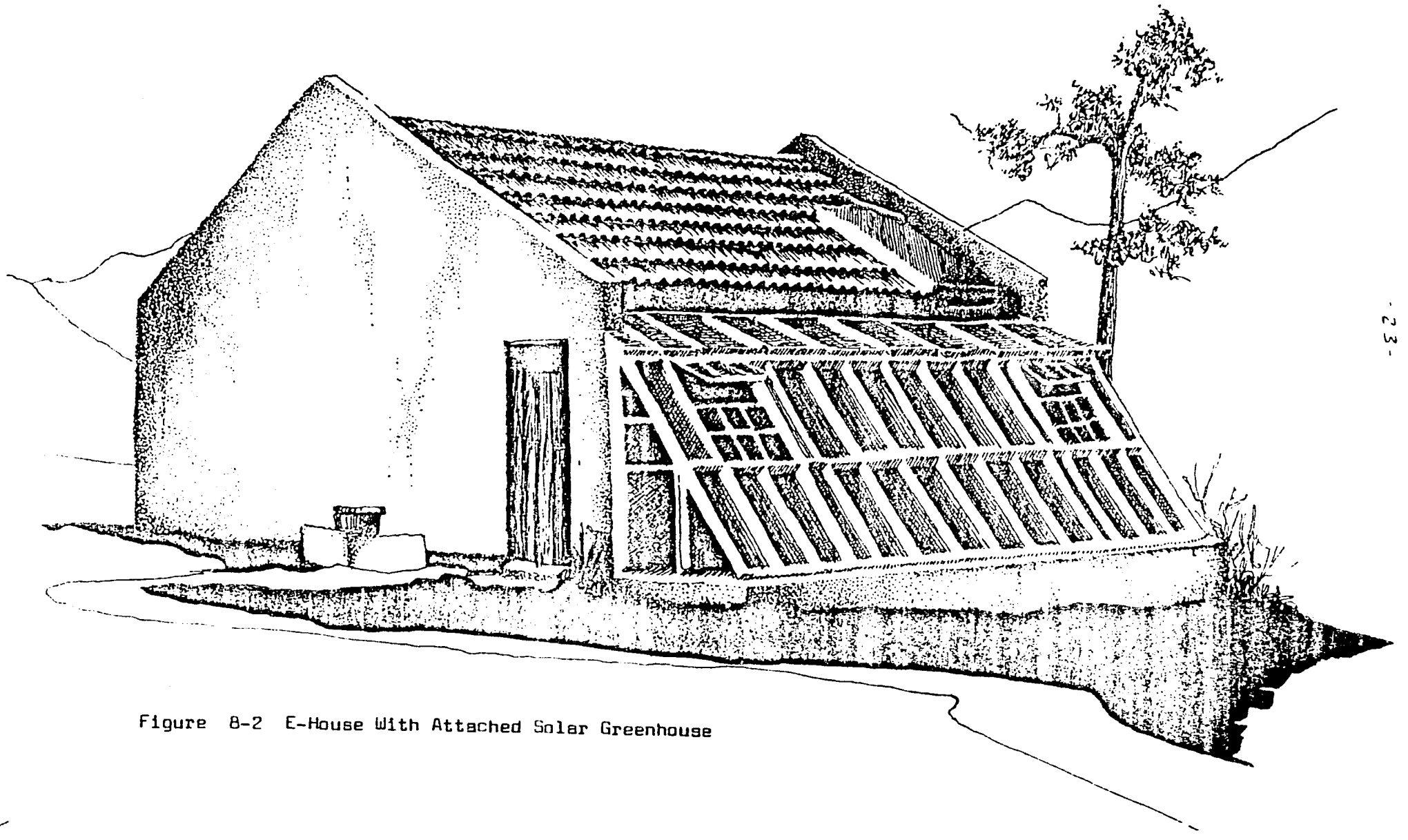
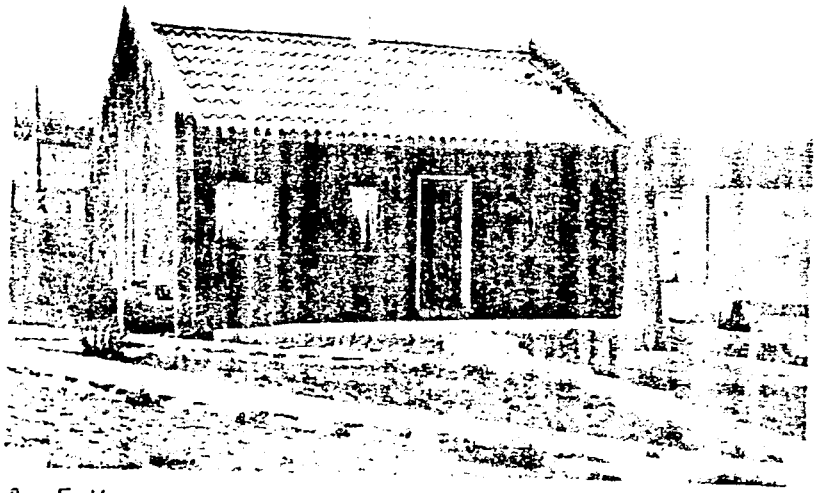
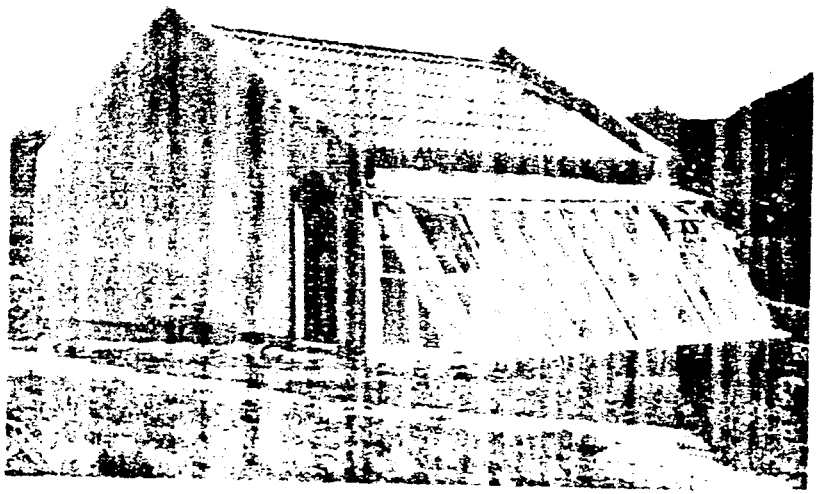


Figure 8-2 E-House With Attached Solar Greenhouse

Figure 8-3

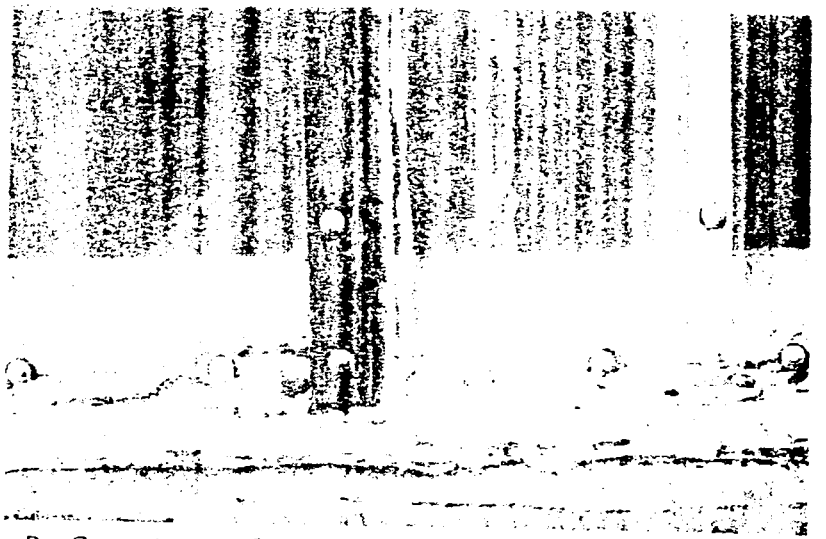


A. E-House

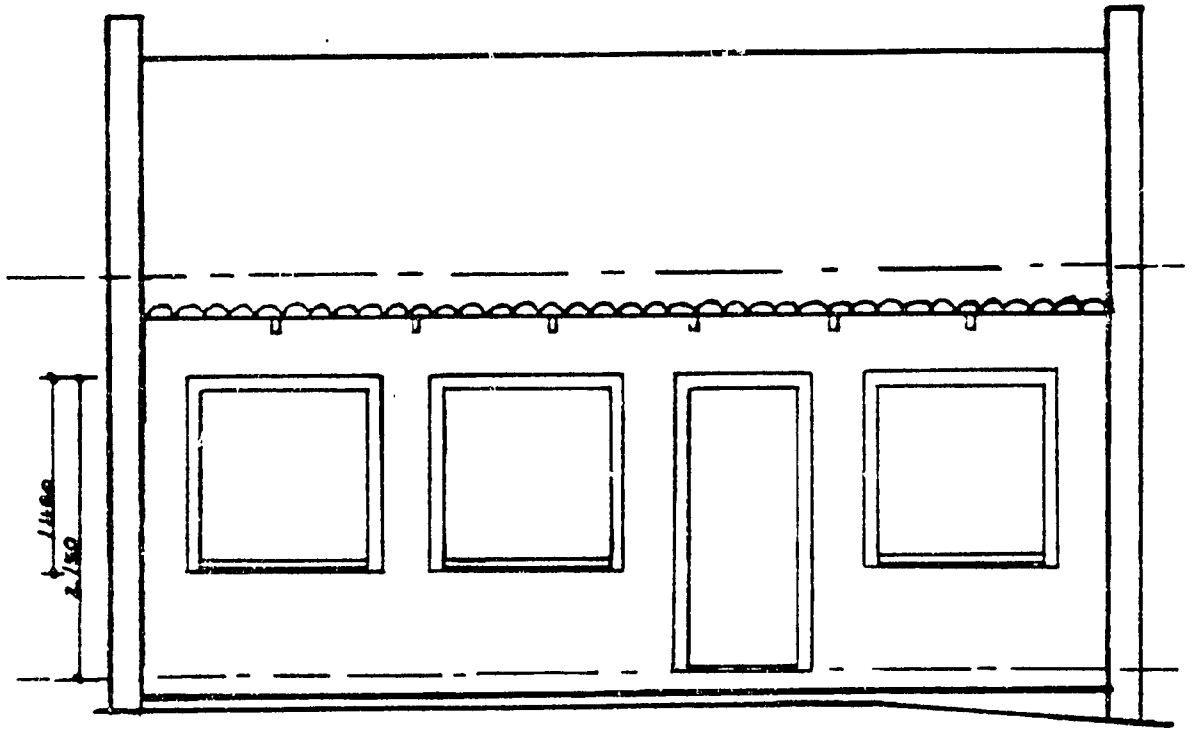


B. E-House with Attached Solar Greenhouse

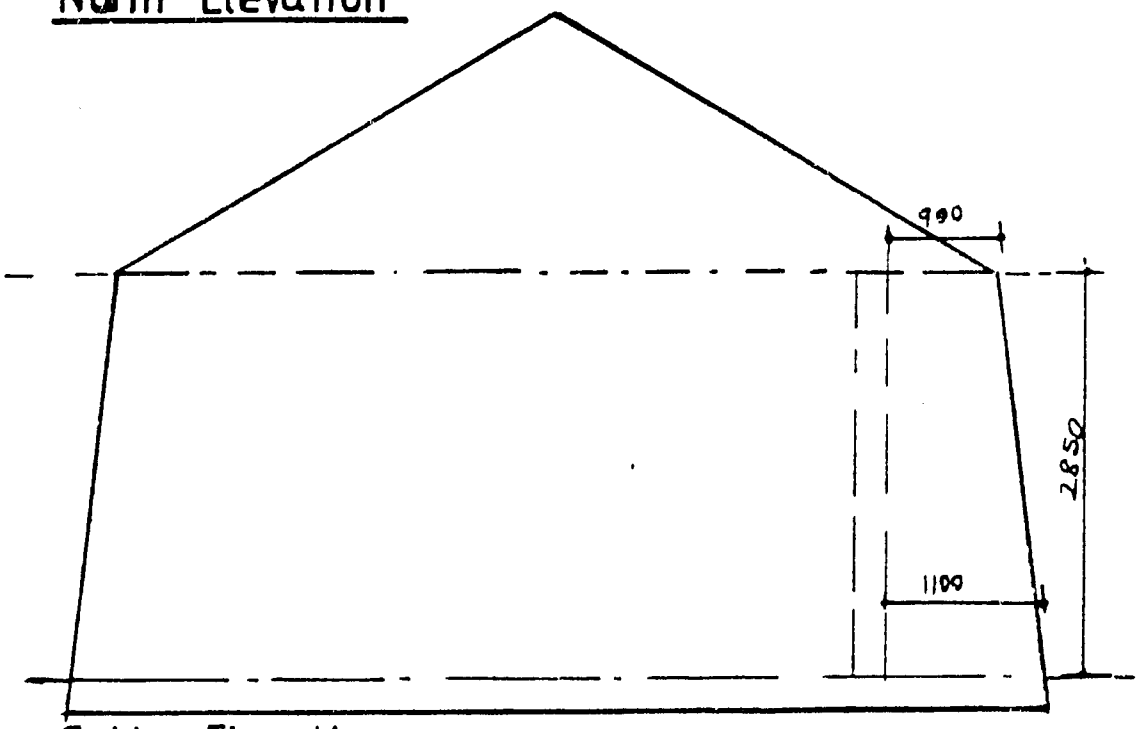
C. Greenhouse Window Detail - cracking putty



D. Greenhouse Glazing Detail

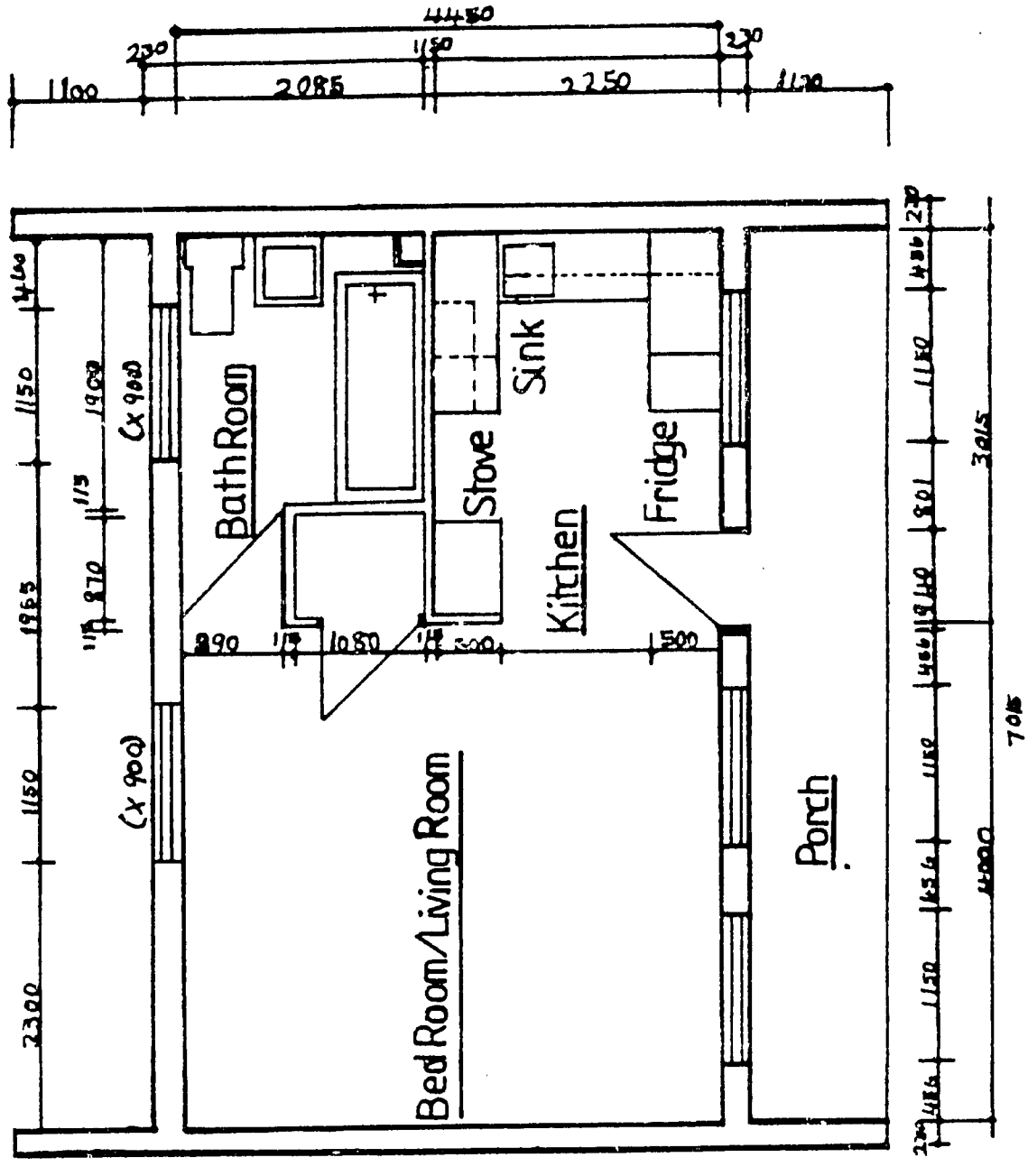


North Elevation



Gable Elevation

Thaba-Tseka Integrated Rural Development Program	Drawing Title:- E-House Elevations	Date:- NOVEMBER 1990 Scale: 1:50 Drawn: M. MASAKDRYE Checked:	Drw. No 8-4



Thaba-Tseka Integrated Rural Development Program	Drawing Title:- E-House Plan	Date:- November 1980 Scale :- 1:50 Drawn by:- M. Masikane Checked:-	Draw. NO 8-5

FIGURE A-6

COMPARISON OF AVERAGE TEMPERATURES OF FOUR BUILDINGS BY MONTH

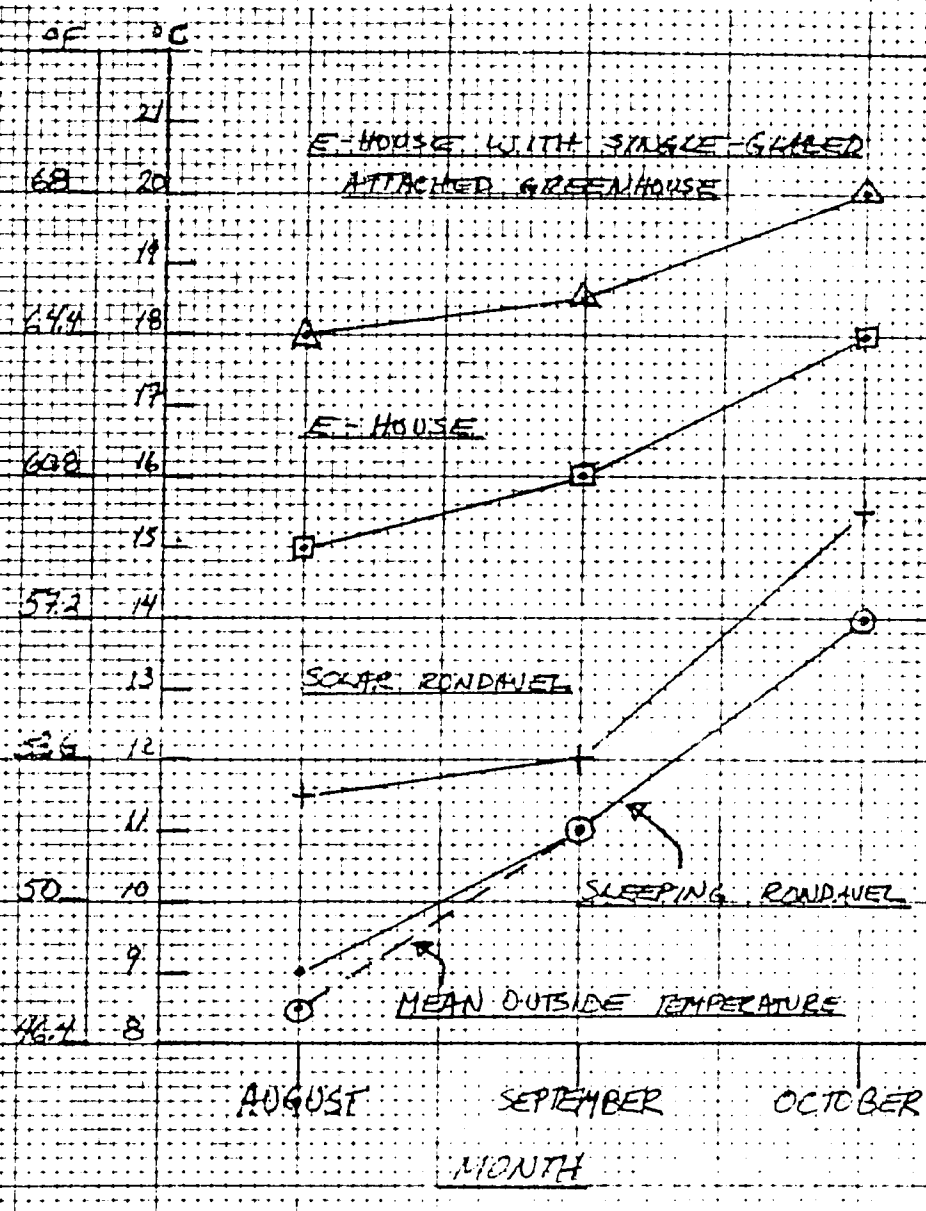


FIGURE 8-7 COMPARISON OF TWO RONDAVELS

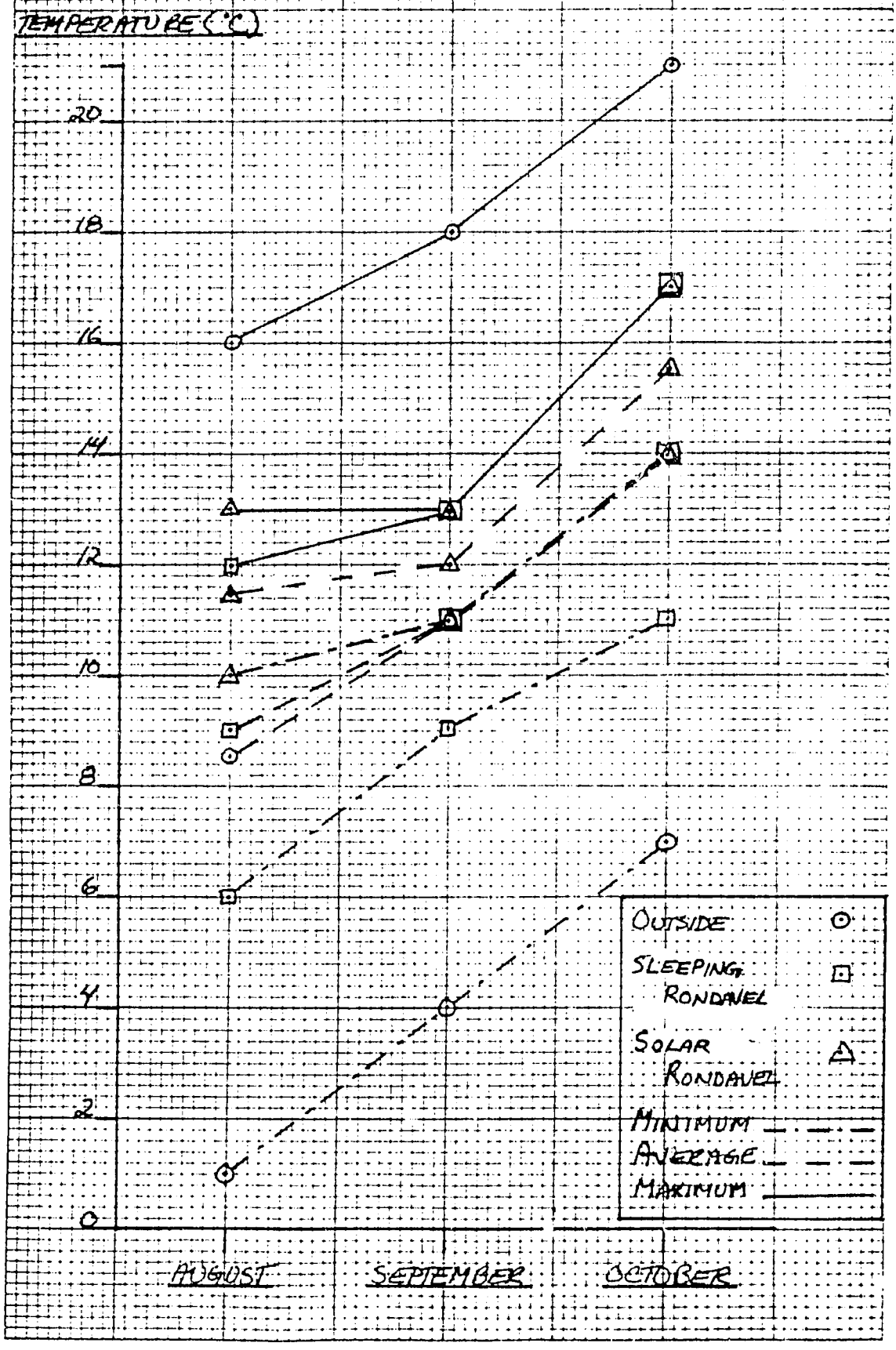


FIGURE 8-8 COMPARISON OF TWO E-HOUSES

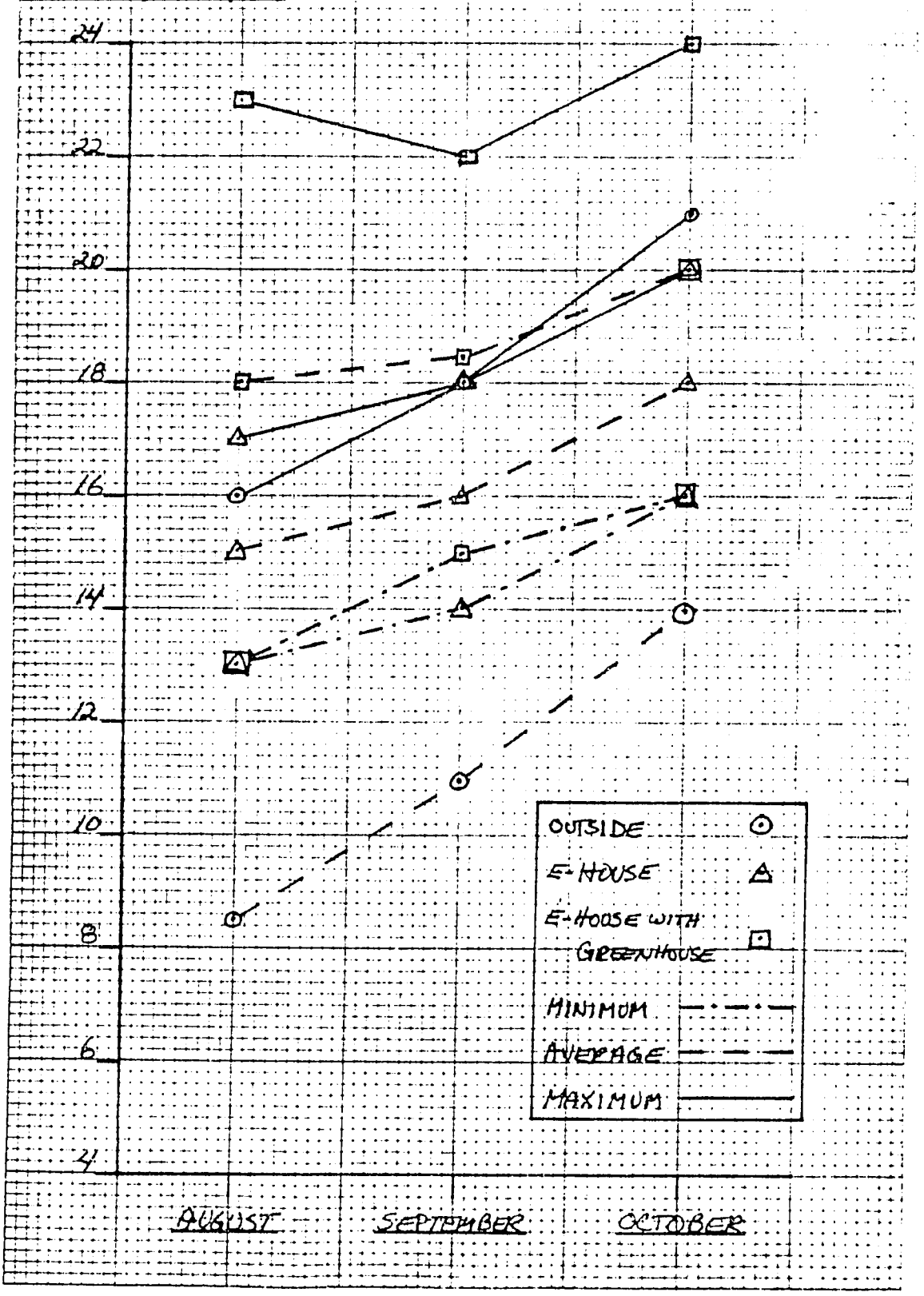


FIGURE 8-9 MOHLAKENG SOLAR PANEL - TYPICAL DAILY TEMPERATURE FLUCTUATIONS FOR SELECTED MONTHS, COMPARED WITH 1980 MEAN OUTSIDE TEMPERATURES

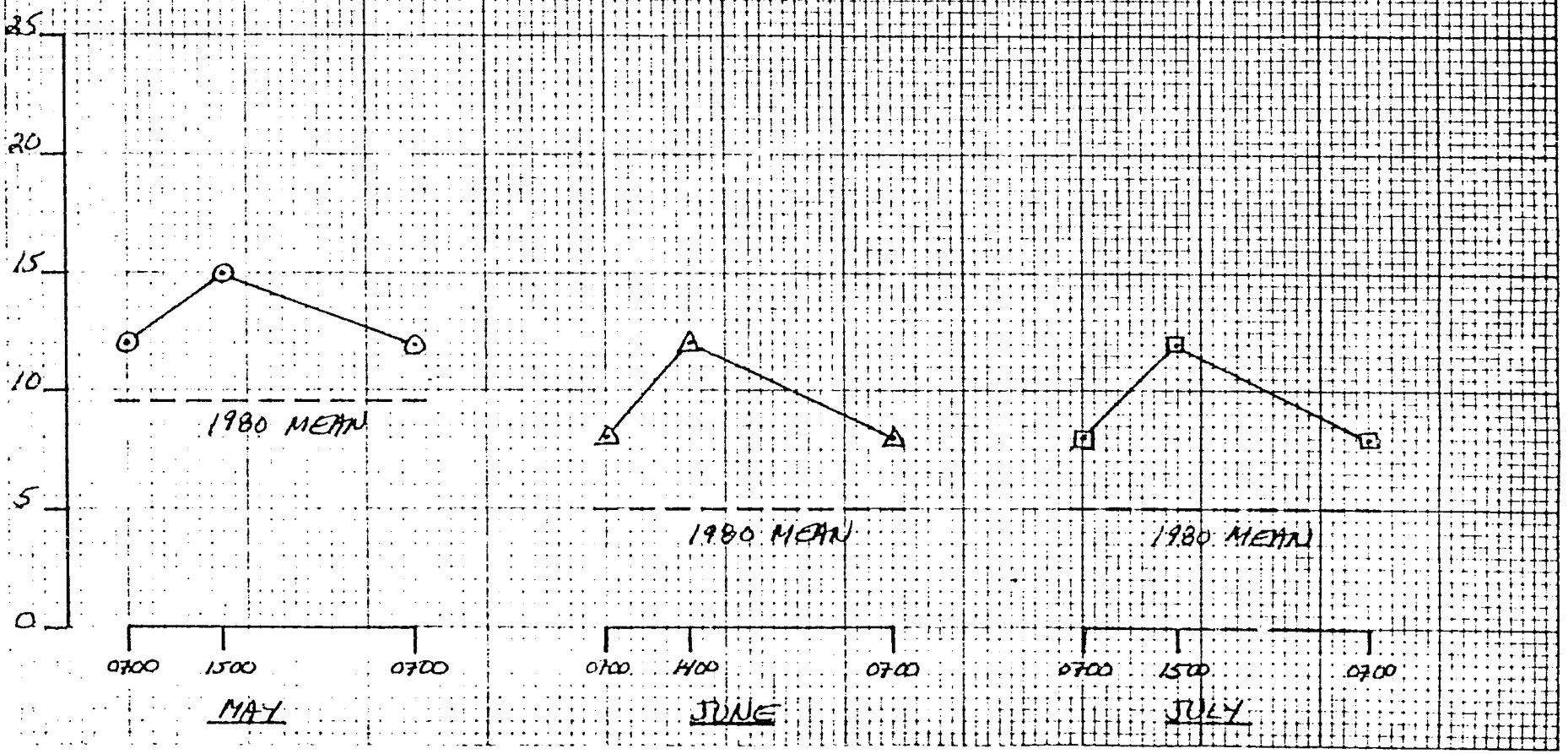


FIGURE 8-10 MOHAKENG SOLAR ROUNDAVEL - TYPICAL DAILY TEMPERATURE FLUCTUATIONS FOR SELECTED MONTHS, COMPARED WITH 1980 MEAN OUTSIDE TEMPERATURES

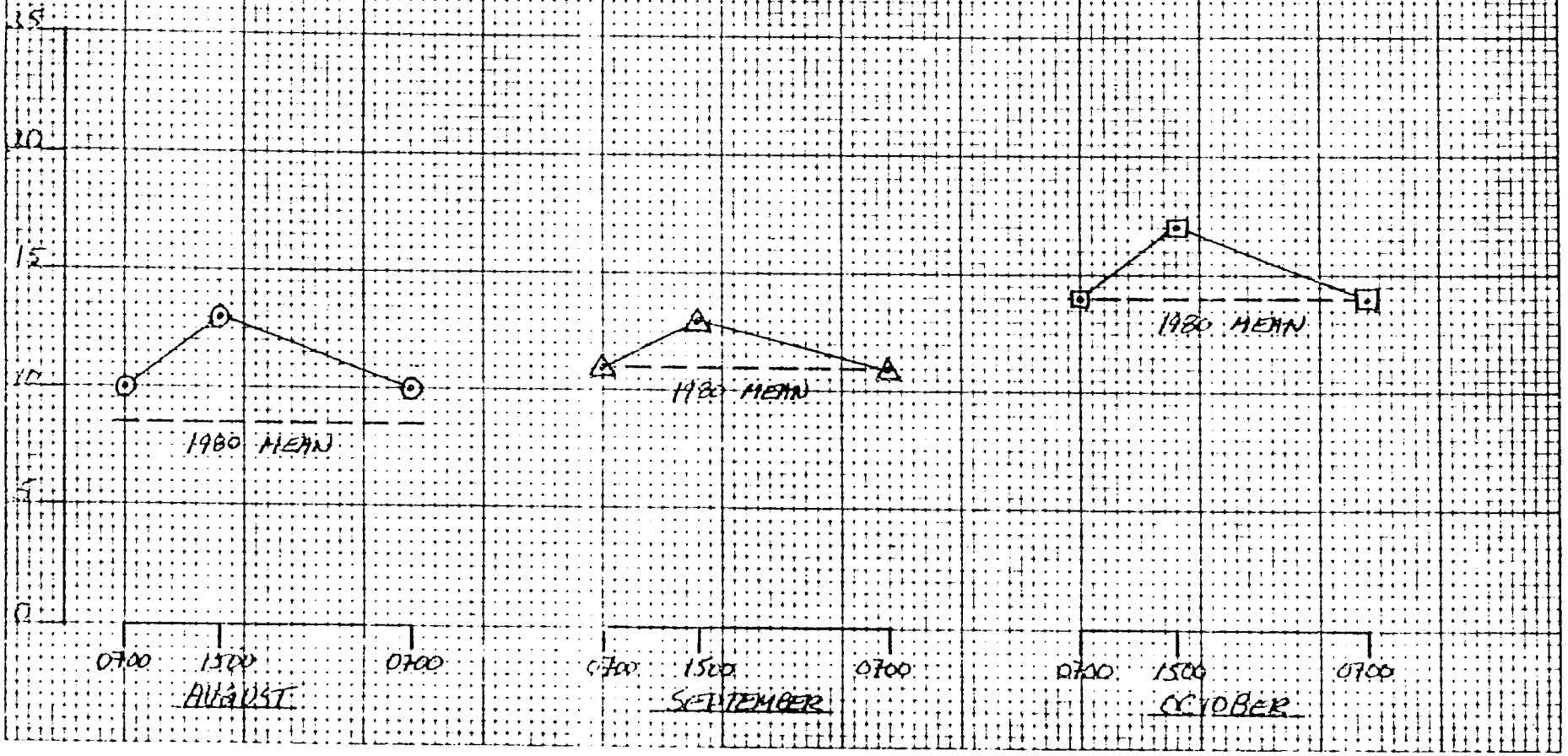


FIGURE 8-11 MOHLAKENG SLEEPING POUNDED - TYPICAL DAILY TEMPERATURE FLUCTUATIONS FOR SELECTED MONTHS, COMPARED WITH 1980 MEAN OUTSIDE TEMPERATURE

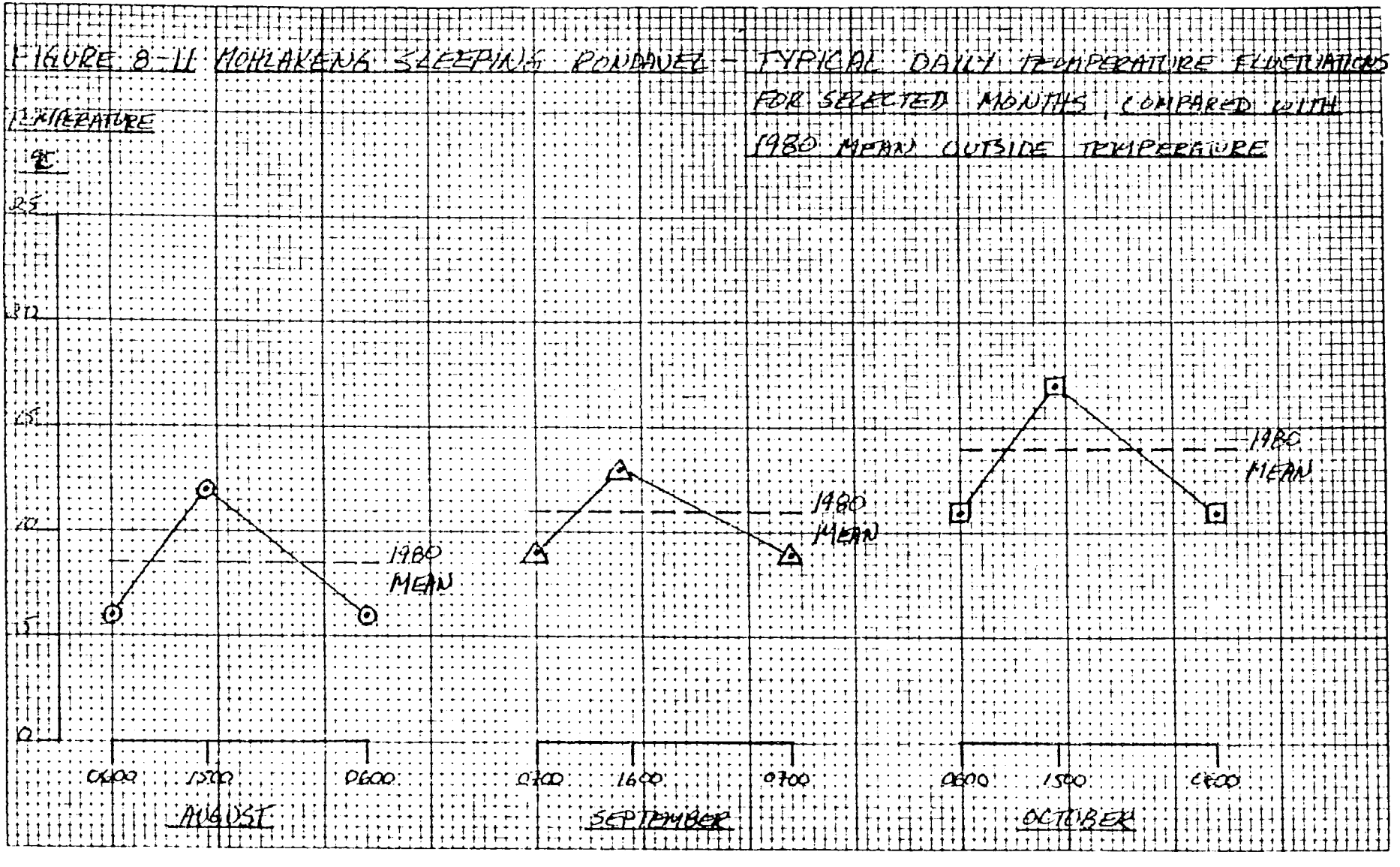


FIGURE B-12 E-HOUSE - TYPICAL DAILY TEMPERATURE FLUCTUATIONS FOR SELECTED MONTHS, COMPARED WITH 1980 MEAN OUTSIDE TEMPERATURES

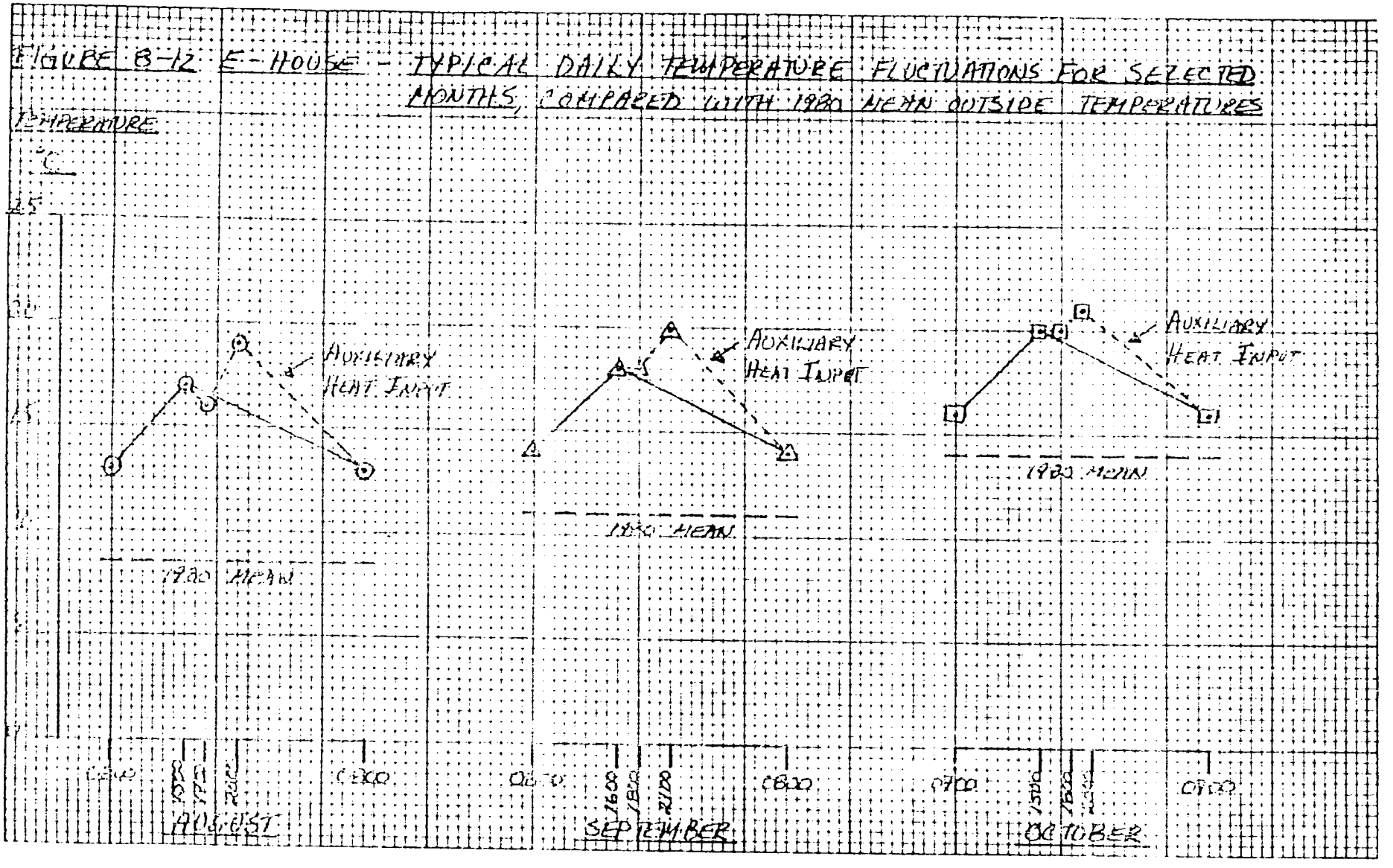


FIGURE 8-B E-HOUSE WITH SINGLE-GLAZED ATTACHED GREENHOUSE - TYPICAL DAILY TEMPERATURE FLUCTUATIONS FOR SELECTED MONTHS, COMPARED WITH 1980 MEAN OUTSIDE TEMPERATURES

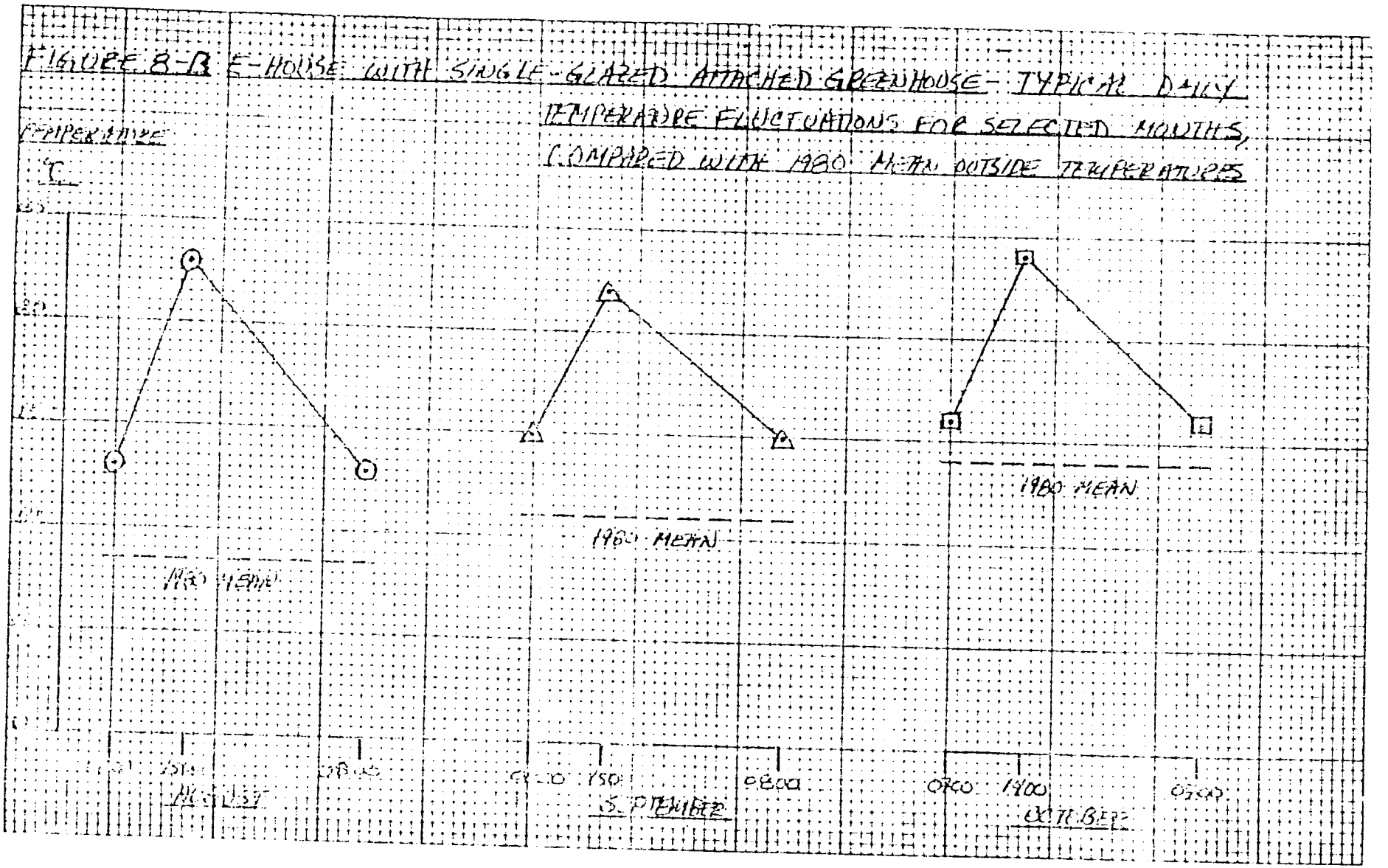


FIGURE 8-14 COMPARISON OF PREDICTED AND MEASURED AVERAGE INDOOR TEMPERATURES FOR TWO RONDAVELS

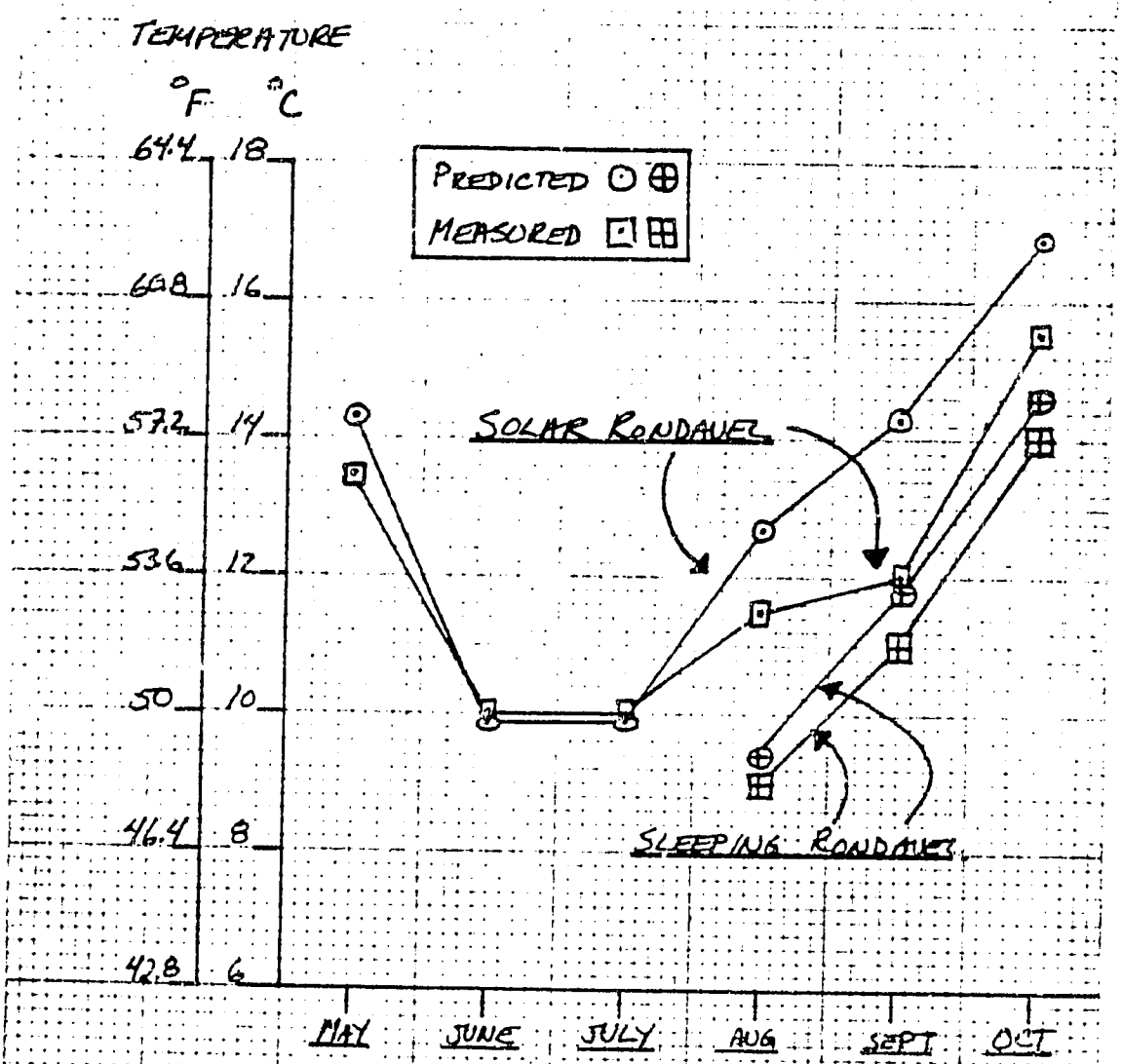
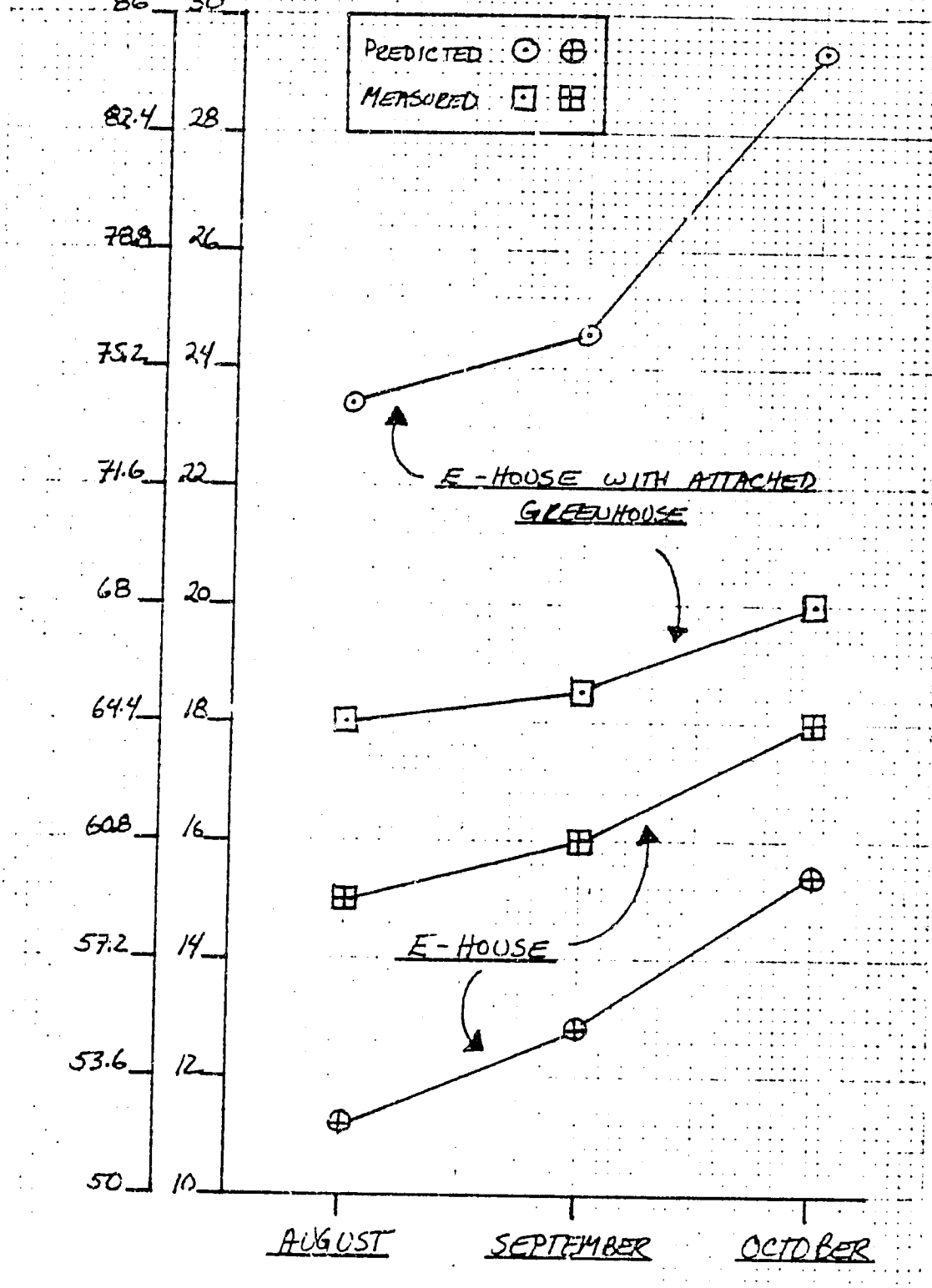


FIGURE B-15 COMPARISON OF PREDICTED AND MEASURED AVERAGE INDOOR TEMPERATURES FOR TWO E-HOUSES



CHAPTER 9 GREENHOUSES AND COLD FRAMES

Experimentation and testing of grenhouses and cold frames has continued through 1980. The Woodlot Section's tunnel greenhouses have been monitored as have some of the free-standing cold frames. The attached cold frames have been observed although not thermally monitored. Results of the analysis of the E-house with attached greenhouse are included in Chapter 8.

Woodlot Greenhouse

These two tunnel greenhouses are used primarily for growing tree seedlings. Early experiences with these greenhouses in Thaba Tseka showed that they were hotter during the day and colder at night than the outside ambient temperatures. Reasons for this were lack of proper ventilation and absence of any heat storage facilities. It was recommended that a total of $5m^2$ of ventilation and 5890 liters of water storage be put into the greenhouse to help correct this situation.

Only a portion of these modifications have been completed. A total of four roof vents and one door are in place, only $3.12m^2$ of ventilation area. Daytime temperature maximums have been reduced but they are still not down to desirable levels. Only half of the recommended water mass has been added to each greenhouse. This has helped prevent nighttime minimums dropping below outside temperatures, but has not stopped the inside temperatures from going below freezing.

Figure 9-1 shows what has occured in the greenhouse from May through October,1980. Inside and outside mean maximums and minimums are compared for each month. It is important to note that the location of the maximum-minimum thermometer inside the greenhouse was changed at the end of July. At that time it was from a position at eye level down to plant level near the floor of the greenhouse. This change is shown in the graph where the differences between the maximums decrease and the differences between the minimums increase. The temperature regime is considerably more stable where the plants are located than at higher positions in the greenhouse.

In conclusion, it should be pointed out that it would be advisable to complete the remainder of the modifications and monitor the effect that they have on the temperature fluctuations. Variations should be reduced and it should be possible to prevent the air temperature from dropping below freezing. While eliminating freezing air temperatures will improve the growth of the tree seedlings, it is more important to prevent the soil surrounding their roots from freezing. Even with only present modifications in place this has not occurred and the plants have grown reasonably well.

As a final note, it should be emphasized that these tunnel greenhouses are not designed for use in the climatic conditions existing in Thaba Tseka. Initial design work has been done on a large-scale greenhouse for an expanded tree nursery. At capacity, the nursery would be able to turn out one million trees each year. The intent of the design is to passively heat and cool the modules that will comprise the greenhouse. If and when this nursery is constructed, the performance of these structures should be carefully monitored.

Attached Cold Frames

The first experience with attached cold frames in Thaba Tseka began in 1978 when a relatively large unit was built onto a B-house. Initial performance information is contained in the interim report of this project. Since that time, two more units have been built, each attempting to correct some of the problems discovered in the previously constructed units. Each will be described in turn.

B- House Cold Frame

This unit is approximately five meters long, one meter wide and one meter high. The unit faces north at a tilt of 45°; ventilation is provided by vents located on the relatively flat, upper section of the cold frame, and by opening the covers. A sketch is shown in Figure 9-2, technical drawings in Figures 9-3, 9-4 and 9-5 and photographs in Figure 9-6.

Operating performance for winter 1980 is essentially the same as for the two previous years. Fresh greens were grown throughout the winter and in fact, during the entire year. The unit was not used as a source of heat for the

house. This was again due to the damp smell of the air and to the fact that cold air infiltrated easily into the greenhouse so that the vents into the house rarely supplied very warm air.

Figure 9-6C shows some of the high and low vents that were put into the greenhouse. It can be seen that not much convective flow would ever be developed because the height differential between the vents is so small. Note the black rear wall and the healthy growth of lettuce and spinach.

Figure 9-6D shows one of the problems that is probably the cause of some of the damp smell in the cold frame air. The swelling of the chipboard (particle board) is evidence of moisture absorption and most likely is associated with rot. Most of the water absorbed by this material comes from inside the cold frame. The rest seeps in from outside through gaps around the poorly sealed fiberglas cover.

The original purpose of the chipboard was to support the inner layer of glass on the cover. It was found that the double layer of glass made the cover too heavy to manipulate easily. Eventually the glass broke and the two sheets of glass were replaced by one of fiberglass. Fiberglass has been used in the other two units. The wide boards used in the construction of the covers also contributed unnecessary extra weight. The width of the boards has been cut in half in the other units.

Figure 9-6B shows why another problem occurred due to moisture. The section next to the wall of the house containing the vents, as well as two large sections of glass, is almost flat. Because of the design, water has trouble draining from this part of the cold frame , resulting in absorption of the water by the wood that is there. This feature has been eliminated in the other designs.

This Figure also shows why cold air can easily infiltrate into this cold frame, There is no obvious method of preventing air from coming in the gaps between the covers. The other designs include a piece of wood between each pair of covers on which they rest. Weatherstripping makes the seal reasonably tight.

C - House Cold Frame

This unit is about three meters long, one meter high and one meter wide. The walls are made of stone with cement mortar which, because of the originally poor finish, has been plastered. The three covers are 900mm x 1200mm and are tilted at 30°. Construction consists of meranti planks covered with fiberglass caulked and nailed to the wood frame. The covers are hinged along a plank that was bolted to the cement wall. Figure 9-7 contains a sketch and Figures 9-8A and 9-8B contain photographs of this cold frame.

The major problem with this unit was that it proved very difficult to bolt the board to the wall so that a flat surface for hinging remained. This resulted in the covers not lying quite the way they were intended. This led to futher complications, most notably when it came time to seal the unit from undesired air infiltration. To do this, the design intended to rely on a tortuous air path to cut down infiltration. Whatever little was left, could be stopped by easy-to-apply commercial weatherstripping. The covers were to rest on the inside of the base of a U channel formed by three pieces of wood. Since the covers were so skewed, these channels were no longer in quite the right location and much filing and planing was required to get things to fit. Finally, it was necessary to use much bulkier, albeit more locally available, sheepskin as weatherstripping to fill up the remaining large gaps. Figure 9-8B shows this in detail.

While these problems were experienced in construction, the owner has been satisfied with its performance in growing vegetables. No attempt was made to use air heated in the cold frame to heat the house. Wintertime operation and structural and materials performance will have to be evaluated in the coming years.

Attached Cold Frame

Construction of this unit attempted to correct the difficulties experienced in the previous design. This cold frame is about two and one-half meters long, one meter high and one meter wide. The walls are 115mm wide cement blocks with cement mortar. The fiberglass cover, tilted at about 30°, is attached to the wood frames with clear silicone caulk and brass screws (added

since the photograph was taken). Figures 9-8C and 9-8D contain photographs, and Figure 9-9 is a sketch, of this cold frame.

The problem of attaching the cover hinges to the board attached to the wall was solved as shown in Figure 9-8C. A board was attached to the wall. Pieces of wood were added perpendicular to this board. The lengths varied such that the board on which the hinges were attached became straight. The joint between this section and the covers was placed so that water dripping off the roof would fall below the joint, thus preventing too much unwanted water from entering the cold frame.

Figure 9-8D shows what was done to control air infiltration. On the two sides of the cold frame the cement was built up so that the wood frame rests below and outside the top edge of the built-up section. A flat board was placed between the two covers so that they rest flat on its surface. Even without weatherstripping air infiltration has been substantially reduced compared to other units. Before winter, weatherstripping will be added.

This cold frame was completed at the end of winter 1980. It has been used to start plants for this summer's vegetable garden and it will be used to grow tomatoes and cucumbers which do not do as well as they might, even in the summer months. It is planned to continue using the cold frame for fresh greens throughout the winter. As before, year-round performance and materials' weathering will have to be monitored in the coming years.

Conclusion and Recommendations

It is felt that the last unit makes the best use of the materials available in Thaba Tseka for constructing attached cold frames. The two units with covers tilted at 30° will have to be compared with the 8-house cold frame to determine which gives the most satisfactory year-round performance. It would be advisable to monitor temperature fluctuation as well as plant growth when making this determination. It will also be necessary to see if ventilation is needed in addition to opening the covers. If so, the design used in cold frame number three can be modified to accommodate this feature.

Free Standing Cold Frames

Three prototypes were built, completed by mid-winter. The objective of this

effort was to determine the ability of the various designs to provide a relatively inexpensive cold frame which could easily be built by villages in the District. The idea was to use a minimum of imported materials, relying on stone and mud to provide the structure which would support the cover. Two of the prototypes were monitored to determine temperature fluctuations.

Prototype 1

This unit was designed and built by a member of the R.T.U. for his home vegetable garden. The cold frame is basically a 45° right triangle with the hypotenuse aligned on an east-west axis and the 90° corner pointing to the south. The cover is set at a tilt of 15°. The walls of the unit are made of large stones with mud mortar. The entire unit is built into the slope of a hill in his yard. Only one side had to be bermed up to give the effect of being completely below grade . Figure 9-10 contains a sketch and Figure 9-11 photographs of this device.

Compared to the other free standing units this one is substantially larger. The sides of the unit are 3.1 meters long and the hypotenuse is 4.4 meters. This gives a rough glazing area of $4.8m^2$. The growing area is just slightly less than this and the enclosed volume is $3.6m^3$. The plastic has been buried in the ground around all three sides of the cold frame, thus reducing the chances for unwanted air infiltration to occur along these edges.(See Figure 9-11B.) It was also applied two layers thick to provide additional strength. For thermal purposes it is equivalent to only one layer of glazing. The door sits quite flat on its supporting frame and because of the plastic covering both surfaces, the air seal is quite good when the cover is closed (see Figure 9-11).

On the whole performance has been quite satisfactory. Growth has been quite good, improving continually since July (see Figure 9-11C). The sturdy construction has caused the unit to hold up well even under the severe wind conditions that have been experienced this past season. It is likely that wintertime performance will be as good as the other units because of the flatter angle of the cover, but this will have to be evaluated during the coming year.

Prototype 2

This cold frame was also built into the slope of a hill, but because of a somewhat steeper cover tilt, approximately 30°, and less rigorous construction, it is not as well thermally insulated by the surrounding ground. The walls are stone with mud mortar, although the stones are not as massive as in the first prototype. The glazing area is 2.1m^2, the growing area is 1.8m^2 and the enclosed volume is 0.53m^3. On top of the walls has been placed a rectangular wood frame to which the cover is attached. The cover is made of 38mm square SAP planks with a two-sheet thick layer of greenhouse grade Uvidex 602 on top and a single layer of the same material on the inside of the frame. Hinges have been made using pieces of an old tire. Sheepskin strips nailed to the bottom frame act as weatherstripping. Figure 9-12 and 9-13 contain a sketch and photographs of this unit.

When the unit was completed in mid-July, thermometers were placed inside and temperature fluctuations measured. It was found that air temperatures frequently dropped below freezing. In order to help decrease the magnitude of the temperature fluctuations and prevent freezing, 14 water-filled one-gallon (3.78 liters) used oil tins were put along the back wall of the cold frame. These were put in two rows, one above the other. In order to determine the amount of energy stored in the water, temperatures were measured at 0800 and 1600 daily.

This unit has suffered more than the first prototype because it is not constructed as sturdily. Figure 9-138 shows the weathering that has occurred on the stone wall. The mud and stones have washed away, mostly on the weather-exposed west side. This has resulted in several air gaps beneath the lower wood frame which allow for a significant amount of air infiltration. It is recommended that future units have wider stone walls which are built up level with the top surface of the lower wood frame.

Other problems have occurred due to animals and the wind. On a number of occasions dogs ate out portions of the sheepskin weatherstripping. The thermometer readings dropped accordingly. It seems that the dogs were after the salt on the skins, so obviously the salt should be scraped off prior to its use as air seal. The wind eventually caused the cover frame to break.

This was probably due to its lightweight construction. Future units should have a cover made of 35mm x 55mm planks with diagonal corner braces.

Plants grew well in this prototype. Its wintertime performance was somewhat better than in the first cold frame. However, as spring progressed, it fell behind the other unit. Nonetheless, it still produced very hardy seedlings.

Prototype 3

This unit is the same size as the previous prototype but several features of the first unit have been incorporated into the design. The cover, a single layer of greenhouse plastic, has been buried into the walls surrounding the cold frame. The door is smaller, occupying only about one-quarter of the surface area of the cover. The combination of these two features was intended to bring infiltration rates below that of the second cold frame prototype. Figures 9-14 and 9-15 contain a sketch and photographs of this unit.

The stone walls were built wider and more nearly level to the top of the cover than in the second prototype. (See Figure 9-15B.) The weatherstripping and the latch are shown in Figure 9-15C. Rubber inner tubes taken from a truck proved to be a useful and fairly durable item.

It was found that the single thickness of the plastic covering tore very easily. Although it doubles the glazing price, it is recommended that future units have a two-layer thick outer covering. Another option is to use fiberglass for the cover. While initial cost is significantly higher, it will not need annual replacement; in fact it should last about 10 years.

A final feature of this unit is that it has a greater height from the cover to the soil at the lower side of the cover. This slightly increased volume will not seriously affect the performance although it should make it possible for the plants to grow taller without coming too close to the glazing. The added effect of increased, below grade, thermal mass may also be beneficial. This will have to be investigated during the coming year.

Test Results

In order to examine the thermal performance of the first and second prototypes two maximum-minimum thermometers were placed in each cold frame. One

have switched positions. It is likely that both of these phenomenon are partially explained by the relationship of the changing altitude of the sun to the cover tilt. Because the angle of tilt is flatter in the first prototype, more energy enters the unit as the sun climbs higher in the sky.

Table 9-4 calculates the average amount of energy stored in the water storage containers that were placed in Prototype 2. The upper row of tins absorbed more energy than the lower row. This is probably due to the fact that a greater surface area of these tins sit higher up in the cold frame where the air temperatures are warmer.

Figure 9-19 compares the temperature fluctuations in the upper and lower rows at 0800 and 1600 readings. At 0800 the temperatures in both rows are identical. At 1600 the temperature in the upper row is generally a few degrees warmer than the lower row. As expected, the fluctuations are less than those of the air temperature for similar periods.

Conclusion and Recommendations

It should be pointed out that there are two many variables to make very good comparisons between the two prototypes. These include shape, surface area, volume, heat storage medium, angle of tilt and relationships between these, such as surface area to storage mass. It is recommended that a series of tests be carried out in the coming year which examine some of these factors. A good place to start would be to keep the surface area and tilt constant and vary the shape and storage medium. This could be done so that triangular units could be compared with rectangular ones and water storage compared with rock storage. It would be advisable to install a thermograph inside of each unit as well as using one to record outside air temperature variations.This would allow the times at which the extremes occur to be examined as well as the extremes themselves.

In any event, at this stage, three freestanding cold frames and three attached units have been built and are being observed. All units work reasonably well. Long-term performance and maintenance and repair requirements need to be monitored. Further thermal evaluations would be advisable, although for widespread adoption in the District, it is felt that more emphasis should be placed on the free-standing units. It will be particularly important

measured soil temperature at about 3 inches in depth, the other measured air temperature at plant height, just above the ground. Readings were taken at 0800 daily. The temperature of the water in the heat storage containers was measured at 0800 and 1600, also daily. The data has been analyzed on a weekly basis from August through October. An exception is mid-September when the readings were discovered to be inaccurate.

Table 9-1 displays the mean minimum, maximum and average temperatures by week beginning in May,1980. The fourth "week" of each month encompasses a period of either nine or ten days rather than the seven used in the other periods. Table 9-2 displays mean average pyranometer readings on a horizontal surface from July through October. The data is shown for the periods 0800 to 1600 and 0800 to 0800.

Table 9-3 compares the temperatures obtained in the two cold frames for each weekly period beginning in August. Data is graphically displayed in Figures 9-16, 9-17 and 9-18. Figure 9-16 compares the air and soil temperatures of Prototype 1 to the outside air temperature. Figure 9-17 does the same for Prototype 2. The air temperatures for both units are compared with the outside air temperature in Figure 9-18.

In cold frame Prototype 1, the minimum air temperature generally followed the pattern of the minimum outside air temperature. The same is true of the maximums. Inside minimum air temperatures never went below minimum outside air temperatures, minimum soil temperatures tended to show less variation than air temperatures. The general trend for all temperatures was to increase from August to October. The same basic patterns are evident in the second prototype. It is interesting to note that during one period in October the minimum inside air temperature dropped below the minimum outside air temperature. It did not, however, go below freezing. The minimum soil temperature was generally about 2°C less than in the first unit.

The minimum inside air temperatures of the second prototype are generally less than the first cold frame. This difference increases from August to October, with the first prototype getting warmer while the second remaining about the same. The inside maximum air temperatures exhibit a different trend. In August, the first unit is below the second, while by October, they

to see how capable these cold frames are at producing fresh vegetables throughout the winter months. As with the food dehydrators, the major initial market will probably be with the large farmers who, during visits to the R.T.U., have expressed interest in these devices.

Table 9-1. Mean Minimum, Maximum and Average Temperatures in °C, by Week, for Selected Months in 1980

	Minimum	Maximum	Average
May 1 -7	3	20	12
8 -14	1	18	9
15 -21	3	18	11
22 -31	0	15	7
June 1 -7	-2	12	5
8 -14	-2	13	6
15 -21	-1	12	6
22 -30	-5	11	3
July 1 -7	-6	10	2
8 -14	-4	13	4
15 -21	-1	14	6
22 -31	-1	14	7
August 1 -7	3	15	9
8 -14	1	14	8
15 -21	-2	15	7
22 -31	2	18	10
September 1 -7	6	20	13
8 -14	2	15	9
15 -21	4	19	11
22 -30	3	19	10
October 1 -7	6	21	14
8 -14	9	23	16
15 -21	6	18	12
22 -31	7	21	14

126

Table 9-2. Mean Average Pyranometer Readings, by Week, for Selected Months in 1980, in BTU/SQ.ft

	8 -16	8 -8
July 1 -7	1090	1130
8 -14	1060	1110
15 -21	1050	1070
22 -31	1130	1160
August 1 -7	1060	1100
8 -14	1080	1190
15 -21	1430	1510
22 -31	1120	1318
September 1 -7	1390	1490
8 -14	1480	1550
15 -21	1490	1560
22 -30	890	1090
October 1 -7	1290	2100
8 -14	1560	1960
15 -21	1540	2080
22 -31	1940	2320

Table 9-3. Comparison of Two Free-Standing Cold Frames - Temperatures in °C

	PROTOTYPE 1				PROTOTYPE 2							
	Air		Soil		Air		Soil		Thermal Mass			
									Upper		Lower	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	0800	1600	0800	1600
August 1 -7	9	24	12	23	9	34	10	23	12	25	12	25
8 -14	7	24	12	21	5	38	10	23	10	26	10	25
15 -21	5	25	12	27	3	33	9	22	10	24	9	20
22 -31	8	26	9	30	5	32	10	24	12	26	12	22
September 1 -7	8	40	11	34	8	31	10	27	14	32	13	26
24 -30	10	30	9	32	4	29	8	17	4	10	4	8
October 1 -7	8	47	12	38	5	44	9	34	9	28	8	24
8 -14	14	48	14	37	9	47	12	39	17	31	16	26
15 -21	13	47	16	42	8	40	12	33	16	27	15	24
22 -31	13	51	14	48	9	46	11	41	17	32	17	31

Table 9-4. Calculation of Average Daily Energy Stored in Water Filled Heat Storage Containers in Free-Standing Cold Frame Prototype 2

	Upper Row			Lower Row					
	Number of gallons	Δ T (°F)	U	Number of gallons	Δ T (°F)	L	U+L	Density lb/gal	Average Daily BTU's Stored
August 1 -7	7	23	161	7	23	161	322	8.34	2690
8 -14		29	203		27	189	392		3270
15 -21		25	175		20	140	315		2630
22 -31		25	175		18	126	301		2510
September 1 -7		32	224		23	161	385		3210
24 -30		11	77		7	49	126		1050
October 1 -7		34	238		29	203	441		3680
8 -14		25	175		18	126	301		2510
15 -21		20	140		16	112	252		2100
22 -31		27	189		25	175	364		3040

FIGURE 9-1

COMPARISON OF TEMPERATURES INSIDE AND OUTSIDE THE WOODLOT GREENHOUSE

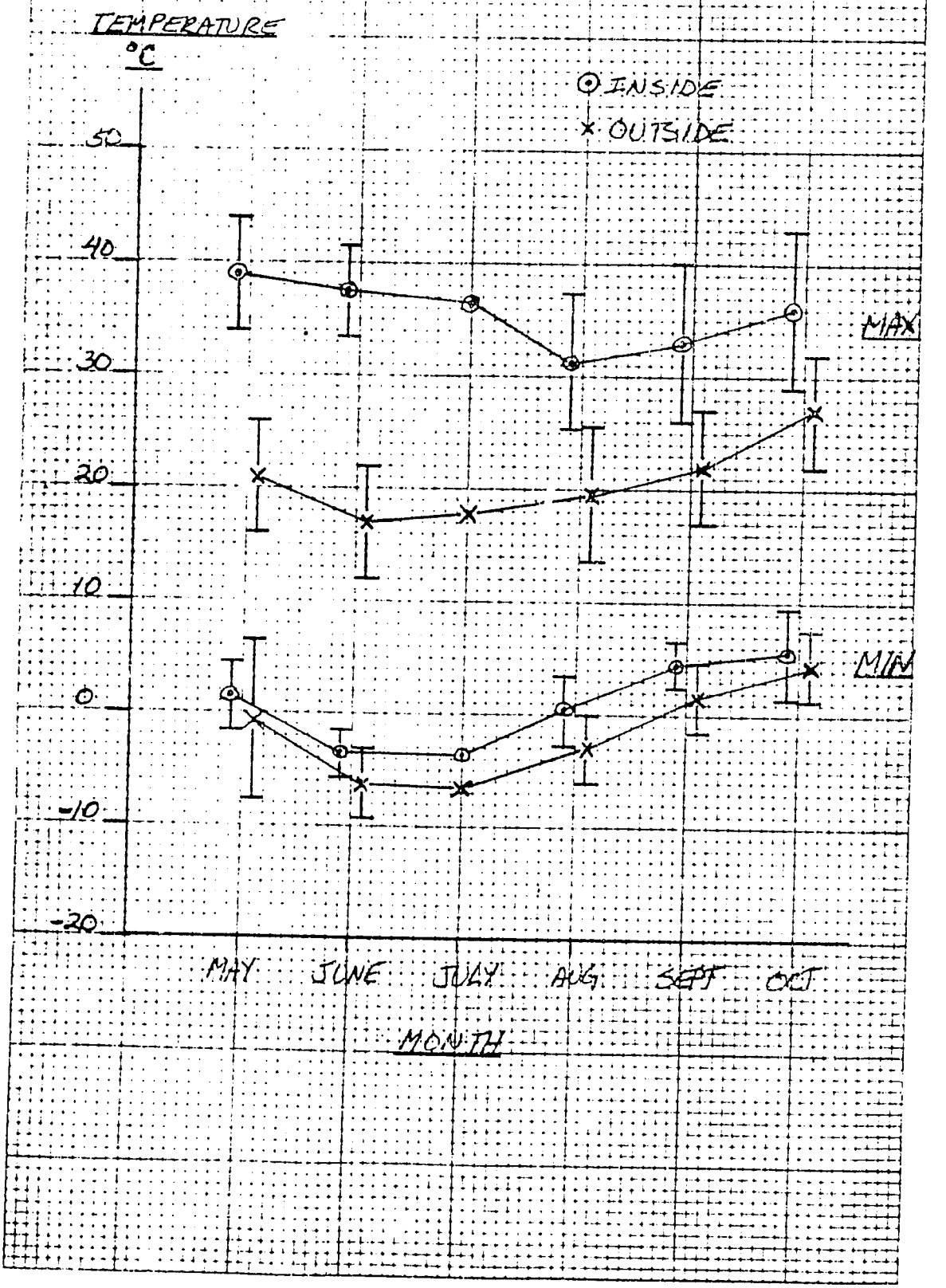
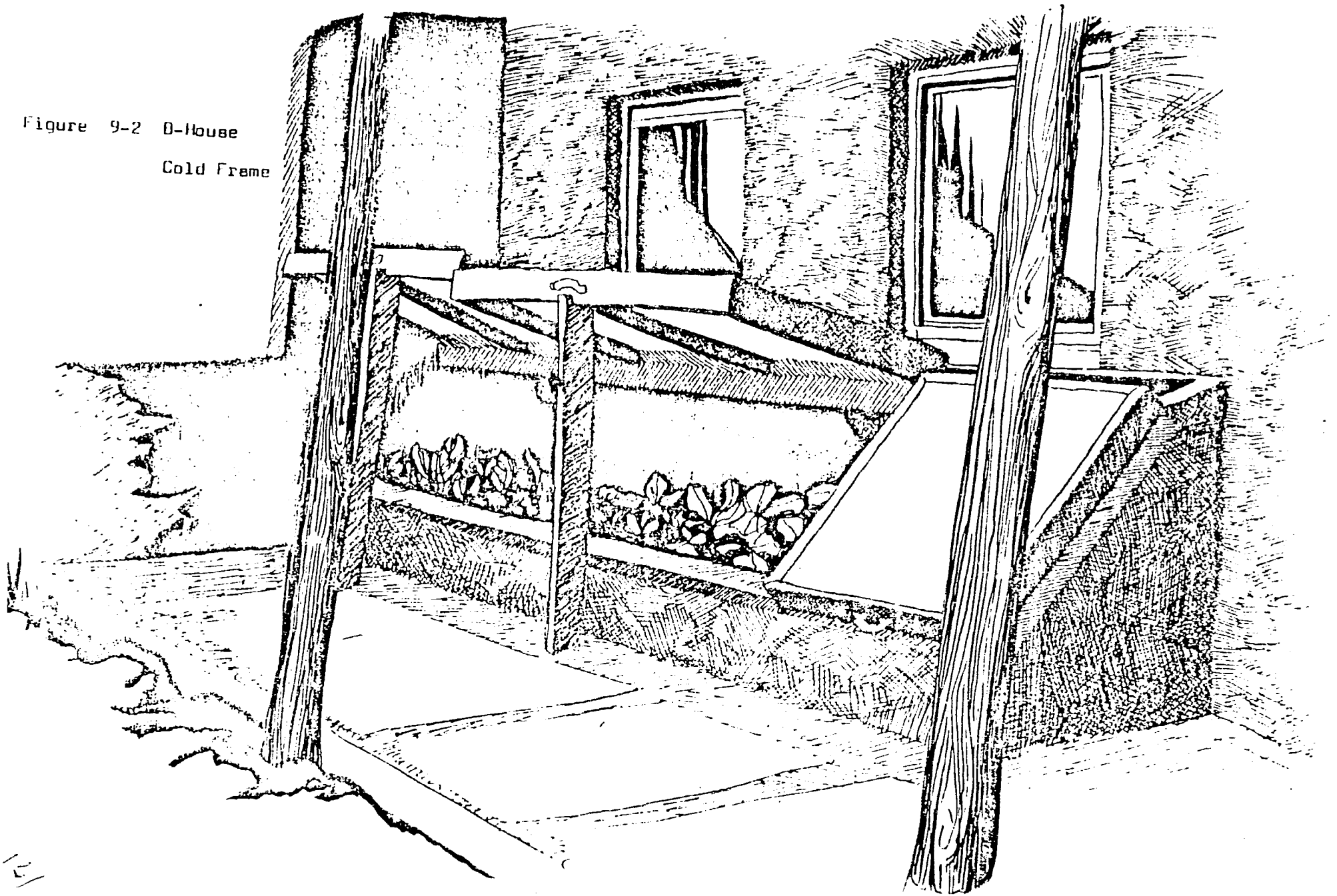
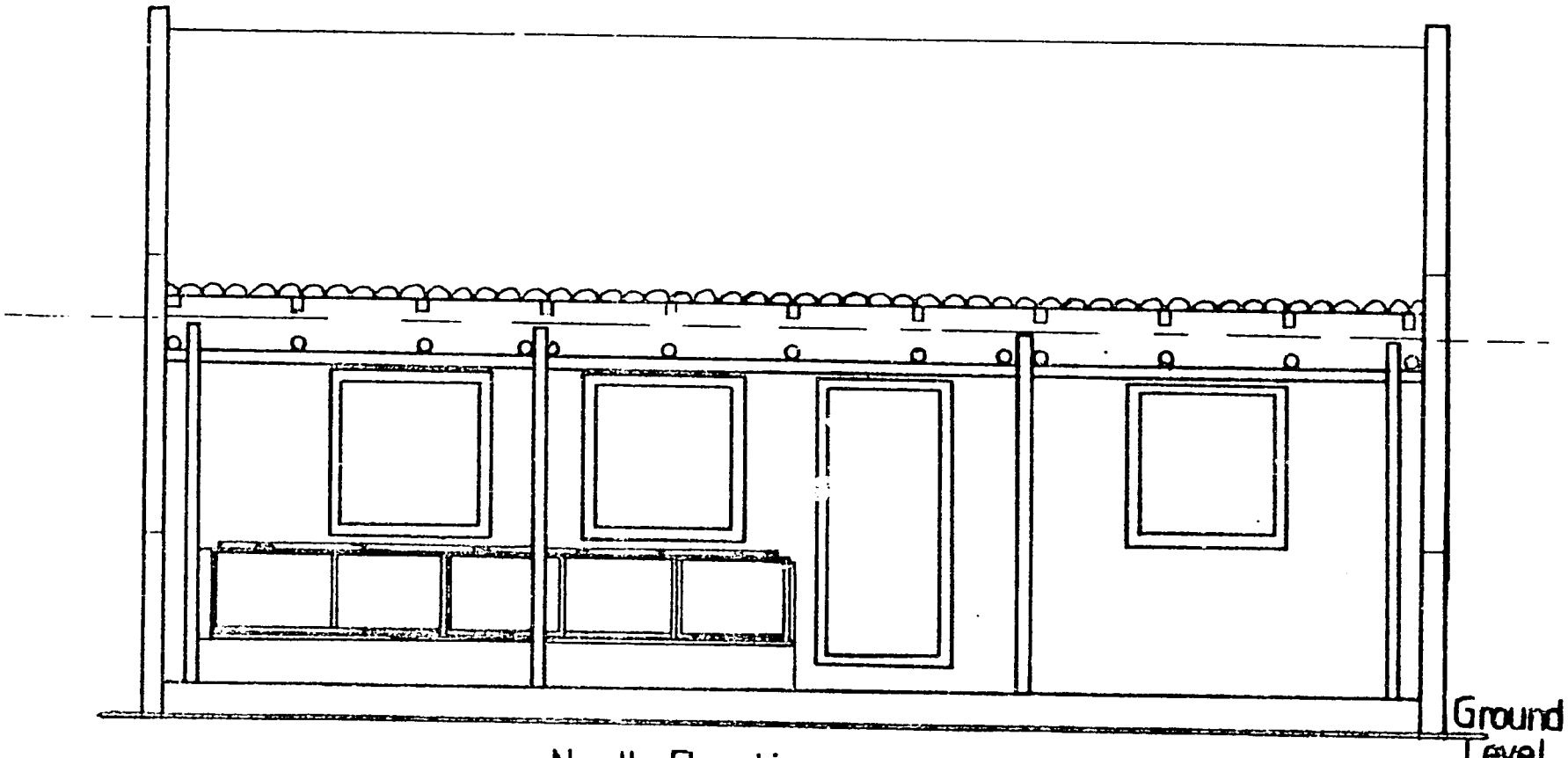


Figure 9-2 O-House

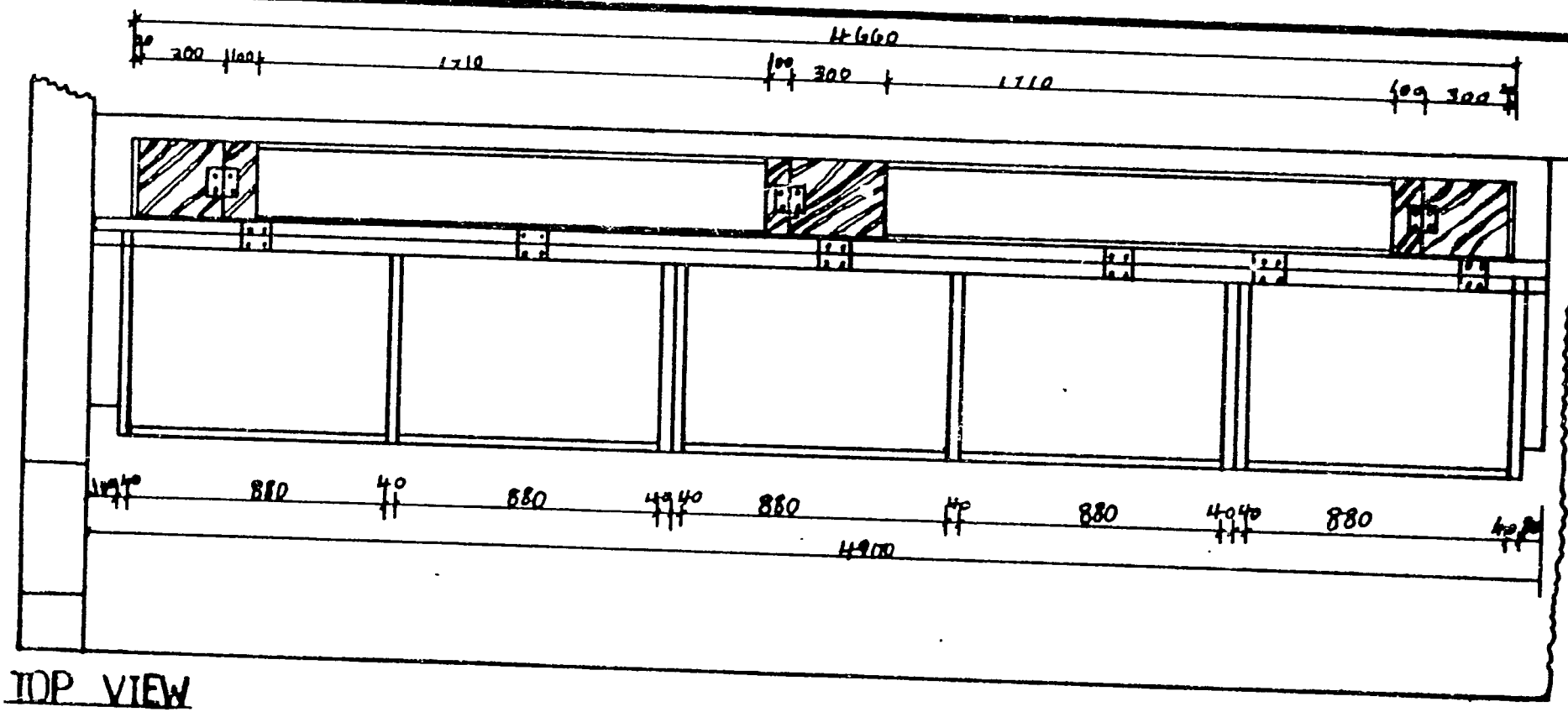
Cold Frame





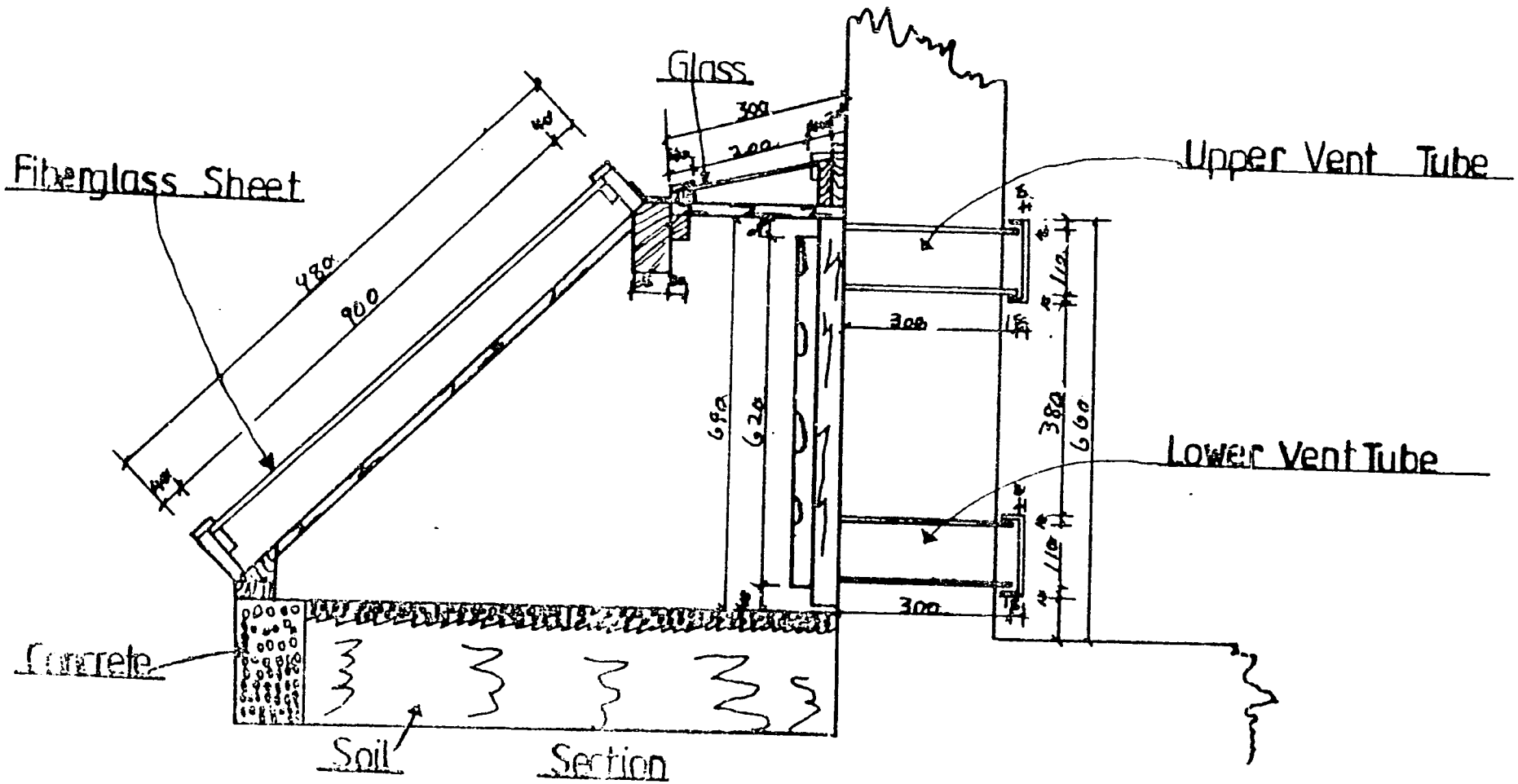
North Elevation

Thaba-Tseka Integrated Rural Development Program	Drawing Title:- Attached cold Frame Prototype - North Elevation	Date:- November 1980 Scale:- 1:50 Drawing by:- M. MASAKOANE Checked:-	Draw. NO 9-3



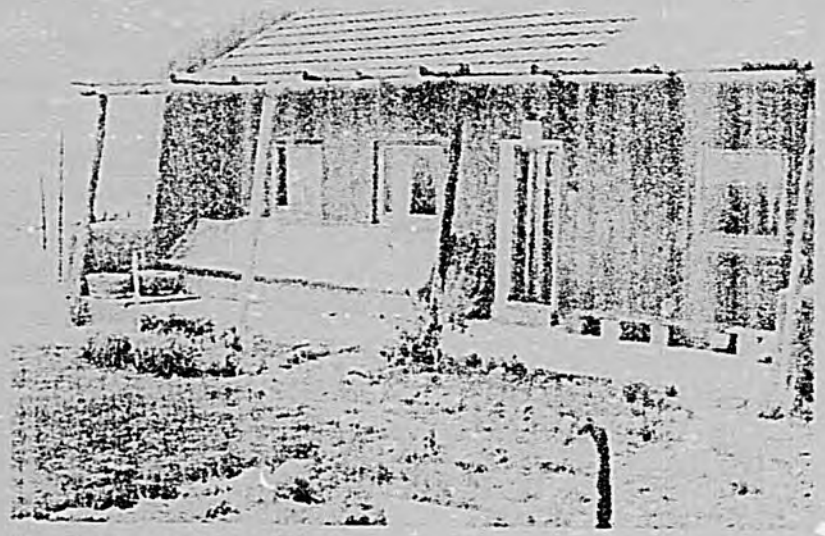
TOP VIEW

Thaba-Tseka Integrated Rural Development Program	Drawing Title:- Attached cold Frame. Prototype 1 -Top View	Date:- November 1980 Scale:- 1:20 Drawn by:- M. MASBAKBANE Checked:-	Drawing NO 9-4

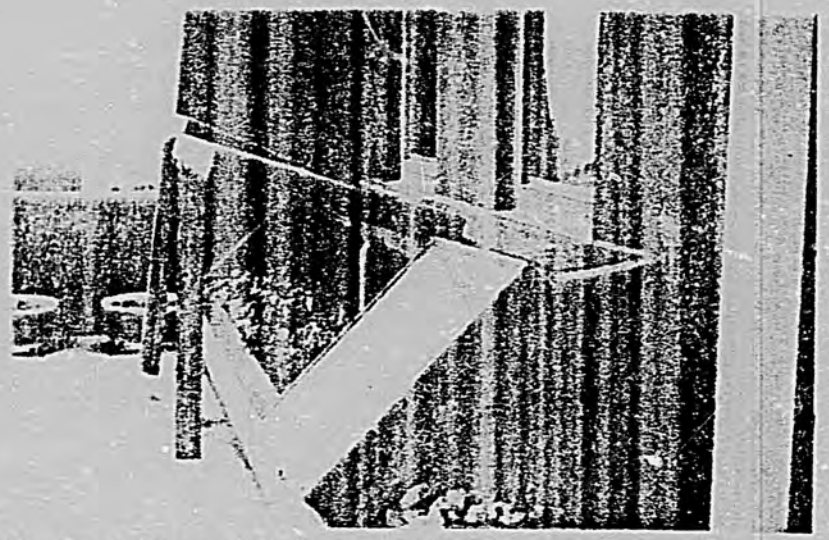


Integrated Rural Development Program	Attached roof Frame Prototype 1-Section	Date: November 1980 Scale: 1:10 Drawn by:	Drawing No. 9-5

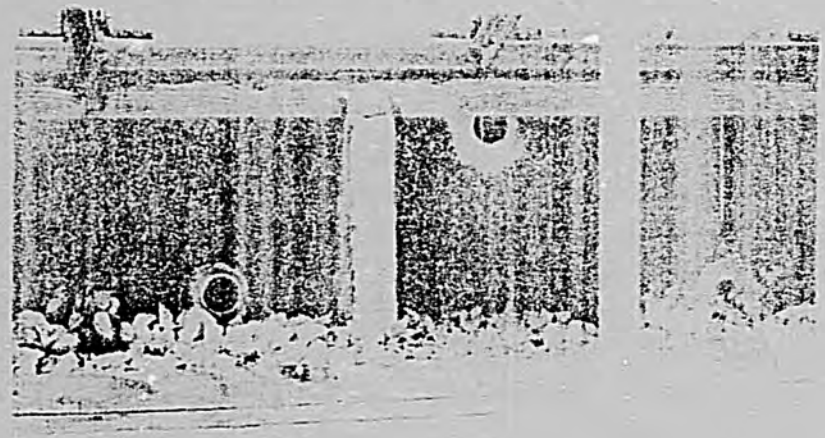
Figure 9-6



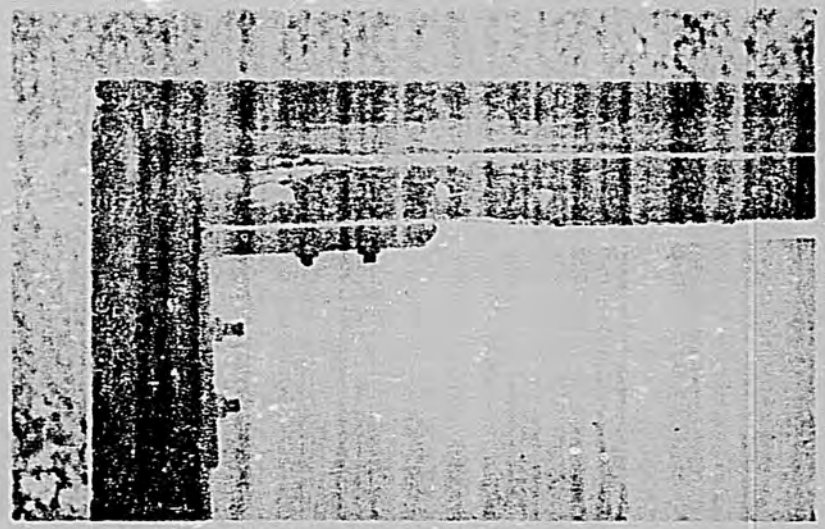
A. B-House Cold Frame



B. East View with Covers Open



C. Inside View showing air vents



D. Cover Detail showing swelling

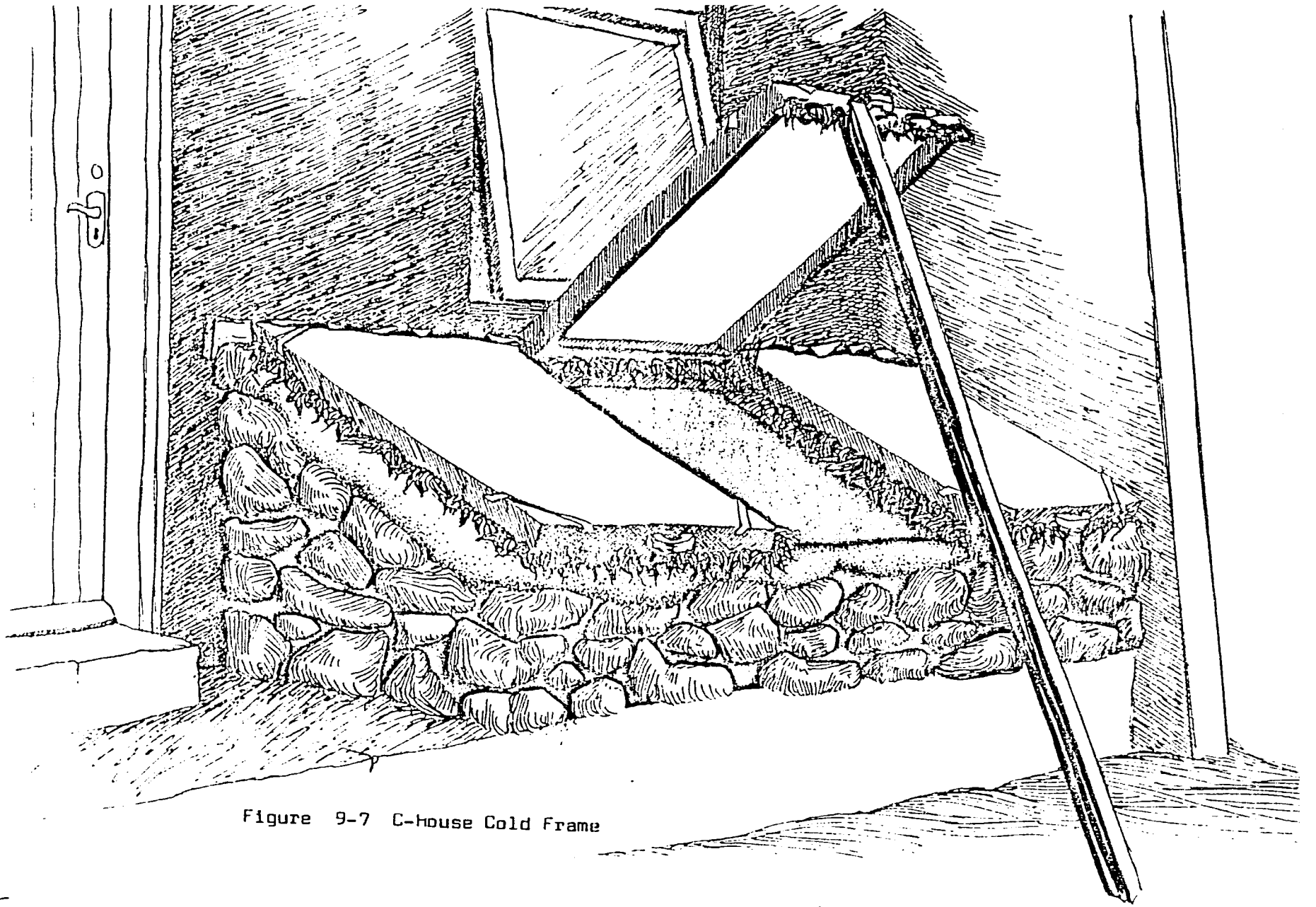
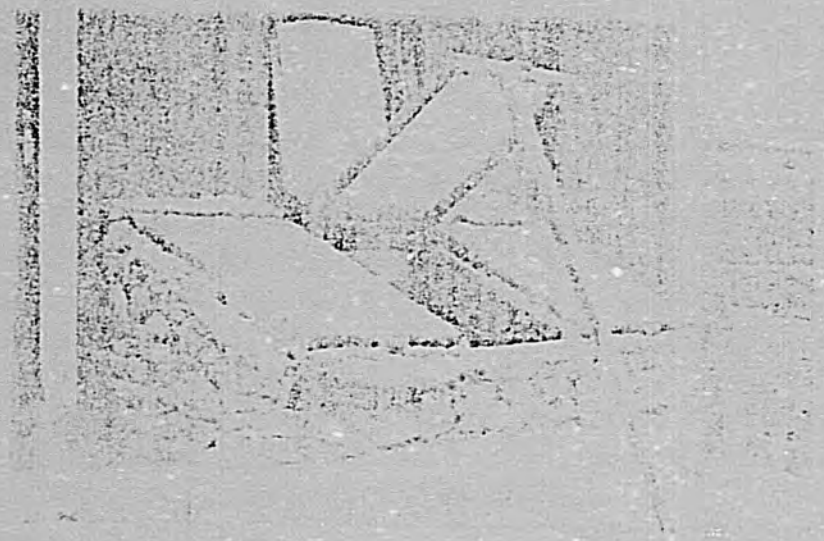
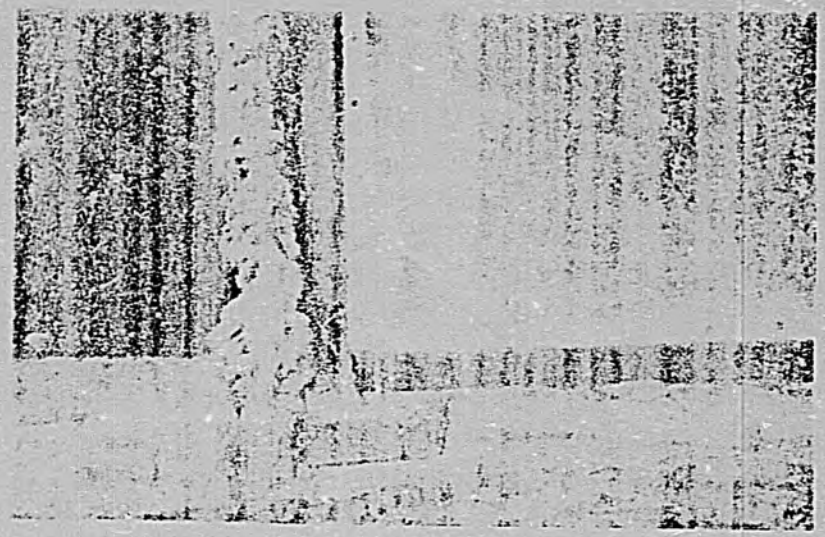


Figure 9-7 C-house Cold Frame

Figure 9-8



A. C-House Cold Frame



B. Cover and Weatherstripping Detail

C.Attached Cold Frame- Northeast view

D. Infiltration Prevention Detail

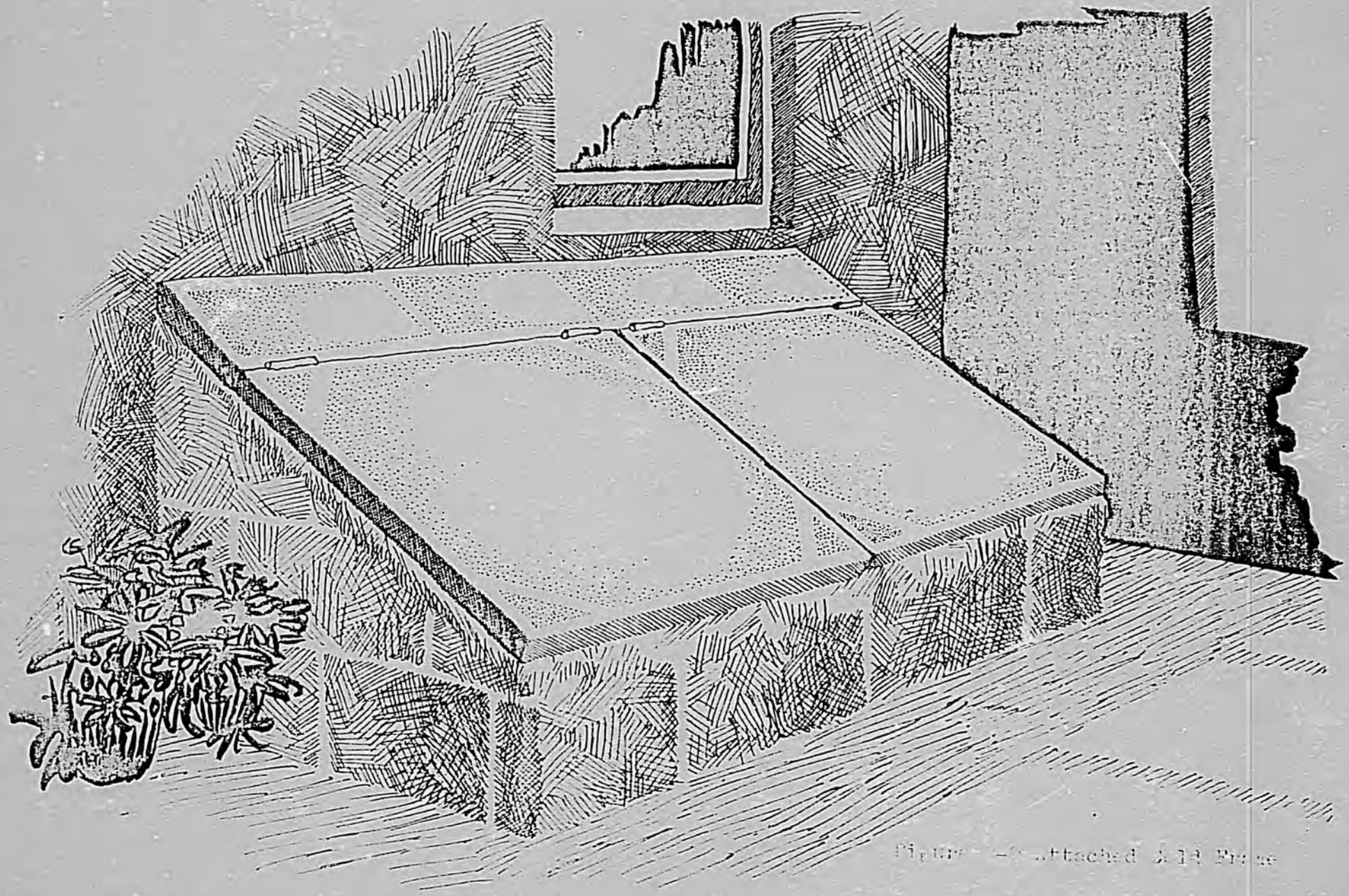


Figure - Attached 3.14 Prime

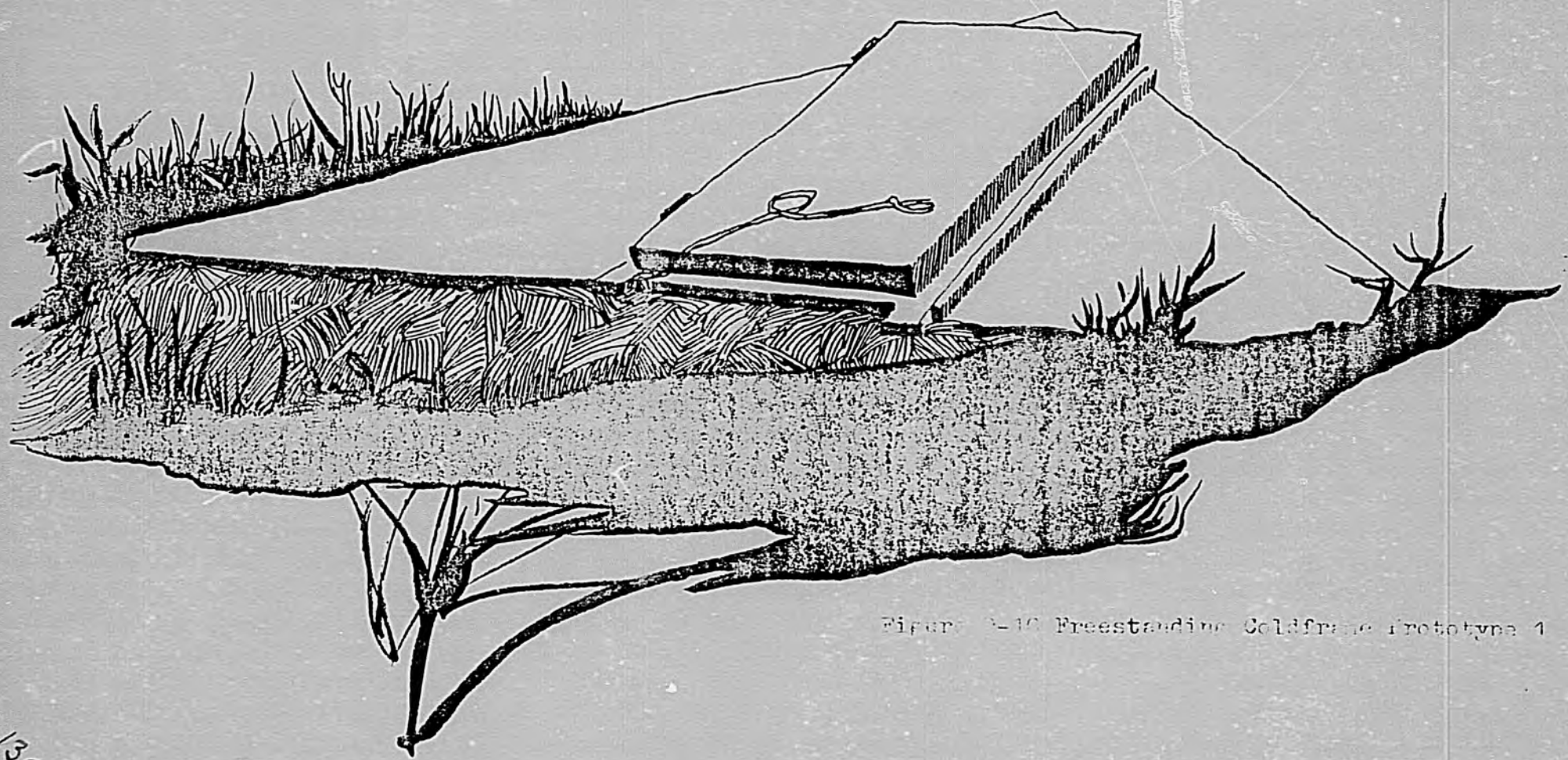
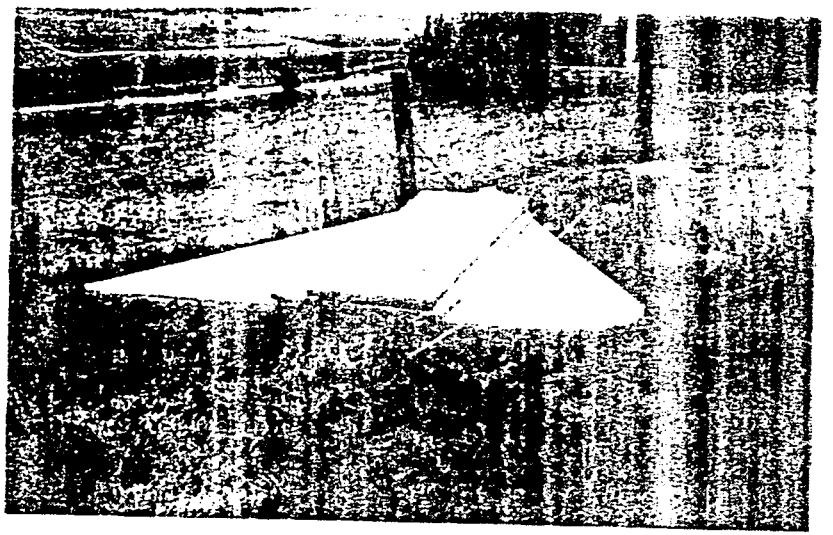
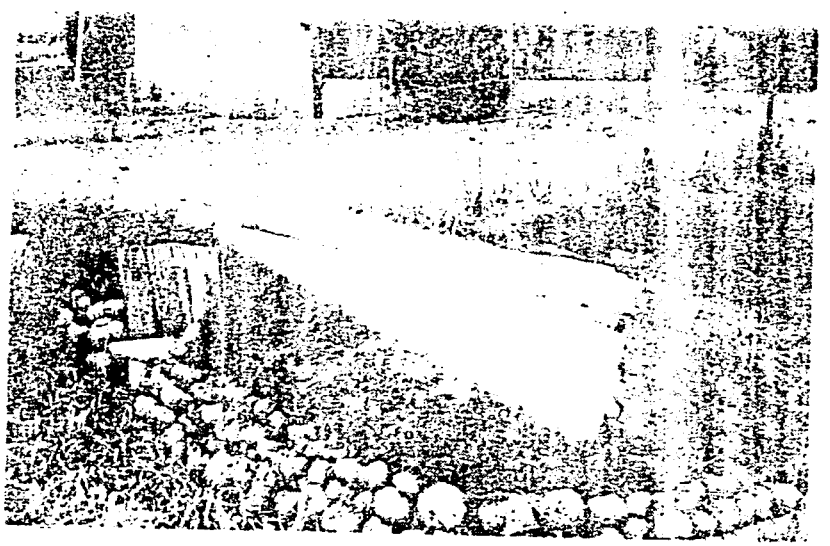


Figure 3-10 Freestanding Coldframe Prototype 1





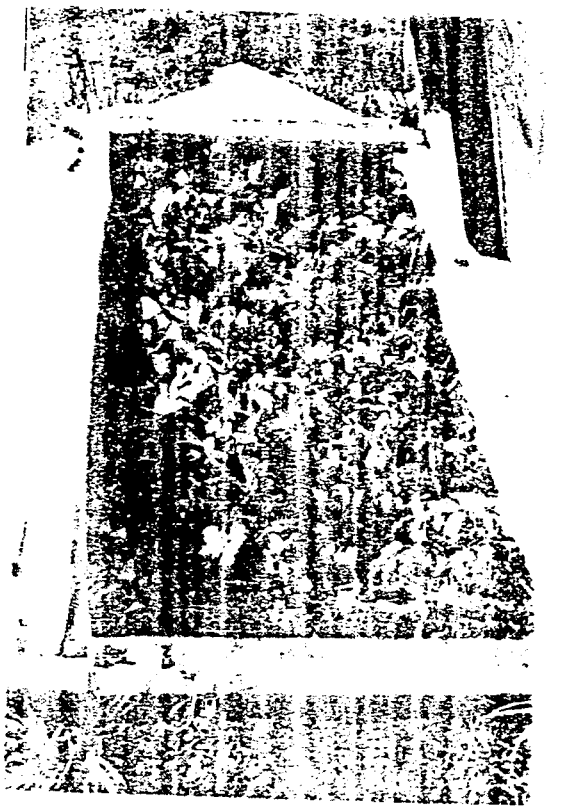


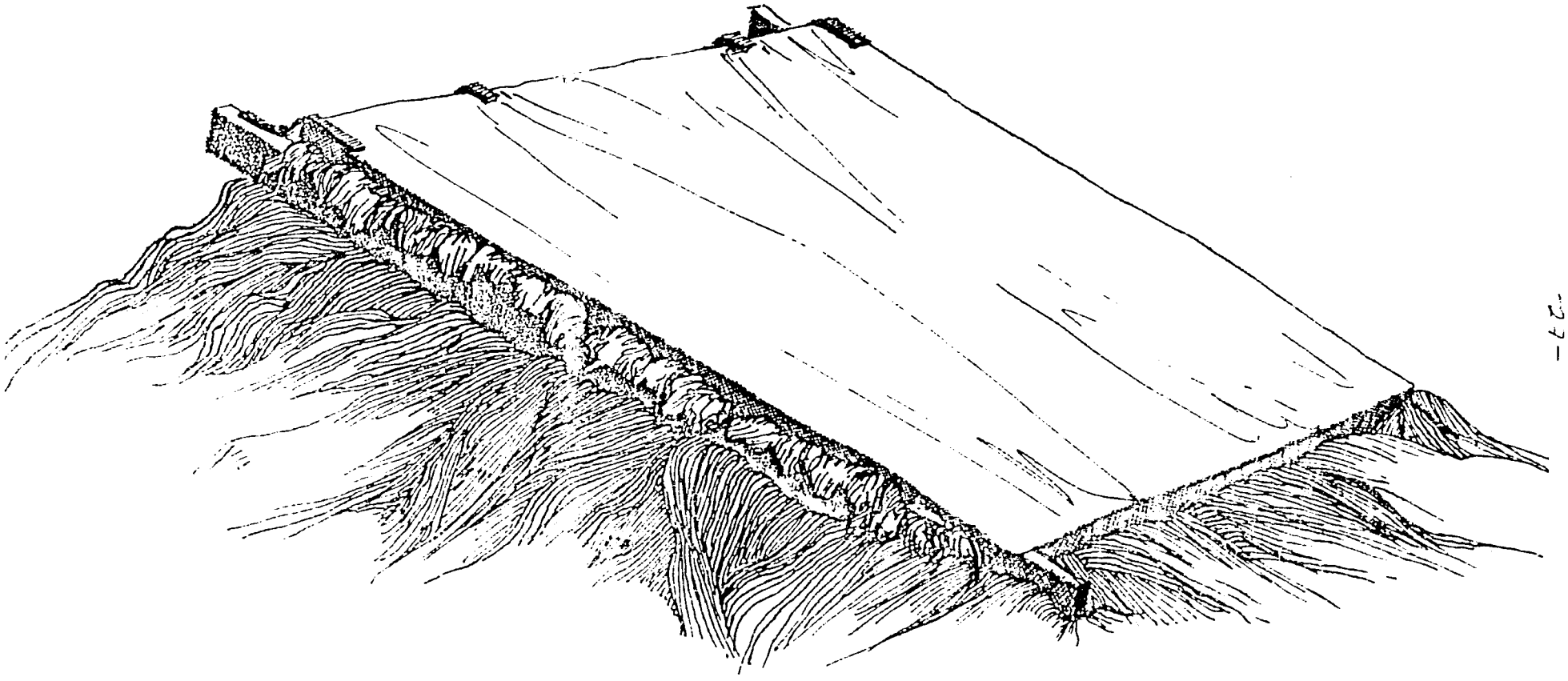
Figure 9-11 Freestanding Cold Frame Prototype 1

A. (Upper left) North view

B. (Lower left East view

C. (Above) Cover open showing plants

Figure 9-12 Freestanding Cold Frame-Prototype 2



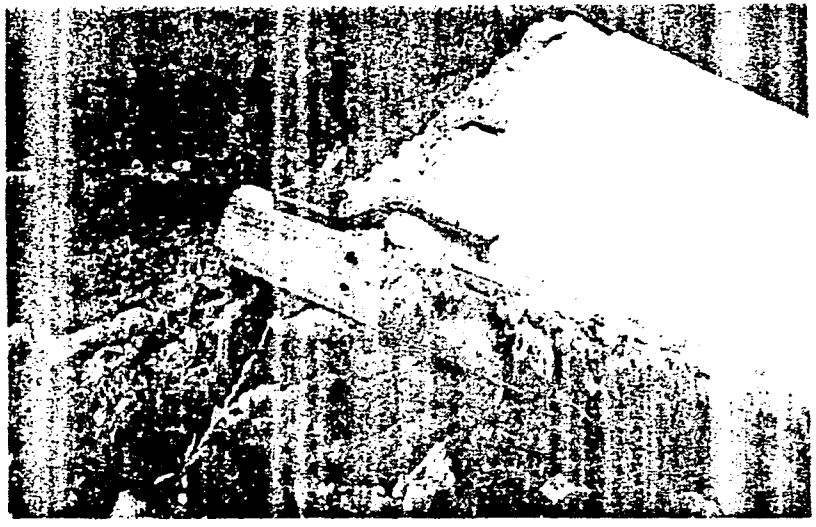


Figure 9-13 Freestanding Cold Frame Prototype 2

A. (Upper left) Northeast view

B. (Upper right) Southwest view showing erosion of wall

C. (Lower left) Cover Detail

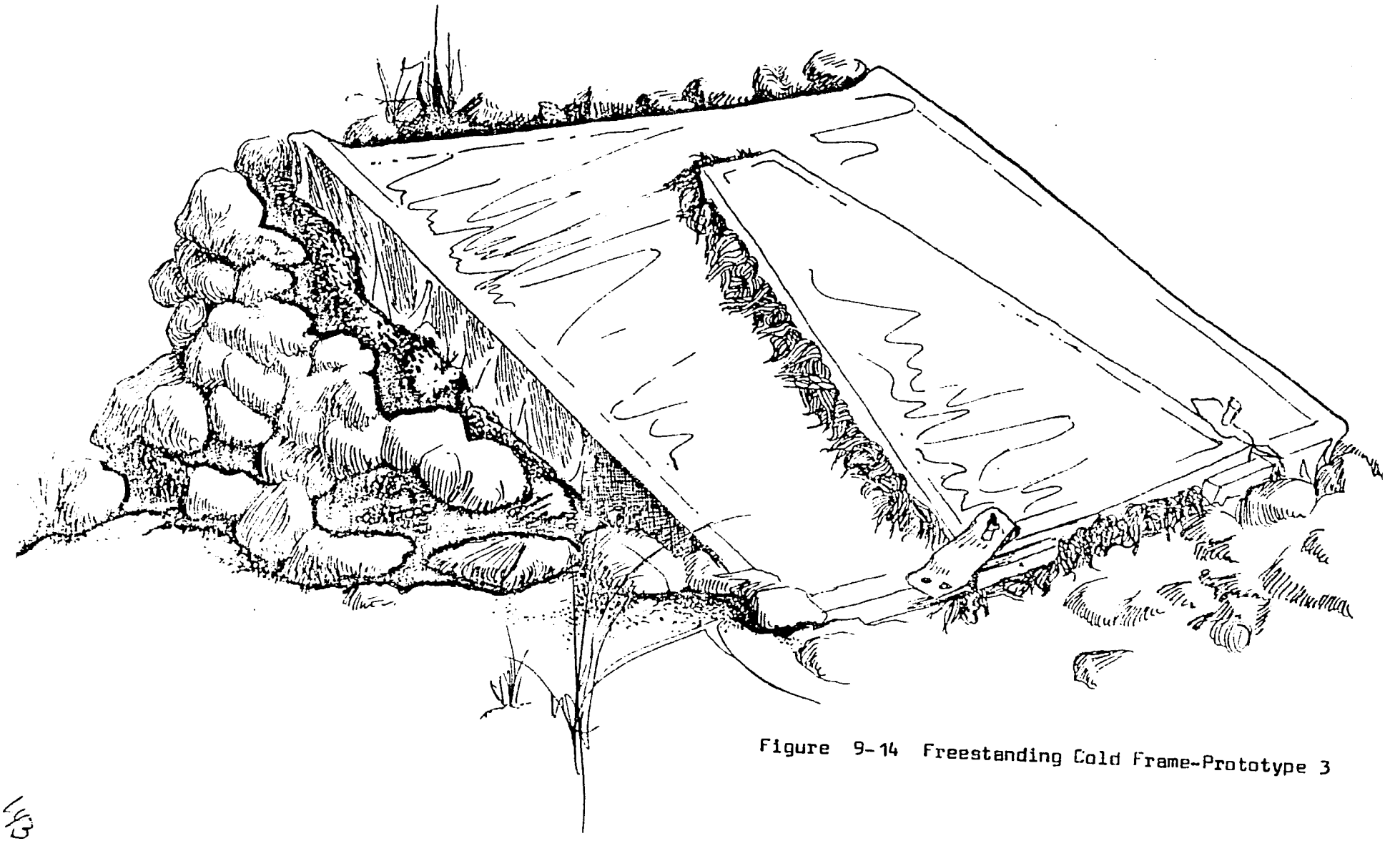
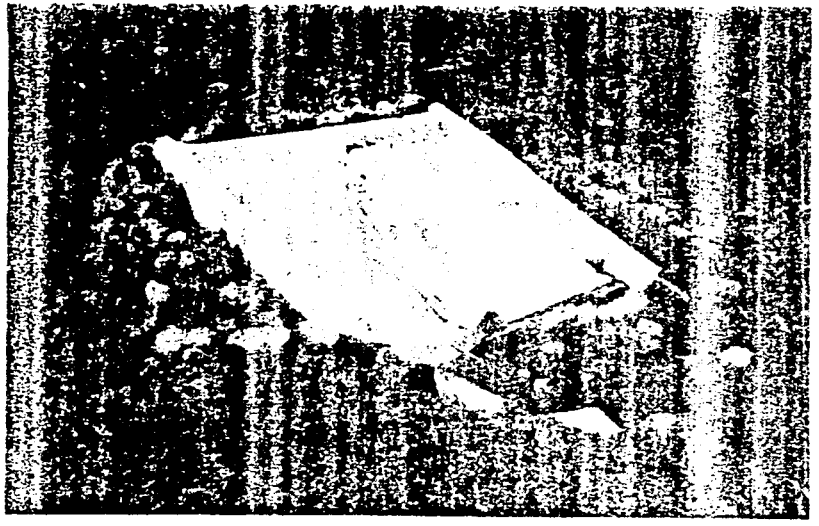


Figure 9-14 Freestanding Cold Frame-Prototype 3



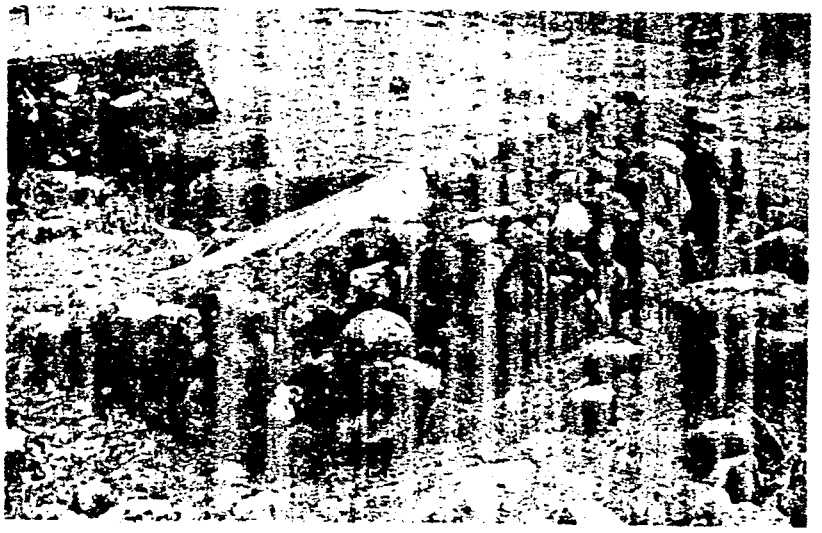


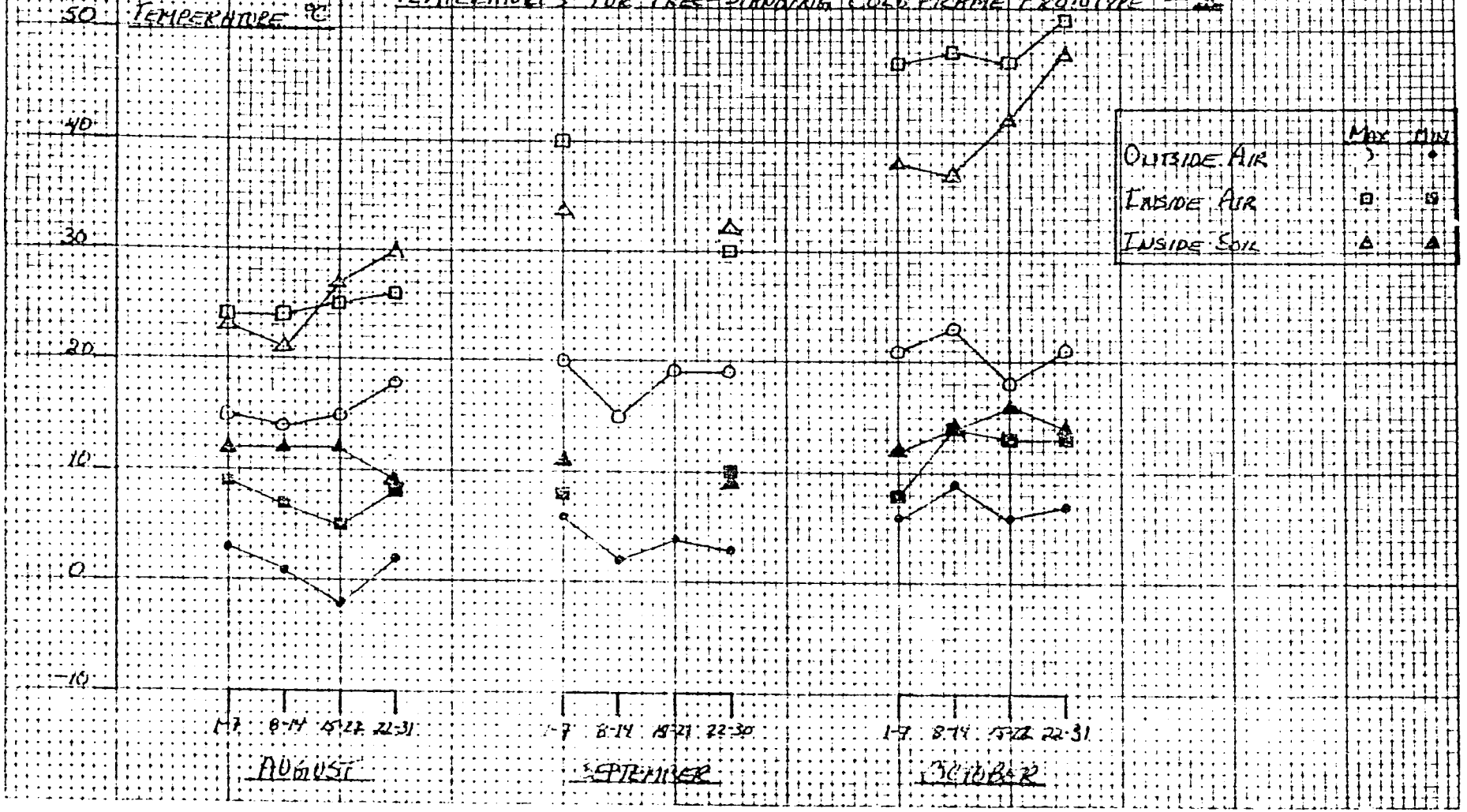
Figure 9-15 Freestanding Cold Frame Prototype 3

A. (Upper left) Northeast view

B. (Upper right) Southwest view showing retaining wall

C. (Lower left) Cover Detail

FIGURE 9-16 COMPARISON OF MEAN MINIMUM AND MAXIMUM OUTSIDE AND INSIDE AIR AND INSIDE SOIL TEMPERATURES FOR FREE-STANDING COLD FRAME PROTOTYPE #1



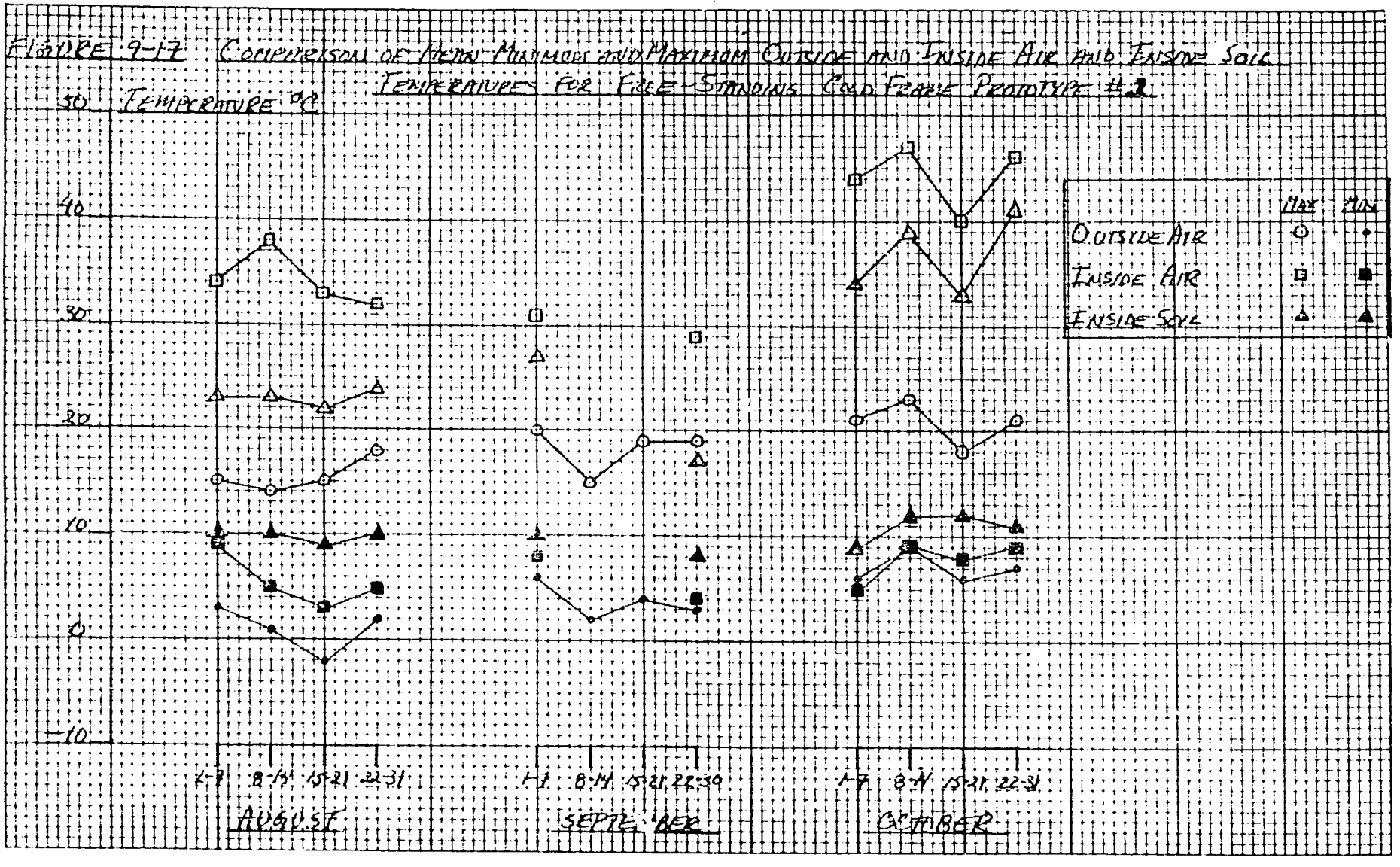


Figure 9-17 Comparison of Mean Minimum and Maximum Outside and Inside Air and Inside Soil Temperatures for Free-Standing Cold Frame Prototype #2

FIGURE 9-18 COMPARISON OF MEAN MINIMUM AND MAXIMUM TEMPERATURES FOR TWO FREE-STANDING COLD FRAMES

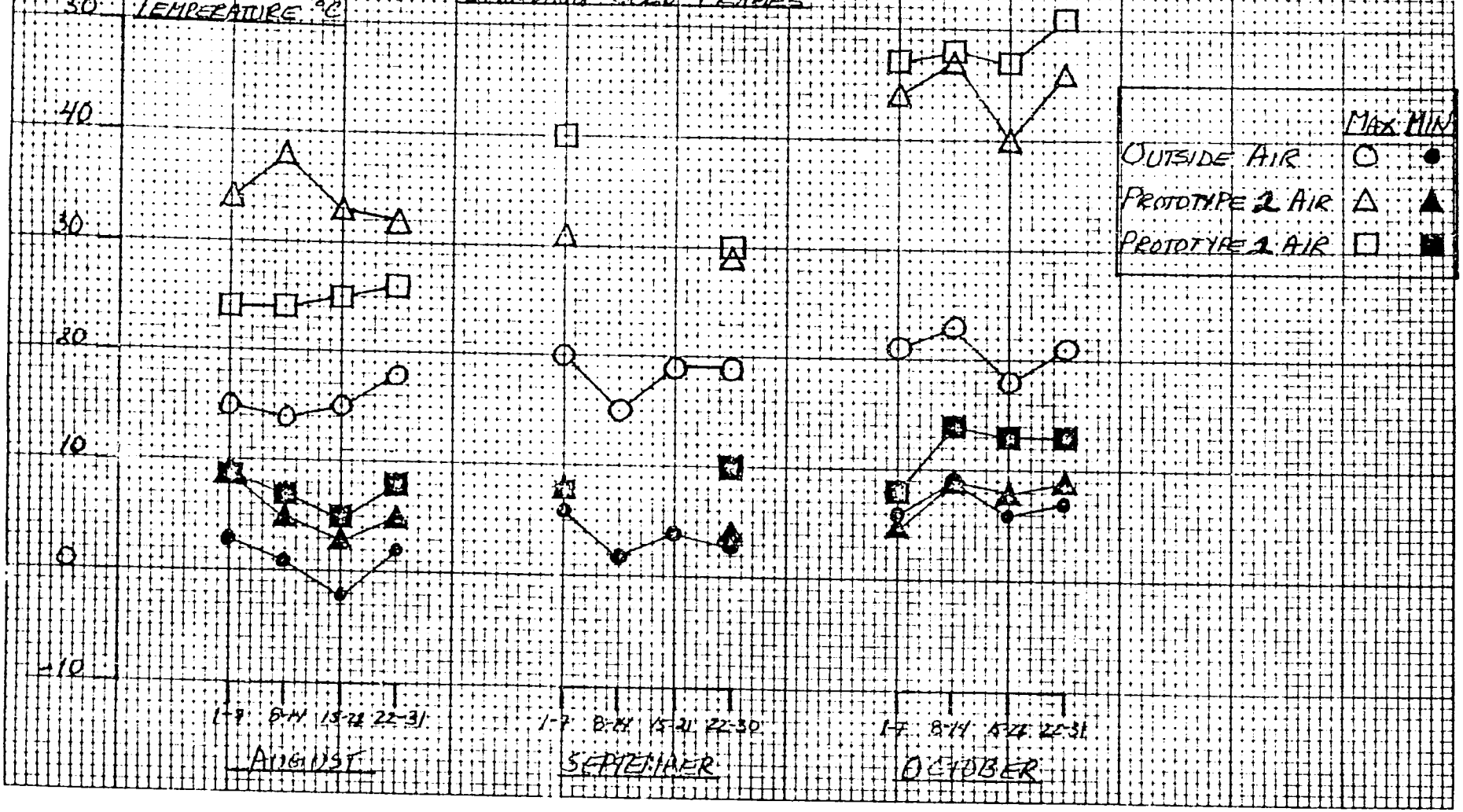
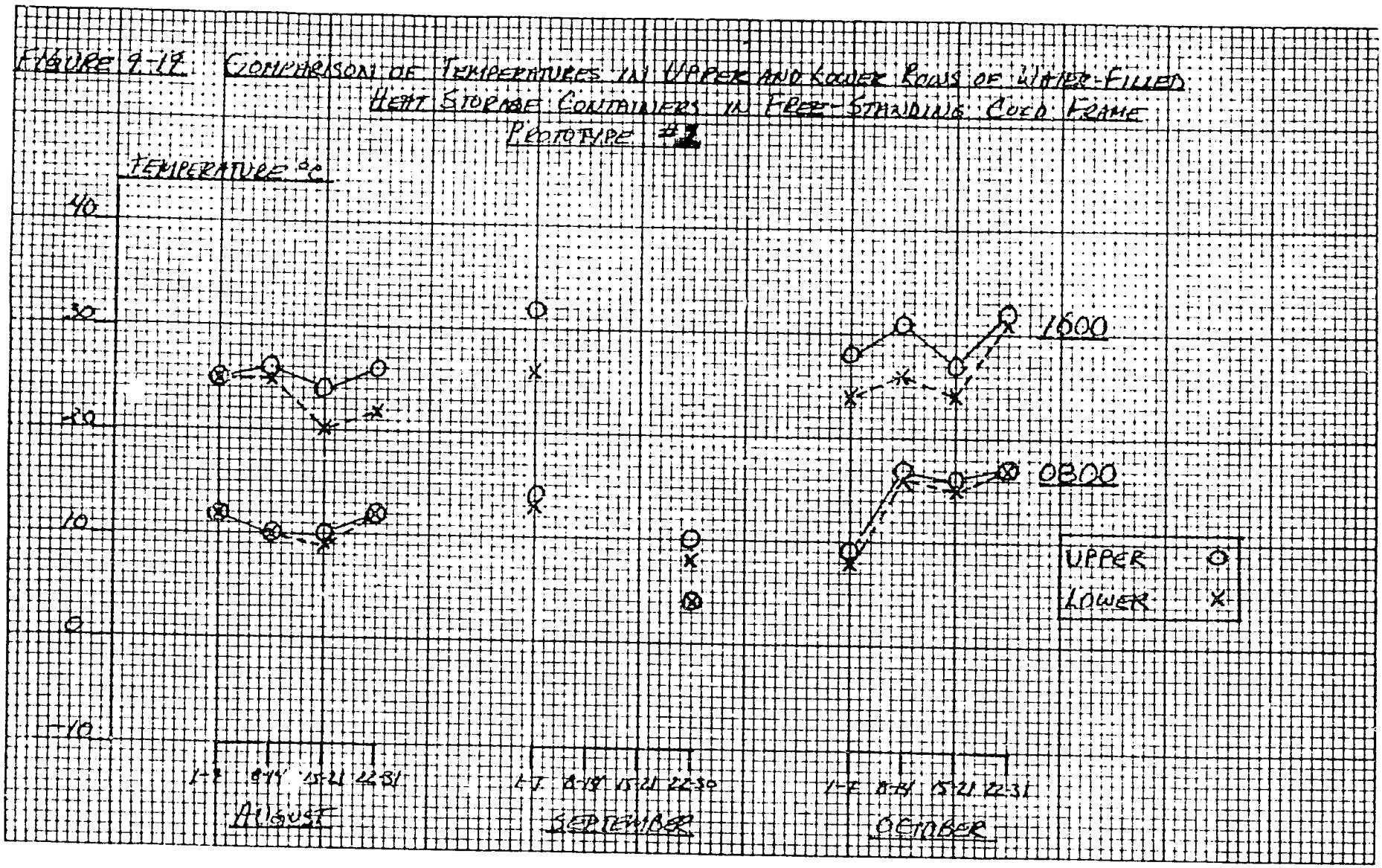


FIGURE 9-17 COMPARISON OF TEMPERATURES IN UPPER AND LOWER ROWS OF WATER-FILLED HEAT STORAGE CONTAINERS IN FREE-STANDING COLD FRAME PROTOTYPE #1



CHAPTER 10 EXTENSION AND MARKETING

The basic pattern of Pitso and in-village construction workshops continued throughout the year. A total of twenty-one lipitso were made in 1980 with the average attendance about 86 people per pitso. If it is assumed that each person represents one household and there are 15,600 households in the District, then approximately 12% of the District households were reached in one year by our extension effort. While a reasonably large number of people in the District have been reached, a much smaller percentage have purchased devices, only about two percent of those spoken to at the pitsos.

As of the end of December,1980, 19 mud-and-stone water heaters and one mud-and-stone food dehydrator were sold to villagers and built for them at their homes. An additional fourteen sheet metal water heaters and ten solar ovens were sold, mostly direct from the R.T.U. For the most part, very little systematic checking of previously sold or installed equipment has been done, although, wherever possible, brief visits are made to people who own the devices.

A more systematic survey was done by the Economic Analysis and Evaluation Division of TTIRDP in October,1980. The people and the units they purchased in Linakeng and Matlatseng were the subject of the study. Two solar water heaters, built of mud and stone, were installed in each of the villages in March during one of the village construction workshops. Of the several aspects of investigation included in the survey, the ones most relevant here concern the profiles of the purchasers and the diffusion pattern of the new idea. It is realized that this survey is of a very small sample but it is hoped the results are relevant to the rest of the District. The survey results are included in Appendix 2 and only the important points will be stressed here.

Of particular importance is the fact that the purchasers were more educated and wealthier than the rest of the sample surveyed. Education levels are based on the attainment of a certain standard or grade as defined by the country's school system. Wealth is based on comparisons of livestock ownership, ownership of farm implements and fields and whether or not one has a paid job. In all categories possible, the purchasers were compared to both

the sample and to the District. In all aspects of livestock ownership and the ownership of fields, the purchasers are significantly wealthier than the rest of the people in the District.

The diffusion pattern of the new idea is interesting. Starting with the purchasers, they were asked whom they had told about the solar water heater and who had come to see it on their own initiative. Some people from both of these groups were surveyed and they were asked who they had told about the device and who they thought were really interested in the idea even though they had not spoken to them directly. Both relationship and the village they lived in were considered. The purchasers both told and were visited by an equal number of relatives and non-relatives, almost all of whom live in the same village as the purchaser. At the second level of interaction, it was mostly non-relatives of the purchaser who told other people and they told their relatives. Again the information tended to stay within the village where the water heater was sold. Although distance was not great, almost every household in each village had been identified by someone in the survey and very few more than once.

These two portions of the survey indicate that it will be the wealthier and more educated people in the District who will be more likely to adopt the use of solar devices in the early stages of their introduction. It is also probable that if as few as two devices are brought into the village of comparable size the whole village will know about it in a fairly short time. If we assume that there are the same proportion of wealthy and educated people spread throughout the District, then about 450 to 780 households might be expected to purchase some new energy device in the near-term future. If these prove beneficial to their owners, it is possible that a very large percentage of the remainder of the population will consider buying one when they have the money available.

Another question asked in the survey relates to the effectiveness of the extension effort in a different manner. The people interviewed were asked what they expected the benefits and disbenefits of owning a solar water heater might be. The purchasers were also asked what actual benefits and disbenefits they had derived since owning their heaters. The owners expected their units to do just what they were capable of doing -heating water

and saving fuel or the time or money necessary to get it. They also derived these benefits upon using the device. However, some of the other people interviewed expected to be able to use the water heaters to cook or to dry food, something which they are not designed to do.

The probable reason for this confusion had to do with the fact that during the pitsos a number of energy devices are discussed and it is quite possible that people got the capabilities of the devices mixed up. It is very important for the R.T.U. extension staff to explain each device and its capabilities clearly so that people are clear as to what each one can do. It was also felt that a booklet describing how to make and use the various items would help solve some of these difficulties which were experienced elsewhere besides in the survey area. A booklet of this type is being developed in cooperation with the Lesotho Distance Teaching Center. The primary language is Sesotho but a limited number of English copies will be available when it gets printed. These booklets will be given to each person who purchases an energy device as well as to people at clinics, schools, churches and stores throughout the District. It is hoped that thorough explanations result in the wider adoption of the new ideas with people more conscious of the decision they are making.

Extension of the new ideas must continue during the coming years. The pitso and village construction/demonstration workshop is a reasonably effective tool for accomplishing this but other methods should be tried. A better dialogue needs to be created among the villagers and the technical staff at R.T.U. One method of accomplishing this is outlined in Chapter 6. The R.T.U. extension agents will need training in how to do this part of their job most effectively and it will take time.

Marketing of tested and proven products must also continue. So, too, must efforts to obtain feedback from purchasers of the various items. This feedback will help produce more useful and better quality products. The marketing of energy products should be done in conjunction with other R.T.U. items. If funds permit, a marketing officer for all of R.T.U. will be hired early in 1981. This will mean that someone will always be out in the villages of the District discussing the new products and ideas and bringing back to the R.T.U. the concerns and comments of the people we are trying to serve. This

seems like a good idea and certainly should be tried.

The work during the past year and one-quarter indicates that the R.T.U. is on the right track when it comes to energy. The major problem is cooking. Future efforts should focus on this while offering solutions to other problems as people request them.

CHAPTER 11 TRAINING

Training in the second half of this project has been essentially the same as that which was explained in the interim report. Because of turnover in staff (only one person remains from the first group of trainees) it has been necessary to redo the basic classroom and practical training that was developed in the initial phase of this work. This has made progress in other areas such as extension and marketing slower than originally envisioned, but the fact remains that, at this stage, the development of a competent staff is more important than the mass marketing of ideas or products throughout the District

As before, several levels of training have taken place. These include R.T.U. staff technical training, supervisor training, produce training. Different people have been involved in each phase and results have varied as will be explained in the following sections.

R.T.U. Staff Technical Training

This activity encompassed several topics: theoretical work, practical training, extension methods, and testing and evaluation procedures. Basic energy and solar energy principles were the core of the theoretical training program, which was explained in detail in the interim report. It has been necessary to cover this material slowly so that concepts and fundamentals are well retained. Even so, it has proved very difficult for the trainees to translate basic concepts into practical situations. This facility will only come as they gain more experience in this field.

Practical training focused on learning how to build and maintain the various devices that are tested,demonstrated and sold. Working in mud,stone, cement, glass, wood and sheetmetal have been part of the program. Part of this training has involved a course on the proper use and maintenance of a wide range of hand tools. The trainees found this two-week course to be useful but it would probably be valuable to repeat it about once per year, particularly whenever new tools are brought into use. All of the trainees have done quite well in this aspect of the training, although they still need to work on

developing these skills.

Extension methods are obviously an essential part of the training program. These include holding lipitso (town meeting), working as trainer in an in-village demonstration workshop and explaining devices to people and groups who visit the R.T.U. While seemingly varied, all of these activities require a combination of technical knowledge and an ability to speak before and with a group of people. Part of this work also involved reporting on what happened during lipitso and workshop sessions, thus strengthening both observational and linguistic skills. (See Appendix 3 .)

Still another aspect of the training involved testing and evaluation procedures for the devices that have been experimented with. Learning to accurately measure weights, temperatures, windspeeds and solar radiation were included in this phase of the program. This information was recorded on a number of different forms, each of which was developed for a specific purpose. Upon completion of a series of tests, the traineens would then help in evaluating the data. At this time, evaluation has to be carefully supervised because the trainees do not have enough experience with numbers to catch the fairly frequent numerical mistakes.

Four or five people have been participating in these areas of training. The Solar project staff consists of four people, one of whom is the supervisor. The fifth person is a student from the National University of Lesotho who works with us during vacations. Three of the people have completed high school, the fourth has completed his Junior Certificate (Junior High School). Given this background, they have done quite well. Nonetheless, more time should be spent on developing basic science, math and linguistic skills.

Supervisor Training

The person originally chosen as supervisor left in May, 1980. Because of this it was necessary to select and train another person to do this job. The person chosen has been working on the project since January, 1980 and has demonstrated the characterics desirable for this task. As of September he began acting as supervisor. Training has involved learning how to run a meeting, planning out the weekly work, budgeting, long-range planning, and basic personnel administration. As with all other efforts, it will

require some time before the concepts are well learned.

Producer Training

In addition to working with our core staff, it has also been found desirable to work with local crafts people to develop the skills necessary to produce the devices that we present. Masons, carpenters and sheet metal workers have all been involved in this effort. Some were already skilled in their craft and others neededto learn it.

The basic procedure was to locate one or more of these crafts people and have them work with us on a particular project, for example, mud- and-stone solar water heaters or solar ovens. These projects often involved more than one craft such as masonry and carpentry, or carpentry and sheetmetal work. Over the course of one year, five carpenters, six sheet-metal workers and four masons, all of them skilled in their trade, have received some form of guidance in building and manufacturing solar devices. At this point in time none of these trades people have truly incorporated these new devices into their normal business. This is most probably due to the limited demand for their new product.

Several issues present themselves when working with these trades people. Among them are "mass" production capability, transiency, and the willingness to try new items. With the exception of one carpenter, none of the crafts people seemed able to devise a method of working that would enable them to produce more than one complete item at a time. For example, we would place an order for 10 sheet-metal solar water heaters and the sheet-metal worker would complete one unit before beginning work on the next. This seemed like a very slow method since each unit had to be measured separately. In an attempt to help them develop a faster and equally reliable production scheme, templates-cutting and bending patterns were introduced. These have been found to be very helpful for the sheet-metal work. A similar technique was developed by the trainees when teaching some villagers how to build mud-and-stone water heaters.

At a minimum, such templates reduce the time spent measuring each device, as well as providing for some standardization of the final product. This can

help reduce materials waste. A more difficult problem was to get the crafts person to see that given an order for 10 units, that dividing the projects into discreet tasks of cutting, then bending, then assembling, for the entire order would help speed up his/her work, so that it would take less time to complete each unit, and therefore, the profitability of production would increase. (Labor was worked out on a per unit basis.) While the local handymen were reluctant to adopt this idea, the solar trainees seemed more willing to do so.

Another problem that was encountered was transiency of the crafts people. When a person had been worked with for several months, they ended up being called to go somewhere else, usually on pressing family business. This was particularly true of the local sheet-metal workers. One of the best carpenters had to leave in order to tend the family's livestock up at the cattle post. Whatever new skills that may have been imparted and whatever products that were produced still do not eliminate the frustration caused by this situation. It is very difficult, if not impossible, to plan a realistic production schedule to take such variations in labor availability into account. One obvious solution is to have more than one crafts person in each trade trained and working with the R.T.U. at any time. In practice, this has been impossible to do.

In an effort to help alleviate this production problem, which was most notable in the sheet-metal items, two approaches were tried. The first involved hiring a woman to train in sheet metal work. Learning basic skills would take place while producing items needed by the solar project. In addition to sheet metal working skills, use of patterns and more rapid production practices were included in the training. This method (of training and providing production) has proved to be satisfactory but is certainly not without flaws.

The second approach involved going to the market in Maseru which includes several sheet metal workers among its vendors. Most of these are highly skilled and have a fairly wide range of items that they produce including: buckets, chimney pipe, rondavel roof caps, boxes, hinged-top grain storage bins and concrete block molds. An examination of these items revealed that the solar water heaters and ovens were well within the range of their

capabilities. Nonetheless, it took almost two months to get one solar oven completed.

There are probably several reasons for this, most of them having to do with the willingness or unwillingness to try new items. The two people who started to make ovens both had similar risks, yet only one completed the oven successfully. Questions arose as to method and form of payment, who would supply materials, what should be done about new or strange materials. An example is in order. When ordering the oven, it was first demonstrated at the market place. Following the demonstration, all of the sheet metal workers were asked if they would be interested in making one. Two said yes. The oven was left at the market so that it would serve as a model and so that accurate measurements could be taken from it. We left, promising to return in a week to review the progress of their work.

After that period, we returned and found that nothing had happened. One man said that we were not being serious enough because we had not paid any money in advance. The other said that he would not begin until we had supplied the materials. Fortunately, we had brought some of the necessary materials with us and we were able to reach an agreement so they would begin work. When asked at that point how long it would take to complete the job, we were told at most a week.

Three weeks later they were still incomplete. One of the major difficulties was the fact that we had to come 175 km to check on the progress and that could not happen as frequently as it ought to have.

Another serious problem seemed to be that because the ovens involved the knowledge of a second craft, carpentry, they were perhaps more reluctant than otherwise to take on the job. Even though the various pieces of timber were precut this still presented major difficulties. A further baffling situation is the fact that not more than 10 meters away were several carpenters who could have either advised them as to what to do, or done that part of the job themselves.

Although one oven is now complete and the other has been abandoned (measurements were too far off to fix easily), we have decided that the Maseru market is too far away to work with on a steady basis. The better alternative

is to train one or more people who are from the District to do the necessary work. Until they have a large repertoire of skills and products, it will probably be necessary to partially subsidize their training by guaranteeing a market for their wares. After they are sufficiently trained it is likely that they will be able to provide themselves at least a supplementary income from their trade, relying primarily on the already apparent needs of the local people. An obvious side benefit is that as demand increases for solar products, they will be able to supply the desired items.

Conclusion and Recommendations

The core staff of the Solar project should continue to receive training in the specific technical skills required for their jobs and more generally in basic science, math and linguistic skills. Theoretical and practical training should be continually incorporated into the regular work program and progress should be checked and skills updated at least twice a year. The trainees should be encouraged to attend the locally available COSC courses (high school equivalency) so that they can improve on the appropriate basic skills.

Since the present project focuses only on energy, it will be necessary to absorb some of the trainees into other projects that make up the now functional Village Technology Section of the R.T.U. Training in the necessary technical areas, initially sanitation and water and wind power, is already envisaged in the Section's plans for the coming years. Because of the emphasis that has been placed on technical training and on extension, it is now clear that the four core trainees will primarily be involved in education and dissemination of new ideas and not so much in the production of the developed items.

Supervisory training will have to continue and the person's performance monitored closely, particularly in the next few months. The supervisor will soon become responsible for the activities of the entire section and will need to be adequately prepared for this task. While the number of people will not change initially, scheduling, budgeting and planning will be more complex and could prove somewhat overwhelming in the early stages of transition. All efforts should be made to make the process as straightforward as possible.

As far as producer training is concerned, it is probably most advisable to train people who already reside in the District to perform the desired tasks. More efforts must be made to link with the existing Trade Centre and certainly with the proposed trade school. Training will have to focus on technical and business skills so that the envisaged entrepreneurs or trades people will know how and whether they are making money. Additional efforts must be made to get the R.T.U. to make the items that are needed so that some of the vagaries of transient labor are minimized. Another option along these lines is for the R.T.U. to provide space for some of the crafts people who graduate from the various training courses so that these people will have a simpler time marketing their wares. This option would serve to eliminate some of the problems encountered when two crafts are needed to complete an item, particularly if these joint skill items were included as part of their training.

A final area of training is that courses and programs that exist in other countries must be sought out. They will obviously need to be examined for their suitability to this particular situation, but a relatively wide variety should prove applicable. To date, it has been very difficult to locate such courses. Another option is to bring in resource people on particular topics for definite and short periods of time, thus upgrading skills within the local context. Both approaches need to be explored as the benefits from either method seem substantial.

CHAPTER 12 Conclusion

Fifteen months of activity have led to a great deal of progress but it must be remembered that more work needs to be done. Many prototypes have been evaluated and subsequently demonstrated to over ten percent of the people in the District. Most of those who have chosen to adopt the new techniques are happy with their decision.

Changing our emphasis to cooking was a good decision. This effort has resulted in the development of both a conservation and a solar technology that promise to be beneficial to the District's residents. The paola can result in a 40- 60% fuel savings and requires a relatively small investment of about M7.00. The basic design has been put into production and early sales have been extremely good. The solar oven that has been marketed represents a substantially larger investment on the part of the householder. However, the oven makes it possible to further reduce the use of traditional fuels and to increase the ease of performing certain cooking operations such as baking. Future units will be modified on the basis of user feedback.

Of the many technologies investigated, two others stand out from the rest. The photovoltaic system at the Linakeng Clinic has been working continuously since installation and seems likely to do so for the foreseeable future. Given the widespread need for small amounts of electricity in remote areas, we would recommend that similar installations be made as the need arises. The other technique, climate-wise building, has also demonstrated its effectiveness. While the performance results indicated the need for some changes in design, the predictive model was shown to be quite accurate. This model and the assumption on which it is based, should be incorporated into the design of future structures. The widespread use of these technologies will help decrease Lesotho's dependence on scarce and expensive imported fuels, thus freeing up capital for other aspects of development.

Equally as important as the technologies, has been the development of trained local people in the field of energy. Although the actual numbers are small, the effect of their effort has been substantial. Their work in increasing energy awareness throughout the District will continue on many

levels ranging from extension to production and their effectiveness is likely to increase with time.

The seeds of a new energy future have been plented. While the initial project has ended, the ideas and people to implement them remain. Other efforts are already underway in Lesotho; hopefully they will be able to grow from the already fertilized ground.

APPENDIX 1 INSTRUMENTATION

Several instrumentations were used to record the various parameters contained in this report. These include thermometers, thermographs, pyranometers, and anemometers. Figure A 1-1 contains photographs of some of these devises.

Temperature readings at the weather station were taken by the standard maximum and minimum thermometers in use by the HYDROMET service throughout Lesotho. These are shake-down types that record in degrees centigrade. No photograph of these has been taken.

Temperatures in other locations have been recorded by means of several other instruments. In the cold frames, and the woodlot greenhouses, a combined maximum-minimum thermometer has been used. This thermometer has a U shaped column of mercury. Magnetic slides rest on the tops of each column. These remain at whatever temperature extremes have been reached until they are reset by a hand held magnet.

Thermographs and thermo-hygrographs have been used to record temperature in the houses that were evaluated. Produced by Campbell- Stokes, these units use a weekly chart which rotates by means of a wind up clock. A bimetallic thermometer operates the temperature arm while changes in the specially treated human hair cause the relative humidity arm to move. Two scales were used, -5°C to 45°C and -10°C to 40°C. An important item to remember is that actual time of day should be synchronized with the time shown on the charts when the charts are replaced. This helps to simplify the analysis procedure. Figure A 1-1A shows a thermohygrograph and a max-min thermometer.

To record temperatures in the solar water heaters, the solar ovens and for the other cooking experiments, three other types of thermometers were used. All were obtained from OMEGA International, Stamford,Connecticut, USA because equivalent units were unavailable locally.

The units included long stem dial type thermometers, a dial type surface thermometer and a three-probe battery operated thermometer. Scales chosen for the long stem units were 0°C to 100°C and 0°C to 300°C. The surface thermometer has a magnet that enables it to be attached to iron based surfaces such as paolas or chimney flues. It has a dual Fahrenheit and centigrade scale that ranges from 50° to 750°F (10° to 400°C). The three probe unit, trade name Fastemp, can read gas, liquid and surface temperatures. It has a low, 12° to 43°C and a high, 38° to 120°C range. The probes each have a 15 foot lead. It was found that the batteries drained down fairly easily and that scale calibration was required at least once per day. Figure A1-1B contains a photograph of the long stem thermometers. Table A1-1 to A1-3 contain specifications of all three types.

The integrating pyranometer was purchased in Australia from Rauchfuss Instruments Division, 12 Monomeeth Drive, Mitcham, Victoria, 3132, Australia (P.O. Box 62, Mitcham, Victoria, 3132). All but two of the solar cells are used to recharge the battery unit that operates the device. The radiation received by the remaining cells is accumulated in the device until a sufficient amount is stored and the counter advances one unit. Specifications are contained in Table A1-4 and a photograph is shown in Figure A1-1C.

Three basic types of anemometers were used to record windspeed; an electric wind odometer, a spectrum analyzer, and a mechanical wind odometer. The electric wind odometer allows for placement of the cups on top of a tower and the counter in a more convenient location at ground level. This device records the number of miles that the cups rotate between readings. By dividing this figure by the time involved, average windspeed for that period can be calculated.

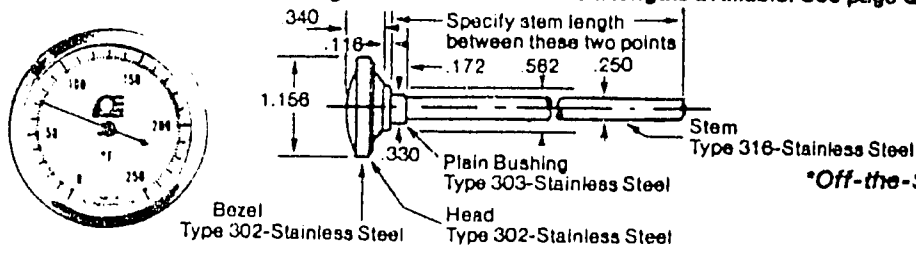
The mechanical wind odometer operates like the electrical unit except that the cup and the counter are in the same unit. This device was used to record wind speeds at a height of two meters where the counter could be easily read from the ground. A photograph of this unit is contained in Figure A1-1D. Finally, the spectrum analyzer records the number of full minutes for which the average wind speed was within a particualar range. This device had ten divisions that were set on arrival in Lesotho. The major advantage of this device is that it allows the user to determine

the actual distribution of the wind at different speeds, in addition to calculating the average wind speed.

Model Q

Normally supplied with plain bushing — Optional Threads 1/4" NPT, 1/2" NPT, 3/8-24 NF

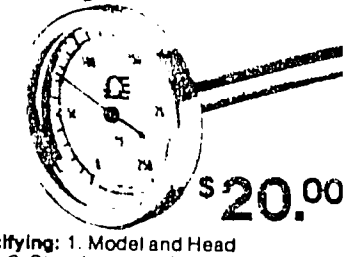
Head 1 5/32" O.D. 9" Stem Length Standard — other stem lengths available. See page Q-11.



Ranges	*Divisions	Ranges	*Divisions
Fahrenheit			
25-125°F	1°	*50- 300°F	2°
-40-160°F	2°	*50- 500°F	5°
*0-200°F	2°	150- 750°F	10°
*0-250°F	2°	200-1000°F	10°
Centigrade			
-40- 70°C	1°	0-150°C	2°
*0-100°C	2°	0-300°C	5°
-10-110°C	2°		

***Off-the-Shelf Ranges**

For installations on any type of equipment or in any location where mounting space must be carefully considered, the Model Q usually provides the perfect answer! External diameter of head is only 1 5/32". Despite this compact size, the dial is extremely legible. Model Q Thermometers receive the same meticulous care in assembly and calibration as do all larger instruments. They are in every sense a fine laboratory device yet are so ruggedly made that they will stand up under all usual service conditions. All metal parts of the Model Q, (except aluminum dial), are made from highest quality stainless steel. No problems with rust or corrosion. Crystal is optically clear. It is pressure fitted between the head and bezel. Stem diameter is 1/4". All parts are brightly polished after assembly so that final units present a handsome, sparkling appearance.



$20.00

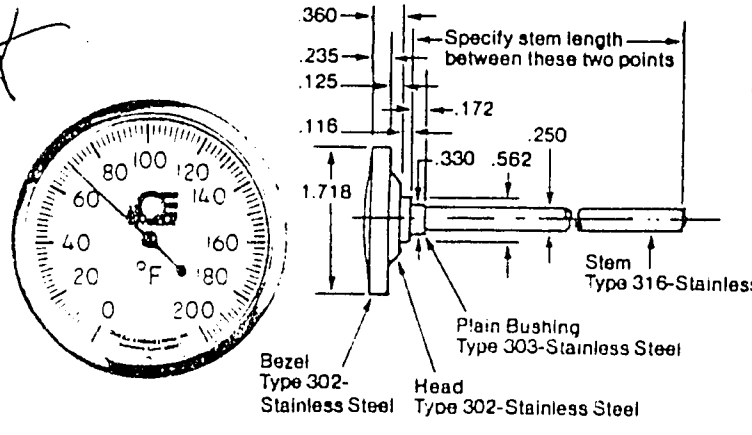
Order by Specifying: 1. Model and Head Size. 2. Range. 3. Stem length. 4. Mounting Connection.

Model G

Made entirely of Stainless Steel except dial

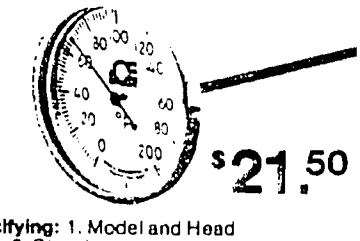
Head 1 11/16" O.D. 9" Stem Length Standard — other stem lengths available. See page Q-12.

Normally supplied with plain bushing — Optional Threads 1/4" NPT, 1/2" NPT, 3/8-24 NF



Ranges	*Divisions	Ranges	*Divisions
Fahrenheit			
25- 125°F	1°	*50- 300°F	2°
-40- 160°F	2°	*50- 500°F	5°
*0- 200°F	2°	150- 750°F	10°
*0- 250°F	2°	200-1000°F	10°
-50- 300°F	10°		
Centigrade			
*0-100°C	1°	0-150°C	1°
-10-110°C	1°	0-300°C	5°
***Dual Scale**			
50-300°F	2°	10-150°C	1°

***Off-the-Shelf Ranges**



$21.50

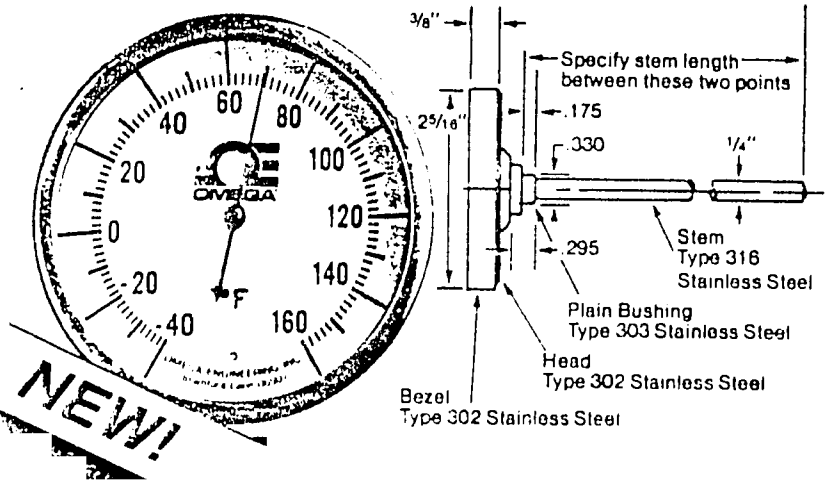
Order by specifying: 1. Model and Head Size, 2. Range, 3. Stem length, 4. Mounting Connection.

Model H

Made entirely of Stainless Steel except dial

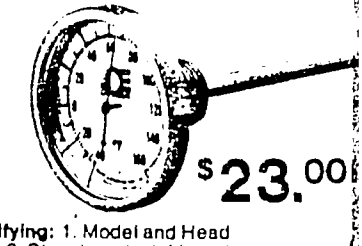
Head 2 5/16" O.D. Stem Length Standard — other stem lengths available. See page Q-12.

Normally supplied with plain bushing — Optional Threads 1/4" NPT, 1/2" NPT, 3/8-24 NF



Ranges	*Divisions	Ranges	*Divisions
Fahrenheit			
25- 125°F	1°	*50- 300°F	2°
-40- 160°F	2°	*50- 500°F	5°
*0- 200°F	2°	*150- 750°F	10°
*0- 250°F	2°	*200-1000°F	10°
Centigrade			
-40- 70°C	1°	0-150°C	1°
*0-100°C	1°	0-300°C	5°
-10-110°C	1°		

***Off-the-Shelf Ranges**



$23.00

Order by specifying: 1. Model and Head Size, 2. Range, 3. Stem length, 4. Mounting Connection

TABLE A1-2

-5-

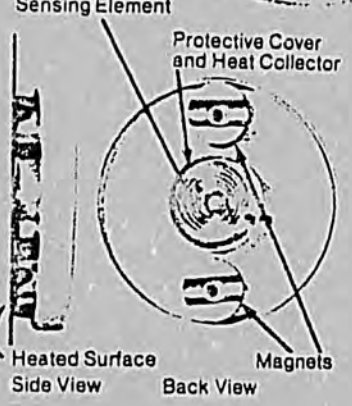
20

DialTemp™ Surface Thermometers

Dual F & C Dials

0° to 150°F -20° to 65°C (Model SUR-15)	*0° to 250°F -20°C to 120°C (Model SUR-25)
0° to 500°F -20° to 260°C (Model SUR-50)	*50° to 750°F 10° to 400°C (Model SUR-75)

Price
$18.75
X20



Specifications:
- **Head Size:** 2 inches (5.08 centimeters).
- **Height:** 1/2 inch (1.27 centimeters)
- **Weight:** 2 ounces (56.7 grams) approx.
- **Dial:** white background, blue marks & numbers.
- **Case:** aluminum with optically clear crystal.
- **Sensing Element:** precision calibrated bimetal coil.
- **Accuracy:** within 2% of full scale.
- **Response Time:** approximately 1 minute.
- **Mounting:** two magnets on back.

Operating Instructions:
This unique, handy little gage is great for use in sensing the temperature of almost any surface. The bimetal sensing element is exposed to allow quick accurate response to surface temperature, but adequately shielded from damage by a protective cover and heat collector. For the most accurate reading this surface thermometer should be used in still air. Place the gage on the surface where you wish to know the temperature — dial face up with bimetal sensing element against the surface. The magnets will allow placing in any position on a ferrous surface. It can also be used on any other material with a horizontal surface. Allow about a minute for the sensing element to stabilize and then read the temperature. Higher or lower air temperatures surrounding the thermometer or a draft over the surface may affect slightly the temperature indicated.

Some Typical applications: Air ducts, Boilers, Cabinets, Drums, Engines, Enclosures, Fire boxes, Manifolds, Platens, Plumbing, Piping, Refrigerators, and many, many others.

To order, specify model number.
*Available from stock

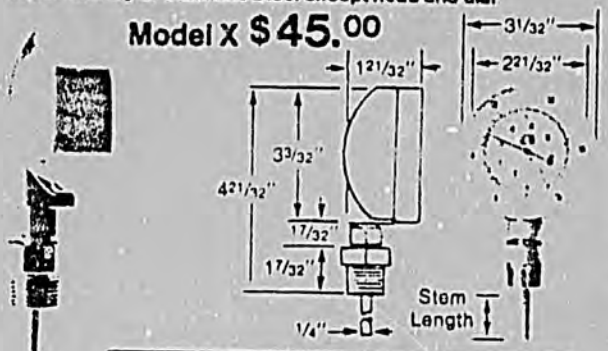
NEW!

Models X and V

Heads: X-3" O.D., V-5" O.D. 9" Stem Length Standard
Normally supplied with plain bushing —
Optional Thread 1/4" NPT or 3/4" NPT,
1/2 NPT Mounting Thread

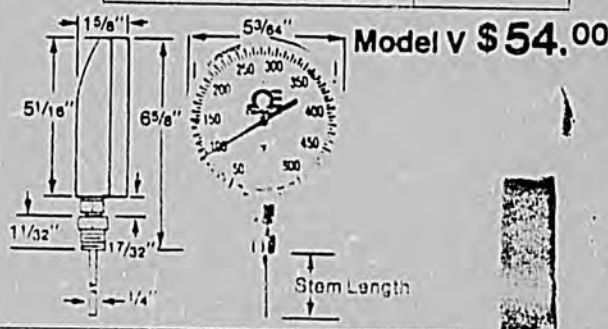
Made entirely of Stainless Steel except head and dial

Model X $45.00



Model X Ranges				*Divisions			
Fahrenheit				Centigrade			
0-100°F	1°	50- 400°F	5°	0- 50°C	1/2°		
25-125°F	1°	50- 500°F	5°	0-100°C	1°		
-40-160°F	2°	250- 600°F	5°	-10-110°C	1°		
*0-200°F	2°	150- 750°F	10°	0-150°C	1°		
*0-250°F	2°	200-1000°F	10°	0-200°C	2°		
50-300°F	2°			0-300°C	5°		
				100-500°C	5°		
Dual							
0-250°F	2°	50-500°F	2°				
-20+120°C	2°	10-260°C	2°				

Model V $54.00



Model V Ranges				*Divisions			
Fahrenheit				Centigrade			
-40-160°F	2°	50- 500°F	5°	0-100°C	1°		
0-200°F	2°	150- 750°F	5°	-10-110°C	1°		
0-250°F	2°	200-1000°F	10°	0-150°C	1°		
50-300°F	2°			0-300°C	5°		

Thermometers of this design are well adapted to installations on top of tanks, boilers, in high locations or other areas where it would be difficult to read the standard ANGLE form instrument.

Heads are made as a heavy die casting from Zamac #5 alloy. They are chromium plated and polished. Bezel is type 302 stainless steel being polished to match the attractive head.

Stems for the Model X and V are 1/4" in diameter. Stem lengths up to 36" can be supplied.

An outstanding feature of the straight form model is the ADJUSTABLE 1/2" N.P.T. mounting nut which is standard on the X and V series. This makes it possible to turn the head a full 360° clockwise or counter-clockwise and to then LOCK it in the exact position desired for maximum visibility.

Although the Models X and V are normally supplied with the stem at the BOTTOM (6 o'clock) position, on special order can be set with the stem protruding at the LEFT (9 o'clock), TOP (12 o'clock) or RIGHT (3 o'clock) positions. If not specified, the standard BOTTOM (6 o'clock) position will be supplied.

Order by specifying: 1. Model and Dial Size; 2. Range; 3. Stem Length; 4. Mounting Nut

166

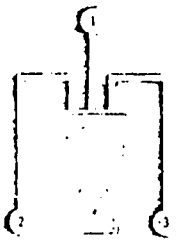
TABLE A1-3

FASTEMP®

Miniature Thermometer and Probes

Locates "Hot Spots" or "Cold Spots" in Seconds

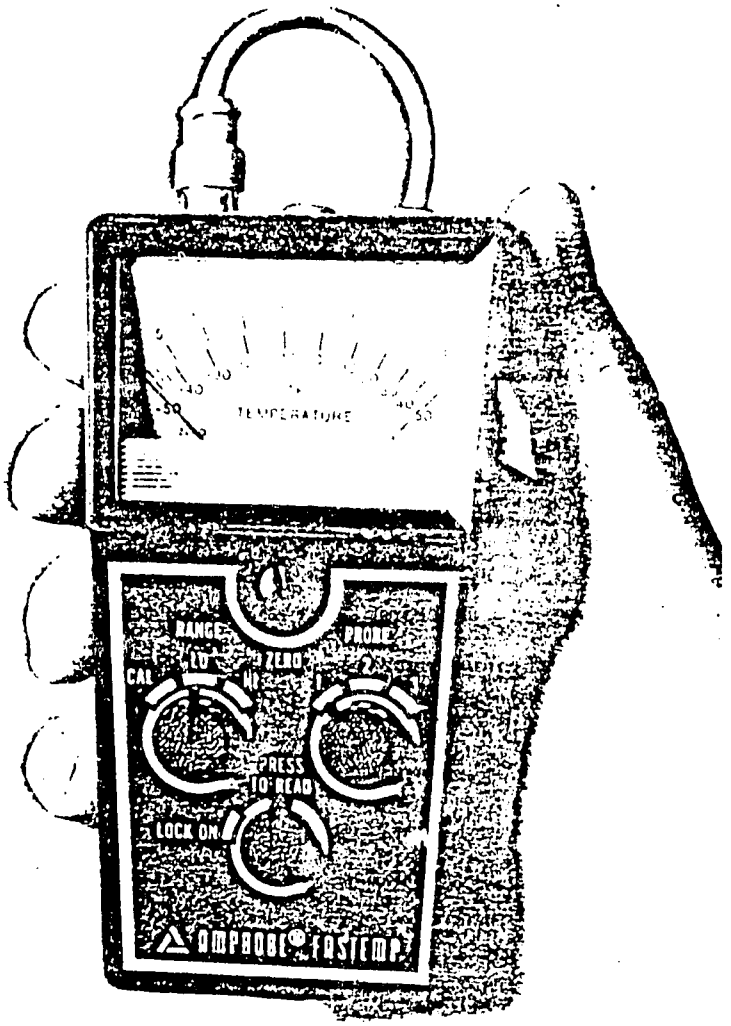
Choice of Two Models in Fahrenheit or Celsius Scale

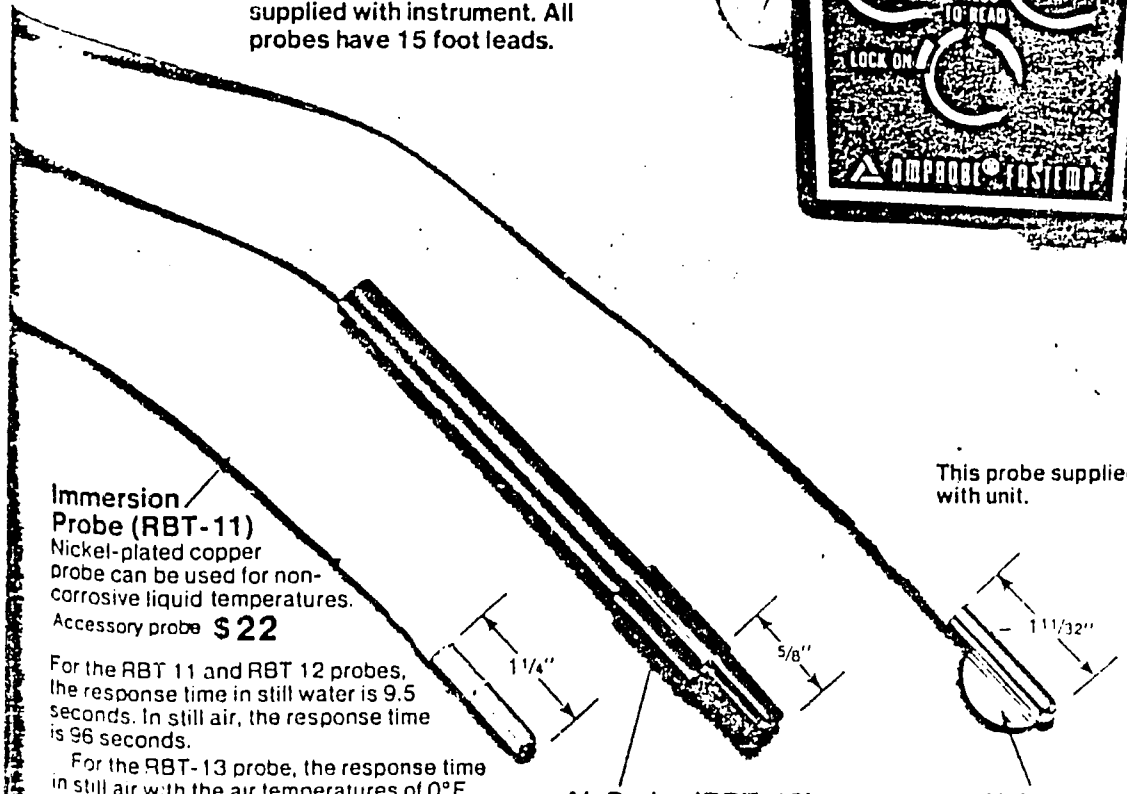


Measures at "3" different locations quickly

$77

Three probes available. One universal model RBT-12 is supplied with instrument. All probes have 15 foot leads.





Immersion Probe (RBT-11)
Nickel-plated copper probe can be used for non-corrosive liquid temperatures.
Accessory probe **$22**

For the RBT 11 and RBT 12 probes, the response time in still water is 9.5 seconds. In still air, the response time is 96 seconds.

For the RBT-13 probe, the response time in still air with the air temperatures of 0°F and 100°F, at the end of 55 seconds, the probe will achieve 63 percent of the change.

Air Probe (RBT-13)
Vented housing permits free flow of air for rapid sensing of temperatures. For air or non-corrosive gaseous temperatures.
Accessory probe **$22**

This probe supplied with unit.

Universal Probe (RBT-12)
Nickel-plated copper probe can be used for non-corrosive gaseous, liquid or surface temperatures.
Supplied with instrument
$22 each for extra probes

Discount Schedule:

1-9 units	Net
10 to 19 units	5%
20 to 99 units	10%
100 or more	15%

Fast • Convenient • Accurate • Versatile • Unique

C.

TABLE A1-4

The RIMCO Electronic Integrating Pyranometer Models R/EIP & R/EIP-C

General Information.

A. Sensing Head - consists of 24 silicon solar cells, 22 cells for re-charging batteries, 2 cells acting as measuring cells.

Sensicivity - output from 2 measuring cells adjusted to give 0.5 mV per mWHr cm^{-2} of radiation.
Cells are operated in current mode through a low impedance (~½Ω) to maintain linearity.

B. Integrator

Input sensitivity 0.5 mV per count per hour (i.e. 50 mV input gives 100 counts/hour).

Counter - capacity - 6-digit
resolution - 1 mWHr cm^{-2} per count

Contact output (optional) change-over contact (2 Amp rating)
1 contact per 10 counts on counter (50% duty cycle)

C. Calibration - instrument calibrated to give 1 count per mWHr cm^{-2} of radiation.

D. Power Consumption - theoretical battery drain per count = 10.4 uA H

Daily consumption based on yearly average of 425 counts per day (Melbourne average) = 425 x 10.4 uA = 4.4 mA H (5 mA H when stand-by drain included).

Stand-by drain - 25 uA per battery.

E. Power Supply - ±4 V. derived from 2 re-chargeable sealed lead acid batteries.

Battery capacity - 900 mA H

Shelf life - 15 months (at 20°C)

Charging - battery charge maintained by 2 banks of 11 silicon solar cells, each bank delivering 50 mA maximum.

F. General Information on Solar Radiation.

With sun at maximum elevation on clear summer day average radiation = 100 mW Hr/cm^2 (this gives 100 counts on counter/hour).

Average daily radiation (for Melbourne) based on figures from CSIRO Aspendale (Div. of Atmospheric Physics) = 425 mW Hr cm^{-2}/day.

Summer maximum approx. 1000 mW Hr cm^{-2} / day
Winter minimum " 50 mW Hr cm^{-2} / day

For RIMCO R/EIP with sensitivity of 1 count/mW Hr cm^{-2} expected yearly accumulated count = 425 x 365 = 155,125 counts.

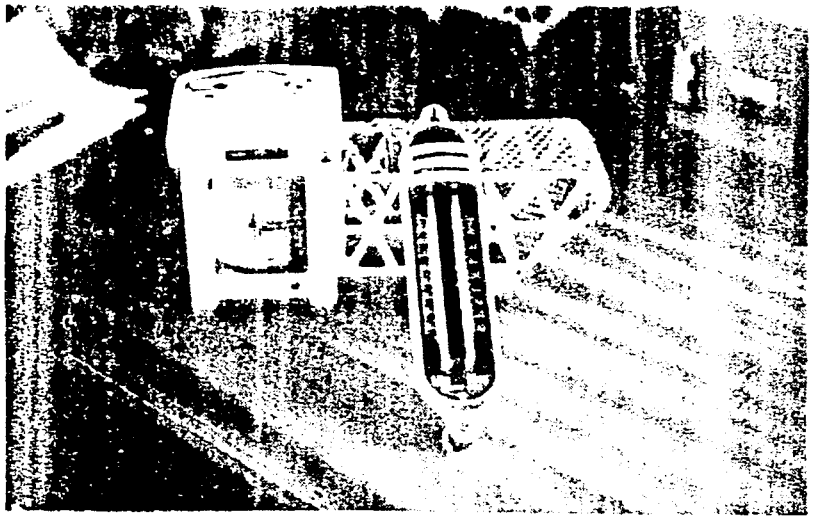
Useful conversion factors.

1 mW Hr = 8.601×10^{-1} calories = 3.17 BTU/ft²

1 mW = 2.389×10^{-4} calories/sec.

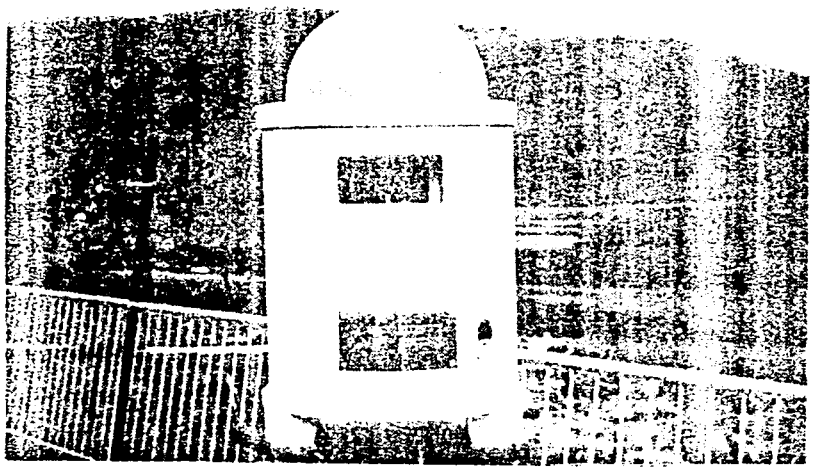
100 mW Hr cm^{-2} = 86.01 calories/cm^2

Figure A1-1

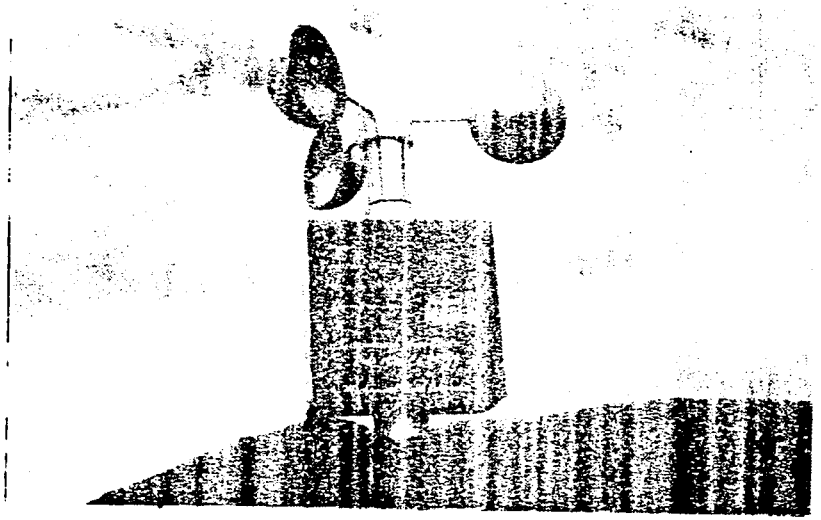


A. Thermohygrograph and Max-Min Thermometer

B. Long-stem Dial Thermometers



C. Integrating Pyranometer



D. Mechanical Wind Odometer

A PRELIMINARY EXAMINATION OF THE

INTRODUCTION OF SOLAR WATER HEATERS IN THE DISTRICT OF THABA-TSEKA

MANUNA KLEIN
Thaba-Tseka Economic Analysis
and Evaluation Division

GARY KLEIN
ATI Consultant

Reprinted with permission of the authors and the
Thaba-Tseka Integrated Rural Development Program

THABA-TSEKA DISTRICT, 1981

170

A2

INTRODUCTION

In September,1980, The Socio-Economic Division of the Thaba-Tseka Mountain Development Program was requested by the Solar Energy Section of the Rural Technology Unit to design a survey that would examine the use, evaluation and the diffusion patterns of solar devices. It was decided to conduct the survey in two villages in the Linakeng area: Matlatseng and Linakeng (Ha 'Mphosi) because in each of these villages two households had bought mud-and-stone solar water heaters in March that same year. Early in October,1980, this survey was carried out.

The main objectives of the survey were:

(a) To determine the usage of different types of fuel by the people in the rural villages;
(b) To get an evaluation of the solar water heaters by those who bought them;
(c) To determine the diffus ion networks of the solar devices.

Methodology

The survey questionnaire was administered verbally to individuals, by a sociologist from the Socio-Economic Division. She was assisted by a senior extension worker from the Solar Energy section, who had been involved in building the mud-and-stone solar water heaters in this area six months earlier. The collection of data was completed in five days. A sample questionnaire can be found in Appendix 1.

Data Analysis

The sample was divided into five groups for data analysis. These groups were as follows:

P - Purchasers
T - People who were told about the devices by the purchasers.
S - People who came to see the devices or enquired about them from the purchasers.
X - A person interviewed because she was a chieftainess. Her couriosity had to be satisfied before permission was granted to interview others in the village. She was also in the 'T' group.
Y - People who expressed an interest in the solar devices and wanted to be interviewed.

The total number of people in all these groups add up to 26, whereas only 25 people were interviewed. This is true because one individual was mentioned by one purchaser as a person who was told and by another purchaser as somebody who came to see the device. As a result he had to fall under both groups.

Not everybody mentioned by purchasers was interviewed because some people happened not to be home in the five days during which the interviews were carried out. Besides that, a few other people who were mentioned lived too far away for interviews to be done in the time allotted.

For the main part of the analysis, groups 'X' and 'Y' are left out. The reason for doing so is that the numbers of people constituting these groups are too small for any significant observations.

ABOUT THE RESPONDENTS

The survey sought profiles of the individual respondents including: age, education, position in the household, occupation and number of members in one's household. This was done to determine whether there were any significant differences between the purchasers and the rest of the population. The general results are as follows:

(a) 80% of the respondents were females

(b) The average level of education of the respondents is standard 5 and it ranges from no formal education at all to Junior Certificate(std.9) and lower Primary Teacher Training Certificate (which is referred to as standard 10 in the technical analysis of data).

(c) 55% of the respondents held the position of wife of household head in their families, 40% were household heads and the rest were mothers, sons, and daughters-in-law of household heads

(d) Ages of respondent range from 22 to 67 years with the average 45 years

(e) 60% of the respondents had unpaid occupations while the remaining 40% had full-time or part-time jobs and

(f) The average number of members in the respondents' households is about 7.

Table 1 shows the averages for the above mentioned issues by groups of P,T,S,X and Y. What is striking from this table is the relatively higher average level of education of the purchaser's group and the fact that three fourths of this group had some type of paid occupation.

In analysing data, significance tests were calculated to compare the mean levels of education and the type of occupation between the purchasers group and the T's and S's.

Table 2 examines the significance of the mean educational level of the purchasers compared to the T and the S groups and to the entire sample. The results show that it is unlikely that their attainment of higher ed-cational levels is purely a matter of chance, although the tendency is not very strong.

Table 3 tries to determine whether or not it is significant that the tendency of the purchasers is to have a paid job. The results also show that it is unlikely that the tendency for purchasers to have paid jobs happened purely by chance.

These tests suggest firstly,that at least during the initial stages of introducing solar technologies, people with higher levels of education will be more willing to adopt the new ideas. Secondly, during such stages it is likely that people who have steady and reliable incomes from their jobs will be more willing to take the risk of buying the new devices.

Access To Wealth

Livestock ownership

Appendix II, Table 1 compares average numbers of cattle, sheep, goats, horses and donkeys owned by various groups in the sample with those that are owned in the Thaba-Tseka District and in the Linakeng area. Figures given for the number of households in the District and the area are taken from the 1979 household survey that was conducted by the Socio-Economic Division of the Thaba-Tseka Program. The boundaries for the area were defined by both the villagers and the Thaba-Tseka Government as being under this area. Linakeng Ha Mphosi and Matlatseng, the villages that were involved

in this survey, are therefore part of the Linakeng area.

This Table shows that purchasers as a group owned more livestock than all the other groups in the sample. On the whole, this group also has higher average numbers of livestock than the figures for both the Linakeng area and the Thaba-Tseka District. Based on comparisons with the Household Survey, the purchasers fall into the category of 5% of the households that own 16% of the cattle, in the category of 1% of the households that own 6.5% of the sheep, and the category of 3% of the households that own 13% of the goats in the entire District. The other three groups are close to, or below the average for the District and the area in livestock ownership.

Table 4 - A,B, and C show the results of significance tests that were carried in order to determine whether or not it happened by chance that the 'P' group owns more livestock. The results show that this was not just a matter of chance. It can, therefore be expected that those people who are rich in livestock will be more willing to put their money into innovation items like the solar devices.

Table 2 in Appendix II shows that the 'P' group had the highest average number of fields as compared to the other groups in the sample and to the District and area averages. 50% of the households in this group were also among the 6% of the households in the District and the 30% of the households in the Linakeng area that owned planters. All four households in this group have at least one plough. These can be indicators of wealth because with more fields than most other households, the 'P' households can sell the surplus produce and get extra cash. When the cash value of a planter, which is about twice the value of a plough is considered, these 'P' households can be classified as being wealthy.

The significance of the 'P' group's greater number of fields was tested and the results were significant as displayed in Table 5.

Access to Additional Sources of Income

Other sources of income that were considered for the respondents are: members of the household that remit money, sale of wool and/or mohair, sale of crops, sale of beer, income from employment, and any other means of earning money. The results (Table 6) show nothing special except to confirm the

findings that were mentioned earlier: that the 'P's tend to earn extra income from selling wool and/or mohair because they own more livestock; and from employment salaries or wages because they had paid jobs. The 'T' and 'S' groups on the other hand tend to earn their additional incomes from the sale of beer and from members of the families that remit money home.

Decision Making and Evaluation

This section examines the people who were involved in making the decision to purchase the solar water heaters, the reasons for having bought or wanting to buy the devices, the expectations, benefits or disbenefits, and the evaluation of the devices by the purchasers.

The tendency among the purchasers was to involve someone in the process of deciding to buy the solar device. Three (75%) out of the four purchasers sought someone else's opinion or consent. Two of these discussed it with their husbands. The other one consulted a fellow villager whose wife also bought one of the solar water heaters. Of the two women who consulted their husbands, one also sought a cousin's opinion.

Although the sample here is very small, it is probable that if women, who are primary users of cooking and heating devices, are going to make decisions to buy solar devices, the trend will be for them to seek their husband's opinion or consent. This is likely to be a long process since in Lesotho a large percentage of the men are away most of the time, working in the Republic of South Africa mines. In cases where men are dead or women never married, there is a possibility that the women concerned will consult some relatives (often males) or friends before they can decide to buy such new devices.

When the people who were interviewed were asked why they decided to buy the devices or why they would like to buy such devices, the main reason (28% of the sample) they put forward was that they believed the solar energy devices help to save fuel. The other reasons given were that solar devices

could help to reduce money spent on paraffin, and that the devices could help to save time spent to collect fuel (both given by 20% of the sample). The first reason can basically mean in cases where fuel is paraffin, saving fuel is the same as saving money usually spent on paraffin. If it is a type of fuel that is collected, saving time devoted to its collection can mean saving energy. Appendix II Table 3 shows the above mentioned reasons that were given, the number of people that gave them and percentages compared to the entire sample. Some people gave more than one reason.

The emphasis that these people put on saving money spent on paraffin and on saving time devoted to collecting fuel shows on the one hand how high the cost of paraffin is for them, and on the other hand, that people can no longer collect fuel near their homes. As a result they walk long distances, three kilometers on average each way, to collect shrubs like Sehala-hala, which is commonly used. These people who are residents of Linakeng Ha 'Mphosi, Matlatseng and Seroala-Nkhoana, however, can rightly be envied by residents of other neighbouring villages because their villages are situated relatively near mountain peaks where shrubs are still plenty. What all this means is that there are some people who travel longer distances to collect fuel and that fuel is one of the problems faced by the people of Lesotho today.

When it comes to expectations that both the people who bought the solar water heaters and those who would like to buy them had of these devices, it is necessary to make a couple of explanations. The devices that were purchased in this part of the District at that time were mud-and-stone water heaters only. These can only heat water and they are the devices that are referred to in the survey. However, earlier on, before anybody bought anything, demonstrations were made in village public gatherings (pitsos) with different devices like hayboxes that finish the cooking process, and food dryers. As a result, some people got confused and thought that solar water heaters could also cook or dry food, or if they were people who were told about the devices and never saw them, they were not clear as to which devices were being referred to. That is why in Table 7 there are expectations like cooking and drying food.

It is encouraging, however, to observe that all four purchasers are among the 64% of the people that expected the solar water heaters to heat water. 65.5% of the 'T' group said they would expect these devices to cook food and the one person who said he would expect to dry food in a solar water heater was also in the 'T' group. This confirms the statement made earlier on that people who were told might not have understood which devices were being referred to. As a result they could be disappointed if they were to buy the devices with wrong expectations. It is therefore important for solar energy extension agents to explain clearly to buyers how each device works.

All the respondents were also asked what benefits or disbenefits they expected to derive from using the solar devices. Table 8 shows the results. Some of the respondents mentioned more than one benefit or disbenefit.

From this table too, the confusion about the functions of the different solar devices that people saw during the demonstrations is evident. Among the four individuals who said they expected to derive a benefit of hot water whenever it is needed, two said in particular that they expected to get hot water in the mornings, or that they did not want to waste time waiting for fire-heated water in the mornings. One of these two purchased one of the solar water heaters. Strangely enough, this person did not say not getting hot water in the mornings was a disbenefit when he was asked about derived benefits and disbenefits after purchasing and using his device. Although he did not say so, what this could mean is that he got a better explanation about the functions of his device when he bought it.

The benefits that were expected by the four purchasers in general were reducing expenses on the other sources of fuel, especially paraffin(75%), saving fuel(25%), getting hot water for washing and saving time waiting for fire-heated water in the mornings(25%).

Evaluation

Table 9 presents data on the fre quency of use and purposes for which the devices were used. What it indicates is that all the purchasers understood that the effectiveness of their solar water heaters was controlled by the weather. This is good, but the solar energy extension agents should make

sure that the buyers understand very well the extent to which the weather can affect their devices' effectiveness. Purchaser No. 1, for example, had her device well covered with plastic when the interviewers visited her home. It was clear that it had been covered most of the winter months. What it means is that it was never clear to this lady that her device could work effectively even in winters as long as the sun was shining.

It was also discovered that P4's device was not serviceable at the time when the survey was conducted because the walls had fallen due to heavy rains. It was one of the three devices that needed their walls rebuilt. While P1's device was still in good condition because it was covered from rains, it needed to have its tilt angle adjusted so that it could be used all the year round.

It has already been indicated that on the whole the purchasers understood how the devices they bought would work, but Table 9 shows a case where one of the solar water heaters was used to finish cooking samp(crushed corn). The lady who did this did not do so out of ignorance or confusion, but she was being innovative. She wanted to see if it would work and when it did, she continued doing it.

As part of the evaluation, the purchasers were asked to state derived benefits and disbenefits since they bought and used their solar water heaters. Table 4 Appendix II shows the results. People seemed to be unsure of their answers for this question. However, the major benefits were that fuel was saved and that expenses on paraffin were reduced. These two benefits corresponded with the first two expected benefits (Table 8). The major disbenefit was that the solar water heaters were not serviceable on cloudy days. The other disbenefits were: taking a long time to heat water, the trouble of keeping the cover indoors in case it was stolen, and being susceptible to destruction by rains. None of these derived disbenefits correspond with the expected disbenefits in Table 8. The general impression that the interviewers got from the purchasers about the devices was neither good nor bad, except for P3 who finished cooking samp in her device and was highly impressed with its effectiveness.

Our recommendation for getting people to evaluate the effectiveness of such

devices is to give them a longer time between the date of purchase and the date of evaluation. This period should also cover most of the seasons of the year. This survey was conducted six months after the solar water heaters were bought and most of these months were winter months and not particularly the best for the solar energy utilization, although certainly a period of great need.

Diffusion Networks

In the attempt to trace diffusion patterns or networks, people were asked if the individuals with whom they discussed the solar water heaters were their relatives or not, and in which villages those individuals resided. Table 10 shows the beginning of the diffusion networks based on a person's relationship to the purchaser. People are represented by a '1' if they are related to that 'P' or by an '0' if they are not related to the 'P' in question. Table 10-8 is continuation of the diffusion networks. This Table shows how the diffusion of the idea spread from the 'T' and 'S' groups.

The pattern that the diffusion followed from the purchasers is such that there is an approximately equal distribution between relatives, non-relatives. However, it was mostly non-relatives of purchasers who told other people about the devices. Non-relatives of the purchasers were also in the majority of those who mentioned other people who they heard were interested in the devices, though they themselves did not tell them about the devices. Even though the sample is small, what this can mean is that the Basotho like to share new ideas with at least their relatives. Possibly, the relatives of the purchasers did not feel they had to bother about spreading the news either because their relatives in the villages had already bought the devices or they already knew about them. The non-relatives of the purchasers, on the contrary, probably felt it was their responsibility to discuss this new idea with their own relatives.

In distance, the diffusion patterns did not go far because most of the people mentioned by the purchasers lived in the same villages as these purchasers. Here are some illustrations: with P1, 67% of the people mentioned lived in Linakeng Ha 'Mphosi where this purchaser also lived. P2 who lived in Matlatseng gave names of people who lived in Matlatseng only. P3 who lived in Linakeng Ha 'Mphosi then (his proper home was Pitseng), had 92% of the

people mentioned living in this same village: finally, among the people named by P4, who resided in Matlatseng, 67% lived in that same village. The other villages of the people who were mentioned are: Matsaile, Seroala - Nkhoana, Pitseng, Pitsaneng and Selomong, all of which are situated in the eastern portion of the Thaba Tseka District. See Table 10-8.

The continuation of the diffusion networks from each purchaser, beyond the 'T' and the 'S' groups was still greater in the villages of the purchaser concerned. The other villages mentioned here were: Pitseng, Ha Khoali, Ha Tokho and Ha Mokoko, all of which are situated in the same portion of the District as the other villages mentioned earlier. See Table 11.

Access to Fuel

This section examines ownership of trees, access to the chief's allocation of trees and access to other different types of fuel. It will also consider distances travelled to collect or purchase fuel and quantities of fuel purchased or collected within a given period of time.

Altogether, 48% of the sample owned poplar trees, 32% owned willow trees, and 24% owned both. People plant trees for different purposes. Some trees may be planted especially for construction purposes, such as for rafters. Such trees are hardly ever cut for firewood, while sometimes a stand of trees is used a number of ways.

In this survey, the major concern was firewood. Therefore respondents who claimed ownership of trees, were asked if they usually cut those trees for firewood and if they did cut some for firewood the previous winter. Responses showed that 60% of the respondents who own poplar trees usually cut them, and of these, 8.3% cut them that year. 62.5% of the respondents who own willow trees and usually cut them, did cut them that year. See Table 12.

This Table also allows for comparison between different groups to be made. Among the three major groups the purchasers group (P) had the greatest percentage of households which owned trees. Out of four households 3 (75%) claimed ownership of trees. Only 2 out of 8 (25%) and 3 out of 11 (27.3%) households in groups 'T' and 'S' respectively claimed ownership of some trees. It is interesting to note that neither of the households that own poplar

trees from the 'T' group usually cut them nor did they cut any that year. One possible reason for this is that the trees were still too young to be cut, or that they were cut occasionally for special purposes.

In Basotho villages, if there are trees that grow naturally within the boundaries of a particular village, those trees fall under the jurisdiction of the chief of the village concerned. Some trees, though they may not have been planted, can spread out of the plots of land allocated to individuals who planted them, and therefore have to fall under the jurisdiction of the chief. It is supposed to be the duty of the chiefs to allocate trees for cutting to those individuals who come to ask for some for their different purposes. This means that in villages where there are trees that are under the chief's allocation, villagers can still have access to some firewood even if they do not have trees of their own.

The survey findings show that 28% of the population that was surveyed had access to firewood from trees that were under the chief's jurisdiction. About 71% of these households that had access to the chief's allocation of trees did not have trees of their own. The question did not enquire about the types of trees that these households were allocated to cut. Furthermore, respondents were not asked about the criteria followed when chiefs allocate trees to individuals. This makes it difficult to explain why in the same village some households get access to trees under the chief's jurisdiction while others do not. See Table 13.

The other types of fuel that the households surveyed used can be grouped into the dung type which includes "lisu" (kraal dung), "khapane" (cow manure) and "bokuluba (horse manure), the shrub type which includes sehala-hala, cheche and lengana, the purchased fuels, in this case, paraffin and coal, and finally the dead twigs which get carried away by rivers. The survey results show sehala-hala as the most commonly used fuel: 80% of the sample mentioned it as one of the fuels used by their households. Second to sehala-hala was paraffin, used by 72% of the population and third was khapane which was used by 68% of the population. See Table 14.

While all other fuels are only used for cooking and heating houses, paraffin is also used for lighting inside buildings at night. The survey findings

show that about28% of the households whose respondents mentioned paraffin did not have any paraffin stoves (primus stoves), which means that for them paraffin was bought solely for use in lighting. The usage of primus stoves in most households was limited to cases where quick cooking was required, e.g. boiling water for tea, or in cases where there was no other type of fuel available. In a few households, however, paraffin was said to be used almost daily for cooking or heating buildings. Finding quantities of paraffin bought and used within a given period of time, is one of the means of determining the usage of paraffin compared to the other types of fuel. Unfortunately, this information was not consistent because people said they did not note how much they bought and used within certain periods of time, therefore it had to be rejected.

As is shown in Table 14, only one household, one of the four that had purchased solar water heaters, had access to coal. This household happened to be the family of a businessman who bought his goods in the Republic of South Africa, and was able to purchase coal there. Since it was found that four households owned coal stoves, more households could have used coal, but they were not able to purchase it.

Besides the purchased fuel, "lisu" (kraal dung) is a fuel which not everybody has access to. It is only those households which have livestock that are kept at home all year, or for part of the year, that can dig "lisu" out of their kraals. Additionally, a few relatives and friends that help in the process do get some "lisu". The rest of the fuels are gathered and it is up to the individual housewife to choose the types of fuel she prefers, depending on the circumstances that may control accessibility and usage. Some types of fuel, e.g. bokuluba, are less preferred, and are used only in cases where a lot of fuel is required and any fuel will do, for example, in the process of brewing beer for feasts.

Appendix 1 (survey questionnaire) shows that an attempt was made to get the number of trees owned by households, the number cut and the amount of fuel that remained. Another attempt was made to get the number of times fuel was collected, distances travelled to collect or purchase fuel quantities collected or used, as well as quantities left.

All these attempts failed because there was no consistency in the figures given and some respondents could not even estimate the figures required. As with the quantities of paraffin purchased, respondents answered that they never bother to count their trees, more especially poplar trees that are often crowded together where they grow. They said they could not give the number of trees they cut in most instances because they never count them and because in some cases they do not cut the whole tree, but just branches. The same problem arose with quantities of fuels collected and number of times they were collected. The interviewers tried to estimate distances travelled to purchased or collect fuel, but that too proved not to be very useful.

Conclusion

This effort was only a preliminary survey concerning the introduction of a new technology to the people of this District. Some aspects of the work were easier to accomplish than others. The most notable difficulty was the portion concerning fuel use. It is hoped that problems encountered as well as the conclusions reached by this study, will prove useful to future ventures in this area.

The people who purchased the solar water heaters had steadier income generating jobs, and were relatively better educated and wealthier than the rest of the sample population. It would seem that being wealthier and having a job make it more likely that someone will risk their resources on a new idea. It is also likely that having a better education means that new technologies and their potential benefits will be more easily understood. We expect that in other portions of the District, people similar to the purchasers in this sample will tend to be the first to adopt the new energy related concepts and technologies that are being presented by the R.T.U..

The decision to purchase a solar water heater tended to be done in consultation with at least one other person. In half the cases, this individual was the purchaser's husband. Since many husbands are working in the Republic of South Africa, while their wives remain in Lesotho, such consultations, which will probably occur, will take a long time to reach their conclusion. This may appear to slow down the adoption of the new technologies but it is not clear how large this effect will be. Also, concerning decision-making, it is interesting to note that the primary reasons given for purchasing or wanting to purchase solar water heaters were to save fuel, to save money spent on paraffin and to save time devoted to the collection of fuel. Fuel is certainly a problem as far as the sample population was concerned and because fuel supplies and costs are similar throughout the District, it is likely to be true in other areas.

The purchasers were generally pleased with their new devices, which performed as they expected them to. While the purchasers were clear as to what the solar water heater could do, many others in the sample were not. It is very important that the energy extension officers make it clear exactly what each device is capable of doing, so that future buyers will not have false expecta-

tions of the units they intend to purchase, Finally, when units are purchased in the future,and the R.T.U. wants to evaluate them, it would be best to wait longer than six months after purchase to do so. Perhaps it would be even better to evaluate performance quarterly over a period of one to one and a half years.

The knowledge of the new technologies has been thorough within each village but has not spread much beyond it. The pattern of the diffusion network has been a relatively equal distribution from the purchasers to both relatives and non-relatives. At this stage, the non-realtives passed information along to their relatives. We expect that these patterns of distance and relationship will occur elsewhere in the District. This suggests that at least in the early stages of introduction, an effort will have to be made to reach as many villages as possible so that the widest adoption of the new technology can occur.

Finally, an attempt was made to determine the nature of fuel used in rural households in the District. Because people do not generally keep records on either their fuel expenditures or on the amount of fuel thev collect or use, it is very difficult to apportion percentages to the different fuels used in each household. However, it was found that the most widely used fuels were sehala-hala, khapane and paraffin. If more exact information on fuel consumption is desired, it will be necessary to keep accurate records of a sample population for a reasonably long period of time.

A3

Table 1

Characteristics of the Respondents

Group	No. of Resp.	Average age	Sex M	Sex F	Occupation Paid	Occupation Unpaid	Average Education (standard)	Position in Household (1) 1	2	3	4	5	Average occup. (2)	Average No. in Household
P	4	47	1	3	3	1	7.5	2	2	-	-	-	.75	7
T	8	43	2	6	2	6	5.1	3	4	1	-	-	.25	8
S	11	39	2	9	2	9	4.5	3	6	1	-	1	.22	6
X	1	58	-	1	1	-	5	1	-	-	-	-	1	7
Y	2	53	1	1	2	-	4.5	2	-	-	-	-	1	4.5
Total	25	45	6	19	10	15	5	1	11	2	-	1	.4	7

(1) Position in Household

1- household head
2- wife of household head
3- mother of household head
4- Daughter -in-law of household head
5- son of household head

(2) Occupations

1- paid job
0- unpaid job

Table 2

Significance of Educational Level (1)

Group	N	$\bar{X}$	Σx^2	T
'P'	4	7.5	254	
'T'	8	5.1	287	2.4 /1.7 = 1.41
'S'	11	4.5	290	2.96/1.5 = 1.97
Sample	25	5.4	937	2.1/ 1.6 = 1.31

(1) N - Number of people in a group

$\bar{X}$ - Mean

Σx^2 - Summation of individually squared observations.

T - 'T' test value

Table 3

Significance of type of occupation

Group	N	$\bar{X}$	Σx^2	T
'P'	4	0.75	3	
'T'	8	0.25	2	0.5 /0.26 = 1.92
'S'	11	0.23	2.25	0.52/0.28 = 1.86
Sample	25	0.42	10.25	0.33/0.24 = 1.38

Table 4A

Significance of Goat Ownership

Group	N	$\bar{X}$	Σx^2	T
'P'	4	23.75	41.25	
'T'	8	5.6	1053	18/11 = 1.64
'S'	11	9	4100	15/12 = 1.25
Sample	25	10.83	1 178	13/11 = 1.18
District	2341	7.96	59250,000	16/11 = 1.45

Table 4B

Significance of Cattle Ownership

Group	N	$\bar{X}$	Σx^2	T
'P'	4	14.25	1001	
'T'	8	4.87	387	9/4 = 2.25
S	11	3.64	526	10/4 = 2.50
Sample	25	6.04	2083	8.2/4 = 2.00
District	2341	3.95	18,130,966	10.3/4.6 = 2.24

Table 4C

Significance of Sheep Ownership

Group	N	$\bar{X}$	Σx^2	T
P	4	51.25	15,825	
T	8	4.12	629	47/18 = 2.61
S	11	3.37	900	47/18.6 = 2.55
Sample	25	19.18	39,870	32/19 = 1.68
District	2341	16.6	321,140,000	34.6/19 = 1.82

Table 5

Significance of Field Ownership

Group	N	$\bar{X}$	Σx^2	T
P	4	3.5	54	
T	8	2.4	44	1.1/0.5 = 2.2
S	11	1.9	56	1.6/0.8 = 2.0
Sample	25	2.6	195	0.9/0.6 = 1.5
District	2341	1.8	108,740,000	1.7/1.5 = 1.13

Table 6

Access to Other sources of Income

Group	No. in group	No. of people per household remitting money	Sale of wool or mohair	Sale of crops	Sale of Beer	Income from employ-ment	Other
P	4	0.5	0.75	0.25	0.25	0.75	0.5
T	8	0.9	0.25	0.37	0.6	0.25	0.37
S	11	0.7	0.45	0.27	0.6	0.27	0.18
X	1	3	0	1	0	1	0
Y	2	0	0.5	0.5	0.5	0.5	0.5

(1) For all the other sources of income mentioned except number of people household remitting money:

1 represents 'Yes' the household has access to the source

0 represents 'No' the household has no access to the source

(2) Other sources of income here include :

(i) Running a cafe
(ii) Selling dishtowels
(iii) Selling eggs
(iv) Selling floor mats
(v) Selling brooms
(vi) Doing part-time work on the roads

Table 7

Expectations, number of people who gave them and percentages calculated from the entire sample

Expectations	Number of people who gave them	Percent (%)
Heating water	16	64
Cooking	9	36
Food drying	1	4
Observing the sun working as fuel	1	4

Table 8

Expected benefits and disbenefits, with percentages calculated from the entire sample

Benefits	%	Disbenefits	%
1. saving money for paraffin	56	1. children and/or animals are likely to play on the mud-and-stone water heaters and destroy them	40
2. saving fuel	24		
3. saving time and trouble collecting fuel	24		
4. getting cooked food for the families	20		
5. getting hot water whenever it is needed	16		
6. reducing expenses on other sources of fuel	8		
7. keeping food warm	8		
8. selling peaches dried in the devices	4		

Table 9

Frequency and purpose of use

No.	Frequency	Purposes
P1	Less in winter when it does not work well and more in summer	Heating water
P2	Daily except when the weather was bad	Heating water
P3.	Two to three times a week depending on the weather	1. Heating water 2. Finish cooking samp
P4	Used every sunny day when it was still in good condition	Heating water

Table 10 A

Relationship patterns in diffusion

Purchaser	T	S
P1	1	0
	0	1
	0	1
P2		1
		0
		1
		0
		1
P3	1	0
	1	1
	1	0
	0	0
	0	0
	0	
	0	
P4	0	1
	1	0
	1	1
	0	1
	1	1
Average	0.5	0.6

Table 10 8

Relationship Patterns in Diffusion (1)

Purchaser	People told by those who were told by purchasers/ came to see or enquire	People who expressed interest to those who were by purchasers/ came to see
P1		4 3 2 1 4
P2		3 4 4 3 3 1
P3	3 3 4 4 2	3 3 4 4 4 1 1
P4	3 3 4 4 3 4 4 3 3 3 3	3 3 3 4 4
Average	3	3

(1)

1. Represents from relative to relative
2. Represents from relative to non-relative
3. Represents from non-relative to relative
4. Represents from non-relative to non-relative

Table 11

Diffusion in Distance

Purchasers	Village of purchaser	S & T Groups			Secondary Network		
		Residents of Linakeng Ha 'Mphosi	Residents of Matlatseng	Residents o. other villages	Residents of Linakeng Ha 'Mphosi	Residents of Matlatseng	Residents of other villages
P1	Linakeng Ha 'Mphosi	4	0	2	5	0	0
P2	Matlatseng	0	5	0	0	6	0
P3	Linakeng Ha 'Mphosi	12	0	1	12	0	1
P4	Matlatsehg	0	7	3	1	13	3

Table 12

Ownership of Trees

Group	No. in group	Poplar			Willow			Both		
		No. owning	No. of those who own that usually cut	No. of those who own that cut that year	No. owning	No. of those who own that usually cut	No. of those who own that cut that year	No. owning	No. of those who own that usually cut	No. of those who own that cut that year
P	4	3	2	1	2	2	2	1	0	0
T	8	2	0	0	2	1	2	2	0	0
S	11	3	3	3	3	1	0	2	1	0
X	1	1	0	0	1	1	1	1	0	0
Y	2	1	1	1	0	0	0	0	0	0
Total	25	10	6	5	8	5	5	6	1	0

Table 13

Access to the Chief's Allocation

Group	No. in group	No. that cut from Chief's allocation	No. that do not own but cut from Chief's allocation	No. that own their trees but still cut from Chief's allocation
P	4	1	0	1
T	8	2	2	0
S	11	2	2	0
X	1	0	0	0
Y	2	2	1	1
Total	25	7	5	2

Table 14

Other types of fuel and Number of Households that use them

Group	No. in group	Dung type			Shrub type				Purchased fuel	
		Ligu	Khapane	Bokuluba	Sehala-hala	cheche	leng-na	dead twigs	paraffin	coal
P	4	3	3	1	3				4	1
T	8	3	4	1	7		1	1	5	
S	11	5	9	1	9	3			7	
X	1								1	
Y	2	2	2		2	1			2	
Total	25	13 (12)	18 (17)	3 (2)	21 (20)	4	1	1	19 (18)	1

(1) The figures in brackets represent the statistically correct totals for these categories after they have been adjusted to account for the household that falls in both the 'T' and 'S' groups.

AR

APPENDIX 1

Survey Questionnaire

A study of the diffusion of new energy UTILIZATION DEVICES with particular reference to Solar Power.

A. ABOUT THE RESPONDENT

1. Date _____ 2. Village _____

3. Name of respondent _____

4. Position of respondent in the household _____

5. Sex _____ 6. Age _____

7. Educational attainment _____

8. Occupation _____

9. Membership of voluntary organisations _____

ORGANISATIONS	POSITION HELD
(a.)	
(b.)	
(c.)	
(d.)	
(e.)	

B. ABOUT OTHER MEMBERS OF THE HOUSEHOLD

NAME	AGE	SEX	EDUCATION	OCCUPATION	PRESENT ABSENT	PLACE OF EMPLOYMENT

C. SOURCES OF INCOME

Does the household own the following?

Number of livestock owned		where kept most of year
(a.) cattle	_____	_____
(b.) sheep	_____	_____
(c.) horses and donkeys	_____	_____
(d.) goats	_____	_____

Fields owned

(a.) Owned by the household _____

(b.) Rented from other households _____

Farm implements

(a.) Ploughs _____

(b.) Planters _____

(c.) Cultivators _____

(d.) Carts _____

(e.) Tractors _____

Other sources of income: Do you receive income from these sources?

(a.) Number of members of household remitting money _____

(b.) Income from sale of mohair and wool last year. Yes____ No ____

(c.) Income from sale of crops. Yes ____ No ____

(d.) Income from sale of beer. Yes ____ No ____

(e.) Income from employment. Yes ____ No ____

(f.) Income from other sources (specify) _____

D. BASIS FOR MAKING DECISION TO PURCHASE DEVICE

Does the household own trees from which it can cut some firewood? Yes ____ No ___. If the answer to 1 is yes, specify the type and

number of trees owned. Please also specify the number cut this winter and state whether more or less trees were cut this year than in other years and if less or more trees were cut, how many are usually cut.

Type of tree	Number owned	No. cut this winter	Number left	Number Usually cut
(a)				
(b)				
(c)				
(d)				

2. Does the household have access to wood owned by the chief/village? Yes ___ No ___. If the answer is yes, how many trees were cut this winter from this source and was this less or more than in other years? (Indicate type of trees and amount(s).

_____

_____

3. What other sources of fuel are available to the household and in the past month, how much of this fuel type did you buy or collect?

Type of fuel	Number of times purchased in last month and where purchased	Number of times collected last month and where collected	Distance travelled to purchase/collect fuel	Quantity purchased or collected	How much is left?
(a.)					
(b.)					
(c.)					
(d.)					
(e.)					
(f.)					

4. Have the quantities of fuels indicated above been less or more than what you usually use, and if so, why have you increased or decreased the use of those particular fuels?

Type of fuel	Trend in use	Reason for trend

5. Do you own a stove and what type of stove is it? _____

6. How often do you use this stove? _____
   If the use is less or more than at an earlier date, reasons for this new trend: _____

7. Why did you buy this device? Date of purchase?

8. Had you seen or heard of a similar device before? If the answer is yes to any of the questions, where did you see a similar device or who told you of a similar device? Were they related to you?

   Name of device _____

Village where device seen or heard of	Heard of or seen	Name of person, owner or teller	Relationship
(a.)			
(b.)			
(c.)			
(d.)			

9. Was someone else involved in deciding whether to purchase the device or not? If the answer is yes, were they related to you? From which village did they come?

Name of Co-decider	Village of origin	Relationship
(a.)		
(b.)		
(c.)		
(d.)		
(e.)		

10. When you first purchased the device, what were your expectations about it? For example, what did you think it would do?

_____

_____

_____

_____

11. What specific benefits did you think you would derive from ownung the device? _____

_____

_____

E. EVALUATION

1. Now that you have purchased the device, how often do you use it and for what purpose? Please explain: _____

_____

_____

_____

2. Since buying the device, has it been altered in any way, for what purpose, and by whom? If the answer is yes, how much did the alterations cost? _____

_____

3. Does the device need alterations? Please explain: _____

_____

_____

_____

4. You have now had the time to find out whether the device is useful or not. Please state all the benefits and dis benefits you have derived from using the device.

Benefits: _____

_____

_____

Disbenefits: _____

_____

_____

_____

F. DIFFUSION

Now that you have bought this device, have you told any of your friends about it? If yes, give their names, villages in which they live, their relationship with you and whether they are female or male.

NAME	SEX	VILLAGE	RELATIONSHIP	AGE
(a.)				
(b.)				
(c.)				
(d.)				
(e.)				

2. Have any other people made enquiries about the device? If the answer is yes, give their name and the village from which they had come.

NAME	SEX	VILLAGE	RELATIONSHIP TO YOU
(a.)			
(b.)			
(c.)			
(d.)			
(e.)			
(f.)			

3. Of these people whom do you think are most interested in owning one of these new devices and why? _____

_____

_____

FOR NON-PURCHASERS, ALTERNATIVES TO SECTION D, QUESTIONS 7-10

1. Would you like to purchase the device? Yes ____ No ____
Why? _____

_____

2. Have you seen or heard of a similar device before? If yes, give the name of the device and where you saw it or who told you about it.

Name of device	Village where seen or heard of	Heard or seen	Name of owner or teller	Relationship
(a.)				
(b.)				
(c.)				
(d.)				

3. What would you expect the device to do if you were to purchase it? What benefits do you think you might get from using it? _____

_____

_____

4. Have you heard of any other people who would like to purchase this device? If yes, please give their names, their villages and their relationship to you.

NAME	SEX	VILLAGE	RELATIONSHIP
(a.)			
(b.)			
(c.)			
(d.)			
(e.)			

5. Have you told other people about this device? If yes, please give their names, their village and their relationship to you.

NAME	SEX	VILLAGE	RELATIONSHIP
(a.)			
(b.)			
(c.)			
(d.)			
(e.)			

APPENDIX II

Table 1

Comparison of Average number of livestock owned by various groups in the sample with people in the area and in the District.

Group	No. in group	Cattle	Sheep	Goats	Horses and/or Donkeys
District	2 341	4	17	8	
Area	243	3	16	15	
P	4	14	51	24	8.5
T	8	5	4	5.6	2.4
S	11	4	4	9	2
X	1	0	0	0	1
Y	2	7.5	77	15	4

N.B.

The 1979 Household survey from which the figures for the District and the area are taken, did not enquire about horses and donkeys.

Table 2

Comparison of ownership of fields and farm implements between the people in the area and the various groups in the sample. (1)

Group	No. in group	No. of fields owned	Ploughs % owning	Planters % owning	Culti-vators % owning	Harrows % owning	Carts % owning	Trac-tors % owning
District	2 342	2	42.5	6			1	0
Area	243	1.9	34	3			0	0
P	4	3.5	100	50	100	0	0	0
T	8	2.4	94	12.5	37.5	12.5	12.5	0
S	11	2	45.4	0	27.3	0	0	0
X	1	3	100	0	0	100	0	0
Y	2	4	50	0	50	50	0	0

(1) The 1979 Household survey did not enquire about cultivators and harrows.

Table 3

Reasons for Buying or Wanting to buy Solar Water Heaters

Reason	Number of times given	Percent
To save fuel	7	28
To save money spent on paraffin	5	20
To save time on collection of fuel	5	20
To be used in times scarce fuel	4	16
The devices sounded like a useful thing to have	3	12
To prove that the sun could work as fuel	3	12
Solar devices were easy to use	2	8
Solar devices were smokeless	1	4
Solar energy was cheaper than other fuel sources	1	4
It would be an additional fuel source at home	1	4

Table 4

Derived Benefits and disbenefits as Stated By the Purchasers

Derived Benefits	Percent	Derived Disbenefits	Percent
1. Less fuel used for cooking	50	1. It takes a long time to heat water	25
2. Knowledge that the sun can work as fuel	25	2. Not working on cloudy days	25
3. Reduced money spent on paraffin	50	3. Trouble of having to keep frames indoors at night	25
4. Saved time devoted to collecting fuel	25	4. Expenses on repairing walls	25
5. Hot water for washing	50		

N.B. Some people mentioned more that one benefit.

APPENDIX 3

RURAL TECHNOLOGY UNIT

Report format - to be used on return from all lipitso and workshop session.

1. Description of village (list items A-D on a file card)

   A. How many people? (approximately)
   B. Name of Chief/Chieftainess.
   C. Name of headman
   D. On what day and at what time should future lipitso be held?
   E. How many animals? What kind? (approximately)
   F. Does the village seem well off?
   G. How is the water suppy?
   H. Is it a "content" village? (That is, are the people united or are there factions - political, religious, etc.) explain.
   I. Are there any interesting features such as windbreaks, trees, stoves, reed ferces, etc? Please list and describe.

2. Fuel situation

   A. What fuels do people use?
   B. Which do they prefer for which tasks?
   C. What is the availability of each fuel? (How many have adequate supplie of lisu? Is there wood available? Paraffin? shrubs khapane) explain.
   D. How far or for how long do people go to collect each type of fuel.
   E. How long does the supply last? How much of each fuel do they use each month?
   F. What is the value of each type of fuel? (This can be in monetary terms or relative to another fuel. An exampe might be that a 50kg sack of khapane is worth a donkey load of sehalahala).
   G. What problems do people have with fuels?
   H. Are there specific problems for heating and staying warm in winter?
   I. What suggestions do people have to help solve these problems with fuel? ("Ha ke tsebe". is n't good enough).

3. Knowledge of R.T.U.

   A. What do people know about the R.T.U?
   B. How many people already know about the R.T.U? Where did they learn about it?
   C. How many items produced by the R.T.U are being used in this village? (Be specific as to which items, if possible)
   B. How do people feel about the R.T.U?
   E. What do people think about the items they have purchased or have seen from the R.T.U? What modifications are required?
   F. What other items would they like to see made or supplied by the R.T.U?
   G. What new ideas did you come across from talking with people? Who said them?

4. Details of Pitso.

A. How many people? (Men, women, children, approximately).

B. What topics did you cover?

C. What were people most interested in? (Explain)

D. Did you get any orders for devices?
If so, please list how many, which items and who wants them.

E. What did you learn that will help you in future lipitso?

5. Details of workeshop

A. How many people participated? (men, women, children, approx.)

B. How many and which devices did you build?

C. Did people help you? If so, how?

D. What problems did you encounter? How did you solve these problems?

E. What did you learn that will help you in future workshops?

F. Did you get any orders for devices in addition to those you built? If so, how many, which items and who wnats them?

G. List on file cards the names, addresses, occupations and the device purchased for each person you worked with.

6. Village Skills Inventory,

Please list on file cards the names, addressess, occupations and level and type of interest in the R.T.U. of the following people.

1. Builders
2. Thatchers
3. Seamstresses/Tailors
4. Weavers (grass or reeds)
5. Spinners (mohair or wool)
6. Girth makers
7. Saddle makers (leatherworkers)
8. Sheet metal workers
9. Wood workers
10. Repair people
11. Shop owners or managers
12. Good farmers
13. Clinic or hospital workers.
14. School teachers
15. Priests, Ministers
16. Members of the Village Development Committee (particulary key individuals)
17. Village Mobilizers
18. Others.

APPENDIX 4 Corrections to Interim Report

Checking the effect of this mistake on the appropriate heat loss and gain tables, we found that it introduces an error of at most 4% in the monthly heat loss and an error of up to 0.2°C in the predicted average indoor temperature. This was felt to be relatively unimportant in overall accuracy so all the tables have not been corrected. It should be noted that only some months are affected by this problem when the calculations are performed, primarily the winter months and in a few cases the summer ones.

Table A 17-4. Day and Night Length by Month

	Day	Night
January	13.7	10.3
February	13.0	11.0
March	12.2	11.8
April	11.6	12.4
May	11.0	13.0
June	10.3	13.7
July	10.3	13.7
August	10.7	13.3
September	11.5	12.5
October	12.3	11.7
November	13.1	10.9
December	13.7	10.3