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A Solar Water Heater for Honduran People

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A Solar Water Heater for Honduran People

A Research Paper for Presentation
to the Graduate Committee
of the
Industrial Technology Department
University of Northern Iowa

In Partial Fulfillment of the Requirements for
the Non-Thesis Master of Arts Degree

By
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April 27, 1979

Approved by:

Technical Advisor	Date
Graduate Committee, Chairman	Date

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CHAPTER I

INTRODUCTION

> The Third World -- well endowed with direct sunlight, green plants, winds and water power -- may forge ahead of United States and Europe in making the transition in solar power according to a report from the Worldwatch Institute. The current high cost of power from other sources has already made solar energy economically competitive in rural areas of Asia, Africa, and Latin American, said Dennis Hayes, author of the study "Energy for Development: Third World Options."
>
> Far from being a futuristic technology, many simple and practical solar devices have already proven themselves in a variety of settings. All that is needed now is the political and financial commitment to building a sustainable solar economy for the poor, he said (Energy Digest, p. 427, 1977).

The above citations are well applied to Honduras, a Central American country, located along "the solar belt," a vast area lying generally between the two 40th parallels (Honduras is located between 13° and 16° North Latitude). As in any developing country, the Honduran people are suffering the economical impact due to the recent large price increases on petroleum products. Such a situation is becoming more critical day by day. On the other hand, Honduran land receives a great deal of the sun's energy which is used in clothes drying only. In other words, we are wasting the only kind of energy that we have!

Problem Statement

The problem of this study is to develop guidelines for the construction of a cheaper solar water heater using materials which are available in Honduras, Central America.

Purpose of the Study

The purpose of this study is twofold:

1. To help Honduran people by giving them basic ideas about how they can reduce their expenses using solar energy in the water heating process.

2. To assist the Technical Educational Department at the Escula Superior Profesorado "Francisco Moraran," in Honduras, in identifying contents associated with Energy Sources.

Definition of Terms

1. Solar Energy: in the technical use of the term, it is the electromagnetic radiation produced on the sun and radiated over 93,000,000 miles, at a speed of 186,000 miles per second, to all us here on earth. The radiation is the result of on-going nuclear reaction on the sun's surface as it comes to us on earth as sunlight as well as ultraviolet and infrared rays.

2. Solar Water Heater: this is a device used in order to heat water with the sun as the energy source instead of electricity or gas.

3. Solar Flat-Plate Collector: is the part of a solar water heater which is used to catch and trap the incoming heat from the sun's rays. It consists basically of a wooden box with a black bottom and a glass top.

4. Insolation: it is defined as the total amount of solar energy intercepted by a horizontal surface of a given area over a given interval of time. It is measured in kilowatt-hours/square meters.

CHAPTER II

REVIEW OF RELATED LITERATURE

Brief History

According to history, the first person to use the sun's energy on a large scale was Archimedes, who reputedly set fire to an attacking Roman fleet at Siracusa in 212 B. C. He accomplished this by means of a burning glass composed of small square mirrors moving every way upon hinges. Serious studies of the sun and its potential began in the seventeenth century, when Galileo and Lavosier utilized the sun in their research. By 1700, diamonds had been melted and by the early 1800's heat engines were operating with energy supplied by the sun. In the early twentieth century, solar energy was used to power water distillation plants in Chile and irrigation pumps in Egypt. By 1930, Robert Goddard had applied for five patents on various solar devices to be used on his project of sending a rocket to the moon. However, most of these projects were considered curiosities because they were ahead of their time (Kreider and Kreith, 1975). By the 1920's and 1930's, practical use was being made of the sun's energy in California and Florida in domestic solar service-hot-water heaters.

Countries such as the United States, Israel, Australia, and Japan have conducted much research on solar energy and its direct application to human needs.

How Solar Energy Can Be Utilized

There are three technological processes by which solar energy can be used:

1. The heliochemical process, through photosynthesis, which maintains life on this planet.

2. The helioelectrical process, using photovoltaic converters, which provides power for all of the communication satellites and ultimately will be very valuable for terrestial applications.

3. The heliothermal process, which can be used to provide much of the thermal energy needed for space heating and cooling and domestic water heating (McDaniels, 1976).

Water Heating Applications

Solar energy can be easily converted into heat and could provide a significant proportion of the domestic hot water demand in many countries.

The most widely known and understood method for converting solar energy into heat is by the use of a flat plate collector for heating water, air or other fluids.

Many different types of collectors have been built and tested by independent investigators mainly in the United States, England, Australia, South Africa and Israel. Tests were carried out in specific locations with wide variation in test procedures and in the availability of solar radiation. The main objective of these tests has been to convert as much solar radiation as possible into heat, at the highest attainable temperature, for the lowest possible investment in materials and labor (McVeigh, 1977).

General conclusions from these works were:

1. Simplicity of construction must be an essential feature of water heating systems.

2. Satisfactory heat collection efficiencies are only obtained where there is prolonged and intense direct radiation.

3. Although a solar water heater is more expensive than a conventional heater, once installed the operating cost is low.

4. Although there may be no direct contact between dissimilar materials in a solar water heating system, corrosion problems may occur whenever copper and steel or galvanized components are used, particularly when the water is cupro-solvent.

5. The solar water heating systems based on the flat-plate-thermosyphon principle are good enough for domestic water heating demands and for small industries inclusive.

6. Experience has shown that tubes smaller than 0.5 inch standard size should not be used in solar-thermosyphon water heater systems.

7. The day-long efficiency of a well constructed and properly designed thermosyphon water heater will range from 45 to 65 percent, depending upon outdoor air temperature and wind velocity.

Water Heater Systems

Although there are probably hundreds of different types of solar water heater designs, most of them have certain features in common:

1. the collector plate;
2. insulating material at the back and sides of the plate;
3. one or two sheets of glass or translucent plastic in front of the collector plate;
4. a casing to contain items 1, 2, and 3; and
5. a hot water storage tank (McVeigh, 1977).

The parts listed before are parts of two main components in a solar water heater system; they are 1) the solar collector and 2) the storage tank.

Solar Collectors

The technological conversion of solar energy to heat involves the same processes by which solar radiation heats the atmosphere. The only difference is that the material heated by the sun in technological conversion (the absorber) is usually a solid instead of a mixture of gases. When solar radiation impinges on a solid material, the incident energy is either reflected at the surface, absorbed by the body of material and converted to heat, or transmitted to emerge from the far side of the solid. The fractions that are reflected, absorbed, and transmitted depend on the properties and surface conditions of the solid and on the wavelength and angle of incidence of the radiation.

Clean metallic surfaces, such as polished aluminum, reflect most of the incident solar radiation, both direct and diffuse; good absorbers, such as a metal surface painted flat black, reflect very little radiation and transmit none. Transparent substances, such as glass, transmit most solar radiation, but absorb most of the long-wave radiation emitted by relatively cool bodies. Window glass and flat black paint reflect only a few percent of the direct solar radiation of zero-degree (normal) incidence, but at an incidence angle of 75 degrees, reflect more than half of the radiation.

When a body absorbs radiant energy, it becomes hotter and must establish a new thermal equilibrium by rejecting the acquired heat to its surroundings. A body is said to be at thermal equilibrium when the energy incidence on the absorber is exactly equal to the heat energy rejected by the absorber. Heat can be rejected in several ways. Some of it is emitted by the absorber as electromagnetic radiation, mostly long-wave infrared rays. This is called the radiative loss. Another portion is carried away by the surrounding air through convection currents and is called the convective loss. More energy is lost through conductive losses to bodies in direct contact with the absorber. The remaining heat can be transferred to a working fluid (or transfer fluid) and be delivered elsewhere for useful purposes. To be effective the solar collector must cut heat losses - radiative, convective, and conductive - to a minimum.

The performance of a solar collector is measured by its collection efficiency, which can be simply defined as the fraction of the available solar energy that is delivered as heat of some specified temperature. A number of factors affect collector efficiency at a given instant, among them: the total solar radiation intensity, the ratio of diffuse to direct radiation, the solar altitude, the ambient temperature, the wind velocity, and the transfer or working fluid inlet temperature. Thus, instantaneous efficiency alone is an incomplete indicator of a collector's performance; it fails to tell us what fraction of the total daily insolation is delivered to the user as heat. An efficiency is needed for calculating the collector area necessary for a particular application and for making cost comparisons with other modes of energy supply (CSPI, 1976, p. 20).

The Flat-Plate Solar Collector

A flat-plate solar collector consists in general of an insulated flat absorbing surface painted black to increase absorption. This surface may be a sheet of metal or a number of tubes, with or without fins on their sides. In the case of a sheet-metal absorber, some form of piping is fastened on one side of it so that water or some liquid may be circulated through the piping to collect the heat. Below the absorbing surface some form of insulation is used, such as glass wool, mineral wool, aluminum foil, wood, sawdust or coconut fiber. Above the absorbing surface are one or more layers of a material substantially transparent to solar radiation, spaced approximately one inch apart. Glass may be found to work satisfactorily (McDaniels, 1975).

Figure 1 shows the parts of a flat-plate solar collector.

The yearly insolation on a flat plate collector can be increased substantially by tilting the collector.

The most favorable orientation of a flat plate collector is facing due south at an inclination angle to the horizontal equal to the latitude of the site plus 10° to 15°.

The location of the flat plate collector has to be selected based on the characteristics of the specific home owner. It can be placed on the roof or on the ground. The main fact is there can not be any interference between the collector and the sun's radiation direction. Figures 2 and 3 are diagrams of a typical roof-mounted solar water heater and a ground-mounted solar water heater, respectively.

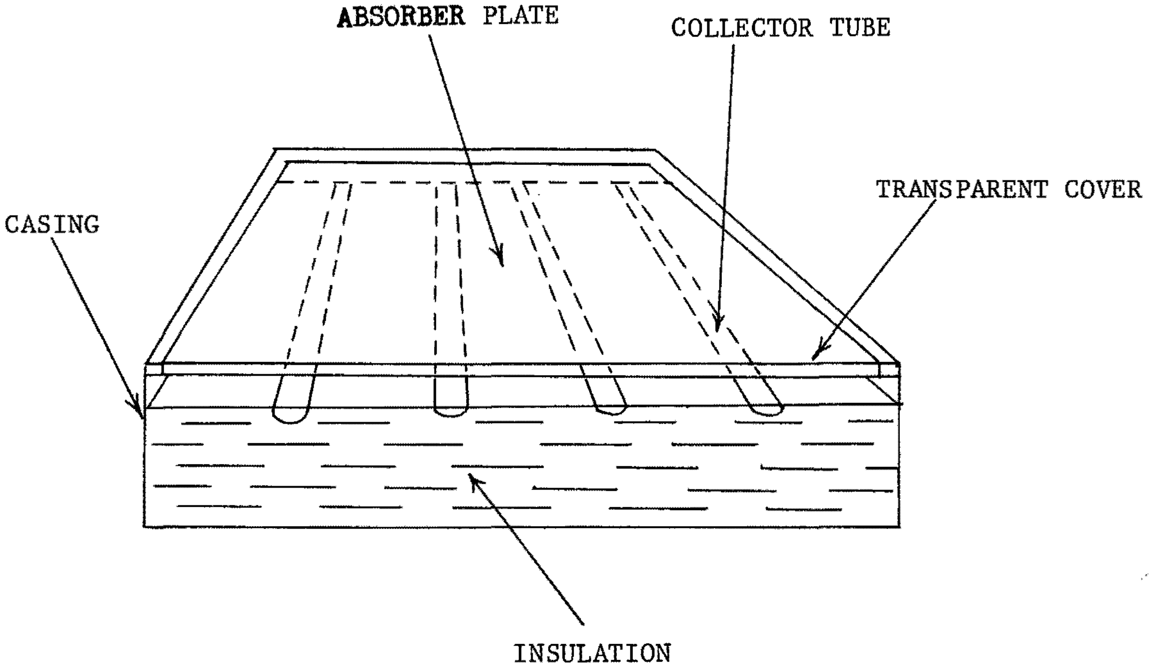


FIGURE No.1

MAIN COMPONENTS OF A FLAT-PLATE COLLECTOR

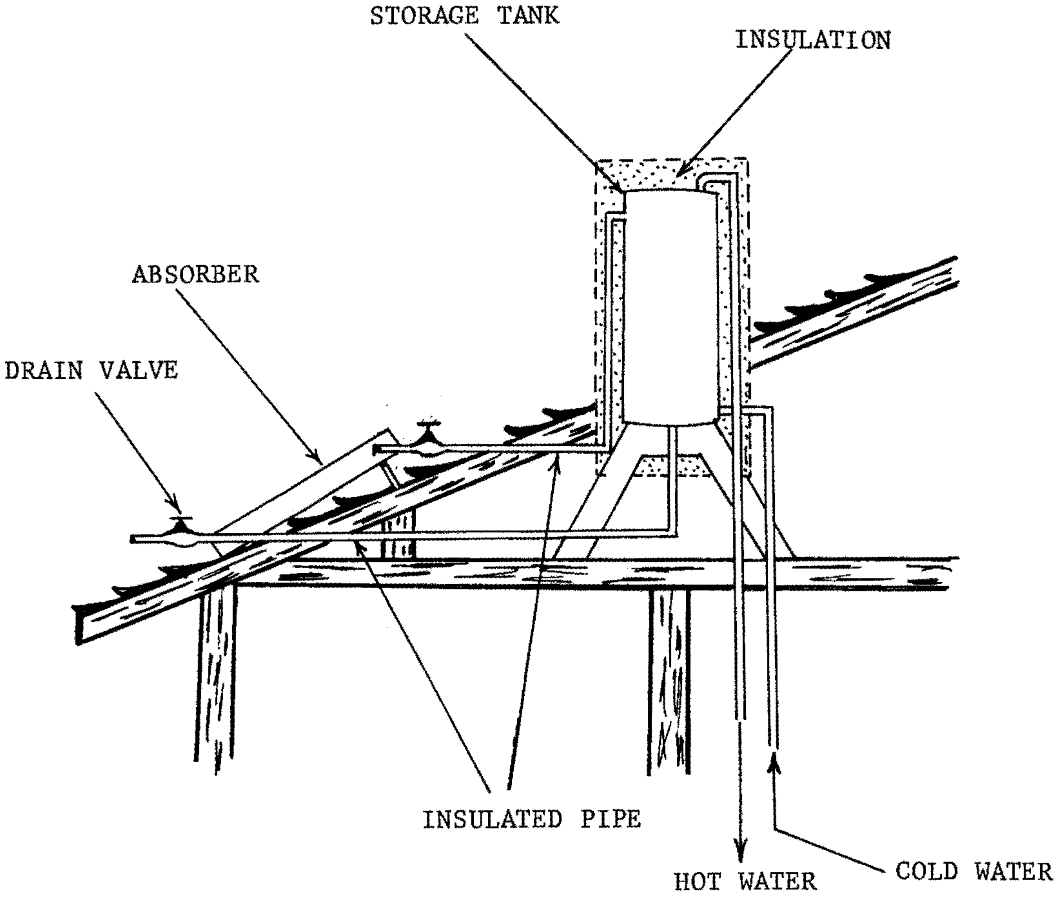


FIGURE No.2

DIAGRAM OF A TYPICAL ROOF-MOUNTED SYSTEM

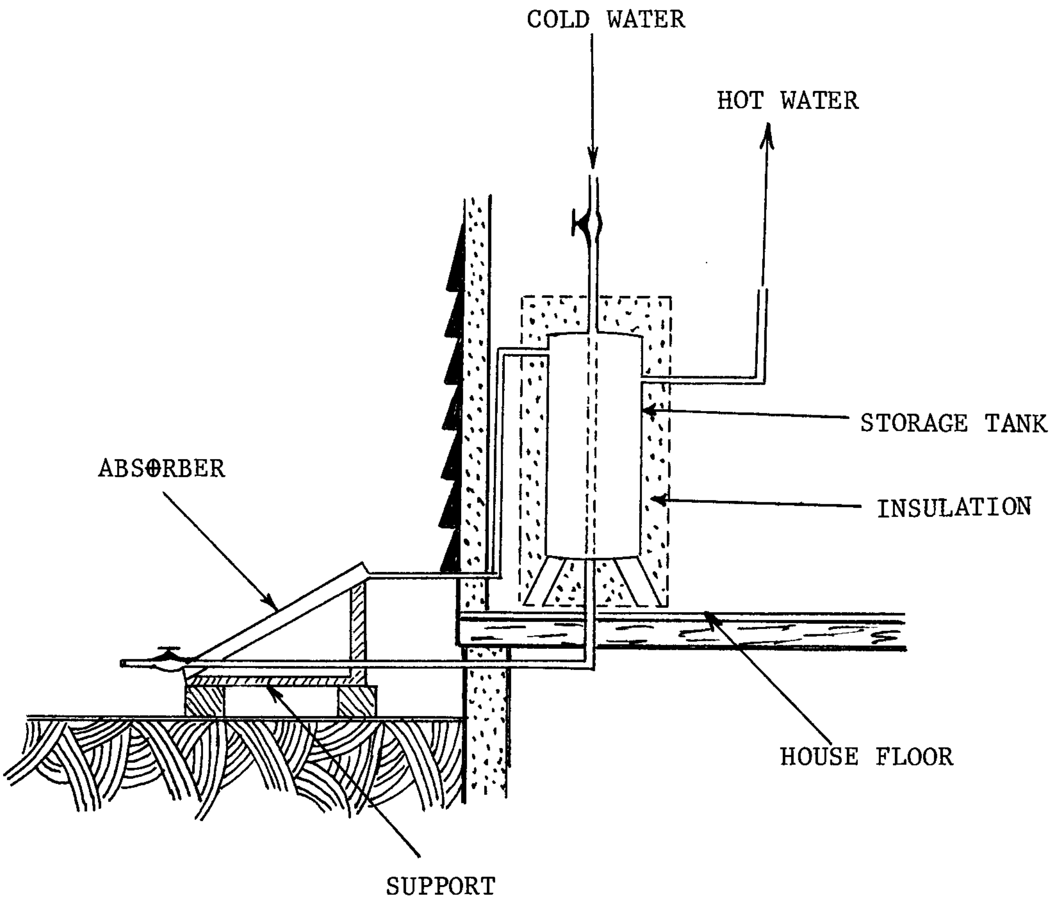


FIGURE No.3

DIAGRAM OF A TYPICAL GROUND-MOUNTED SYSTEM

The Storage Tank

The effectiveness of a solar water heating system depends greatly upon an adequate thermal storage system. Correlation of tank size to collector area is an important factor in attaining maximum efficiency. If the collector is too small to heat the tank, the water will never be hot enough. If the opposite is true, the water will be too hot and the collector efficiency will be diminished. The studies conducted in the Miami area indicate that a well-engineered unit will produce 1.5 to 1.5 gallons of water, at 130 degrees Fahrenheit, per square foot of collector. The table below illustrates some of the guidelines used on the Florida survey (Ewers, 1976, p. 55).

RESIDENCES

No. of Bedrooms	Occupants	No. and Sizes of Collectors	Size of Tank (gal.)
1 or 2	3	one 9 ft. 10 in. x 4 ft.	66
2 or 3	4	one 12 ft. 3 in. x 4 ft.	82
2 or 4 (baths)	4	one 14 ft. 8 in. x 4 ft.	100
Small Duplex	6	one 15 ft. 11 in. x 4 ft.	120

APARTMENTS

No. of Units	No. and Size of Collectors	Size of Tank (gal.)
3	two 14 ft. 8 in. x 4 ft.	200
6	three 14 ft. 8 in. x 4 ft.	300
10	five 14 ft. 8 in. x 4 ft.	

A solar water heater system operated on the thermosyphon theory for circulation of water in the collector-tank circuit is based upon the fact that hot water is less dense and rises to the top of the collector as it heats and stays at the top of tank as cold water returns from the tank bottom to the collector bottom to start the re-heating process again. The ideal separation between the collector top and tank bottom was found to be two feet. The main reason for this is to stop reverse circulation when the sun is not shining. The addition of insulation on the pipe from collector to tank bottom also aided in that regard.

In addition, it was found that the hot water pipe from the collector should enter the upper section of the storage tank at a level lying between two-thirds and three-quarters of the total tank capacity; loss of efficiency occurs when this entry point is lowered (McVeigh, 1977).

The piping distance between the solar collector and the storage tank has to be as short as possible.

CHAPTER III

LABORATORY ACTIVITY

Objective

To understand the construction of a solar flat-plate collector.

Procedure

1. Detect kind, and prices of materials available in Cedar Falls.

2. Design the solar flat-plate collector with its respective specifications.

3. Build the solar flat-plate collector.

4. Test the final product.

5. Develop conclusions.

Design of the Solar Flat-Plate Collector

The following table refers to Figure 4.

LIST OF MATERIALS

Part No.	Description	Material	Size
1	wood container	wood	4 pieces, 4 in. x 22 in. x $\frac{1}{2}$ in.
2	sides insulation collector casing	foam insulation wood	4 pieces, 2 in. x 26 in. x 2 in.
3	collector casing	wood	20 in. x 20 in. x 2 in.
4	collector tube	copper pipe	$\frac{1}{4}$ in. I. D., $\frac{1}{2}$ R. bend.
5	black-flat painted absorber plate	galv. steel sheet	22 gauge, 20 in. x 20 in.
6	transparent cover	window glass	20 in. x 1 in. x 1/8 in.
7	back insulation	foam insulation	

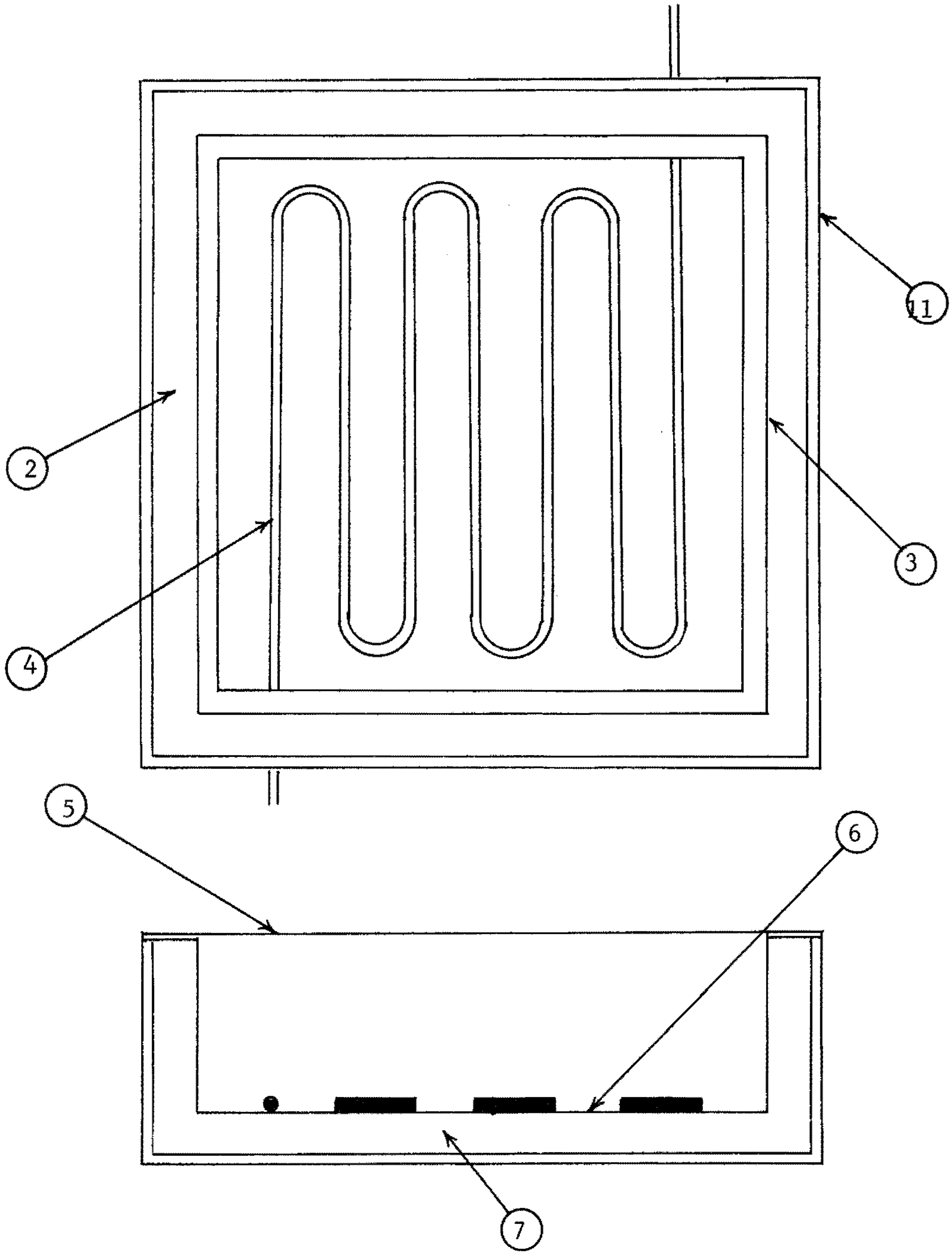


FIGURE No.4

DIAGRAM OF THE FLAT-PLATE COLLECTOR DESIGN

Building the Solar Flat-Plate Collector

1. Cut the galvanized 22 gauge steel sheet to 20 in. x 20 in.
2. Bend the copper pipe to get the form shown in Figure 4.
3. Solder the collector tube to the absorber plate.
4. Make the collector casing.
5. Join the absorber collector, the collector casing and the transparent cover.
6. Seal all junctions made in item 5.
7. Put on sides and back insulation.
8. Make the wood container and assemble it with the product obtained in item 7.

Testing the Final Product

During this part of the procedure, there were difficulties in operating the product as a result of the large amounts of precipitation in Cedar Falls during July. The results finally obtained are described in Figure 5.

Conclusions

In Honduras:

1. Solar water heaters could be economically competitive with conventional water heaters.
2. The practicality of the solar water heater suggested to be used in Honduras will have to be tested there in order to determine the appropriate relationship between the size of the solar collector and the storage tank.
3. The amount of solar radiation which falls over Honduras has to be measured before this solar water collector can be put into use.

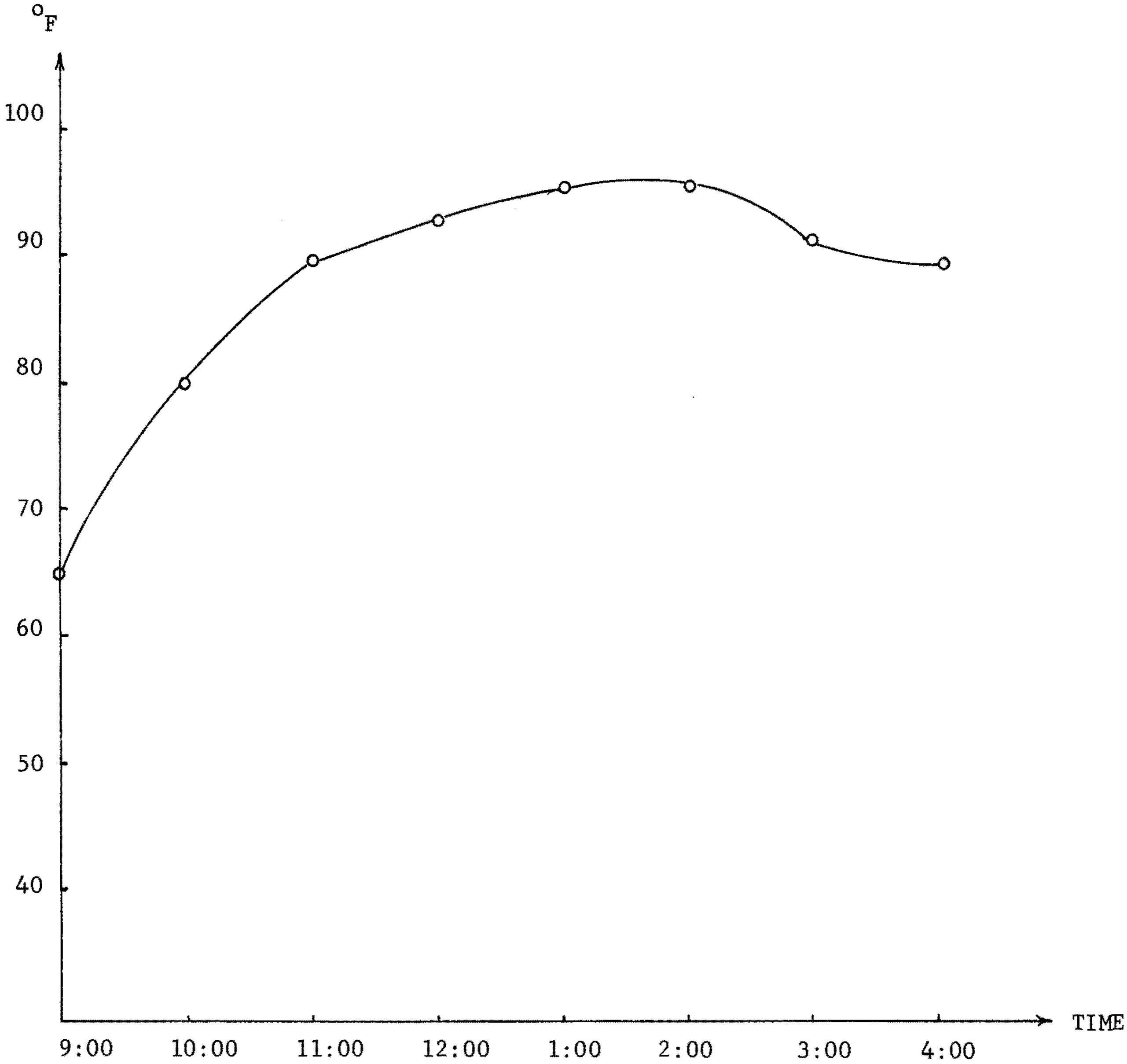


FIGURE No.5

RESULTS OBTAINED ON JULY 24 IN CEDAR FALLS.

4. A comparative study has to be made in Honduras in order to determine the most advantageous features and specifications of a solar water heater for the Honduran people.

CHAPTER IV

SUGGESTED SOLAR WATER HEATER FOR HONDURAN PEOPLE

Honduras's Conditions

Average temperature = 83° F.

Latitude = 13° - 16° North Latitude.

Approximate insolation: 6 $Kw\text{-}h/m^2$.

Approximate daily solar radiation = 2200 BTU per square foot per day.

Figure 6 shows the average temperature at some places in Honduras. The following solar water heater built and tested by the Brace Institute, McGill University, Quebec, Canada, in Barbados, West Indies, is specifically designed to be constructed of simple low-cost materials available almost everywhere, including remote areas of developing countries, like Honduras. The heater is designed to provide from 30 to 40 gallons of hot water per day ranging in temperature from 100 to 130 degrees Fahrenheit, depending upon local conditions (Evers, 1976, p. 58). The cost could be approximately $80 for all components including: the collector, hot water storage tank, cold water storage tank, and the connecting piping. Labor is not included, and this would be applicable on a do-it-yourself project. Maintenance of this unit consists of draining and cleaning the entire system twice annually.

The required components consist of four main parts:

1. The collector/absorber which absorbs the sun's rays and heats the water.

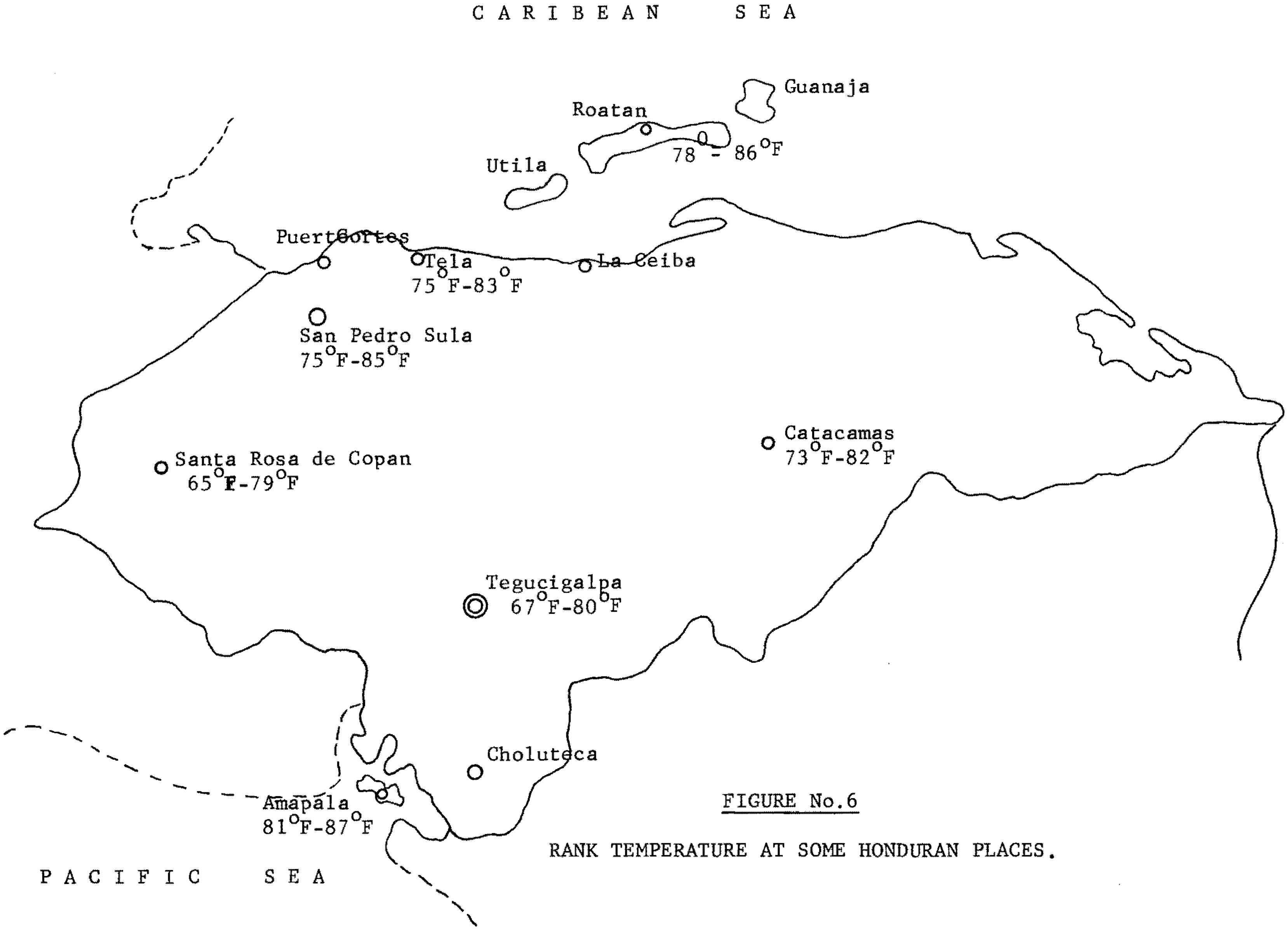


FIGURE No.6

RANK TEMPERATURE AT SOME HONDURAN PLACES.

2. The collector casing which houses the absorber, and insulation materials.

3. The hot-water tank, properly insulated, to hold heater water.

4. The cold water feed tank.

Figure 10 shows the system in a roof-mounted fashion.

MATERIALS LIST

Part No.	Amount Of	Material	Size
A		THE ABSORBER	
1	1	corrugated galv. steel sheet (corrugations 3 in. apart and 3/4 in. deep)	22 gauge, 8 ft. x 26 in.
2	1	flat-galv. steel sheet	22 gauge, 8 ft. x 36 in.
3	28	galv. steel rivets	$\frac{1}{4}$ in. dia. x 5/16 in. long
4	2	galv. steel water pipes	$\frac{1}{2}$ in. I. D., 9 in. long
5	2	m.s. machine screw	3/16 in. dia., $\frac{1}{4}$ in. long
6	2	sticks of solder	
B		THE ABSORBER CASING	
7	1	flat galv. steel sheet	24 gauge, 8 ft. x 3 ft.
8	8	galv. rivets for ends of casing	$\frac{1}{4}$ in. dia., 5/16 in. long
9		coconut fiber or equivalent insulation	20 lbs.
10	6	22 gauge galv. steel sheet	1 in. x 1 in. x 3/4 in., supporting "L
11	6	felt strips or suitable insulation	1 in. x 1 in. x 1/8 in. thick
12	6	galv. rivets for post #10	$\frac{1}{4}$ in. dia.
13	4	22 gauge galv. steel sheet	1 in. x 3/4 in. x $\frac{1}{2}$ in. hold-down
14	4	galv. steel self threading screws for part #13	1/8 in. dia. x $\frac{1}{2}$ in. long "L" clamps
15	1	galv. steel sheet	27 1/8 in. x 2$\frac{1}{2}$ in. to make glass support rib.
16	4	galv. rivets for part #15	$\frac{1}{4}$ in. dia., 15/16 in. long
17	2	sponge rubber strip, e.g. "Dor-Tite"	$\frac{1}{4}$ in. x 1/8" x 17 3/4 in. long
18	1	sponge rubber strip, e.g. "Dor-Tite"	$\frac{1}{4}$ in. x 1/8 in. x 22 ft. long
19	2	window glass	27 3/4 in. x 44 3/4 in. x 1/8 in. thick
20	1	sylicone type sealant or equivalent	12 oz. cartridge

(cont.)

Part No.	Amount Of	Material	Size
B		THE ABSORBER CASING Continued	
21	1	black plastic electrical insulating tape	one roll, 1 in. wide
22	16	22 gauge galv. steel sheet	1 in. x 3/4 in. x 3/4 in., hold-down "L" clamps
23	12	sponge rubber strip, e.g. "Dor-Tite"	$\frac{1}{4}$ in. x 1/8 in. x 3/4 in. long
24	16	galv. steel self-threading screws	1/8 in. dia. x $\frac{1}{2}$ in. long
C		HOT WATER STORAGE TANK	
25	1	used steel oil drum	standard size 45 gallon
26	2	flat galv. steel sheet	24 gauge, 8 ft. x 4 ft.
27		coconut fiber or equivalent insulation	30 lbs.
28	2	deal wood boards	1 in. x 12 in. x 9 ft. long
29	1	heat resistant paint	1 pint tin
30		diesel oil	1 pint
31		gasoline	1 pint
D		COLD WATER FEED TANK AND PIPING	
32	1	used steel oil drum	standard size 45 gallons ($\frac{1}{2}$ required)
33	1	plumbing float control valve	$\frac{1}{2}$ in.
34		$\frac{1}{2}$ in. steel pipe and fittings	to suit particular installation
35	1	rust-oleum or similar paint	1 pint tin

(Ewers, 1976, p. 62)

Building the Collector

In the following procedure, refer to Materials List and Figure 7.

1. Cut the corrugated sheet to 26" x 88 5/8" with a pair of metal shears.

2. Cut the flat sheet to $26\frac{1}{2}$" x 90 5/8", also 22 gauge.

3. Place a sheet of stiff cardboard against end of corrugated steel, and trace shape of corrugations with a pencil. Cut along the traced line for later use as a pattern. Place the cardboard pattern

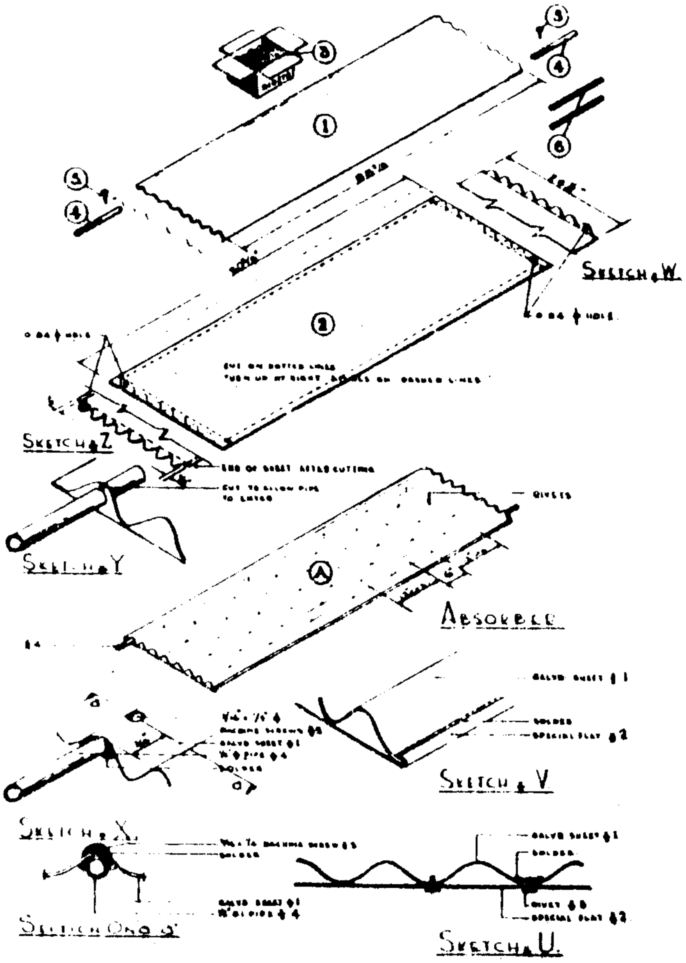


FIGURE No.7

THE COLLECTOR ABSORBER - PART A.

on each end of the flat sheet steel-part #2, Figure 7, and mark the corrugations. Cut along the marked lines with metal shears.

4. Drill two holes, 0.84 in. diameter, one at each end of part #2 to allow future placement of a length of ½ in. pipe.

5. Attach a 9 in. length of pipe, ½ in. dia., to each end of the corrugated sheet (#1) as shown in sketch X. Screw into the galvanized pipe and solder the pipe to the corrugated steel sheet.

6. Bend both ends of the steel sheet (#2) at right angles per the sketch W. The bent ends should be 1 in. long. Place the corrugated sheet (#1) on top of the flat sheet (#2) and slip the ½ in. pipes (#4) into the corresponding holes, but it will be necessary to cut the sheet (#2) at the end, as sketch Y shows, to allow the pipe to enter the hole.

7. Bend the edges of sheet #2 over the corrugated sheet (#1) as shown in sketch V, and solder as shown. To best bend the edges of the flat sheet over ¼ in. from edge as needed, clamp the sheet between two pieces of angle iron along the edge to be bent and strike with hammer to get a right angle.

8. Drill ½ in. holes for rivets in the inverted corrugations, as shown in sketch U. Place ¼ in. rivets (#3) in the holes with the heads resting on the flat sheet, as shown, and peen the rivet heads. Solder over the rivet heads to complete construction of the collector absorber.

Test for leaks by placing the unit in a sloping position, such as standing up against a building, and fill with water not under pressure from a water system, and allow it to stand for some time.

After the leaks are repaired, allow the unit to stand in the sun, filled with water. Then, paint corrugated side with two coats of flat black paint.

Building the Absorber Case

Again, refer to Materials List and Figure 8 in the following procedure.

1. The base of the absorber case is also made from flat-galvanized steel, 24 gauge. Start with a 3 ft. x 8 ft., and cut to 33 3/8 in. x 96 in., and round off the corners per sketch S, Figure 8, and bend the sheet at right angles along the dotted lines shown in the sketch. After the sheet is bent, sketch T, rivet the four corners with ¼ in. rivets (total of eight rivets). Drill 2½ in. drain holes in one end of the case, as shown in sketch T. When final assembly is complete, the holes are at the lower end of unit for condensed moisture outlet. Holes are for later installation to case with rivets.

2. Cut part (#10) which consists of six each L-brackets, and drill ¼ in. holdes for the rivets in the brackets.

3. Bend 1/3 in. thick felt strips (#11) cut 1 in. x 1 in. to L-clamps.

4. Check sketch T and drill six each ¼ in. holes in the case. Install L-clamps (#10) onto case with flat head rivets (#12) with head facing to the outside.

5. Place insulation into bottom of case, sketch T and V, per the Materials List, use a 2 in. layer of whatever insulation you want.

6. Place the absorber into the case over insulation but resting on the L-supports, and with the black corrugated surface facing upward.

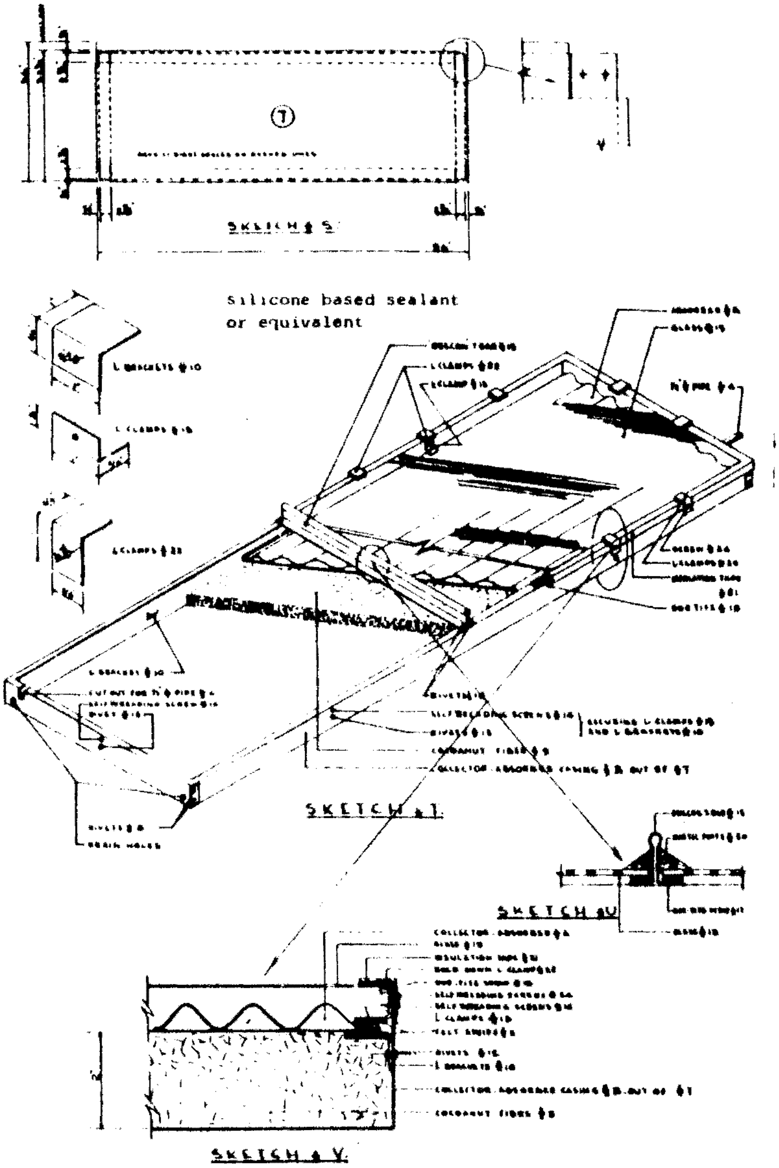


FIGURE No.8

THE ABSORBER CASING - PART B.

7. Make four each L-clamps (#13) from 22 gauge steel-size ½ in. x 3/4 in. x 1 in. Use self-tapping screws (#14) and screw the L-clamps in place, sketch T, to hold absorber to the case.

8. Make a T-rib per sketch T, and form it from a sheet of 22 gauge steel. Make it the same width as the case, and rivet the rib to case with two galvanized rivets each end.

9. Place the ¼ in. Dor-tite or whatever rubber stripping you are using on the rib (#15) per sketch U.

10. Place ¼ in. wide stripping all around the ¼ in. edge of case.

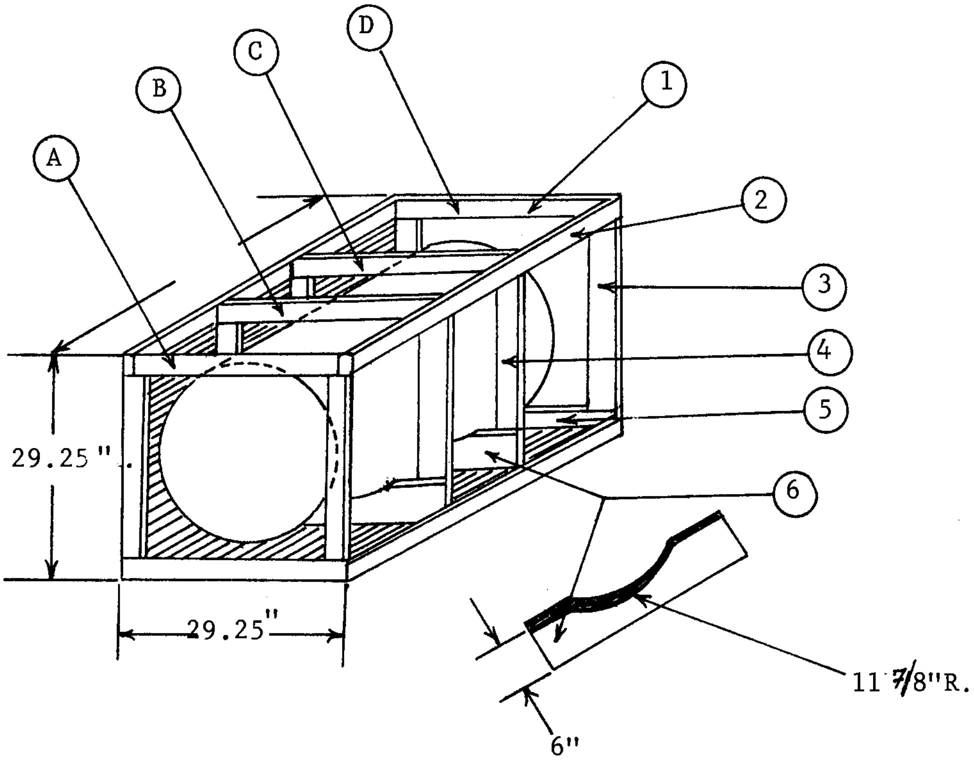
11. Place the two sections of window plate glass, size 27 3/4 in. x 44 3/4 in. x 1/8 in. thick (#19) into place on the case, and make sure they rest evenly on the stripping, all around the case.

12. Apply silicone or similar sealant between the glass and center and the edge supporting ribs. Allow 1/8 in. on each side for expansion of glass. Seal the glass to the case with black electrical tape wide enough to cover the seams.

13. Make 16 each L-clamps (#22) 3/4 in. x 3/4 in. x 1 in. from the 22 gauge steel, drill 1/8 in. hole in each. Place 3/4 in. sponge rubber strips (#23) on the glass over the tape, and attach the L-clamps in places indicated on sketch T and V. Press clamps over the rubber strips and drill a hole into the case, 1/8 in. and insert the self-threading screws (#24) into the clamps, until all are in place. This completes the collector units.

Building the Hot Water Storage Tank

Now refer to Materials List and Figure 9.



Frames A and D made from 1/2"X 3"X29.25" deal.
Frames B and C made from 1/4"X 3"X 29.25" deal.
1,3,and 5 : 8 pieces 1/2"X 3" X 29.25" deal.
2 1/4" X 2" X 36".

FIGURE No.9

DIAGRAM OF THE HOT STORAGE TANK.

1. Use a 45 gallon oil drum, or a similar size as available, and rinse the interior with a half pint of diesel oil, then rinse again with a half pint of gasoline to dissolve the diesel oil, which should have the drum grease free, and dry enough to paint.

2. Pour a pint of heat resistant paint (#29) into the drum and shake thoroughly until interior of the drum is coated with paint. Place drum aside and allow it to dry.

3. To build a wooden frame for the oil drum, refer to Figure 9.

4. Cut frame according to dimensions on the drawing.

5. Insert the oil drum into the frame work and cover the frame with sheets of 24 gauge steel sheet (#26), but leave the top open so you can fill the empty spaces with the pieces of insulation.

6. Place reducers in the two oil drum holes, and attach one length of galvanized pipe 6 in. x $\frac{1}{2}$ in. in each opening. After the pipes are in place, fill remaining spaces with insulation and attach top and frame in place.

Building the Cold Water Feed Tank

1. Cut a standard 45 gallon oil drum in half (#32 in Materials List) and install a $\frac{1}{2}$ in. flat valve (#33) as shown in Figure 10.

2. Paint the inside of the drum with two coats of rust-oleum paint and allow it to dry.

3. Obtain lengths of piping as needed to suit your application, and connect the system per illustrations in Figures 10 and 11 and the following instructions.

Assembly of Components

1. Use pipe sealant on all connections before tightening the final time. Make all connections in elevations showed in Figures 10 and

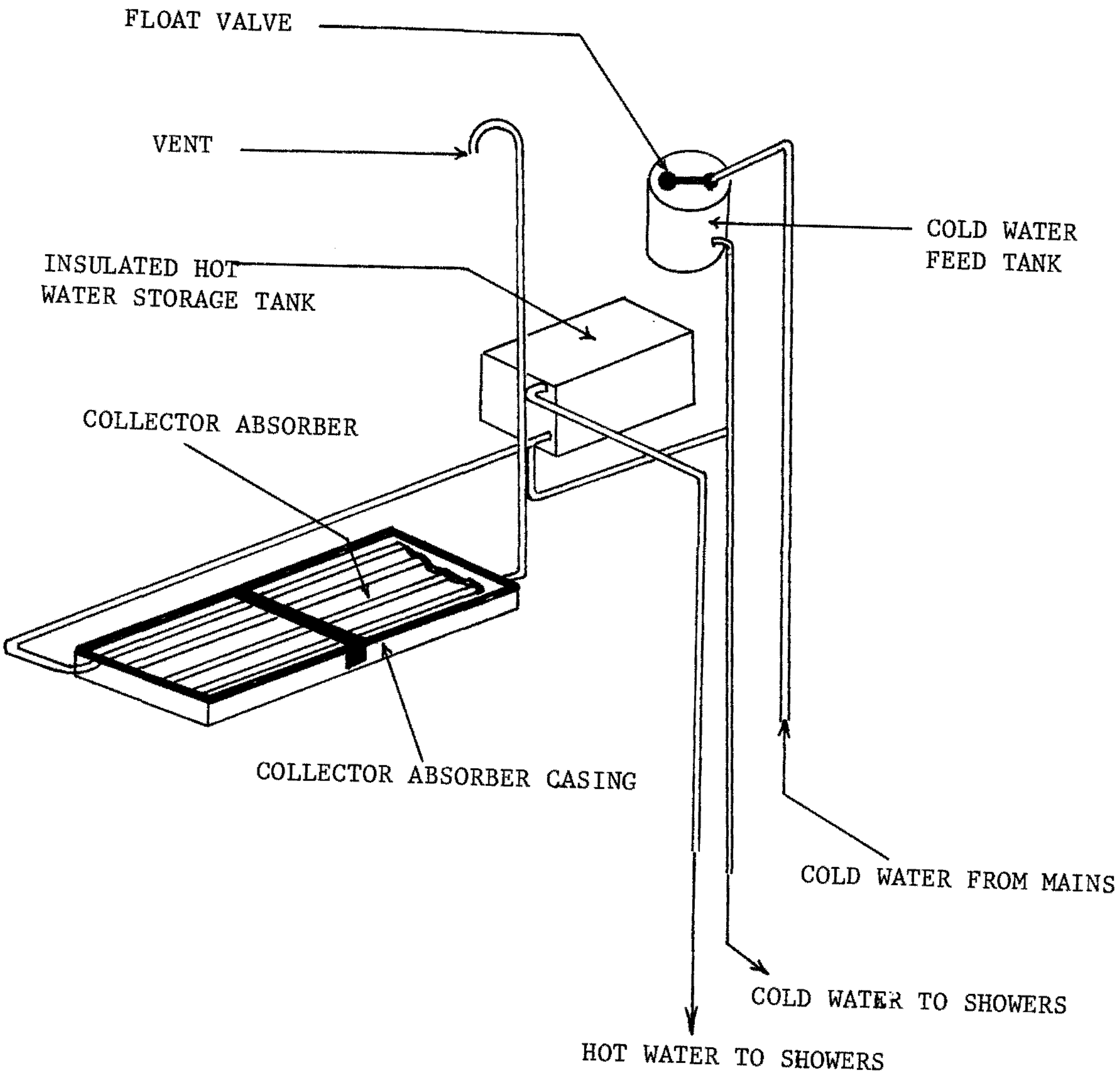


FIGURE No. 10

GENERAL SCHEMATIC OF THE SOLAR WATER HEATER

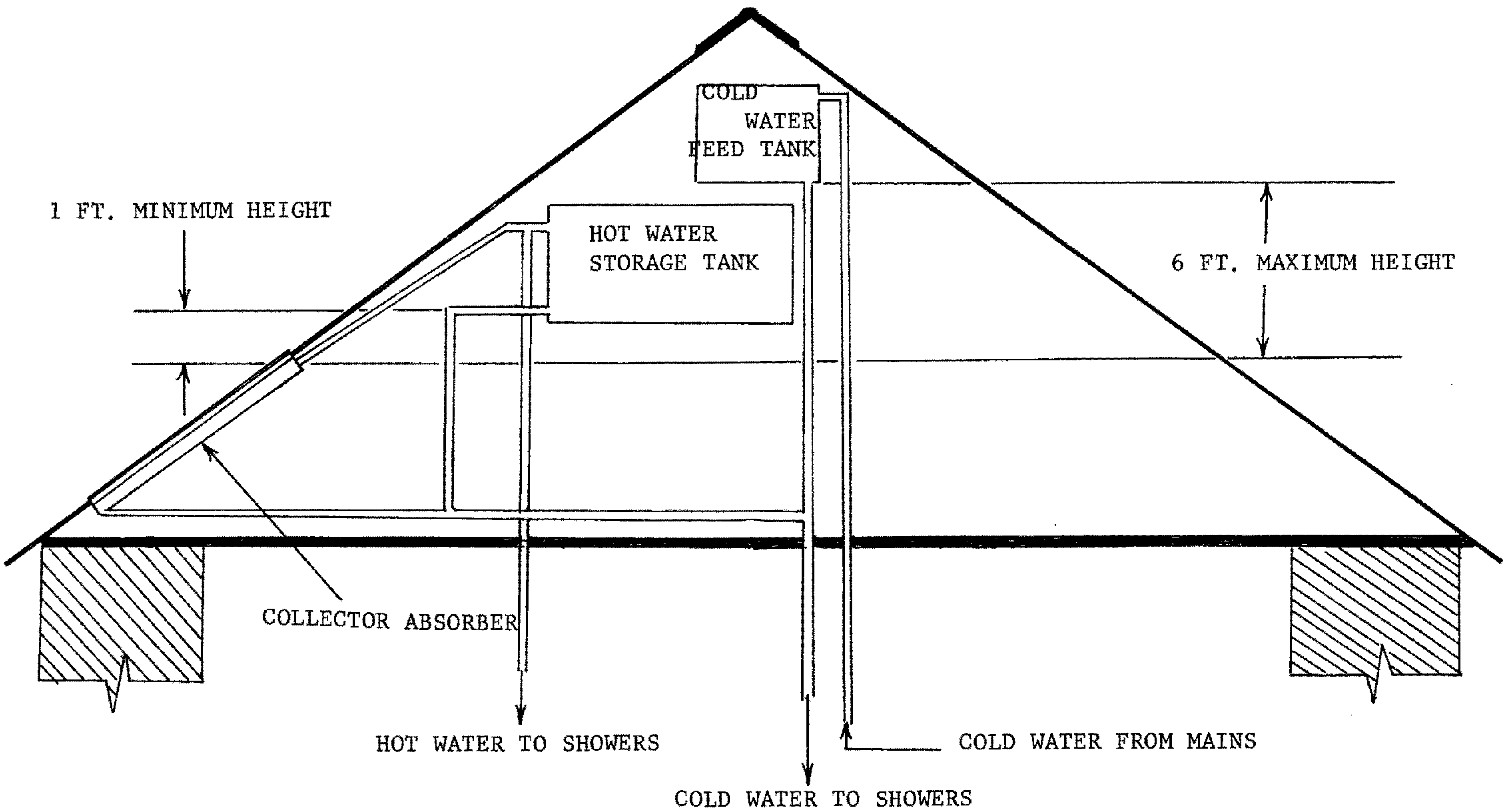


FIGURE No.11

ELEVATION OF THE SOLAR WATER SYSTEM

11. Note specially the 1 in. difference between the top of the collector and bottom of the hot water storage tank.

3. The collector must face to the south (or north, if south of the equator) at an angle equal to the latitude of the area, plus 10 degrees.

3. The layout will be more functional if piping is kept to short distances. If for some reason the hot water drum cannot be placed adjacent to the collector, use 1 in. pipe instead of $\frac{1}{2}$ in. If this is not done, the hydraulic resistance of the piping may be so high that natural convectional circulation of the water between absorber and tank will be badly restricted, and the system's efficiency will be severely reduced.

4. Finally, allow the unit to function for at least one day before drawing hot water. This will give the system enough time to heat up. Be sure there is enough water in the system at all times. Too little water can create abnormal heat in the unit and cause considerable damage. If it becomes necessary to empty the system (e.g. to clean it), cover the collector with a sail cloth.

CHAPTER V

STUDY UNIT

An instructional unit on solar energy and its direct use would be valuable to all secondary school students in Honduras. They should become familiar and aware of the many uses of solar energy and its great potential in the solution of human needs in the future.

Objectives of the Course Content

1. To inform students of the history and development of direct use of solar energy.
2. To inform students on recent solar energy theory.
3. To develop with each student an understanding of the importance of a direct use of solar energy and its effect on our society.
4. To provide the students with an opportunity to practice some of their skills and to learn the problems involved in the construction of a solar water heater.

Course Outline

I. Introduction to Solar Energy and Its Direct Use
  - A. History.
  - B. Importance to society today.
  - C. Origin of solar energy, solar radiation in the atmosphere, insolation.
  - D. Applications:
    1. Water heating.
    2. Space heating.

3. Space cooling.
4. Electricity from the sun.

II. Solar Water Heaters

- A. The flat-plate collector:
    1. Materials properties for flat-plate collector construction.
    2. Factors involved in the flat-plate collector efficiency.
- B. The storage tank.
- C. The thermosyphon principle for water circulation in a solar water heating system.
- D. Assembly of components.

III. Shop Activity

Build a small solar water heater unit using mass production technique. This unit may meet the features of the one described in Part III of this paper (Laboratory Activity).

Safety Precautions

- A. During laboratory activities all students must wear safety glasses or goggles.
- B. General laboratory safety:
    1. Physical safety.
    2. Clothing safety.
    3. Tool safety.
    4. Material safety.
- C. Specific safety rules while operating power tools.

Student Evaluation

Students may be evaluated by:

1. Tests.
2. Interest, attitude and cooperation.

3. Class participation.
4. Laboratory work.

Text and References

The following are suggested texts and reference materials that would supply some information needed for the development of the proposed study unit.

1.	C.S.P.I. Energy Series IX	*Solar Energy: One Way to Citizen Control*. Center for Science in the Public Interest, 1757 "S" Street, Northwest, Washington, D. C. 20009
2.	Ewers, William L.	*How To Use Solar Energy*. Sincere Press Inc., Box 17599, Tucson, Arizona 85731
3.	AJA Research Corporation	*Solar Dwelling Design Concepts*. Government Printing Office, Washington, D. C. 20102

Tool Information and Supplies

In a well-equipped shop, no special types of tools are necessary in building a solar water heater. For a particular person who would like to build his own solar water heater, the following information may be helpful.

Tools needed.

1. A pair of metal shears.
2. A rivet gun.
3. A hammer.
4. A hand saw.
5. A simple solder.

Suppliers. All materials and tools needed for the construction of a solar water heater can be obtained from the following store-supply:

1.	Quinchon Leon & Co.	Tegucigalpa D. C.
2.	Sears	Tegucigalpa D. C. and San Pedro Sula
3.	Larach & Co.	Tegucigalpa D. C. and San Pedro Sula
4.	Casa Marrugat	La Ceiba
5.	Ferreteria Valerio	San Pedro Sula
6.	Casa Capeyados	La Ceiba

REFERENCE NOTES

The Association for Applied Solar Energy, World Symposium on Applied Solar Energy, Stanford Research Institute, Menlo Park, California, 1955.

C.S.P.I. Energy Series, Solar Energy: One Way to Citizen Control. Center for Science in the Public Interest, Washington, D. C. First Edition, 1976.

Daniels Farrington, Direct Use of the Sun's Energy. The Colonial Press, Inc., Clinton, Mass. First Edition, 1964.

Energy Digest, Volume VII, No. 24, December 31, 1977.

Energy Research and Development Admin., Look to the Sun, VT-24, Wagner Resource Center, Dept. of Industrial Technology, Univ. of Northern Iowa. 12½ minute color film.

Energy Research and Development Admin., Project Sage, VT-24, WRC, DIT, UNI. 8½ minute color film.

Energy Research and Development Admin., The Solar Generation, VT-35, WRC, DIT, UNI. 33 minute color film.

Energy Research and Development Admin., Sun Power for Farms, VT-24, WRC, DIT, UNI. 12½ minute color film.

Ewers, William L., How to Use Solar Energy. Sincere Press, Inc. Tucson, Arizona, First Edition, 1976.

Kreider, F. Jan and Frank Freith, Solar Heating and Cooling: Engineering, Practical Design and Economics. Hemisphere Publishing Corporation, Washington, D. C. Second Edition, 1977.

McVeigh, J. C., Sun Power. Pergamon Press, New York, First Edition, 1977.

"World Weather Records" 1951-1960.