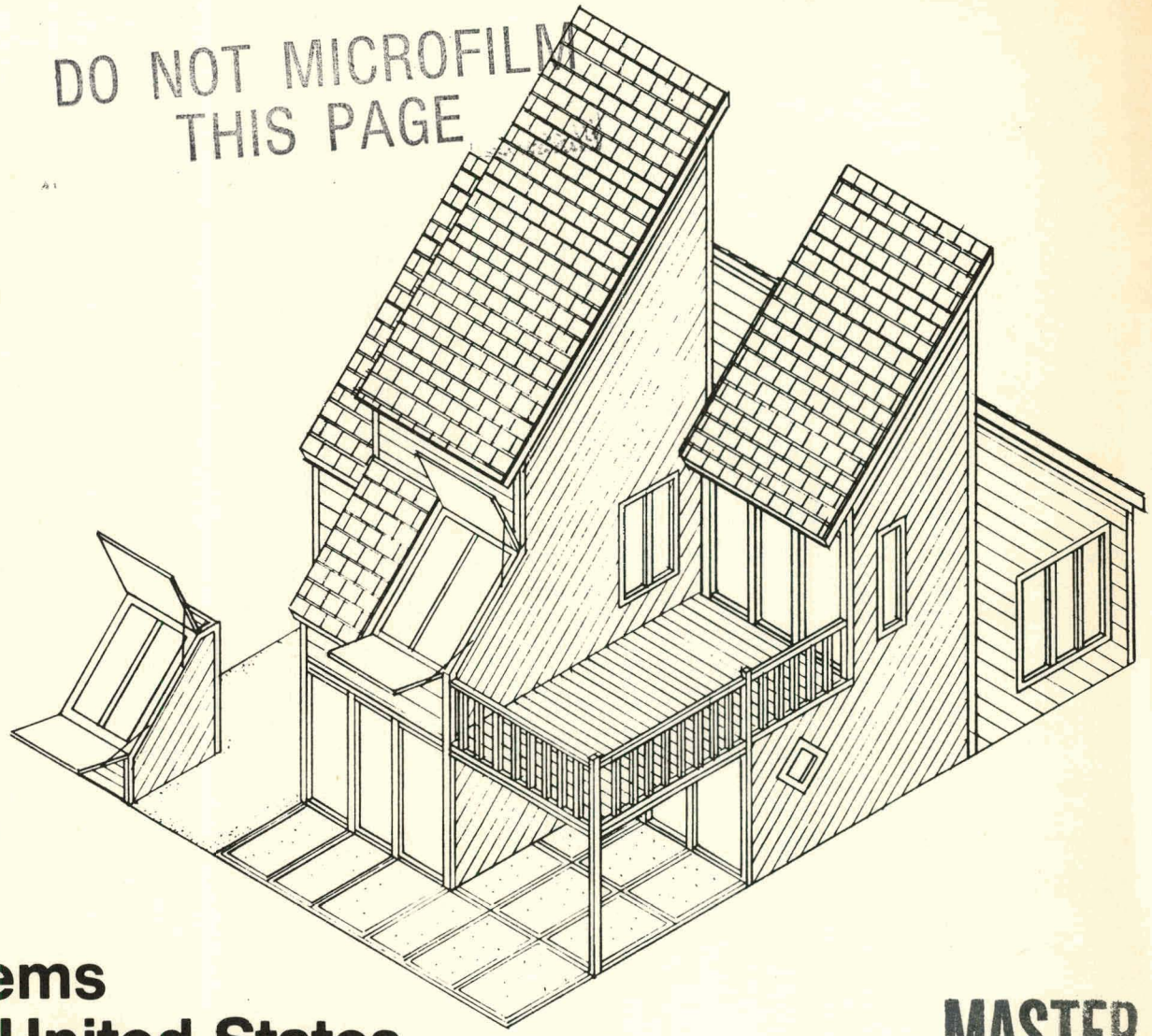
u. s. department of energy
region – IV atlanta, georgia
office of appropriate technology



# Solar Hot Water Systems for the Southeastern United States



# Principles and Construction of Breadbox Water Heaters

## DISCLAIMER

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# Solar-Hot-Water Systems for the Southeastern United States:

# Principles and Construction of Breadbox Water Heaters



Prepared by
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**Atlanta, Georgia**

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## APPROPRIATE ENERGY TECHNOLOGY SMALL GRANTS PROGRAM

Appropriate technology is defined in this book as those technologies for which the level of sophistication involved in producing energy is suited to the task being done. Appropriate technology generally utilizes local skills, tools, and conditions to supply energy for local needs.

The U.S. Department of Energy has offered a small grants program in support of small scale, appropriate technologies. The goal is to encourage development demonstration, and dissemination of information about local, small scale energy technologies.

This book presents principles and methods of breadbox water heater construction which are appropriate in the eight southeastern states included in Region IV. Those states are Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

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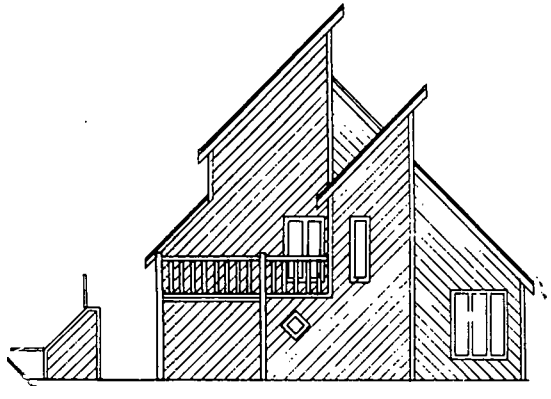
# INTRODUCTION

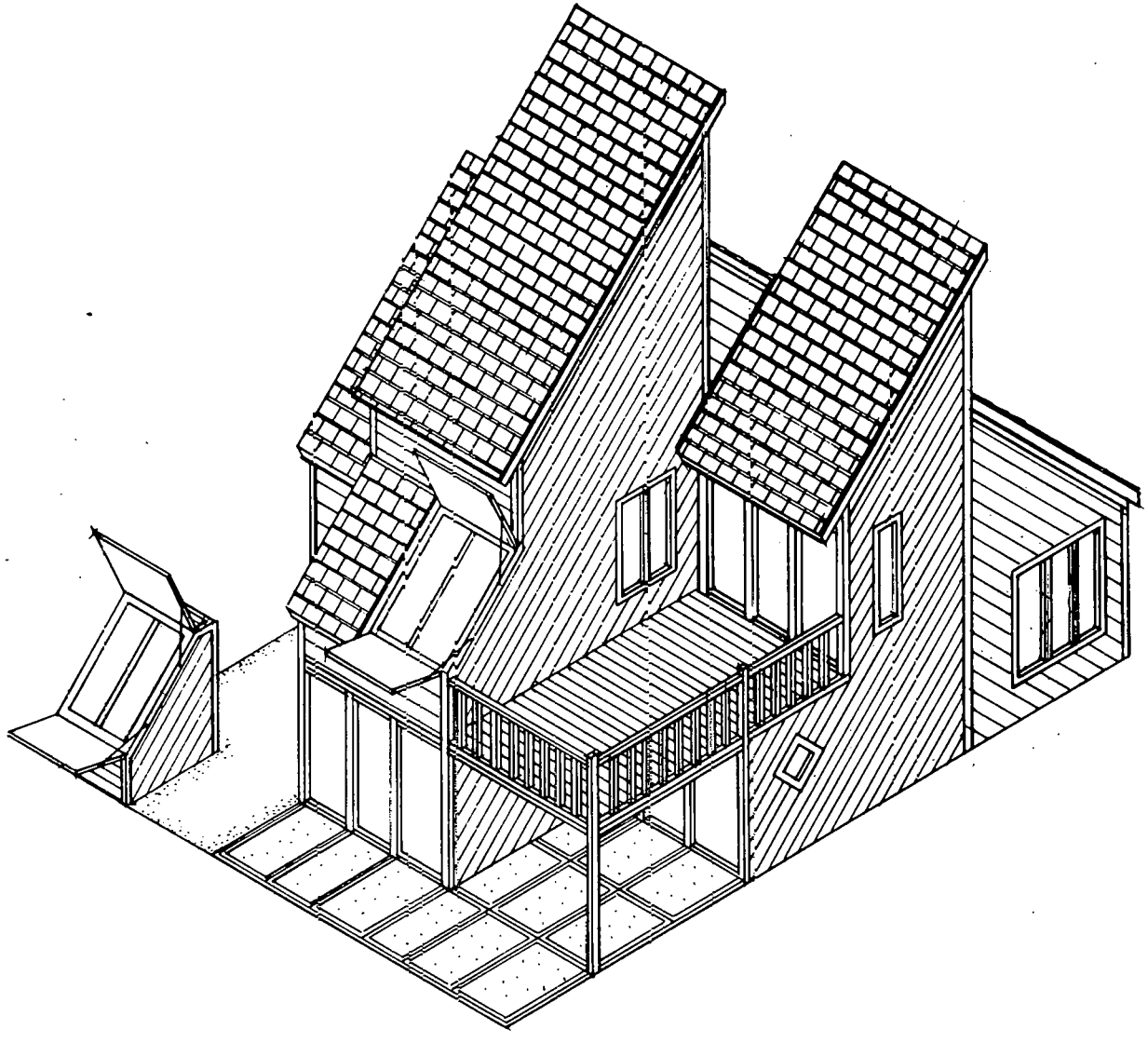
The use of solar energy to provide hot water is among the easier solar technologies for homeowners to utilize. In the Southeastern United States, because of the mild climate and abundant sunshine, solar energy can be harnessed to provide a household's hot water needs during the non-freezing weather period mid-April and mid-October.

This workbook contains detailed plans for building breadbox solar water heaters that can provide up to 65 per cent of your hot water needs during warm weather. If fuel costs continue to rise, the annual savings obtained from a solar water heater will grow dramatically.

The designs in this workbook use readily available materials and the construction costs are low. Although these designs may not be as efficient as some commercially available systems, most of a household's hot water needs can be met with them. The description of the breadbox water heater and other types of solar systems will help you make an informed decision between constructing a solar water heater or purchasing one.

This workbook is intended for use in the Southeastern Unites States and the designs may not be suitable for use in colder climates.





# 1. SOLAR HOT WATER SYSTEMS

## ENERGY CONSERVATION

The first rule of good solar design is to employ wise energy conservation practices. Steps for hot water conservation include adjusting the water heater temperature, reducing usage, insulating the regular hot water heater tank and pipes, and turning down the pilot flames.

Reducing the water heater temperature is usually easy. Gas-fired water heaters have a dial saying "Low, Medium, High," or "120°, 140°, 160°." Electric water heaters sometimes have a metal cover over the thermostat. Upon removing the cover a small dial with a screwdriver slot is revealed. Turn the dial to a suitable setting—for general household uses the recommended temperature range is between 120 degrees and 130 degrees. A dishwasher requires 140 degree water.

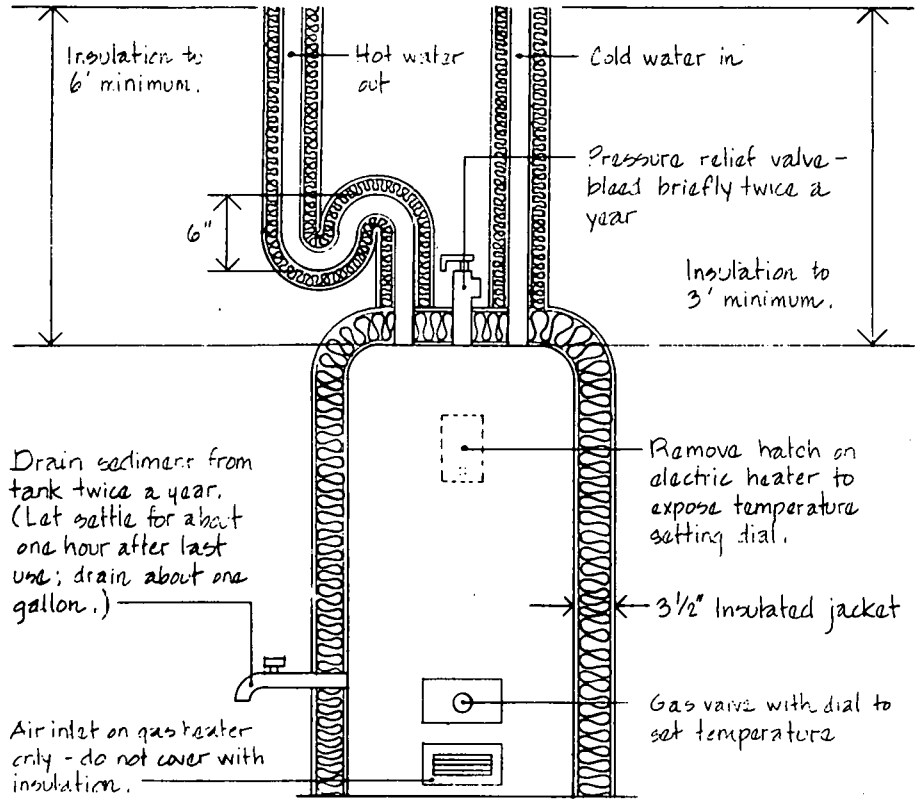
In addition to adjusting the temperature of the hot water, steps should be taken to reduce hot water usage; this provides double savings — consuming less water and using less energy. Low-flow showerheads and faucets, which release water at the rate of two to three gallons per minute instead of the usual six gallons, are an excellent investment. Be sure to repair all leaky faucets and pipes. When washing clothes, set the water temperature on low and use cold-water detergents. Wash only full loads of clothes (or dishes) unless your machine has water-level settings for small loads.

Another important step is to insulate the water heater tank and some of the piping. A water heater insulation jacket can be purchased from a building materials store or fiberglass batt insulation can be wrapped around the water heater tank. In either case, do not block the air inlet and exhaust ports on a gas water heater. Otherwise, you risk the danger of fire emanating from the water heater's burner.

A few feet of both the hot and cold water pipes should be insulated near the water heater, especially when the system has copper pipes. Although it may seem odd to insulate the cold water inlet pipes, it is recommended because hot water can rise into the pipes from the water heater. Once the hot water enters the uninsulated pipes, it quickly gives up its heat, wasting energy.

If the regular water heater is gas-fired, turn down the pilot light as low as it will go without blowing out. When the burner ignites visually verify that the flames are blue, not yellow. A yellow flame on any gas appliance indicates improper and inefficient combustion and should be corrected.

A timer could be a good investment for an electric water heating unit. The timer deactivates the water heater during periods of little or no usage and reactivates the water heater to provide hot water when needed. The savings from a water heater timer can run 30 per cent or more.




'THE WELL-DRESSED WATER HEATER

## SOLAR ENERGY PRINCIPLES

After you have conserved all the energy you can around your hot water system, the next step is to create or harness additional energy from sources such as the sun. The basic solar principle used by the solar water heating designs in this workbook is called the greenhouse effect. You have experienced the greenhouse effect if you have ever left a car parked out in the sun with the windows rolled up. The temperature inside can quickly exceed 130 degrees, which is sufficient for heating your household water.

The reason the temperature rises is that glass, plastics and other glazings transmit light energy rather freely, but heat energy does not travel through as quickly. When sunlight enters an auto as short-wave light energy, it strikes the interior and is converted to long-wave infrared radiation, otherwise known as heat energy, and is trapped within. The temperature rises as the sunlight continues to beam through the car's windows until the rate of heat escaping equals the rate of heat entering.

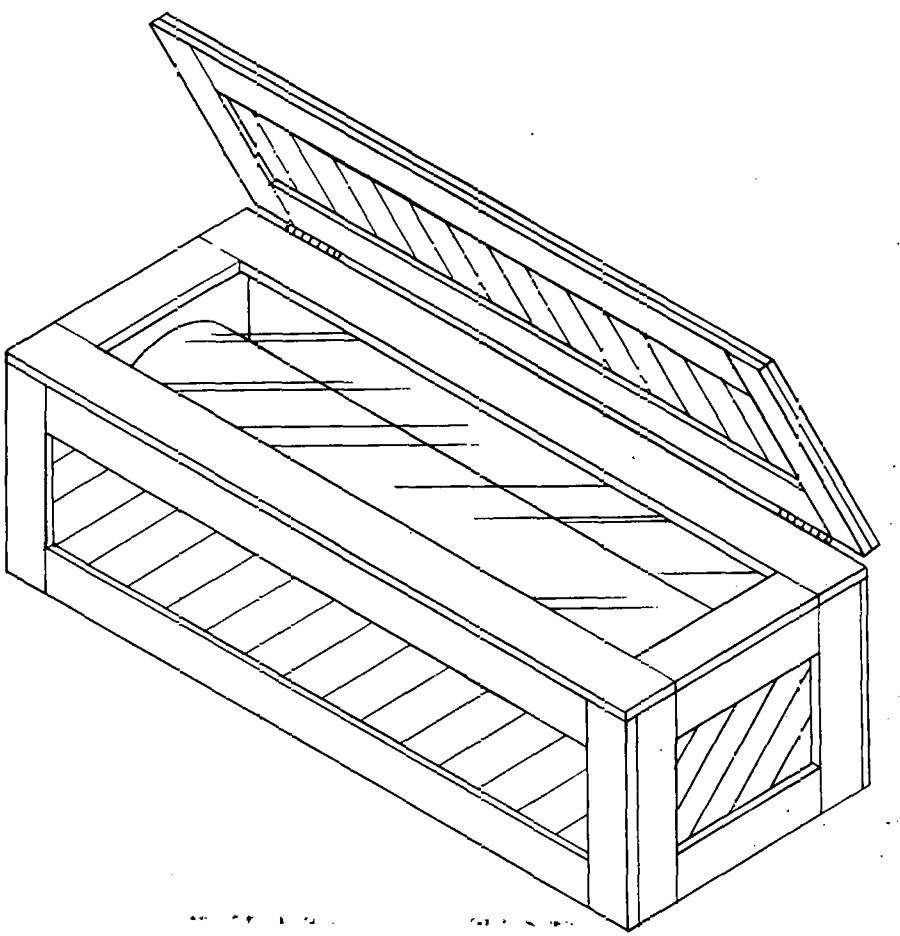
If, instead of a car, we were considering a glass-covered box, the same thing would happen. A thoroughly insulated, tightly built box, with energy absorbing surfaces, could produce temperatures approaching several hundred degrees. These kinds of boxes are called solar collectors.

To take advantage of the heat gained by the greenhouse effect for a water heating system, you must have an efficient means of transferring the heat from the box to the plumbing system. One way is to place water storage tanks in the collector itself. The sun hits the tanks directly and heats the water inside. The heated water is then fed into the regular water heating system. This kind of design, called a breadbox water heater, has some special advantages and disadvantages which are discussed in this workbook. Another way is to install piping inside a solar collector and let the heated water rise into a storage tank. This kind of design is called thermosiphon water heater.

## SOLAR WATER HEATING DESIGN OPTIONS

The breadbox water heater is the simplest and least expensive kind of solar water heater to build. However, because it contains the water storage tanks, the breadbox is a rather large and heavy unit. Shutters which cover the breadbox must be opened in the morning and closed at night.

The way a breadbox water heater works is straightforward. Water enters the storage tanks in the breadbox to be preheated and then goes to your regular water heater. When

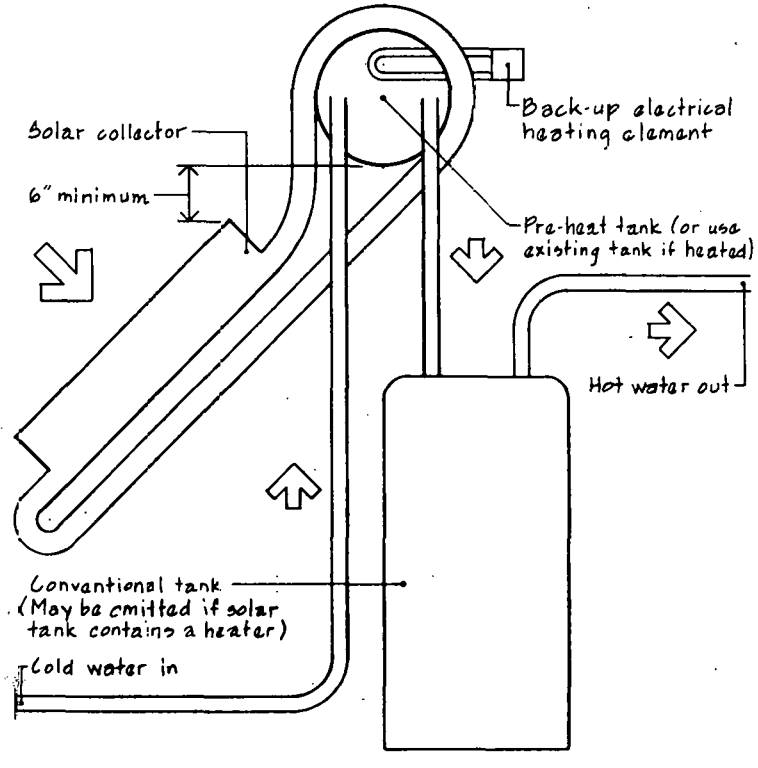


the solar-heated water is sufficiently warm, the burner in the water heater does not ignite. If the water coming from the breadbox is not hot enough, the regular heater boosts the temperature to the desired level.

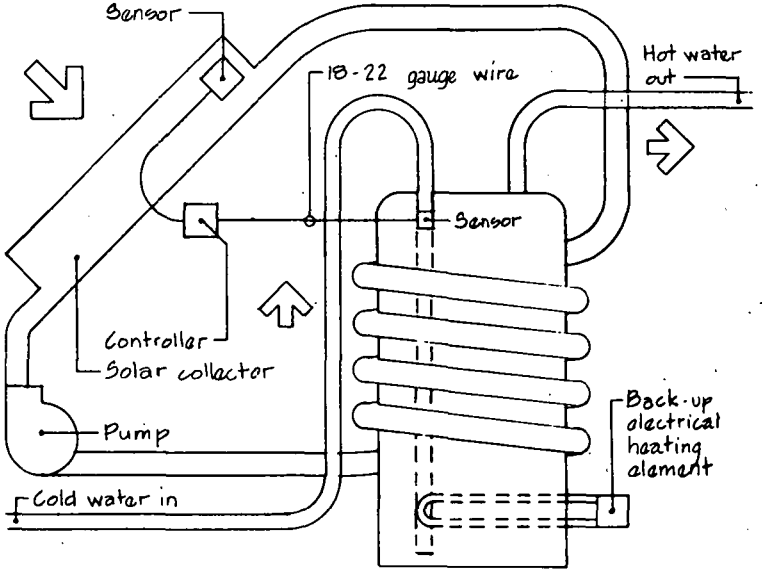
Thermosiphon water heaters use the power of convection, heat rising, to circulate the water. The storage tank must be higher than the collectors so that the water heated in the collectors will rise into the tank. Cooler, heavier water at the bottom of the tank sinks back into the collectors for reheating. Once the water is heated by the sun, it rises again into the tank. The process is automatic, fail-safe, consumes no external energy and is dependent only on the proper placement of the collectors and storage tank.

Another kind of solar water heating system is called an active system. It is nearly identical to the thermosiphon system except that it requires a pump, temperature sensors and controls. Active systems are available commercially and require more construction skills than the average person possesses.

The Bibliography contains several sources that explain how to build thermosiphon and active systems. Check your local library for other books on these subjects. Several solar catalogs, such as the "People's Solar Sourcebook" and the "Solar Components Catalog" have descriptions of books and kits available for building active solar water heaters. Kits usually come with manufactured collectors tanks; you just have to mount the collectors, install the tank and connect the plumbing and wiring.




THERMOSYPHON SYSTEM




ACTIVE SYSTEM

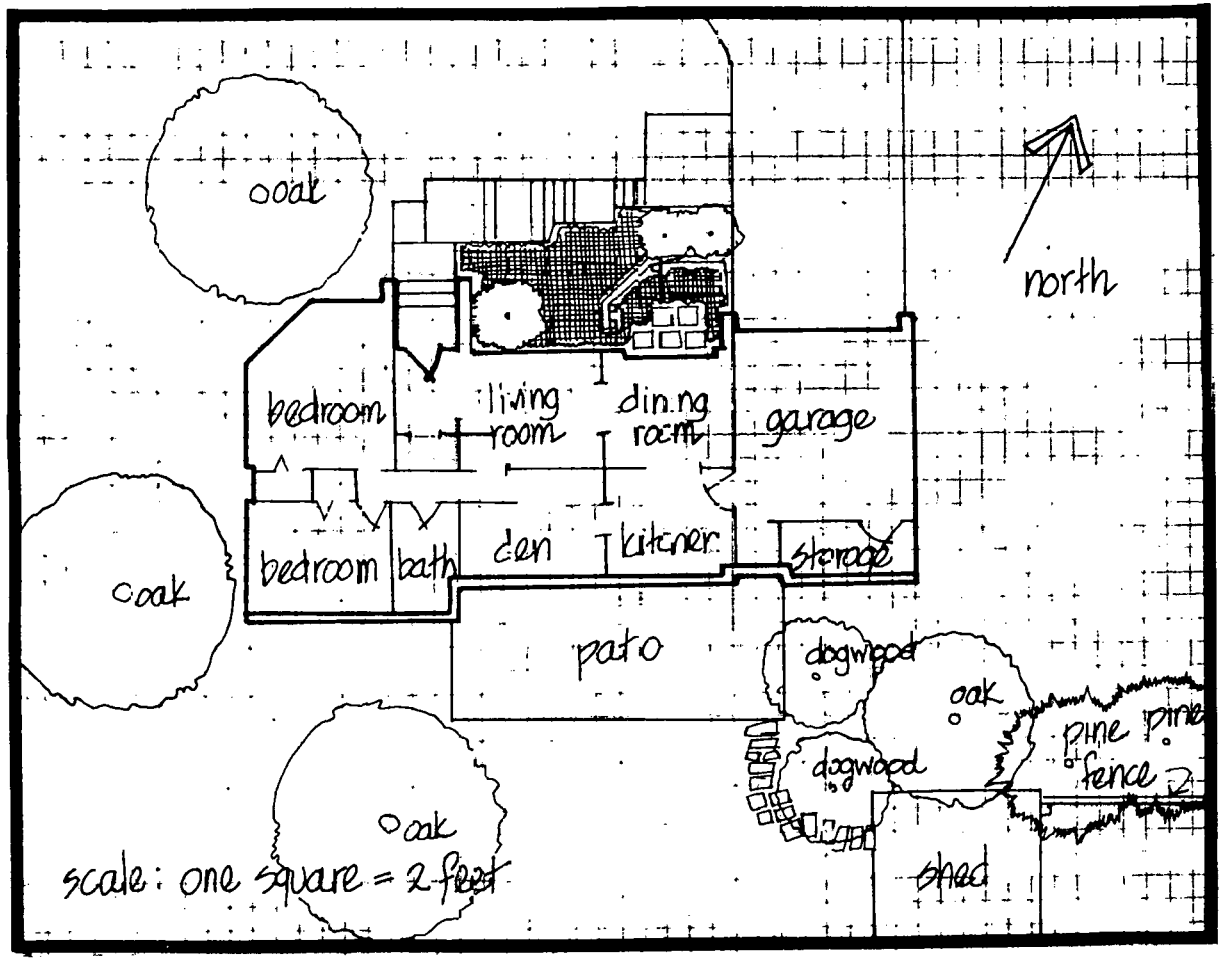
## SOLAR SITE SURVEY

A good site is a necessity for the performance of a solar hot water system. The glazing on the system must face south and remain unshaded most of the day during the months when you plan to operate your solar water heater. A solar site survey will help identify good sites. The materials needed to conduct a site survey are:

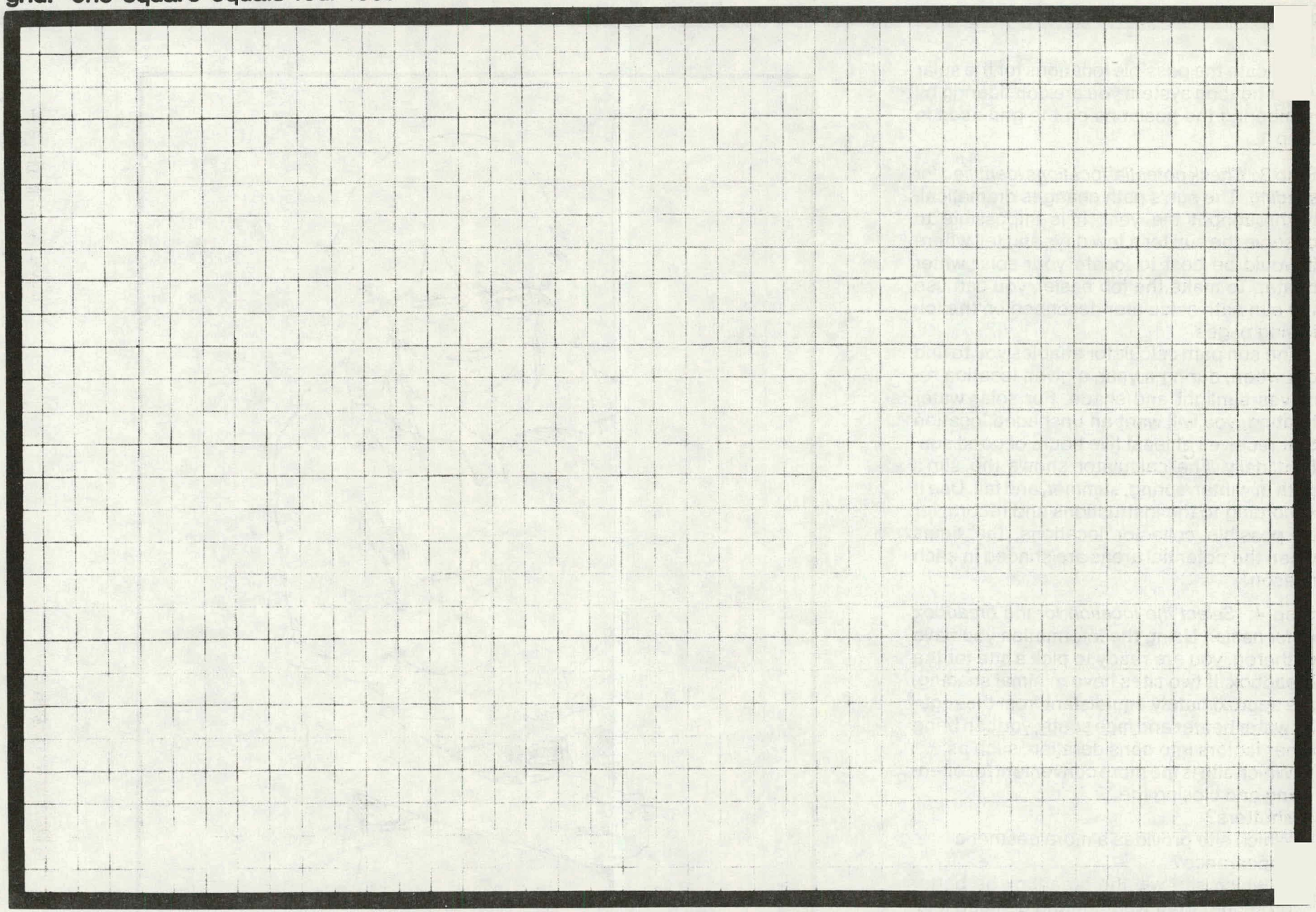
Directional compass
Tape rule
Scissors
Ruler
Piece of clear acetate transparency, 10" by 17"—5 mil
Black china marker with a hard point
Scotch tape
Piece of stiff cardboard or posterboard, 6" by 10"
Pencil
2' Level (for measuring roof slope)
Way to reach roof (for example, a ladder)

Step 1: *Draw plan of lot and directional orientation of house.* Sketch your lot and house on the grid below. Using a compass, find south. Draw an arrow pointing due south on the grid. Also draw any possible obstructions to incoming sunlight, such as trees, buildings, hills, etc.

Step 2: *Identify possible locations for the breadbox solar water heater.* The breadbox has a great deal of flexibility in location. It can be placed on the ground, on a roof that can support its approximate 700 pounds or within a clerestory. The breadbox water heater must face south, have access to sunlight and be relatively close to your existing water heater tank. Any questions as to whether your roof can support the weight of a breadbox can be answered by an architect, building engineer or knowledgeable builder.



grid: one square equals four feet



Draw the outline of your house and locate trees, walks, etc. here. Add an arrow pointing north; make the most southerly wall extra dark.

Indicate the possible locations for the solar water heating system you are considering by numbering the positions on the grid used in Step 1.

Step 3: *Check potential locations identified for shading.* The sun's path changes dramatically throughout the year. It is impossible to observe the sun for a few days and tell where it would be best to locate your solar water heater. To make the job easier, you can use the sun path calculator described on the following pages.

The sun path calculator enables you to find out when, during a year, a given location receives sunlight and shade. For solar water heating, you will want an unshaded location that receives at least five hours of good sunlight daily. The calculator shows the sun's path in winter, spring, summer, and fall. Use it according to the instructions and record, for all possible collector locations, the times when the potential areas are shaded in each season.

Step 4: *Select the location for the breadbox water heater.* Using the information you have gathered, you are ready to pick a site for the breadbox. If two sites have minimal shading, are approximately equidistant from the regular water heater and face south, you can bring other factors into consideration, such as:

- Which site is the more convenient for opening and closing the shutters?
- Which site provides a more aesthetic appearance?
- In which site will the breadbox be better protected from weather and damage (e.g. from children playing nearby)?

## SUN PATH CALCULATOR

The sun path calculator is a tool that enables you to evaluate the shading characteristics of your lot and home. The calculator is a simple, hand-held device that shows the approximate position of the sun through out the entire year. When facing due south from a particular spot, you will be able to see how much sunlight strikes that spot in every month of the year. If used according to the instructions, the sun path calculator will reveal the suitability of a given location for any solar application.

The Sun Path Calculator has two components — a semi-rigid base and a sun chart. To make the base, start with a piece of thin posterboard, flexible enough to fold and crease. Use the pattern shown below to cut, fold, and tape together the base. Follow the steps listed.

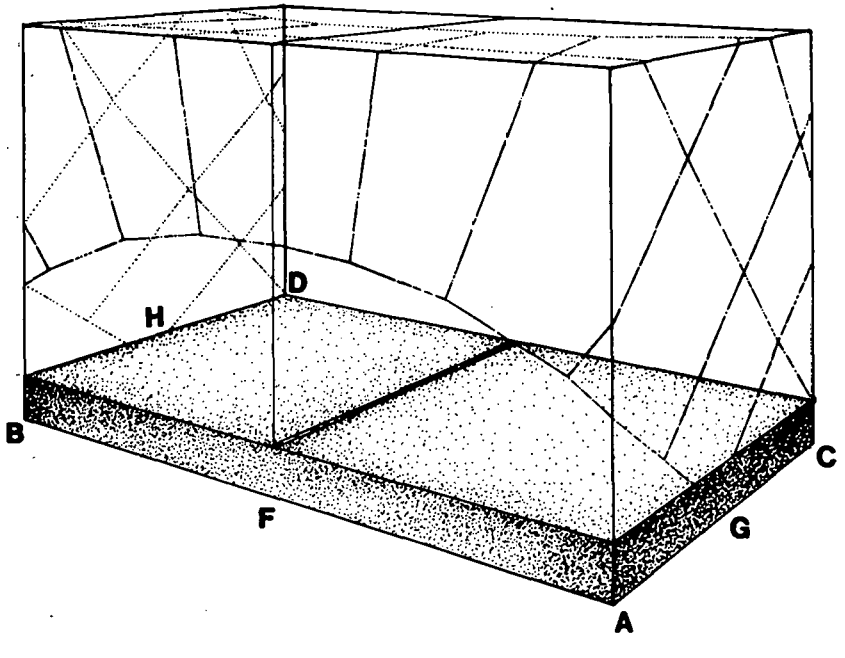
1. Cut material to size. Draw "middle line" onto base as shown on pattern.
2. Cut notches A, B, C, & D.
3. Fold and crease along lines AB, BD, CD, and AC.
4. Tape the corners formed at each notch.

Now make the sun chart, using the chart which most closely approximates your site's latitude. The chart is covered with lines that represent the sun's path during different times of the year. In order to see through the calculator, you will need to use a hard marker and copy the sun chart onto a sheet of clear .005" acetate or other clear material.

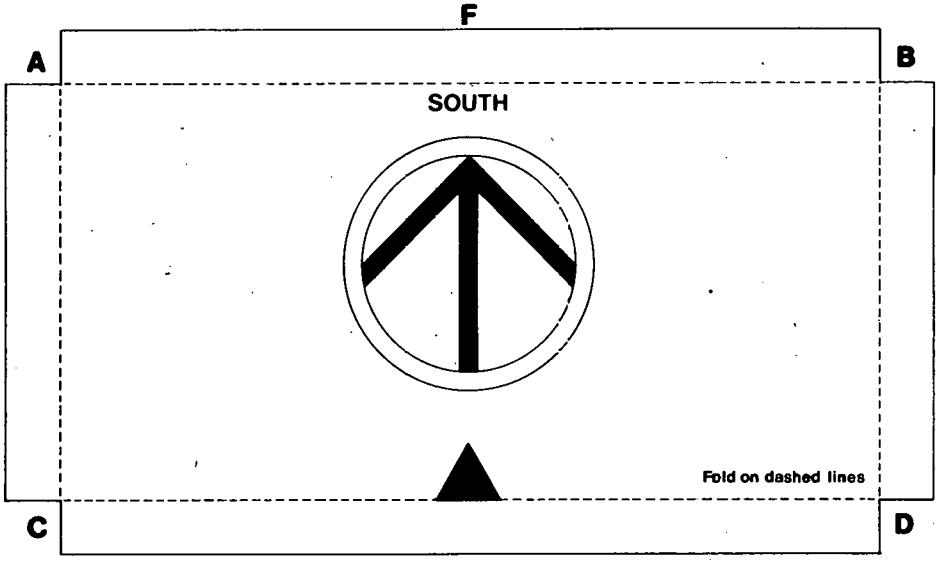
The sun chart needs to be transparent so that you can see objects that may block incoming sunlight. Use the instructions below to put the sun chart on the base of the sun path calculator:

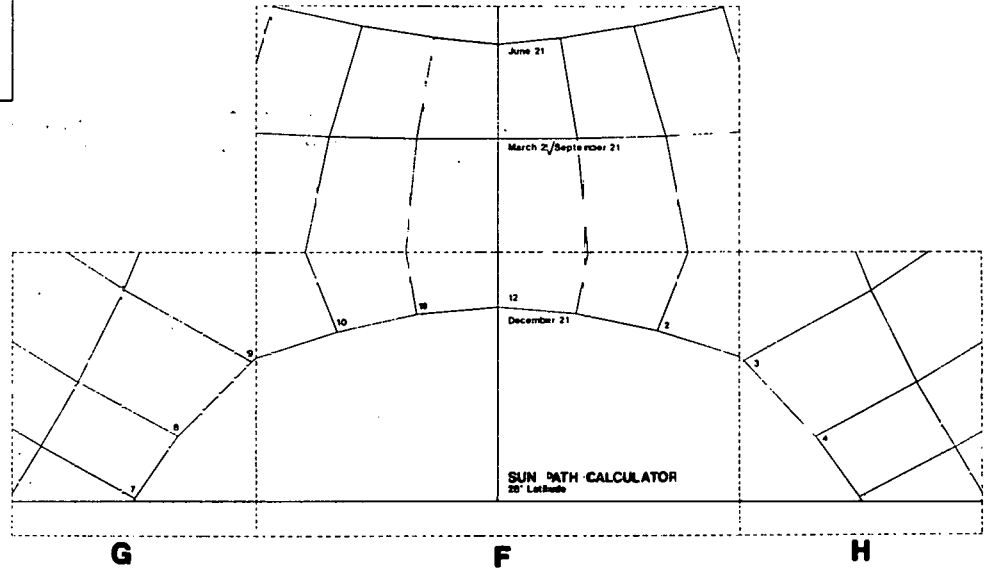
1. Cut out the shaded portions of the sun chart.
2. Fold and crease along the dashed line on each side and at the top.
3. Tape or staple the front edge (section F) of the sun chart to the long edge of the base (Section F of the base).
4. Tape or staple side edges (Sections G and H) of the sun chart to the short edge of the base.
5. Fold down the top section of the sun chart and tape its sides to the upper edges of each side of the chart.

Patterns for sun path calculator materials and assembly are included at the rear of the book.



# SAMPLE SUNSPACE CALCULATOR COMPONENTS




**Sunspace Calculator patterns are included in the back of this booklet**

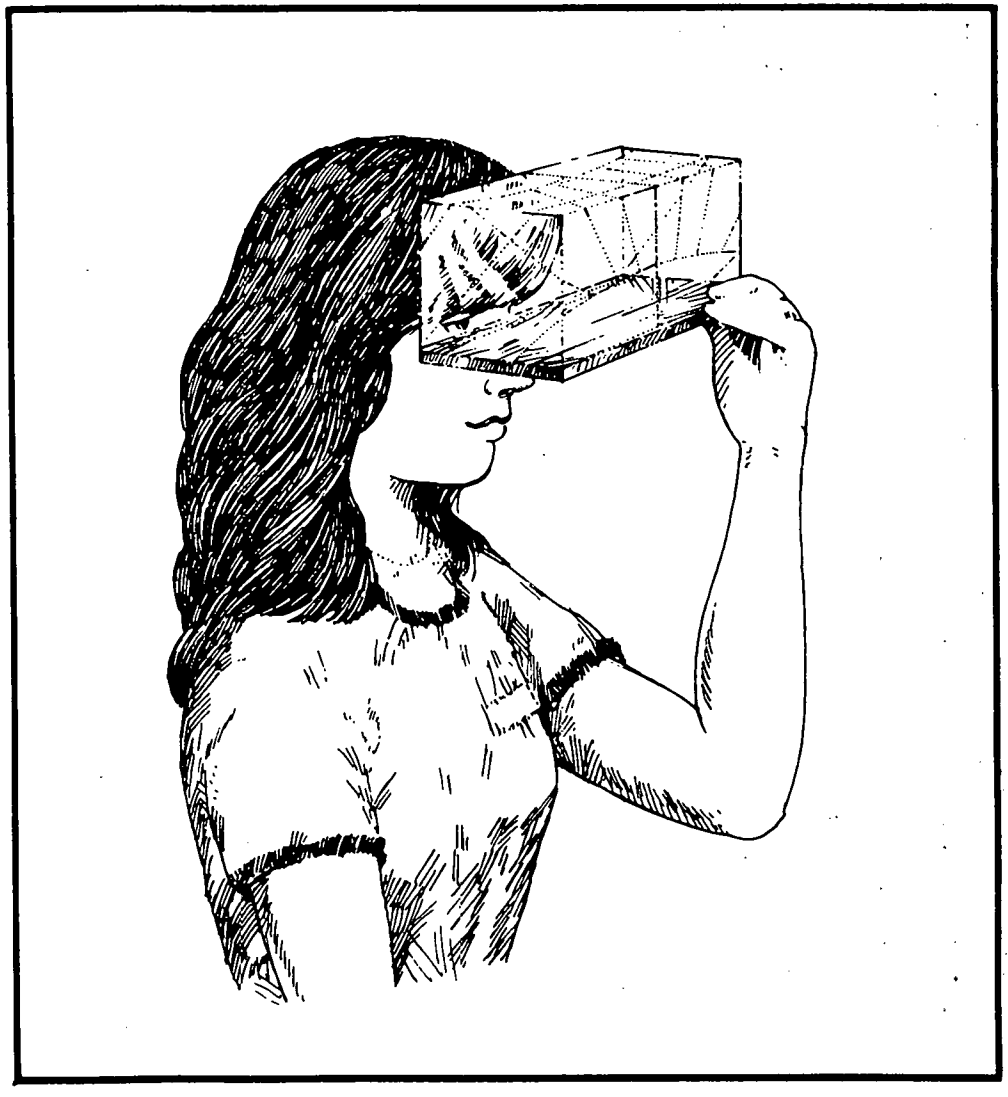
## USING THE SUN PATH CALCULATOR

Keep several things in mind as you use the sun path calculator: 1) the base should be horizontal at all times (a level can help here; you could even make the base out of wood and use a tripod to ensure more accurate readings); 2) the due south middle line on the base should point due south at all times; otherwise, you will get a poor picture of how the sun actually moves; 3) use only one eye to sight through the calculator and keep the eye on the middle line.

At the site, stand with your head at the same level and at the location you want to evaluate. You may have to crouch or stand on a step ladder to bring your eyes to the right level. Using the calculator works easiest if you have someone write down the readings as you call them out.

Once you are in the proper position to begin sighting, place one eye (the open one) right at middle line of the base. For solid objects, note the times during which the sun will be obstructed — times are indicated by the dashed lines slanting down toward the curved, solid sun path line. Call these times out to the recorder.

Next, sight along the spring/fall and summer lines following the same procedure. After recording all the shaded times for this site, move on to the next site that you are considering. One note about sighting along the high, summer line is to keep your cheekbone touching the base and your open eye on the middle line in order to ensure an accurate reading.



## COLLECTOR SLOPE ANGLES

The south-facing glazed surface of the solar water heater should ideally slope at an angle equal to your latitude. Fortunately, quite a bit of variation from the ideal still produces good results. For instance, a range in the collector slope of plus or minus 15 degrees will make very little difference in performance. The map shown in Figure 2 suggests optimum slopes for solar collectors that are used for water heating.

## DECIDING WHETHER TO BUILD OR BUY

Once you select the type of solar water heater you want and know where you would like to put it, you must determine how much of the work you want to do yourself. If you possess basic skills in plumbing and carpentry, you will have no trouble building and installing your own system, and you will derive a good deal of satisfaction in the process. If you do not have these skills but aspire to obtain them, now is a fine time to begin learning. However, building and installing solar water heaters is not simple, and the designs contained in this workbook are probably not the best place to start on your own. You may be able to find a skilled person willing to work with you as your learn.

Another way you might consider building is by organizing a series of workshops with people who do have the skills required and, in a round-robin fashion, helping each other build solar hot water systems.

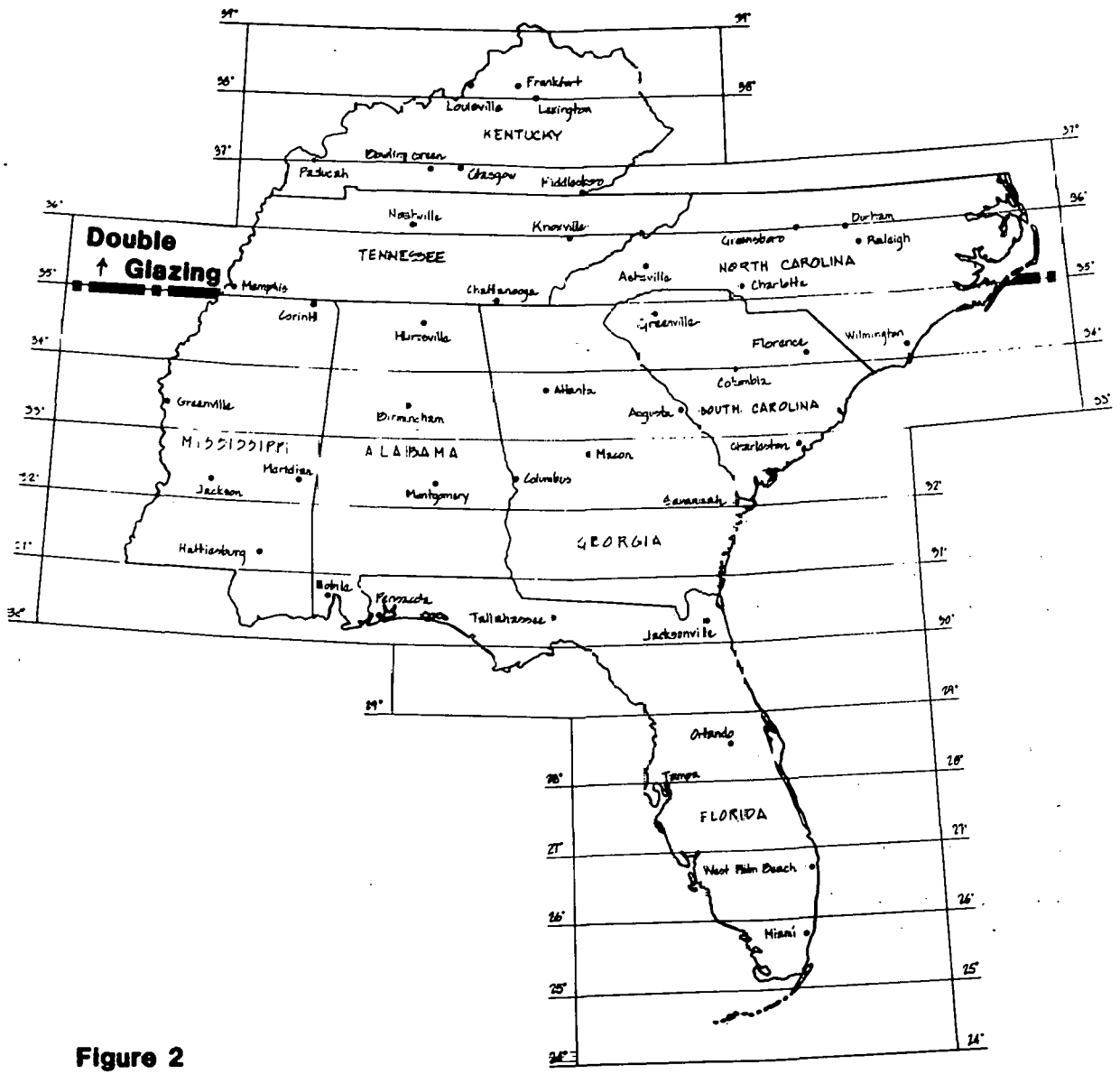
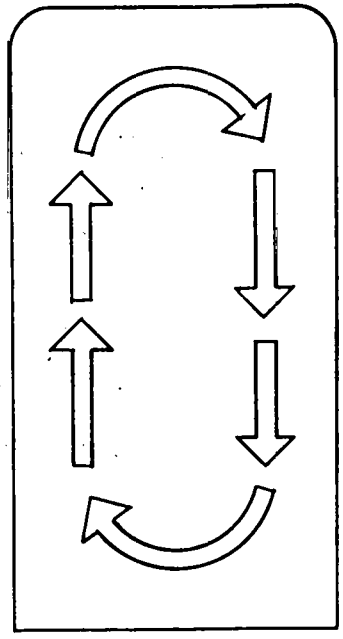



**Figure 2**

# 2. BREADBOX WATER HEATERS

A major consideration in breadbox water heater design, after siting, is the number and position of the water storage tanks. Early breadbox designs used single horizontal tanks laying inside an insulated box. The horizontal breadbox works well, but its performance improves when the tank is in an upright, slanted position so better thermal stratification can occur. Thermal stratification is the tendency of hot water to congregate at the top of the tank and cooler water to drop to the bottom. Good thermal stratification enables an upright, slanted tank to supply hotter water to the house than a horizontal tank.



To determine the size of your breadbox, you need to know how much hot water you use. Families generally consume 20 gallons per person each day. Two 40-gallon tanks in a breadbox water heater can supply the daily needs of a family of four.

This chapter discusses the various components of the breadbox in detail. The steps for construction are shown with drawings. Instructions for operating and maintaining the finished breadbox follow and a list of materials appears at the end.

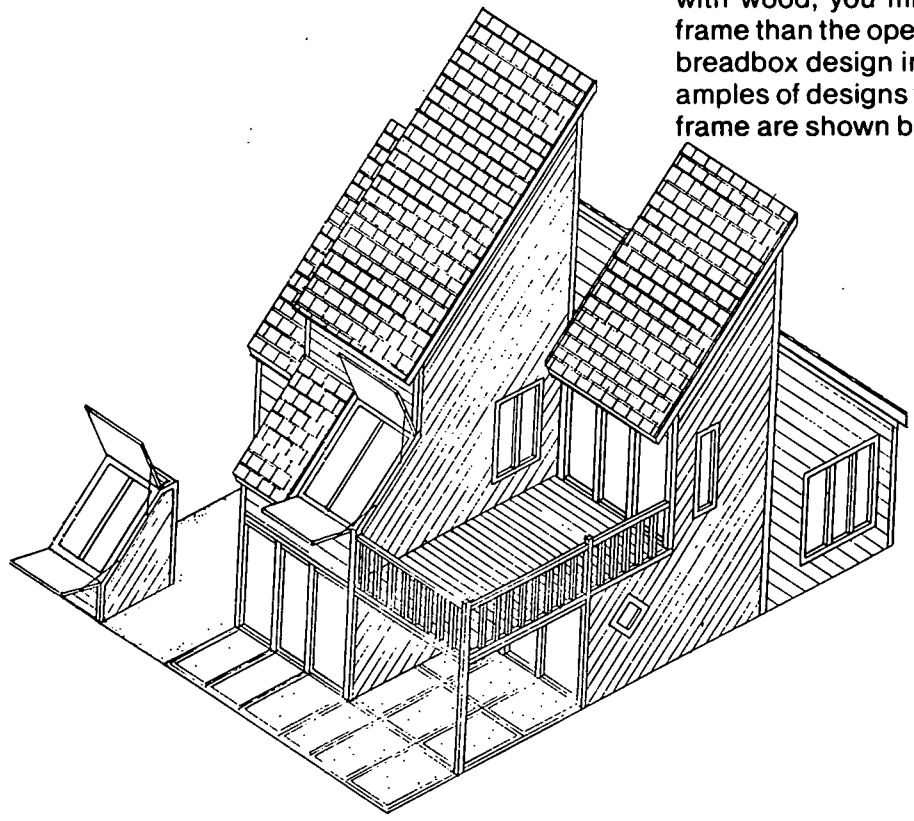
## INSULATED BOX AND STAND

The insulated box and stand form the major structural element of the breadbox water heater. The box houses the water tanks and should be insulated to a value of at least R-10 on the sides and the bottom. The top will be covered with one layer of glazing.

The stand should be constructed of pressure-treated lumber. For ground-mounted systems, the stand should be set on concrete block footings or bolted to posts anchored into the ground with poured concrete. The construction drawings show a simple design for the stand. Table 1 shows how to compute the stand's dimensions.

The box attaches to the stand so that the glazing is tilted at the optima slope indicated in the Collector Slope Angle section of this workbook. The space under the box can be used as a storage area for such implements as lawn mowers and garden tools.

Numerous options exist for the construction of the breadbox frame. If you like to work with wood, you might want to build a nicer frame than the open one shown as part of the breadbox design in the workbook. Some examples of designs for the completed box and frame are shown below. The drawings depict



roof-mounted breadboxes as part of an existing structure; remember to ascertain whether it can support the storage tanks, which when filled with water weigh 300 pounds each. A two-tank breadbox hot water system, when operational, can weigh 850 pounds.

TABLE 1
STAND DIMENSIONS FOR OPTIMAL SLOPE

| | Stand Dimensions | |
|---|---|---|
| Latitude | Height | Length |
| 28° | 3.7′ | 4.7′ |
| 30° | 3.9′ | 4.6′ |
| 32° | 4.0′ | 4.5′ |
| 34° | 4.2′ | 4.3′ |
| 36° | 4.3′ | 4.2′ |
| 38° | 4.4′ | 4.0′ |
| 40° | 4.6′ | 3.9′ |

In order to tilt the breadbox at the desired slope angle for your latitude, simply build the frame to the dimensions shown. When you bolt the breadbox to the frame, it will tilt at the proper angle.

## STORAGE TANKS

The storage tanks can be the most expensive single component of the breadbox water heater. Tanks can be purchased new or in used condition. The least expensive tanks are those from discarded electric, glass-lined water heaters. You should use glass-lined tanks instead of galvanized tanks, which may rust. Test any used tank for leaks. To perform the test purchase two fittings, one which connects to a garden hose from the inlet side of the water heater and another which plugs up the outlet side. Turn on the garden hose water and see if any leaking occurs. If so, look for another tank. If you cannot find a suitable used tank to recycle, purchase an inexpensive new electric water heater.

Prepare the tank for use in the breadbox by tearing off the outer skin and insulation. Clean the bare exterior with a wire brush or sandpaper and paint the tank with a flat-black, heat-resistant paint. Two types of paint are suitable. Spray paint intended for high-temperature applications, such as exhaust manifold paint, is relatively inexpensive and effective.

A more efficient, but higher cost option is a selective surface coating. Selective surfaces coatings reduce the amount of heat emitted from the warm tank. It is best to apply these kinds of coatings in very thin layers. Emissivity, the measure of how easily a breadbox water heater loses heat through radiation, can be reduced from .93 to .45-.60 with a selective surface paint.

A more effective selective surface product is a special foil that can be attached to the breadbox tank. The foil cuts the emissivity of the tank to .10-.15. However, the foil is even more expensive than the selective surface paint. The resource list contains sources for selective surface products.

## PLUMBING

There are many good books available that explain how to do basic plumbing. These should be consulted if you have little plumbing experience. The breadbox water heater can be plumbed with copper, galvanized or plastic piping. Copper is the most expensive and requires experience to install, but it does not corrode like galvanized, which is much easier to install.

There are two types of plastic piping which can be used. These are chlorinated polyvinyl chloride (CPVC) piping and polybutylene tubing. Both are easy to use.

CPVC piping is the more common of the two plastics anc is very simple to install. A few pointers on working with this material are:

- Joining CPVC is accomplished with a special cleaner and a CPVC solvent.
- Pipe lengths and elbows are joined by brushing the outside of the pipe and the inside of the elbow with the cleaner. The solvent is applied to the same area. The two pieces are pressed together, turned a quarter of a revolution, and held together for 30 seconds. This gives a watertight seal that can withstand normal water pressures.
- If a leak occurs the joint cannot be disassembled. The pipe must be cut, the pieces discarded and the joint made with new pieces.

The other plastic piping option is polybutylene tubing. Polybutylene is a very flexible product. Making joints requires either a relatively expensive crimping tool or the use of fairly expensive fittings. The major advantage of polybutylene is its resistance to damage if the water in it freezes. Because of the susceptibility of exterior breadbox piping to freezing, polybutylene is desirable for these applications. However, it is a new product, and may not be carried in many hardware or plumbing stores. Polybutylene can be ordered from several national distributors indicated in the resource list.

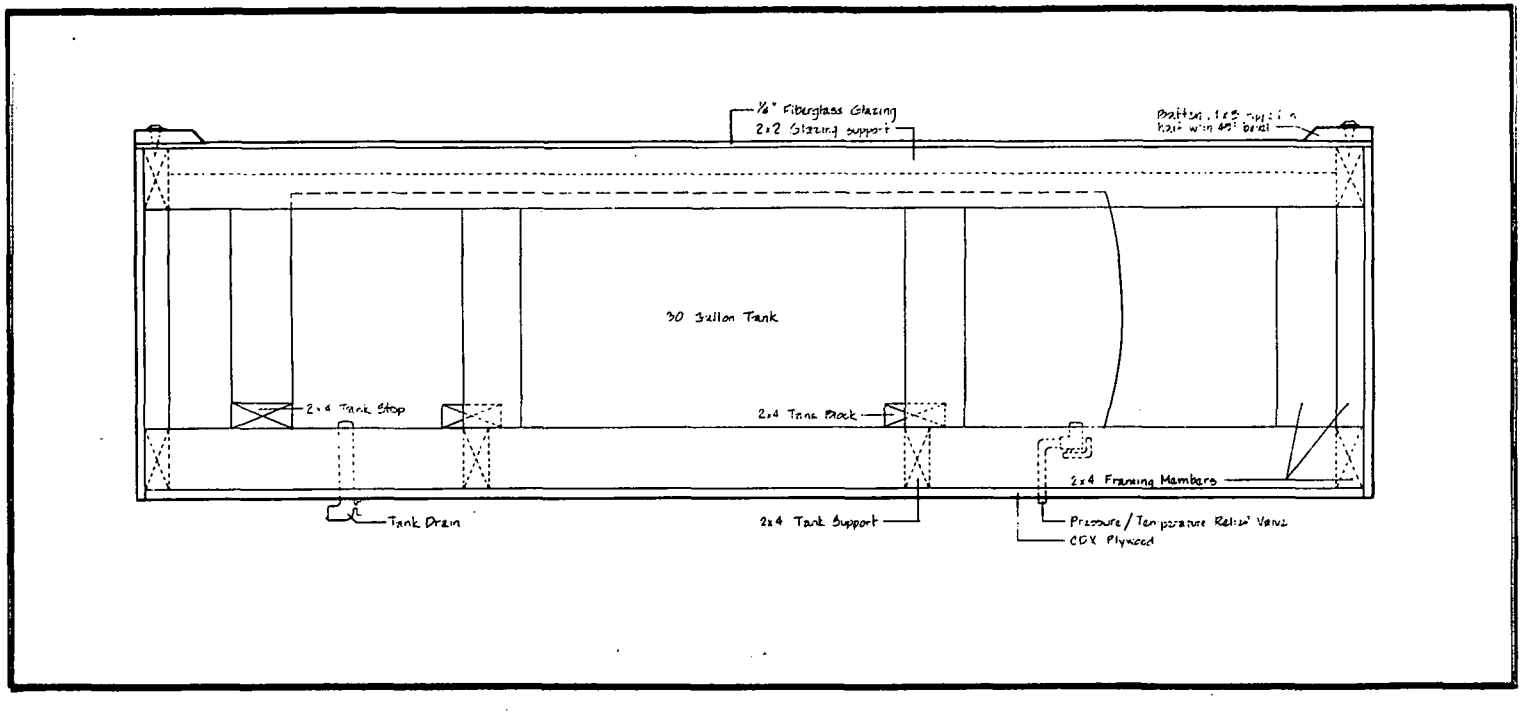
Either type of plastic piping degrades when exposed to the ultraviolet rays of the sun. Therefore, insulation must be put over the piping inside the breadbox. Since pipe insulation may also deteriorate, the insulation must be painted or covered with aluminum tape, the kind used in heating systems. Duct tape should not be used inside a breadbox water heater because it loses its adhesive properties very quickly in extreme temperature conditions.

## GLAZING

The clear surface used to cover the breadbox is called glazing and can be glass or plastic. The designs illustrated in this workbook use fiberglass-reinforced polyester (FRP) glazing. Several FRP products are designed specifically for solar applications. Fiberglass and plastic glazing products decay when exposed to the ultraviolet rays of the sun; the best kind to use are premium grade FRP products rated to last 20 years. Periodically the fiberglass glazing must be checked for the yellowing or roughness that indicates deterioration. If decay is detected, a FRP weatherable surface coating should be applied to further protect the material.

Glass is the most resistant of all glazing options to ultraviolet radiation. Tempered glass should be used for breadboxes because of its strength. Some solar and glass distributors sell factory-seconds of large panes of tempered glass at lower prices per square foot than FRP glazing. However, tempered glass is more difficult to install because you cannot nail or screw through it. Tempered glass is also heavy and cannot be cut; the size of the glass determines the outer dimensions of the breadbox.

In colder areas of the southeast, you should use two layers of glazing to cover your breadbox. See the map on page 14 to determine whether you need double glazing.



## FREEZE PROTECTION

In most of the southeast, it is unlikely that the water in the storage tanks of the breadbox will freeze, but water in the pipes going to and from the regular water heater may freeze. Three options exist for protecting your breadbox from freeze damage in the winter: 1) drain the breadbox when cold weather approaches; 2) use electric heat tape, very heavy insulation and earth covering for piping runs; 3) use polybutylene tubing and insulate heavily.

Draining the breadbox is the safest option. Table 3 shows the time of the first and last freeze in various locations in the Southeastern United States.

A system not drained during the winter encounters the risk of freezing damage. Several measures can reduce the likelihood of damage. Use of heat tape on all piping is a first step, especially for exterior pipe runs. Be careful not to let any portions of the heat tape cross or an electrical fire could result. Heat tape should not be applied to polybutylene tubing.

Two options exist for protecting the tank. One or the other should be applied in all areas north of the double-glazing line shown on the map on page 14 unless you plan to drain the tanks before freezing conditions occur. One measure is to use the electric elements inside the tanks used in the breadbox. Set their thermostats to a very low temperature, such as 40°F. Call your local electric utility or a heating contractor if you do not know how to adjust the thermostat.

## SHUTTERS

Nighttime shutters seal the heat collected during the day inside the breadbox. The shutters have interior reflective surfaces which, when open, bounce additional sunlight into the breadbox. Opening the shutters in the morning and closing them in the evening is an easy and important task in insuring proper function of the breadbox.

Shutters should be durable, well-constructed and as lightweight as possible. Double shutters, such as those presented in the construction drawings, are smaller, lighter and therefore easier to handle manually than single shutters that fit over the entire glazed surface.

If you want to open and close the shutters without going outside, you can use a system of cables and pulleys. In such a system, gravity will close the shutter, and the pulley will open it. A single shutter or hinged shutter on a track needs only one pulley assembly; double shutters need two or three assembles.

Several options are available for the construction of shutters and for the mechanisms by which they open and close. You must select a shutter design suitable for your lifestyle. If you are unable to operate the shutters at the proper time, the performance of the breadbox may not be satisfactory and a more automatic solar water heater, such as a thermosiphon or an active system may be considered.

Seasonal adjustment of the shutters will further enhance the performance of the breadbox water heater by properly reflecting the sunlight onto the tanks. For the manual shutters presented in this workbook, the angles that the upper and lower shutters should make with the horizontal are shown in Table 2. It is not difficult to provide for the seasonal adjustment once the shutters are hinged to the breadbox.

Automatic, motor-driven shutter controllers are also possible. For example, one designer uses a windshield-wiper motor to open and close a breadbox water heater. Motors can be operated by timers, temperature or sunlight-sensitive controls, or manual switches. Mechanical controllers increase the cost of the breadbox, but they add convenience. These types of controllers must be custom-made since they are not available commercially.

Shutters built of wooden framing and plywood sides are the most durable and the easiest to build. However, they are heavier and do not reflect light as well as those having exposed foil-faced insulation on the interior side. Another advantage of shutters is that they reflect additional sunlight into the tanks during the day.

As an alternative to shutters, some designers suggest that you put two or even three layers of glazing over the breadbox. These measures will cause the performance of the breadbox to decline for two reasons. Each added layer of glazing reduces the amount of light that enters the box, and without an insulated cover at night, the amount of heat loss increases. However, if shutters are not used, two, or preferably three, glazing layers are recommended. Several commercially sold breadboxes use an outer layer of acrylic glazing and two interior layers of a glazing film that blocks little incoming sunlight. In shutterless breadboxes, the tanks should be covered with a selective surface foil, as described on page 16.

Some research has been conducted on the comparative performance of shuttered and shutterless breadboxes. The initial results indicate that shuttered breadboxes perform better than those having two or three glazing layers, a tank with a selective surface and no shutters. However, when a new product, called Heat Mirror,™ is added as a glazing layer, shutterless breadbox performance approximates that of breadboxes with shutters. Unfortunately, Heat Mirror™ is not yet available in small quantities. Breadboxes using Heat Mirror™ will probably be more expensive than those with shutters.

TABLE 2: DESIRED SHUTTER ANGLES

| | Noon Solar Angle | | | Lower Shutter Angle | | | Upper Shutter Angle | | |
|---|---|---|---|---|---|---|---|---|---|
| Latitude | W | S/F | S | W | S/F | S | W | S/F | S |
| 24° | 47° | 66° | 86° | 25° | 45° | 60° | 80° | 90° | 90° |
| 28° | 41° | 62° | 82° | 20° | 40° | 55° | 80° | 90° | 90° |
| 32° | 37° | 58° | 78° | 15° | 35° | 50° | 75° | 85° | 90° |
| 36° | 33° | 53° | 74° | 10° | 30° | 50° | 70° | 85° | 90° |
| 40° | 27° | 47° | 67° | 5° | 25° | 45° | 70° | 80° | 90° |

TABLE 3: OCCURENCE OF FIRST AND LAST FREEZE SELECTED LOCATIONS

| | Spring Date | | Fall Date | | Mean Number of |
|---|---|---|---|---|---|
| | Mean | Latest | Mean | Earliest | Days 32° or Less |
| Mobile, AL | 2/17 | 3/20 | 12/12 | 11/14 | 20 |
| Atlanta, GA | 3/19 | 3/29 | 11/10 | 10/28 | 60 |
| Louisville, KY | 4/1 | 4/19 | 11/7 | 10/15 | 95 |
| Jackson, MS | 3/10 | 4/13 | 11/13 | 10/17 | 50 |
| Charlotte, NC | 3/21 | 4/16 | 11/15 | 10/15 | 74 |
| Raleigh, NC | 3/24 | 4/25 | 11/16 | 10/24 | 85 |
| Columbia, SC | 3/14 | 4/13 | 11/21 | 11/1 | 65 |
| Memphis, TN | 3/20 | 4/15 | 11/12 | 10/17 | 60 |
| Nashville, TN | 3/28 | 4/19 | 11/7 | 10/17 | 81 |
| Jacksonville, FL | 2/6 | 3/14 | 12/16 | 11/9 | 11 |
| Miami, FL | * | 2/6 | * | * | 0 |

*If the locality experiences freezing less than one year in ten, no mean values are given.

Adapted from the *Statistical Abstract of the United States*, 1978, U. S. Department of Commerce, Bureau of the Census, pg. 218.

# 3. BUILDING THE BREADBOX: ONE STEP AT A TIME

The following steps are recommended for building the breadbox design described in this workbook.

GETTING STARTED

- Conduct solar site survey.
- Decide where breadbox heater will be located.
- Obtain appropriate permit(s) from your building inspection office.
- Make sure you have the tools required for the job. A suggested list of tools required for this project is:

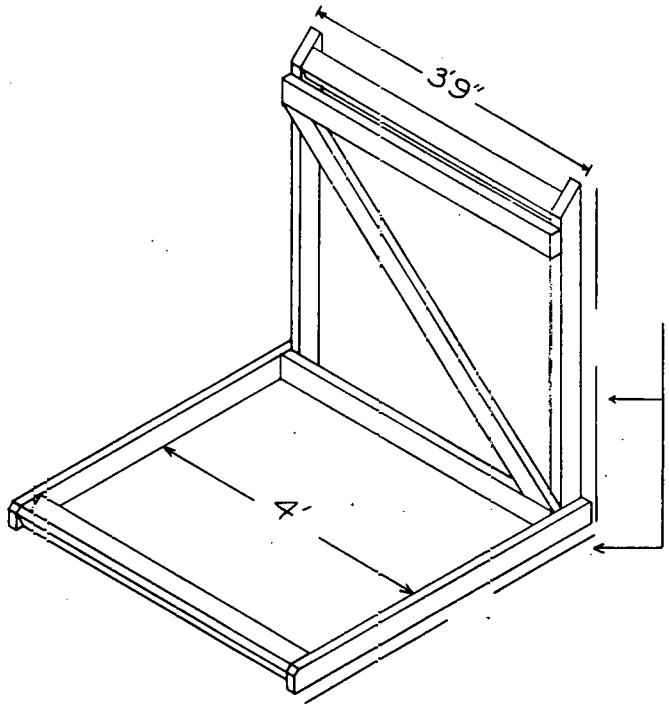
REQUIRED

Circular saw
4' straight edge or chalkline
Tape rule
Square
Hammer
Caulk gun
Pencil
Utility knife
Screwdrivers: Slotted & Phillips
Crescent wrench
Hack saw
Metal file
Pipe wrench
Electric drill
Drill bits: Kit of small bits and a 1" wood bit
Paint brushes and thinner
Chisel
Sandpaper or Wire brush
Staple gun and staples

OPTIONAL

Table saw
Hand saw
Masonry chisel or drill (or Plumber's tools)
Round file

- Secure all of the materials that you will need for constructing the breadbox described in this workbook. See the materials list.




dimensions shown on page 16, table 1.

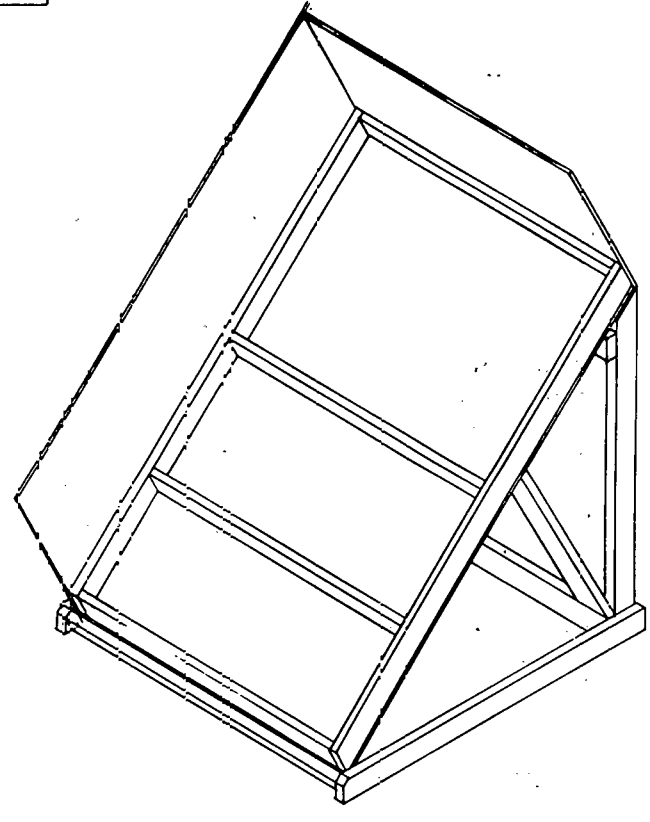
- Review the breadbox illustrations and begin building your solar water heater using the following procedures:

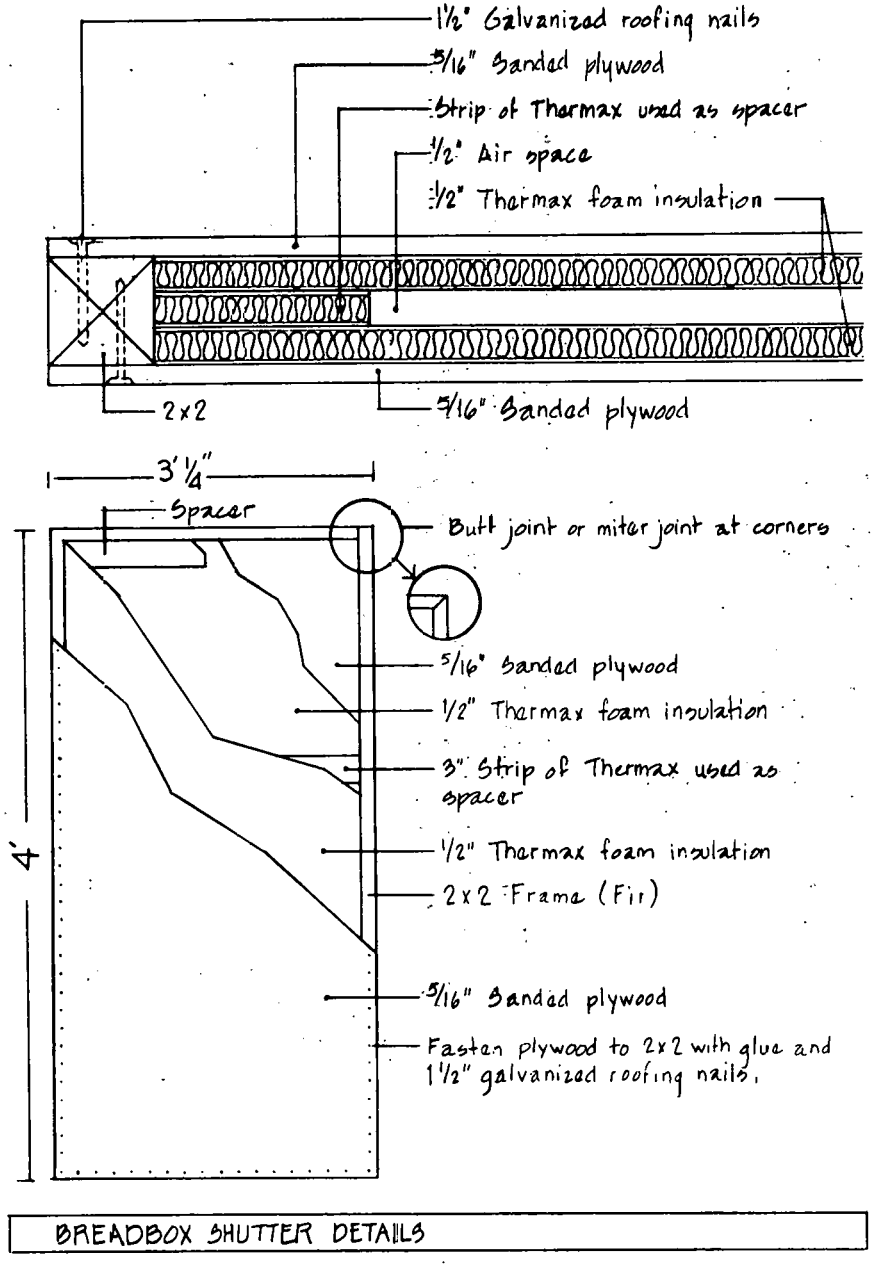
BUILD THE STAND (See Illustration)

- Build stand for box.
- Prime or stain the stand.

BUILD THE BOX (See Illustration)

- Cut plywood and batten pieces to size.
- Frame box with 16d common nails.
- Sheath sides and bottom of box with plywood using acrylic latex caulk and 8d galvanized nails.
- Prime or stain exterior of box to blend with the dwelling. Paint upper and lower edges to prevent exposure to the weather and elements.
- Paint 2" x 2" fir crosspiece black; paint or stain battens.





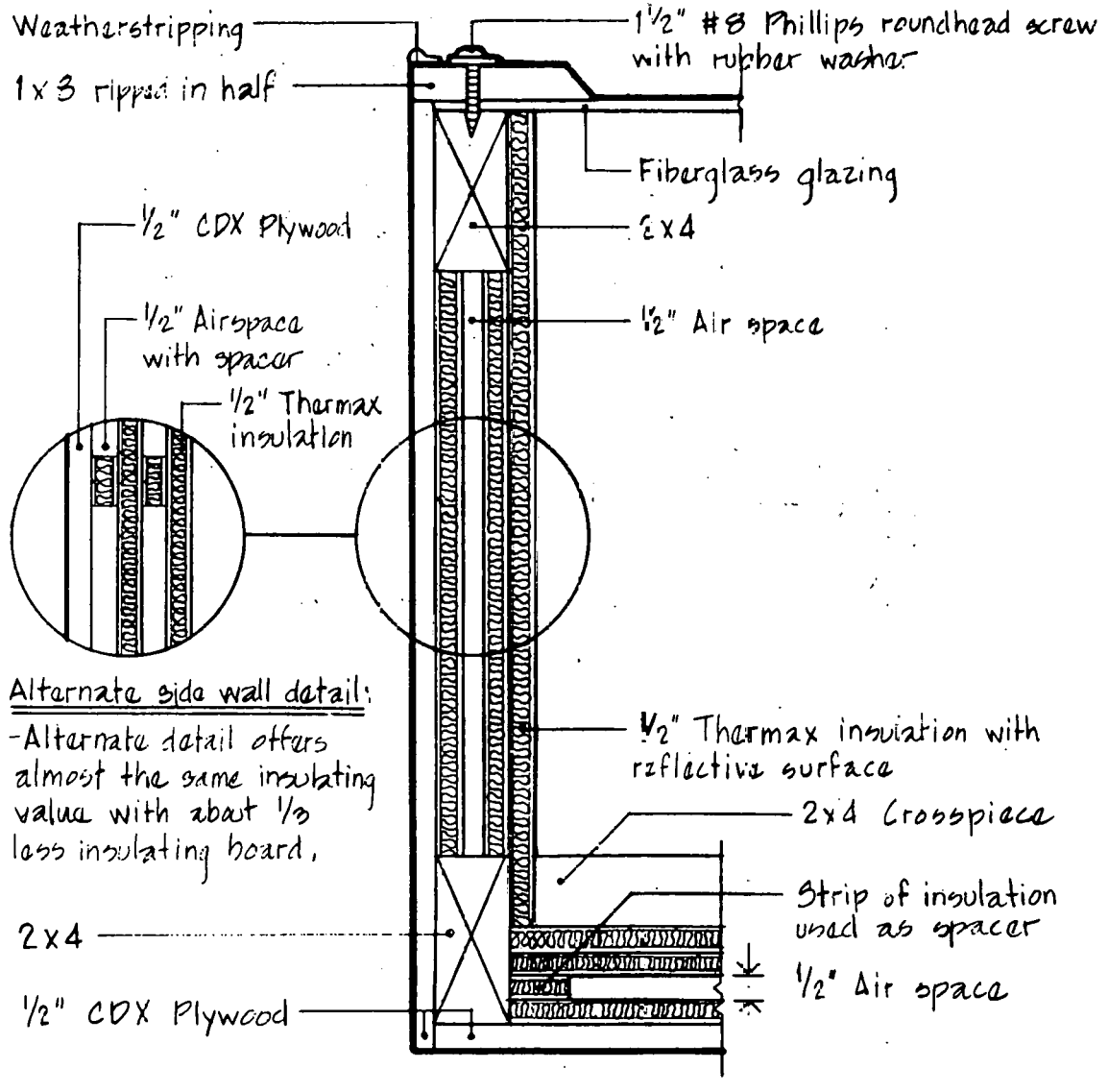

BREADBOX SHUTTER DETAILS

BUILD THE SHUTTERS (See Illustration)

- Construct shutter frames.
- Cut plywood and install with glue and nails, one piece at the bottom of each shutter.
- Cut rigid board insulation and glue inside shutter frame.
- Glue and nail top of shutter into place.
- Prime or stain shutter.

PREPARE THE TANKS

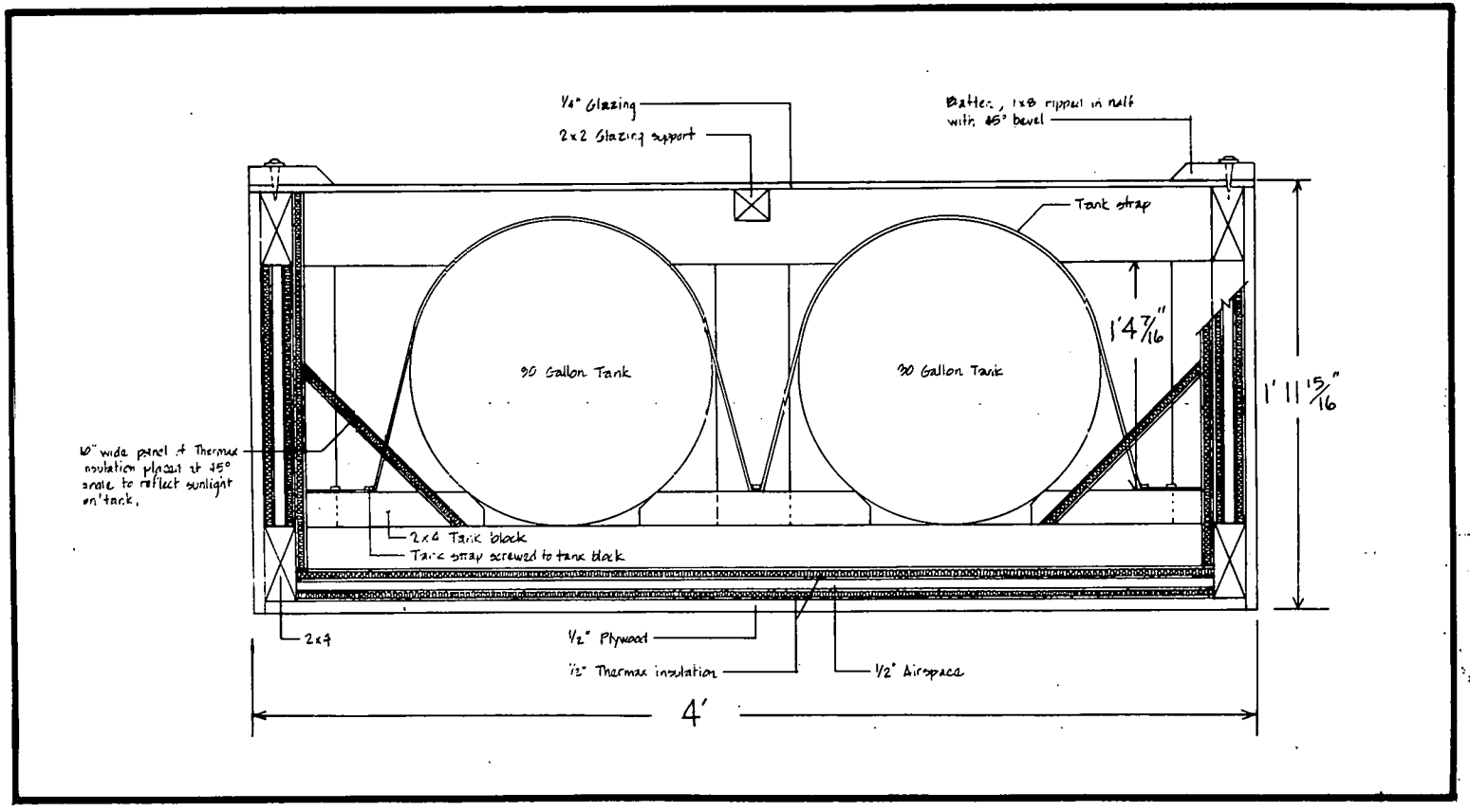
- Strip jacket off water tanks.
- Sand tanks and clean.
- Paint with flat black, heat resistant paint or very thin layers of a selective surface coating.



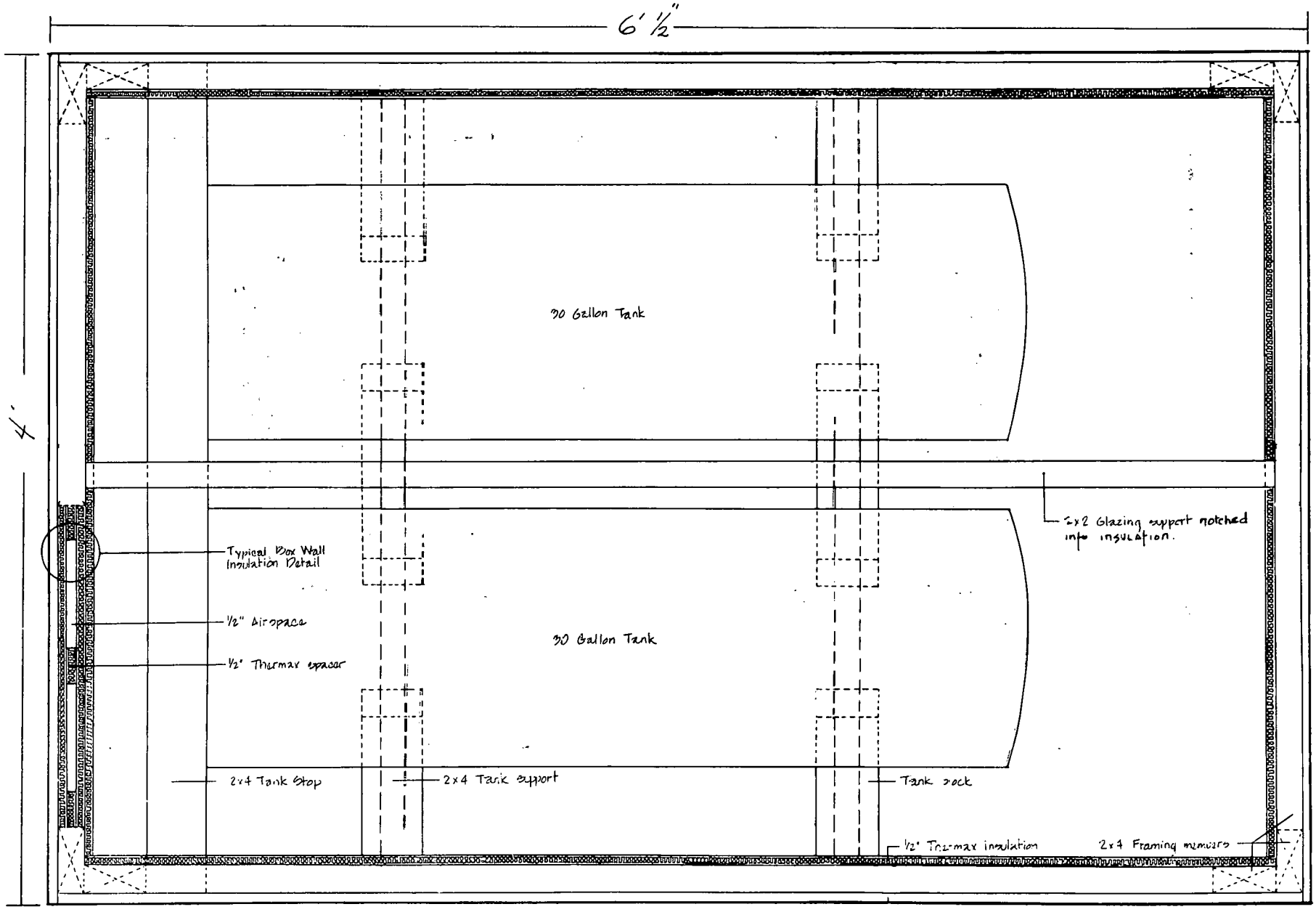

BREADBOX - SECTION OF SIDE WALL

INSULATE THE BOX

- Make certain paint is dry.
- Cut board insulation to size and install in box with glue and roofing nails. All surfaces should be covered as shown in the construction drawings.




**Cross section through collector box and tanks: end view.**




**Cross section through collector box and tanks: top view.**

## INSTALL AND PLUMB THE TANKS

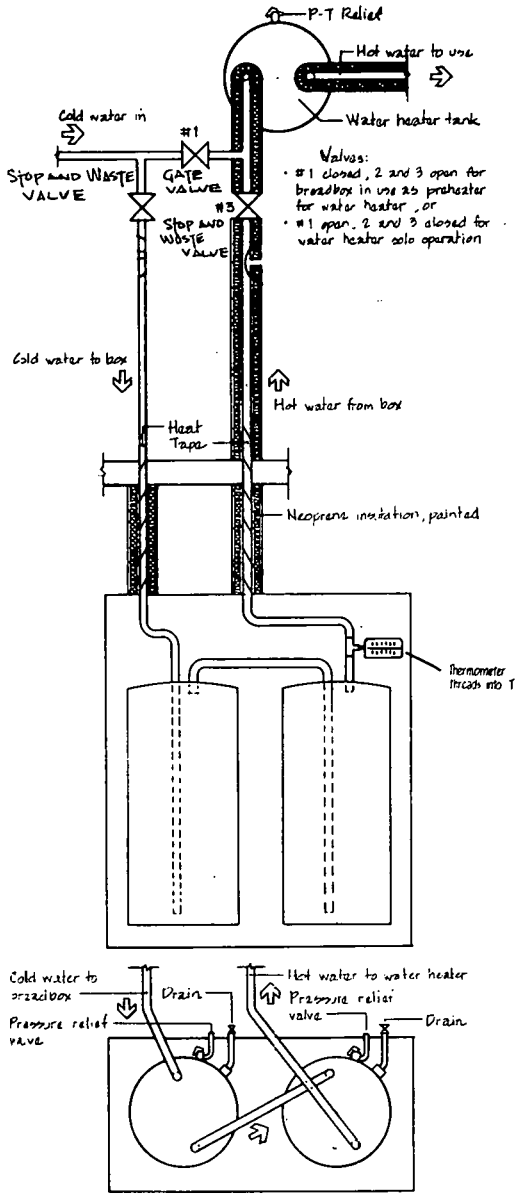
- Install tanks without straps.
- Loosely connect all plumbing lines.
- Locate and cut holes through box for inlet line, outlet line, pressure relief lines, and drain lines.
- Plumb drain lines at bottom.
- Plumb pressure-relief valves and overflow
- Secure tank by screwing straps into bottom.
- Plumb crossover line.
- Plumb inlet and outlet lines.
- Plumb thermometer.

## TEST THE PLUMBING

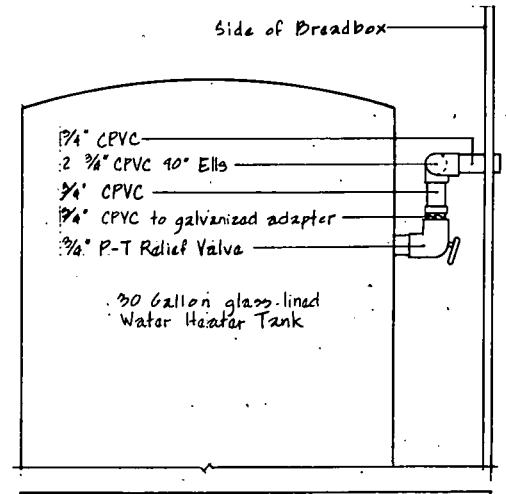
- Install hose fitting on inlet line and install gate valve on outlet line; connect water hose to inlet line.
- Leave outlet valve open to allow air to escape while you fill the tanks with water.
- When full, close outlet valve quickly and check for leaks. Redo the plumbing if necessary.
- Install plumbing insulation inside box and paint; label the lines as hot or cold.

## INSTALL THE GLAZING

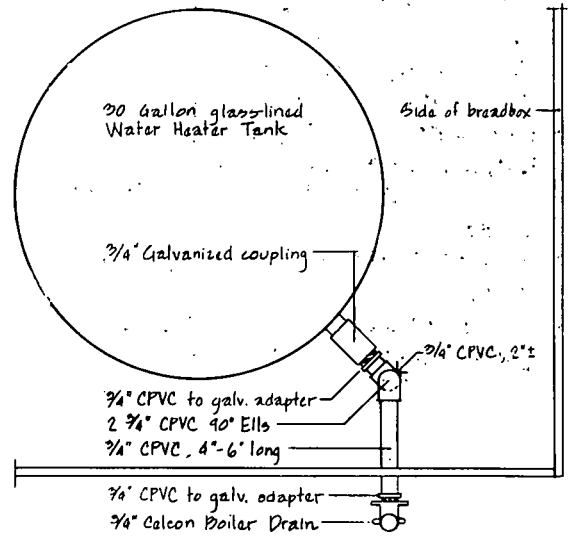
- Install middle glazing support.
- Cut glazing to size and lay in sunlight for about on hour.
- Cut 8½" pieces of insulation board at 45° to fit along sides and on bottom of box in between crosspieces. Tape all joints with aluminum tape. See drawing below.




PLUMBING SCHEMATIC



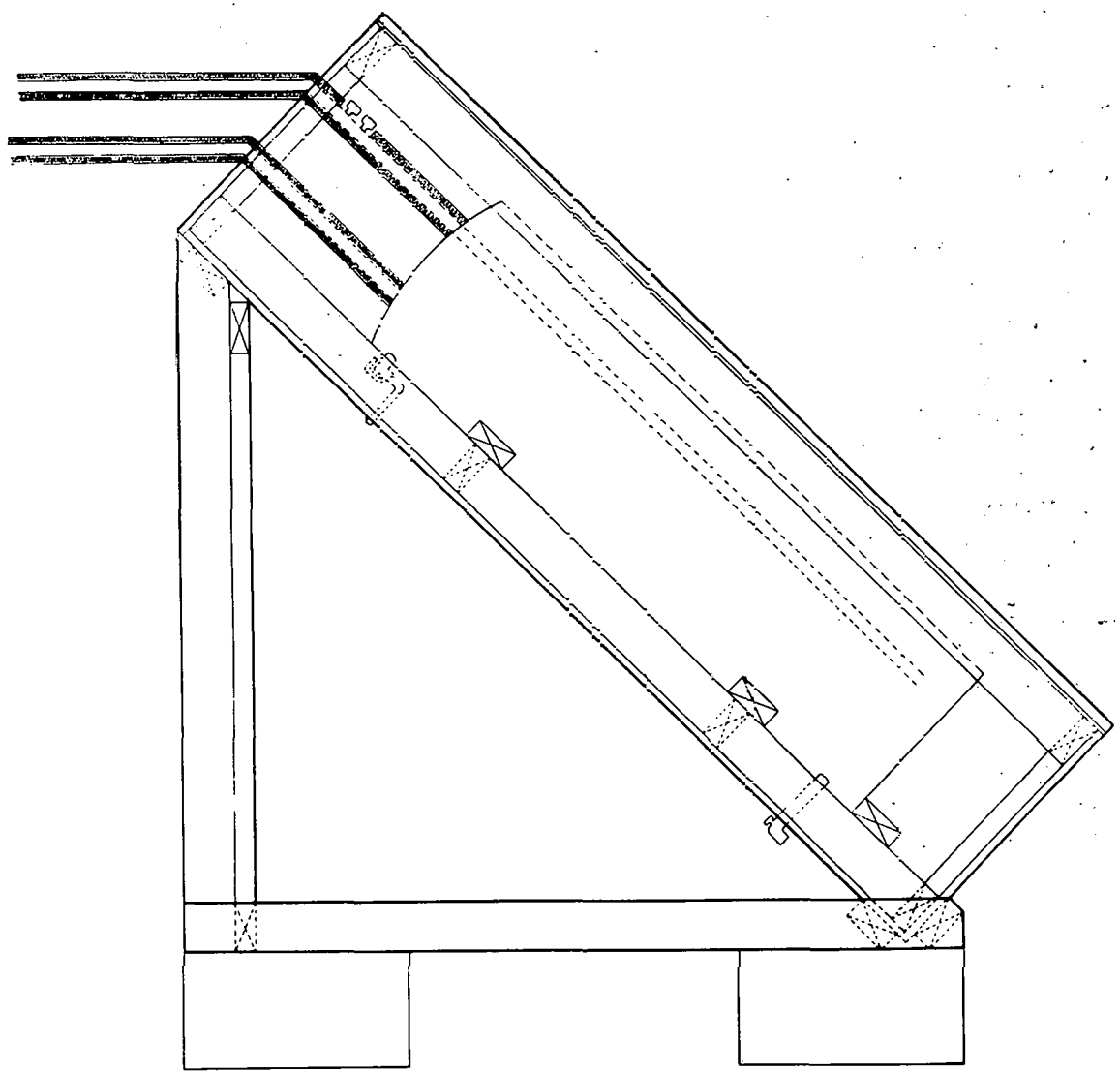

SIDE ELEVATION
PRESSURE RELIEF VALVE ASSEMBLY DETAIL

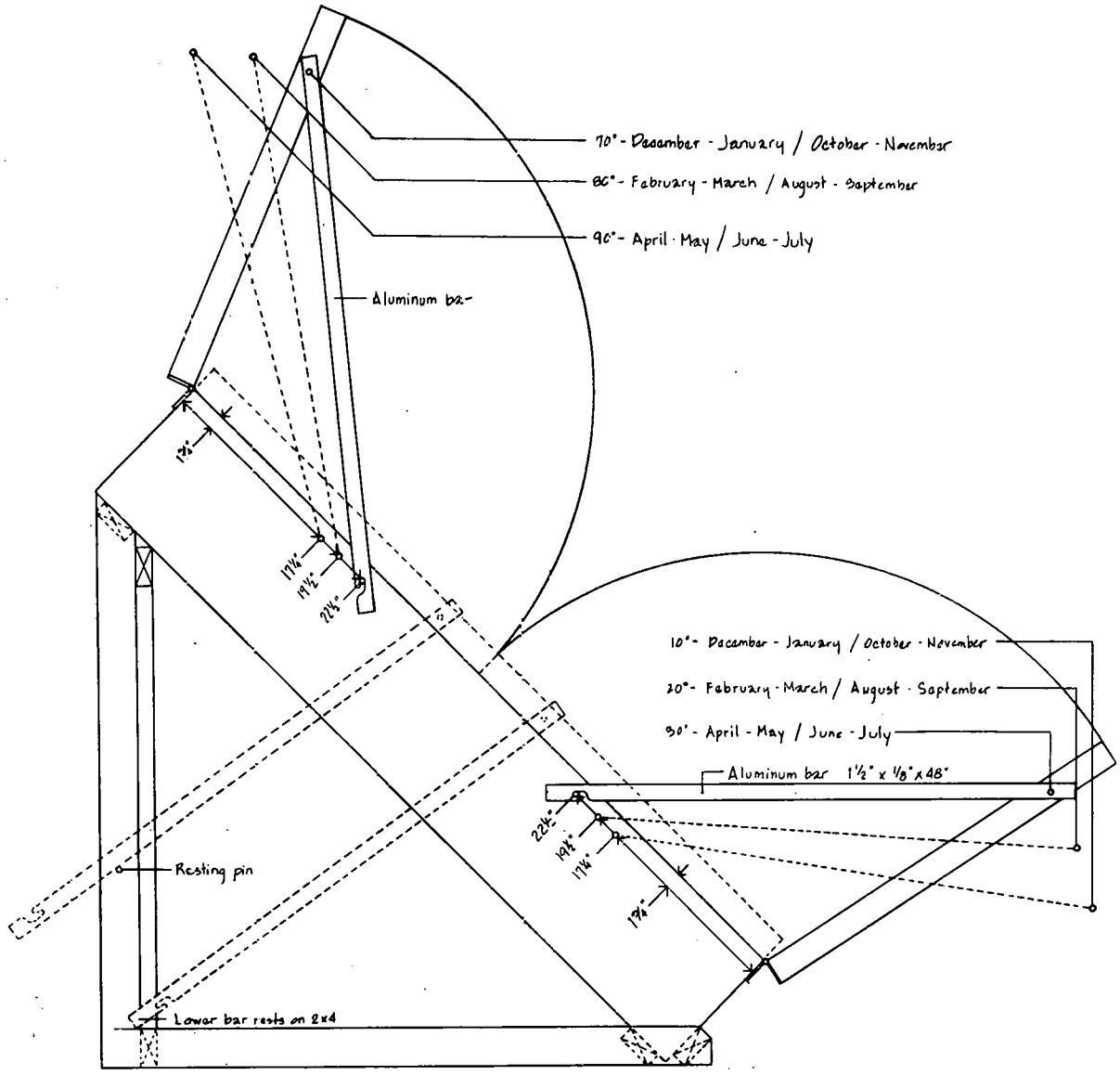



END ELEVATION - DRAIN ASSEMBLY DETAIL

INSTALL THE BREADBOX (See Illustration)

- Level the cinder blocks so that the bread-box will sit evenly.
- Drain tanks and set box into place.
- Install plumbing to regular supply line.
- Cut off water to supply line for regular water heater.
- Plumb breadbox line into regular water heater line. See illustration on page 25.
- Turn water on and test for leaks; re-plumb if necessary. See page 28 for filling instructions in the next section, Operating the Breadbox.
- Install heat tape on pipe runs through exterior air, if you do not use polybutylene plumbing and do not want to drain the system in winter.
- Insulate, tape and paint all exterior and interior pipe runs as necessary.
- Have plumbing inspected if required.
- Monitor and maintain.
- Set glazing and battens in place; label edges (top, bottom, left, right).
- Drill battens and glazing with bit 1/16" larger than batten screws.
- Drill through and into box with bit sized for screw.
- Remove battens and glazing; caulk edges of box.
- Set glazing and battens in place; stretch glazing tightly and screw into place.






INSTALL THE SHUTTERS (See Illustration)

- Attach hinges to both box and shutters. Make sure box closes squarely over upper framing of box.
- Attach a weather-tight batten onto edge of top shutter to act as a weather-tight seal that closes over bottom shutter.
- Attach hanger bolts to box in position shown as adjustable arm pins for both shutters.
- Cut metal shutter bars and attach to side of shutter as shown in construction drawings.
- Use protractor or other angle setting device with a level to align shutter at the desired summer angle. While someone holds the shutter in position, bring the shutter bar down to the hanger bolt and mark it. Using this same procedure, mark the position for the winter adjustment and the spring and fall adjustment. Mark the setting for all four shutter bars in this manner.
- Drill out a groove everywhere you have marked as shown in the construction drawings.
- Test the shutters to make sure they work.
- Label months for adjustment on shutter bar.
- Weatherstrip box where shutter will seal well.
- Attach latches.

## OPERATING THE BREADBOX

Once your breadbox is installed and operating, you will receive free hot water on sunny days. With some minor changes in lifestyle, such as washing clothes and dishes in the evening and taking showers at night, you will be using the solar-heated water at its peak temperature and supply.

Like all appliances, breadbox water heaters require periodic maintenance. The following tasks indicate what you need to do to keep your breadbox working for many years.

**Daily:** Open shutters when you get up, or when the sun rises. Close shutters before the sun goes down. Leave shutters closed on heavily overcast or rainy days. Adjust shutter to the correct monthly setting.

**Every 6 Months:** Oil hinges.

**Once a Year:** Check the paint for peeling or cracking, repaint if necessary. Check also the caulking for peeling or cracking and reapply where needed. Drain one gallon of water out of the bottom of each tank.

**While Away:** Summer — Close Shutters. Winter — Close shutters and drain system to prevent freezing.

**Every 5/7 Years:** Check fiberglass glazing for cloudiness or roughness. If needed, coat with weatherable surface.

**Freeze Protection:** Plug in heat tape if a freeze is predicted or drain the system, depending on which form of freeze protection you have chosen. If your electric power goes off during very cold weather, drain the tanks unless you have polybutylene tubing. If the water in the tubing freezes, shut off the valves to the breadbox, open the drains, the vacuum relief valve and the bypass valve to supply the regular water heater.

**Draining Procedure:** Shut gate valves to and from breadbox. Open gate valve to conventional water heater. Open air purger gate valves. Open drains for each tank of the breadbox and let the water exit.

**Refilling Procedure:** Close drain valves on breadbox tanks. Close gate valve to conventional water heater. Leave air purger gate valve open on hot side (#3 on page 25). When filled to valve, close it. Open gate valves to and from breadbox. Open hot water faucet in kitchen and bathroom to get air out of the pipes (it will gurgle for a few minutes).

# BREADBOX WATER HEATER MATERIAL LIST

| QUANTITY | MATERIAL | SIZE | PURPOSE |
|---|---|---|---|
| 2 | CDX Plywood | ½" x 4' x 8' | Box |
| 2 | CDX Plywood | ¼" x 4' x 8' | Shutters |
| | foil-coverd ins. board (Thermax or Tuff R) | ½" x 4' x 8' | Box & Shutters |
| 2 | 2 x 4 pine | 12' | Frame |
| 5 | 2 x 4 pine | 8' | Frame |
| 2 | 2 x 4 press treated | 8' | Stand |
| 3 | 2 x 2 fir | 8' | Glazing & Shutters |
| 1 | 2 x 2 fir | 12" | Shutters |
| 1 | 1 x 8 clear pine | 12' | Glazing |
| 2 | 2 x 4 press treated | 10' | Stand |
| 4 | Cinder blocks | 8"x 8"x 16" | Foundation |
| 2 lbs. | Common nails (or CC) | 16d | Box Frame & Stand |
| 1 lb. | Common Galvanized Nails | 6d | Box Plywood |
| 1 lb. | Common Galvanized Nails | 4d | Shutters & Foam |
| 8 | Lag Screws & Washers | 5/16"x 3' | Stand |
| 24' | Vinyl Bulb Weatherstrip | | Shutters |
| 1 Box | Staples | ¼" | Shutters w/Strip |
| 2 | Draw catch latches w/screws | 3¼"x 1¼" | Shutters |
| 1 | Aluminum Bar Stock | ⅛"x 1½"x 8' | Shutters |
| 4 | Primed or Zinc-Plated Butt Hinges | 3" | Shutters |
| 8 | Hanger Bolts | ¼"x 2" | Shutters |
| 8 | Washers & Wing Nuts | ¼" | Shutters |
| 25 | Round Head Sheet Metal Screws | 1½"x #10 | Battens |
| 1 oz. (25) | Neoprene Washers | For Screws | Battens |
| 6' | Fiberglass-Reinforced Plastic Coated for Ultra Violet Protection | .040 x 48" wide | Glazing |
| 2 tubes | Clear Silicone Caulk | 11 oz. | Glazing |
| 4 tubes | Construction Adhesive (Max Bond on Liquid Nails) | 11 oz. | Box & Shutters |
| 20 | Round Head Sheet Metal Screws | 1½"x #14 | Tank Straps & Door Chains & Bars |
| 20' | Galvanized Pipe Hanging Strap | | For Tanks |
| 10' | Zinc Plated Chain | 1" Link | |
| 1 gallon } | Exterior Wood Primer } | | Box & Shutters Ext. } |
| 1 gallon } OR | Exterior Wood Paint } OR | | Box & Shutters Ext. } OR |
| 1 gallon } | Exterior Wood Stain } | | Box & Shutters Ext. } |
| 1 quart | Exterior Wood Paint | Gloss White | Shutters Interior |
| 1 quart | Flat Black Metal Paint | | Tanks |
| 2 | Elec. Water Heater Tanks Glass-Lined | 30 Gallon | Tanks |

# BREADBOX WATER HEATER MATERIAL LIST

| | | | |
|---|---|---|---|
| 2 | Pressure Temperature Relief Valves | If not included | Plumbing |
| 10'-100' | Pipe Insulation (Rubatex or Armaflex) | ¾" Pipe | Plumbing |
| 1 roll or can | Adhesive for Pipe Ins. | | Plumbing |
| 2 | Celcon Threaded Gate Value | ¾" | Hook Up Plumbing |
| 3 | Celcon 45° Threaded Boiler Drains | ¾" | Drain & Vacuum Relief |
| 2-6 | Galvanized Couplings | ¾" | Plumbing |
| 1 | Galvanized Tee | ¾" | Thermometer |
| 0-3 | Galvanized Ell | ¾" | Cold/Hot Lines |
| 10'-100' | Silver or Black Polybutylene | ¾" | Plumbing |
| 10-20 | Adaptor from Polyb. to Male Pipe | ¾" | Plumbing |
| 0-12 | Crimp Ells for Polyb. | ¾" | Plumbing |
| 20-30 | Crimping Rings | ¾" | Plumbing |
| 2-4 | Crimp Tees for Polyb. | 1" | Plumbing |
| 1 | Angle Bulb Thermometer | 30-260°F | Monitoring |
| 1 | Galvanized Bushing | ½" to ¾" | Thermometer |
| 2 Rolls | Teflon Tape | ½" | Plumbing |
| 1 Roll | Aluminum Tape (not duct tape) | 2" | Insulation in Box |
| 4' | Moulding | ½"x 2" | Shutter Overlap |
| 0-7 | Galvanized Street Ells | ¾" | Plumbing |
| 1 | Hose Fitting (¾" hose to ¾" male pipe thread) | ¾" | Testing Plumbing |
| 0-10 | Galvanized Close Nipples | ¾" | Plumbing |
| 0-2 | Galvanized Male Plugs | ¾" | Plug Holes in Tanks |
| 0-1 | Galvanized Nipple | 4" or 6" or 8" | Thermometer |
| 1 | Crimping Tool | | Plumbing |

The parts above assume polybutylene plumbing; some adjustments may be needed for copper, galvanized or CPVC piping.

# 4. APPENDIX

RESOURCE LIST

BIBLIOGRAPHY

GLOSSARY

ENERGY CONVERSIONS

MATERIALS AND COSTS SHEET

STATE ENERGY OFFICES IN SOUTHEAST

# Resource List

| PRODUCT | BRAND | ADDRESS |
|---|---|---|
| Glazing | | |
| Fiberglass-Reinforced Plastic | Kalwall | Solar Components Corporation<br>See address next page (or below) |
| | Lascolite | Lasco Industries<br>Florence, KY 41042 |
| | Filon and Tedlar-Coated Filon | Filon Division of Vistron Corp.<br>12333 S. Van Ness Ave.<br>Hawthorne, CA 90250<br>(213) 757-5141 |
| | Glasteel | 6520 Powers Ferry Rd.<br>Suite 200<br>Atlanta, GA 30339<br>(404) 952-3697 |
| Tempered Glass | Factory-seconds or rejects | Call local solar manufacturers, glass companies and surplus building material outlets |
| | Sunadex (special low-iron glass) | ASG Industries, Inc.<br>P.O. Box 928<br>Kingsport, TN 37662<br>(615) 245-0211 |
| | HelioLite™ | C-E Glass<br>Division of Combustion Engineering<br>825 Hylton Rd.<br>Pennsauken, NJ 08110<br>(609) 662-0400 |
| Other types of glazings | Plexiglas<br>Lucite<br>Acrylic | Acrylic single paned |
| | Acrylite SDP<br>Cor-X-Acrylic<br>220 Twin Wall<br>Polylux | Acrylic double paned |
| | Merlon<br>Lexan<br>Tuffak Twinwall | Polycarbonates |

# Resource List

| PRODUCT | BRAND | ADDRESS |
|---|---|---|
| | Polyethylene | Standard<br>U-V Resistant<br>Monsanto 602 |
| | Polyesters | Mylar |
| | Polyvinyl-Flourides | Tedlar |
| | Flurocarbons | Teflon FEP |
| Glazing coatings | Kalwall Weatherable Surface | Solar Components Corp.<br>P.O. Box 237<br>Manchester, NH 03105<br>(603) 668-8186 |
| Special glazings | Heat Mirror | Southwall Corporation<br>Palo Alto, CA 94303<br>(415) 962-9111 |
| Insulating board | Thermax High-F | Available at most hardware stores and lumber companies. |
| Pipe insulation | Rubatex | |
| | Armaflex | |
| | Self-Sealing High Density Fiberglass | Owens Corning |
| Tank Coating | | |
| Selective surface paint | Dampney<br>(Absorptivity = .96<br>Emissivity = .42-.60) | The Dampney Company<br>85 Paris Street<br>Everett, MA 02149<br>(617) 389-2805 |
| | Microsorb<br>(Absorbtivity = .92,<br>Emissivity = .60) | Solar Usage Now, Inc.<br>420 East Tiffin Street<br>P.O. Box 306<br>Bascom, Ohio 44809<br>(800) 537-0985 |

# Resource List

| PRODUCT | BRAND | ADDRESS |
|---|---|---|
| | Jones-Blair Flat Black Spray Paint (Absorptivity = .93, Emissivity = .52) | Solar Usage Now, Inc. (See address above) |
| Selective surface foil coating | Scotch Selective Surface Foil Maxorb Solar Foil (Absorptivity = .97, Emissivity = .10) | Solar Usage Now, Inc. and Solar Components Corportion (See addresses above) |
| Vacuum relief valve or air purger | Watts No. 36A | Solar Usage Now (See address above) |
| | Vacuum relief valve or air purger | Solar Components Corporation (See address above) |
| | Taco valves | Taco, Inc. Bernham St. Evanston, RI 02920 (401) 942-8000 |
| Piping | CPVC Galvanized Copper | Local hardware store or plumbing store |
| | Polybutylene | Local hardware store, plumbing store or Solar Components Corporation |
| Thermometers | Stem or Rectangular Lab Thermometers | Ametek U.S. Gauge Division Bartow, FL 33830 |
| | | Solar Usage Now, Inc., or Solar Components Division (See addresses above) |
| | | Check yellow pages for local distributors. |

# Resource List

| PRODUCT | BRAND | ADDRESS |
|---|---|---|
| Catalogs of Solar Products | Solar Components Catalog (67 pages) | Solar Components Corporation<br>P.O. Box 237<br>Manchester, NH 03105<br>(603) 668-8186 |
| | People's Solar Sourcebook (349 pages) | Solar Usage Now, Inc.<br>420 East Tiffin Street<br>Bascom, OH 44809<br>(800) 537-0985 (except Ohio) |
| | The First Passive Solar Catalog (70 pages) | The Passive Solar Institute<br>P.O. Box 722<br>Davis, CA 95616 |
| | Solarware | Pawlet, Vermont 05761 |
| | A to Z Solar Products | 200 East 26th St.<br>Minneapolis, Minn. 55404 |
| | Solar Age Catalog | Solar Vision, Inc.<br>Manchester, N.H. 03450 |
| | Soft Tech | Coevolution Quarterly<br>P.O. Box 428<br>Sausalito, CA 94965 |

# References

**Books on Solar Water Heating**


*How to Buy Solar Heating . . . Without Getting Burnt.* Malcom Wells and Irwin Spetgang. Rodale Press, Emmaus, Pennsylvania.
A very good step-by-step guide to buying solar.

*Solar Energy Thermal Processes.* John A. Duffie and William A. Beckman. John A. Wiley and Sons, New York, 1974.
A very detailed text on solar engineering; for the advanced solar water heater designer.

*The Solar Decision Book: Your Guide to Making a Sound Investment.* Richard H. Montgomery. Dow Corning Corporation, Midland, Michigan, 48640, 1978.
A good guide to active solar water heating components, design and performance.

*The Integral Passive Solar Water Heater Book.* David A. Bainbridge. Passive Solar Institute, P.O. Box 722, Davis, CA 95617. 1981.
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# Glossary

**Absorber Plate:** Black surface inside a collector that absorbs solar radiation and converts it to heat.

**Active System:** Solar heating system that, unlike a "passive" system, requires external mechanical power to move the collected heat.

**Batch Solar Water Heater:** See Breadbox Water Heater.

**Breadbox Water Heater:** A solar water heater that locates the storage tanks in an insulated box or room in direct sunlight.

**British Thermal Unit (BTU):** Heat needed to raise 1 pound (1 pint) of water 1°F. BTU are used to express the amount of energy used in heating. About the amount of energy in one kitchen match.

**Collector:** Device that absorbs solar radiation and converts it to heat.

**Convection:** Heat transfer through moving currents of air or liquid. Natural convection occurs when the fall by gravity of heavier cool fluid causes a lighter warm fluid to rise. (See Thermosiphoning.) Forced convection occurs when the fluid is circulated by a fan or pump.

**Degree Day:** Unit of heat measurement equal to one degree variation from a base temperature, 65° for example, in the average temperature during one day. For example, if the base temperature is 65°F, and the average temperature every day for a week is 25°F, then the number of degree days for the week is 280.

**Double-Glazed:** Covered by two panes of glass or other transparent material.

**Fiberglas Reinforced Polyester (FRP):** A type of glazing that is more durable, lighter

and less transparent than glass. It has excellent transmission qualities, but must be treated to protect from ultra-violet radiation.

**Glazing:** Transparent or translucent covering (e.g., glass or plastic) that reduces heat loss from a solar device.

**Heat Exchanger:** A metal surface, such as a coiled copper tube immersed in a tank of water, that transfers heat from one fluid to another.

**Insulation:** Material with high resistance (R-value) to heat flow.

**Orientation:** Direction that a collector surface faces.

**Passive System:** With reference to water heating, a thermosiphoning or breadbox system which requires no external energy input other than that which is environmentally available.

**Polybutylene:** A tubing that is flexible, but will not be damaged if the water inside freezes.

**Reradiation:** Emission of previously absorbed radiation via invisible infrared heat.

**Retrofit:** Applies to renovations that are done to save energy; to retrofit with solar means to equip an existing building with a solar energy system.

**R-Value:** See Thermal Resistance.

**Selective Surface:** Absorber plate coating that absorbs visible light, but emits little infrared radiation, thereby reducing heat losses.

**Solar Noon:** Time of day when the sun reaches its maximum altitude for the day and is due south; this occurs exactly midway between sunrise and sunset.

**Solar Radiation:** Energy from the sun which comes to earth in the form of direct, diffuse, or reflected rays.

**Stratification:** In solar water heating systems the tendency for stored water to remain in layers of different temperature, with the coldest on the bottom and the warmest on top.

**Thermosiphon Water Heater:** A passive water heater that uses the thermosiphoning effect. See Thermosiphoning.

**Thermosiphoning:** Upward movement, by natural convection, of fluid warmed in a solar collector to a storage tank directly above it.

**Thermal Resistance (R-Value):** Tendency of a material to retard the flow of heat; the higher the R-value, the greater the insulating value of the material.

**Ultra-Violet Degradation:** Ultra-violet rays travel in very short waves as light energy. They tend to cause the breakdown of many plastics, so care in the use of plastic glazing materials is required.

# Energy Conversions

## ENERGY CONVERSIONS

| | |
|---|---|
| 1 British thermal unit (Btu) | = 0.000 293 07 kilowatt-hour |
| | = 0.000 393 01 horsepower-hour |
| | = 778.156 foot-pounds |
| 1 kilowatt-hour (kwh) | = 3412 Btu |
| | = 2,655,000 foot-pounds |
| | = 0.001 666 7 barrels of oil at point of consumption |
| 1 barrel (bbl) of oil | = 42 gallons |
| | = 600 kwh (approx.) at point of consumption |

## POWER CONVERSIONS

| | |
|---|---|
| 1 horsepower (hp) | = 0.7457 kilowatts |
| | = 42.408 Btu per minute |
| | = 33,000 foot-pounds per minute |
| 1 kilowatt (kw) | = 1000 watts |
| | = 1.3410 horsepower |
| | = 56.87 Btu per minute |
| | = 737.56 foot-pounds per second |
| 1 megawatt (mw) | = 1000 kilowatts or 1,000,000 watts |
| 1 gigawatt (gw) | = 1000 megawatts or 1,000,000,000 watts |

## OTHER CONVERSIONS

| | |
|---|---|
| 1 acre-foot | = unit of volume in a reservoir |
| | = 43,560 cubic feet |
| | = 325,851 U.S. gallons |
| | = 1 acre of water 1 foot deep |

# State Energy Offices

**Alabama:** Alabama Department of Energy, 25 Washington Avenue, Fourth Floor, Montgomery, Alabama 36130. Telephone (205) 832-5010.

**Florida:** Governor's Energy Office, 301 Bryant Building, Tallahassee, Florida 32304. Telephone (904) 488-6146.

**Georgia:** Office of Energy Resources, 270 Washington Street, S.W., Atlanta, Georgia 30334. Telephone (404) 656-5176.

**Kentucky:** Kentucky Department of Energy, P.O. Box 11888, Lexington, Kentucky 40578. Telephone (606) 252-5535 or 1-800-432-9014.

**Mississippi:** Department of Transportation & Energy, 510 George Street, Third Floor, Watkins Building, Jackson, Mississippi 39202. Telephone (601) 961-4733.

**North Carolina:** North Carolina Department of Commerce, Energy Division, P.O. Box 25249, Raleigh, North Carolina 27611. Telephone (919) 733-4490 or 1-800-662-7131.

**South Carolina:** Governor's Division of Energy Resources, SCN Center, Suite 1130, 1122 Lady Street, Columbia, South Carolina 29201. Telephone (803) 758-8110 or 1-800-922-5210.

**Tennessee:** Tennessee Energy Authority, 226 Capitol Boulevard Building, Suite 707, Nashville, Tennessee 37219.
Telephone (615) 741-2994 or 1-800-342-1340.

# Materials and Costs

The following table may serve as an organizational guide in helping you plan your system. List all materials needed, tasks to be accomplished.

TABLE 7. Materials and Cost.

| Materials: Item | Quantity | Cost per Unit | Cost Total | Date Order | Date to Receive | Shipping | Notes |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Tasks: | | | | | | | |

| Item | Hours | @ $/hr | Cost | Date Begin | Date Complete | Graph - Draw a line connecting beginning and ending dates. Use different colors for different years. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | J | F | M | A | M | J | J | A | S | O | N | D |
| | | | | | | | | | | | | | | | | | |