Breadbox Designs

- Jeff Reiss
and
- David Bainbridge

Numerous types of solar water systems have been developed, but the flat-plate collector water heating system is the predominant type being used today. The flat-plate collector system has received most of the solar publicity and most poeple think immediately of flat-plate collectors when they think of solar heating. But here is a different type of solar water heating system, the breadbox solar water heater.

The breadbox solar water heater combines solar heat collection with storage. This integrated solar heating system consists of one or a series of tanks which are painted black to absorb heat from the sun. They are enclosed in an insulated box and covered with glazing material (usually glass or a special fiberglass) to retain the heat.

The range of quality and cost for breadbox water heaters can vary considerably. The performance of the breadbox water heater can equal or exceed a flat-plate collector system on a BTU per dollar basis, as typically a flat-plate collector system will cost from two to five times as much as a breadbox water heater. Currently, most operatig breadbox solar water heaters are simple home-built systems constructed from inexpensive materials such as recycled electric water heater tanks. In most cases, the breadbox solar water heater will be the cheapest solar water heater for homeowners to install. However, the breadbox water heater also has good potential for mass marketing in tract houses and/or commercial applications.

History

Breadbox solar water heaters are not a new concept. The first patents on breadbox heaters were taken in 1891 for the Climax heater and in 1898 for

---

David Bainbridge lives in a waterwall type passive solar home and works for the California Solar Office in the passive program. David is also a private consultant on energy efficiency planning and passive research and design. He can be reached at: 2446 Bucklebury, David, CA 95616.

Jeff Reiss lives in an old house he has retrofited with a beautiful solar greenhouse and works full time for the Solar Office of the California Energy Commission on technology transfer and the passive program. He will install abreadbox solar water heater this fall. He can be reached at: The Solar Office, MS 42, California Energy Commission, 1111 Howe Avenue, Sacramento, CA 95825.

Reports on other operating bread boxes with performance and photos would be much appreciated.

Figure on 2.5 gallons per square foot of glazing as a maximum for heating water.

Frank Walker's system. They were used widely in California and Florida during the early 1900s. Breadbox water heaters performed well in those early days, but gradually disappeared as artificially cheap natural gas became available and was aggressively promoted. Ken Butti and John Perlins describe this history in the Fall 1977 issue of *Co-Evolution Quarterly.*

F.A. Brooks tested several breadbox water heaters in 1936 at the University of California. He demonstrated that tanks in insulated boxes are capable of producing hot water over 48°C (120°F). Furthermore, he found that upright tanks placed on an incline deliver hotter water than horizontal tanks. He concluded that breadbox water heaters were efficient solar energy absorbers, but were poor for storing hot water overnight.

Contemporary investigators have improved on Brooks' original heaters by adding nighttime insulation and reflectors onto the boxes. However, they have sometimes ignored his more basic discoveries about tank placement, and thus achieved poor performance. Steve Baer, John Brand and others have placed insulated lids on the box. Baer's lids also reflect solar radiation onto the tanks during the day. Horace McCracken wrapped the tanks in transmissive insulation to prevent nighttime heat losses, but this insulation also decreases the daytime collection efficiency. More recently, Marshall Hunt, Gary Starr and the Soldyne Group of Davis, Calif., and David Bainbridge have constructed and studied breadbox water heater performance in Davis.

With the few afore mentioned exceptions, there has been very little research concerning the cost, performance, and optimum design of breadbox water heaters. Recently, however, the California Energy Commission has contracted with California State University at Sacramento to conduct a side-by-side comparison study of six solar water heating systems, including a low cost three-tank breadbox water heating system and a modified "builder special" breadbox water heating system. These breadbox water heaters will be compared with two thermosyphon systems (a horizontal and a vertical tank system) and with two pump systems (a one-tank and a two-tank system). The preliminary results should be available late in 1978.

Although there is currently very little information describing breadbox water heater design, performance, and cost, it is apparent that they hold real promise for solar water heating. Breadbox water heaters will surely be the focus for increased activity in the near future, with the potential for commercial kits and installations being particularly exciting.

We will consider two different solar breadbox water heater designs in this article: the Single-Tank and the Three-Tank (Hunt) Breadbox Water Heater.

Single-Tank Breadbox Water Heater

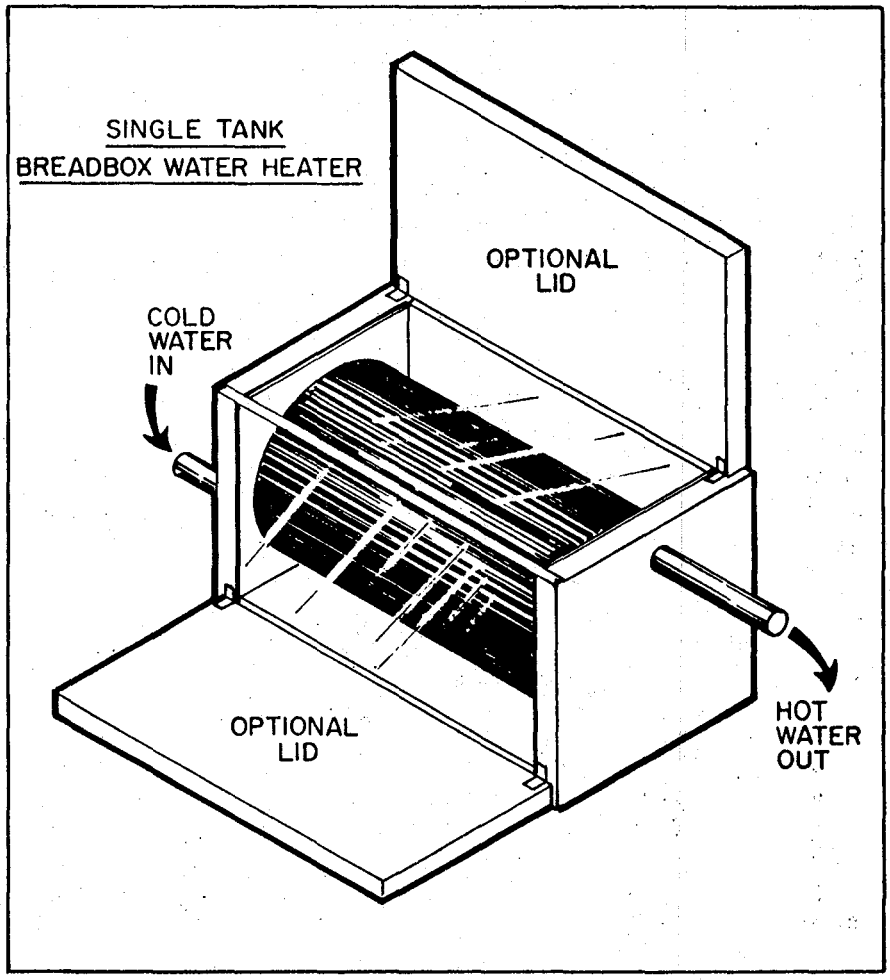
The single tank breadbox water heater can be easily constructed using readily available materials and employing conventional construction techniques. A standard tank is painted black and enclosed in a well-insulated box. Glass or another glazing material covers the south side of the box. Operational lids can be installed to increase performance of the breadbox. Incoming water from the main line enters the breadbox at a low point. The solar heated warm water is drawn from a high point and routed to the existing back-up water heater.

The Soldyne Group built and tested a single-tank breadbox in

Soldyne is a solar research and educational group. Under contract to the National Science Foundation, Soldyne sponsored the "Resource Conservation for Residential Buildings" project. A copy of the 166-page report is available through Soldyne. Currently, Soldyne is building passive solar homes in Sonoma County. The group is also giving slide shows in the area. Contact Gary Starr, Soldyne, P.O. Box 682, Forestville, CA 94536. (707) 887-7145.

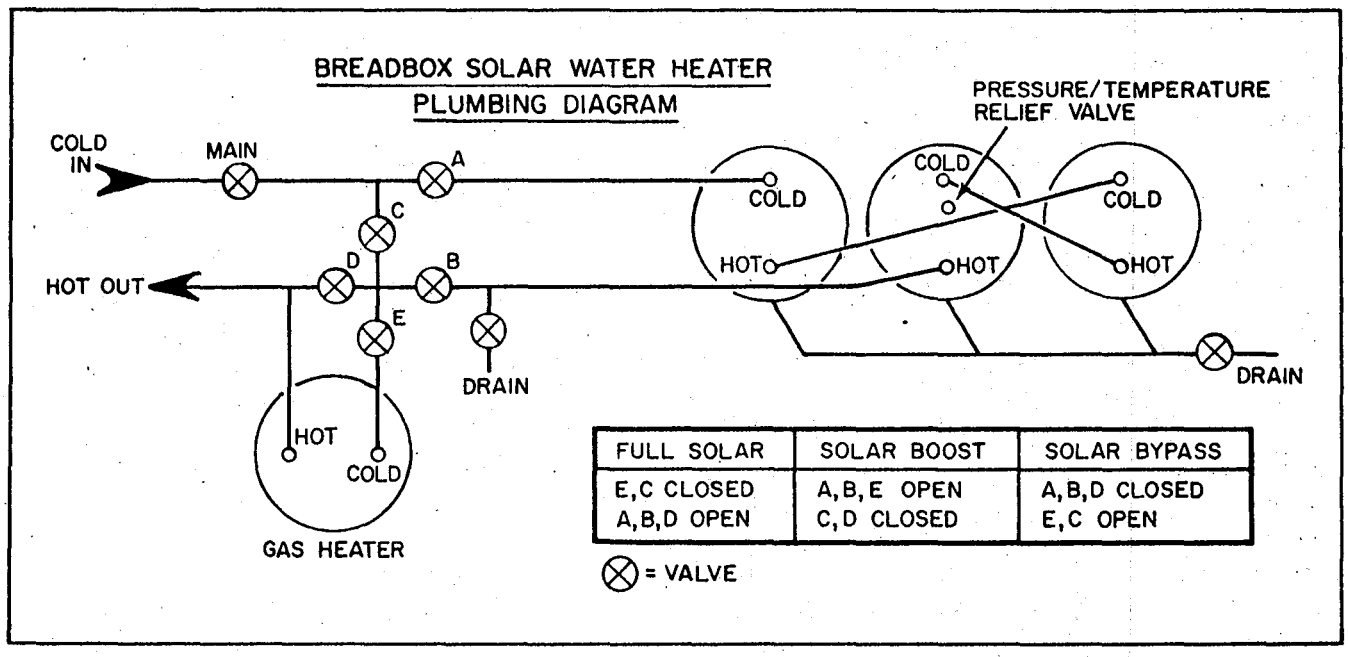
1977. The plans were modified to accomodate the size of the tanks and the available materials. The box was covered with a single layer of clear polyethylene – rather than a double layer of glass – in order to allow easy access to the inside of the box. All the tests were conducted with this plastic glazing. **It is important to emphasize that considerably better performance would easily be obtained by using glass or fiberglass which are not infrared transparent.**

The single-tank breadbox water heater was tested under several operating conditions, but only the performance of the heater when connected to the domestic water heating system is presented here. The lids were opened in the morning and closed at night. Tank temperatures were monitored by thermocouples placed inside the tank. The insulated lids were opened each day and closed each night. The effect of drawing hot water from the single-tank breadbox is shown by a sharp drop in tank temperatures. The tank temperature drops as warm water is drawn out and cold water at approximately 18°C (65°F) enters. As the cold and warm water mix, the tank temperature gradually rises. The tank showed a maximum temperature of 132°F and a minimum of 82°F during a typical day. Single tank heaters do not function nearly as effectively as multi-tank heaters because of the mixing problem.



Three-Tank Breadbox Water Heater (Hunt, Soldyne, Bainbridge)

The three-tank breadbox water heater can be easily constructed using readily available

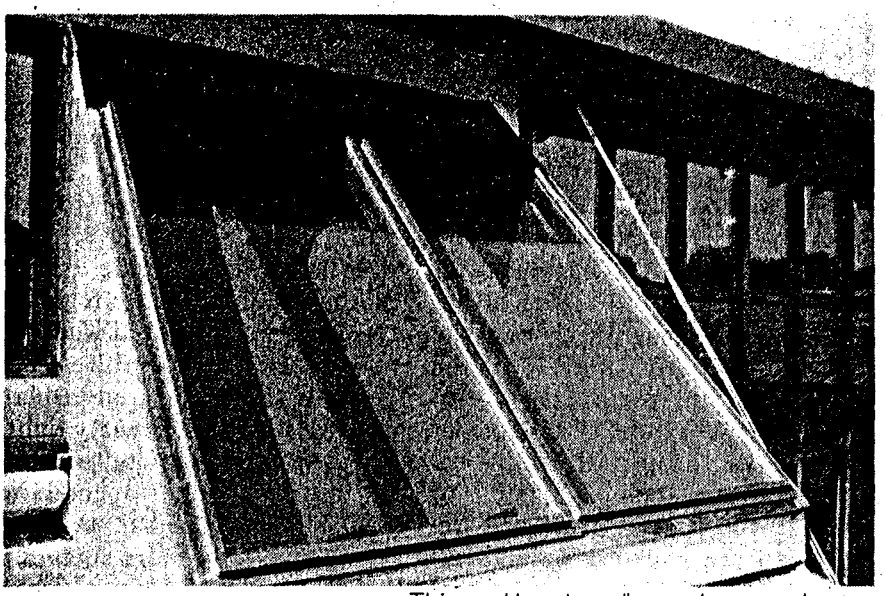


A great untapped market exists for commercial breadbox and modified breadbox, kits and complete water heaters. The table below presents the cost for a commercial breadbox system. It should be very competitive with flat plate systems. Construction and installation require fewer tools and simpler skills and should be possible for any plumber or handyman.

FEASIBILITY FOR COMMERCIAL CONSTRUCTION AND INSTALLING THREE-TANK BREADBOX

Material for breadbox	
$400 less 50% for wholesale discount	200.00
Tax	10.00
Materials for installation	
Installation costs vary from house to house. Costs should range $40-$90, assume $65	65.00
Labor - construction and installation	
40 hrs. x $10/hr.	400.00
Subtotal	675.00
Profit and overhead 15% of subtotal	135.00
Total	$ 810.00
Total breadbox cost comparable flatrate	$2000.00

Estimated by the author, July 1978



Thigpen-Hunt breadbox solar water heater.

materials and conventional construction techniques. Three standard glasslined water heater tanks are painted black and enclosed in a well-insulated box. Glass or another glazing material covers the south side of the box. Lids or interior insulated drapes can be installed to increase performance of the breadbox. The tanks are plumbed in series with the central tank as the final stage because Soldyne's experiments showed that the center tank stayed warmer than the end tanks.

The Bainbridge house in Davis, Calif. uses a breadbox consisting of three 30-gallon tanks, plumbed in series and mounted at a 45° angle in an insulated box. The box is glazed on the south side and currently has no shutters or drapes to prevent nighttime heat loss, although they are planned. The water is always drawn from the hottest tank, with very little mixing with incoming water.

The 45° angle mounting of the tanks serves four purposes. First, 45° is close to the optimal winter collector angle for the Davis, Calif. latitude. Second, it is easy to use in construction. Third, the 45° mounting of the tanks allows very strong temperature stratification to develop in the tank and insures that the hottest water is always being drawn. And finally, mounting the tanks on an angle allows for a compact arrangement within the box. This reduces both the material cost and the heat loss through the box and the glazing.

The box was also designed to minimize heat loss through the glazing. With the tanks mounted on a 45° angle, it might appear natural to build a simple triangular-shaped box to enclose the tanks. However, by truncating the triangular-shaped box on the top, reduced heat loss and glazing costs were achieved. Three 30-gallon tanks, 16"x36", spaced 8" apart (24" center-to-center) were used in the breadbox. This spacing allowed maximum exposure of the tanks during the winter.

This type of system has been in use for over 2½ years on the Hunt/Thigpen house in Davis, Calif. and provides full solar heat for 9 months of the year. More recently, similar designs have been included in two other tract houses built by Thigpen. Unfortunately, little monitoring had been undertaken until this summer when Bainbridge built his solar water heater.

On several days of operation of the Bainbridge breadbox in July 1978, the kitchen faucet temperatures ranged from 104°F to 148°F. It is important to note that this is delivered temperature in the kitchen af-

ter an uninsulated pipe run. Further tests are planned with various insulation, drape, and shutter modifications.

Build Your Own Breadbox Solar Water Heater

The breadbox water heater uses a very simple design to heat water. Water flow is provided by routing the cold water intake line through the breadbox and on to the back-up (natural gas or electric) water heater. The backup heater should be off and bypassed in the summer. This eliminates the need for expensive pumps and/or controls. The breadbox may serve as a preheater or provide all of the hot water needed. The following list of basic considerations can help you design and install a breadbox water heater for your own home or business.

Design Suggestions

● Find a sunny location (facing south) preferably close to the back-up water heater (to minimize pipe run) for the breadbox water heater. Make sure it will be exposed to the sun all year. Next, determine how the breadbox water heater will be installed, keeping in mind that it is fairly heavy. **A three tank system, filled with water, weighs approximately 1,000 pounds.** For a retrofit, it may be most practical to install the breadbox on the ground or on a special platform. It may be possible to reinforce an existing roof or carport to accomodate the breadbox water heater. Another possibility is to include a breadbox water heater system when you are adding a new room, deck or patio.

● Determine what type and size of breadbox water heating system you want. There are single and multi-tank systems to choose from, **bearing in mind a rule of thumb used for sizing water heaters – hot water consumption equals 20-40 gallons/person/day.** However, even a small, undersized system will preheat water and provide some energy savings.

● Decide what type of tank(s) will be used for the water heater. Tanks come in a wide variety of sizes and shapes. Almost any size and shape will work, but long and thin tanks will work best. This configuration has a greater surface area to water volume ratio, which will improve solar heating. New water heater tanks (minus the heating element, insulation and sheet metal cover) can be ordered from the manufacturer. Mobile home tanks are ideal for breadbox water heaters, because they are long and thin. Old water heater tanks can be obtained for no charge or purchased for a low price, then stripped down to the bare tank with the heating element taken off. Be sure to test the tanks thoroughly for leaks and rust, and patch them carefully. Other types of tanks, i.e., pipe, etc., may also be used, but a glass lined tank may be preferable. Acrylic or latex black paint can be used.

● Develop the system schematics. Your plan will depend on number of tanks, placement of plugs in tanks, utilization of dip tubes, etc. Remember, draw the warm water from the top of the tanks and enter the cold (or incoming) water at the bottom of the tanks through the plugs or dip tubes. Include plans to access the water main and return to the back-up water heater. Be sure to include a drain at the bottom of the system for draining the breadbox water heater if it is necessary to do some repair or protect it against freezing. Additionally, add a pressure/temperature relief valve at the top of the system to release pressure in case the temperature builds to high levels.

● Design a support structure (box) for the breadbox water heater. The tanks may be placed horizontally, vertically with a reflector, or tilted for maximum heat capture. The tilt for the tanks should be roughly equal to the degrees of latitude where the system will be installed, although it is often desirable to optimize for winter heat collection by adding approximately 10 degrees to the pitch.

● Make sure that the box is well sealed and insulated with 6-8 inches of fiberglass insulation.

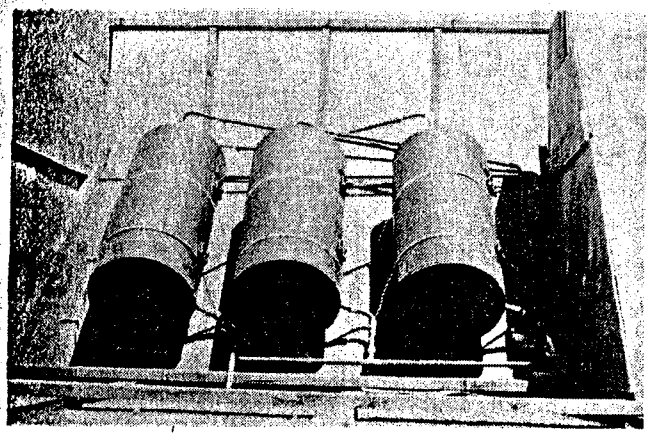
● Glazing is important for heat retention. There are a number of options: 1) Single or double pane tempered glass; 2) Tedlar coated fiberglass exterior with Tedlar fiber interior glazing; 3) Acrylic glazings; and 4) Other glazing materials.

It is advisable to use two panes of glazing material to provide for maximum heat retention. In mountainous or other areas where freezing temperatures occur frequently or for prolonged periods, a third glazing layer may be advisable. Be sure to caulk and tightly seal the glazing. First simulation runs by Davis Alternative Technology Associates* suggest that about 2.5 gallons per square foot of glazing is a maximum for best heating.

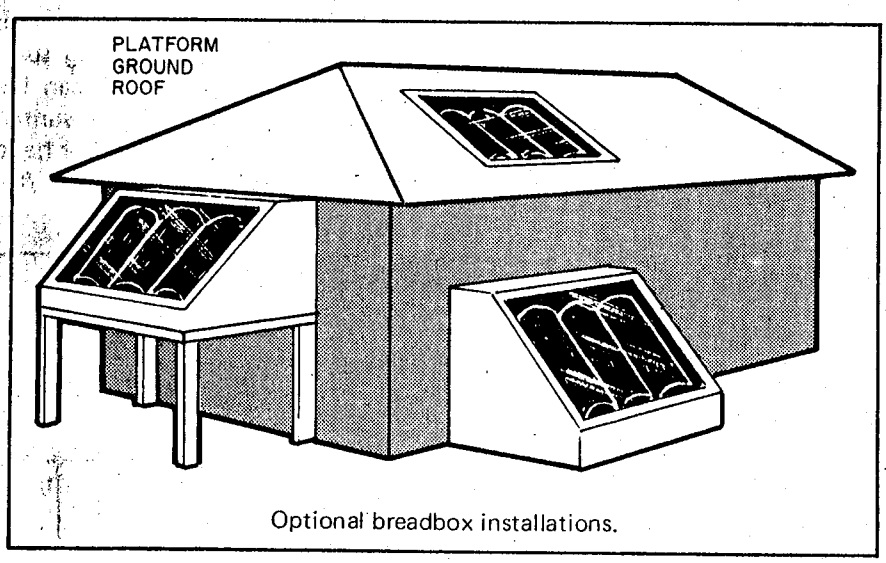
● Operating lids are optional in the milder climatic regions of the U.S., but essential where regular freezing temperatures occur. The lids should be well-insulated and designed to seal tightly. They may be manually operated or automatically opened and closed using a heat motor or freon transfer system such as the Zomeworks skylid.

● Reflectors may be used to increase the solar heat gain. Foil, or other material with a shiny surface, is installed around the breadbox water heater and placed at an angle to focus additional solar energy onto the tanks. There is a variety of materials and methods used to construct reflectors. If operating lids are

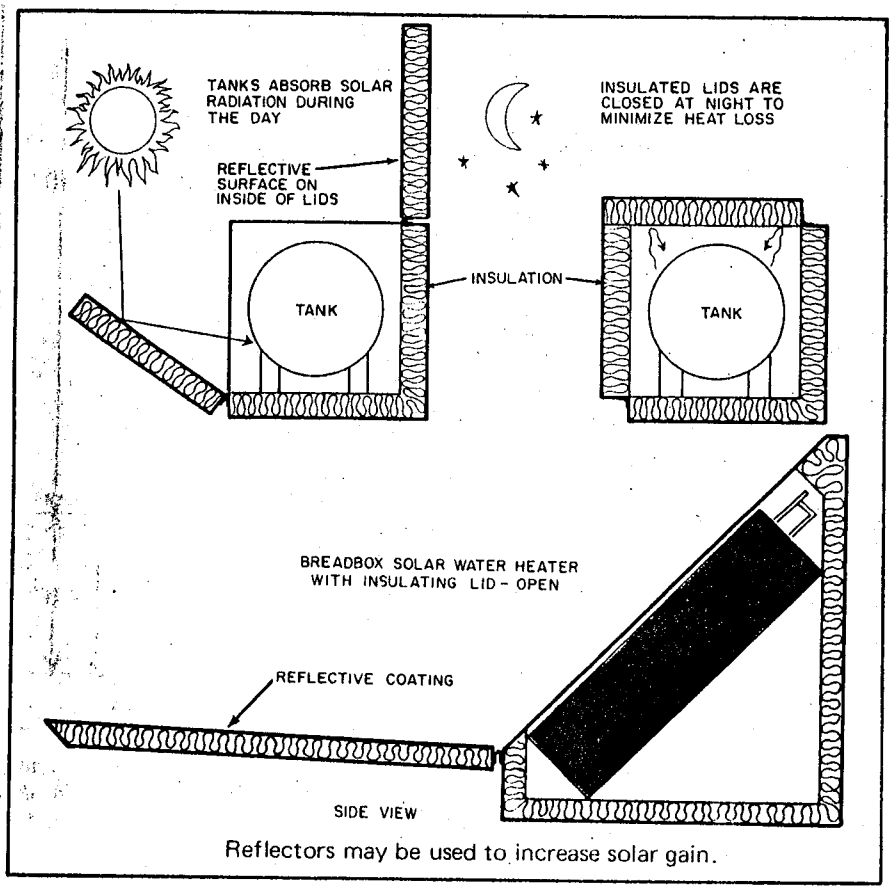
** PO Box 503, Davis, CA 95619*



Conventional building practices and the common sense employed in other building projects are required for installing a breadbox water heater.



Optional breadbox installations.



Reflectors may be used to increase solar gain.

installed, it is usually simple to make them reflectors.

The breadbox water heater can be placed almost anywhere with good solar exposure. It is important to minimize the pipe run to the backup water heater.

In many houses the breadbox can be built on the ground, near the hot water closet. This makes installation easier, and also makes shuttering more straightforward. There are numerous other possibilities for placement of the breadbox. It can be put on a carport, patio, or roof if it is strong enough. If necessary, it can be placed on a special platform.

The installation of the breadbox water heater is straightforward. Conventional building practices and the same type of common sense employed in other building projects are required.

Below is a partial listing of installation precautions.

- Obtain required building permits and approvals.
- Locate the breadbox water heater as close as possible to the backup water heater to provide better thermal performance and lower the plumbing hookup costs.
- Make provision for draining and disconnecting the solar heater from the existing water heater for repairs, and in areas with severe freezing.
- A T&P (temperature and pressure) relief valve and line should always be installed on the solar preheater tank to prevent rupturing.
- Be sure that water lines leading from the home to the breadbox are well insulated and protected from water penetration.
- Be sure that the support structure is adequate to hold the weight of the breadbox water heater (total weight is around 1000 pounds for a three tank, thirty gallon system).
- When the breadbox water

continued on p. 45

estimates should be doubled to two years for electrical back-up heat and about four years for oil-furnace back-up heating. In addition, this may have to be extended further depending on the proportion of cloudy days over the heating season.

Nevertheless, I suspect that the "Sun Sucker" is probably going to pay for itself reasonably quickly.

Daniel Blum
4004 Brainard Ave.
Kensington, MD 20795

Table 1

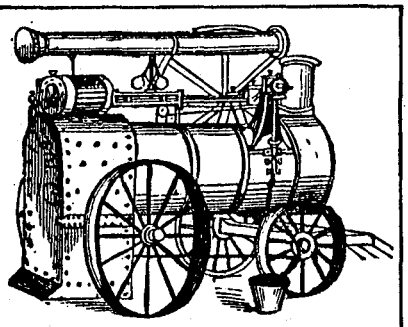
Cost Itemization
Three Tank (Soldyne) Breadbox Water Heater*

Item	Amount	Price/Unit	Total
2x4's	134 ft.	.19/ft.	25.46
Plywood - 3/8 AC exterior	4 sheets	8.16/sheet	32.64
Masonite 1/8	1 sheet	7.98/sheet	7.98
Insulation - R-11 fiberglass	16 sq. ft.	.16/sq. ft.	2.56
Breadboard 1½"	1 sheet		
Breadboard 2"	1½ sheet		(est.) 30.00
Caulk - Arch. grade	2 tubes	1.23/tube	2.46
Tanks - 30 gal. 36x16	3 tanks	41.25/each	123.75
Glazing - Tufwal		31 sq. ft.	
	(2 sheets)	45.00/sheet	90.00
Paint - Bar-B-Q black	½ qt.	7.79/qt.	3.90
Paint - exterior latex	2 qt.	11.55/gal.	5.76
Wood sealer	2 qt.	9.95/gal.	4.96
Flashing - assorted sizes		20.00	20.00
Plumbing			
Dialectric flex conn.	2	7.35	14.70
3"x¾ gal. nipples	6	.43	1.29
3/4 plugs	5	.49	2.45
18"x¾ pipe	2	1.99	3.98
Hose bibs	3	2.49	7.47
		Subtotal	379.36
		Tax (6%)	22.76
		TOTAL	$402.12

Note: All costs are retail prices.

The Bainbridge breadbox was built for about $400 in July 1978. It took about 40 hours to build.

*Constructed by the Soldyne Group in Davis, California - Summer, 1977.



heater is installed, it is important to bleed the air out of the system to assure good performance. Most tanks have enough plugs to make this easy.

● If galvanized tanks are used with copper pipe, make sure they are separated properly with a dielectric fitting to prevent accelerated corrosion.

Water Heater Maintenance

Excessively high hot water bills often reflect neglect of your existing hot water heater. Three areas of neglect are: 1) Exposing the water heater to the weather, or poorly insulating the room in which it is housed; 2) very high water temperature setting or faulty thermostat control; and 3) buildup of sediment deposits within the water heater tank. Unless a water softener exists between the cold water supply line and the domestic hot water heater, all heaters should be drained and inspected for sediment deposits annually. It makes good sense to tune-up your water heater when you install your breadbox – or even if you don't plan to install one.

Cost

Table 1 itemizes the costs for construction of the three-tank breadbox water heater built by the Soldyne Group in the summer of 1977. Of course, cost figures will change over time and be subject to local supply and demand conditions. The cost figures presented here give an indication of the range of costs that can be expected. It is apparent from this table that the material cost for breadbox water heaters can be quite low. Cost can be reduced by using recycled materials which are often free or very inexpensive. In fact, effective breadbox water heaters have been built from recycled materials (a water tank and refrigerator) for under $30. If quality is a consid-

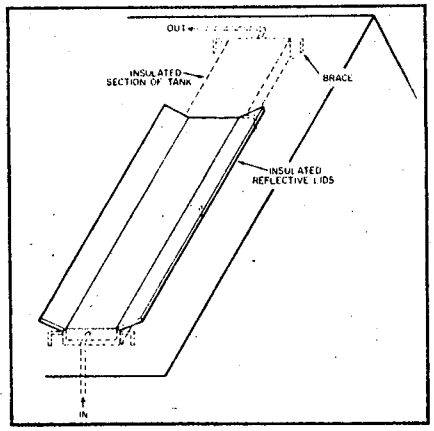
eration, breadbox water heaters can be built with more expensive materials and better construction for longer life and better performance.

Table 1 shows the cost for materials only because breadbox water heaters are ideal do-it-yourself projects. The simplicity of their construction and installation means that the labor cost can be cut completely. For contractor-built systems, labor is usually estimated to be about equal to the materials cost. Therefore, the total system cost would be approximately twice the cost of materials. It is evident that the cost for breadbox water heaters is significantly lower than flat plate solar collector water heaters, although the performance of breadbox water heaters may be lower than flat plate collector solar water heaters. The California tax credit is applicable to breadbox water heaters, and it can be used to return 55% of the total cost for materials and labor.* The typical payback period for the breadbox water heaters is thought to be about two years for the owner-built system and four years for the contractor-built system.

Conclusions

Three-tank breadbox water heaters have performed substantially better than the one-tank breadbox water heaters tested to date. With a collector area of 48 square feet, full solar heating is provided for 9 months in Davis. This is comparable to flat plate performance. However, even a small, simple one-tank system will prove effective as a water heater or a preheater, and will help reduce utility bills. A solar breadbox water heater can effectively provide much of the annual hot water demand for a household in most climates.

Sizing and system optimization are still fairly crude, but may be kept crudely right if collection area is based on flat plate considerations. A detailed investigation of heat flow is needed to establish whether the breadbox heater performs better than a flat plate collector. It might, because the area of exposed surface of actual water container may be 2-3 times that in a flat plate collector, and the heater will typically be cooler -- thus reducing back radiation and increasing efficiency. At this time, no one knows for sure.



Even a one-tank system will prove effective as a water heater or preheater.

One possible design concept which has not been tried or tested would be more simple and considerably less costly (per unit of hot water) than the three tank residential system. It would include a single long tank of 90 to 120 gallons (either round or rectangular) built into the roof. The tank should include brackets for hanging between rafters and be braced off a wall. Properly done, it might be retrofitted under an eave overhang. The upper part of the tank would be insulated to contain the heat in the water and reduce nighttime heat loss. This type of system could be developed for small scale (residential) use and larger scale (multi-family, commercial and industrial) applications.

There are many variations to the designs presented here. As the breadbox water heater concept becomes more popular, it will stimulate a flurry of research and development activity that will present many different design options. Currently, the field is wide open for experiments and innovative designers. Developments are needed in ways of increasing the collecting area of the tank as well as in ways of insulating the tank in colder climates. We hope to present results of further testing within the year. ●

** Labor is eligible for the tax credit only if it is paid for. You can't pay yourself and claim it as a tax credit.*

Further Reading

Akers, D. (1978) "$30 Homestead Solar Water Heater", *Mother Earth News,* May-June 1978 No. 51.

Baer, S. (1975) **Breadbox Plans,** Zomeworks, Box 712, Albuquerque, New Mexico 97103.

Bainbridge, D. and Reiss, J. (1978) **The Breadbox Solar Water Heater, The** Solar Office, Calif. Energy Commission, 1111 Howe Ave., Sacramento, CA 95825.

Brooks, F.A. (1936) **Solar Energy and Its Use for Heating Water in California,** UC Berkeley Agric. Exp. Station, Bulletin 602. Available from OAT, 1400 Tenth Street, Sacramento, CA 95814.

Butti, K. and Perlin, J. (1977) "Solar Water Heaters in California 1891-1930," **CoEvolution Quarterly,** Fall.

L.A. Times Home Magazine, May 1, 1977.

Lucas, T. (1976) **Economical Solar Water Preheater,** 10371 Stone River Court, Fountain Valley, CA 92708.

Maeda, B. (1978) Personal communication, r/e simulation runs of breadbox performance, Davis Alternative Technology Associates, P.O. Box 503, Davis, CA 95616.

McCracken, H. (1976) **Passive Solar Water Heater,** Rte. 1, Box 417, Alpine, CA.

Missouri Department of Natural Resources, (1978) **Solar Water Preheater.**

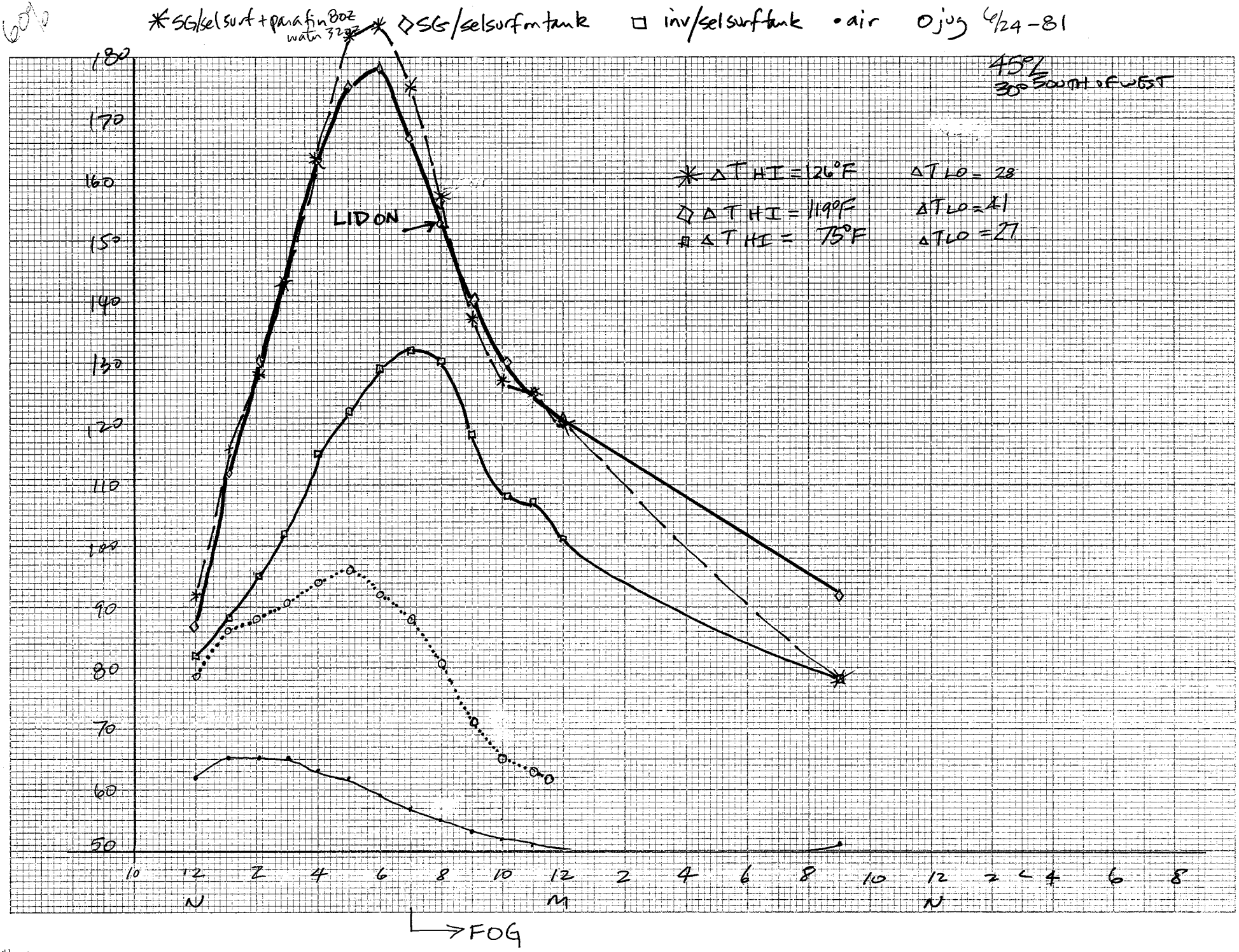
Morgan, E. (1976) "Solar Bubble," *Popular Science,* September, P. 101.

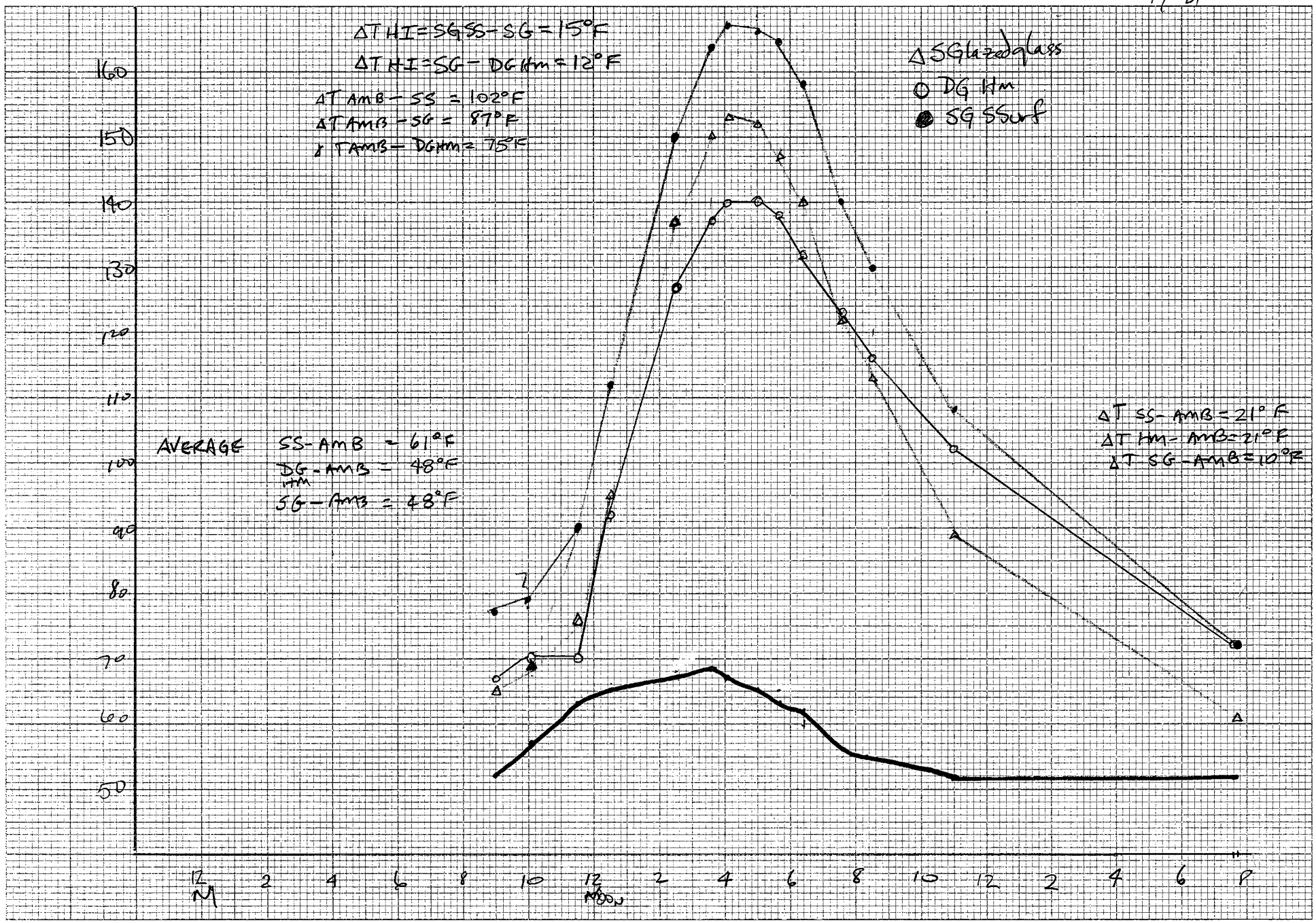
Starr (1978) "Analysis of Energy Conservation Techniques: Davis Retrofit Program," City of Davis/ Sedway-Cooke.

Starr, G., Melzer, B. et al., (1978) *Resource Conservation for Residential Buildings,* N.S.F. Grant 77-05558, Davis, CA.

Union Electric (1978) *A Simple Approach to Solar Heating of Domestic Hot* Water, Union Electric Co., St. Louis, MO.

Zweig, P. (1978) **Inexpensive Do-It-Yourself Solar Water Heaters or Preheaters,** PCRI, 3875 Jackson Street, Riverside, CA 92503. ●





#1 60°

BARK
45° SW

5/1/61

NATIONAL 12-282 Made in U.S.A.

Squares to the Inch