Power Boosted Solar Cookers

by

Roland Saye

PREFACE

Being an inventor-for-hire, I've spent a lot of time inventing things for clients. I keep seeing different ways to do interesting things that cross my path. I can't help it; it just happens. Sometimes the ideas are good, sometimes not.

In June this year I attended the World Conference on Solar Cooking Use and Technology held by Solar Box Cookers International, so I joined SBCI and it's happening again.

I try not to be pushy about my ideas and offend people who are happy with how they are doing things now, so usually I don't mention an idea unless there's a good reason. In the case of solar cooking, so many people could benefit from better solar cookers that I am writing this to share ideas and observations that may be helpful to those interested in making, using, or promoting solar cookers.

Another reason for writing this is to clarify my thinking about what ideas to try and how to test them. Some of what I have to suggest is not now in use and may even be new in the patentable sense of new. My rights to any thing new described here I give to the public for all to use.

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Power Boosted Solar Cookers

THESIS

Solar cooking would be easier if sunlight were a little more powerful and heat paths were shorter. Cranking up the power would be simple using nonimaging concentrators; the concentrator is the crux of the problem.

INTRODUCTION

Present day solar box cookers rely on about three square feet of sunshine to heat an oven-like box to cooking temperature. Design is centered around getting the box hot, not easy to do. Instead, maybe design ought to center on getting the food hot.

Heat in the box is generated by absorbers such as black pots and black sheet metal. Cooking temperature depends on conserving heat with insulation and glazing. Extra sunlight reflected into the box helps. Heat finally reaches the food through the walls of the pots which are heated by radiation from the sun and hot things in the box. It's a roundabout path to get heat from three square feet of sunshine into a pot of food. The food winds up at the cool end of the heat path.

The corollary to boosting solar power is improving heat transfer into the food. Wherever possible, sunshine falling directly onto the food could provide the shortest heat path. Where this isn't practical, solar absorbers in direct contact with the food provide short heat paths. Nothing is available to do this at present because food is cooked in solar cookers in whatever pots are on hand, black ones with lids being preferred. No special utensils or accessories designed for solar cooking are available commercially.

Three projects to improve solar cookers are indicated:

1. Develop a simple 2 to 4X solar concentrator.
2. Shrink the "box" in box cookers to pot size.
3. Develop absorbers that heat food directly.

Note: Suggested improvements are set off in borders.

ILLUSTRATIONS

3D SUN FUNNEL

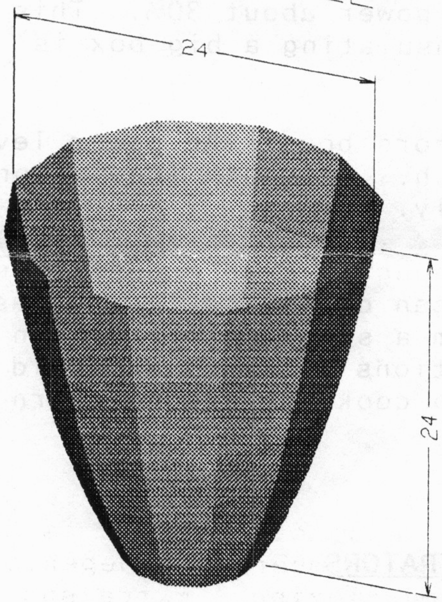
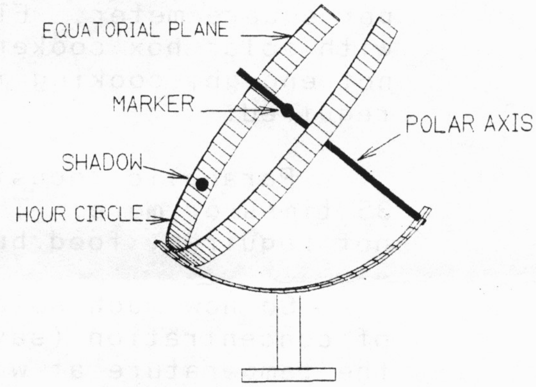


FIGURE 1



SUN DIAL

Figure 3

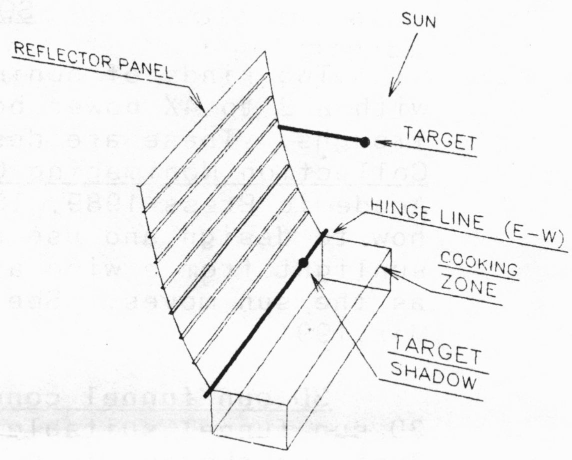
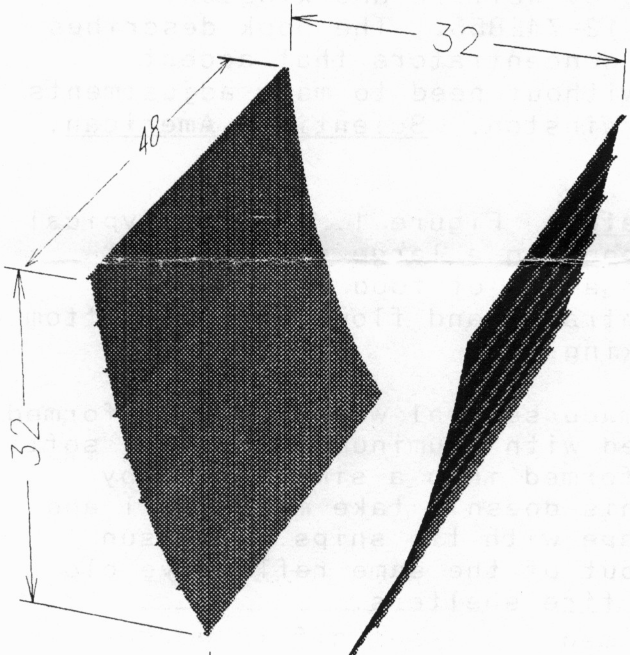


Figure 4

HALF-TROUGH SOLAR CONCENTRATOR



2D TROUGH - FIGURE 2

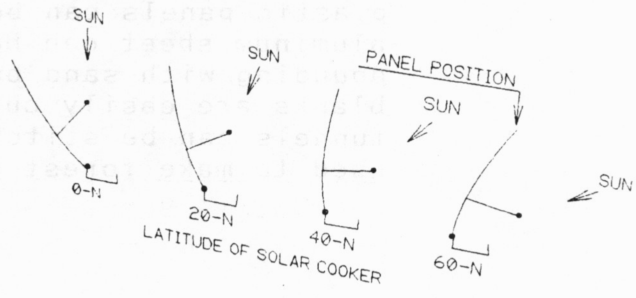


Figure 5

PANEL POSITION vs LATITUDE

SUNSHINE

Power density of natural sunshine is about one kilowatt per square meter. Flat nonimaging concentrators now used with solar box cookers only boost power about 30%. This is not enough; cooking is slow and insulating a big box is required.

Parabolic focusing concentrators boost the power level 35 times or more. This is too much. Although insulation is not required, food burns too easily.

So how much solar power is enough? Even modest levels of concentration (say 1.5 to 2X) can dramatically increase the temperature at which heat from a solar collector can be extracted efficiently. Concentrations of 2 to 4X would allow for some heat loss, speed up cooking, and not burn food easily.

SOLAR CONCENTRATORS

Two kinds of nonimaging solar concentrators fit in well with a 2 to 4X power boost. They are 3D sun funnels and 2D troughs. These are described in detail in the book High Collection Nonimaging Optics by Welford and Winston, Academic Press 1989, ISBN 0-12-742855. The book describes how to design and use solar concentrators that accept sunlight from a wide angle without need to make adjustments as the sun moves. See also Winston, Scientific American, Mar,1991

3D sun funnel concentrator: Figure 1. shows a typical 3D sun funnel suitable for cooking a large pot of food. Just set the sun funnel over a pot of food so sunlight shining in the top is concentrated and flows out the bottom into the pot and you're cooking.

3D sun funnels can be made several ways. Vacuum formed plastic panels can be covered with aluminum foil. Or, soft aluminum sheet can be hand formed into a simple mold by pounding with sand bags. This doesn't take much skill and blanks are easily cut to shape with tin snips. Or, sun funnels can be stitched up out of the same reflective cloth used to make forest service fire shelters.

2d trough concentrator: Figure 2. shows a 2D trough suitable for cooking several pots of food at once. It works in a fashion similar to the funnel in Figure 1. Both 3D and 2D units shown are designed to accept sunlight up to 20° either side of the axis of symmetry.

2D half-trough concentrator: When the sun comes from the extreme angle off the axis of symmetry, the side of the trough toward the sun is in shadow and may be eliminated. This leaves a 2D half-trough concentrator (my terminology). Figure 4. shows the general arrangement of a half-trough as it would be set up for cooking.

The concentrator panel is hinged at the bottom along an east-west axis and carries a target rigidly attached to it. Panel position is adjusted to shine light into the cooking zone by swinging it on its horizontal hinge until the target's shadow falls on the hinge line. Direct sun light is also falling at full strength into the cooking zone. Total concentration consists of the sum of direct and reflected light.

> 2D Half-trough concentrators are easy to make. The mild curvature required on the reflector is a single curved surface easy to bend to shape on a simple wooden frame. Reflective anodized aluminum seems to be the best material. The whole project would be ideal for do-it-yourselfers with modest wood working tools. Plans and a sheet of aluminum could be shipped almost anywhere and finished with hand tools and local wood supplies. This is my first choice.

Adjusting 2D half-trough concentrators: Figure 3. uses a sundial to illustrate how the sun's path relates to adjusting a half-trough concentrator. The dial shown can be tilted for use at any latitude. It happens to be set for 38° N latitude (my home) so its hour circle is tilted south 38° from vertical which makes it parallel to the earth's equator. The rod along the polar axis is inclined 38° upward toward north and passes through the center of the hour circle.

The sun's path is illustrated by the marker and its shadow in Figure 3. Move the marker along the rod until its shadow lies on the hour circle as shown. (The marker position also acts as a calendar.) As each day progresses, the shadow travels along the hour circle from west to east. It is not necessary to adjust the marker again for several days until the shadow slowly slides off the hour circle. (Then, reset it to show the current date.)

As the season progresses and the sun moves higher or lower in the sky, readjusting the marker keeps the shadow centered on the hour circle. Once adjusted, the shadow moves along its path without attention. A half-trough solar concentrator with its axis lying east and west can be set the same way.

Figure 5. shows the position of half-troughs set at each of several latitudes. Each concentrator can be adjusted as it is used by moving the target shadow as described above.

IMPROVING OLD BOX COOKERS

Thousands of box cookers are in use throughout the world. A great number of them, used by SBCI to introduce and promote solar cooking, are made of cardboard , aluminum foil, and sheets of plastic because they were designed as training aids and examples for do-it-yourself fabricators. They cook well but they could be simpler and more compact.

> The easiest way to improve performance of an existing SBCI box cooker might be to bend its flat reflector so it concentrates more sunlight in the narrow band along the hinge side of the box where the food is placed. Like a 2D half-trough concentrator would do. It's worth a try.

Another improvement to box cooker performance might be made by leaving the lid off the old pot and replacing it with a heat-transparent-floating-absorber. See description below in the paragraph <u>Absorbers</u>

STARTING FROM SCRATCH

Significant improvement of solar cookers requires understanding two necessary processes: generating heat, and conserving heat.

<u>Generating Heat:</u> There is no heat in sunlight. The heat that we sense as something hot comes into being only when sunlight is absorbed, for example by our skin. Heat forms in the absorber. Since black bodies are good

absorbers, we put black things into solar box cookers to generate heat that cooks the food. Concentrated sunlight generates more heat than natural sun light. The trick is to get heat from the absorbers into the food before it gets lost somewhere, not easy to do in a big box.

Conserving Heat: Heat is lost by radiation, conduction, and convection. Radiation loss can be reduced by using a glass lid (glazing) and keeping the food hotter than the pot. Conduction loss can be reduced by making the pot out of glass which is a poor heat conductor and surrounding it with a large still air space filled with fluffy material, like a tea cozy. This also reduces convection losses in breezy, cold places. So, a pot with a wide mouth covered with glass to admit sunlight, some insulation, and an absorber to generate heat eliminates the big cardboard box altogether. Set the pot in concentrated sunlight and start cooking.

An observation is offered here to those planning insulation for solar cookers. Still air is the best insulation available against loss by conduction. Note the words still air. The only purpose for stuffing an air space is to prevent air circulation and stop convection loss. Any stuffing in an air space, newspapers for example, has higher heat conductivity than plain, still air; so the less used the better.

I suggest plain, clean cotton bolls as a good stuffing for air spaces. A package of cotton seeds could be included with each solar cooker kit for inveterate do-it-your-self types.

Absorbers: Heating the food hotter than the pot can be done by judicious use of the absorbers required to generate heat. Two examples explain how they work.

The first consists of an aluminum foil pie plate painted black inside and selected to fit inside the pot so it lies on the food, or floats on it. The thin aluminum foil is virtually transparent to heat. It's astonishing how fast it gets hot sitting on your hand in the sun. Heat is transferred to the food directly, just as fast as it is to your hand, and the food gets hotter than the pot.

A second example is for cooking potatoes and the like. Shaped like a big thumb tack and made of aluminum, it has a 2 to 3-inch diameter plate painted black on top with a heavy spike or two coming out the bottom to stick into the food. Cut the potatoes in half and set each piece in the pot with a big "tack" stuck firmly into its top. The head of each tack and the heavy aluminum spike carry heat directly into each potato before any is lost to the pot.

DEVELOPMENT PROJECTS

Prototypes and testing are needed to show that simple solar concentrators combined with proper pots, absorbers and insulation can cook well and fill a need. If a market for solar products develops the products will appear to supply it. Development should focus on things saleable in stores. Products that might bear Coleman or Rubbermaid trademarks.

Solar Concentrators: The object is to provide a portable solar concentrator to intensify light falling on a solar cooker. When set up along an east-west axis, frequent adjustment for sun motion should not be required; but the unit should be useable at any latitude.

Tests will be made to determine best curvature of the reflective panel and to measure solar concentration actually obtained. Ease of operation and adjustment are important goals.

Cook Pots: Various combinations of glass and metal utensils with glazing and insulation will be tested to prove convenience and cooking performance. Double walled glass baking dishes will be compared with single walled units. Availability is a primary goal.

Insulation: Insulation systems integral with utensils will be tested and compared with bags for heat retention and access to the food by the cook during food preparation.

Solar Lunch Boxes: People who would enjoy a hot meal at lunchtime often work in remote places far from food services, so they carry lunch boxes. A solar lunch box to heat leftovers and TV dinners could fill their need. Heating food requires less heat and time than cooking food. Tests will be made on a prototyype of such a lunch box equipped with a folding concentrator, glazing, absorbers,and insulation.

Solar Cookers: Prototype solar cookers suitable for use at a campsite or on a boat will be designed and tested. Portability will be comparable to a propane camp stove so they can be set up on a sunny table or tailgate. Equipment to cook fish will be featured.

Power Boosted Solar Cookers - II

by

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PREFACE

The first paper in this series proposes: 1) using solar concentrators to boost power and 2) shrinking solar cookers down to pot size. Details and references in that first paper describe using solar concentrators for power boosters and using solar absorbers to heat food directly. This paper describes shrunken cookers using solar concentrators and absorbers (as yet untested.)

INTRODUCTION

Reversing the orthodox approach often suggests new solutions for old problems, for example, starting with the food and working outward shrinks a solar cooker down to basics. Shining sunlight directly on food heats the food hotter than the pot and improves efficiency so everything can be smaller and less expensive.

Start by imagining a gob of food suspended in space with sunlight streaming down on it from above, warming it.

Of course the food won't hang in space for long unless something is put under to hold it up. A pot will do. And the pot needs something to sit on, a base of some sort, a board maybe. So now we have imaginary food in a pot, sitting on a board, sitting in the sun, getting warm.

But warm isn't good enough. Hot is necessary, so more is needed. For example: a solar concentrator to give a little boost to solar power; a solar absorber to concentrate heat on the food; insulation to isolate the hot food from its cool surroundings thereby conserving heat.

We now have in mind all the basic elements of our imaginary solar cooker: 1) food, 2) pot, 3) insulation 4) sunshine, 5) solar concentrator and 6) solar absorber. Let's see what they might look like.

GENERAL ARRANGEMENT

Sunlight comes down naturally from above to heat things on the ground. Solar box cookers are arranged to receive sunlight this way which seems the best arrangement for a solar cooker.

Some solar cookers have not taken advantage of this natural arrangement. For example, parabolic focusing concentrators reflect light upward and must be placed below the pot of food. This shines painful light into peoples eyes and requires expensive poles and derricks to support pots of hot food high in the air at the parabola's focal point. But they do get very hot.

In contrast, nonimaging concentrators could gather sunlight on its downward path, deflecting it but little, so it would fall naturally into the top of a pot of food sitting on a table or the ground. The hot food would be safe - both low and stable. Light would be directed down into the food, not into the cook's eyes.

When the sun is low in the sky, nonimaging concentrators would slant sunlight from its low angle down into a steeper slope, a more useful direction for heating food - an added benefit from this arrangement.

BASIC COOKER

Figure 1 shows the basic elements of a simple cooker: a covered pot of food, an insulated base, and a nonimaging solar concentrator all sitting on a table. The concentrator panel is long enough to cook several pots at once. Figure 2 shows the cover raised off the pot so the cook can stir the food.

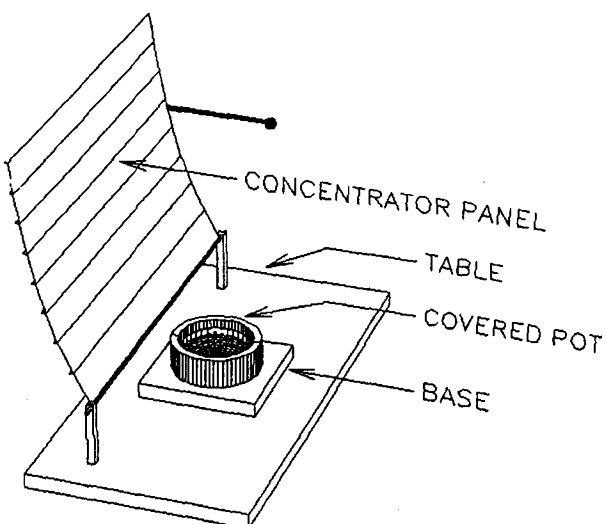

FIGURE 1
BASIC SOLAR COOKER

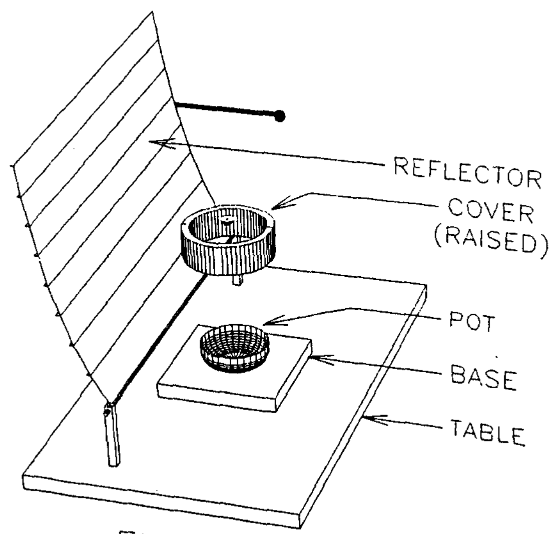

FIGURE 2
BASIC SOLAR COOKER WITH COVER RAISED

The Pot: Wide shallow pots present more area to receive sunlight than tall narrow ones. The pot shown in Figure 1 has good proportions. It is a 2 liter pyrex casserole with a 9-inch diameter and 3-inch depth. A baking dish would also be a good choice. Metal could serve instead of glass, but glass being such a poor heat conductor doesn't lose much heat to things it touches. I prefer glass.

The Base: Heat flows away from hot food in all directions. Some heat leaves as radiation, some is carried away by the air, and some is carried away by things the food touches. The base that supports the pot of food performs two functions. First, it blocks heat loss in the downward direction. Second, its flat top surface forms a seal with the insulated cover.

Figure 1 shows the base as a low platform, flat on top. It could be a plywood box stuffed with insulating material and aluminum foil sheets. Or, it could be a plank. Choices depend on the solar power density being used - higher power requires less careful insulation .

The Cover: The hot food and hot pot must be covered so wind can't blow heat away. Covers should make a draft-proof seal with the flat base to keep wind out. Cover walls should be insulated to stop heat loss to the surroundings. Finally, the top, which must let sunshine in, should be glass covered (preferably double glazed) to trap radiant heat as well as to keep wind out. Figure 2 shows the base and pot with the cover lifted up so the cook can work with the food.

Covers could be made of high-tech foam with glazing molded into the foam. Or they could be cardboard rolled with aluminum foil into a cylindrical shape with glass taped on top. Or, double-walled cloth sleaves stuffed with cotton bolls between them could be tied around glass disks on top and set on the base. Or, a pot with a glass lid could sit in a basket of cotton bolls, omitting the separate base and cover altogether - this is the simplest system.

With imagination, simple, basic solar cookers could be made from available materials by people living in very primitive conditions provided they have the means to buy, make, or somehow get a solar concentrator.

MAKING SOLAR CONCENTRATORS

It need not be difficult nor expensive to make solar concentrators adequate to family cooking needs. Jay Campbell's 60^{o} cone concentrators described in Home Power magazine, #31, October/November 1992 are made of cardboard and aluminum foil and are within reach of all.

Nonimaging concentrators invented by Winston were described and illustrated in my first paper in this series. These sun funnels are more difficult to make but are adaptable to a wider variety of applications. Folding, portable units for suggest.

But the simplest concentrators and probably the easiest to make without machinery are the half-trough concentrators described in my first paper. These consist of a flat sheet of reflecting material curved into a parabolic arc. Accuracy of the parabolic curve is probably not critical, because no image must be formed. Only testing will determine how much contour variation is permissible.

Stay tuned....