THE TRACKING SOLAR COOKER

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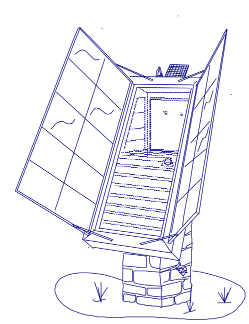
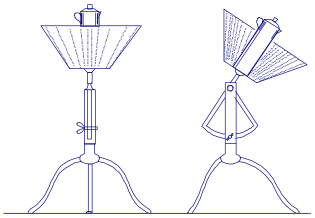
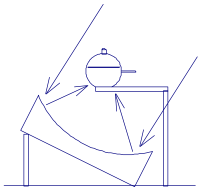


INTRODUCTION

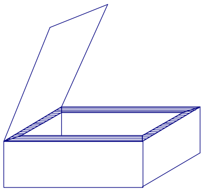


The concept of solar cooking began over 220 years ago and was used by the French Foreign Legion starting in the 1870's. All solar cookers work on the principle of concentrating the direct solar rays to raise food or water to cooking temperatures. Cooking temperatures begin at about 150 degrees F. although temperatures of 250 to 400 degrees F. are preferred.

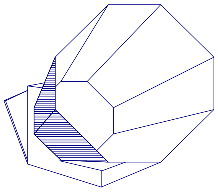
Open reflector type solar cookers focus the sun's rays on open cooking pots or pans. Solar ovens trap the sun's heat inside insulated boxes with transparent lids. Most solar ovens are variations of the bread box type developed by two Arizona women, Barbara Kerr and Sherry Cole.



These simple box cookers created in the 1970's are now being used world wide to overcome food shortages in developing countries. In places like Eastern Africa native women travel 20 to 30 miles to gather a two day supply of cooking fuel. In other parts of the world increasingly high rates of malnutrition are caused by a lack of fuel. Basic grain foods cannot be cooked without cooking fuel and water infected with chronic bacteria must be heated before drinking. Continued gathering of wood cooking fuel by chopping down trees has resulted in eroded hill sides with loss of precious topsoil thus reducing their ability to grow food.



In America we concern ourselves with such things as operating costs, air pollution, acid rain and the green house effect. Let's say it takes one hour to cook a pot of beans on an electric stove using one kilowatt. The coal fired power plant that supplied the electricity consumed one pound of coal and released 17.5 cubic feet or two pounds of CO_2. The power plant also consumed 0.7 gallons of ground water and released traces of SO_2 as acid.



Suppose you are cooking outside. Five pounds of steaks on a grill will use a ten pound bag of charcoal and five ounces of lighter fluid. This fire will produce approximately 160 cubic feet or fifteen pounds of CO_2 and untold air pollution. Wood fires are even worse.

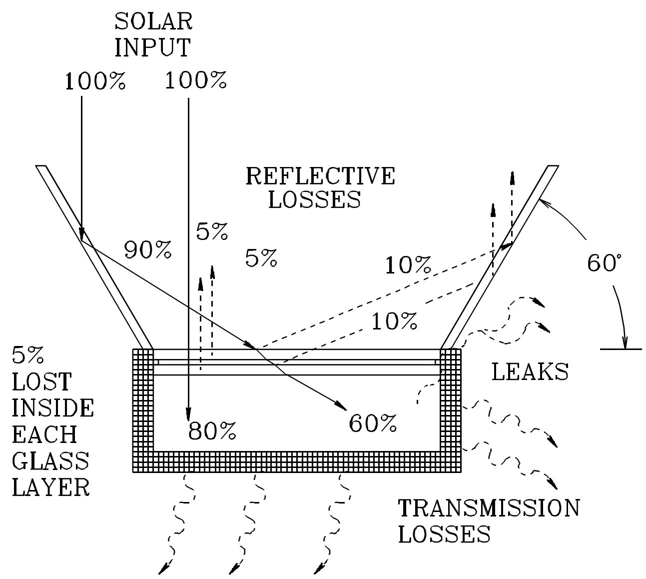
Cooking in the home averages over 100 hours a year consuming approximately 1,175 kilowatt hours. At a cost of $0.10 a kilowatt hour this amounts to $117 a year. During the summer cooking adds $50 to the air conditioning bill bringing the total to $167 a year. In Arizona, solar cooking can replace 70% of the cost of cooking. This will save 1,675 pounds of coal and 3,000 pounds of CO_2 generation from coal fired electric utilities.

Clearly solar cooking has come of age.

A solar oven's cooking temperature is reached when the solar gain equals the heat losses. Thus an oven's cooking temperature is a balance between solar gain and heat losses.

Heat losses fall into five categories:

1. Reflective losses
2. Absorption Losses
3. Transmitted Losses
4. Leakage Losses
5. Food losses (Heat Lost To Cooking)

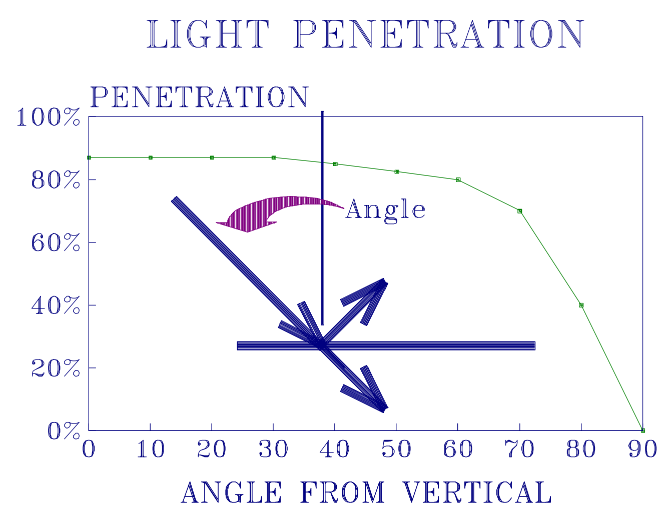


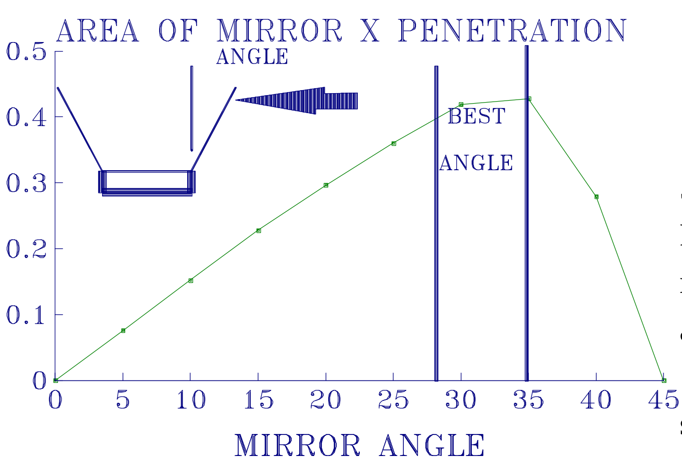
Solar gain is a factor of the total area exposed to the sun and the effectiveness of collection.

For the reflectors this property is acceptable but for the cover glass, light must enter the cooking chamber, or the mirrors are of no use. As a stone skipping across water, sunlight will skip off the surface of glass without penetrating if the angle is too shallow.

An angle of about 30 degrees from the vertical for the mirrors or reflectors yield good penetration with a healthy spread for an optimum use of materials. As it turns out a reflector equal to the width of the cooking chamber produces an optimum design for use of materials.

With such a fortunate set of circumstance the reflectors can be folded to cover the cooking chamber making the cooker portable!



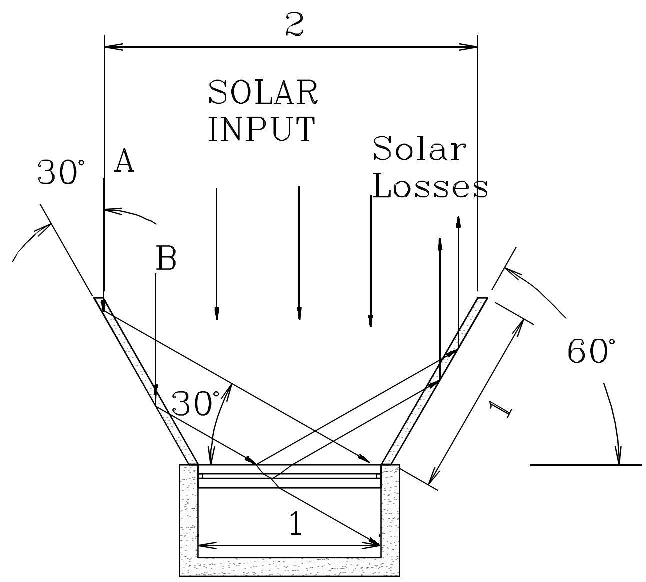


Mirrors have a reflection of about 99% but lose 5% each time the light passes through the glass. Polished metal surfaces have about 90% reflection but no losses due to glass. The result is that each behaves about the same.

Light striking the far edge of the reflector should enter the cooking chamber at the far edge opposite the reflector to be beneficial. An angle of 30 degrees from the vertical (or 60 degrees from the horizontal) with each reflector equal to the width of the cooking chamber will allow all the light striking the reflectors to enter the cooking chamber. With this geometry you can still fold the mirrors!

An optimum sized cooker will cook just about anything you put in it. Extending the reflectors to make the collector larger will produce more heat and will cook food faster. If you extend the reflectors the cooker becomes less portable. Doubling the length of the reflectors increases its width by only 20% because the angle must be steeper. The shallow sun angle on the reflectors makes them more reflective. The penetration into the cover glass improves somewhat because of the more vertical angle.

Of the five factors affecting a cooker's cooking temperature three of them were thermal loss. Transmitted losses are controlled with insulation. Double glass covers have twice as much insulation value as single glass covers. Leakage losses are controlled with good tight construction. The chamber should be well fitted and protected from moisture on the inside.



OPTIMUM REFELECTORS

Solar heat is transferred into the food by three mechanisms. First by direct solar rays, that is sunlight striking the food directly. This is somewhat like a broiler. Second by convection, that is by the hot air surrounding the food inside the chamber. Third by conduction of heat from the tray upon which the food rests. If the tray is a heavy metal conductor such as steel or aluminum the sun's rays will heat the tray and conduct the heat under the food like a stove. All three mechanisms combine to make the food cooking process very efficient.

Finally, as the sun's energy is transferred into the food the thermal loss drops the oven's temperature 25 to 50 degrees initially. This loss is only temporary.

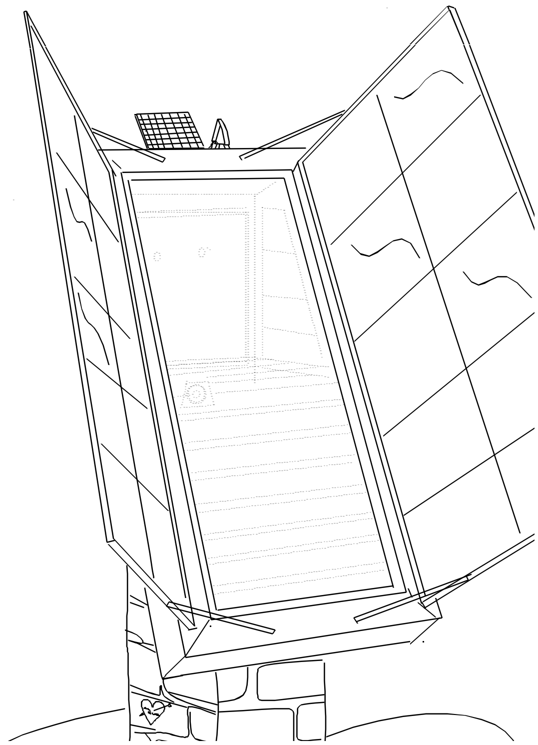
As the food approaches the oven's temperature the aroma begins to fill the air, that's the whole idea behind solar cooking.

INTRODUCTION TO THE TRACKING SOLAR OVEN

This modified box cooker has been labeled high tech, because of its ability to follow the sun under its own power. The design described here is not that of a portable oven. Materials used are durable and meant for many years of outdoors use.

The main features are:

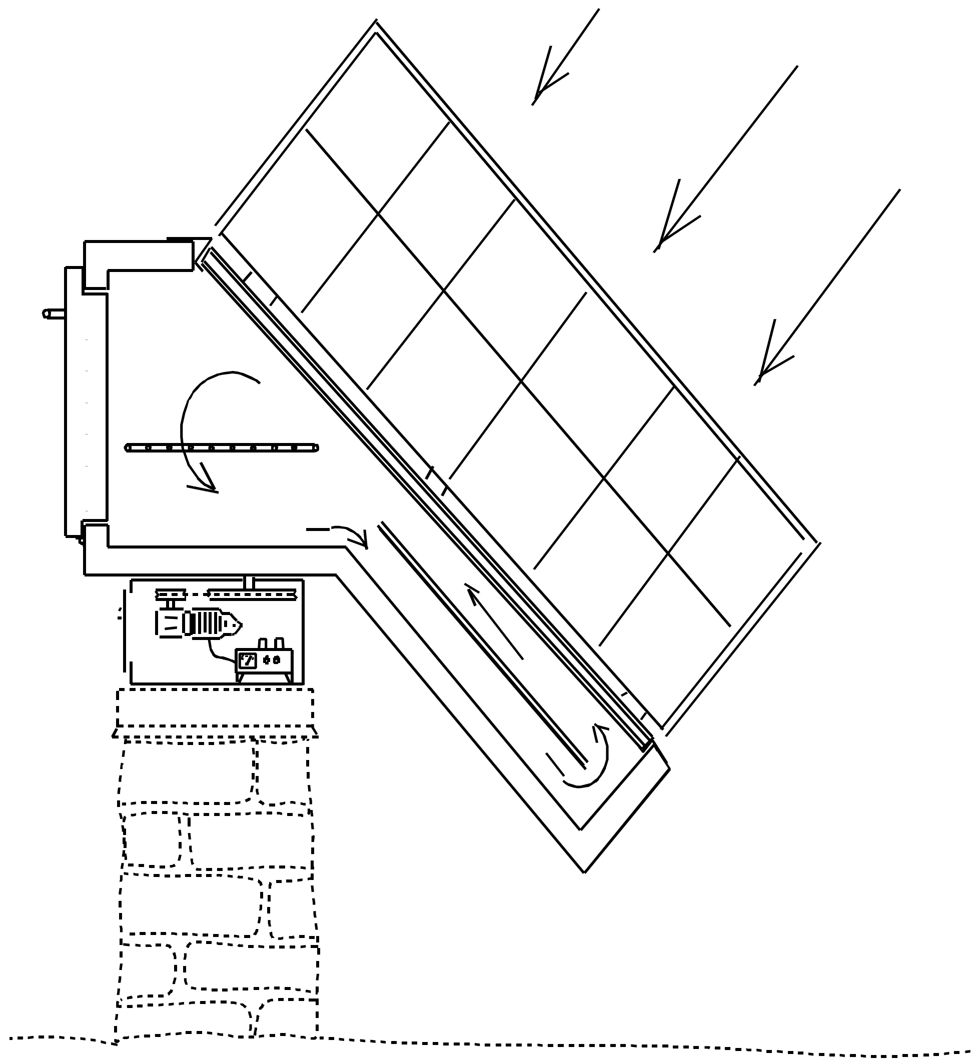
- Pedestal mounted where the oven is at counter height.
- Fixed tilt such that the collector does not have to be adjusted for the time of year.
- Uses both mirrors and flat plate collector to concentrate the sun's heat into the cooking chamber.
- Natural air movement increases convection cooking and warms the cooking tray.
- Rotation about a fixed vertical axis allows tracking of the sun during the day by manual or automatic means.
- Capable of heavy food load.



Energy saving is best achieved when the solar device is used to its fullest extent, thus the design of this oven is targeted for widespread use by those who demand convenience. This design requires no attention during the day when cooking a large meal.

These instructions will provide a basic summery of the construction techniques for building a tracking cooker of your own. There are many construction techniques that will produce the same results.

HOW THE OVEN WORKS



As with all solar cookers, mirrors intensify the sun's rays into a glass covered, insulated box with a door for placing and removing food. This oven uses a built in flat plate collector to collect heat on the bottom to increase efficiency. The flat plate is very efficient and therefore reduces the over-all size yet providing a larger cooking chamber. The high temperatures required for cooking require the use of mirrors.

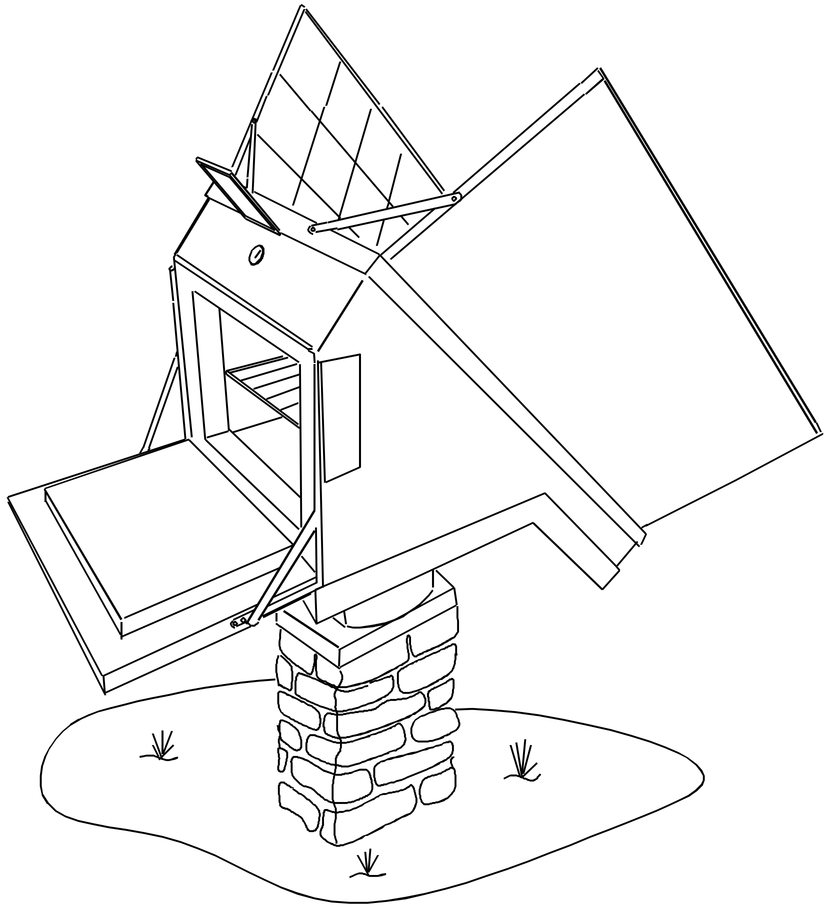
The diagram shows the hot air circulation pattern within the oven and cooking chamber. The mirrors may fold for easy transportation of the cooker.

The oven mount is a fixed pedestal with a Lazy Susan bearing. This allows the cooker to track the sun all day long. The tracking mechanism uses a very small amount of electrical energy making it possible to operate the oven on small batteries and a photo cell charger.

The oven door is at counter top height and is a standard oven size. These features make cooking with the sun as familiar and easy as cooking in your own kitchen.

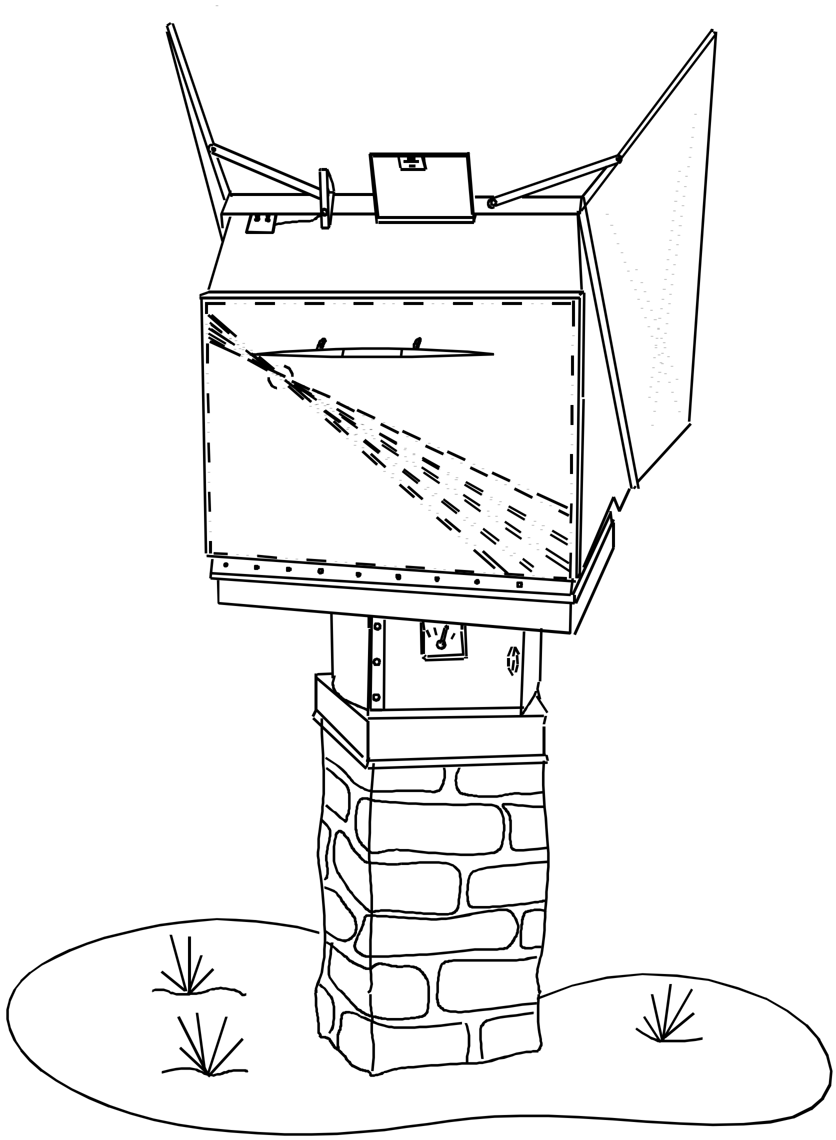
SHELL CONSTRUCTION

There are many different ways to build an insulated box or shell. My first oven used foil covered 1 inch Duct Board used in the air conditioning trade. Using a sharp knife and a flat iron you can form up the shell in any size you want using commercial heat seal tape. Set the angle of the face at about your latitude plus ten degrees measured from the horizon (42 degrees in Tucson) for the best average performance all year. When the shell is complete another layer of Duct Board is used to form a liner. This will yield a total of two inches of insulation, with foil on both sides.



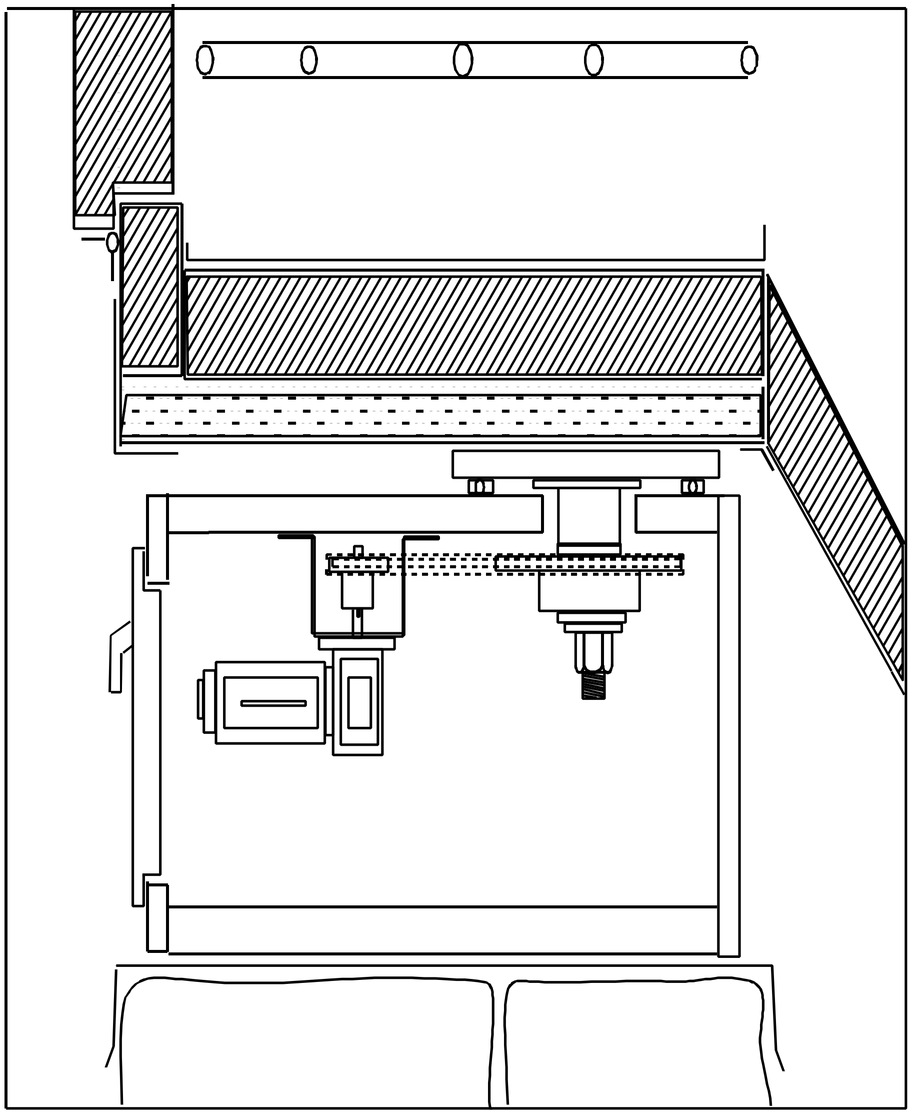
Sheet metal trim can be used to finish the shell, but most of the metal used consists of small sheets of scrap metal. After the openings and corners are trimmed the large areas of the sides are left unprotected. The duct board has been exposed to the weather for eight years without harm (except for the woodpeckers); however, it is best to cover the sides completely with metal.

The door is sheet metal, one inch thick encasing duct board and two inches thick at the opening. A leveling compound of silicone gasket paste was used to form a flat face gasket that is nearly air tight. The door is attached with a piano hinge and a counter-weight, such that the door forms a shelf when opened against fixed stops.



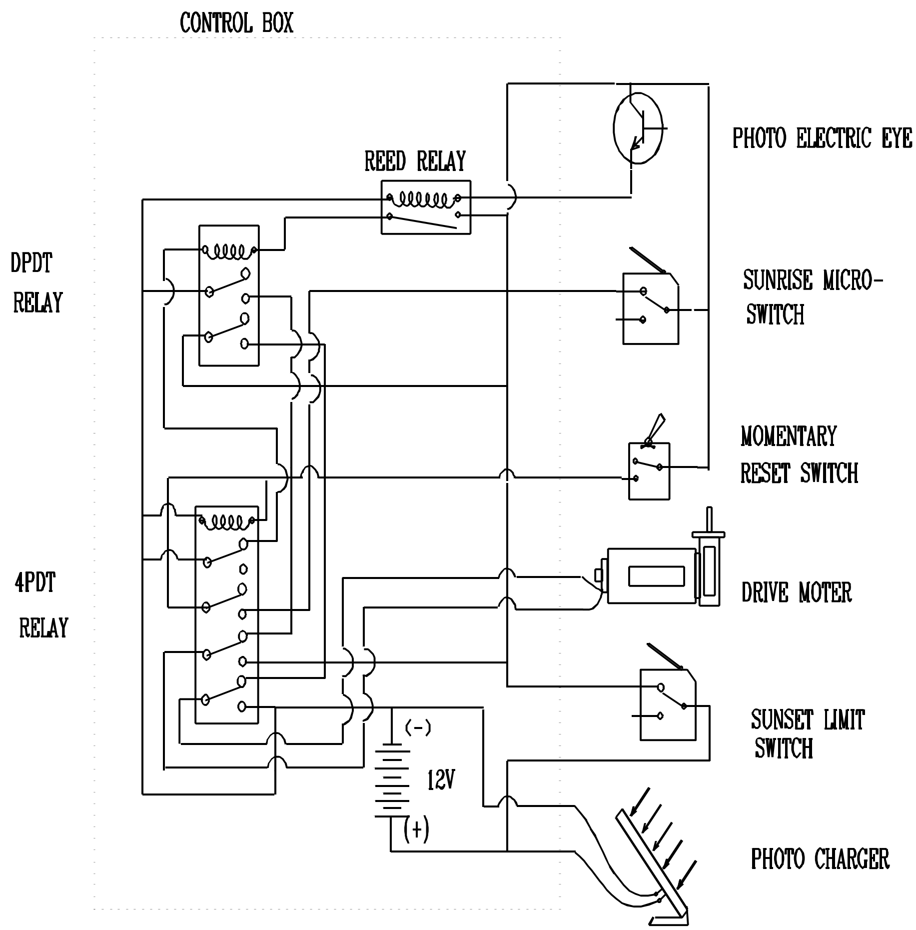
The insulated glass panel is easy to make from ordinary window glass and glass spacers. Have the glass store cut half-inch strips of quarter-inch plate glass and two sheets of single weight glass slightly smaller than your opening. Use the glass strips and silicone adhesive to form two layers of single weight glass separated by a frame of quarter-inch glass spacers around the outer edge. This forms an air space between the two glass sheets. A drain or vent hole to prevent pressure buildup inside the air space is required. The glass panel can now be sealed into the opening making the oven rain-tight. Recently I added a third glass layer to make a triple-insulated cover that increased the cooking temperature 25 degrees F.

The mirrors should be the twelve inches plain edge type mirror tiles glued onto two overlapping flat pans. Mirror tiles have the thinnest glass and make the best reflectors. The mirror pair will then nest together when closed. The mirrors must be mounted at sixty degrees from the opening for best performance. Knee hinges from an old folding table have work very well to hold open the mirrors and later to fold up when needed.



The base should be cylindrical shaped with a flat side for the door. Since the oven is supported by the base, the material used should be strong enough not only to hold the weight of the oven but support it during high winds as well.

The motor is a critical part of the design. A 12 to 24 volt DC reversible gear head motor is needed which turns at 1 to 5 R.P.M. To further slow the turning rate of the oven, a chain and sprocket with a ratio of about 3 to 1 seems to work very well for final turning speed of 1 to 1/2 R.P.M. The large sprocket should be placed on the shaft connected to the oven base between leather washers to form a slip clutch to protect the drive motor and for safety reasons.



TRACKER CONTROLS

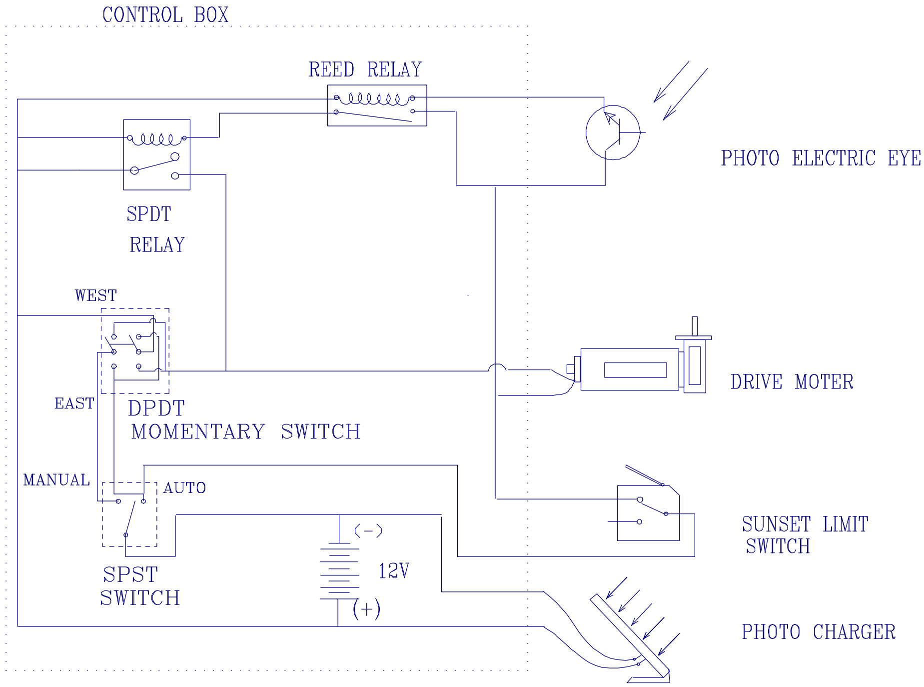
The heart of the Tracking Solar Oven is the electronic control. A Very simple control may be built from a photo diode (Electric Eye) and 12 volt DC relays. Most of the parts are available at local radio parts stores.

The photocell battery charger that works well is the new thin film, glass-encased type that produces 18 to 20 volts and measures only 6 inchs square. The batteries are simple AA nickel cadmium rechargeable cells in series to produce 12 to 15 volts at 50 to 80 milliamperes.

The photo diode (Electric Eye) is really a photo-transistor using only the emitter and collector leads which conduct electricity in the presence of light. A simple shadowbox will shade the electric eye when the oven is focused on the sun and will cause the motor to stop. At first, the photo diode is far too sensitive. To adjust the sensitivity black silicone can be dabbed over its surface then removed with a toothpick until it responds only to direct sunlight. The reset switch will send the motor into reverse until the sunrise switch is tripped. The oven is now positioned for the next day. A wind-up 12-hour timer switch on the reset switch will allow timed cooking; it sends the cooker to the sunrise setting when done and even sounds a buzzer.

Conventional solar trackers are available and can be adapted for use on this or almost any other solar cooking oven.

After experiencing trouble with the tracker control I disassembled the controller only to find the problem was caused by a sheet metal screw that penetrated one of the wire cables. When I reassembled the controller I found it works equally well without all the extra automatic features. This simplified version of the controller is now in use and serves the purpose.



SIMPLIFIED TRACKER CONTROLS

The material costs are about equally split between the shell, glass and electronics. The total Cost was approximately $300.

The tracking solar oven is a unique design. The idea for the oven was conceived in 1985 after the annual solar cooking demonstration in Tucson. The design received the "Clifford C. Sawyer Achievement" for individual technological achievement in application of engineering principles, American Consulting Engineers Association, 1993.