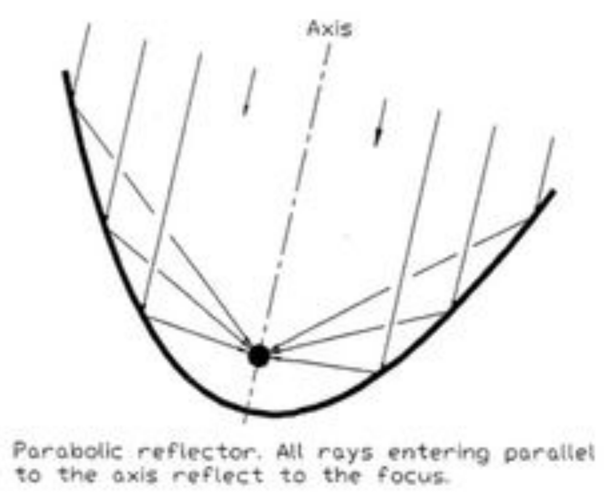
Parabolic solar reflectors

The original author of this article is Dr. Ashok Kundapur. Find more of Dr. Kundapur's work on his website: http://www.solcooker.net/Cindex.htm.

NOTE: Strictly, a **parabola** is a two-dimensional shape, which could be drawn on a flat piece of paper. The three-dimensional shapes discussed below are **paraboloid**s. The distinction is like the one between circles and spheres. However, use of the word "parabola" for a three-dimensional shape is common. The authors of most of the following material have used it that way. Likewise, they have used the adjective "parabolic" in place of "paraboloidal". Readers should understand these words accordingly.

Parabolic geometry is well known, and it was probably the very first type of solar cooker. In this category, there are maximum variations. The reason for its popularity was the focus which was much better and sharper than that of other types of reflectors, but at the same time it was very sensitive to even a slight change in the position of the sun and hence the use of such reflectors means constant tracking.



Parabolic reflector diagram

It is very important to learn about the geometry of the parabola. (See also Wikipedia article) There are many reviews, but the prolific programmer mathematician Mr. Mike Scirocco, from California, recommends the paper presented in Solar Energy, of 1978 by Dr. M. Srinivasan et al. Mike has taken lot of trouble to convert the text into a web page. This is not all. Mike has a small program which can give you a lot of dimensions on parabola. You just have to enter the diameter and depth of the parabola and you get a whole lot of data. Mike seems to have taken my suggestion seriously and is planning to add more data display boxes which would tell a interested person as to the diameter of flat circle of sheet from which a parabola of desired focus and diameter are to be constructed. Visit Mr. Mike Scirocco's site to download his excellent program. It is freeware. (In 2011, David Williams developed a simple formula which enables this calculation to be done easily with a pocket calculator. See "Dimensions of a paraboloid", below.)

One disadvantage of a parabolic reflector is that the solar energy is concentrated in a very small area, which may be too small for a particular purpose. Moreover, this area moves quickly across the cooking container, unless the parabola is adjusted frequently or moved continuously by a sun-tracking mechanism. On the other hand, if the cooking vessel is blackened in the small area where the sunlight is focused, and polished elsewhere, highly efficient use can be made of the sunlight. Small parabolic reflectors can quickly cook large amounts of food.

Parabolas with focal lengths of 1 to 3 meters (3 to 10 feet) are most useful for solar cooking. The focal length is the distance from the center of the parabolic surface to the focus. The solar image diameter is about 1/120 the focal length. For focal lengths in the range above, the image of the sun will be 8 to 25 mm (1/3 to 1 inch). As the earth rotates, the image moves 87 to 260 mm (10 image diameters) in 20 minutes.

Rigid parabolas Edit

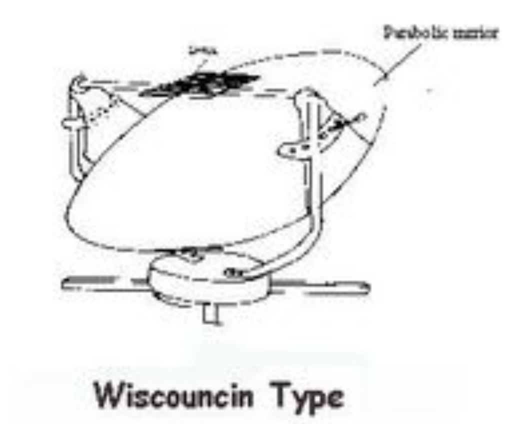
Under this category, three major types have been identified:

(i) Shallow parabolas, where the focus is outside the rim of the reflector,

(ii) Deep parabolas, where the focus is within the rim of the reflector. A sub-category of deep parabolas consists of paraboloids with coincident focus and centre of mass.

(iii) Asymmetrical parabolas, which are partial parabolas.

Shallow parabolic cookers Edit



Wisconsin design

There are just two variations in this design. The oldest design (right) has a stiff U-shaped stand which holds the cooking post as well as the reflector. It is on record that Mouchet built such a cooker for the French troops of Napoleon III. The popular model, however, is known as the Wisconsin design of 1959 (Figure 5). In this design, the reflector has a plastic base on which mylar was stuck. The design was not stable in the wind and there was also some problem of spilling of cooking material while the reflector was adjusted, and, hence, several designers have tried to improve upon it. Other variations are basically similar but for some modifications in the stand, orientation mechanism or materials used for the reflector, etc. Among them the WHO design, was most the sophisticated in terms of design and materials used. The Chinese type has a reflector, which has a rectangular shape and is made by sticking small pieces of mirrors on to a parabolic base. The vessel is kept on a separate stand to avoid spilling. Test data was not available. A Wisconsin design with 1.0 m reflector could boil 1 liter of water in 10–20 minutes, provided the assembly was aimed at the sun every 15 minutes. Recently, Kumar (1994) has conducted technical analysis of the parabolic mirrors.

Kulkarni reports that even chapatis could be fried in this cooker. This design was being marketed by M/s Jyothi Industries of Baroda. Another design with a 2 m^2 reflector was that of Walton et al. (1977). It is also known as Volta type.

Professor Ghai's (Anon. 1970) parabolic concentrator was of a different type. Evolved in the 1950s, the reflector was made from spun aluminium sheet. It had a hole at the centre through which an arm projects from the stand to hold the cooking vessel. Part of the reflector was cut out at one end of periphery to enable easy access to the vessel. The entire unit had to be turned to face the sun.

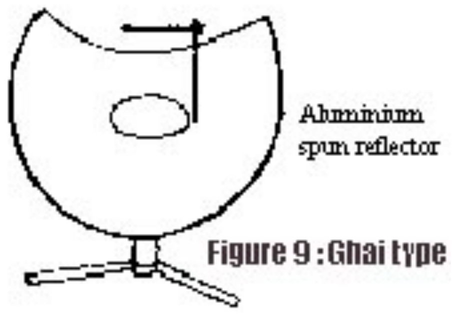


Figure 9 : Ghai type

These types of cookers did not become very popular, but The German News, 38 (June-July): 5-6, 1997, informs that 180 m^2, parabolic concentrators have been installed at an institute at Mount Abu, to generate 600 kg. of steam at 16 bar pressure and cook food for 1200 people (Herms 1977).

Recently Sintex Plastics of India seems to have entered the Solar Market in a big way. They had been manufacturing solar water heaters of plastic, but now they are trying their hand at solar cookers, the parabolic as well as box type cookers. The photo presented here has been copied from their site, though it does not display any innovations, the price is very competitive at just Rs. 2500 ($55). Of course, much depends on the reflective coating too, and again details regarding the same have not been received. With a long lasting Reflective material, and at the suggested price of Rs 2500, this parabolic Cooker should steal the market.

Another recent addition to the family of parabolic cooker comes from the prolific inventor Mr. Deris of California. The parabola it-self is simple, he seems to have discarded the interesting design of square Parabola invented by him earlier. The parabola he uses is held vertically, and it directs the focused rays on to a Cooking vessel kept on a reflector kept horizontally on the ground.

Once again, another inventor Tim Norton of Florida ,USA has presented The Tripod Solar Hybrid Grill,in the year 2006. He,in fact, is selling the plans for building such cookers. Readers are advised to visit his site and also read his personal page here. Parabolic cookers are in use in Africa (right), also.

Parabolic cooker in Africa

Attempts are on to form base of parabolas from other materials. In India it is being made from mud. The photo, taken from the Solar Cooking Archive, confirms this.

Many interesting variations, especially in the stand and grill, have been reported, and some of the following photos, taken from the Solar Cooking Archive, are self explanatory. Note the light but stable stand arrangement, looks like it could be easily tucked in a corner and easily transported as well.

The photo below shows a novel design by Deris of USA. Metal sheets comes in the shape of rectangle or square, and thus a sq. parabola is sensible design to reduce wastage, but details were not available (Ref. solracooking.org site).

Prof. Ajay Chandak of India has another interesting variation of Square parabola.

Prof. Ajay Chandak and his group comprising of Prof. Deepak Dubey and Rahul Kulkarni have completed installing 363 parabolic community cookers in Maharashtra, India. This is the worlds' largest solar cooker project. Prof. Ajay selects SK-14 type parabola over Schefflers design as it is simple to make. Each parabolic dish is 2.3 meter diameter and cook variety of food for tribal school children. It is estimated that together these cookers would save 54 tons of LPG per year!. Cost of cooker is around Indian Rupees 26,000 that works out to about US$ 560. Cooker is supplied with 22 kg pressure cooker, goggles, gloves. A small platform can help easy access to the cooking pot, and an umbrella tied to a pole can provide shade for the cook. Author congratulates Prof Ajay Chandak on this excellent work completed within record 40 days. The photo below shows two large parabolas being used in a hotel.

The interesting variation of parabola, shown below, was designed by active workers from Nepal by Ram Ashis Sharma and Hannu Virtanen. To increase the area of reflection, they add two reflecting flaps on the side of parabola. Other details were not available at the time of uploading this design on this page.[1]

A new and interesting design of parabolic cooker has been presented by a German Group. It is called 'Papillon', for it looks like a butterfly - with wings open. Though a parabolic cooker, Dr. Kundapur classifies this as a *dual parabola*, which has been in vogue in China and Nepal. But the Papillon could be considered as an improved version over that of Nepal Design. It is a very attractive design and it could be as efficient as it is claimed. But appears rather unstable in wind. This can be improved by widening the base. Each wing like reflector measurers One meter square, so together it make it a 2 Sq. meter reflector delivering 1.2 Kw. The designer group, BSW Alternative Energie, has listed a lot of features and data on the cooker and a visit to their site (www.bsw-energie.de) is a must. It would be better if the design can be made in such a way that it can be assembled only with nut-bolts (without brazing,) and other activities like forming a parabola at the site. The efficiency could be improved by 'enclosing' the cooking vessels.

Recently Zhu and Kim have evolved a parabolic cooker which they claim, as non-tracking. May be the geometry is such that it may not require constant tracking. In which case, it would be more of a deep parabola as detailed in the next section.

Matt West built this parabolic cart cooker using a discarded satellite dish covered with reflective signmaking decal material. See Matt West's Solar oven inventions at this link: http://solarcooking.wikia.com/wiki/Matt_West.

Scheffler cookers Edit

Main article: Scheffler Community Kitchen

A Scheffler cooker (named after its inventor, Wolfgang Scheffler) uses a large ideally paraboloidal reflector which is rotated around an axis that is parallel with the earth's by a mechanical mechanism, turning at 15 degrees per hour to compensate for the earth's rotation. The axis passes through the reflector's centre of mass, allowing the reflector to be turned easily. The cooking vessel is located at the focus which is on the axis of rotation, so the mirror concentrates sunlight onto it all day. The mirror has to be occasionally tilted about a perpendicular axis to compensate for the seasonal variation in the sun's declination. This perpendicular axis does not pass through the cooking vessel. Therefore, if the reflector were a rigid paraboloid, its focus would not remain stationary at the cooking vessel as the reflector tilts. To keep the focus stationary, the reflector's shape has to vary. It remains paraboloidal, but its focal length and other parameters change as it tilts. The Scheffler reflector is therefore flexible, and can be bent to adjust its shape. It is often made up of a large number of small plane sections, such as glass mirrors, joined together by flexible plastic. A framework that supports the reflector includes a mechanism that can be used to tilt it and also bend it appropriately. The mirror is never exactly paraboloidal, but it is always close enough for cooking purposes.

Sometimes, the rotating reflector is located outdoors, and the reflected sunlight passes through an opening in a wall into an indoor kitchen, often a large communal one, where the cooking is done. Interestingly, way back in 1980, Ashok Kundapur had proposed that a reflector/focusing device kept outside the house would focus the sun into the house, which could then be used for cooking. Scheffler implemented this design for the first time a few years later, in 1986.

Diagram showing structure of Scheffler cooker.

Scheffler's reflective cooker, a 2.7 m diameter cooker, is located just outside an Indian home. The photo is from ecosolar.com.

Deep parabolas Edit

Professor Von Oppen (1977), while working in India, proposed a do-it-yourself deep parabola. The focus of the reflector was inside the rim of the mirror, almost at the base. This design was unique in several respects; it made use of locally available materials like bamboo, paper pulp, aluminium foil for the reflector, and a unique and simple method for tracking the sun.

The method was simple, a master mould was made to form the shape of the deep parabola, paper mache was smeared and dried, fine paper pulp was used to make the interior smooth, and this shell was reinforced with bamboo from outside. The interior of the shell was then coated with Aluminium foil. The cooking vessel was hung from a string. Focusing once in 30 minutes was found adequate. Provision was made for automatic tracking.

A pipe of about 15cm diameter and 100 cm height was buried near the basket and filled with water. A bottle, half filled with water, was hung on into this pipe with the help of a string, and the other end of the string was tied to the basket. A small hole at the bottom of this pipe let out water and as the water level goes down, the half-filled bottle sinks, pulling and turning the basket suitably. However, effective cooking power was estimated to be only 250W. Initially, the cooker created a sensation. There were many difficulties in using the cooker, bright reflected light hit the eyes, it was difficult to handle the hot cooking vessel, and the basket was not stable in strong wind (GATE 1979).

In 1979, the German Appropriate Technology Group (GATE) proposed another shallower parabola. The reflector was 1.4 m^2 and was supported on a firm stand. The cooking vessel was to be hung from a separate stand (GATE 1979). Kapur (1982) described a similar design with further improvements in the stand like adding castor wheels. Following drawings give some idea.

Another interesting design from Nepal uses two parabolic mirrors. The parabolic base is made of various materials including clay and is coated with probably with Aluminised polyester.

Hannu Virtanen and his team is doing excellent work at Nepal and his site is worth visiting for excellent photos, plans and comments. (listed under Links). The Classical Chinese design presented bellow is one such example.

Parabolic reflector with coincident focus and centre of mass Edit

Main article: Focus-Balanced Paraboloidal Reflector

Paraboloidal reflectors used as solar concentrators have to turn at 15 degrees per hour to follow the sun's motion in the sky. Ideally, the focal point, where the cooking pot or other energy collector is located, should not move. This means that the rotation axis must pass through the focus. If the rotation is driven by a low-power machine such as a clock, only a small torque is available. In order to rotate the reflector with this small torque, its centre of mass should be on the rotation axis. These two requirements can be simultaneously met if the paraboloid is such that its centre of mass and focal point coincide.

If the paraboloid is axially symmetrical and is made of material of uniform thickness, this coincidence occurs if the depth of the reflector, measured along the axis of the paraboloid from its vertex to the plane of its rim, is 1.8478 times its focal length. The radius of the rim is 2.7187 times the focal length. (The closeness of this number to "e", the base of natural logarithms, is just a chance coincidence, but can be a useful mnemonic.) The angular radius of the rim, seen from the focus, is 72.68 degrees.

If the cooking pot is held at the end of a fixed arm that enters the reflector along the line of the paraboloidal axis at noon, the rim of the reflector, which is rotating at 15 degrees per hour, will not strike the arm for more than four hours before and after noon. The device can therefore be used from before 8 a.m. until after 4 p.m. without any need for re-adjustment. Usually, this includes the whole part of the day when the sun is high enough in the sky for solar cooking to be practicable.

Asymmetrical parabolas Edit

To enable the cook to be as close as possible to the cooking vessel, an asymmetrical parabolic reflector probably originated. In fact, in some of the earlier designs, like in case of Ghai's variation, part of the reflector was cut out to facilitate this. But Tabor (1966) proposal could be considered as original design. He used several smaller parabolic mirrors and arranged them in an asymmetrical parabolic configuration. The unit has a 'U' frame rotating on a pivot fixed to a strong base.

Tabor's design seems to have made a comeback. Recently a solar cooker group from Mexico have devised a bigger version of this type of cooker. The device has a built-in tracking unit.

The frame has a stand at the top for the cooking vessel. Focal length of the reflector was 83 cm and the area was 0.8 m^2 A temperature of 300^o C could be attained though the effective cooking power was estimated to be 185 W.

A Chinese design first described by Fang, Susan (1979) was indeed classic (Figure 11). The concentrator could be easily adjusted, access to the cooking pot was easy. The assembly rests on a firm stand. The reflector had an aperture of almost 2 m^2 Designers claim that it delivered 560 W of power, rather a high figure when compared to any other type of cooker. A prototype built here at Udupi performed satisfactorily. It is unfortunate that the designr has not become popular.

Concept II, envisages the use of strips of reflector material for fabricating the Chinese type of cooker described above. This would make the fabrication easy and may perhaps increase the efficiency and maintenance of the reflector. Further, an insulating cover around the cooking vessel would increase the efficiency and would add aesthetic value.

Patel (1982), working independently in India, had evolved another design which he calls Suryakund (Indian Patent 233/234, Bombay – 80, and No 100/Bombay/81). This design has a deep asymmetric parabola without a point focus. The cooking vessel located inside a glass chamber at the focal point is easy to handle. But the focus would be a ring focus rather than a point focus. Designed with mass production in mind the reflector was moulded ABS plastic support to which aluminized polyester was stuck. The whole assembly can be easily rotated, even with the cooking vessel, to track the sun and all these features make this a novel design. However, the size of aperture is rather small and can be of use to campers or by people who wish to warm their food.

For those who wish to cook from inside the house, or at least near a window where sun shines, Murthy (1982) presented an interesting variation (Figure 13). The device is a large, asymmetrical parabola of alminium sheet hooked on to a strong stand which can rest on a window frame (a provision had been made to adjust for the declination angle of the sun). The author calls it an *offset-feed parabola*, a by-product of space technology. The author claims that the design delivered 994 W, which appears rather high (the reflector used was only an aluminium sheet). Murthy suggests a south – facing window for better results. An insulated cover around the cooking vessel would increase efficiency. The design should incorporate easy folding facility such that it could be shifted easily from one window to another as the sun moves.

Prof. Ajay Chandak, is a prolific designer based at Dhule, Maharastra, India. His design called as Balcony Cooker is presented here. It is very close to Murthy's concept of asymmetric parabola. The Balcony Cooker must have been evolved independently by Ajay. The cooker can cook food kept in a 5 kg pressure cooker.

Chinese inventors have presented another interesting Parabolic reflector, which is popular in china and also in Nepal. It is called by Li-Yan Zhu as 'Three Circle Reflector'(http://solarcooking.org/research/Chinese-Reflective-Cooker-Theories.htm) Details as to the performance and especially wind stability could not be obtained.

The Heatmoth

As I had remarked earlier, there is no limit for innovations. Here we have Franco Bartolini, who has presented yet another type of asymmetrical Parabola. It is bit like Chinese three circle reflector, but very different. As the photo shows, it has two large parabolic reflectors on the side of a firm stand on which cooking vessel is kept. The levers to adjust reflectors can not be seen very clearly, but as it is an essential component, it must have been provided. Reflectors appear to be fairly big being 1.2 m in height and 0.6 m in width, each. Bartolini has named his cooker the *Heatmoth*

Ways of designing and making rigid parabolas Edit

Dimensions of a paraboloid Edit

The dimensions of a symmetrical paraboloidal dish are related by the equation:

$$4FD = R^2$$

where ***F*** is the focal length, ***D*** is the depth of the dish, and ***R*** is the radius of its rim. Of course, they must all be in the same units. If two of these three quantities are known, this equation can be used to calculate the third.

A more complex calculation is needed to find the diameter of the dish *measured along its surface,*.i,e, the distance from the rim along the surface to the vertex, then back along the surface to the rim. This is sometimes called the "linear diameter" of the dish, and is useful in determining the size of the material needed to make it. It is the diameter of a flat, circular sheet of material, usually metal, which is the right size to be cut and bent to make the paraboloid.

In the calculation (using the above symbols), the value of ***R*** is required. If it is not initially known, it should be found with the equation above. If ***R*** is known, either ***F*** or ***D*** is also needed, but not both.

Two intermediate results are used. The first is ***P***, such that:

$P = 2F$ or $P = \frac{R^2}{2D}$ These are equivalent expressions, using ***F*** and ***D***. Their values are identical.

The second intermediate result is ***Q***, such that:

$$Q = \sqrt{P^2 + R^2}$$

When ***P*** and ***Q*** have been calculated, the diameter of the dish, measured along the surface, is given by:

$$\frac{RQ}{P} + P \ln\left(\frac{R+Q}{P}\right)$$

where $\ln(x)$ means the natural logarithm of x, i.e. its logarithm to base "e".

The volume of the dish, the amount of liquid it could hold if the rim were horizontal and the vertex at the bottom (e.g. the capacity of a paraboloidal wok), is given by

$$\frac{1}{2}\pi R^2 D$$

where the symbols are defined as above. This can be compared with the well-known formulae for the volumes of a cylinder and a cone. Of course, πR^2 is the aperture area of the dish, the area enclosed by the rim, which is proportional to the amount of sunlight the reflector dish can intercept.

The surface area of a paraboloidal dish can be found using the area formula for a surface of revolution, which gives:

$A = \frac{\pi R}{6D^2}\left((R^2 + 4D^2)^{3/2} - R^3\right)$, providing $D \neq 0$.

Single and compound curves Edit

A lot of difficulty is encountered in the fabrication of parabolic reflectors, even with thin sheets of steel, since a paraboloid is a "compound curve", which cannot be made simply by bending a flat sheet of metal. To make a paraboloid exactly, the metal has to be stretched, which is difficult to do with simple equipment. Many fabricators have presented methods to make the construction of a parabolic shape easier by doing it approximately. Srinivasan (1979) proposes a method wherein a circular sheet was cut out into suitably shaped petals, each of which is a "single curve", which can be made by bending a flat sheet., The dimensions of the petals are carefully arrived at after detailed calculations. The petals are then joined to form the parabola, But this method too was found rather difficult, especially cutting out ‘curved petals’ from the sheet.

Fabricating Parabola from a single plane. Edit

So, a simpler method has been proposed – (Concept I) by Ashok Kundapur– which involves cutting the circular (1-1.5 m diameter) GI sheet or aluminium into ‘petals’ with straight cuts which is easier. Large sheet of one to one-and a half m diameter is taken. Center is marked and a small circle of 15 cm in drawn from this circle. Then up to to 8 or 16 lines are drawn to the perimeter of the outer circle from the center (radius). 5 mm holes are drilled at the junction of this inner circle and the line of straight cuts. This would assist in easier overlapping (Figure 4). Then, the ‘petals’ are fixed overlapping one another, only at the edge. The width of this overlap was calculated using standard formulae (Baumeister et al. 1978; Kundapur 1995). Recently Mikes site mentioned above give more accurate dimensions of the over lap, one need enter just the number of 'petals' and length of focus in his chart and lo ! the width of overlap shows up. Once you get the values of over lap, drill small holes at the outer periphery of circle just adjacent to the radial lines based on the width of over lap so as to aid in joining of the 'petals'. Also drill a 5 mm hole in the center of the circle. Now cut the circle into petals along the radial li e perfected by pushing or pulling at the hole at the center of parabola. When finished, the parabola has to be fixed to a frame work made of Steel or Aluminium flats. The frame work has to be fixed on to a U shaped stand. (

Mechanical Mathematician Edit

Mr Genevieve of France has described a simple way to form a parabolic dish. either from cardboard panels or with mud. He made both. He calls it the Mechanical Mathematician. http://www.sciences.univ-nantes.fr/physique/perso/gtulloue/conics/drawing/para_string.html has a super applet that shows the principle really well. In practice, a setsquare cannot be used as it would go through and destroy the parabolic shape! The mechanical mathematician makes use of the principle but does not go through the parabolic dish.So a dish can be made directly. It has several advantages. No math needs to be calculated and the material for making the mathematician can change depending on what is available. In practice, a The focal length can be changed really quickly to suit the material used. It can be set up on site pointing in the best direction, etc. find more on the web about it, mechanical mathematician and cob can be searched. Here is a simple animation to show how it works.

03:59

The parts of the mechanical mathematician

One big advantage is that the only outside input needed is kitchenfoil and a demonstration. The above video now shows all the parts of the device. People could even make parabolic dishes or partial dishes as part of their outside walls. Brian White --Gaiatechnician 08:27, 24 September 2007 (UTC))

Forming a Parabolic dish with cardboard segments. Edit

This is a design for a large cardboard parabolic reflector that could be used to focus sound(light) onto a microphone(cooking vessel). The method was presented in Scientific American by Alex McEachern and Paul Boon. Detailed instructions of how to layout the segments are here.

Forming a parabolic dome to make ferroconcrete reflectors Edit

07:29

PARABOLIC SOLAR COOKER FERROCEMENT, MOLD

(Note: A paraboloidal reflector made of ferroconcrete, with a diameter of two metres and a thickness of two centimetres (as suggested by the video presenter) would have a mass of about 200 kg (450 lbs). Mounting such a reflector so it can be steered to follow the sun's apparent motions in the sky would be challenging in a third-world situation. It might be better to make reflectors that are shaped as segments of spheres, and use them something like the Auroville Solar Bowl.)

finished cardboard parabola

Paraboloids made by rotating liquids Edit

Although paraboloids are difficult to make from flat sheets of solid material, they can be made quite simply by rotating open-topped containers which hold liquids. The top surface of a liquid which is being rotated at constant speed around a vertical axis naturally takes the form of a paraboloid. Centrifugal force causes material to move outward from the axis of rotation until a deep enough depression is formed in the surface for the force to be balanced by the levelling effect of gravity. It turns out that the depression is an exact paraboloid.[2] If the material solidifies while it is rotating, the paraboloidal shape is maintained after the rotation stops, and can be used to make a reflector.[3] Materials can be used such as epoxy resin, which solidifies by chemical change, and glass and candle wax, which are initially molten and solidify as they cool. Materials such as concrete, plaster, and pot-making clay have also been suggested, but they are not sufficiently fluid to take the paraboloidal shape exactly when they are soft. Vibrating them would make them more fluid, but this does not yet seem to have been tried. This rotation technique is sometimes used to make paraboloidal mirrors for astronomical telescopes, and has also been used for solar cookers.

The focal length of the paraboloid is related to the angular speed at which the liquid is rotated by the equation:

$$2f\omega^2 = g$$

where f is the focal length, ω is the rotation speed, and g is the acceleration due to gravity. They must be in compatible units so, for example, f can be in **metres**, ω in radians per **second**, and g in **metres** per **second**-squared. The angle unit in ω must be radians. 1 radian per second is about 9.55 rotations per minute (RPM). On the Earth's surface, g is about 9.81 metres per second-squared. Putting these numbers into the equation produces the approximation:

$$fs^2 \approx 447$$

where f is the focal length in metres, and s is the rotation speed in RPM.

Other ways of making rigid paraboloids. Edit

Good parabolas can be fabricated with the help of large lathes. VITA (1961) recommends several simpler techniques such as: (i) soil-cement depressions in the ground, (ii) molded vermiculites, (iii) wire reinforced concrete shells, and (iv) paper-mache shells. The Boeing Company made hi-tech parabolas from composite honeycomb structure was reinforced with fiberglass epoxy sandwich, to which a reflector material, polished aluminum sheet, was stuck. The reflector surface was further protected by vacuum deposited silicon oxide coating. It was reported that such a hi-tech reflector delivered about 437 W of power compared to 300 W of spun aluminum reflector of the same size. The size of the reflector is directly proportional to the performance of the cooker, and hence, it is a very important parameter. However, in most of the cases the size of the reflector was 1 m^2 only.

Instructions for laying out a paraboloid shape from a flat sheet of material can be seen at How to build a paraboloid

Collapsible parabolas Edit

Parabolic reflectors were bulky and were difficult to transport and hence collapsible concentrators were designed. A Swedish design, called Umbryoler, was probably one of the first designs to emerge on the scene (Figure 14). It was mainly designed with campers in mind, and the unit would open out as an umbrella. The reflector was made from strips of aluminized polyester or sheets. Fluttering focus and unstable reflector were the chief drawbacks of this otherwise good looking designs (Annon 1981a). Chinese (Fang, Susan 1979) and Japanese designs are variations of this design.

In 1961, the VITA group tried out an interesting design, the famous inflatable concentrator (VITA 1961). Though it had a checkered history the design is still in vogue and, recently, it has appeared again with more firm materials in solar water pumping application (Beale 1981). Basically, the reflector is a large round aluminized polyester sheet of slightly thicker gage, over which a clear polyester sheet was fused all along the outer edge. When this assembly was tightly but evenly stretched and tied between a frame and inflated, a Perfect parabolic reflector was formed . Fluttering focus was the main drawback.

Sobako (Figure 16) was an ingenious design from Germany. It was a foldable parabola with a stainless steel reflector. When opened, the reflector focused the sun's rays at the base of a copper plate housed in a double glazed glass box. The area of the reflector was about 0.75 m^2 Kanua (1979) has worked extensively on this design and finds that the glass box broke often, and difficulties were encountered while folding the reflector. He suggests many modifications but it is felt that unless the reflector area is increased the unit may not perform well. Egypt cooker is another design based on similar principles, Here, the reflector was a cylindrical parabolic mirror. A specially designed 5 liter box was fixed at the center for holding the cooking vessels but the German group found the unit rather bulky, and maximum temperature attainable was only 180^{o}C. This German group evolved a similar but smaller cooker where the triangular box is hosed in the glass box.

The modified umbrella is, in fact, nothing but an umbrella with an aluminized polyester sheet stuck to the concave side of it. Though a modified design, the reviewer still considers it as a main type for it converts an ordinary umbrella into a solar cooker . Recent, some reports indicate that this design was getting popular in north India. As seen in Figure bellow, instead of keeping the vessel on the grill fitted to the handle, the vessel could be placed on a fixed platform and the umbrella adjusted to focus the sun rays which may give a better result, but cooking on a windy day would still be difficult and tricky.

Recently Brett White has taken up this very useful concept. He has in fact used a beach umbrella and this appears to perform better. The cooker can double as a regular umbrella. For more information visit his site. Brett White's design form his site You can buy a folding cooker from him.

Umbroyler is another design, more carefully planned. The reflectors fanned out beautifully, into two half parabolas. Once gain the fluttering focus and instibility were major problem with this type of cooker.

Umbrellas have always enthused solar innovators. Recent entry is by Juan Francisco Paredes, and he dubbs his design as Barbacoa Cooker. He has a very illustrative web site (http://club.telepolis.com/elcatamaran/barbacoa-solar/) is a must visit for all. He has barbecued meet on it and thus showing its effectiveness. Marc Ayats has also presented this idea in a slightly different manner.

The Russian folding cooker was probably the largest folding cooker ever designed. It had a reflector of 1.5 m^2 in diameter. It has been designed with lot of care to avoid flaws, as it was meant for use of Military personnel. The Handle to rotate angle adjusting screw indicated that mirror adjustment was easy and the cooking pot could be kept in an insulated receiver. It is claimed that the cooker could double as a rain shade or tent at night.

Swedish designers (cited by Venkatesan 1980) had come out with a very neat package of a solar cooker that fits into a specially designed suitcase. It is ideal for campers, but for day to day use the reflector has to be larger.

VITA (1961) announced another interesting design which was evolved in China. The foldable reflector, evidently a section of the parabola, made up of small mirror pieces, opens out at the base of a tripod stand holding the cooking vessel. To some extent, the design resembles the Sobaco type described earlier.

Deris, a prolific inventor from California, USA has brought out another interesting parabolic cooker. It is very interesting in various ways. It is 2'x2' square Parabola, collapsible at that. It does not focus the light at the bottom of the cooking vessel, but on the sides as indicated in the photo. He claims that it cooks food very fast. For more details and prices you should visit his web site.

Deris's design form his web site (listed under other links) You can buy a folding cooker from him too from the USA.

Parabolic troughs Edit

Single Troughs Edit

Parabolic trough cooker designed by Ivan Yaholnitsky bakes 10 loaves of bread at one time.

Cookers that use parabolic troiugh reflectors have advantages over those that use paraboloids. The trough is a "single curve", which can be made simply by bending a flat sheet of metal. If the cooker is optimally aligned, it does not need to move to track the sun for a period of several hours around noon each day. If it is used only during these periods, no automatic tracking needs to be incorporated into it. The trough focuses sunlight to an extended line, along which large amounts of food can be placed and cooked simultaneously. However, the temperatures reached by a trough are lower than those reached by a paraboloid.

Using Two Perpendicular Troughs to Simulate a Paraboloid Edit

Main article: Naeve Cross solar concentrator

It is possible to use two parabolic troughs, curved in perpendicular directions, to bring sunlight to a point focus as does a paraboloidal reflector. The incoming light strikes one of the troughs, which sends it toward a line focus. The second trough intercepts the converging light and focuses it to a point. The diagram shows the principle.

Two troughs bring parallel rays of light to a point focus.

Compared with a single paraboloid, using two partial troughs has important advantages. The troughs are "single curves", which can be made by bending sheets of metal without any need for cutting, crumpling, or stretching. Also, the light that reaches the target - the cooking pot - is directed approximately downward, which reduces the danger of damage to the eyes of anyone nearby. On the other hand, there are disadvantages. More mirror material is needed, increasing the cost, and the light is reflected by two surfaces instead of one, which inevitably increases the amount that is lost.

The two troughs are held in a fixed orientation relative to each other by being both fixed to a frame. (See photo.) The whole assembly of frame and troughs has to be moved to track the sun as it moves in the sky. There are commercially available cookers that use this arrangement.[4]

Parabolas Modified to Reduce Sun-Tracking Edit

Simple parabolic trough cookers work satisfactorily for several hours each day (sometimes more), without having to be moved to follow the Sun's motion in the sky. This is an advantage compared with paraboloids, which have to be moved continuously or frequently to keep the image of the Sun focused on the cooking pot. However, troughs pay for this advantage in terms of reduced efficiency. If a cooking pot is located somewhere along the focal line of a trough, only a small part of the trough reflects sunlight onto it. As the Sun moves, the useful part of the trough moves along its length, but it remains a small part of the trough. Sunlight reflected from the rest of the trough misses the cooking pot.

Reflectors have been designed that are essentially compromises between troughs and paraboloids. They are less efficient than a paraboloid, but more efficient than a trough, and they have to be moved to track the Sun less often than a paraboloid, but more often than a trough.

Troughs in a wooden frame.

One design uses a reflector dish that is literally a compromise between a paraboloid and a trough. It is curved more sharply in one direction than in the perpendicular one, giving it what opticians call "astigmatism". Sunlight is focused onto a line, but a much shorter one than is produced by a trough. The dish is set up so that, as the Sun moves in the sky, the line moves along its length. The cooking pot is located on the line, so, for some period of time, some of the sunlight reaching the dish, but not all of it, strikes the pot, and the dish does not have to be moved to track the Sun. At the end of this period, when the line moves away from the pot, the dish has to be moved so as to start the process again.

Single astigmatic reflectors are quite difficult to design and make, but the same effect can be obtained much more simply by using two troughs curved in perpendicular directions, as described above. If the troughs are further apart, or closer together, than the ideal distance that produces a point focus, the focus is astigmatic. If it is set up correctly, the assembly does not have to be moved very often to track the Sun. Again, some light is inevitably wasted.

Many automobile headlamps illustrate a different design. They have reflectors that are paraboloidal, but with a set of narrow vertical ripples in the surface. The ripples have the effect of spreading the light out horizontally, so that the driver sees not only straight ahead, but also some distance (or angle) to each side. If used as a solar concentrator, this type of reflector can accept sunlight from a range of angles and focus much of it onto the cooking pot. The reflector is aligned so that the motion of the Sun keeps it within the acceptance angle for some period of time, during which sun-tracking is not needed. Some sunlight misses the pot, and occasional tracking is needed. A compromise has to be reached between the two.

Another design is called a "compound paraboloid". This is essentially several paraboloids side by side and fused together. They share a common focal point, but their axes aim in slightly different directions. When the reflector is set up correctly, first one of the component paraboloids focuses sunlight onto the cooking pot, then, as the Sun moves, another paraboloid takes over, and so on. At any given time, only one paraboloid is being used, and light reflected by the others is wasted. Again, a compromise must be reached between efficiency and reduced need for tracking

Designs such as solar funnels, which are not parabolic, can also focus some sunlight onto a cooking pot for some period of time without being moved to track the Sun. They, too, embody a compromise betwen efficiency and reduced tracking. This is an essential factor in the designs of concentrating reflectors.

Satellite dishes and reduced tracking Edit

Many people have used discarded satellite dishes to make concentrating reflectors for solar cookers. Most satellite dishes are off-axis segments of paraboloids. The axis of the paraboloid does not pass through the centre of the dish. For its original purpose, this has two advantages. The beam of microwaves coming from the satellite is not obstructed by the receiver module, which is located on the paraboloid's axis, out of the beam (usually below it). Also, if the receiver is below the beam, the dish is more nearly vertical than one with the axis passing through the centre. which reduces the amount of precipitation that falls on it. In locations where snow falls, having the dish nearly vertical prevents snow from accumulating on it and degrading reception.

If a dish that was designed as an off-axis one is used as a solar concentrator with the cooking pot on the line that aims from the centre of the dish toward the Sun, and is perpendicular to the surface of the dish at its centre, it focuses the sunlight astigmatically. *If the dish is aligned correctly*, the astigmatism can be used to reduce the need for tracking, as described above. To do the alignment, the designer must be aware of the characteristics of the particular dish he is using. At a glance, it may look circular, but rotating it affects the astigmatic focus. Trial and error are usually needed.

Solar Funnels Edit

First Patent Edit

It appears that the first USA patent on the class of solar cookers known as concentric parabola as given to Ronald Winston of Chicago along with Arnulf Rabl in 1978. The patent number is US 4130107.

However in the patent itself, there is no description of the reflecting surfaces as being parabolic in nature and conceivably that description is wrong.

Ronald Winston has been a active serial inventor and has developed the science of such cookers as "Non Imaging Optics". He has written several books on the topic and continues to be active in the field.

In India, at Aurovile in Pondicherry state, it is planned to set up such cookers that are so big that they are whole buildings in themselves!

Because the Non Imaging cookers work, each day,for considerable time as effectively as Tracking cookers, they represent an important forward looking solutions.

--Ashok Mathur2 11:31, September 3, 2010 (UTC)

The patent appears to be for devices in the class known as "solar funnel cookers". Light enters the wide end of an approximately funnel-shaped reflector and emerges from the narrow end, where the cooking pot would be located. (The funnel is not paraboloidal, so maybe this should be on another page of the wiki.) The device works reasonably well for a fairly wide range of angles for the incoming light, so it continues to work for some time as the sun moves in the sky. Its main disadvantage is that much of the light is reflected several times from the side of the funnel before it reaches the narrow end, so unless the reflector surface is very good and clean, much of the light is lost. Since the funnel is often quite long and narrow, cleaning its interior is difficult. If there is a cooking pot at the bottom, dirt and grease accumulate rapidly.

DowenWilliams 14:18, September 3, 2010 (UTC) David Williams

Swiveling-pot design Edit

This concept was developed as a solution to the hazard created by highly focused sunlight, where proximity to the focal point is dangerous, if not impossible. In this design, the pot is suspended on a swiveling arm, enabling the user to rotate the pot, or other cookware, away from the focal point of the sunlight, allowing easy access to the food and greatly reducing the risk of injury.

Audio and video Edit

July 2011:

Freir patatas en cocina solar

The AlSol 1.4 parabolic solar cooker very effectively fries potatoes.

July 2010:

Parabolic solar cookers for making tea and ironing napkins

Parabolic solar cooker works in cold winter weather, and for heating household appliances.

Quick Notes Edit

Read here for an article on how trough solar cookers are among effcient solar cookers.Ashok Mathur2 13:04, September 4, 2010 (UTC)

It states the "efficiency" is 350 degrees Celsius! What does that mean? DowenWilliams 14:08, September 4, 2010 (UTC) David Williams

I found the answer to my own question. Efficiency is not measured in degrees Celsius, of course. That statement was just a bit of nonsense written by some ignorant journalist. What the original advertisement said was that the efficiency of the trough at 350C is 68%. I think that means that, if the temperature of the fluid that is being heated is 350C, then 68% of the energy striking the trough gets transferred to the fluid. That makes sense, and it is a good figure.

But is it important? Sunlight is free. Using it efficiently doesn't achieve much.

Incidentally, 350C is not a particularly high temperature. There's a solar furnace in France, which uses a field of heliostats and a big paraboloidal reflector, which has generated temperatures of about 3,500C. Note the additional zero!

DowenWilliams 20:51, September 4, 2010 (UTC) David Williams

See also Edit

- All parabolic cooker designs on this wiki
- All construction plans for parabolic solar cookers on this wiki
- Mechanical Mathematician - A simple mechanical device for calculating a parabola
- Solar design T-Square - A device using lasers to arrive at a design for a parabolic reflector that can cook longer without being turned
- Parabolic Solar Cooker as Pedagogic Instrument - Imma Seifert and Dieter Seifert
- Focus-Balanced Paraboloidal Reflector
- **January 2009:** Performance Analysis Solar Parabolic Concentrator for Cooking Applications - *P. Rajamohan, S. Shanmugan, K. Ramanathan,* ***D. Mutharasu***

External links Edit

- Information on parabolic solar cookers from Humbolt State University Campus Center for Appropriate Technology
- DIY - How to Make your own Parabolic Mirror!
- Instruction booklet for using a parabolic cooker - *Sun and Ice*
- Using Spinning Liquids to Simplify the Construction of Parabolic Reflectors in Solar Cookers
- Making a Parabolic Reflector Out of a Flat Sheet (Also in French) - *Solar Cooker Review*
- Alsol Solar Technologies
- Computer program for calculating the shape of parabolas for concentrating solar cookers
- "Compound" parabolic solar cooker, make a template with technical drawing
- An Alignment Template for Unattended Solar Cooking - *Li-Yan Zhu and Yun K. Kim*
- Parabola Calculator program
- Solare Bruecke Scheffler's site. Multilingual. Many details.
- Appropedia Sun Related Calculations page Many formulae.
- How to build a paraboloid