Manual making of a parabolic solar collector

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This article offers an illustrated description of a method to produce a closed parabolic trough solar energy collector box based on the elasticity of the material. What is described here is basically a manual method to make high efficiency solar collectors against very low cost, which is particularly suited for teaching, research or demonstration purposes. But it is hard for a manually made collector to match the efficiency, lifetime and water tightness standard of an industrial product using the same method. It will also cost more than the industrial collector. The method for industrial production of elastic closed parabolic trough boxes will be described in another article later.

A parabolic trough solar collector uses a mirror in the shape of a parabolic cylinder to reflect and concentrate sun radiations towards a receiver tube located at the focus line of the parabolic cylinder. The receiver absorbs the incoming radiations and transforms them into thermal energy, the latter being transported and collected by a fluid medium circulating within the receiver tube. This method of concentrated solar collection has the advantage of high efficiency and low cost, and can be used either for thermal energy collection, for generating electricity or for both, therefore it is an important way to exploit solar energy directly.

Known methods to form the parabolic cylinder reflective surface consist either of forming a curved plate material under high temperature, or of adding pre-formed ribs at the back of a flat reflective plate, then force the plate to follow the curve of the ribs. Both methods are expensive, and both have difficulties to reach a high precision. Our method uses the natural elastic deformation of a planar plate to form a curved surface close to a parabolic cylinder, then redress the approximation error of this surface, again using elasticity. As it is easier to get higher precision by natural elastic deformation, this method has the following advantages.

1. Simplicity and low cost. It is actually the only known method for home making high performance parabolic trough solar collectors without any special tools. Not only the production cost drops to far blow the other manufacturing methods of parabolic troughs, but also it makes the solar energy collecting cost substantially lower than any fossil fuel. The economic and social signification of the method may be huge.

2. Better performance and quality of the product. It is a general understanding that the smaller a parabolic trough is, the lower is its performance, although smaller parabolic troughs are much more useful than bigger ones. The fundamental characteristics of the performance of a parabolic trough solar collector are its concentration ratio and its optical efficiency. Today, the concentration ratio of a parabolic trough collector of width between 1m and 2m is limited to about 50 times under industrial manufacturing conditions and with high cost, while our method can achieve an effective and efficient concentration ratio of over 80 times for a manually made parabolic trough of width less than 1m, together with a higher efficiency.

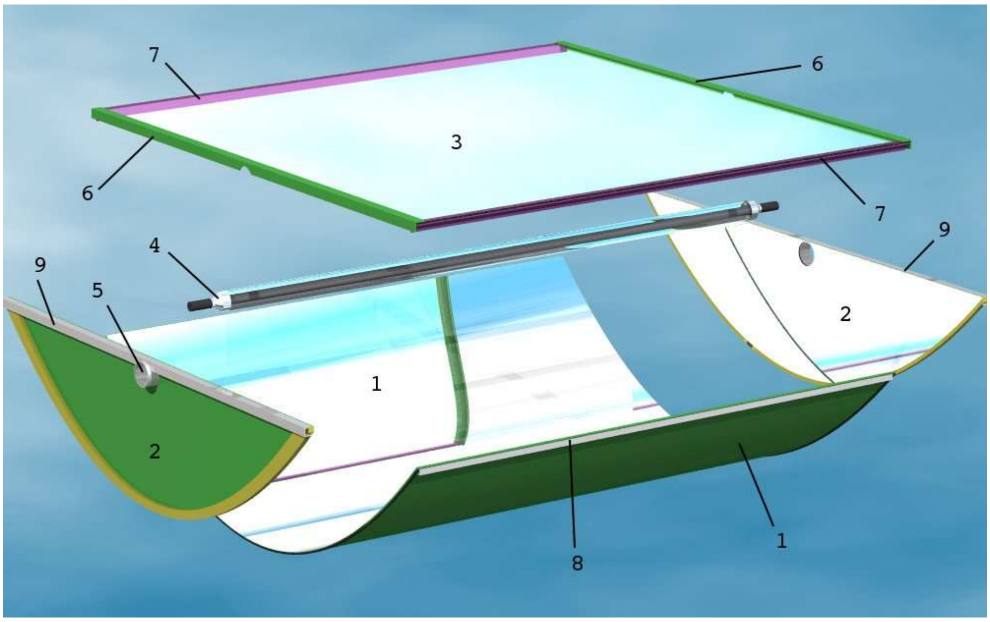
The solar collector described here has several usages, and changing the usage amounts simply to replacing the receiver tube. Beside the simple low-temperature receiver described in this article that can be used for water heater, space heater or heat source for an absorption cooler, there are also tubes covered by photovoltaic cells useful for combined heat and electricity generation, and evacuated high-temperature receivers. The latter can be combined with thermal storage devices to be described in a coming article, to form round the clock electricity generating systems of sizes ranging from individual home energy systems to large solar power plants. The low costs of the collector and the storage device guarantee that all these applications will lead to an energy cost significantly below that of fossil fuels.

The theoretic design principle of a closed parabolic trough box can be found in [1]。

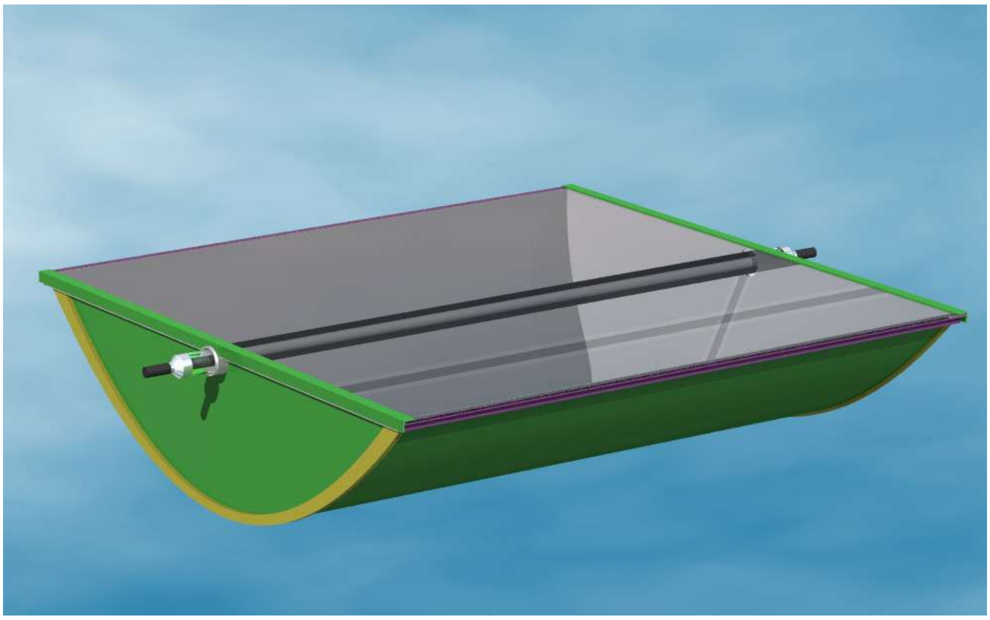
The method described here is patent pending. But the patent assignee allows royalty-free manual use of this method for non-profit purposes. For commercial exploitation of the method or product, please contact the author.

1. Dimensions and parameters

The solar collector is a closed box composed of the following principal parts. In the picture, 1 is the back plate, 2 is the end plate, 3 is the cover, 4 is the receiver (the glass tube surrounding the receiver is only needed only for high temperature applications), 5 is the bearing, 6 is the end angle of the cover, 7 is the side angle of the cover, 8 is the side angle of the back, 9 is the reinforcement bar of the end.



The assembled collector box is as follows.



There are two basic choices of the materials forming the collector box. One can either use all-plastic plates for the body of the box, or use glass cover plus metal back and ends. The cost and performance of the two choices are very close. For manual work, it is easier to make and to manipulate a plastic box. Therefore our description will be given for the plastic case. But it is easy to adapt the description to glass and metal boxes.

In general, glass and metal boxes are more suitable for high concentration ratios, due to a higher dimensional stability and lower thermal exansion coefficients.

The pictures below show a finished plastic collector.

In the following table, we give several concrete examples of the dimensions of a collector box, where all the parameters are in milimeters. In the table, example 1 is for regions with metric system, so that plates are commonly cut to 1m*1m; example 2 is for regions with US standard system, where plates are commonly cut to 1.22m*1.22m. Example 3 is a case based on industrially produced joints.

Content	*Symbol*	*Example 1*	*Example 2*	*Example 3*
Length of the back	L_b	1000	1219	970
Width of the back	W_b	1000	809	1124.1

Content	*Symbol*	*Example 1*	*Example 2*	*Example 3*
Thickness of the back	T_b	2	2	2
Length of the end, i.e., the width of the reflective surface	L_e	856.5	690	967
Height of the end	W_e	228.1	186.7	253.5
Thickness of the end	T_e	2	2	2
Length of the cover	L_c	1000	1219	1000
Width of the cover	W_c	890	723	1000
Thickness of the cover	T_c	2	2	2
Outer diameter of the bearing	D_o	40	40	40
Distance from the bearing's center to the upper border of the end	I_{up}	28	28	24
Distance between the two site angles of the cover	I_s	859.5	693	970
Diameter of the receiver	D_c	14	11.5	16
Collecting area		0.84m^2	0.83m^2	0.96m^2
Lower boundary equation of the end		$y=228.1-0.001244x^2$	$y=186.7-0.001569x^2$	$y=253.5-0.001085x^2$

Readers desiring to make collectors of dimensions not covered by the above examples can use the online tool [2] to compute the necessary data.

For glass plus metal collectors, the thickness of the back and the ends can be anywhere between 0.4mm and 1mm, and a thickness of the cover between 3mm and 6mm.

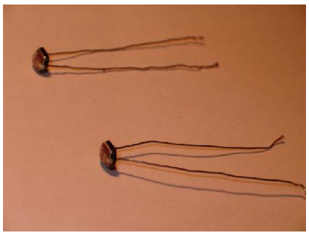
Remark. The concentration ratio (linear ratio) is the ratio between the length of the end and the diameter of the receiver. So the concentration ratio can be changed by using a receiver with a different diameter. A higher concentration ratio allows the collector to reach a higher working temperature with minimal thermal loss, but requires higher manufacturing precision too. A very carefully constructed and adjusted collector may reach an effective concentration ratio as high as 100. The data given in the above table correpond to a concentration ratio of 60, which is suitable for beginners because the manufacturing difficulty is considerably lower, as the optical precision requirement for a concentration ratio of 100 is 2.3 times that of a ratio of 60. If the collector is used for water heating, space heating or air conditionning, the working temperature does not exceed 100°C, for which case a concentration ratio of 60 is sufficient. In such cases, a lower and optimal concentration ratio is even preferred from the highest concentration ratio, because the former offers a better efficiency when the sun is slightly veiled. However, it is better to use a thinner receiver during the optical adjustment, for this gives a better precision of the adjustment.

The pictures in this article are taken from a concrete manual construction using dimensions of example 1. A receiver tube of diameter 10mm is used, leading to a concentration ratio of 85.6. A field test shows that the optical efficiency is above 70% with an aluminium reflective surface, meaning that the optical precision is excellent for this concentration ratio.

2. Preparation of the materials

The following table lists the quantity and specification of materials needed to make one collector box. All the lengths are in milimeters.

Usage	*Spec.*	*Quantity*	*Nature and quality*
Back	See §1	1	polystyrene plate，preferably HIPS，anti-UV. One can buy a mirror coated plate, or get an ordinary plate then glue a plastic thin mirror sheet on its surface.
End	See §1	2	idem
Cover	See §1	1	Preferably high-transparency polycarbonate plate, but HIPS or PMMA can also be used. Must be anti-UV. The external surface is preferably applied a layer of transparent hardener for scratching resistance.
Bearing	See §1	2	Joins for 40mm PVC plastic sewage pipes can be adapted for this. 
Receiver	See §1	1	Any metal round tube, length about L_c+50mm, thickness 0.5mm or more.
Side angle of the cover	15*15*L_c	2	Aluminium angle, thickness 1-2mm. 
End angle of the cover	15*15*W_c	2	idem
Side angle of the back	10*10*L_b	2	idem
End reinforcement bar		2	Aluminium bar, length L_e，width 20-30mm，thickness 2mm.
Short alu angles	15*15	0.5m	For the joints of the back and the end. Thickness 1mm will be enough.
Edge redressing bar	15*2	2m	Aluminium 
Body redressing supporter	12*12 至 20*20	2	Aluminium angle, thickness 1-2mm.
Body redressing wire	2-4mm diam.	5m	Plastic covered iron/steel wire.
Bolt/nut	3*6	100 pairs	Iron, the length should not exceed 8mm.

Usage	*Spec.*	*Quantity*	*Nature and quality*
3mm washer		100	Iron
Bolt/nut	4*10	30 pairs	Iron
4mm washer		20	Iron
Redressing adjustment bolts	4*40	10	Iron, with 20 nuts.
Photoresistance		2	Reference model A9060 or GL5537. Shape as shown. 
Auxiliary materials			Silicone, epoxy, adhesive ribbon, paint, tube hoops, etc.

As the business develops, more and more vendors and supplies of the various parts for making the collector will appear. The up-to-date supply information of parts and kits will be given in the webpage [3].

3. Making the back

The back is a flat plate, one of its surface being a mirror. The plate will be bended to form the reflective surface.

The first thing to do is to determine the direction of the plate used to make the back. The production of a flat plate, either of plastics or of metal, is done either by extrusion or by rolling. We call the direction of the die or the roller the *transversal direction* of the plate, and the direction of the output of the plate the *moving direction*. The crucial point is to avoid bending the back in the transversal direction, because the plate is usually less uniform in that direction, with more inherent curvature, internal stress and variations of thickness. This will lower the optical precision of the back, and add to redressing difficulty.

So the correct method is to bend the back in the moving direction.

In general, for an entire plate of size 1m*2m (metric system) or 48*96 inches (standard system), the direction of its length is the moving direction, and that of its width is the transversal direction. If an off-the-shelf plate is already cut to smaller sizes, one has to observe the natural bending of its surface, either putting the plate at an horizontal flat position or slightly bended. Along the transversal direction, some very slight and regular local inherent bending can often be noticed, especially near the borders of the plate. There should be less local inherent bendings along the moving direction.

If a mirror coated plate is to be used, please notice it should be a front surface mirror, that is, the plate body is not transparent, and the reflected light does not travel through the body of the plate. And a good mirror coated plate must have two protective plastic sheet layers before the mirror surface, with a temperary outer layer protecting the mirror against scratchings during transportation and working, and a permanent inner layer protecting the reflective metal coating from oxydation and corrosion. The former is easy to tear off, but the latter is much less obvious. However, if the plate is cut by a saw, one will be able to see local tearing offs of the permanent layer near the edge of the cutting.

The permanent layer must be left intact after the working, or the mirror surface won‘t last long. However, there is an important risk that it be teared off by error. In fact, the temperary layer should be left on while cutting the plate, to be teared off once the back and the ends are assembled. However, if the temperary layer is to be teared off from an edge, and if the edge is cut during the working, it is very likely that the two protective layers are still bound together, while the permanent protection layer is locally disjoint from the substrate, so that an tearing error is very easily induced. A solution consists of tearing off a small portion of the temporary protection layer before cutting the plate, and when tearing off the temporary layer after assembling the box, begin the tearing from that small portion.

To begin with, holes for photoelectric detector should be drilled on the plate cut off according to the dimensions. The two holes at the ends are for fixing bolts, and are of diameter 4mm, which is slightly bigger than the diameter of the bolts. This helps for the adjustment of the positionning of the detector. The two holes at the middle are for the leads of the photoresistances, and are of diameter 6mm, slightly bigger than the diameter of the photoresistances. The bolt holes must be strictly located on the center line of the back.

The picture on the right shows the holes on an assembled back, but holes should be drilled before assembling. This also indicates that the photoelectric detected is preferably made first.

Cut the side angle of the back to length L_b, then at the middle of one side of the angle, drill a bolt hole every 5mm. At the other side of the angle, drill a 4mm bolt hole every 25cm (4 holes if L_b is close to 1m). Holes on the two sides should not meet. The hole positions should be symmetric with respect to the center of the angle.

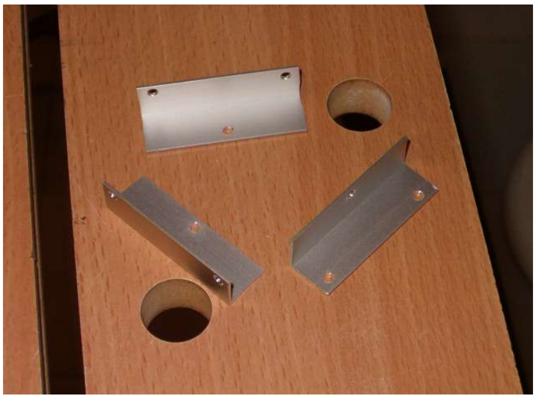
Drill a range of holes on the back plate according to the positions of the 3mm holes on the side angle. The side angle is place on the non-mirror side of the back, with the vertical side facing the interior. And a space of 3mm should be left between the edge of the angle and the edge of the back.

Fasten the side angles on the back using 3mm bolts and washers as shown, one at each side. Check that the tails of the bolts do not exceed the straight line joining the two outer edges of the angle. If they exceed, the exceeding part must be cut off.

Do not fasten the bolts too much, or the plastic plate may crack.

Cut ten pieces of 5cm each from the joint angle.

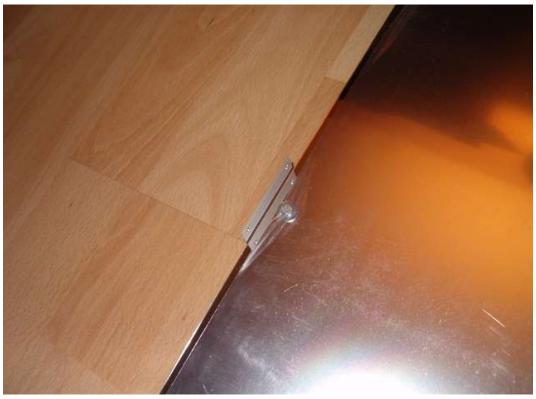
Drill three 3mm bolt holes on each piece. Precise positionning of the holes is not required, but they should be close to the border of the pieces.

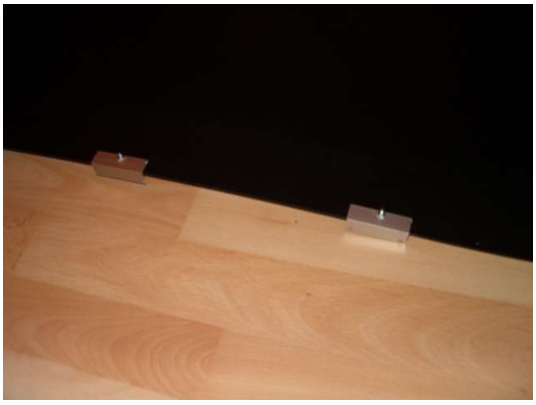


Fasten five above pieces on each end of the back, each fixed by one 3mm bolt, with the head of the bolt on the reflective surface.

The middle piece must be precisely located at the center of the back, the outer side of the side pieces has a distance of 5cm from the corner of the back. The position of the other two pieces has no strict requirement.

Before fixing the pieces, apply a small amount of silicone around the bolt hole to prevent water infiltration.

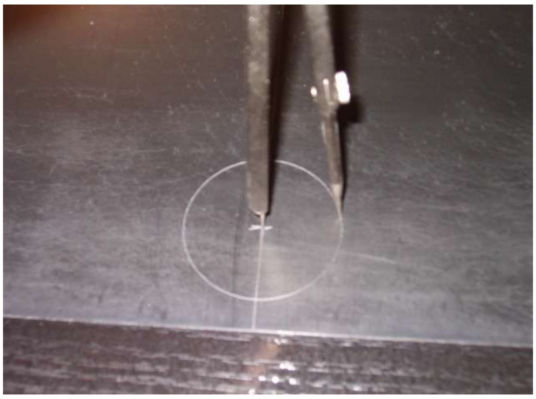




4. Making the ends

Cut out the down side curve according to the parabolic equation. The equation and the point coordinates can be calculated in [2].

Draw the bearing hole with a compass.



Cut off according to the curve, and rectify the irregularities of the cutting.

Cut out the bearing hole with a wire saw.

Smoothen the hole with a file, to the point that the bearing can be inserted neither too tight nor too loose.

Cut the end reinforcement bar to L_e or slightly shorter, and cut out a notch at the center for the position of the bearing.

Take note that the upper edge of the reinforcement bar should be 2mm above the upper edge of the end.

Fix the reinforcement bar on the end by a few 3mm bolts placed at the lower part of the reinforcement bar.

After drilling the bolt holes and before inserting the bolts, apply silicone to the joining surfaces for water tightness. The clips are there to squeeze silicone.

5. *Making the cover*

Add angles to the four edges of the cover. The angles can be fixed by some bolts, not fastened too tight. Before fastening the bolts, apply silicone to the joining surfaces.

The end angle should be notched at the center, for the position of the bearing.

The distance between the two side angles (l_s) must be as precise as possible, because the optical precision depends on it.

The side angles are put below the cover, with vertical side towards the interior; the end angles are put above the cover, with the vertical side towards the edge. Note that in the picture, the cover is in an upside down position.

A gap of 2.5mm should be left between the edge of the cover and the vertical side of the end angle. When the cover is assembled, the end reinforcement bar will enter this gap.

Due to the transparency of the cover, this gap is not clearly seen in the picture.

If industrial joints are used, this gap does not apply, and the vertical side of the end angle shoud be put tightly against the end edge of the cover.

Adjacent angles are fixed by a bolt at the corner of the cover. This picture also shows the gap between the edge of the plate and the vertical side of the end angle.

This picture shows the cracking of the cover by the bolts. This phenomenon is quite noticeable when a polystyrene plate is used for the cover. No cracking is observed when a polycarbonate or HIPS plate is used.

To protect the outer surface of the cover against scratches, the easiest method is to put a thin plastic film on it. The plastic food wrap is good for this, but a thicker one would be better. Care must be taken not to leave air bubbles between the film and the plate. There will be no light loss if there is no air bubbles.

When the plastic film is scratched or become dirt, replace it.

6. Joining the back and the ends

Drill bolt holes near the lower edge of the end, for the fixation of the joints.

First make the holes for the central piece, taking care of the precise matching of the center line of the back and the end. Insert bolts and fasten.

Next, make the holes for the end pieces. When drilling the holes, pull the back at the edge to ensure that it fits tightly against the lower edge of the end. Insert bolts and fasten.

Then the remaining pieces. After the drilling, remove all the bolts and take off the end.

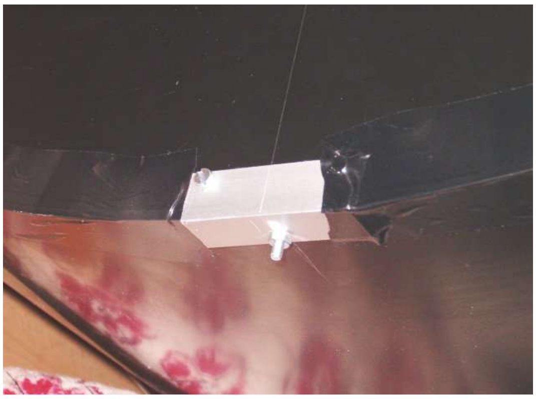
Apply silicone to the joining surfaces, then re-insert bolts and fasten, according to the direction shown in the picture.

Remember not to fasten the bolts too much.

Inside view of the joint.

And the global view after joining.

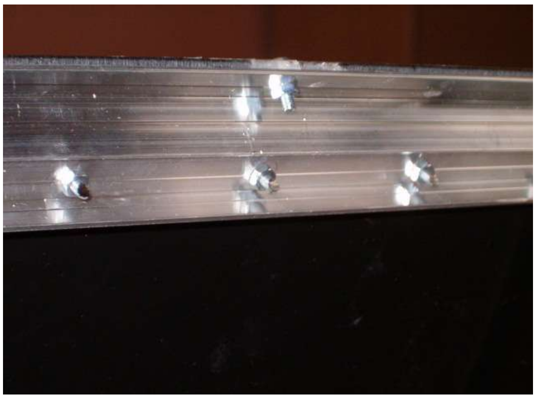
Use a flexible adhesive ribbon to close the gap between two adjacent joints. Here the adhesive ribbon is of the same color as the plates, so it is not easily distinguishable.

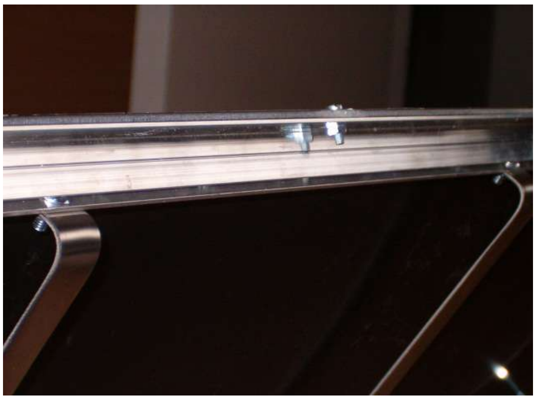


7. Joining the cover

Tear off the temperary protective sheets protecting the mirror surfaces of the back and the ends.

Place the cover on the joint back and ends, and ress the sides of the back so that the side angles of the back enter into the space between the two side angles of the cover.

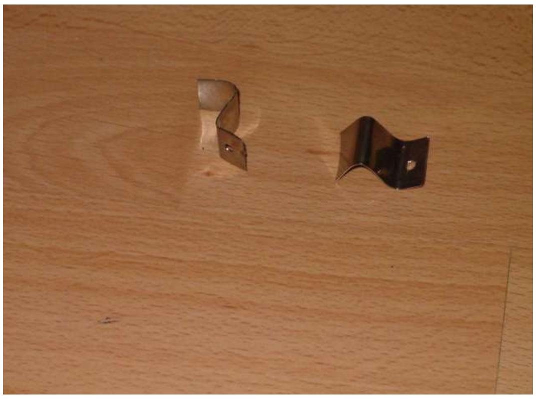




Press down the cover, so that the edge of the back plate reaches the lower surface of the cover.

And press down the cover at the ends so that the upper edge of the end reinforcement bar enters into the gap between the edge of the cover plate and the vertical side of the end angle of the cover. Fix the position using adhesive ribbons. Do not apply a more permanent fixation means unless you are sure that you won‘t need to reopen the box.

After finishing all the tests, the gap between the end and the cover can be completely closed by adhesive ribbons or silicone.



Make several holders as shown from a thin steel/inox sheet.

Use a nut to fix the holder on the side angle of the cover, to prevent the detachment of the back. Note that the holder should not put pressure on the side angle of the back, in order not to deform the latter. So a small moving space should be left between the holder and the side angle of the back.

8. The bearing and the receiver

The receiver described in this section is only designed for low-temperature thermal collection, such as solar water heating or space heating, or for supplying heat source for an absorption space cooler. Besides this, our collector can also be used for combined heat and electricity collection using a photovoltaic-covered receiver, or for high temperature thermal collection using an evacuated receiver. But these receivers cannot be manually made, so they are not in the scope of this article. The interested readers can try to buy them through [3].

Insert the bearing into the hole of the end, with the neck against the reflective surface of the end.

If the material is too long, cut it to fit.

Add the end reinforcement bar.

Cut out a ring from the bigger tube.

Put the ring as shown, then fix the assembly by epoxy. Close all the gap to prevent water infiltration.

Take care that the epoxy does not prohibit the end angle of the cover from entering into its position.

Carefully correct any possible bending of the receiver tube, even the slightest.

Paint the receiver tube with matt black lacquer, preferably high temperature resistant.

Wrap the ends of the receiver with a thick high temperature rubber tape.

Adjust the wraping such that it just enters into the bearing and is able to turn around, neither too tight nor too lose.

Check that once inserted into the bearing, the receiver is exactly positionned at the middle, but not biased towards one side. Otherwise, adjust the wrap.

If the receiver is to be inserted into a closed collector box, insert with the box in a vertical position so that the receiver entering into it will not touch the back or the cover.

Once the receiver inserted, a tube hoop can be fastened outside to prevent the receiver from moving along its axis.

The bearing can be supported by a wood board with a hole in it. The hole must allow the bearing to rotate freely without too much friction.

9. The edge redressing mechanism

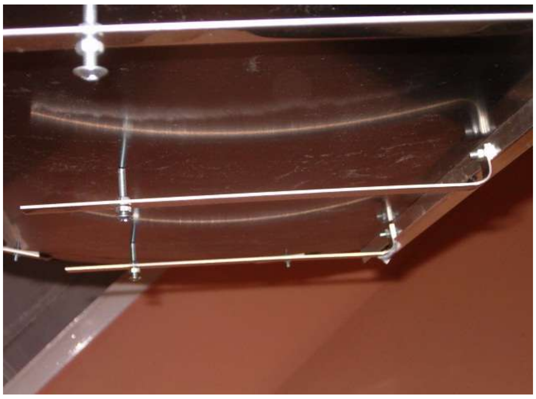
This mechanism is necessary for correcting the curvature of the reflective surface near the edges of the back. Without this mechanism, an important portion of the radiation will be lost due to defocussing.

Cut the edge redressing bar into several pieces as shown, and bend the head of each piece. Make 4mm holes for the bolts.

The distance from the adjustment bolt hole to the head of the bar should be from $0.15W_b$ to $0.18W_b$. Use $0.18W_b$ if body redressing mechanism is used, and $0.15W_b$ otherwise.

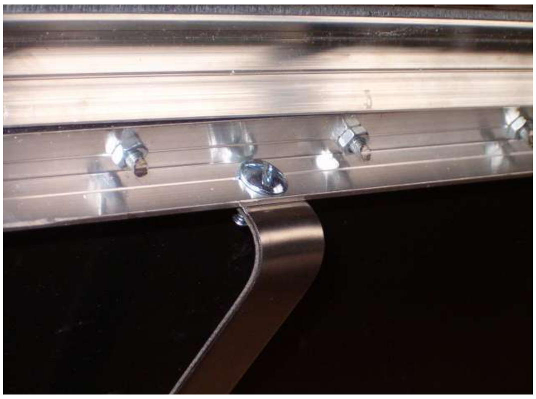
One can also drill several adjustment bolt holes on the end of the bar, in case where the bolt position should be modified.

Use two nuts for each adjustment bolt, in order to fix the adjusted position.



The head of the bolt fixing the bar to the side angle of the back must not exceed the straight line joining the two edges of the angle.

After fixing, the head of the redressing bar must not touch the back plate, otherwise it may deform the plate.



Global view of the back after the edge redressing mechanism being installed.

The initial position of the adjustment bolts can be put to 1cm above the natural position of the bar, before the more precise field adjustment.

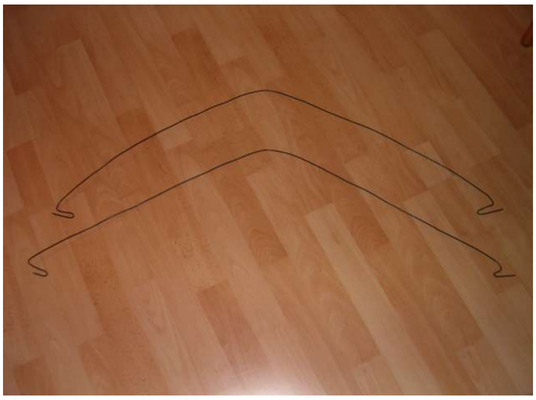
10. The body redressing mechanism

This mechanism is necessary only when curvature leaking is observed. See below. This is because curvature leaking only occurs when the concentration ratio is very high, or when the back plate has poor uniformity.

Fix the two body redressing supporters on the back of the collector. Only the two ends of the supporter need to be fixed, preferably by adhersive ribbons to facilitate later adjustment.

Under standard conditions, the supporter should be fixed to a position whose distance towards the center of the back is 1/4 of the width of the collector. But this can be modified according to the bending situation of the back.

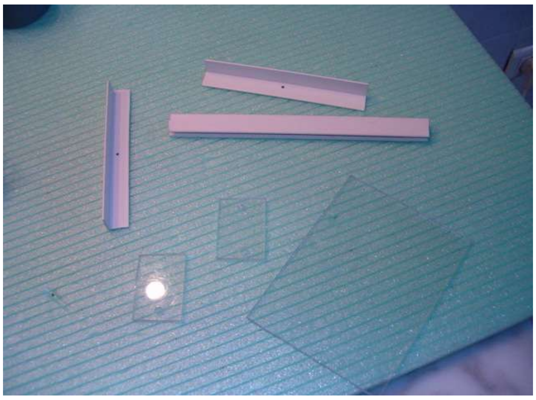
Cut and bend body redressing wires as shown. Here two wires will be enough.



Put the wires to the back of the collector, and adjust the length and bending angle of the wires so that they press on the supporter. The initial pressure can be adjusted to about 300-500g at each pressing point, before the field adjustment.

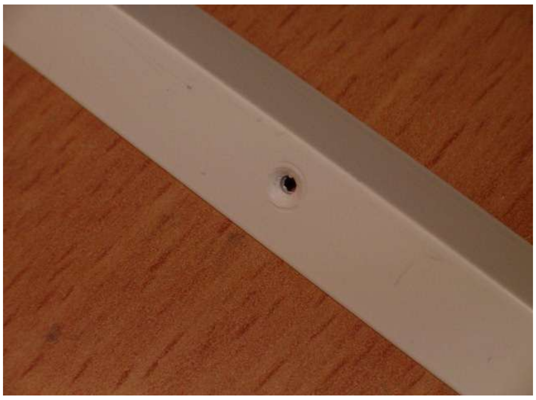
11. The Photoelectric detector

Cut out the various parts shown in the picture from scrap materials. Here the bigger plate is of width 6cm and length 8cm; the angles is of width 10mm and length 8cm; the cap bar is of length 12cm, and its base width should be approximately $0.7D_c$.



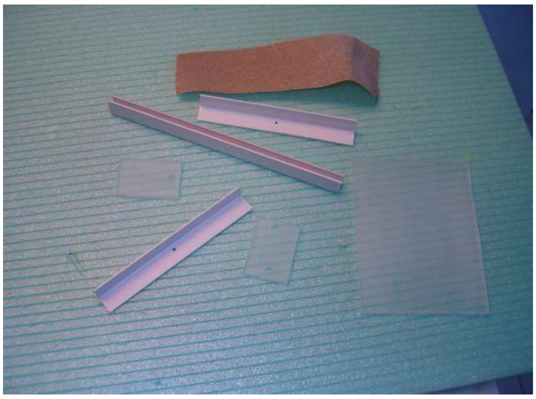
Drill a small light hole of diameter 1.5mm in the middle of each angle. The position of the holes should be such that the distance between the two holes in the assembled detector is equal to D_c.

All the parts must be in plastics, for the weight of metal parts might deform the back.



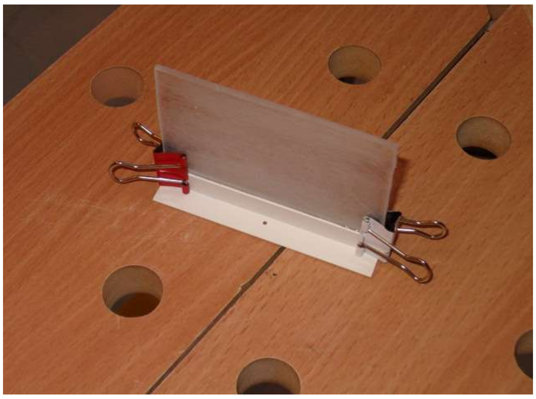
Cut out a cone at the outside base of the light hole, using a drill bit of large diameter. The depth and scope of the two cones should be as similar as possible.

Scratch all the surfaces to be glued with a sandpaper.



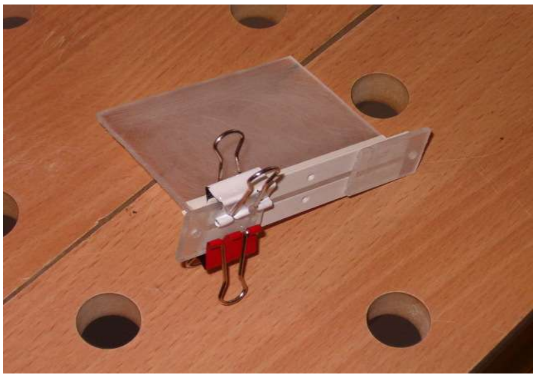
Glue the angles and the bigger plate as shown. Make sure that the bases of the two angles after gluing are exactly at the same level.

Press and wait for the glue to dry.

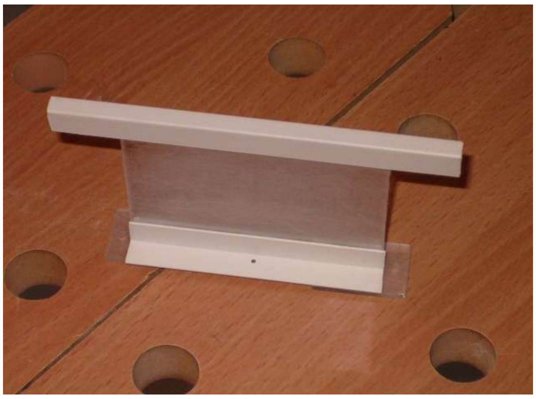


Then glue on the two base pieces. Note that the two 3mm bolt holes on the base pieces must be exactly located on the center line of the assembly, with a tolerance not exceeding 0.2mm. Space should be left above the hole for the head of the bolt.

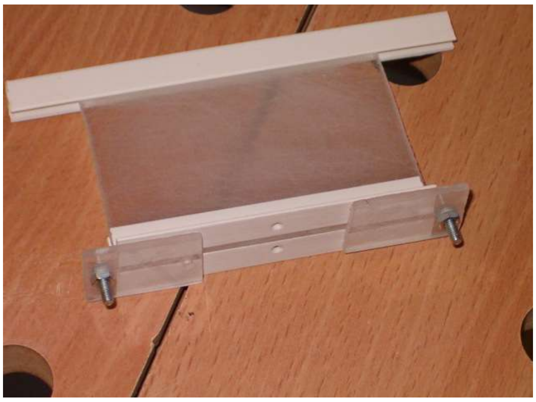
If ever a positioning error of the holes is observed after gluing, the hole can be slightly enlarged to compensate.



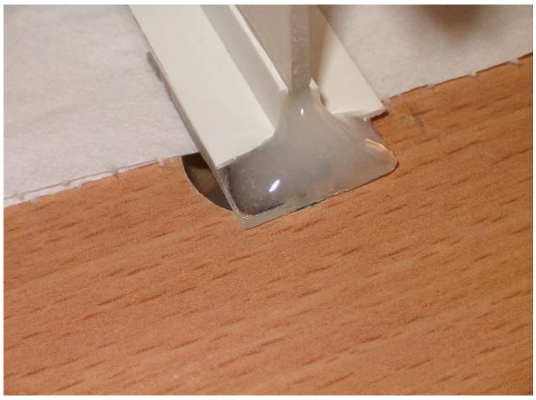
Glue on the cap. The form of the cap is of no importance, but its positionning should be accurate. Avoid gluing it to one side of the assembly.



Insert two bolts into the holes, and tighten by two nuts. Adjust the positions to fit accurately on the center line.



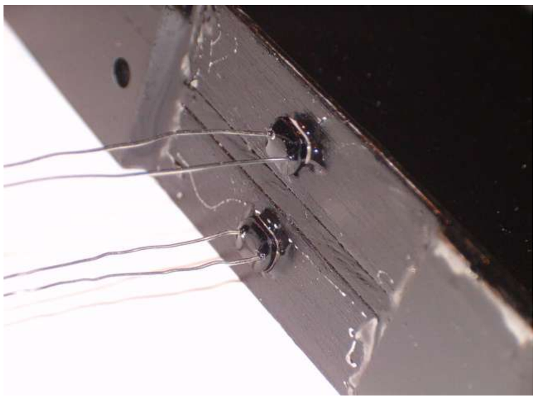
Seal the heads of the bolts with epoxy.



Paint the assembly to black. The surfaces of transparent materials must be carefully blackened in order to prevent interference by leaked lights.

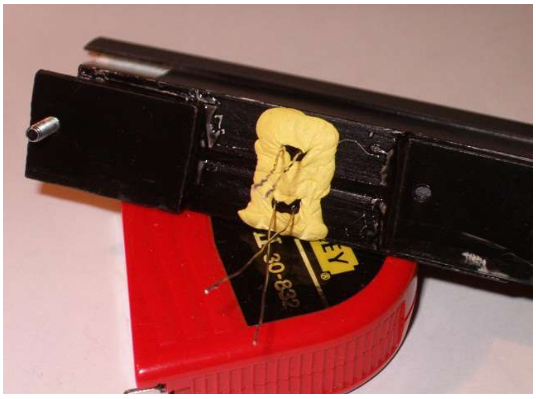
Wait for the lacquer to dry, then remove the lacquer entering into the light holes.

Glue a photoresistance to the back of each light hole.



Le the glue dry, then fill the surrounding sace with blu-tack to stop light leaking.

To check the quality, tightly obstruct the light hole, then measure the resistance of the photoresistance. The measurement should read at least 100K.



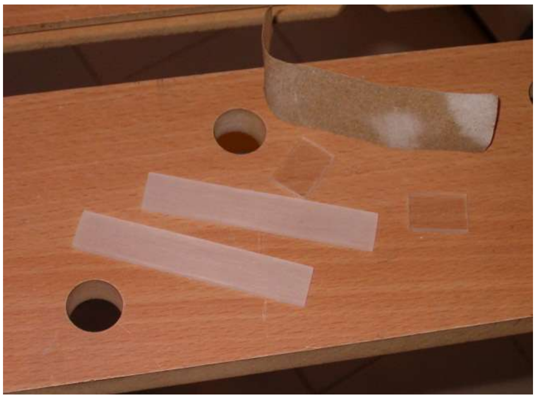
Add a layer of thin white plastic sheet in front of the light holes to attenuate the light getting into them. Several materials may need to be tested, for example pieces cut from plastic bags. The objective is to make the measurements of the photoresistances as close to 700 ohm as possible under direct sunlight.

And check the uniformity of the two photoresistances. Exposed to the same lighting condition, the difference between the readings of the two photoresistances should not exceed 15%.

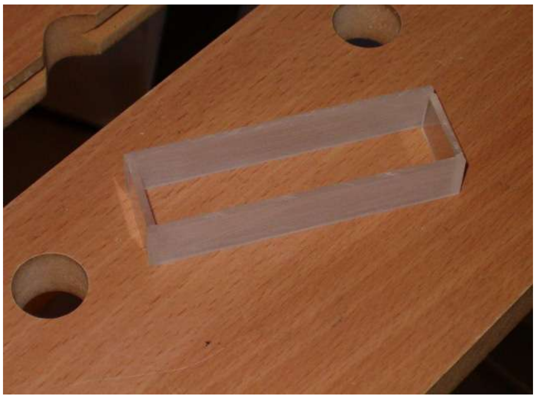
The big plate of the detector should be painted to white. An easier method is to cover it by a piece of white paper.

In order to prevent interferences by lights reflected and concentrated by the back then re-reflected by the cover, a scatterer should be installed around the base of the detector. The scatterer is made with transparent plastic bars of width 15mm. The longer bars are slightly longer than the base length of the detector, and the shorter ones have a length that exceeds by 0.5mm the width of the base.

Thoroughly scratch the surfaces of the two longer bars with coarse sandpaper, to create a scattering effect.

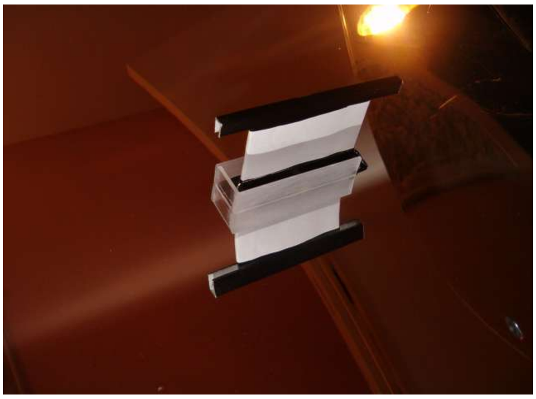


Glue together to form the scatterer.



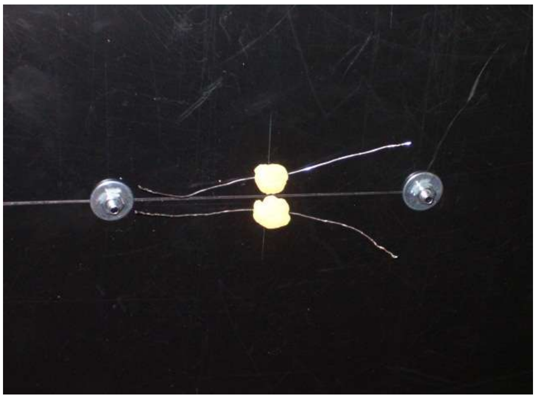
Glue the scatterer to the base of the detector, then install the detector to the bottom of the back.

The scatterer in the picture is too short, so that one side is missing. But this does not affect the result.

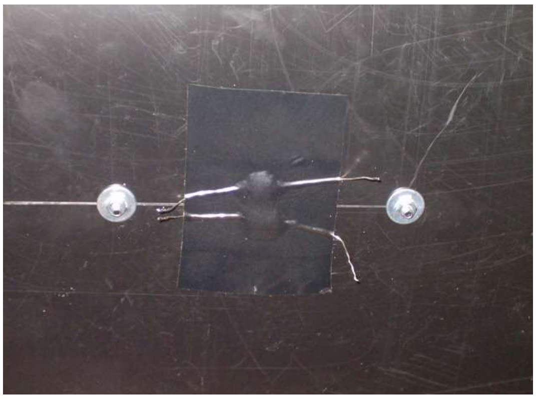


Add nuts. Do not fasten, or the back would be deformed. Just slightly touching so that the detector will not move without external forces.

Fill the lead holes with blu-tack, in order to prevent light leak and water infiltration. Don‘t force too much, or the back would be deformed.



Put a water-proof adhesive ribbon around.



Once the position of the photoelectric detector is adjusted during field test, fix the tail of the two bolts with silicone or lacqer, to prevent movement and water infiltration.

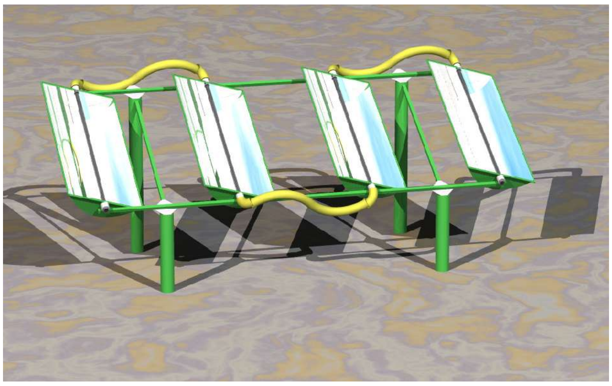
Remark. The photoelectric detector uses the shade of the receiver to detect the position of the sun relative to the collector. Therefore the precision of the detection depends on the positionning precision of both the detector and the receiver.

12. The chassis

Here we show a testing chassis with no resistance to rains, assembled using simple wood boards. All the accessories are fixed on the chassis.

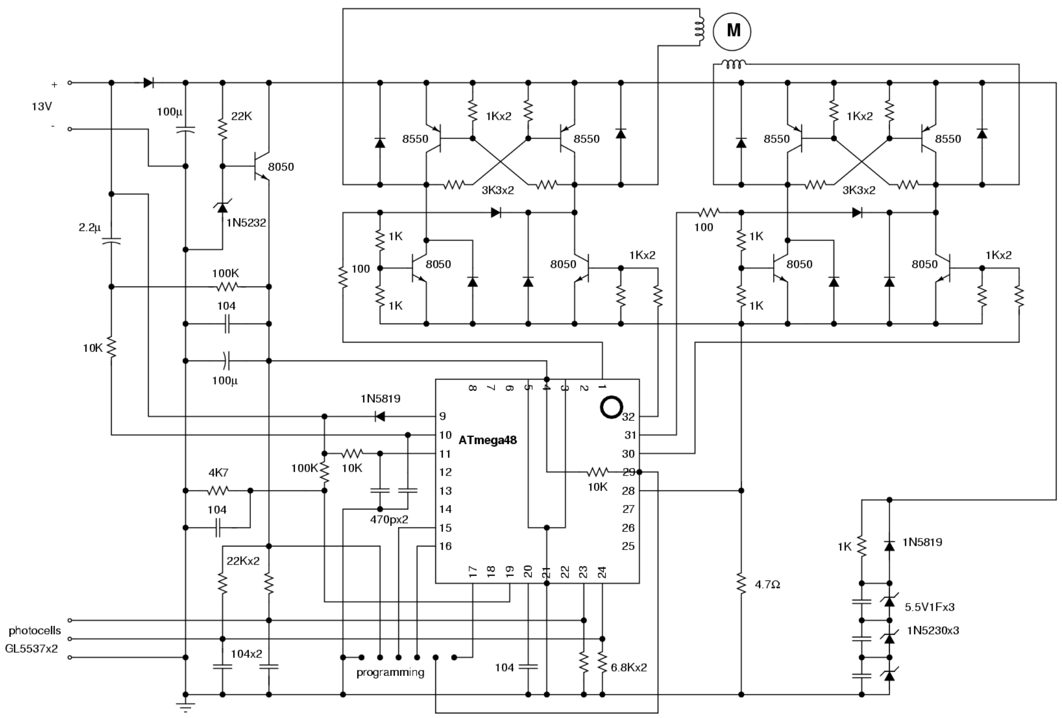
The angle of the chassis.

The chassis of a permanent collector array can be made from square tubes. There are many possible configurations.



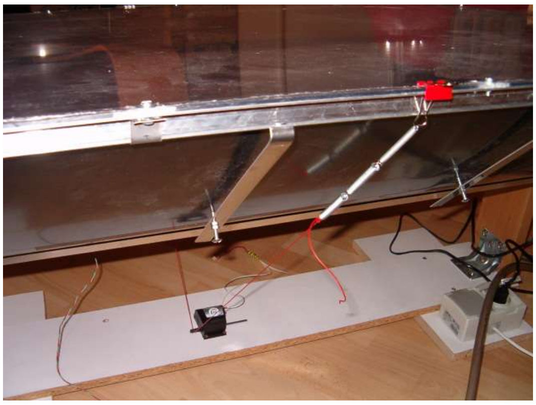
13. The controller and the tracking gear

The circuit schematic of the controller is shown below. This circuit is designed for driving a stepper motor, but it can be adapted to drive an ordinary geared DC brush motor, using only one set of the two driving circuits, and a simplified microcontroller program [3]. Of course, many important features will be lacking in such an adaptation, and the lifetime of a DC motor is limited. A better solution is to order a commercial controller set, see [3].

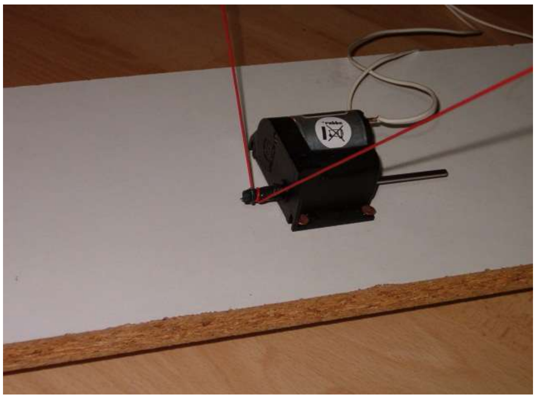


The simplest method to manually mount a tracking mechanism is to use a traction wire. Here an ordinary plastic covered electric wire is used, which is directly wrapped on the output axis of the geared DC motor.

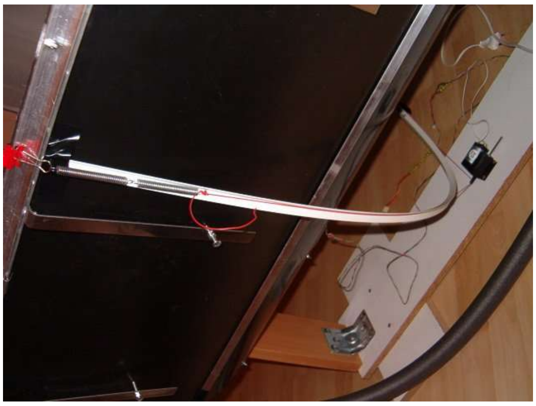
Springs are put on one end of the wire to compensate for the variation of the wire length when the collector position changes. The wire is temperary fixed on the sides of the cover by two binder clips.



A flexible adhesive ribbon is first wrapped on the output axis of the motor to increase friction.



The traction wire is put in a guiding channel made of a bended angle, to reduce its length variation when the position of the collector changes.



14. The fluid circulation system

For a low temperature circulation system, a simple aquarium pump will be enough. The pump can be directly fixed on the chassis.

Here flexible PVC tubes are used for the circuit, in which case the working temperature must not exceed 60°C. Consider insulating the circuit using foam tubes to reduce heat loss.

With heat resistant circuit and pump, the working temperature can go up to 100°C, while keeping a high efficiency if the circuit is properly insulated.

A circulation system for high temperature heat transfer fluid is much more complicated to make, so it is outside the scope of this article. Interested readers will be able to find supplies through [3].

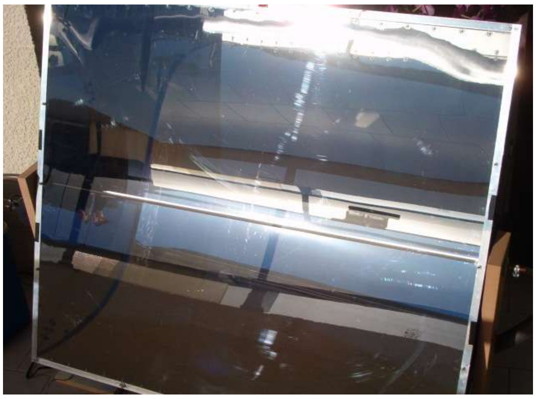
15. The optical adjustment and the collecting tests

Warning. Never dry burn the collector under the sun without fluid circulation! Due to its high efficiency, even the low temperature water heating receiver can reach a temperature of several hundred degrees in less than one minute without circulation, hot enough to damage the cover, melting the plastics or breaking the glass.

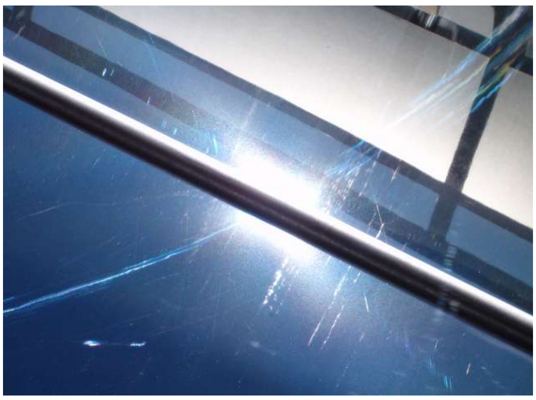
Please always adhere strictly to the following operating procedure. When starting up, first turn on the pump, make sure that the fluid circulation is established, then turn on the tracking. When finishing, first turn off the tracking power supply. The controller with supercapacitor backup will automatically untrack the collector when its power supply is lost. Wait for the collector to get far enough from the tracking position before turning off the pump.

When observing the tracked collector under the sun, always ware protective lenses, preferably special ones rather than a pair of ordinary sunglasses which do not offer enough protection. In any case, avoid as much as possible looking directly into the reflected sun, to protect your eyes.

The basic method for checking the optical precision of a solar collector is to put it into tracking position under the sun, then observe the receiver from all positions and angles. Under ideal conditions, no sunbeam reflected by the collector mirror should leak from around the receiver, from any observation position and angle.



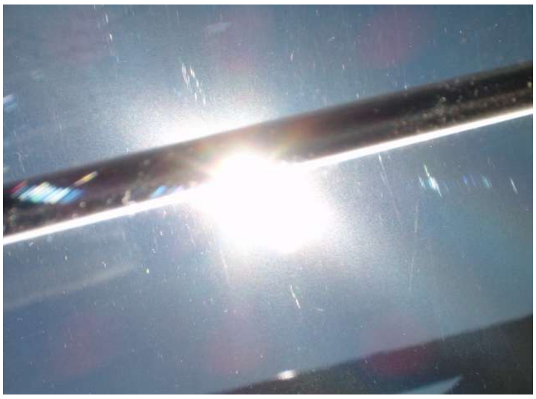
A tracking collector. Can you tell where is the position of the sun reflected by the mirror of the collector?



An excellent reflection: the reflected sun is precisely behind the receiver.

Leaking from the above: some sunbeam appears from above the receiver. It is a partial leaking, in the sense that only a quite small portion of the sunbeam misses the receiver.

Leaking from the below: some sunbeam appears from below the receiver. Partial leaking too.



A small mirror can help the observation from difficult angles.

Paper stripes can be put on the cover to check leaking, as a leaking will illuminate portions of the stripes. This is particularly useful for checking leaking coming from the middle portion of the reflective mirror.

Make sure that the shades of the stripes do not interfere with the operation of the photoelectric detector.

Or for checking leaking coming from edges of the mirror, a flat plate can be used. Here the lower portion of the plate is illumated by some slight leaking from the upper edge of the collector, due to the double reflection phenomenon (see below).

In any case, a leaking of sunbeam means defocussing and loss of collector efficiency. Therefore sunbeam leaking must be kept to as little as possible, by correcting the causes. Each type of leaking has its particularities and causes.

1. Biased leaking: most or all leaking appears from one side of the receiver, either above or below. This is due to tracking error, caused by positionning error of the photoelectric detector, horizontal positionning error of the receiver or the bearing, or a bended receiver.

2. Sided leaking: the leaking from one side of the collector appears from above the receiver, while that from the other side appears from below the receiver. The reason may be the vertical positionning error of the receiver; or an error of the width of the reflective surface, that is, a wrong distance between the two side angles of the cover; or a bended receiver.

3. Axial leaking: the leaking from one end of the receiver appears from above, while that from the other end appears from below. This suggests a twisted collector box, probably due to the fact that the back or the cover is a parallelogram not very rectangular. For this, note that the design allows a certain freedom of gliding between the sides of the cover and that of the back. Forcing the cover to glide in the good direction against the back can correct a minor twist of the box. If this is not enough, the box will have to be reconstructed.

4. End leaking: sunbeams reflected through an end leak out. Check the flatness of the end plate and its verticalness with respect to the back. In particular, check whether the bearing is subject to an unbalanced stress making it to distort the end. If the latter is the case, adjust the chassis to eliminate the unbalanced stress.

5. Joint leaking: leaking appearing from the joining region between the back and the ends. This is due to manufacturing errors of the joints and local stress, and is hard to avoid completely under manual working conditions. If the collector is carefully constructed, this type of leaking only has a limited effect on the optical efficiency.

6. Curvature leaking: leaking due to curvature error of the back. When the collector is in an horizontal position, and the observer moves the observation point from a higher position to a lower position, a leaking from the above first appears, then it disappears only to reappear from the below a bit further. This means that within the middle region where the leaking disappears, the curvature of the reflective surface is too high. One can apply a pressure behind that reagion of the back, with the help of the body redressing mechanism, to eliminate this kind of leak.

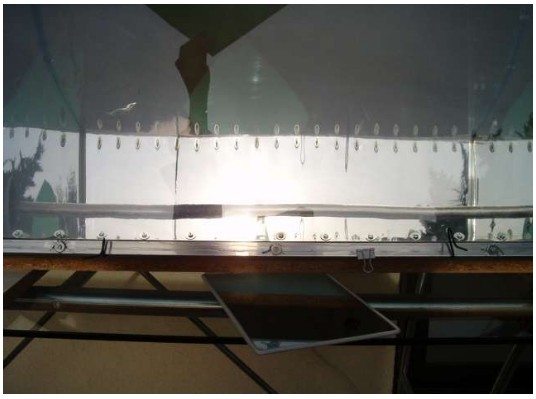
Care must be taken in doing this, for if the leaking appears in the opposite manner, then the curvature of the middle region is too low, and applying pressure behind will only worsen the situation.

7. Edge leaking. The best method to check edge leaking is to use double reflection, as shown below.

Observe the collector from the front of it, near the edge of one side. One can see the reflected image of the receiver, whose background is the blue sky.

Use something to cover the direct sunlight reaching the observing side of the collector, which would interfere with the observation.

For positions difficult to observe directly, a small mirror can be used.



If there is a leak, it will be observed. In the picture at the right, the leak appears from below the image of the receiver, which means that one should add pressure of the edge redressing mechanism, by adjusting the bolts. But what should be adjusted is the redressing mechanism of the other side (here the upper side), but not the observing side!

By the way, the above two pictures show an image of the receiver which is still quite straight and regular near the edge of the collector. This image is an important indicator of the optical quality of the collector, and at the same time a difficult one. The reader can compare this to the large number of published pictures of other parabolic troughs, in order to appreciate the quality of this realisation: the others usually give far worse images.

The field testing of the home made collector used for taking pictures in this articles gives the following result. The testing is done at Nice, France, located at latitude 43.7 degrees, on a sunny winter solstice day. The maximal height of the sun is therefore 22.8°, from which one can estimate the irradiance to be not exceeding 800W. At a concentration ratio of 85.6 times, the maximal heat output of the collector is about 570W, heat losses being reduced to a negligeable level by a fluid temperature close to that of the environment. So the global optical efficiency of the collector is above 70%. As the reflectivity of the mirror surface is measured to be 86%, the transmittance of the cover is 92%, and the absorptivity of the black lacquer is about 95%, the loss due to optical leaking can be estimated to be not exceeding 3-5%, a value that coincides with the field observation of the leaking.

It should be noted that the mirrored plate used to make the back of this collector is of remarkably poorer uniformity than most non-mirrored commercial plastic plates, in terms of inherent local curvature. Most of this lack of uniformity has been successfully compensated by optical adjustments, but a better result can be exected if a more uniform plate is used.

References

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3. Solar equipment suppliers, http://wims.unice.fr/xiao/solar/equipments-en.html