

How to Build the CTI Solar Oven

A Parabolic Trough Solar Concentrator

Overview

This document tells how to build a high-performance, multi-purpose solar oven. It includes:

- Instructions
- Recommended Tools List
- Bill of Materials
- Full Size Template
- Drawings

PHOTO: PARTIALLY BUILT SOLAR OVEN WITHOUT ABSORBER OR REFLECTIVE FILM



PURPOSE OF THIS AND RELATED DOCUMENTS

This is one of several related documents describing parabolic trough solar concentrators. The first, “The CTI Solar Oven,” is an overview of the purposes, design, and usage of these ovens. The second, a collection entitled “How to Build the CTI Solar Oven,” includes instructions, drawings, parts list, etc. The last, a paper entitled “Performance and Design of the CTI Solar Oven,” is a discussion of factors that should be considered when modifying the design of these devices or predicting their performance under various conditions. These are minor revisions of documents originally written in March 2001.

Instructions

All dimensions and other relevant parameters are contained in the drawings, bill of materials, and template at the end of this document. While this is sometimes inconvenient, it allows the instructions to be used for various sized ovens.

Preparation

1. Read the article “The CTI Solar Oven” for background information. If you plan to modify the design, read “Performance and Design of the CTI Solar Oven” before starting.
2. Get the step-by-step instructions (what you are now reading), drawings, and template. These may be reused to build many solar ovens if you are careful with them.
3. Get the tools listed on the Recommended Tools List. These may be borrowed because they will not be needed after construction is complete
4. Get the items listed on the Bill of Materials.
5. Before starting to build, review the instructions while examining the materials and tools to make sure that you understand each step.

Reflector Assembly

1. Find the center of the large sheet of plywood by marking where lines between diagonally opposite corners intersect. Pin the template, Drawing A10, to the sheet of plywood with point “c” exactly over the center mark and the corners of the template, points “a” and “b”, on the corners of the plywood. Push pins through points “c”, “d”, “e”, and “f”.
2. Mark the centers of circles and holes by pushing an awl through the template, into the plywood. Mark the parabolic curves every few centimeters with an awl. Do not mark the narrow parts of the yoke pieces separately where they share a line with the parabolic curves.

3. Remove pins at “d”, “e”, and “f” from the template, rotate it 180 degrees, and pin it to the opposite side of the plywood. Make sure that the points already marked near the center of the plywood (“d” and “e”) line up with points “e” and “d” on the template.
4. Mark the remaining curves and centers of circles with an awl.
5. Remove the template and draw the circles with a compass. Draw lines through the awl holes so the plywood looks like Drawing A11 (without labels and dimensions). Make sure that the dashed line looks different from the others so you do not accidentally cut on it.
6. Cut along the long, solid parabolic curves, using a saber saw or jigsaw. Do NOT cut along the dashed line. This creates two parts “A”, the trough ends.
7. Cut the remaining plywood in half, between parts “B”, the yoke pieces.
8. Cut out each of the four parabolic cleats, parts “C” and “D”.
9. Rough cut the area with the disks from each yoke piece.
10. Drill 3 mm (1/8 in) pilot holes at the center of each disk, hole, and circular curve marked with a “+”.
11. Finish cutting out each yoke piece as shown in Drawing A12. If available, use a fixture to cut the circular curves smoothly.
12. Screw the parabolic cleats to the inside of the trough ends as shown in Drawing A13. Make sure the top of each cleat is exactly on the dashed parabolic line.
13. Position each yoke piece on the outside of a trough end by pushing nails through pilot holes “h” and “i” of the yoke and holes “f” and “g” of the trough end, respectively, as shown in Drawing A14. Screw each yoke piece to the trough end. Remove the nails.
14. Enlarge the pilot hole through each yoke at position “h” and continue right through the trough end at position “f”. The top support bar will go through these pivot points.

15. Cut and drill the aiming sight blocks, parts “G” and “H”, as shown in Drawing A15.
16. Screw the aiming sight blocks to the inside of one of the trough ends as shown in Drawing A13. Use the predrilled holes in the trough end and the pilot holes in the sight blocks.
17. Cut six wooden cross members as shown in Drawing A16. Four are slightly shorter than the other two because they butt up to the parabolic cleats.
18. Butt one of the cross members against the trough end, flush with the dotted line representing the reflector. Drive two screws with washers through the trough end, the parabolic cleat (for four shorter ones only), and into the end of the cross member. Repeat the last step until each of the cross members is attached to one of the trough ends, making sure that the shorter cross members butt against the cleats and the longer cross members butt against the trough end.
19. Now screw each of the cross members to the other trough end.
20. Cut 16 or 20 small cleats to hold the reflector against the larger parabolic cleats.
21. Sand and paint wooden parts.
22. Cut the backing for the reflective film as shown in Drawing A17. It is preferable to make the backing from one large sheet, but two smaller sheets may be used if large enough material is not available. If using two sheets, a gap should be left at the shaded area in the center.
23. Cut reflective film to fit the backing. It should be no larger than the backing, but may be a bit smaller. Two pieces of film may be used, even if the backing is made from one large sheet. It is not necessary to cover the shaded area with reflective film.
24. Carefully clean all foreign material from the backing so it is smooth.
25. Spread a very thin coating of high temperature grease on the entire backing using a spatula or wide putty knife. Spread it as thinly as possible, but make sure every point is covered, especially near the edges.
26. Apply the reflective film over the grease and press it down with a wallpaper roller. Work out all bubbles and wrinkles so that the surface is smooth.
27. Remove any excess grease from the reflector and other parts using a clean, soft cloth and mineral spirits.
28. Lay the reflector backing(s) on the trough frame. If one sheet is used, it should extend from one outermost cross member to the other. If two smaller sheets are used, they should each extend from an outermost cross member to the nearest cross member at the bottom of the trough. There will be an opening between the two sheets, but it will be in the shade of the absorber.





29. Drill and screw the ends of the reflector to the cross members or use cleats to keep it from sliding up or down.
30. Screw small cleats into the trough ends above the reflector to secure it in place.
31. Drill and attach the aiming chain hook to the center of the outermost cross member on the same side as the aiming sight.

Support Assembly

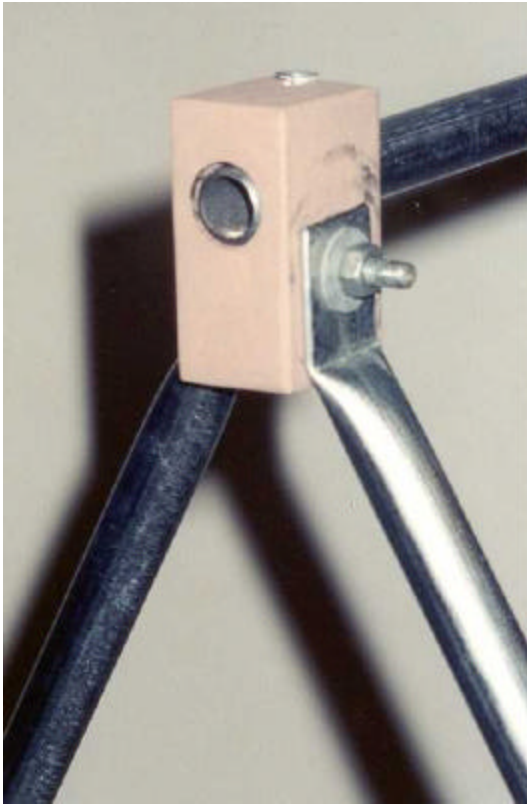
1. Using a hack saw or pipe cutter, cut all nine bars to length as shown in Drawing A18.
2. Flatten and bend the ends of six bars with a vise.
3. Flatten the ends of two more bars. The last bar is not flattened or bent.
4. Drill bolt holes through all flattened ends.
5. Cut and drill hardwood blocks to support the top bar as shown in Drawing A18.
6. Cut eight wheel disks from plywood parts "E", as shown in Drawing A11. These should already be marked and have pilot holes from earlier steps. Use a circle-cutting fixture, if available.
7. Assemble each of four wheels by gluing and screwing two disks together as shown in Drawing A19. Push a nail through the pilot holes to keep them aligned.

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8. Remove the nail and enlarge the axle hole through each wheel.
9. Drill or file two slots in each axle hole, enlarging it enough to allow the wheel to slide over the flattened end of the lower frame bars.
10. Sand and paint the support blocks and wheels.
11. Slide two wheels onto each lower bar. Position them and drill small holes through the bar on each side as shown in Drawing A19. Insert removable nails in the holes to prevent the wheels from sliding.



12. Assemble the support frame using nuts and bolts at each joint and with the top bar through the support blocks.
13. Drill small holes through each top bar support block and top bar. Insert removable nails to hold the top bar in place.



Absorber Assembly

1. Cut three spacers from plywood parts "E" as shown in Drawing A11. Cut the kerf and cut the center out with a jigsaw or saber saw. Sand the inside and outside to eliminate any splinters or roughness. The kerf allows the spacer to compress on the tube when squeezed by the hose clamp.
2. Slide the spacers onto the tube as shown in Drawing A20
3. Cut the clear film to size.
4. Wrap the film around the spacers as tightly as possible, forming a cylinder around the tube. Overlap the edges where they meet and tape them together with a small piece of tape over each spacer.
5. Remove the clear film jacket and slide it over a flat piece of lumber with the overlapped seam up.
6. Using a long straightedge and a razor knife, cut through both overlapping edges. Remove the two long scraps.



7. Tape the long butt joint from one end to the other.
8. Pull the lumber out of the film jacket and slide the jacket back over the tube and spacers.
9. Install a hose clamp around each spacer, tightening just enough to prevent the jacket and spacer from moving.
10. Cut and drill two plugs using Drawing A22 as a template. Plugs should be made from wood that can withstand heat and moisture.
11. Create a beveled edge on each plug that allows the plugs to be inserted into the tube even if it is slightly bent or distorted.
12. Cut and drill two plug caps from plywood parts "F". Use Drawing A23 as a template.
13. Cut and drill parts for one crank arm and handle from hardwood. Use Drawing A24 as a template.
14. Assemble one end plug using a plug, plug cap, carriage bolt, and two pegs as shown in Drawing A21.
15. Attach the two pegs to each end cap by drilling small holes in the pegs and end caps and tying them with a short nylon cord.
16. Assemble the other plug with the same items, plus the crank arm.
17. Assemble the crank handle.
18. Insert each plug into the tube. Drill two small holes near the end of the tube and into the edge of the plug. Insert removable nails.

Peanut Loader - Agitator

1. Mark the centers of six disks on sheet metal, as shown in drawing A26. Mark the circumferences with a compass.
2. Cut out the disks and make the radial cut with a tin snips.
3. Drill the center holes.
4. Bend four of the disks 90 degrees along the dashed line as shown in the drawing, forming a pie shaped tab. Bend tabs on the other two disks the opposite direction.
5. Cut the paddle as shown in Drawing A27.
6. Assemble the disks on the rod with nuts and washers as shown in Drawing A25. The two center loading disks should not rotate, but the loading disks and dampers on the ends should be able to turn with hand pressure.
7. Drill and rivet the paddle onto the four loading disks.
8. Cut, drill, and sand hardwood knobs for the ends of the rod as shown in Drawing A27.
9. Twist the knobs onto the rod ends, cutting threads in the wood.

Optional Tube Adaptor Plate

1. Cut two adaptor plates from plywood as shown in Drawing A28. Adapt the dimensions to the desired tube diameter. The center of the tube must be centered on a line between the two side mounting holes.
2. Drill three mounting holes through the adaptor plates to match the mounting holes on the yoke pieces.
3. Sand and paint the plates.
4. Attach the adaptor plates to the yoke pieces with nuts, bolts, and washers.

Overall Assembly

1. Pull nails and remove top bar from support frame.
2. Insert top bar through its holes in the reflector assembly.
3. Lift reflector assembly and reinstall top bar on support frame. Reinsert nails.

4. Attach aiming chain to one lower support bar and feed it under the other one. Attach the free end to the hook on the reflector frame.
5. Place absorber assembly in yoke.
6. Insert loader/agitator into tube.
7. Install plug(s) and crank on tube.
8. Install wire cross braces on reflector if needed for stability.
9. Install wire cross braces on support frame if needed for stability.

Inspection

1. Is any part split, bent, or damaged?
2. Are all screws and nails secure?
3. Are any sharp edges exposed?
4. Is the support frame sturdy?
5. Do the wheels turn properly?
6. Is the reflector assembly rigid?
7. Does the reflector rotate to any elevation without obstruction?
8. Does the reflector stay secure and parabolic at all elevation angles?
9. Does the aiming chain hold securely?
10. Is the reflective film smooth and stuck down everywhere?
11. Is the jacket smooth and secure?
12. Do the end plugs fit the tube snugly?
13. Does the tube rotate smoothly in the yoke?
14. Does the loader/agitator slide in and out easily?
15. Do the loader disks fit tightly enough inside the tube?
16. Does the agitator paddle fit tightly enough against the tube?
17. Does the sun reflect onto the center of the tube when the aiming sight pattern is correct?
18. Is the light pattern on the tube uniform from one end to the other?
19. Does a laser beam parallel to the axis reflect to the tube from all locations above the reflector?
20. Does the tube reach 200 degrees Celsius (400°F) in average sunlight?

Recommended Tools List

Template for plywood parts	
Push pins	
Awl	
Compass	
Jigsaw or saber saw	
Router with circle fixture	Optional
Crosscut saw	
Table saw or radial arm saw	Optional
Hand drill, bits	
Drill press	Optional
Sand paper	
Power sander	Optional
Paintbrush, thinner, etc.	
Screwdriver	
Straightedge (1.25 m)	
Razor knife	
Spatula or wide putty knife	
Wallpaper roller	
Hacksaw	
Pipe cutter	Optional
Vise	
Wrenches	
Tin snips	
Pop riveter	

Bill of Materials

Qty	Component	Qty	Material
1	Roaster tube	1	5" diam. galv. vent duct - 60"
1	Roaster tube paint	0.5	12 oz. spray can flat black grill paint
1	Roaster crank arm and handle	1	Hardwood 1"x1" – 16"
1	Roaster crank handle	1	5/16"x6" galv nut, bolt, washers
3	Jacket spacers	3	scrap 3/4" plywood - 7" diam
1	Jacket film	1	4 mil clear polyester film - 22" x 48"
1	Jacket tape	1	60" length of 1" polyester tape
3	Jacket clamps	3	Stainless steel hose clamps - 4"-7"
2	End plugs	2	3/4" hardwood, 5" diameter
2	End plug caps	2	3/4" plywood, 8" diameter
1	Agitator rod	1	3/8" threaded rod - 6'
6	Agitator disks	1	galv sheet metal - 6" x 36"
12	Agitator nuts & washers	12	galv. 3/8" nuts & washers
1	Paddle	0.5	galv. roof edge flashing - 10'
8	Rivets	0.1	box 1/8" x 1/8" steel pop rivets
2	Agitator knobs	2	2" x 2" x 2" hardwood
1	Loading trough	1	galv sheet - 12" x 16"
1	Loading trough clamp	1	Stainless steel hose clamp - 4"-7"
1	Thermometer	1	Ekco oven thermometer
2	Reflector film	2	1 mil reflective polyester film - 48" x 48"
1	Reflector backing	1	galv sheet metal 4' x 9'
1	Reflector adhesive	0.2	14 oz high temp grease
6	Cross bars	3	2x2s - 8', pressure treated
8	Parabolic cleats	0.25	3/4" plywood - 4'x8' BC exterior
2	Parabolic sides	1	3/4" plywood - 4'x8' BC exterior
2	Yokes	2	3/4" plywood - 1' x 3' each
2	Trough cross braces	4	1/4"x4" eye bolts, scrap wire
2	Aiming blocks	2	3/4" hardwood - 2" x 3"
6 doz	Wood screws	1	lb misc wood screws
1	Plywood sealer	1	quart exterior enamel
9	Frame bars	5	10 foot conduit (3/4" EMT)
4	Frame joints	4	5/16 galv bolts & nuts: 2 @ 2", 4 @ 1"
2	Top bar joints	2	Hardwood 1.5" x 1.5" x 3"
2	Frame cross braces	2	8' wire plus 1/4"x4" eye bolt
4	Wheels	8	3/4" plywood, 7" diam
1	Elevation chain	1	15' #3 INCO double loop chain
1	Elevation chain hooks	1	Small screw eye or bolt eye
10	Cotter pins or equiv	10	1.25" galv roofing nails

Full Size Template

A full sized template, referenced by the preceding Instructions, is a necessary part of this document.

-00 Plywood Template

Drawings

The following drawings, referenced by the preceding Instructions, are necessary parts of this document.

-01 Plywood Parts Layout
-02 Yokes
-03 Trough Ends (Inside)
-04 Trough Ends (Outside)
-05 Sight Blocks
-06 Trough Cross Members
-07 Reflector
-08 Support Frame
-09 Wheels
-10 Jacket and Spacers
-11 End Plugs
-11A Plug Template
-11B Plug Cap Template
-11C Crank Arm Template
-12 Loader-Agitator Assembly
-12A Loading Disks and Dampers
-12B Knobs and Paddle
-13 Tube Adaptor Plates

Acknowledgement

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