

# Prefabricatable Oven Final Report Fall 2011

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Alex  
Chilly  
Ha  
Han  
Jocie  
Joon  
Sarah

## Intro

Las Mujeres Solares de Totogalpa have expressed interest in designing a cooker that can be prefabricated and easily shipped to new locations as their business expands. Dr. Richard Komp PhD, Director of Skyheat Associates, a long time advisor and cooperater with Las Mujeres ... and Frupo Fenix, described an instance in Peru when people who constructed ovens could not transport the ovens to their homes due to the unwieldiness of carrying a large, heavy oven up a mountain on a llama.

*A very happy llama :*



The goal of our group this semester was to design, construct, and test a box cooker that can easily be shipped, manufactured, and transported. The idea was to create a new design that would be lighter - by replacing the wood and other heavy materials, with lighter alternatives. The new design also would make the actual manufacturing of the solar cooker into an easy process. One of the ways we hoped to make the cooker easier to ship and transport was to make it out of prefabricated parts. Of course, to design and create a solar oven that is easily transportable and assembled, we attempted to reduce the overall mass of the solar oven.

## Procedure/Timeline

We began the semester by researching materials for the prefabricated solar cooker. We looked specifically for materials that were light weight, but still durable and able to withstand the high temperatures inside the box cooker. The team took four weeks to research the materials. Designing the prefabricated solar cooker was the second step. The solar cooker was designed keeping in mind the goal that it must be easily shipped and transported in smaller section. This began two weeks after the team began to research materials and took two weeks. The third step was the construction of the prototype. Once the materials were selected and a preliminary design was created, the team acquired the required materials and began construction of the solar cooker. This step took five weeks. The final step was to write the final report on the work accomplished by the team during the semester.

Week of	10/3	10/10	10/17	10/24	10/31	11/7	11/14	11/21	11/28	12/5	12/12
	Research Materials										
			Design								
					Construction of Prototype						
										Write Final Report	

### Evaluation/Conclusion

The team gained many skills during the construction of solar cooker. We took into consideration a lot of the same concepts that the past cookers had in order to move forward with our cooker. There were a few difficulties when we began to construct our cooker, such as: trouble with the standard dimensions of wood (US construction wood is typically called out as 2"x 4", though it is actually 1 1/2" by 3 1/2" in dimension), specifics in the types of material we would need, and a few logistical details of the cooker. However, throughout our whole process, we kept in mind our main goals: lightweight and prefabricated cooker. There are still a few kinks that need to be worked out from our original design, but now that the team has nearly completed a prototype, we have a better idea of the process of building a cooker, it will be easier to fix on the second cooker constructed.

### Future Work

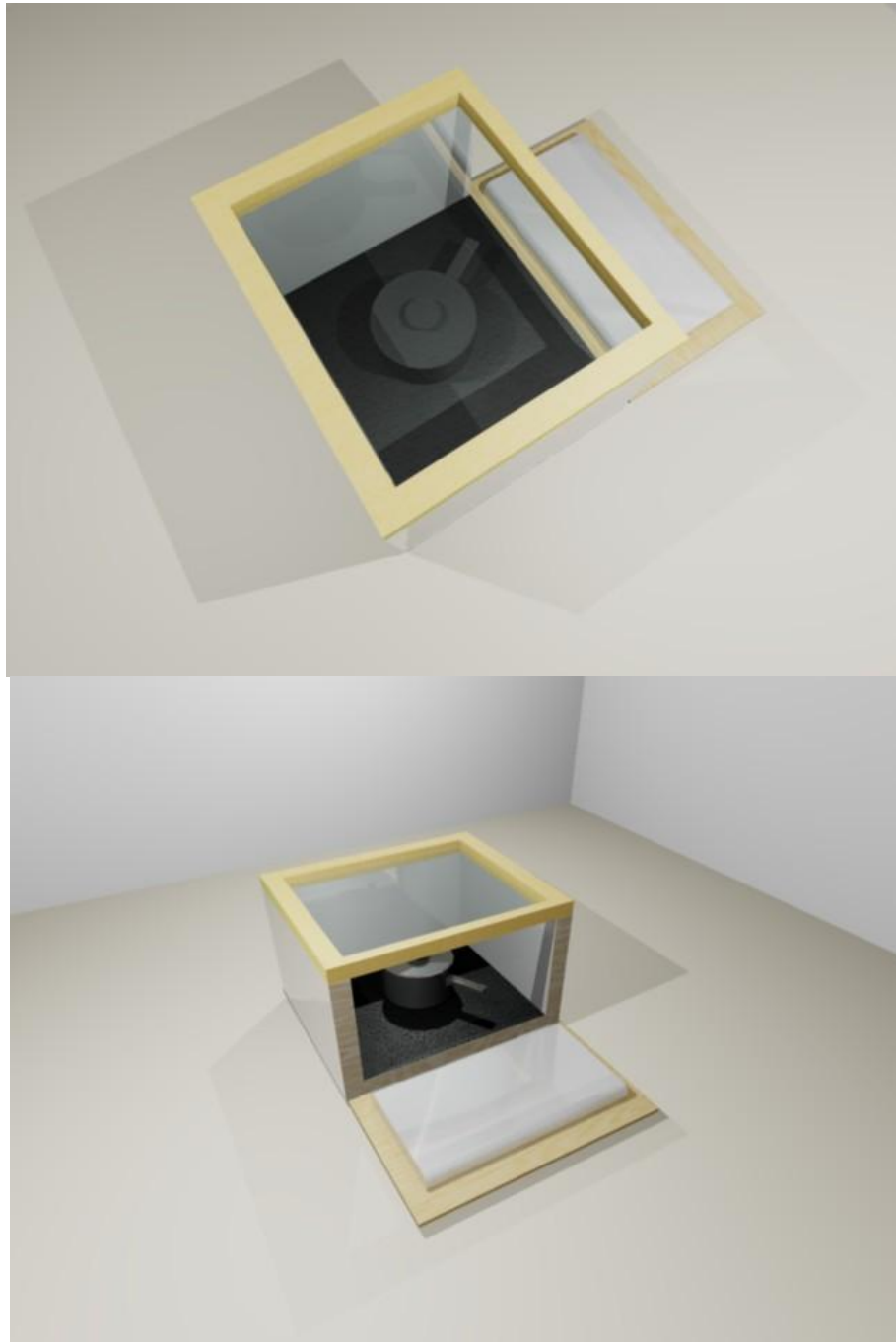
Now that the prototype has been built and all the members have a feel for how solar ovens are designed and this solar oven is constructed, the team will be focused on improving the solar cooker. We would like to use other insulating materials than fiberglass. There are other good insulation materials with high R-values, such as isocyanurate, polystyrene, cellulose, and cardboard. All of which are obtainable. Prefabrication team will work with the insulating testing team in order to pick out the better insulation material for use.

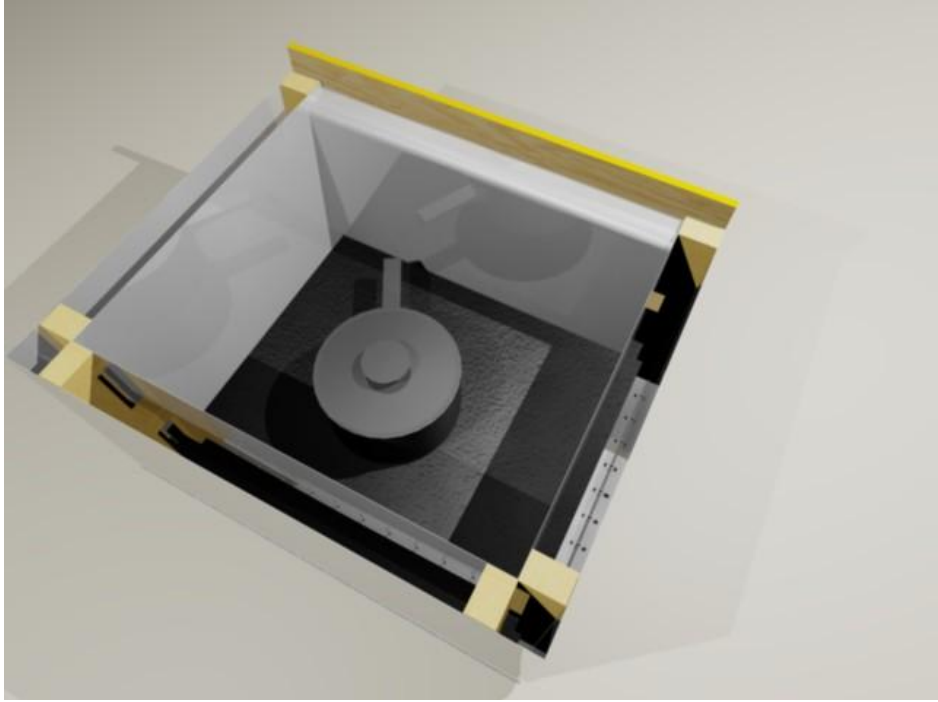
Pyranometer testing will be conducted on alternative transparent sheet plastics in order to choose the best material for the transmission of light to replace glass in the oven. We will use a LabVIEW program controlling a data acquisition system for measuring the quality of light transmission by various materials into the oven. Glass for the windows of the cooker is heavy, fragile and costly. A plastic sheet replacement for the glass would aid in reducing the weight of the cookers. Glass and polymers will be the materials in main focus. We hope to find a polymer material that would be more lightweight and as transparent as glass.

There will be a drastic move towards reducing the weight of the oven while keeping the working volume of the oven large enough to allow cooking with standard pots. Ovens are getting smaller and smaller and we would like to keep doing that until it is possible to carry even two ovens at once.

We hope to assemble another solar oven that is prefabricatable and shippable before spring break to take to Nicaragua during our spring break and present to the women. After a discussion with the women, we would like to finalize our design and fabricate an oven with all the features that the women prefer while in Nicaragua.

### 3D autocad views of Prefabricatable Oven





## Appendix

# Prefabricatable Oven Construction Manual

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## Materials

The materials consist of the following:

### Sheet Metal

Part Name	Material	Quantity	Size (inches)
Outer Box Back Panel	26 Gauge Metal	1	30 x 16.25
Outer Box Bottom Panel	26 Gauge Metal	1	30 x 25
Outer Box Side Panel	26 Gauge Metal	2	25 x 16.25
Inner Box Back Panel	26 Gauge Metal	1	25 x 12.5
Inner Box Bottom Panel	26 Gauge Metal	1	27 x 23.5
Inner Box Side Panel	26 Gauge Metal	2	22.5 x 12.5

### Wood

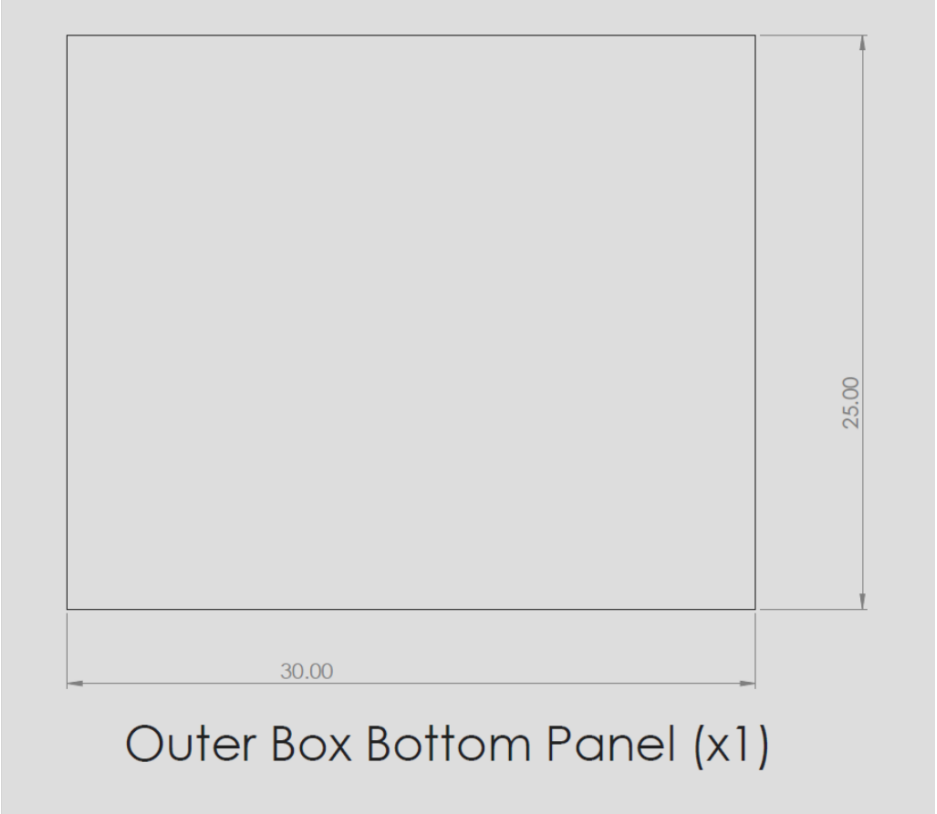
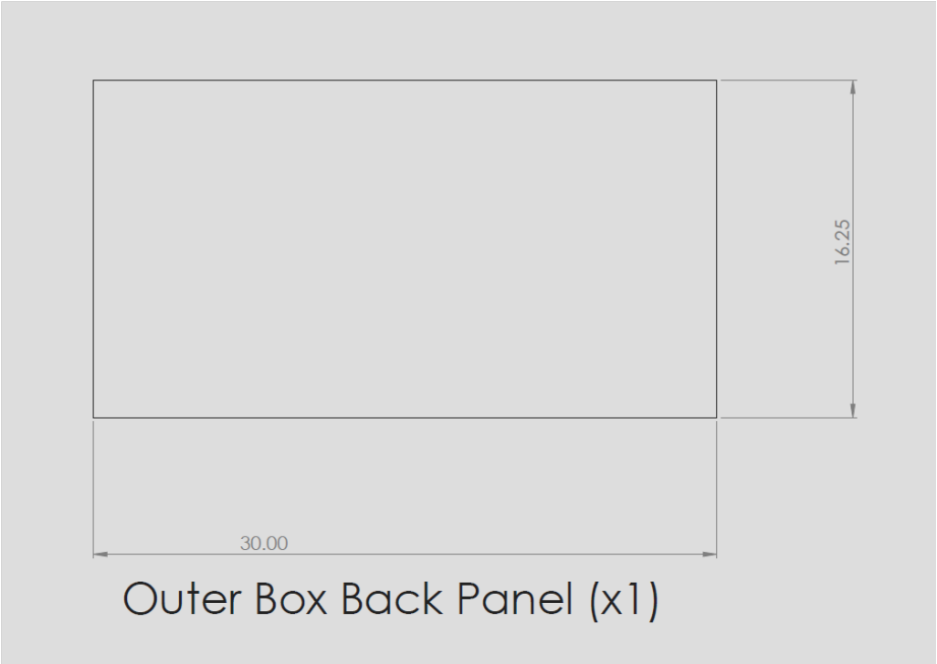
Part Name	Material	Quantity	Size (inches)
Door Bar- main	Wood	1	27 x 2.5 x 1.5
Glass Frame- main	Wood	4	25 x 2 x 1.5
Glass Frame- added depth	Wood	8	25 x 2 x 0.5
Base Blocks	Wood	5	2.5 x 1 x 1
Columns	Wood	6	14.5 x 1.5 x 1.5
Column Blocks	Wood	12	1.225 x 0.8 x 0.8

### Hinges

Part Name	Quantity	Size (inches)
Door Hinges	2	3-1/2
Outer Box Rear Piano Hinge	1	30
Outer Box Side Piano Hinge	2	25
Inner Box Rear Piano Hinge	1	25
Inner Box Side Piano Hinge	2	22.5

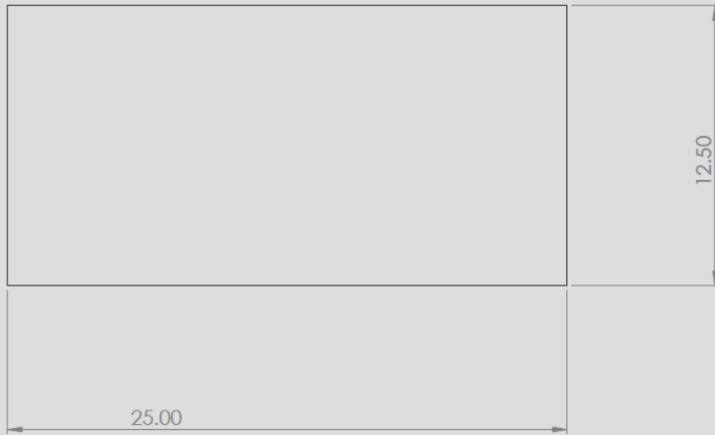
**Diagrams of Materials**

*Sheet Metal*

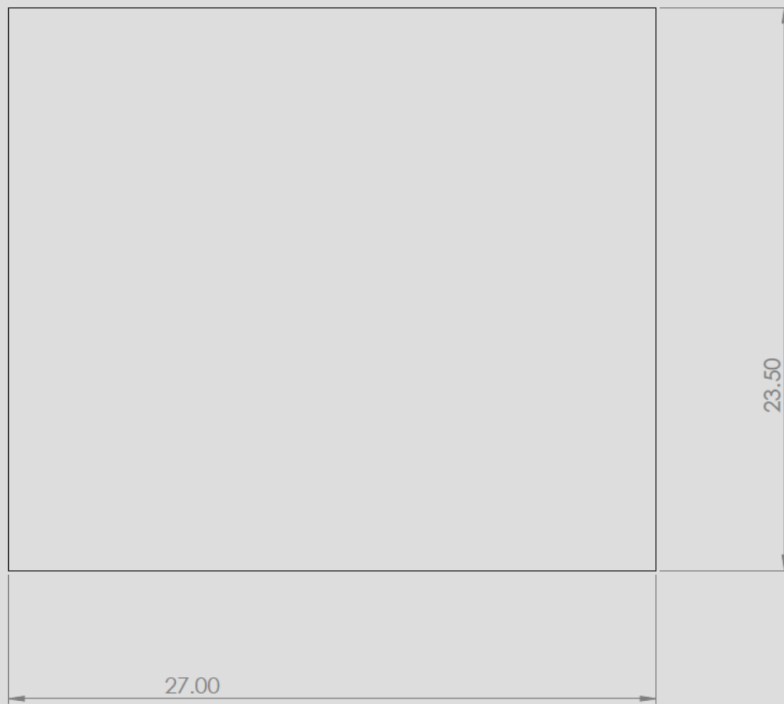




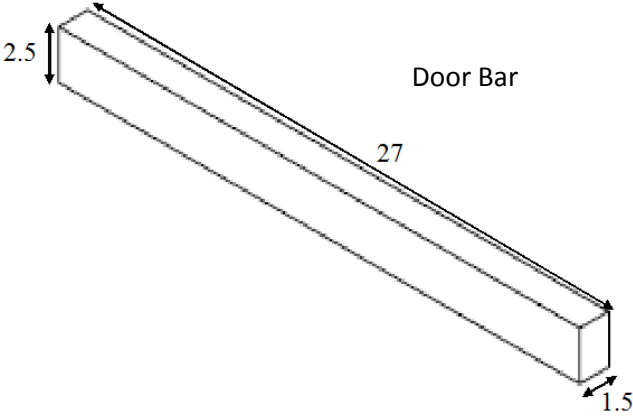
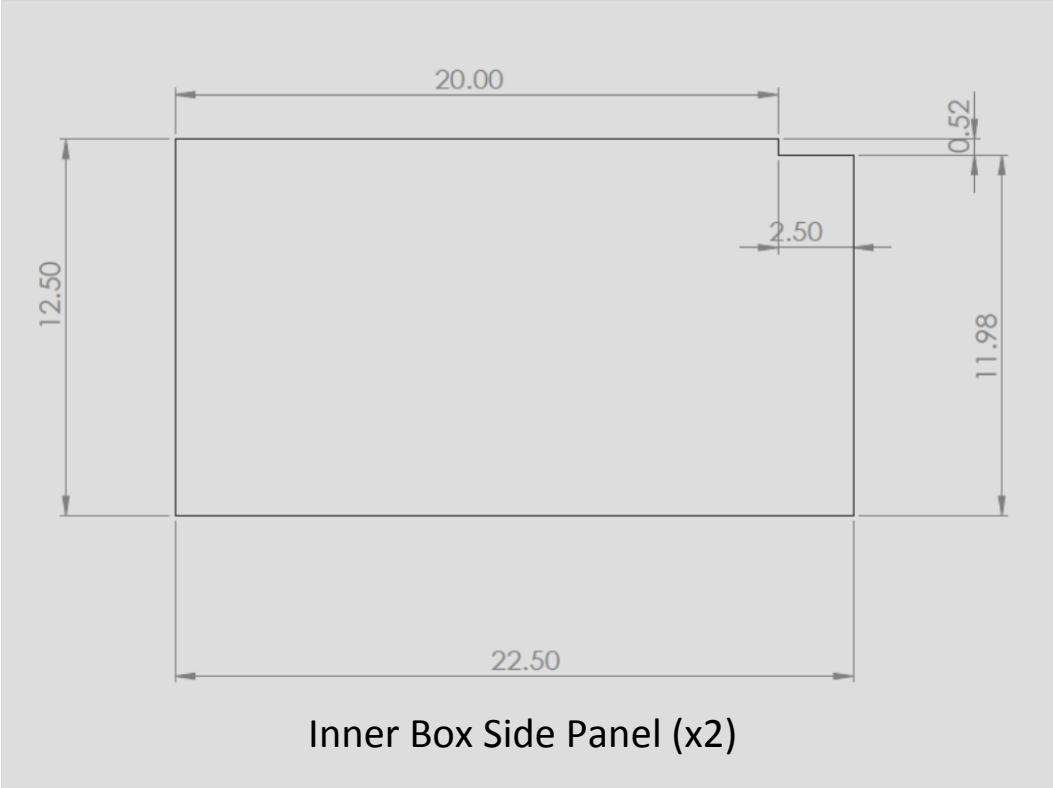




Inner Box Back Panel (x1)

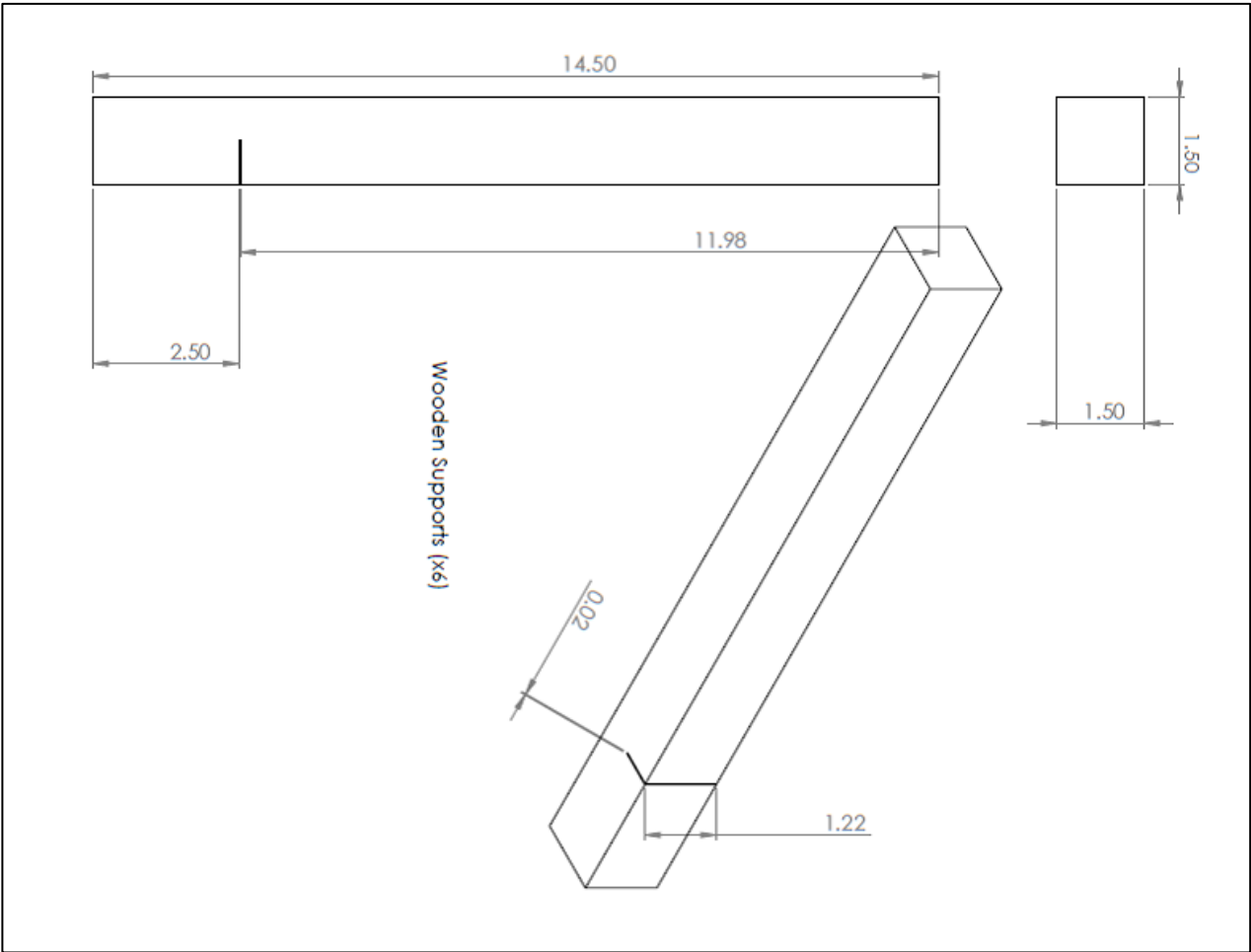


Inner Box Bottom Panel (x1)



## Construct the Wooden Column Supports

The 6 columns to support the inner box were made of wood cut down to the following dimensions:

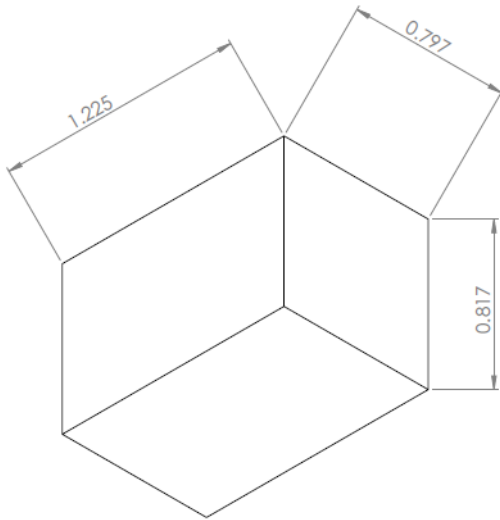


Since a beam that is 1.5" x 1.5" isn't available as a standard size, we created the above part by cutting down a 2" x 2" into 6 pieces that are 14.5" long and sliced off any excess to the width of the columns.

The notches in which the inner box would slide into were made by using a saw to create a slit as shown in the diagram above.

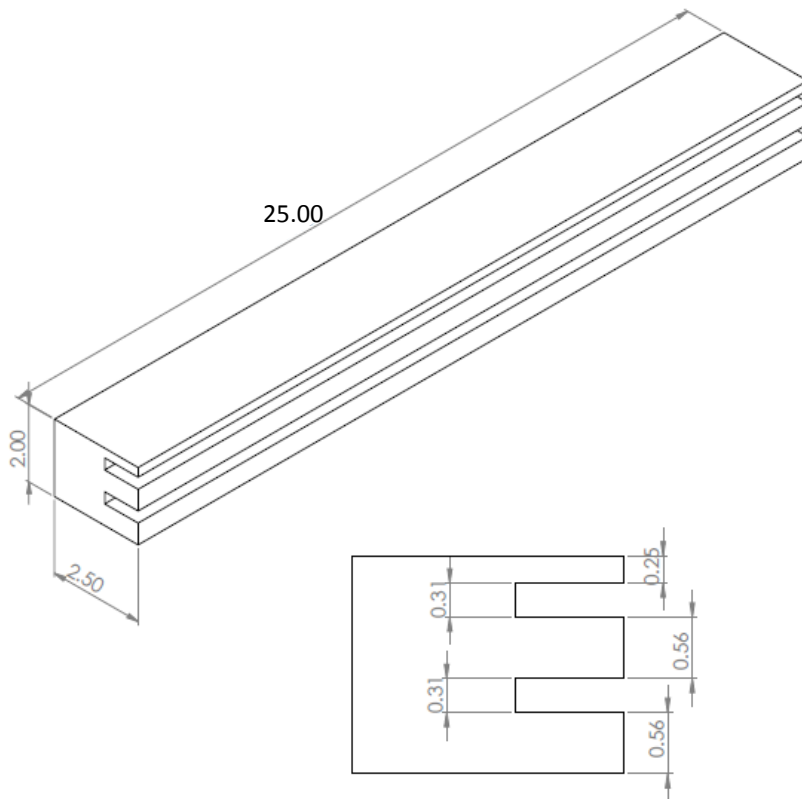
To create a space for the inner box walls to attach to the wooden columns, we had to attach two intermediary column blocks (seen in the figure below) to the top and middle of the columns.

## Column Blocks

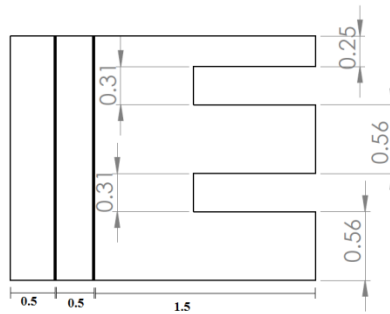


## Construct the Glass Frame

The glass frame was made of 4 identical beams with the following dimensions:



Since a beam with 2.50" thickness was not available, we created the above part by gluing together two 0.5 x 2 x 25" and one 1.5 x 2 x 25" bars, as shown below:



The following steps should occur to attach the glass frame to the oven (these steps are based on "Grupo Fenix Manual - CJ Colovito - 4/2009"):

- 1) Flip the base right side up so that the columns are on top
- 2) Lay a side-piece of the glass frame across the two columns on the side. It is important for the front of the cooker to be a flat plane surface so that you can make a good seal to it with the door.



Figure 1: Lay a side-piece of the glass frame across the two columns on the side

- 3) Spread glue on top of the side-front and side-rear columns where you will attach the first side glass rule.
- 4) Screw the side glass frame to the columns
  - (a) Drive in a 3" screw through the side rule and into the center of the front column. Make sure that the screw is not interfering with the glass channel.
  - (b) Drive 2 screws into the rear column.



Figure 2: Left- One 3" screw is used to attach the side of the frame to the front column. Right- Two 3" screws are used to attach the side of the frame to the rear column

- 5) Repeat steps 2-4 for the other side
- 6) Attach the rear glass frame piece
  - (a) Test fit the rear glass frame piece by laying it across the two rear columns. Use a carpenter's square to verify that the two rear corners of the glass frame are square. It is important that they are at least close to 90° angles so that the glass fits correctly.
  - (b) Remove the rear glass frame piece and spread glue over the area of the two rear columns that are exposed
  - (c) Lay the rear glass piece across the two columns
  - (d) Verify that the channels are lined up correctly in both corners. It is very important for the channels to line up properly or the glass won't fit.
  - (e) Put one 3" screw in on one end of the rule.
  - (f) Check the alignment of the glass channels in each corner again. Test the fit with one of the sheets of glass by carefully sliding it into the channels from the front of the cooker.
- 7) Repeat Step 6 for the front glass frame piece.

### Construct the Outer Box

- 1) Using the piano hinges as a guide, mark and drill holes along the back and side edges of the outer box bottom plate.
- 2) Again, using the piano hinges as a guide, mark and drill holes along the bottom edges of the side and back sheet metals.
- 3) Using rivets, attach the walls of the outer box to the hinges and attach that assembly to the bottom plate.

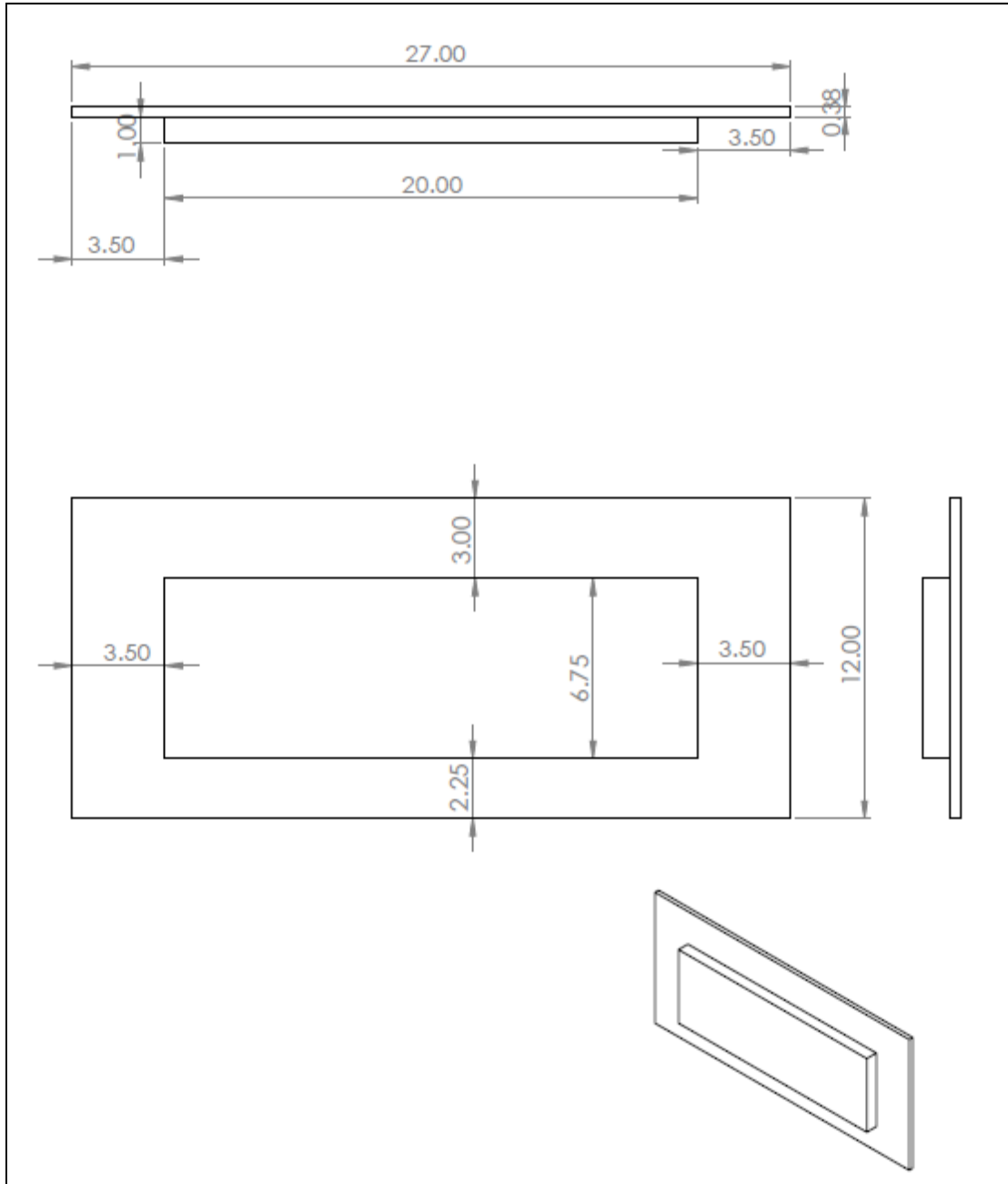
### Construct the Inner Box

- 1) Using the piano hinges as a guide, as well as marking out where the piano hinges should go, drill holes as necessary on the inner box walls and the bottom plate (NOTE: The walls of the inner box should NOT line up on the edge of the bottom panel of the base plate of the inner box)
- 2) Use rivets to attach the walls to the hinges and the hinges to the base plate.
- 3) Slide in the 6 columns
  - 2 per each side (left, right, and back)

- 4) Mark where screws should go based on the column blocks that touch the outside of the inner walls.
- 5) Drill holes where you marked in step 4 and screw in screws.
- 6) Measure out a length of 2x4 piece of wood and cut out a length of 27 inches. Trim down the size of the bar to 1.5 x 2.5. This will be the door bar on which the door hinges will be attached.
- 7) Drill holes and screw in the door bar to the front of the inner box.

## Construct the Door

The door had the following schematic and dimensions:



The following steps should occur to construct the door (these steps are based on "Grupo Fenix Manual - CJ Colovito - 4/2009"):

1) Measure the correct size and cut out the door.

(a) Measure the front of the cooker frame, height and width.

(b) Subtract  $\frac{1}{4}$ " from the height and ADD  $\frac{1}{4}$ " to the width and cut a piece of  $\frac{1}{2}$ " thick plywood to these dimensions. (if the door is too tall it will interfere with the reflector when it is closed; we add  $\frac{1}{4}$ " to the width to allow for a little extra room so we can make sure the door is flush with both sides of the cooker when it is attached. We need it to be flush with both sides so that the latches will work correctly.)

2) Make the inner door box

(a) Place the plywood door over the front of the cooker and make sure it is centered from side to side and flush with the bottom of the cooker.

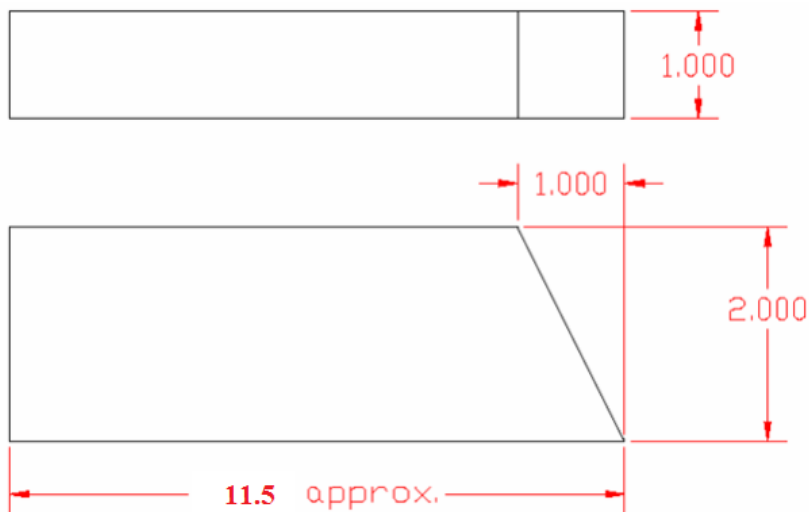
(b) Carefully trace the opening of the door way on to the plywood. Use an arrow to mark which side is the top.

(c) Measure the height of the door opening on the cooker frame, it should be about 12"

(d) Cut 3 wood support blocks out of wood that is 1" thick by 2" wide. The height of each support block should be equal to the height of the door opening minus  $\frac{1}{2}$ ".

(about 11-1/2")

(i) Cut each block into a trapezoid shape as indicated in the drawing below.



(ii) **Make sure all three are exactly the same height.**

(e) Place the three wood support blocks onto the plywood door inside the trace of the door opening. Put one just inside each side line (about  $\frac{1}{8}$ " in from the edge) and one in the middle. Center all of them from top to bottom. **Make sure the angled side is pointed at the top of the door.**

(f) Trace each wood support block in its place and remove them as shown below





(g) Measure and mark  $1\frac{1}{2}$ " down from the top of each traced rectangle of the wood support blocks and  $\frac{1}{2}$ " up from the bottom of each one. Make your marks in the center of each rectangle from side to side.

(h) Drill a  $\frac{1}{8}$ " hole at each mark to indicate where the screws will go as shown below.



(i) Glue each wood support block into its place over the traced outline. Let them dry for 10-15 minutes.

(j) Flip the plywood door over carefully and drive two  $1\frac{1}{2}$ " screws into each wood support block from the front of the plywood door, using the holes previously drilled. Be careful not to shift or move any of the wood support blocks, they must be in their exact places or the door won't fit properly.



(k) Test fit the door on the cooker. If there is a problem, you can fix it by using a planer to shave own wood, or reposition the problematic wood support blocks.

(l) Measure the width from the outside edge of the left most block to the outside edge of the right most block.

- (m) Cut a piece of fiber board for the bottom of the inner door box that is  $\frac{1}{4}$ " less than the width measured by  $1\frac{7}{8}$ " high.
- (n) Nail the bottom of the inner door box to the flat side of wood support blocks using 1" nails. drive two nails into each block, one at the middle and one at the base of each block. You will need to leave space at the top for another nail later on.
- (o) Cut another piece of fiber board to the same with as the previous piece and a height of  $2\frac{1}{8}$ ".
- (p) Nail the top of the inner door box to the wood support blocks. Drive two nails into each block, one at the middle and one at the base of each block. Again, you will need to leave space at the top for another nail later on.
- (q) Test fit the door onto the cooker again and make adjustments as necessary.
- (r) Use the silicon gun to place a small bead of silicon around the inside perimeter of the inner door box. This will seal the box, helping it to insulate.
- (s) Cut a piece of printing plate sheet metal to the same length as the two fiber board pieces and a width equal to the size of the opening on the front of the inner door box plus  $1\frac{1}{4}$ ".
- (t) Lay the metal onto the front of the inner door box and make sure it is straight and centered. Bend the edges over both sides where there is fiber board, making a crease at the four corners of the box.
- (u) Take the sheet metal off and use the creases as a guide to fold it over the edge of the table to 90°.
- (v) Test fit the printing plate metal again to make sure it is straight and fits properly.
- (w) Remove the metal and fill the door box with insulation
- (x) Place a small bead of silicon around the perimeter of the opening in the inner door box
- (y) Place the printing plate metal over the opening and nail it into place with 1" nails. Use 3 nails across the front of each wood block and one nail in each side.



### 3) Attach the door hinges.

- (a) Measure and mark 6" in from each side of the door on the same side as the inner door box.
- (b) Place two 3" hinges on the door so that they are both just inside the marks.
- (c) Trace the hinges in place

- (d) Use a chisel to cut out the rectangular area of the traced hinge. Cut it 1/16" deep, the thickness of the hinge.
- (e) Screw each hinge into its recessed area with 1/2" screws, 3 for each hinge. If there are no 1/2" screws available use the shortest screw you can find and cut off the point that protrudes through the front of the door with a hacksaw.
- (f) File down the points of the 6 screws that poke through the other side of the door with a metal file.



Figure 3: Left- Trace the door hinge in place. Right- use a chisel to cut out a recessed area for the door hinge.

#### 4) Attach the door to the cooker

- (a) Lay the cooker on its back side so that the door opening is facing upward.
- (b) Fit the door into the front opening making sure that it is centered from side to side and flush with the bottom of the cooker.
- (c) Screw in the hinges.
  - (1) Make sure the hinges lay over the bottom side of the cooker.
  - (2) Use a nail to puncture the sheet metal in the center hole of the hinge and then drive in a 1 1/2" screw. There should be 3 screws for each hinge.
  - (3) Screw in only the middle screw on each hinge first, and then check the door to make sure it opens and closes properly.
  - (4) Test the door fit by closing and opening it.
  - (5) Add the last two screws to each hinge.
    - (a) Make sure that the door is flush with both sides of the cooker because it has to be flat to attach the latches properly. If the door is too big on one side you can use the planer or file or sand paper to flatten the door down to the width of the cooker. Remember we made the door 1/4" larger than the cooker to allow for room to plane here. If the door is too small on one side you may need to add some material to the side to make it flat for the latches. A strip of fiber board or cardboard works well.

(b) Check that the door fits again, if the door extends past the height of the front glass piece you will need to use a planer to plane it down. Otherwise, it will interfere with the reflector. The door should be about 1/8" below the top of the front glass piece.

5) Attach the sheet metal to the front of the door

(a) Cut a piece of sheet metal to perfectly match the size of your door after you have attached the door to the cooker and made any needed adjustments with the planer/file.

(i) Round off the corners of the metal piece before screwing it to the door, cut a very small curve into the corner to take off the sharp point using the tin snips

(b) Place the sheet metal over the door, be careful to center it and leave no sharp edges hanging off.



Figure 4: Left- Screw in the hinges on the bottom side of the cooker. Right- Attach the sheet metal to the front of the door using 1/4" or 1/2" screws or nails

(c) Use 1/4" or 1/2" screws across the top and bottom, spaced 5" apart. On the sides only 3 screws are needed, at the top middle and bottom. Use a hammer and a nail to puncture the metal before driving in the screws.

(1) As you are adding screws make sure to maintain the sheet metal flat and start at one end of the door adding screws to both the top and bottom sides equally working your way towards the other edge. This will prevent bubbles in the sheet metal.

(2) If no 1/4" or 1/2" screws are available you can cut 1" nails down to size and use them.

These nails will be very short and you will need to use some needle nose pliers to hold the nail while driving it in.

(d) Use a hammer and bend over any part of the sheet metal on the door that is hanging over the edge.