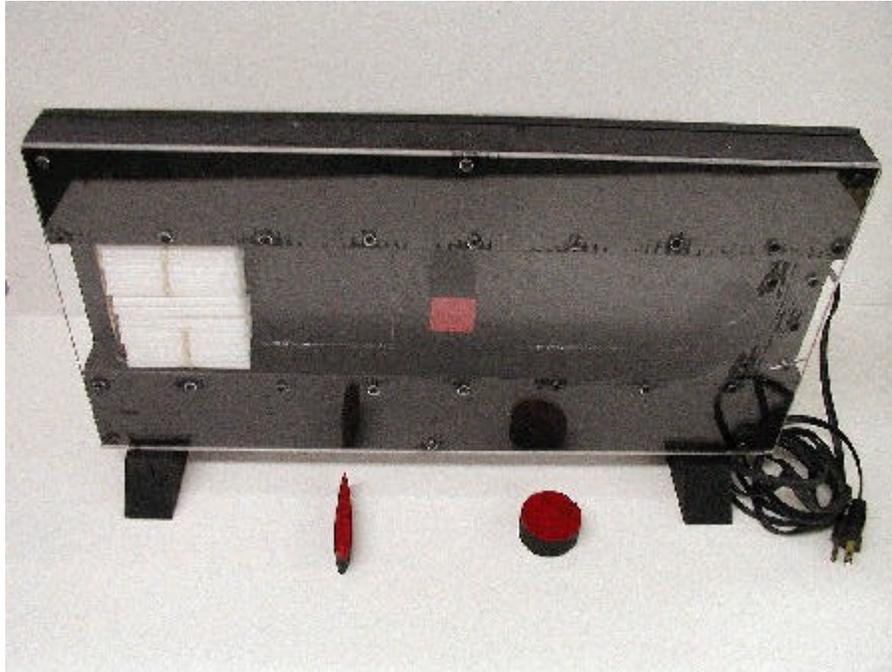


NASA GLENN RESEARCH CENTER**“LITTLE SMOKIE” WIND TUNNEL PROJECT**

The purpose of this project is to give educators and students a cost-effective means to demonstrate airflow over different objects using a simple type of wind tunnel called a “



The information is found in four sections:

1. Material list (all Items needed to construct the smoke tunnel)
2. Tool list (an optional list of tools required to construct the project)
3. Written Instructions (Construction and Assembly)
4. Schematics of the Assembly.

NOTE: Some items listed can be replaced with more expensive items if desired. The object of this project was to keep the expense and the construction to a minimum. If different objects are available, they can be substituted for the listed items. This will be the decision of those participating in the assembly of the project.

NASA takes no responsibility for any resulting action from assembling this project.

Section I

REQUIRED MATERIAL LIST

Quantity	Item Description
1	2" x 4" x 6' construction grade wood
1	12" x 24 3/8" piece of plywood
1	6" x 6 3/4" piece of plywood
1	12" x 24 1/4" piece of clear Plexiglas
1	4" cooling fan, 110n volt AC (used for cooling electrical devices)
1 box	Restaurant straws (9" height, 200 count)
1*	Glue (model glue, hot glue, or Silicon Sealant)*
1 quart	Black Paint
1 box	1" Drywall screws
5	2" wood screws (Philips head)
4	3" wood screws (Philips head)
1	3' piece of 1/2' CPVC plastic pipe (5/8" outside diameter)
1	1/2' CPVC elbow (90 degree angle)
1	4" piece of 3/4" pvc pipe (1" outside diameter)
2	4" piece of 1/4" dowel rod
1 box	Incense (cone shaped)
1	Small can (metal bottom and plastic top)
1	12" piece of 1/4" plastic pipe (3/8" outside diameter)
1	Plastic VCR tape case
1	12" x 12" piece of aluminum foil
1	6" x 6" piece of window screen
1	Package of craft sticks or wooden stick matches

*Silicon Sealant may be used in place of Glue in instructions

Section II

REQUIRED TOOL LIST

The list below contains suggestions for tools needed to complete the project. When properly handled, any manner of power tools or specialty tools may be used to construct the project.

HANDBSAW

HAND DRILL

WOOD BIT SET

DRILL BIT SET

MEASURING TAPE

MARKING PENCIL

RAZOR KNIFE

SANDPAPER

PHILIP SCREWDRIVER

PAINTBRUSH

BLACK MARKER

Section III

ASSEMBLY INSTRUCTIONS

NOTE: Before proceeding with any assembly, lay out all of the pieces of the project in preparation.

LAYOUT



NOTE: You will purchase your plastic pipes based on the Inside Diameter (ID) (Ex. 1/2" ID plastic pipe), but you will be drilling based on the Outside Diameter (OD) (Ex. 5/8" OD, which may vary). So if there is any uncertainty, MEASURE before drilling a hole.

Step 1: Lay out the 3/8" plywood. This will become the backing plate of the wind tunnel.

Step 2: Cut two lengths of the 2" x 4" construction grade wood at 24" lengths. These will become the top and bottom rails for the tunnel. Mark one of them as the top rail and mark the other as the bottom rail. (See Fig. 1)



Fig. 1 (Top Rail, Bottom Rail, Backing Plate, Air Funnel)

Step 3: Cut one piece of the 2" x 4" construction grade wood to measure 5" in length. This piece should fit between the top rail and bottom rail (the cut ends should touch the top and bottom rail). This is the air funnel.

Step 4: Locate the center of the 5" air funnel (side to side and top to bottom), mark the center point, and drill a 1" hole through the center point. Put the air funnel back into the tunnel assembly. (See Fig. 2)



Fig. 3

Fig. 2 Air Funnel

Step 4a: Line up the right side of the air funnel with the edge of the plywood, making sure that the top and bottom are touching the top and bottom rails. Using a pencil, trace the hole onto the 3/8" plywood backing plate. (See Fig. 3)

Step 4b: Drill a 1" hole through the backing plate. This will be the exit hole for the air coming through the smoke tunnel.

Step 5: Take the air funnel shown in Fig. 2. Draw a line from the top left corner to the highest point of the drilled hole on the air funnel. Draw a line from the bottom left corner to the lowest part of the drilled circle on the air tunnel. Cut these two lines with a handsaw. (This piece should resemble Pac-man). This will be the air funnel to route the air to the fan. (See Fig. 3)

Step 6: Carefully lay all the pieces back into place making sure all edges are flush with the backing plate. Trace all pieces with a pencil so you can put them back into the correct position. The pieces will be removed often during construction, and these tracings will be used as a reference point during the assembly. (See Fig. 4)



Fig. 4

Step 7: Examine the fan motor. At each corner of the assembly are mounting holes. Check to make sure that the 3" wood screws fit through these holes (all fans are different). If they do not, carefully drill them out.

Step 8: Turn over the backing plate. On the back, place the fan motor over the drilled hole at its lowest point where it can still draw air through the exit hole. It may be helpful to picture a clock face and make the exit hole at twelve o'clock in reference to the circular area of the fan blades. (See Fig. 5)

Fig. 6

Fig. 7



Fig. 5

Step 9: Trace the outline of the motor area on the plywood backing plate for a reference as to where the motor will mount. Keep in mind that the power cord should be on the bottom.

Step 10: Lay the fan motor on the 6" x 6" x 3/4" piece of plywood. Trace the outside as well and the inside of the fan. Mark the location of the screw mounting holes of the fan. This will be the fan restriction plate. Carefully cut the marked outside edge, then cut out the inside circle. (See Fig. 6)

Step 11: Drill the marked holes for the mounting screws with an 11/64" size drill bit. This is not critical, but will insure that the screw moves freely through the mounting holes in the restriction plate.

Step 12: On the bottom left hand side approximately 1" from the edge, **CAREFULLY**, drill a 5/8" hole from the outside edge to the inside circle. You must drill a pilot hole through the center to make sure you are in the middle of the wood. If you do not drill straight, you may drill through the side of the restriction plate. Attach fan to mounting plate.

Step 13: Paint all wood surfaces black.

Step 14: Cut a piece of the window screen to the size of the motor, this screen is inserted between the motor and the restriction plate in order to keep small fingers out of the area.



Fig. 11

Step 18: Place the smoke tube into the bottom rail hole. Make sure the drilled holes on the smoke tube are facing towards the air funnel. Using a black marker, mark the side of the smoke tube that is exposed in the 1" hole on the backside of the backing plate. Remove the smoke tube and cut away part of the tube with the black mark. This will be where the smoke will enter the tube and continue up and out the holes. (See Fig. 11 and Fig. 12)

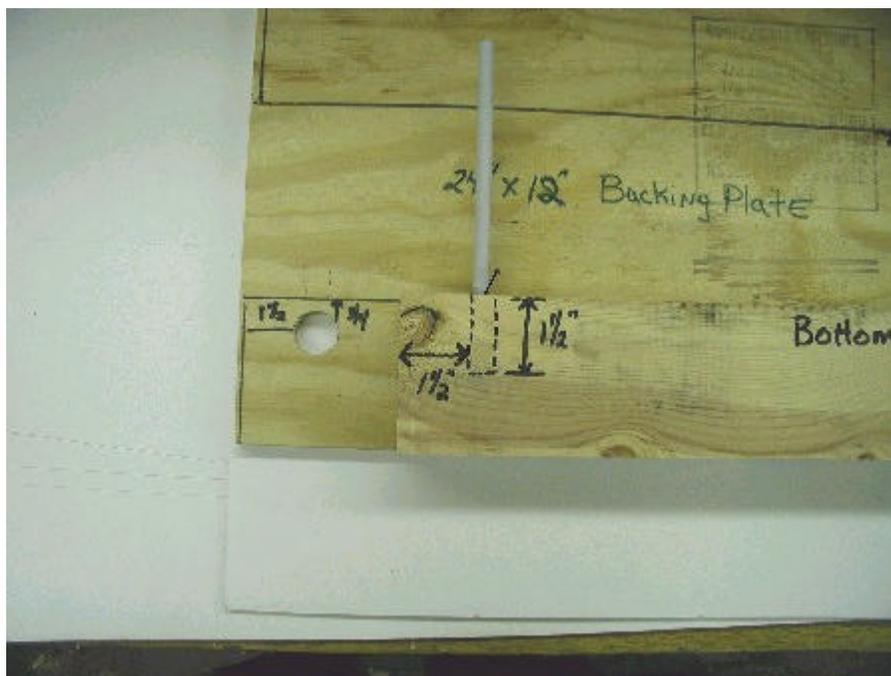


Fig. 12

Step 19: On the front left side of the backing plate, place a mark $1\frac{1}{2}$ " from the left edge and $\frac{3}{4}$ " down from the top of the bottom rail. Drill a 1" hole through the backing plate to complete the path for the smoke to travel into the smoke tube. (See Fig. 12)

Step 20: Lay out all the pieces for the tunnel, matching all the traced outlines. Draw a line from the top rail to the bottom rail 10" from the left of the tunnel. Draw a second line from the top rail to the bottom rail 14" from the left of the tunnel. These are the outside edges of the access doorway. (See Fig. 13)

Fig. 13

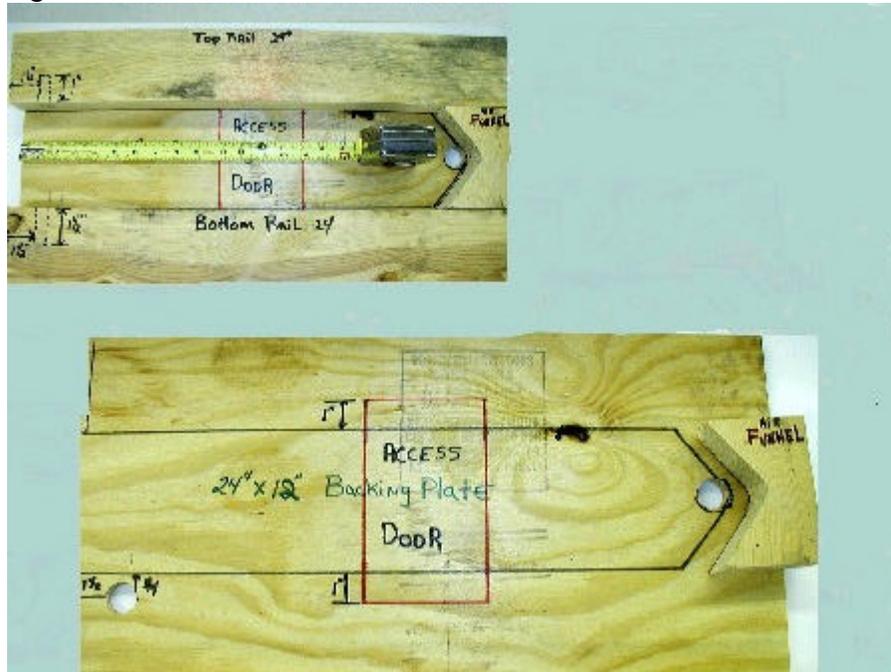


Fig. 14

Step 20a: Remove the top and bottom rails. Extend the two lines up and down for another 1". This will give you an edge that overlaps the top and bottom rails and holds the door in place. (See Fig. 14)

Step 20b: Drill a relief hole in all four corners of the access door; the size of these holes will depend on the size of the saw blade that will be used to cut out the door (the smaller the better). Cut out the access doorway.

Step 20c: Remove the access door, and place a mark in the center of the door.

Step 21: Cut two pieces, $1" \times 1" \times \frac{1}{4}"$ from the $2" \times 4"$ extra construction grade wood. This will be the collars that hold the sting arbor (mounting assembly for models) in place when mounting the airfoil on it.

Step 21a: Glue these pieces (collars) to the center of both sides of the door. Let glue dry. (See Fig. 15)

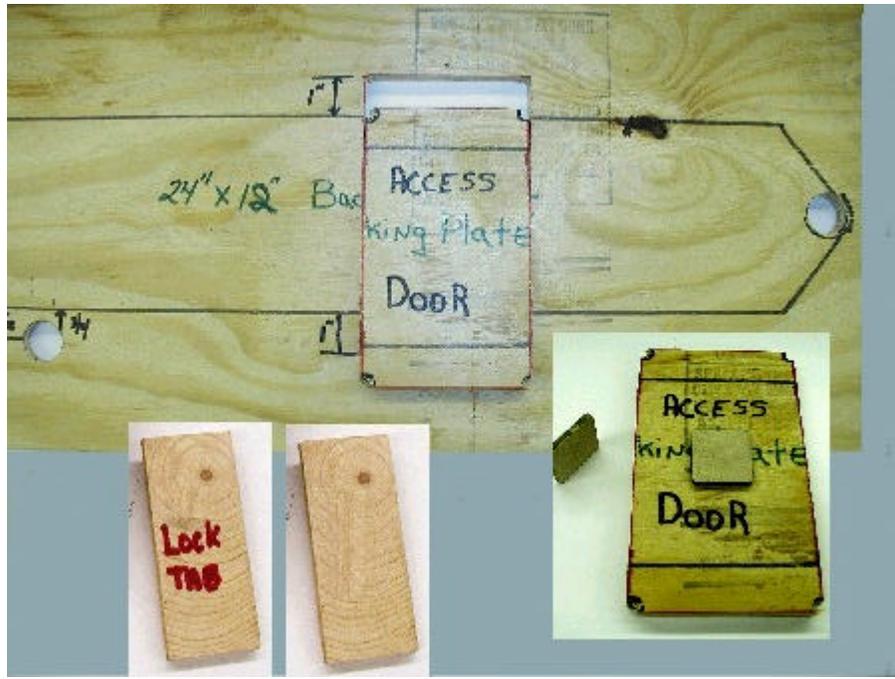


Fig. 16

Fig. 15

Drill 21b: Drill a $\frac{1}{4}$ " hole through the center of the collar. This is to allow the $\frac{1}{4}$ " dowel rod to slide through the hole and to be able to turn in a clockwise direction. Make sure it is not too tight or it will not turn easily. Use sandpaper on the dowel rod until it does.

Step 22: Cut the $\frac{1}{4}$ " dowel rod to 4" length, this will be the sting arbor. The length may need to be adjusted later after the tunnel is complete.

Step 22a: From the 2" x 4" construction grade wood, cut 2 pieces, 3" x 1 $\frac{1}{2}$ " x $\frac{1}{4}$ ". One of these pieces will be used as a rest for the bottom of the access door and the other will be a locking tab to hold the access door in place. (See Fig. 16)

Step 23: Paint the top and bottom rail, the air funnel and the front side of the backing plate black.

Step 24: Assemble all the front pieces of the tunnel. Make sure that the smoke tube is connected into the top and bottom rail. Carefully turn the entire tunnel over onto the backside (Tape the pieces to make it easier to flip over).

Step 25: Place the access door in its hole. Double check to make sure all of the edges are square. Put one drywall screw into each end of the top and bottom rail. (See Fig. 17)

Fig. 17



Fig. 18

Step 25a: Put one drywall screw into the air funnel. These are to hold the pieces in place. (See Fig. 17)

Step 25b: Put four evenly placed screws across both inside edges of the top and bottom rails. (A dotted line may be traced from end to end to make sure that the screws don't penetrate the inner chamber) (See Fig. 17)

Step 25c: Place two more evenly placed screws into the top and bottom of both rails. This should pull all outside edges flat. If not, use more screws. (See Fig. 17)

Step 26: At the bottom of the access door take one of the pieces of 3" x 1 1/2" x 1/4" of wood and drill two holes in the lower half using an 11/64" drill bit. These holes will be to screw the door rest in place. (Pre-drilling makes sure the thin wood does not crack when being screwed into place). Screw the door rest into place so there is a 1/2" overlap on top of the access door. (See Fig. 17)

Step 27: Take the second piece of wood and pre-drill a hole in the top, this will be the locking tab. Lay it on top of the access door so when it is moved from the 6 o'clock position to a 3 o'clock position, it will move out of the way of the access door. NOTE: When placing the screw in the locking tab, make sure the tab can still move. If it is too tight, it will crack the wood. (If the door is too loose from using a large saw blade, glue a straw into the top and bottom to tighten it up). (See Fig. 18)

Step 28: Place the fan motor and the restriction plate over the traced area on the backside of the backing plate. (See Fig. 17) Check to make sure the air exit hole is at 12 o'clock and that the electrical plug is hanging towards the bottom. Make sure the screen is in place to protect small fingers.

Step 28a: Take three, 3" wood screws and put them in the top left hole, the bottom left hole, and the bottom right hole.

Step 28b: Take a 2" screw and put it in the top right hole (A 3" screw here would go into the middle channel).

Step 28c: Screw the fan motor into position.

Step 29: Find the 1" entry hole going to the smoke tube. Take the $\frac{3}{4}$ " piece of plastic pipe and push it into the hole until it stops up against the wood. Some sanding may be required. NOTE: This should be very snug.

Step 30: Mark a line 1" from the back of the tunnel. Cut this tube at the mark. Cut the bottom portion out to the tube out to allow the smoke to flow up into it. Glue it into place in the back of the tunnel. (See Fig. 19)



Fig. 19

Step 31: Paint the smoke chamber can (Potato chip, soft drink, snack items) black. This smoke can must have a metal bottom and a plastic lid.

Step 31a: Line the bottom of the smoke can with a piece of aluminum foil. This will help dissipate heat and extend the life span of the smoke can.

Step 31b: Place the can behind the $\frac{3}{4}$ " inlet pipe for the smoke tube and trace the pipe on the can. Drill a 1" hole in the side and slide it on to the pipe. Make sure there is enough room to put incense in from the top. If you needed, cut the pipe back further, make sure to leave enough edge to glue to. (See Fig. 20)

Fig. 20



Fig. 21

Step 32: Measure and cut enough CPVC pipe to go from the bottom of the fan restriction plate where you drilled a 5/8" hole down and into the CPVC 90 degree elbow. Measure and cut another piece of CPVC pipe to fit from the CPVC 90 degree elbow to the smoke can and go through the side approximately 1/2" from the bottom of the can. (See Fig. 21)

Step 32a: Put all the pieces together and check to make sure you have enough CPVC pipe inside the smoke can to glue it. Also, make sure there is enough room on the metal bottom of the can to set 2 pieces of incense without touching any plastic pipe or any of the walls of the can. Note: Glue should not be needed on the fan backing or on the CPVC pipe itself, but is needed to glue all the smoke connections on the can. (See Fig. 20)

Step 33: Turn the tunnel over to the front side; carefully support it so not to damage any of the items on the back. Place the Plexiglas cover on top and line up all the edges flush. Using a pencil or a marker, that you can wipe off, trace the inside of the tunnel. Make a mark for a screw every 3 inches around the entire inner channel; the idea is to pull the Plexiglas down tight enough so that no air will escape. NOTE: Countersinking the heads of the screws will make for a smooth finish, BUT be careful not to go too deep while countersinking. (See Fig. 22)

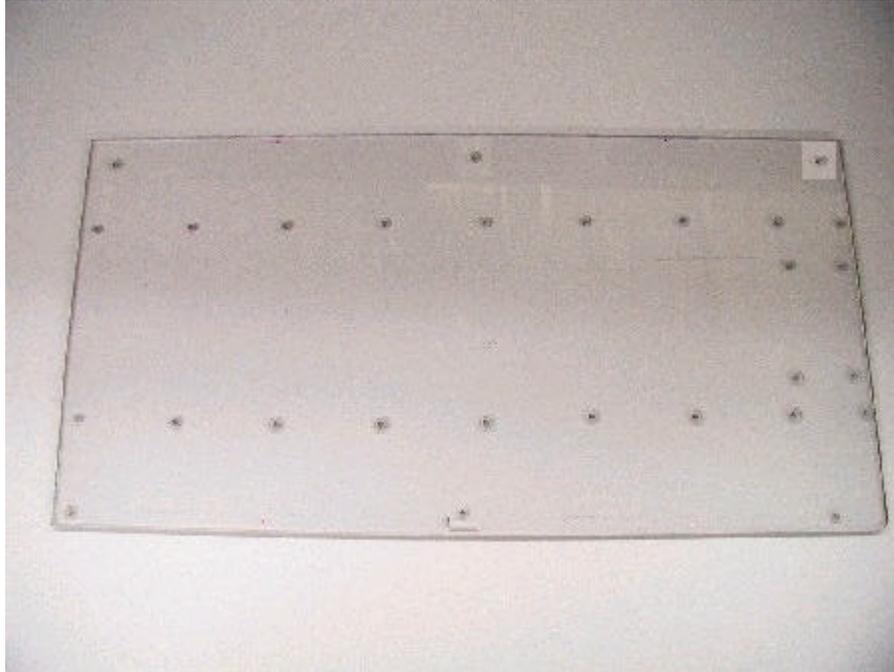
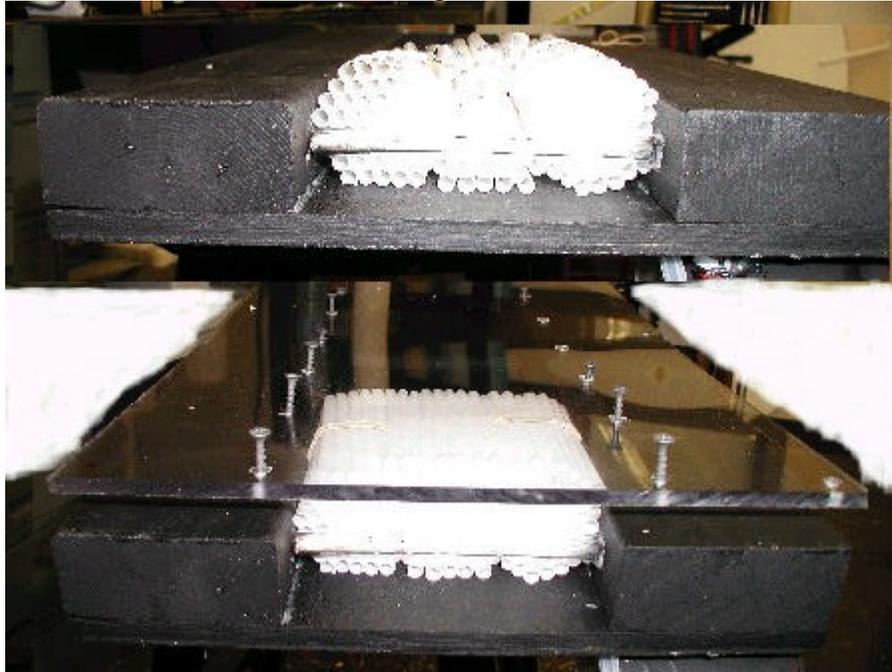


Fig. 22

Step 34: Glue all joining surfaces of the wood inside the tunnel; just a thin coat is needed unless the two joining surfaces have a big gap. Put three screw holes in the Plexiglas along the top edge and bottom edge just to pull the edges down. **DO NOT SCREW INTO PLACE YET.** (See *Fig. 22*)

Step 35: Take approximately 100 straws, cut the straws to four inches in length. Use a rubber band to hold together 80 straws in two groups of 40. Make sure the rubber bands are loose; they need to be able to move.

Step 36: Place the straws together in the very front of the wind tunnel. Line the straws up behind the smoke tube. Stack the straws in the tunnel until they are about $\frac{3}{4}$ " above the sides of the tunnel. (See *Fig. 23*)

Fig. 23*Fig. 24*

Step 37: Carefully place the Plexiglas cover on the top to push the straws down. Completely fill the void tightly, but do not smash the straws flat. When the proper amount of straws are in place, start putting screws in from the back end of the tunnel (where the air funnel is). Slowly place the screws in the holes and walk the Plexiglas down all the way to the end. (See Fig. 24) Place the six screws in the top and bottom of the rails. NOTE: Do not torque the screws too tight or the Plexiglas cover may crack.

Step 38: Take the 2" x 4" stock, cut two pieces 1" x 1" x 5" for the legs. Place them under the tunnel at opposite ends. Try to position the legs to support the smoke can, if this is not possible place them close to each end, at the same distance from each end.

Step 39: Pre-drill 2 holes per leg to mount to bottom of tunnel. Make sure to drill into the wood and not the Plexiglas cover; two screws per leg will be sufficient. NOTE: Cut a 45-degree angle on the front of the legs, it will add a streamline look to the front (save extra pieces).

Step 40: Cut out a section approximately 3" x 5" from the plastic VCR cassette case. This will be used to create the restriction on the fan and push air into the smoke chamber. (See Fig. 25)



Fig. 25

Step 40a: Tape this cover on the back of the restriction plate, lining it up with the bottom. This plate will be moved over time to different positions to adjust the airflow and smoke flow. DO NOT permanently attach it at this time.

Step 40b: After experimenting and locating the best area to create the restriction for the smoke, remove the lower left hand screw and put the cover under the screw so it can be moved up and down like a train crossing gate. (See *Fig. 25*)

Step 41: From the 2" x 4" extra stock, cut one piece 1" x 3 ½" x 3 ½", this will be the material to cut the test pieces from. Use the dimensions provided or create your own. Cut the following shapes: 1" x 2" diameter circle, 1" x 1 ½" x 1 ½" square, 1" x 3 ¼" long air foil. (See *Fig. 26*)

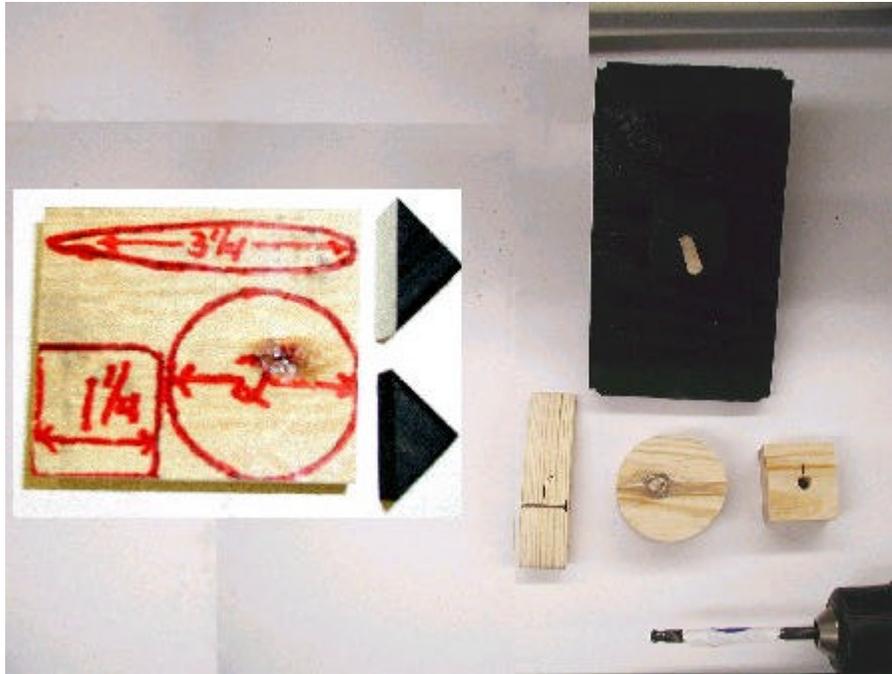


Fig. 26

Step 41a: Take the triangle piece that was cut off for the legs to use as an indicator knob on the sting arbor.

Step 41b: Find the center of each of the test pieces and drill a $\frac{1}{4}$ " hole, $\frac{1}{2}$ " deep into center point of each piece, and the triangle indicator knob. (See *Fig. 26*)

Step 41c: Take the $\frac{1}{4}$ " dowel rod; this will be the sting arbor. Cut the arbor to $2\frac{2}{3}$ ". Take the sting arbor and slide it all the way into the triangle knob. Make a mark where it stops. $\frac{1}{8}$ " from this mark, drill a $\frac{7}{64}$ " hole through the arbor, use the mini craft sticks or wood book matches to make a stop on the arbor. This stop will also be used to indicate the angle of the airfoil. Make sure it is at least 2" long. (See *Fig. 27* and *Fig. 28*)

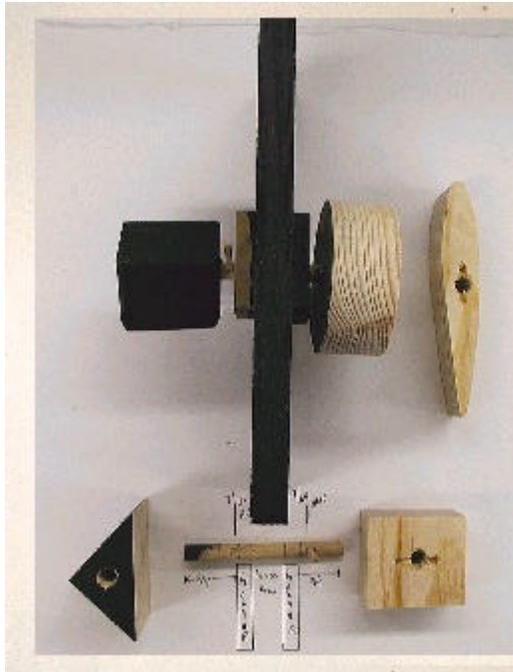


Fig. 27

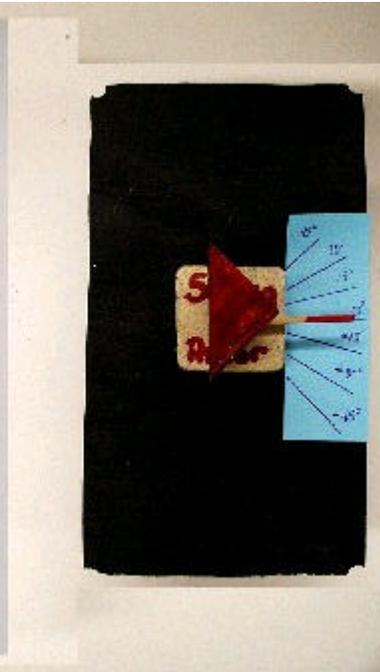


Fig. 28

Step 41d: From the first hole measure 1" and mark the next 7/64" drill hole. Make sure these holes are directly across from each other. Glue the triangle indicator and make sure the point of the triangle is straight in line with the first craft stick stop. Make sure that at least 3/4" is sticking out past the knob. (See Fig. 27)

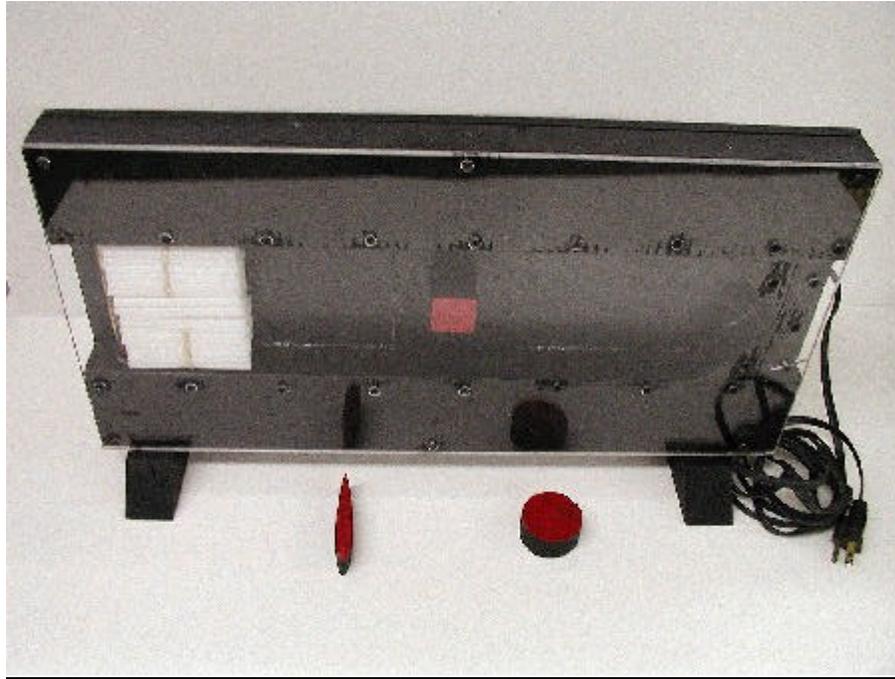
Step 41e: Slide the arbor through the access door. Check the arbor to make sure the airfoil test piece will fit on the end and will fit it into the test channel in the tunnel before the hole is drilled. Make sure there is a little play (movement) so the piece can be adjusted. (See Fig. 27)

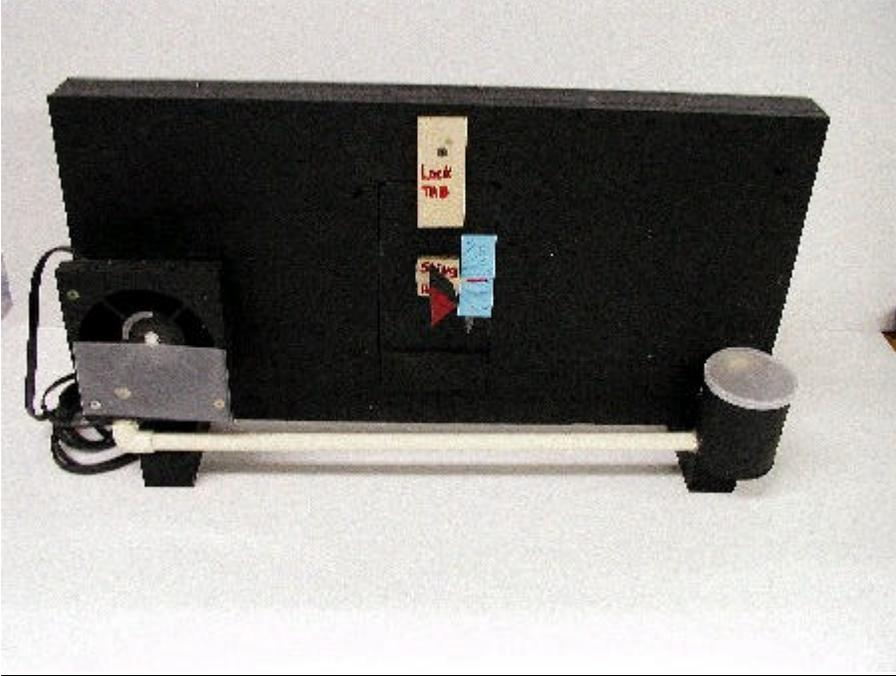
Step 41f: If everything fits, drill a 7/64" hole on the second mark, cut a craft stick to 1/2" in length for this hole. Slide the arbor through the access door and glue the 1/2" craft stick in place. NOTE: The craft stick on the inside section of the tunnel is a dual-purpose item: it will keep from pulling the arbor out of the access door and also be used as a locking key for test pieces. (See Fig. 27)

Step 41g: Lay out one of the test pieces with the 1/4" hole facing up. Use the 7/64" drill bit to drill one hole on each side of the 1/4" mounting hole. Drill in approximately 1/8" or the thickness of the craft stick. Measure 1/4" from the edge of the center hole. Drill down 1/8" then slowly lay the drill bit down towards the mounting hole. This will make a shallow groove that will be connected to the mounting hole. Repeat this on the opposite side and a slot will run across the mounting hole. When the slot is lined up with the craft stick through the sting arbor, it will not only hold the test piece in place but, working in conjunction with the stick in the back it will provide the opportunity to make an angle indicator on the back. (See Fig. 27)

Step 41h: Measure the distance from the sting arbor to the edge of the access door. Cut a piece of paper to this width and 4" high. Use a protractor to draw angles from 45 degrees to -45 degrees. Tape this paper to the back of the door under the indicator stick. (See Fig. 28)

The finished "LITTLE SMOKEY" wind tunnel should resemble:







OPERATION

1. Choose the test piece, mount it on the sting arbor, and secure the access door.
2. Plug the tunnel in and check for motor operation.
3. Light 2 pieces of incense and place them in the bottom of the smoke can (needle nose pliers work well for this).
4. Place cover of aluminum foil over can and then place plastic lid in place. Smoke should be immediately visible in the tunnel (If not check to make sure incense has not gone out).
5. Rotate the test piece and see how the airflow is different over each of the different objects.
6. Run the tunnel for only 10-12 minutes at a time.
7. After 12 minutes, open top of the can, remove the incense, and allow the tunnel to run for 1 minute with plastic lid off the smoke chamber. This will cool all plastic items inside the smoke tunnel.
8. Remove the burnt incense from the can with pliers. There should be a solid bottom left on the incense to grab.

NOTE: YES, this tunnel will burn incense longer than 10-12 minutes at a time, but after that time, the plastic items will become heat soaked and their life expectancy will deteriorate rapidly.

PLEASE FOLLOW THE DIRECTIONS AND OPERATE THE TUNNEL SAFELY.