http://cmgm.stanford.edu/pbrown/protocols/Ozone_Prevention.pdf

The Ozone Annihilator

Dan Klass and Dan Hogan

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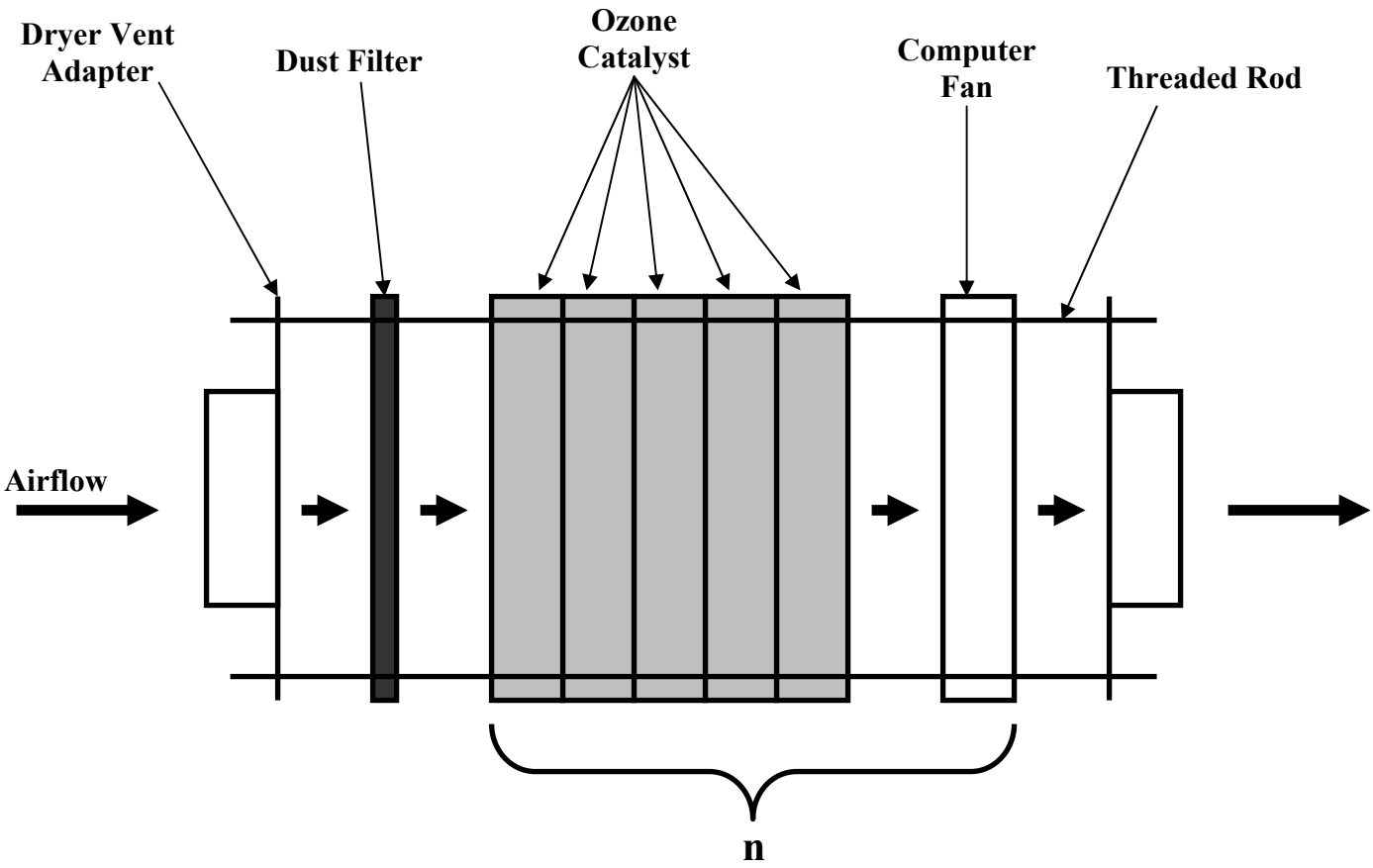
Overview:

The Ozone Annihilator is intended to remove ozone from the ambient air, to prevent the destruction of the ozone sensitive dyes used in microarrays. When combined with plastic enclosures for array scanning, washing, and storage, ozone destruction can be entirely avoided. Cy5 destruction has been reported after 10-30 second exposure to ozone levels above 5-10 ppb, especially during the array washing, drying, and scanning steps[1]. The Ozone Annihilator was designed to be 1) functional, 2) inexpensive, and 3) simple to assemble. The basic idea is to force a column of air through several layers of a honeycomb-like ozone catalyst material (usually manganese oxide). The conversion of $2O_3$ into $3O_2$ is catalyzed by contact with the manganese oxide.

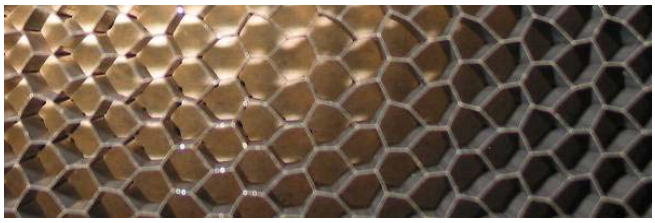


[1] Fare TL,et al. Effects of Atmospheric Ozone on Microarray Data Quality. Analytical Chemistry 1;75:4672-5

Parts List:

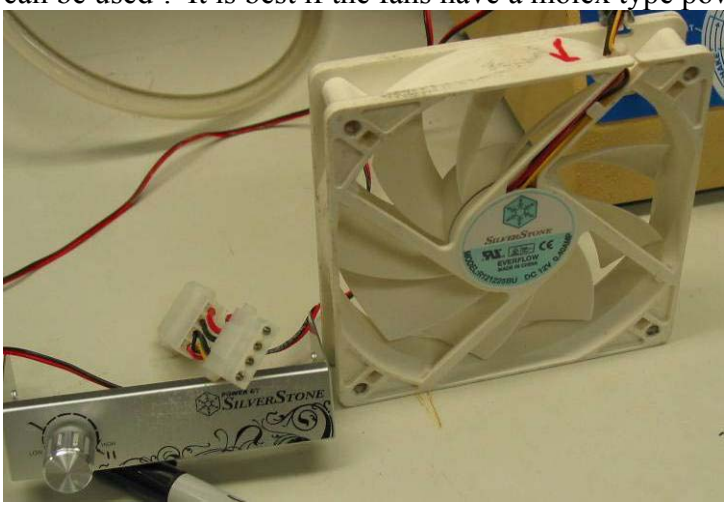
All parts were obtained from The Home Depot unless otherwise stated.

1. Catalyst
   a. (1x) 26"x47" sheets of an aluminum honeycomb-like material with an ozone catalyst coating were obtained from the BASF Catalysts LLC (formerly Engelhard) of Iselin, NJ for "a few hundred dollars" each[2,3].



2. Threaded Rod (not required if using the Ozone Annihilator Box, see page 5)
   a. (4x) pieces of 6/32" threaded rod 36" long at $1.50 each.

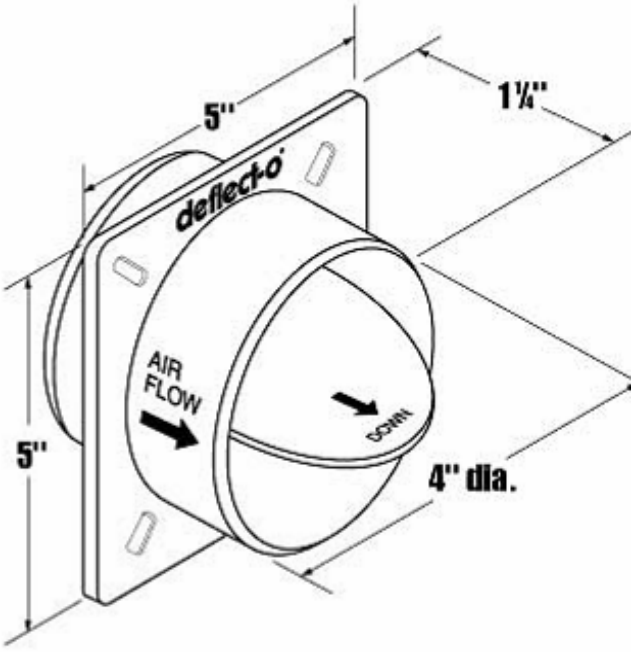
3. Nuts
   a. (24x) 6/32" nuts at $1.50 for 25. (not required if using the Ozone Annihilator Box, see page 5)
4. Fans
   a. (7x) SilverStone model FM121 120mm computer fans were obtained from Fry's Electronics for $20 each. These fans use 0.5 Amps at 12 V DC, and they move 110 cubic feet per minute (CFM) of air with a fan speed of 2400 RPM. They also have an adjustable fan speed. Any 120mm 12 V DC computer fan with a similar airflow rating can be used[4]. It is best if the fans have a molex type power connector.



[2] It took 7 months for our catalyst order to be delivered, hopefully BASF will deliver much faster. Previous price of $200 removed at request of BASF.
[3] Contact Vince Patram vince.patram@basf.com (732) 205-6236 or Paula Satterfield paula.satterfield@basf.com (256) 464-6343 at BASF for purchasing.
[4] When selecting fans, keep in mind that there is a "slight" negative correlation between air speed and ozone removal because the catalyst must contact an O_3 molecule convert it to O_2. However, placing each fan in between several layers of catalyst in the Ozone Annihilator significantly decreases its effective airflow.

5. Power Supply
    a. (1x) A standard 300W ATX 12 V DC computer power supply was obtained from Fry's electronics for $25. Any ATX 12 V DC computer power supply can be used[5].

6. Duct Tape (may not be required if using the Ozone Annihilator Box, see page 5)
    a. (1x) Duct tape rolls at $3 each.
7. Dryer Vent Adapter
    a. (2x) deflect-o Hardware brand 4" diameter Dryer Vent Draft Blockers at $8.00 each.



[5] It must be an ATX (an industry standard, not a brand) power supply, because otherwise the pin assignments will be different and you will have to figure out how the pins on your non-ATX power supply correspond to the ATX pin assignments to make it work.

8. Dryer Vent

a. (1x) 4” diameter 8’ long deflect-o Hardware brand Dryer to Vent Hook-Up Kit at $16.00 each. This is just a standard dryer vent hose (we won’t use the white plastic ends).

9. Dust Filter

a. (1x) 120mm black foam dust filter for 120mm computer fans was obtained from Fry’s Electronics for $3.50 each. We won’t use the plastic grill, just the black foam inside.

10. Hose Clamps

a. (2x) 4-5” diameter hose clamps of the screw/band clamp variety at $1.50 each.

11. Cable Ties

a. (3x) ~12” cable ties, nothing special

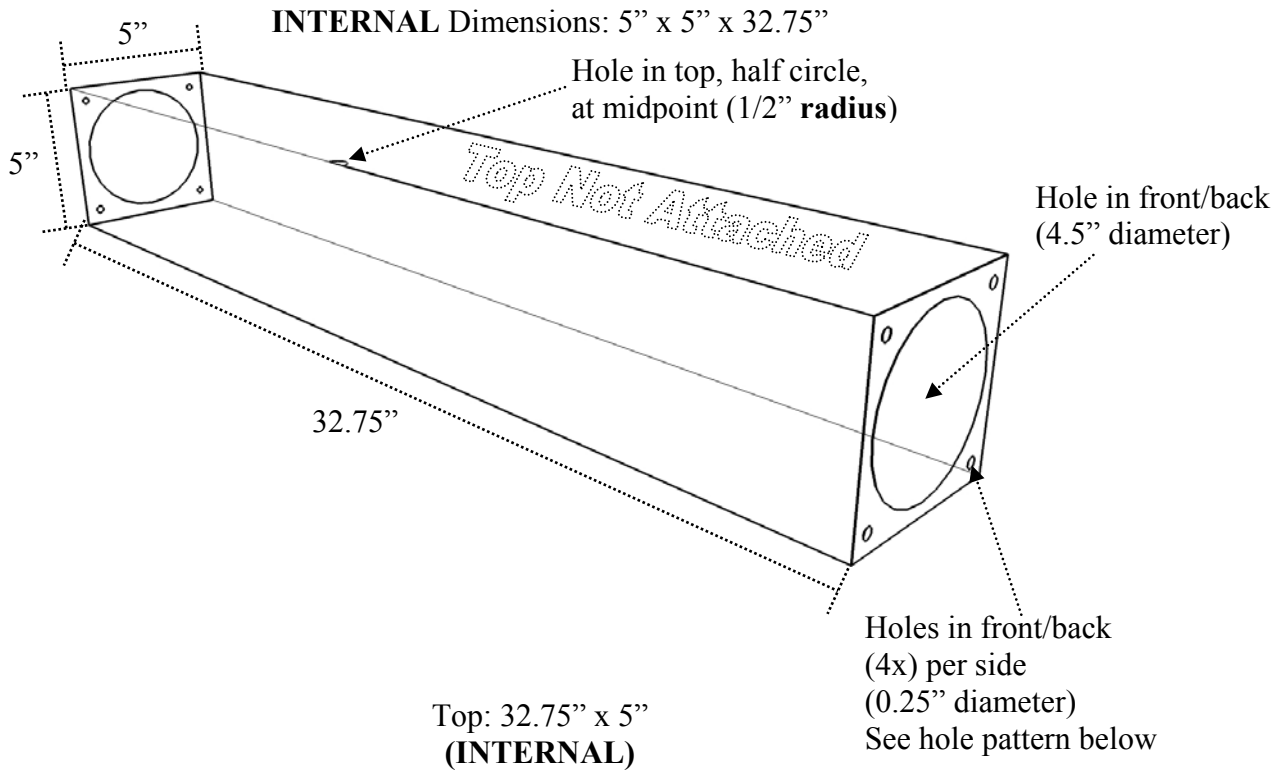
12. Ozone Annihilator Box

a. The Ozone Annihilator Box is a custom built acrylic enclosure for the Ozone Annihilator from TAP Plastics in Mountain View, CA. The Ozone Annihilator Box adds ~$170 to the total cost of the Ozone Annihilator.

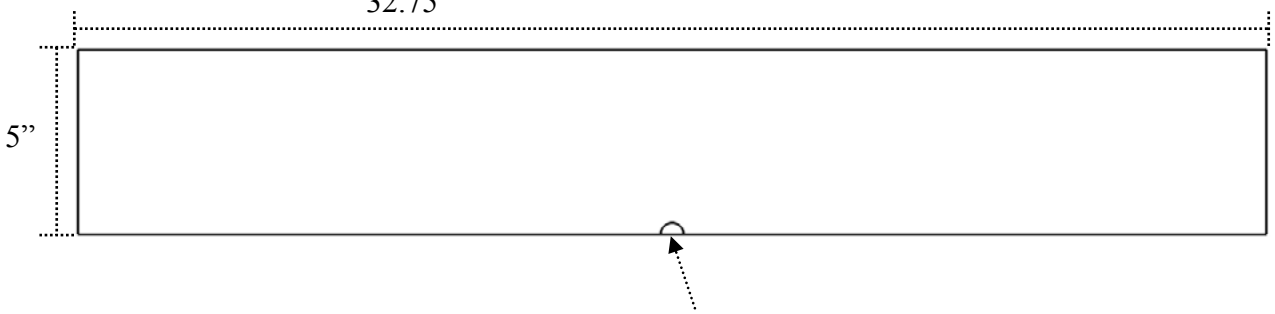
b. Detailed plans for the Ozone Annihilator Box can be found on page 6.

(dimensions ~33”x5”x5”, lid not shown, see page 6 for further details)

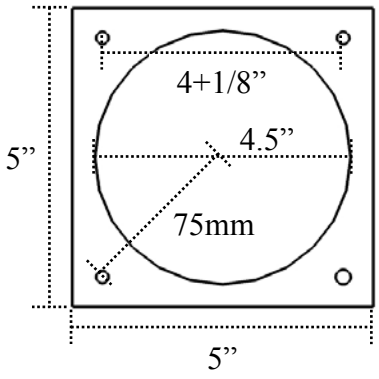
Blueprints for all boxes:



Top: 32.75” x 5”
(INTERNAL)
Top Not Attached



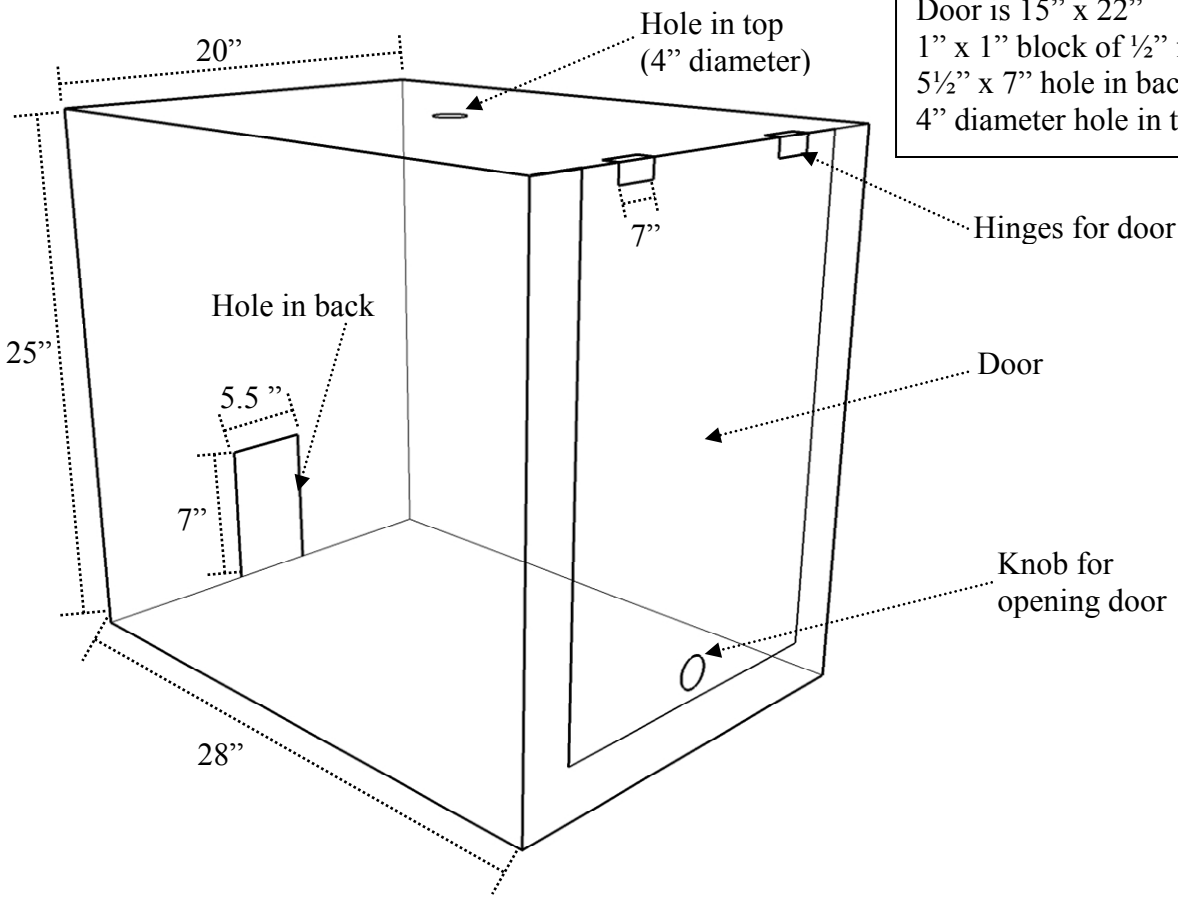
Front/Back: 5” x 5”
(INTERNAL)



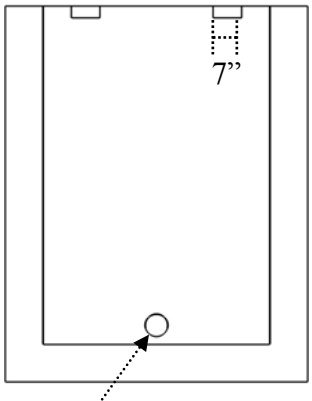
Ozone Annihilator Box
¼” opaque blue acrylic (non-transparent)
4.5” diameter holes in center of front/back
(4x) holes ¼” diameter in front/back
Center-center distance for ¼” holes of 4+1/8”
Center-center distance for 4.5” hole to ¼” holes of 75mm
TOP NOT ATTACHED
Half circle hole in top, at midpoint, ½” **radius**

Axon Autoloader 4200 Box
¼" clear acrylic
13" x 21" door opening
Door is 15" x 22"
1" x 1" block of ½" for door latch
5½" x 7" hole in back
4" diameter hole in top

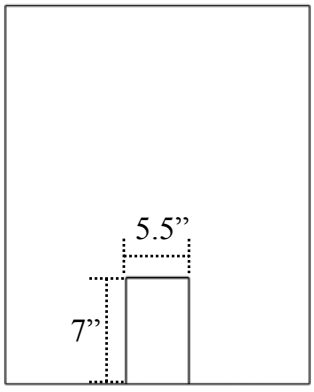
INTERNAL Dimensions: 28" x 20" x 25"



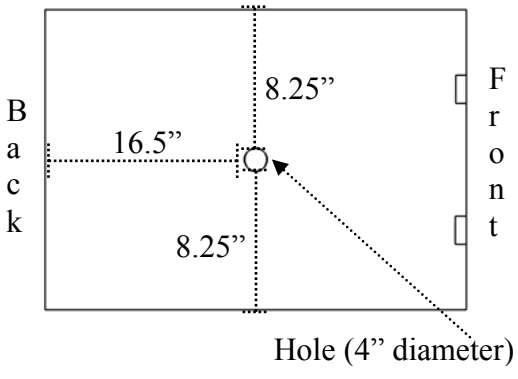
Front: 20" x 25"
(INTERNAL)

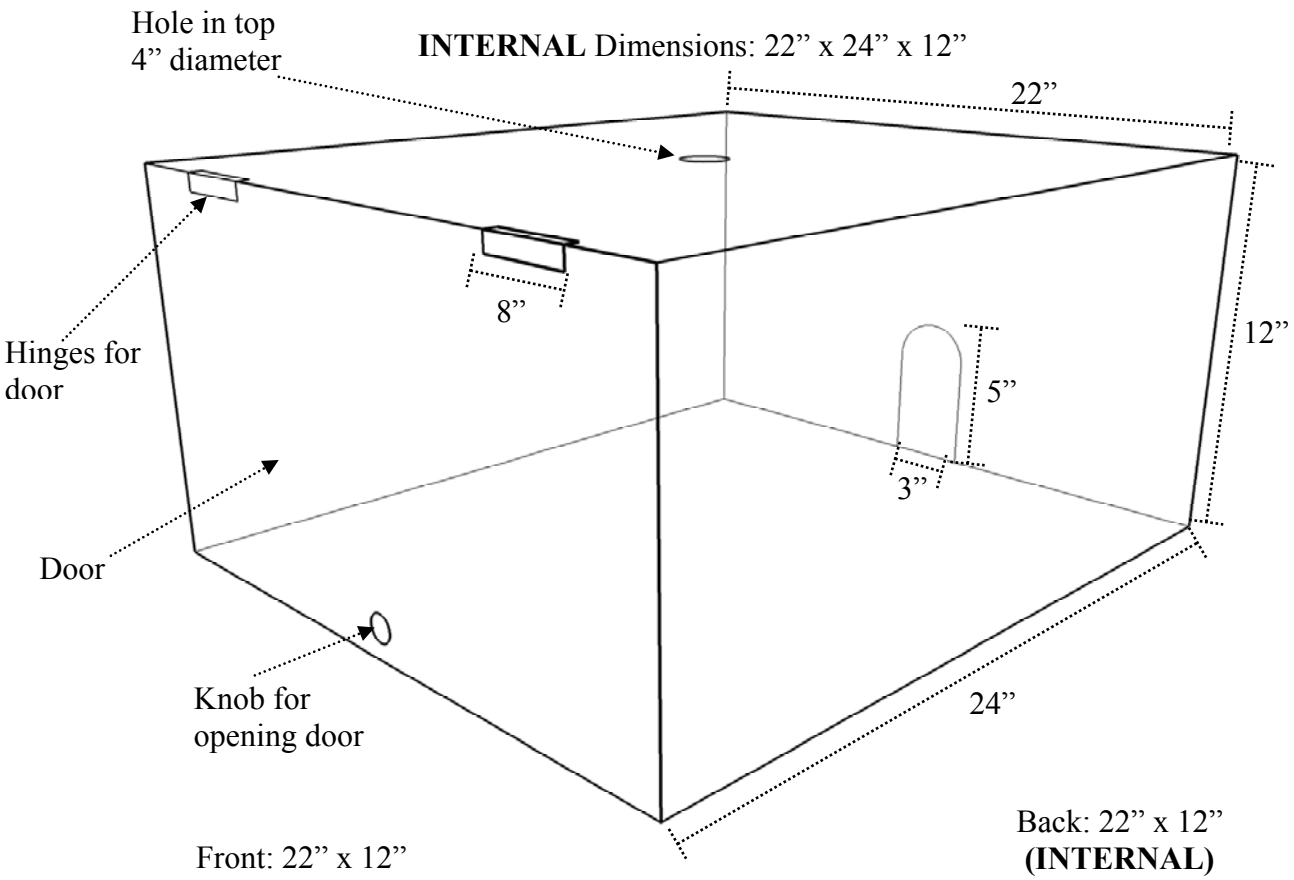


Back: 20" x 25"
(INTERNAL)

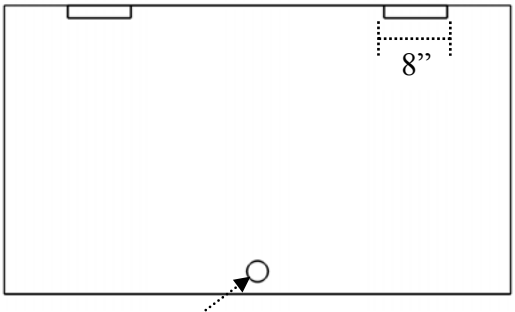


Top: 28" x 20"
(INTERNAL)



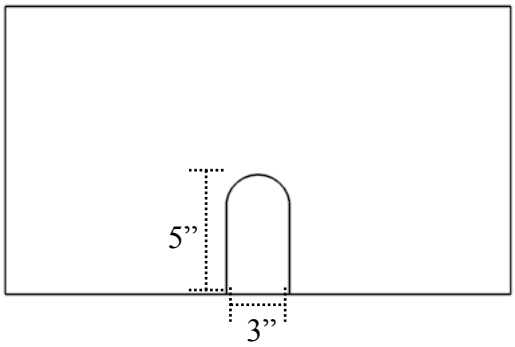


Front: 22” x 12”
(INTERNAL)

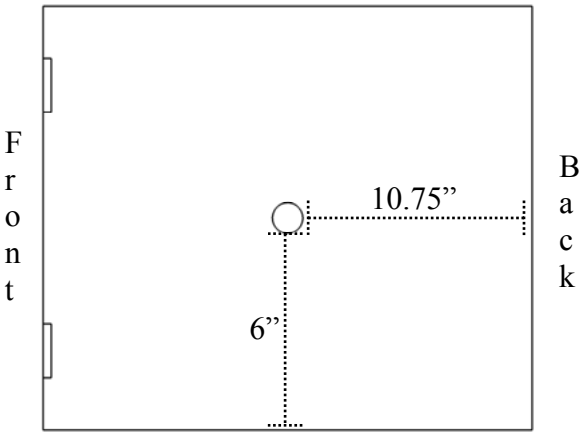


Knob for
opening door

Back: 22” x 12”
(INTERNAL)



Top: 24” x 22”
(INTERNAL)



Axon Scanner 4000 Box
¼” clear acrylic
Latched front door
2” strip inside door
5” x 3” hole in back
4” diameter hole in top

Ozone Free Enclosure for Array Drying Centrifuge
(Rough design, but it works!)

Parts:
1. Centrifuge under a table
2. Clear shower curtain
3. Scotch Reclosable Fasteners Velcro tape
4. Sleeves from rain poncho
5. Duct tape
6. Ozone Annihilator

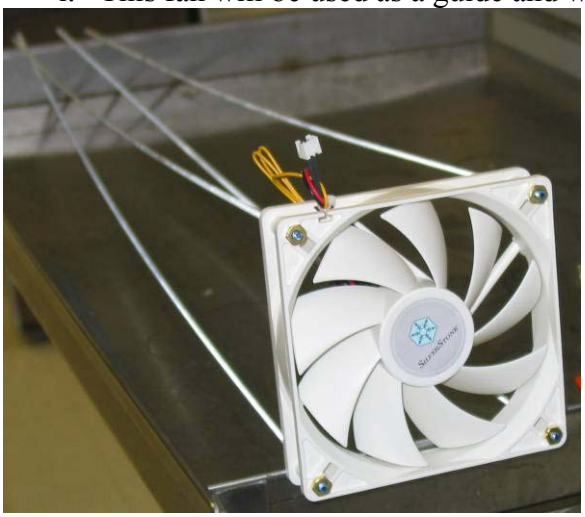
Assembly:
1. Cut shower curtain to fit opening under table.
2. Cut sleeves off of rain poncho.
3. Cut holes in front of shower curtain for rain poncho sleeves.
4. Duct tape rain poncho sleeves to holes in shower curtain.
5. Make vertical cuts in shower curtain and re-close with Velcro tape
6. Duct tape shower curtain onto table (front and back, seal well).
7. Tape to floor or use a large weight (like our large crowbar).
8. Duct tape dryer vent from Ozone Annihilator into enclosure.
9. Power on Ozone Annihilator and check for positive pressure (curtain bulge in picture below).

Assembly:

1. Cut Catalyst
    a. Cut 40 ~4.8”x4.8” squares of catalyst using a band saw[6]. Less catalyst can also be used. See the Design Variations section.

2. Cut Dryer Vent Adapters
    a. Remove the plastic disc from the center of each adapter and cut off one of the ends.

3. Assemble on Threaded Rod (if you are using the Ozone Annihilator Box proceed to page 9)
    a. Screw one nut onto the end of each piece of threaded rod.
    b. Slide one threaded rod into each hole in the first fan.
        i. This fan will be used as a guide and will be relocated later.



    c. Slide the dryer vent adapter on so that the uncut end faces the fan.

[6] A carpet knife can also be used, but a band saw is more effective. Be careful not to smash the honeycomb catalyst structure.

d. Pull the threaded rods back so that just a ¼" of threaded rod is sticking out from the cut end of the dryer vent adapter.

e. Carefully match up the end of each threaded rod with a hole in a square of catalyst and TWIST and GENTLY push it through. It helps to brace the catalyst on the other side with your finger. If you line it up properly, there should be some resistance, but it should not be difficult[7].

f. Add 4 more layers of catalyst (5 total), just like in step e.

[7] If lined up improperly, much more force will be required, and you will eventually rip out a chink of catalyst. This is not the end of the world, but makes it more likely that your catalyst squares will fall off of the assembled Ozone Annihilator. Also, it gets *much* more difficult as more layers of catalyst are added, and work gloves may be required to prevent blisters.

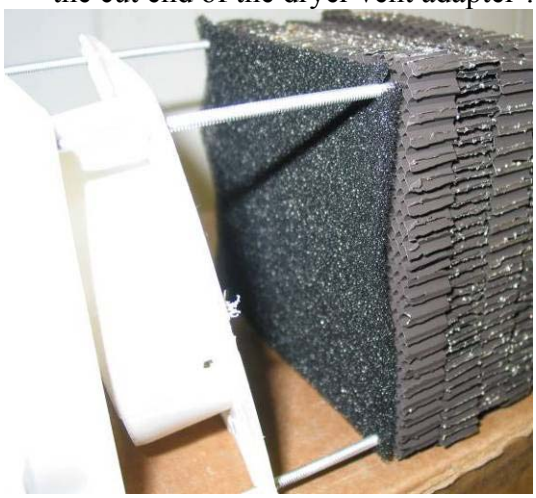
g. Slide a fan onto the threaded rod, making sure that the arrow on the fan indicating the direction of airflow is pointing away from the previously added catalyst and dryer vent adapter.

h. Remove the nuts from the end and slide off the fan that was put on as a guide in step b. Replace the nuts on the ends of the threaded rod.

i. Repeat steps e, f, and g until 35 squares of catalyst and 7 fans have been added[8]. Again, make sure that the airflow indicator arrows on the fans are all pointing in the correct direction, and it also helps to have all the power cables on the same side.

j. Now add 5 more layers of catalyst, just like in step e.

k. Place the foam dust filter on the air intake end, between the first layer of catalyst and the cut end of the dryer vent adapter[9].



l. Now add the second dryer vent adapter, with the cut side facing the catalyst.

[8] Less catalyst can also be used. See the Design Variations section.

[9] Since the catalyst depends upon contact with the O_3 for catalysis, dust collection on the catalyst can lower the catalytic efficiency and must be prevented with a dust filter.

m. Screw one nut onto the ends of the threaded rods. Hand tighten the nuts.

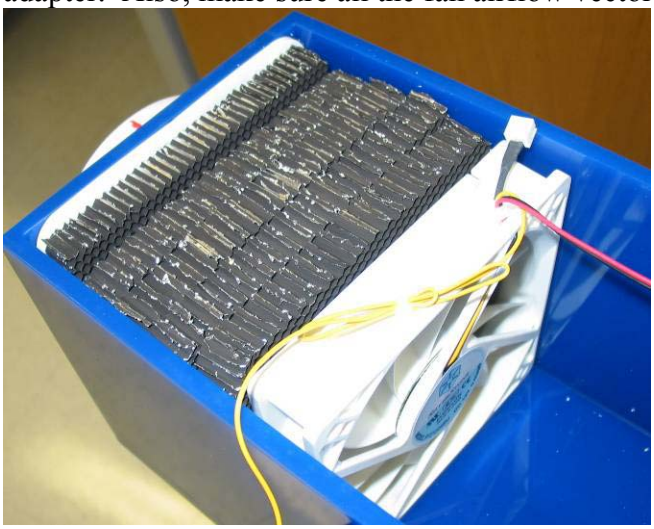
4. Assembly with the Ozone Annihilator Box

a. Put the dryer vent adapter through the hole in one end of the box.

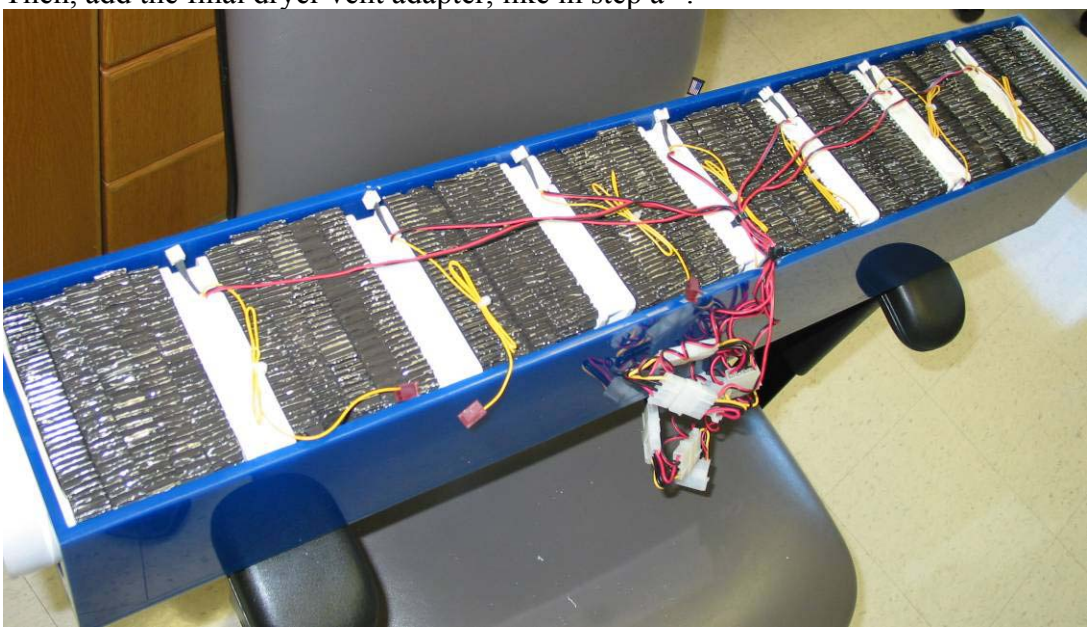
b. Next, simply drop in 5 cut catalyst squares. Place a 120mm foam dust filter between the dryer vent adapter at the air intake end and the first layer of catalyst[10].

[10] Since the catalyst depends upon contact with the O_3 for catalysis, dust collection on the catalyst can lower the catalytic efficiency and must be prevented with a dust filter.

c. Then, drop in a fan. Make sure the arrow that the arrow on the fan indicating the direction of airflow is pointing away from the previously added catalyst and dryer vent adapter. Also, make sure all the fan airflow vectors are pointing in the same direction!

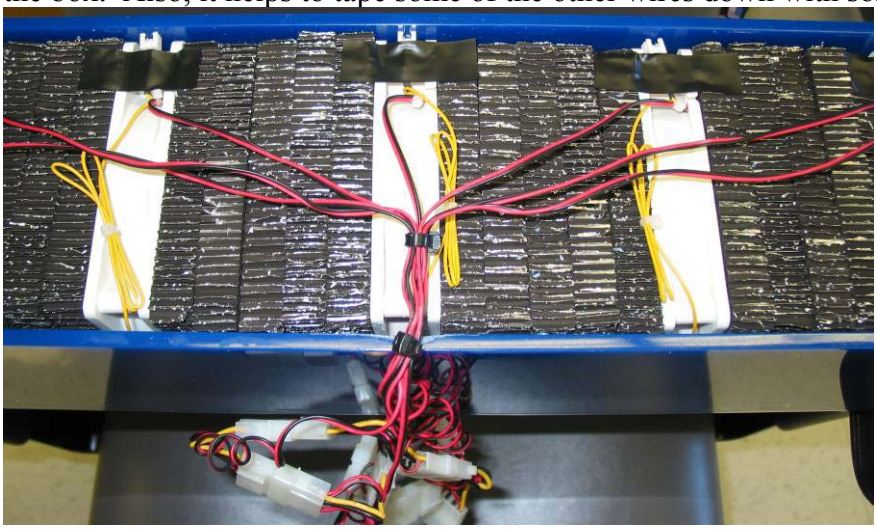


d. Repeat steps b and c until 35 squares of catalyst and 7 fans have been added. Again, make sure that the airflow indicator arrows on the fans are all pointing in the correct direction, and it also helps to have all the power cables on the same side.
e. Now add 5 more layers of catalyst, just like in step b.
f. Then, add the final dryer vent adapter, like in step a[11].



[11] I like to draw airflow vectors on the dryer vent adapter. This makes it easy to hook up the Ozone Annihilator in the proper orientation once it's finished.

g. Organize the wires with a couple cable ties so that they form a bundle at the midpoint of the box. Also, it helps to tape some of the other wires down with some electrical tape[12]

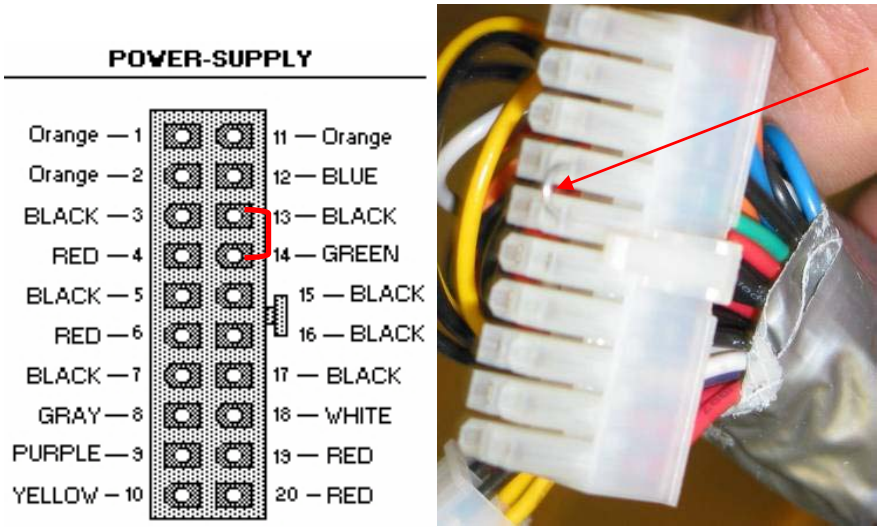


h. Then, put on the lid of the box. Line up the notch in the lid with the bundle of red and black power wires. Attach the lid with red safety tape, masking tape, etc[13].

5. Power it On

a. Plug each fan's molex power connector into the power supply.

b. Using a short length of wire, such as a piece of a paperclip, create a jumper to connect the green wire (pin 14 on the connector) to any common ground, such as the black wire (pin 15 on the connector). This allows you to turn on the power supply without a computer attached.



c. Plug in the power supply and make sure that each fan is spinning freely by plugging them each in one at a time first[14].

[12] Duct tape can also be used, but do not used duct tape directly on wires or other electrical parts with exposed metal, since duct tape DOES NOT provide the same electrical insulation as electrical tape.

[13] It is best to use a reversible method to attach the lid, because this allows you to open the box at a later date to perform any required maintenance or impress your friends.

[14] If any fans don't spin freely or rub against the catalyst, first try loosening the nuts. If that doesn't work, create small spacers (1/4"x1/4") by folding pieces of paper and use them to increase the space between the catalyst and the fan that is rubbing. Sequentially powering individual fans on/off can help you locate the problem fan.

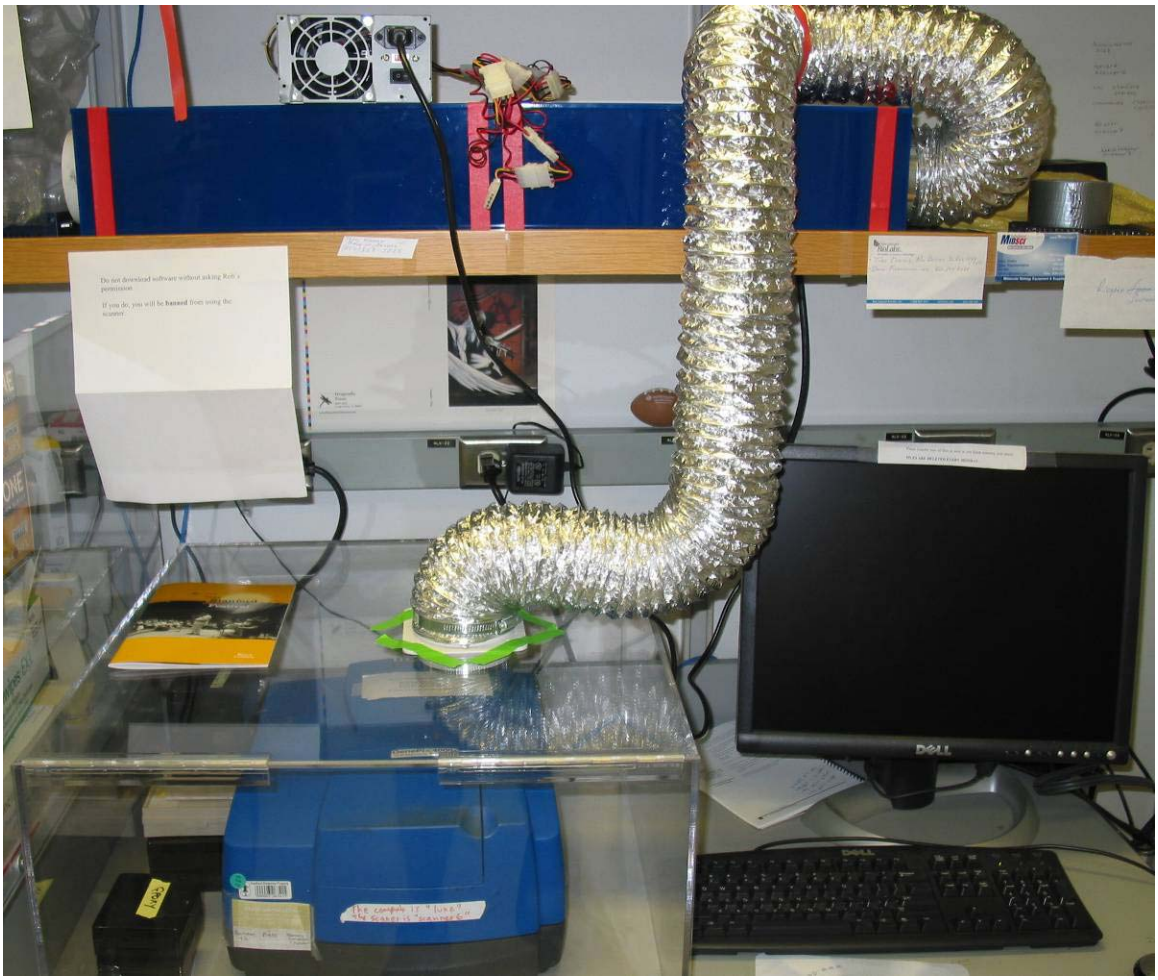
6. Tape it Up (this step is not required if you are using the Ozone Annihilator Box)
    a. Thoroughly wrap the entire Ozone Annihilator assembly in duct tape, from one dryer vent adapter to the other. Rub the tape to ensure a proper seal.

7. Attach the dryer vent to the dryer vent adapter using the hose clamp.

8. Attach the dryer vent to the plastic enclosure surrounding your scanner, etc.

Here is an Ozone Annihilator without a box, wrapped in duct tape to ensure proper air flow:

Here is an Ozone Annihilator with a box.



Testing:

The Ozone Annihilator testing was performed with the SciGene Model 805 Ozone Monitor. This monitor is accurate to 2ppb. It costs ~$6,000. They might consider leasing it if enough interested people contact them. Alternatively, Dan Hogan and Dan Klass have access to a SciGene Model 805 Ozone Monitor that you can rent. Most of our testing was done on an Ozone Annihilator with 25 layers of catalyst. Presumably, the Ozone Annihilator design with 40 layers of catalyst will be more effective at removing O_3 from the air, but we have not yet been able to test this hypothesis.

Using an Ozone Annihilator with 25 layers of catalyst, the steady state O_3 concentration was brought down to 1-2ppb with an ambient O_3 concentration of 29ppb. The Ozone Solutions Inc NT-70 Ozone Interceptor, which retails for $1,500, brought the steady state O_3 concentration down to 10-12ppb with an ambient O_3 concentration of 31ppb. The parts for the Ozone Annihilator cost much less than $1,500. An Ozone Annihilator with 25 layers of catalyst was able to bring the O_3 concentration down to steady state in ~90 seconds for a scanner box with a volume of ~3.7 ft^3, and steady state was reached in ~120 seconds for an array washer box with a volume of ~15.9 ft^3.

Design Variations:

There are several possible design variations. Increasing the number of layers of catalyst between fans will decrease the airflow. We have found that five layers between each fan provide good airflow and good catalyst performance. If the O_3 clearance time within the box (after opening the door, etc.) is less important than getting the O_3 levels inside the box as low as possible, more layers of catalyst between fans can be used. Also, if slightly higher O_3 levels inside the box are acceptable, fewer total layers of catalyst can be used. Even with 25 layers of catalyst, our testing indicates that a steady state concentration of 2(+/-2)ppb O_3 can be achieved after a few minutes.

We have noticed a decrease in O_3 levels inside the scanner enclosure after wrapping an Ozone Annihilator in duct tape. Wrapping the Ozone Annihilator in duct tape is a cheap and easy solution, but it can also be placed inside a custom built plastic box, or within a length of PVC pipe. The custom acrylic box for the Ozone Annihilator eliminates the need for wrapping the unit in duct tape. It also looks *way* cooler, which is always important when doing science. Allied Electronics sells circular fans that may work well with a PVC pipe housing. The important thing is to ensure that air can only enter and exit the Ozone Annihilator through the dryer vent adapters at each end, and not somewhere in the middle. We welcome your suggestions and improvements to this design.