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HumidOSH: A Self-Contained Environmental Chamber with Controls for Relative Humidity and Fan Speed V.2

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Soon Kiat Lau

ABSTRACT

Relative humidity is a measure of water availability in air that can affect physical, biological, and chemical changes in biological samples through modification of water activity and is also known to be important in the fabrication of sensitive electronic devices. The HumidOSH is a free, open source, and self-contained system for creating a controlled relative humidity environment within the range of 3 to 97 % with a 0.2 % tolerance. Each HumidOSH unit also comes with a fan with adjustable fan rotational speed to improve moisture uniformity inside the chamber. The system includes many additional features such as glove ports for manipulating samples, a sample door for transferring objects in and out of the system, ceiling lights for illuminating the work area inside the chamber, and two-point calibration for the relative humidity sensor. While relative humidity and fan rotational speed readings are displayed in real-time on the built-in user-friendly interface, the readings can also be recorded through a USB connection to a laptop or computer and the optional computer program. The design files, source code, and build instructions of the HumidOSH can be accessed at <https://dx.doi.org/10.17605/OSF.IO/WCKHM>.

MATERIALS

All the required materials are listed in the bill of materials that can be downloaded from <https://osf.io/d2evx>

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We use this protocol and it's working

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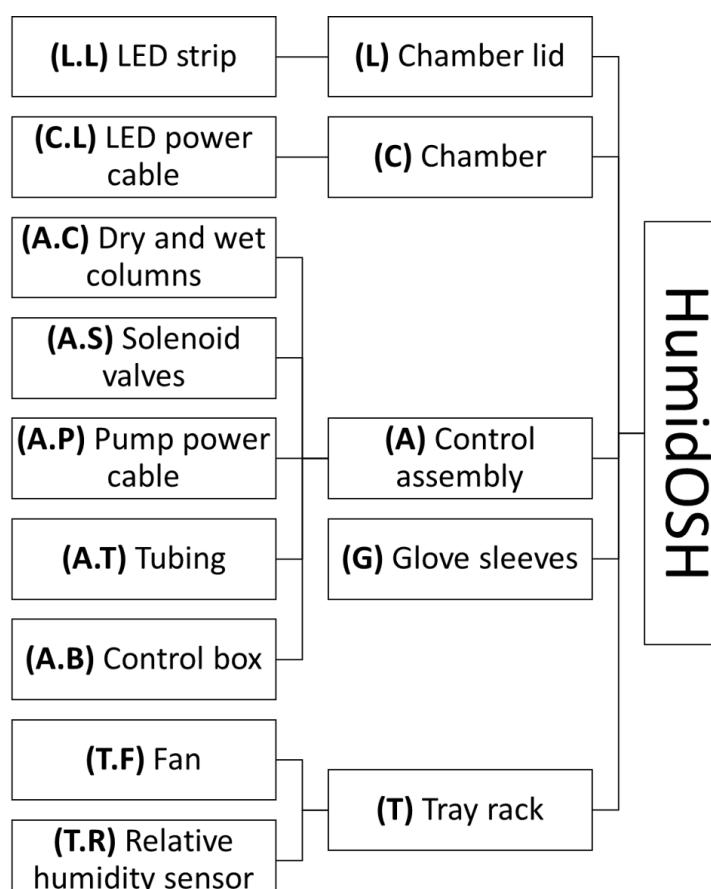
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BEFORE START INSTRUCTIONS

Please refer to the bill of materials that can be downloaded from <https://osf.io/d2evx>. These build instructions use the references/designators defined in the bill of materials for brevity purposes.

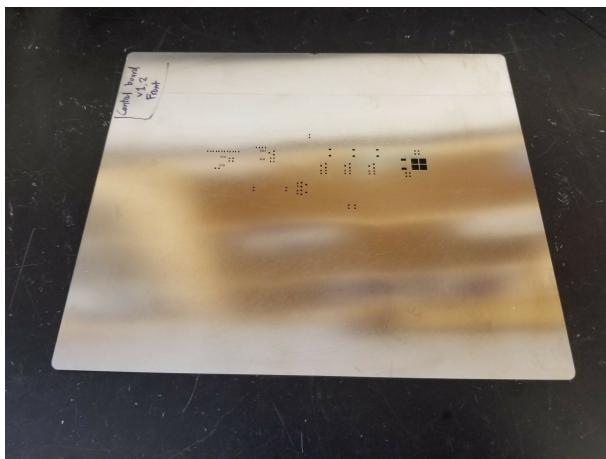
HumidOSH is constructed from a few parts that are independent of each other. During assembly, these parts can be assembled independent of each other before coming together for the final assembly. Therefore, the construction workflow can be made efficient by assigning the construction of each independent part to different individuals/days. **The relationship of these parts are shown in the diagram below.** If a part is connected to a part on the left with a line, that means that the part on the left needs to be constructed before the part on the right can be built.



Printed Circuit Boards

- 1 There are two printed circuit boards (PCB) used in HumidOSH: the control box PCB and the relative humidity sensor PCB. The PCB design files (<https://osf.io/579fq/>) can be sent to a PCB

manufacturer (e.g. JLCPCB or OSHPark) for manufacturing. When ordering the PCB, it is recommended to order PCB stencils in preparation for the next step.



PCB stencil for the control box PCB



PCB stencil for the relative humidity sensor PCB

- 2 The electronic components to be soldered onto the PCBs are listed under the "Control box PCB" and "RH sensor PCB" sections of the bill of materials available at <https://osf.io/tua34/>. The entries from the "References/Designators" column of the bill of materials are printed as labels on the PCBs.

The electronic components consist of through-hole and surface mount components. To assemble the surface-mount components, it is highly recommended to use a PCB stencil to ensure consistent and accurate solder paste distribution. A tutorial on using PCB stencils can be found at: <https://www.sparkfun.com/tutorials/58>.

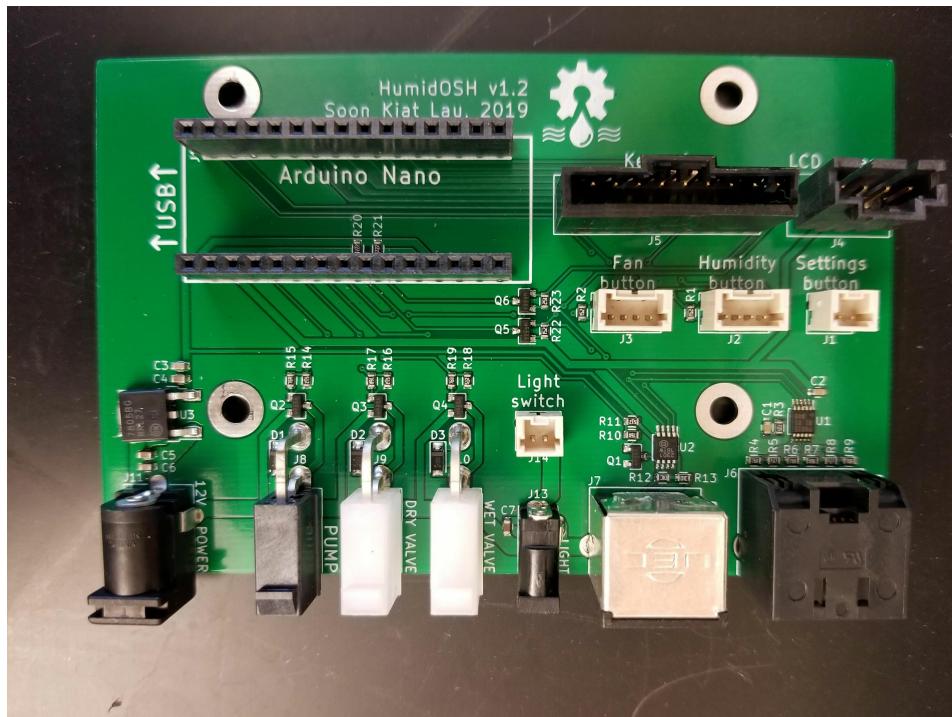
The remaining through-hole components can be soldered on using a soldering iron. A tutorial on using a soldering iron is given by Sparkfun: <https://learn.sparkfun.com/tutorials/how-to-solder-through-hole-soldering/all>.

The through-hole components for the control box PCB are:

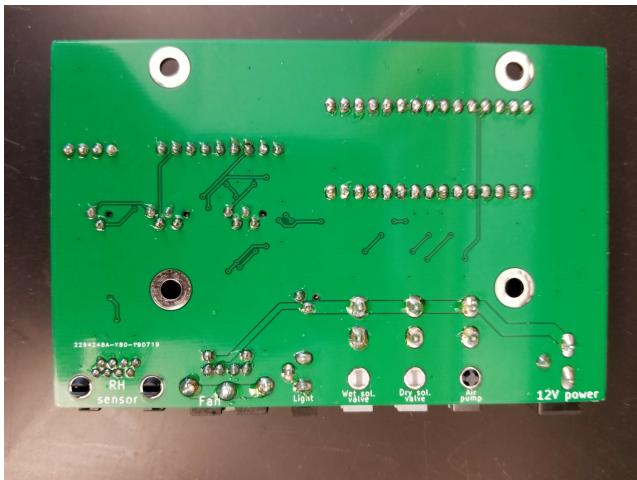
- J1 to J14

The through-hole components for the relative humidity sensor PCB are:

- J1 and J2



Control box PCB, front view. **NOTE the orientation of the keypad and LCD connectors. Credits to Colleen Harper**



Control box PCB, back view



Relative humidity sensor PCB, front view



Relative humidity sensor PCB, back view

(L.L) LED strip

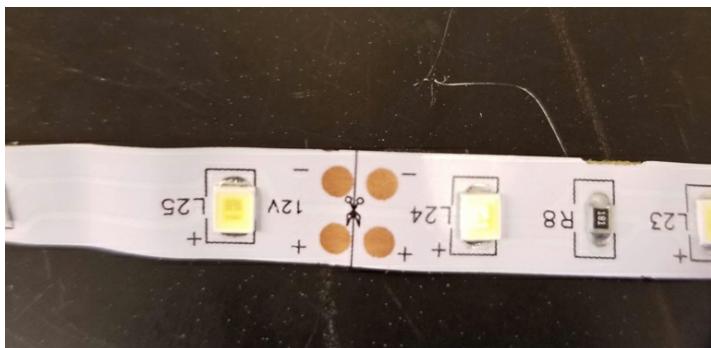
3 The LED strip (L.L) will be attached to the chamber lid (L). The parts required are:

- 59.5 cm of L.L1
- 1 ea. L.L2



4 L.L1 needs to be trimmed to a length of approximately 59.5 cm. When cutting it, ensure that the

cut is being made on the line that has a scissors symbol on it.



Look for the scissors symbol

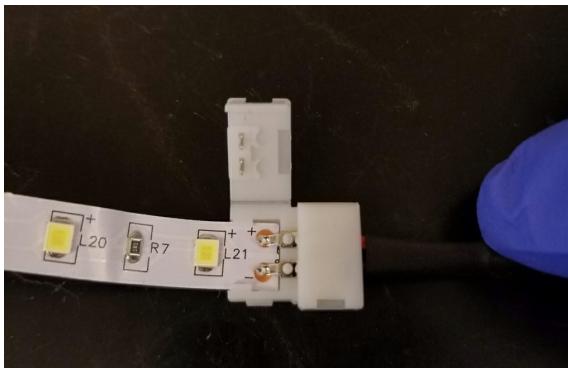
- 5 Partially remove the plastic backing at the back of one end of the trimmed L.L1. This will expose the adhesive.



- 6 Open the white clip of L.L2 and place the previously exposed end of L.L1 on it. **Ensure that the terminals match up; a mismatch of terminals could destroy L.L1.**



To match the terminals, check that the (+) and (-) symbols on both L.L1 and L.L2 are lined up. Subsequently, close the clip of L.L2 and the LED strip is ready.



(L) Chamber lid

- 7 The chamber lid (L) will go on top of the chamber (C). The parts required are:
- 1 ea. L.L (LED strip assembled from earlier steps)
 - 1 ea. C1 (only the lid)
 - 15 oz. L1 (same volume for each bottle)
 - 240 cm L2
 - 10 ea. L3 (only the strike plate)
 - 20 ea. L4
 - 20 ea. L5
 - 1 ea. L6
 - 1 ea. L7

Consumables required:

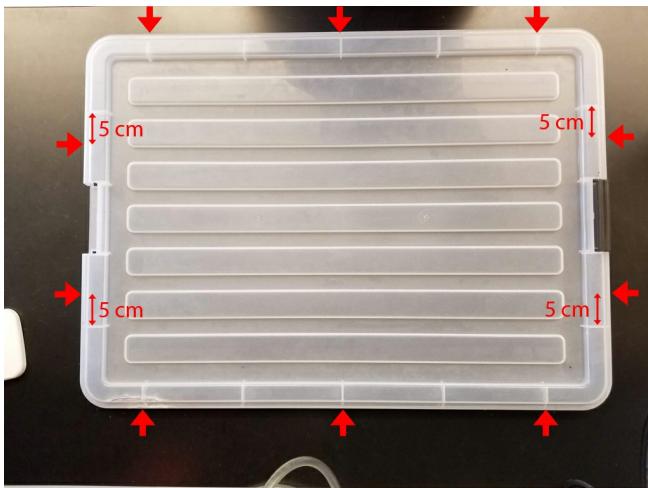
- A droplet of X2



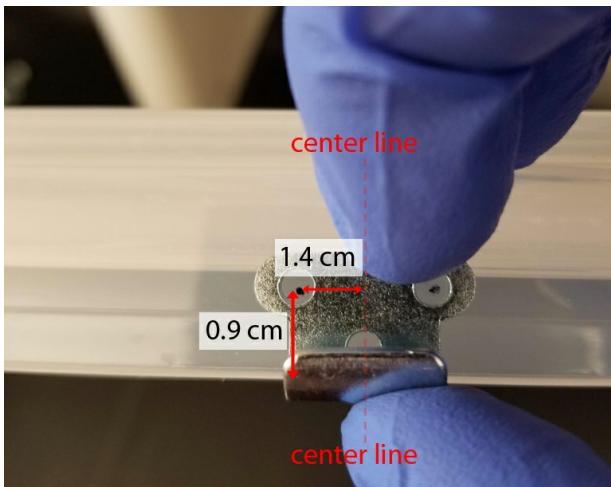
Parts for the constructing the chamber lid. Not all parts are shown.

- 8 L3 is a latch assembly consisting of two parts: the latch and the strike plate. Only the strike plates are needed for the chamber lid. Reserve the latches for later steps.

Using the pictures below as guides, mark the locations for drilling holes for the strike plates. Use a 9/64" high speed steel (HSS) drill bit to drill the holes.

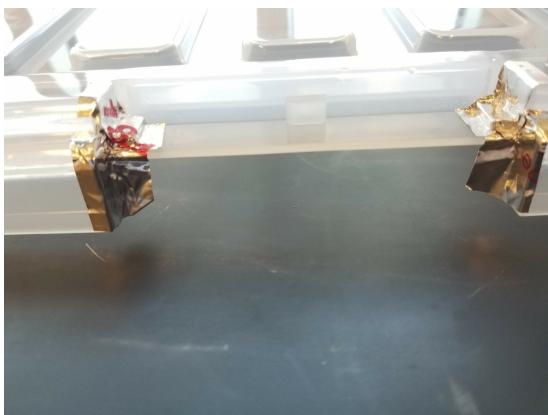


Locations of the centers of the 10 strike plates. Note that the strike plates along the long edge are aligned with the plastic ridges in the lid, while the ones along the short edge are located 5 cm away from the ridges.



Location of the screw holes relative to the center of the strike plate. and the bottom of the lid.

- 9 Remove the black handles on the lid of C1, taking care not to break the lid itself. Seal off the openings using rigid tape such as aluminum tape. The tape should form a "wall" that prevents liquid inside the lid from spilling out. Place the lid on a flat surface, with the inside facing upwards and with paper towels underneath the locations where the handles were pulled out from.



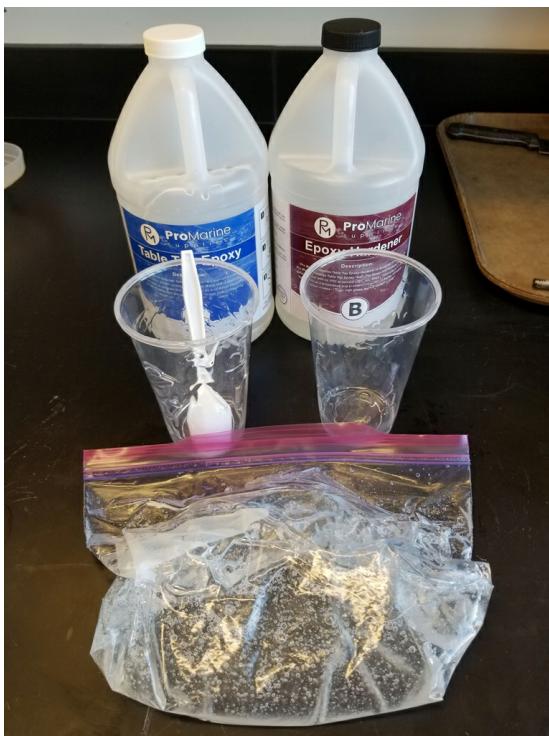
Taping off the openings that held the handles



Placing the lid on a flat surface

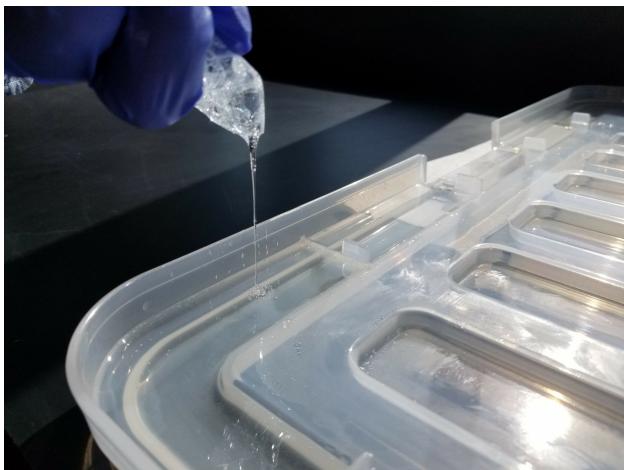
- 10 L1 is an epoxy kit that consists of two bottles, the resin and the hardener. Pour 15 oz. of each bottle into separate disposable cups, then combine both liquids into one plastic bag. Mix the mixture thoroughly by hand-massaging the bag for at least 4 min.

Once mixed, the L1 mixture must be used within 30 min because it will begin to thicken up and eventually harden to a solid.

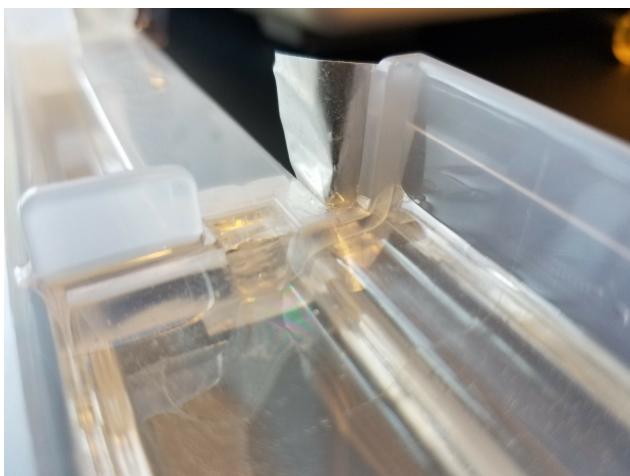


Preparation of L1

- 11** Cut a corner of the plastic bag containing the L1 mixture and gently pour the L1 mixture into the **channels on the edges** of the lid of C1. The goal is to fill up the channels such that they will be level with the rest lid.



Pouring the L1 mixture into the channels at the edges of the lid of C1



Ensure that the channels are filled up so that they are level with the rest of the lid. Check that the epoxy mixture is not leaking out of the taped-off openings from earlier steps.

- 12** When mixing the L1 mixture, bubbles of air may form. These bubbles should not be a problem,

though sometimes a large amount are formed that could result in a bumpy surface on the cured L1 mixture. This is undesirable because a flat surface is needed for subsequent steps.

Use a lighter to pop the bubbles on the surface of the poured L1 mixture. It is not necessary to get every single bubble; the goal here is to remove large masses of bubbles that would prevent a flat surface from forming.

Allow **at least a day** for the L1 mixture to cure and harden before moving to the next step.



Pop the bubbles!

- 13 Remove the plastic backing from L2 to expose its adhesive and apply it onto the cured epoxy on the lid. The lid itself has white "lines" on the channels; use these as guide for placing L2.

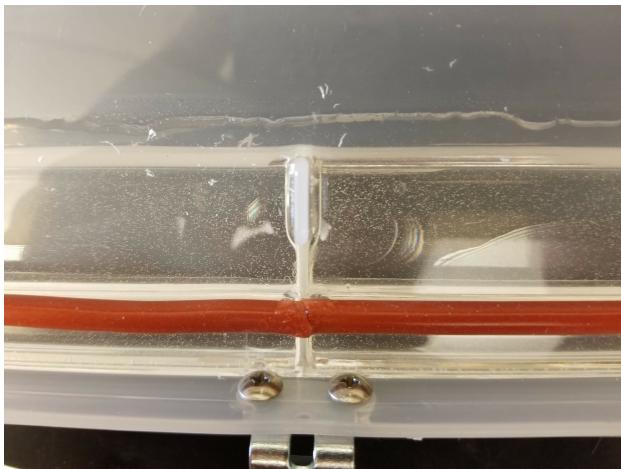
Trim off excess L2 and join the ends together with a small droplet of X2. Allow the droplet of X2 to cure for at least a day.



Align L2 with the white "lines" in the channels of the lid



For the short edge of the lid, simply extend L2 across the plastic. If the L1 mixture was poured level with the lid, this procedure would be easier.



Join the ends of L2 with a droplet of X2

14

Once L2 has cured, remove the plastic backing of L.L and apply it onto the lid by following the picture below. **The orientation is important**; placing it in the opposite direction will make it difficult to connect power to L.L. Secure the black cable of L.L onto the lid with L6 and L7.



Once this has been done, the lid is complete.



Placement of L.L on the lid. Note its location relative to the "channels" in the center of the lid.



View of the completed lid from the outside.

(C.L) LED power cable

- 15 The LED power cable (C.L) is attached to the chamber itself (C) and provides power to the LED strip (L.L) that is fixed to the chamber lid (L). The parts required are:
- 1 ea. C.L1
 - 1 ea. C.L2



- 16 Insert C.L1 through the black plastic shaft of C.L2 and align the wires of C.L1 with the metal piece of C.L2.

Using a soldering iron and some solder, solder the red and black wires of C.L1 onto the metal piece of C.L2 by referring to the picture below.



- 17 Screw the black shaft of C.L2 onto the metal piece. C.L is now complete.



(C) Chamber

18 The chamber (C) is the main body of HumidOSH. The parts required are:

- 1 ea. L (chamber lid)
- 1 ea. C.L (LED power cable)
- 10 ea. L3 (only the latches)
- 1 ea. C1 (without the lid)
- 2 ea. C2
- 12 ea. C3
- 12 ea. C4
- 12 ea. C5
- 1 ea. C6
- 8 ea. C7
- 8 ea. C8
- 8 ea. C9
- 20 ea. C10
- 20 ea. C11
- 20 ea. C12
- 20 ea. C13
- 1 ea. C14
- 1 ea. C15
- 1 ea. C16
- 1 ea. C17
- 3 ea. C18
- 1 ea. C19
- 1 ea. C20
- 1 ea. C21
- 1 ea. C22

Consumables required:

- Approximately half a cartridge of X2

Recommended special tools:

- Z2
- Z5



Overview of parts needed for assembling the chamber (C). Some of the parts are not shown.

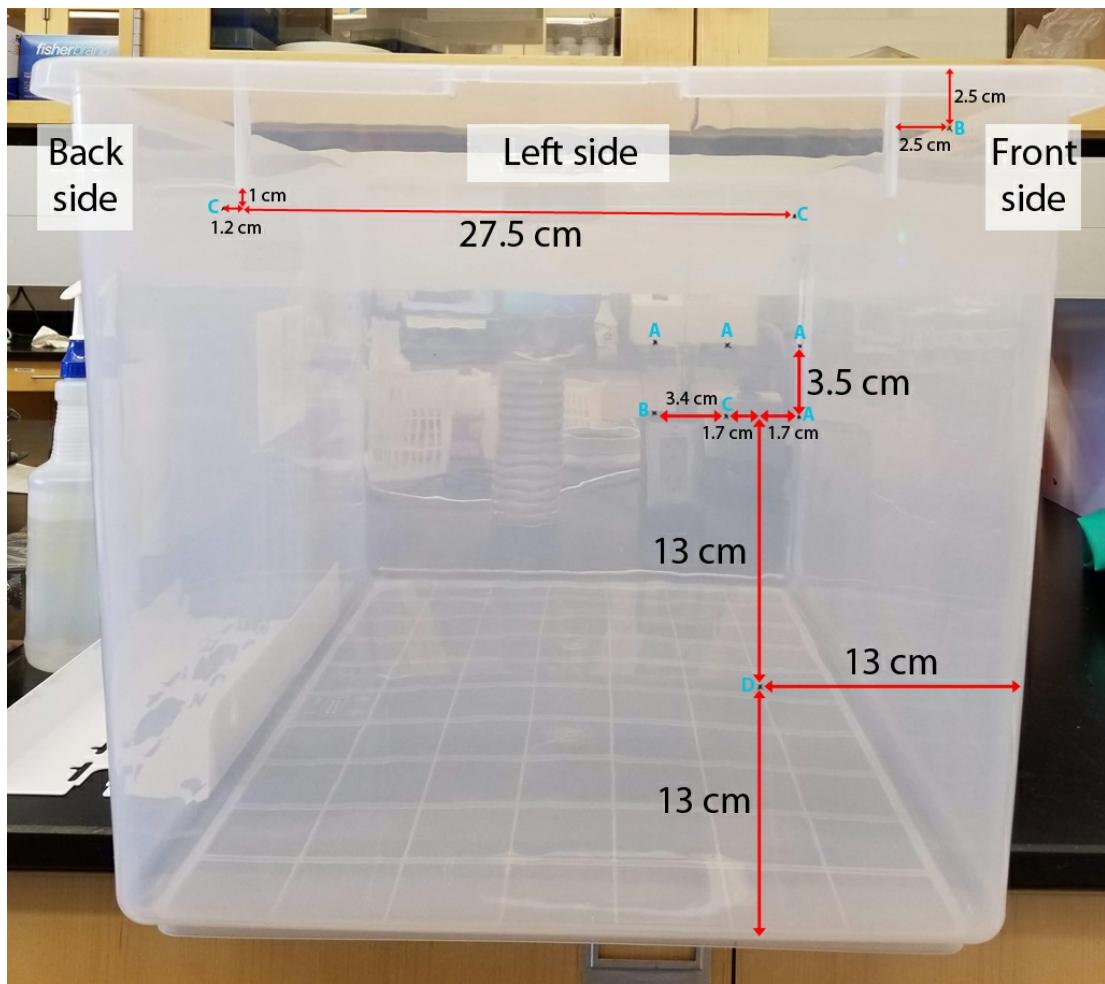
19



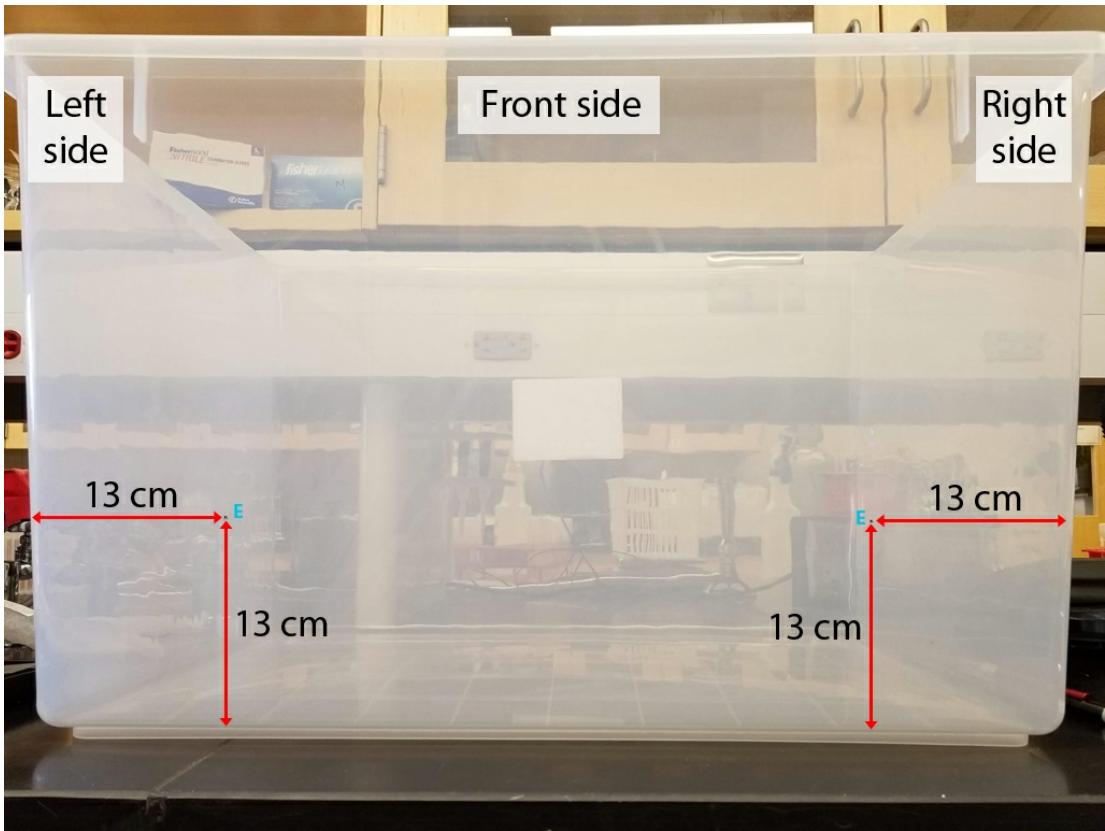
Using a permanent marker, mark the locations of holes that will be drilled onto the chamber by referring to the picture below. **Ensure that the chamber is orientated correctly** when making these marks; improper orientation will make it extremely difficult to assemble the chamber later on.

Drill the labelled holes with the following drill bits:

- A: 1/2" drill bit from Z2
- B: 5/8" spade bit
- C: 13/16" spade bit
- D: Z5 set to cut a 6-1/2" diameter hole
- E: Z5 set to cut a 5" diameter hole



Location of drill holes on the left side of the chamber.



Location of drill holes on the front side of the chamber.

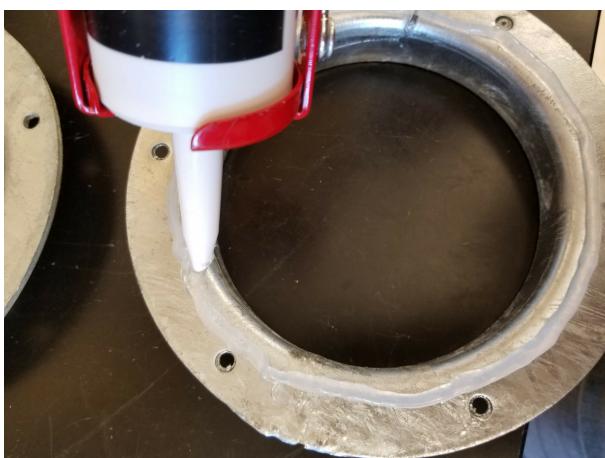
- 20 Align C2 with both of the 5" diameter holes drilled onto the front of the chamber such that their openings line up. Use a permanent marker to mark the locations of the holes on the lip of C2. Use a 5/16" drill bit from Z2 to drill out these holes.



Align the openings, mark the holes, and drill the holes.

- 21** Apply a generous amount of X2 along the lip of both pieces of C2 and align them to the holes previously drilled on the front of the chamber. Fix both pieces of C2 onto the chamber with C3, C4, and C5. The screw (C3) should go from inside the chamber to outside, while C4 and C5 should fasten onto C3 from the outside.

Wipe off any excess X2 from the edges of C2.



Applying X2 onto C2



Fasten C2 onto the chamber with C3, C4, and C5

- 22 Discard the red plastic bag and black gasket of C6. Align C6 onto the 6-1/2" diameter hole drilled onto the left side of the chamber and mark the holes on the lip of C6 with a permanent marker. It is recommended to mark the holes in the pattern shown in the picture below so that the door of C6 opens in the proper orientation once installed. Drill out these holes with a 1/2" drill bit from Z2.



Discard the red bag and the gasket (left side of picture)



Mark the holes on the chamber

- 23 Apply a generous amount of X2 onto the lip of C6 and align it to the holes previously drilled. The hinge of C6 should be oriented towards the back of the chamber, which also means that its door handle should be towards the front of the chamber (see picture below). Fix C6 onto the chamber with C7, C8, and C9. The screw (C7) should go from inside the chamber to outside, while C8 and C9 should fasten onto C7 from the outside.

Wipe off any excess X2 from the edges of C6.



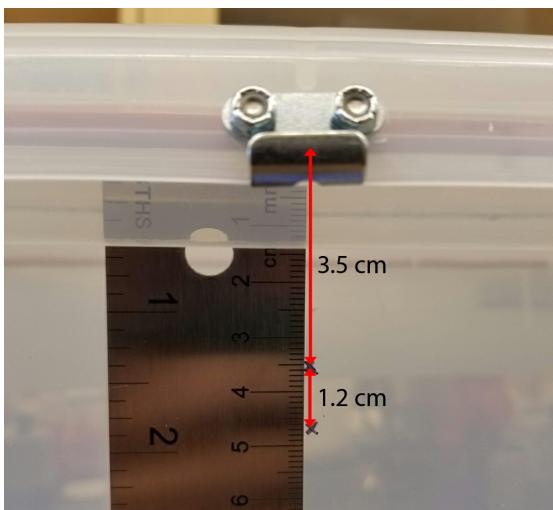
Apply X2 onto the lip of C6



Fasten C6 onto the chamber with C7, C8, and C9. Note the orientation of the hinge and handle of C6.

- 24 Place the assembled lid (L) onto the top of the chamber. Mark holes onto the chamber by referring to the picture below, making sure that the holes are aligned with the center of the strike plates fixed onto the lid. The measurements start from the highest point of the lip of the chamber, so a flat ruler will be useful when making these measurements.

There are a total of 10 strike plates on the lid, therefore there should be 20 marked holes on the chamber (2 per strike plate). Drill out the holes with a 9/64" high speed steel drill bit.



Mark the locations of the drill holes

- 25** Fix the latches of L3 onto the drilled holes with C10, C11, C12, and C13. Ensure that the latch is oriented properly by referring to the picture below. From inside to outside, the parts would be arranged as: C12, chamber wall, C10, latch, C13, C11.



Fix the latch onto the chamber



View from the inside of the chamber

- 26** Use a blade or a pair of cutting pliers to remove the strain relief molding on one end of C15.



Before removing the strain relief molding



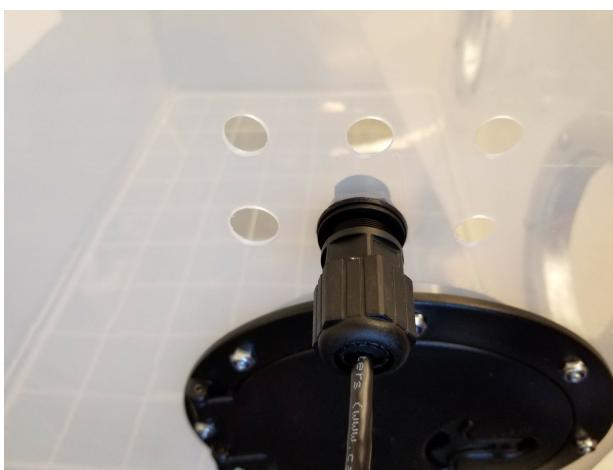
After removing the strain relief molding

- 27** Plug the modified end of C15 into C14 by referring to the picture below. The individual parts of C14 should be disassembled prior to doing this.

Re-assemble C14 by screwing the parts together, except the locknut (the rightmost component in the picture below).



- 28** Insert the C14 and C15 assembly into hole "C" drilled onto the left side of the chamber earlier. Tighten the locknut from the inside of the chamber.



View of the C14 and C15 assembly from the outside

of the chamber



View of the C14 and C15 assembly from the inside of the chamber

- 29 Install C16, C18, and C19 into the other holes by referring to the picture below.



View of C16, C18, and C19 from the outside of the chamber



View of C16, C18, and C19 from the inside of the chamber

- 30 Cut off the plug (**NOT THE SOCKET**) of C20. Strip off some of the outer yellow insulation to expose the wires, then strip off some of the insulation on each of the three wires to expose the copper wires.



- 31 Insert the modified end of C20 **from the inside of the chamber** through the C19 installed earlier. Pull the entire length of C20 through C19 until the receptacle of C20 is left in the chamber. Tighten the gland nut of C19 to immobilize C20.

The length of C20 in the chamber can be adjusted at any time by loosening the gland nut of C19.



Installing C20 onto C19.

32



Install the exposed wires of C20 into C21 by referring to the picture below and the markings on C21. The black wire of C20 is the "Live" wire; white is "Neutral"; green is "Ground." **Ensure that the wires are connected correctly;** improper connections could result in damage of electrical equipment. Double, triple, and quadruple check the connections before closing and tightening C21.

If you are uncomfortable with this step, seek assistance from a qualified electrician.

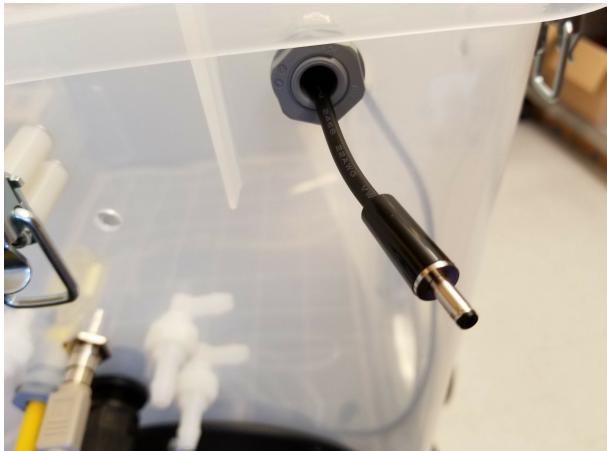


Connect the wires of C20 correctly!



Close and tighten C21

- 33 Install C22 and C.L into the upper right hole "B" drilled onto the left side of the chamber earlier.



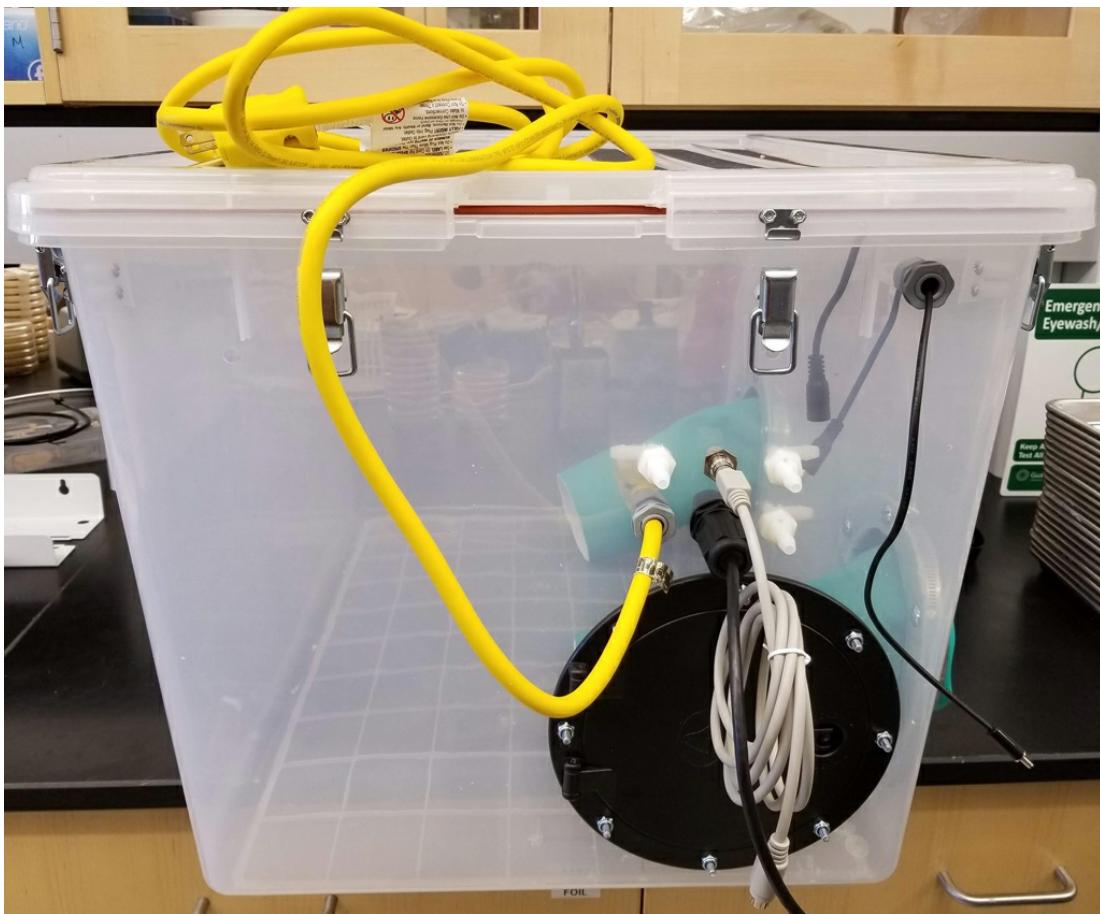
View of the installed C22 and C.L from the outside of the chamber



View of the installed C22 and C.L from the inside of the chamber

- 34 Plug C17 into the C16 installed earlier. The chamber is now complete.

The X2 applied to C2 and C6 should be allowed to cure overnight before using the chamber in further assembly, and for at least three days before operating the chamber with samples.



A completed chamber. Ignore the green glove sleeves inside the chamber; those are installed in later steps.

(A.C) Dry and wet columns

35 The dry and wet columns (A.C) will contain reagents for humidifying and dehumidifying the air inside the chamber. The parts required are:

- 2 ea. A.C1
- 2 ea. A.C2
- 4 ea. A.C3

Recommended special tools:

- Z3
- Z4



Overview of parts needed for assembling the dry and the wet columns (A.C). The roll of tape with a red label is a roll of teflon tape which is optional.

- 36** Discard the sponges inside both pieces of A.C2. Insert each A.C2 into each A.C1, taking note of the orientation in the picture shown below. The gasket of A.C2 must face outwards.



Discard the sponges inside A.C2



Place A.C2 inside A.C1 with the gasket facing outwards

- 37 Fix two pieces of A.C3 onto each A.C1 according to the locations and orientation shown in the picture below. Specifically, the A.C3 on the "OUT" side should be pointing towards the top, while the A.C3 on the "IN" side should be pointing towards the left side if viewing A.C1 from the top.

(Optional) Teflon tape can be applied onto A.C3 before fixing it onto A.C1.



Locations and orientations of A.C3

- 38 Using Z3 and Z4, tap screw holes into the four holes at the top of both A.C3.



(A.S) Solenoid valves

- 39 The solenoid valves (A.S) control air flow into the dry and wet columns (A.C). The parts required are:
- 2 ea. A.S1
 - 4 ea. A.S2
 - 4 ea. A.S3
 - 2 ea. A.S4

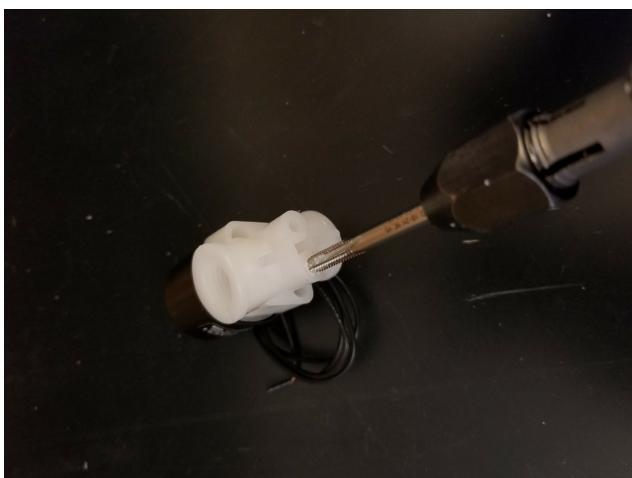
Recommended special tools:

- Z1
- Z3
- Z4



Overview of parts needed for assembling the solenoid valves (A.S.). The roll of tape with a red label is a roll of teflon tape which is optional.

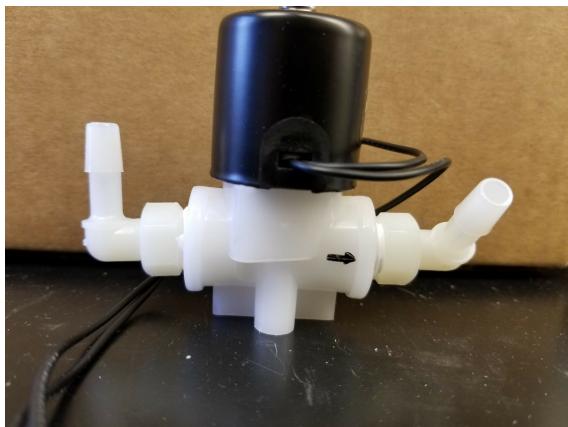
- 40 Using Z3 and Z4, tap screw holes into the two holes at the bottom of both A.S1.



Fix two pieces of A.S2 onto each A.S1 according to the locations and orientation shown in the

- 41 picture below. Specifically, the A.S2 on the side of A.S1 with a painted black arrow should be pointing 45° away from the top, while the A.S2 on the other side should be pointing straight towards the top. In addition, the direction of the A.S2 pointing 45° away from the top should be mirrored for the other A.S1.

(Optional) Teflon tape can be applied onto A.S2 before fixing it onto A.S1.



The A.S2 on the side of A.S1 with a black arrow
should point 45° away from the top, while the other
A.S2 points straight up.



The direction of the A.S2 pointing 45° from the top
should be mirrored for the other A.S1.



View of the completed A.S1 and A.S2 assembly.

- 42** Crimp two A.S3 onto the wires of each A.S1 assembly. This process should be done with Z1. A tutorial on this crimping process can be found at <https://www.instructables.com/id/Make-a-Good-Dupont-Pin-Crimp-EVERY-TIME/>

Once all the A.S3 have been crimped onto the wires of both A.S1 assemblies, insert the crimped ends into A.S4. When inserting them, they should make a soft "click" sound. The solenoid valves are now complete.



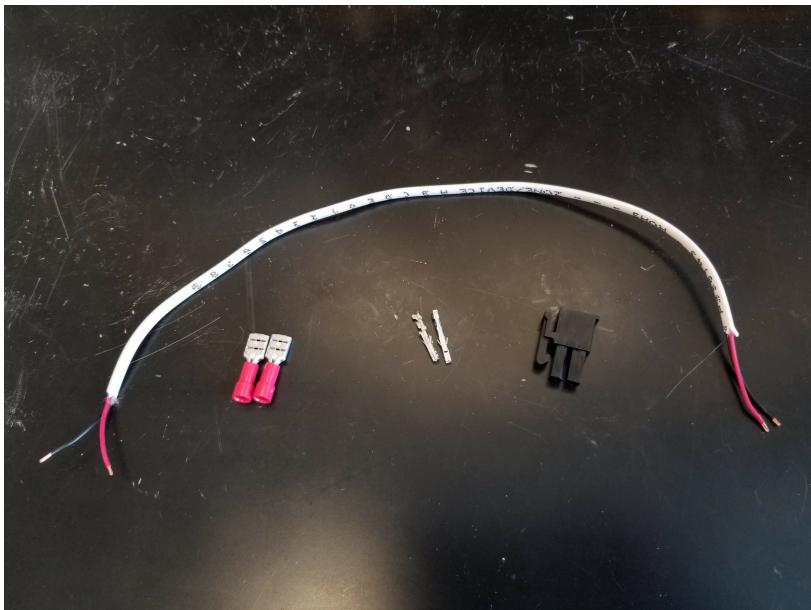
A complete solenoid valve.

(A.P) Pump power cable

- 43 The pump power cable (A.P) is used to provide power to the air pump during operation. The parts required are:
- 15 cm A.P1, insulation stripped at both ends
 - 2 ea. A.P2
 - 2 ea. A.P3
 - 1 ea. A.P4

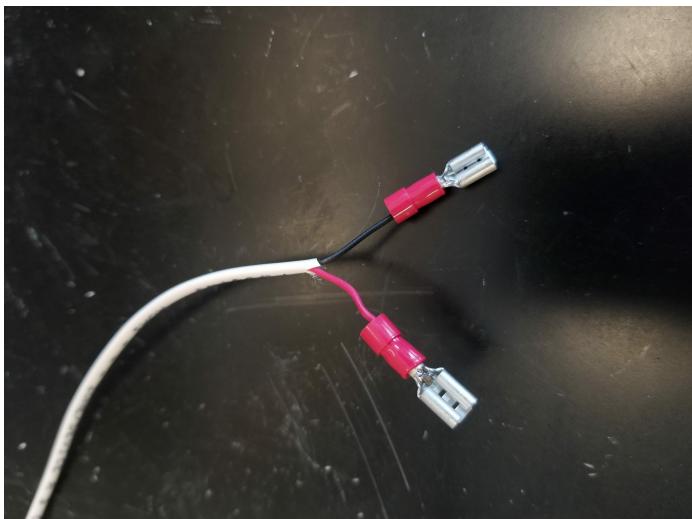
Recommended special tools:

- Z1



Overview of parts required for the pump power cable

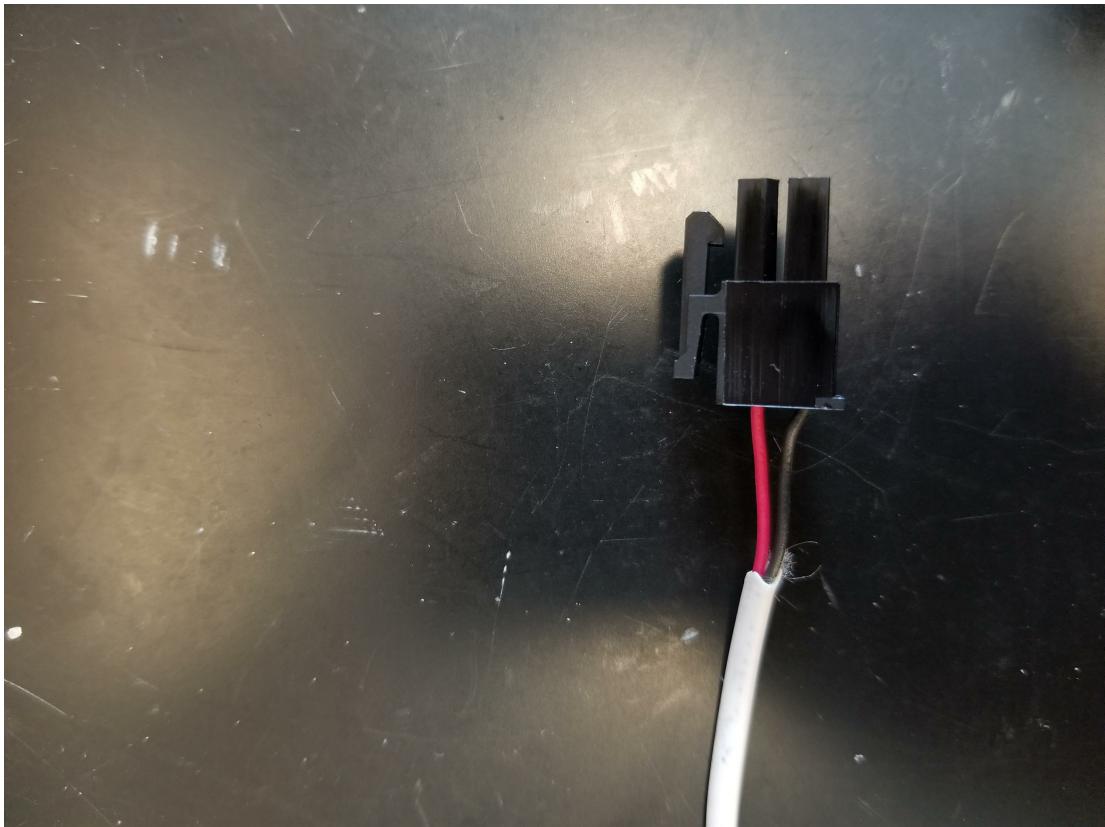
- 44** Using a soldering iron, solder two pieces of A.P2 to the two wires at one end of A.P1.



- 45** Crimp two A.P3 onto the wires at the other end of A.P1. This process should be done with Z1. A tutorial on this crimping process can be found at <https://www.instructables.com/id/Make-a-Good-Dupont-Pin-Crimp-EVERY-TIME/>



- 46 Insert the crimped ends of A.P1 into A.P4. When inserting them, they should make a soft "click" sound. The pump power cable is now complete.



(A.T) Tubing

47 The tubing assemblies connect the various pneumatic components of the system together. The parts required are:

- A.T1
- 1 ea. A.T2
- 2 ea. A.T3
- 2 ea. A.T4

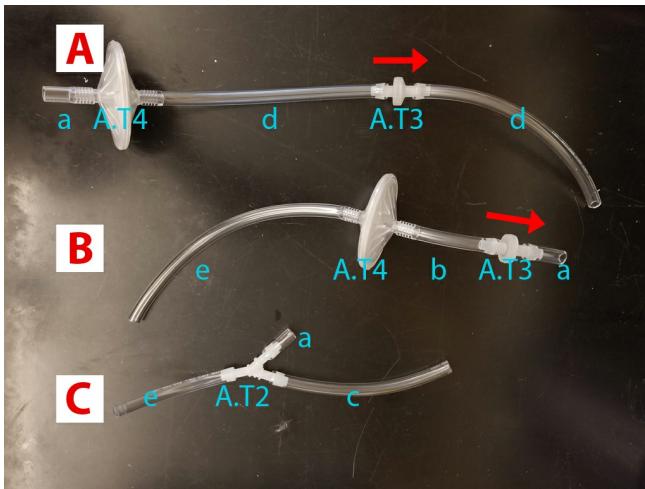
48 Cut A.T1 into several lengths as listed below. Each tube section is labelled for assembly in subsequent steps.

Tube section	Quantity	Length (cm)
a	3	4
b	1	7.0
c	1	14.5
d	4	18.5
e	2	20.5
f	1	22.5

49 Assemble the tubing sections as shown below. The labels (red capital letters) for each tubing assembly will be used in later steps.



A.T3 is a check valve that only allows air to flow in one direction. **Therefore, its orientation is extremely important;** an incorrect orientation will prevent air from flowing in the HumidOSH system. In the picture below, red arrows have been placed to indicate the direction of air flow. The body of A.T3 itself is shaped like an arrow (zoom in the picture to see A.T3 on tubing assembly A) which indicates the direction of air flow. Alternatively, the user could try blowing air through both ends of A.T3 to identify the direction of air flow.

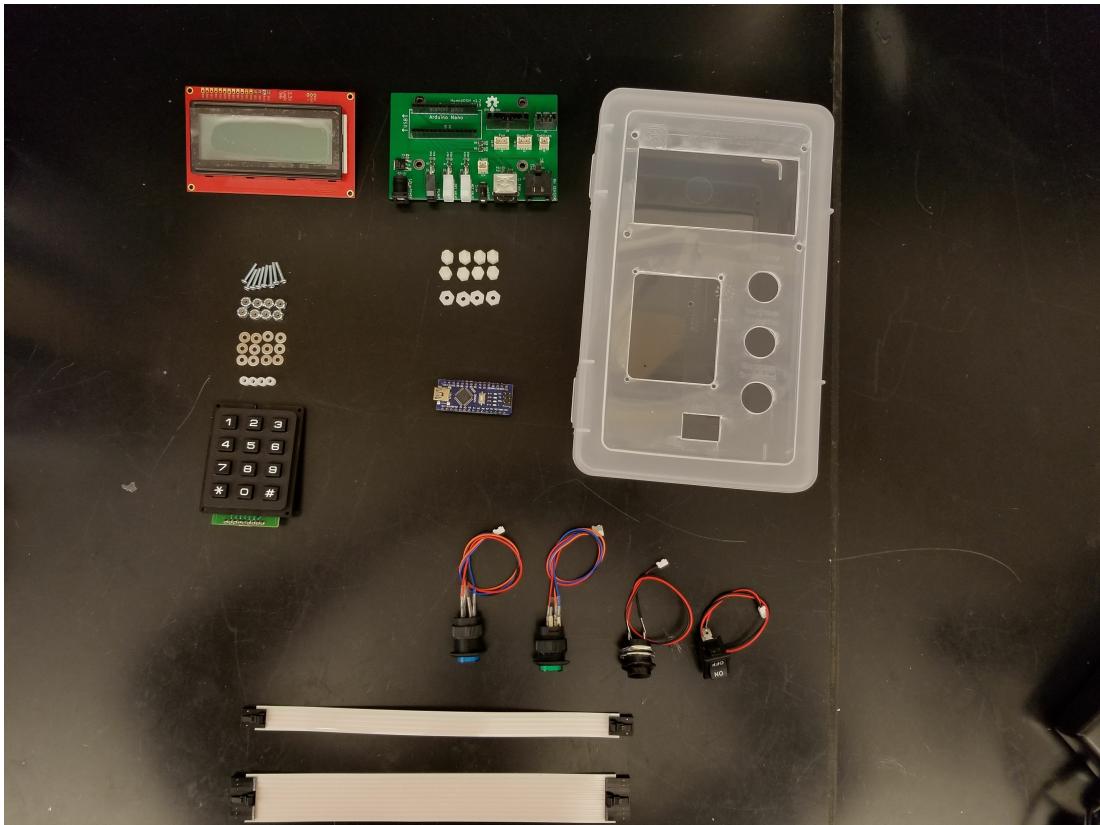


(A.B) Control box

50 The control box (A.B) contains the "brains" of HumidOSH. The parts required are:

- 1 ea. assembled Control Box PCB
- 1 ea. A.B1
- 8 ea. A.B2
- 4 ea. A.B3
- 1 ea. A.B4
- 1 ea. A.B5
- 1 ea. A.B6
- 2 ea. A.B7
- 1 ea. A.B8
- 1 ea. A.B9
- 2 ea. A.B10

- 1 ea. A.B11
- 1 ea. A.B12
- 1 ea. A.B13
- 1 ea. A.B14
- 1 ea. A.B15
- 1 ea. A.B16
- 8 ea. A.B17
- 16 ea. A.B18
- 4 ea. A.B19
- 8 ea. A.B20



Overview of parts for the control box. Some parts are already pre-assembled in this picture.

51

The buttons and switches (A.B5, A.B6, A.B8, A.B9) need to be soldered onto the cable assemblies (A.B7, A.B10). Specifically, A.B5 and A.B6 are soldered to A.B7 while A.B8 and A.B9 are soldered to A.B10. The pictures below show which terminals the wires should be soldered to.



A.B7 only has two wires and polarity does not matter, so the wires can go onto any terminals of A.B5 and A.B6.

A.B10 has four wires and **polarity matters for the red and black wires**. The picture below shows

which terminals the wires should be soldered to.



A.B7 soldered onto the terminals of A.B5. The same thing should be done to A.B6.



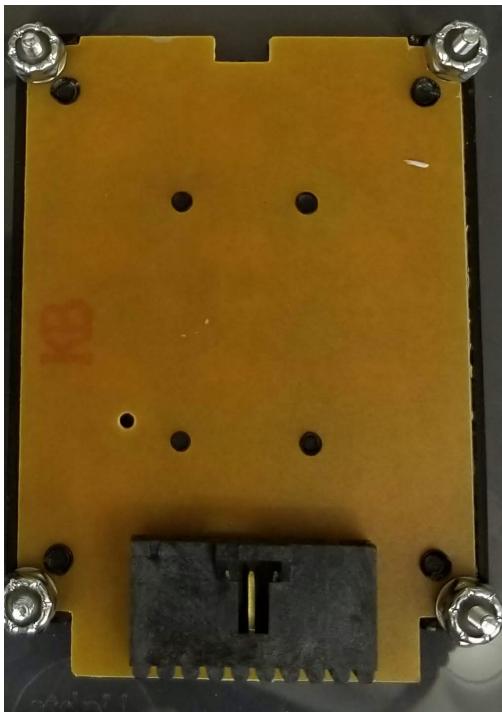
A.B10 soldered onto the terminals of A.B8 or A.B9. The red wire is soldered to the terminal with a "+" sign, while the black wire should be soldered to the "-" terminal. The orange and blue wires can be soldered to the remaining two terminals in any order.

- 52 Solder A.B12 onto A.B11 by referring to the picture below. Note the location and orientation of A.B12.



A.B12 is the black rectangular plastic piece; A.B11 is the red board.

- 53 Solder A.B15 onto A.B14 by referring to the picture below. Note the location and orientation of A.B15.



A.B15 is the black rectangular plastic piece;
A.B14 is the brown board. Ignore the nuts on
the corners of A.B14.

- 54** Hole cutouts must be made on the front of A.B1 before the other parts can be installed onto it. It is highly recommended to use a laser cutter with the provided template files at <https://osf.io/qg5f6/>. Alternatively, the laser cutting template can be printed out and be used as a template for manually cutting out the holes with a utility knife or hobby knife.

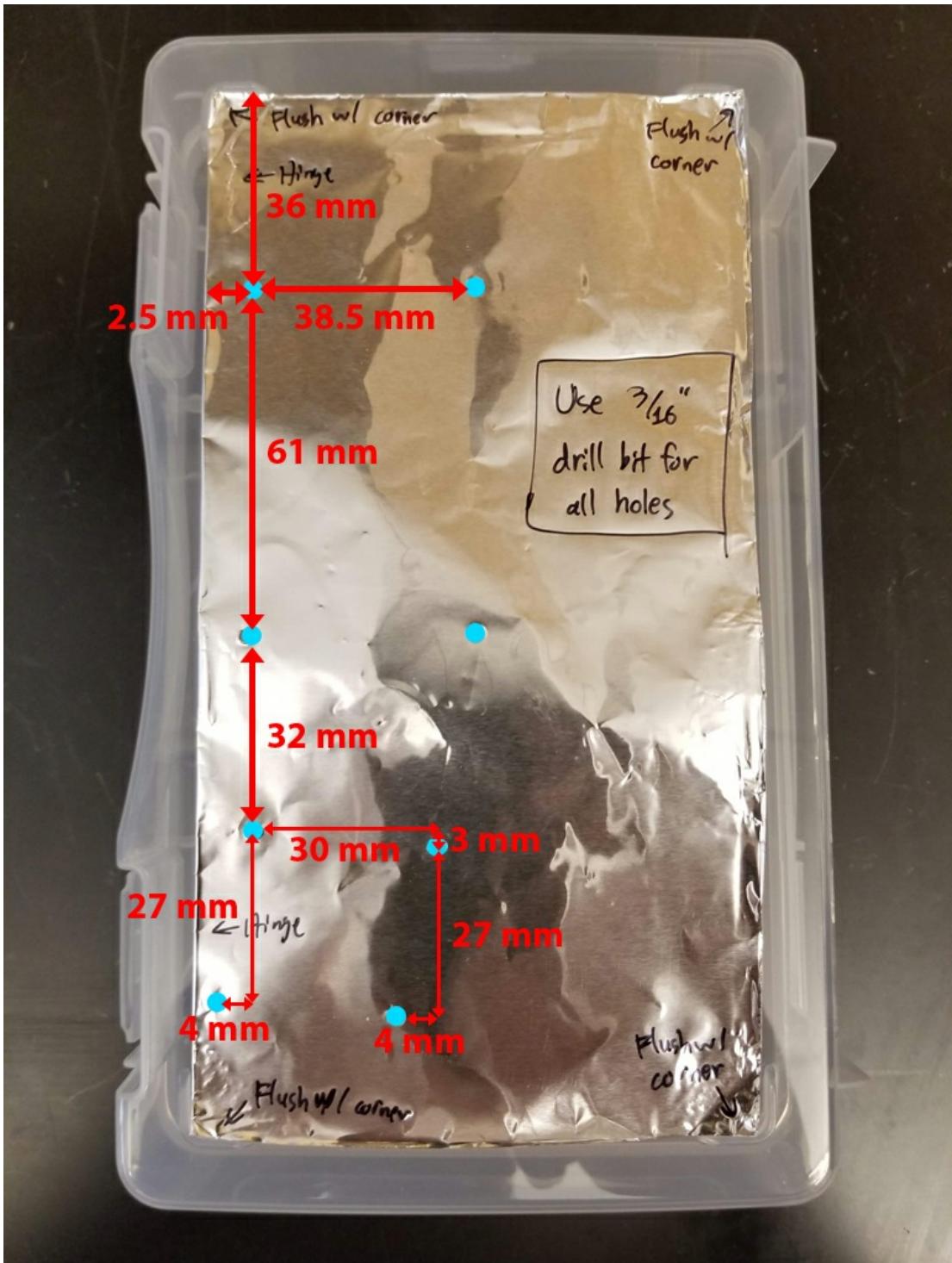
A rectangular hole on the right side of A.B1 must be carved out manually using a utility knife or hobby knife. The hole should be approximately 10.5 cm long and 2 cm high. It should be located close to the upper hinge of A.B1 (see the picture below).

NOTE: When manually cutting holes with a utility knife or hobby knife, it is recommended to heat A.B1 in an oven to 45°C to soften the plastic and make it easier to cut. Take all necessary precautions when handling the sharp knives.

A few holes need to be drilled into the back of A.B1 for mounting the electronics and the box itself. The picture below shows the location of the holes. It is recommended to use a template when drilling the holes for multiple A.B1. The holes should be drilled using a 3/16" drill bit.



Rectangular hole on the right side of A.B1



Locations of holes to be drilled onto the back of A.B1. An aluminum foil was used as a template here.

Notice the orientation of the box, especially the curved side on the left.

- 55 Install the assembled A.B5, A.B6, A.B8, A.B9, A.B11, and A.B14 onto the hole cutouts at the front of A.B1.

A.B5, A.B8, and A.B9 have a locknut that must be removed before inserting the body through the hole cutout. Then, the locknuts should be installed to secure the buttons onto A.B1.

A.B6 is installed by simply pushing it into the hole cutout.

A.B11 is installed with A.B17, A.B18, A.B19, and A.B20 on each of its four corners. The picture below shows how each part is installed.

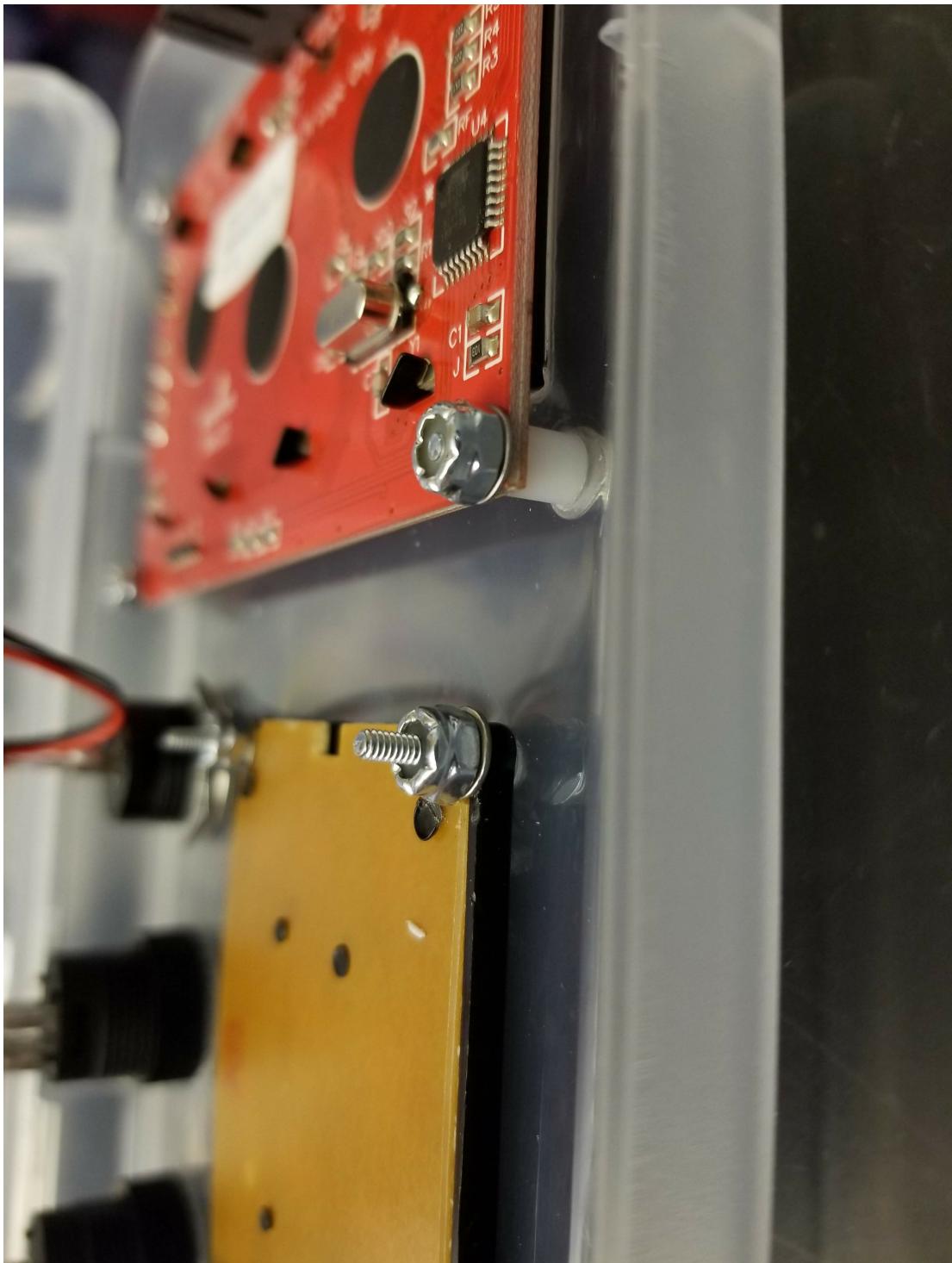
A.B14 is installed with A.B17, A.B18, and A.B20 on each of its four corners. The picture below shows how each part is installed.



Outside view of the parts installed on the front of A.B1



Inside view of the parts installed on the front of A.B1



Close-up view of how the fasteners are fixed onto A.B11 and A.B14.

- 56 A program/sketch needs to be uploaded to the Arduino microcontroller (A.B4). There are two ways to do this:

Quick & easy (only for Windows computers**)**

1. Download the compiled hex file (HumidOSH.ino.eightanaloginputs.hex) from <https://osf.io/m8wek/> and a hex file uploader program (XLoader) from <http://www.hobbytronics.co.uk/download/XLoader.zip>.
2. Extract the XLoader zip file to an appropriate location.
3. Connect A.B4 to the computer using a USB cable.
4. Open the XLoader.exe inside the folder extracted in step 2.
5. Click the "..." button beside the "Hex file" field and select the compiled hex file downloaded earlier.
6. Click the arrow button under "Device" and select "Duemilanove/Nano(ATmega328)."
7. Check that the "Baud rate" has a value of 57600.
8. Click the arrow button under "COM port" and select the port that corresponds to A.B4. If you are unsure which is the correct port, some trial and error might be required here; simply choose one from the list and press the "Upload" button. Most of the time, the port is NOT COM 0 or COM 1. If an error occurs or the program doesn't seem to function after a while, repeat the upload process with another port until you find one that succeeds.
9. The HumidOSH program is now uploaded.

Advanced method (**requires knowledge of Arduino IDE, but works in all operating systems**)

1. If you do not have the Arduino IDE, it can be downloaded from <https://www.arduino.cc/en/main/software>
2. Download the source code and libraries for HumidOSH from <https://github.com/kiatAWDSA/HumidOSH>.
3. Install the libraries by following the "Manual installation" instructions at <https://www.arduino.cc/en/guide/libraries#toc5>.
4. Connect A.B4 to the computer using a USB cable.
5. Upload the HumidOSH.ino sketch, making sure to choose Arduino Nano for the board, ATmega328P for the processor, and selecting the correct port.
6. The HumidOSH program is now uploaded.

57

Install the Control Box PCB into A.B1 at the locations of the holes and rectangular cutout made earlier, as shown in the picture below.



To install, first install four pieces of A.B2 into the four holes and secure them from the outside with four pieces of A.B3. Subsequently, align the Control Box PCB on top of them and secure the PCB with four more pieces of A.B2.

Install the programmed A.B4 onto the PCB by referring to the picture below. **Note that the orientation of the USB jack is extremely important;** wrong placement may render the system unuseable.

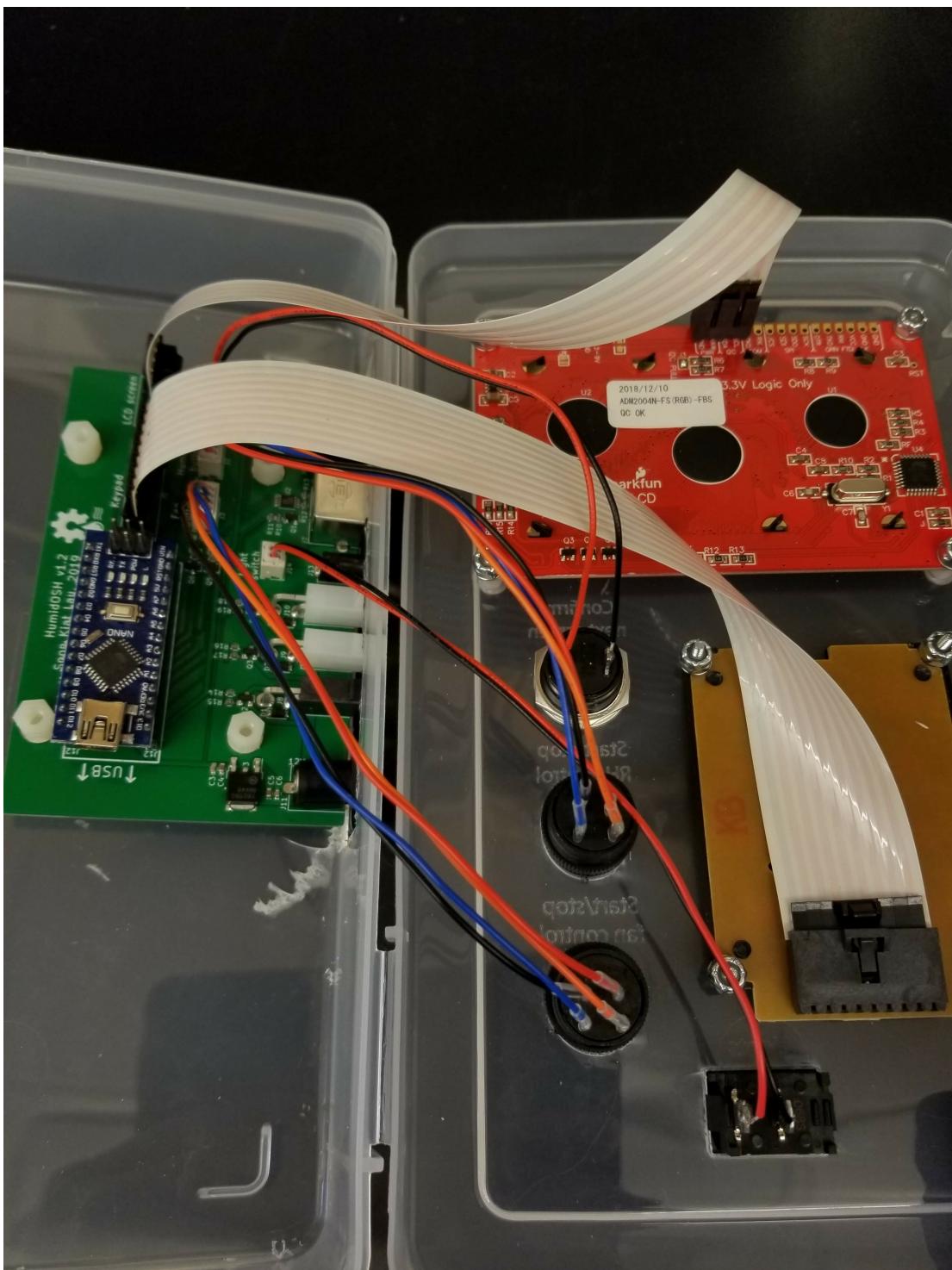


Location of the Control Box PCB relative to the rectangular hole cutout.



Side view of the fasteners used to secure the Control Box PCB.

- 58 Connect the electronic parts to appropriate ports on the Control Box PCB using specific cables by referring to the list and picture below.
- A.B5 to "Settings button" or "J1" using the cable soldered onto A.B5
 - A.B6 to "Light switch" or "J14" using the cable soldered onto A.B6
 - A.B8 to "Humidity button" or "J2" using the cable soldered onto A.B8
 - A.B9 to "Fan button" or "J3" using the cable soldered onto A.B9
 - A.B11 to "LCD screen" or "J4" using A.B13
 - A.B14 to "Keypad" or "J5" using A.B16

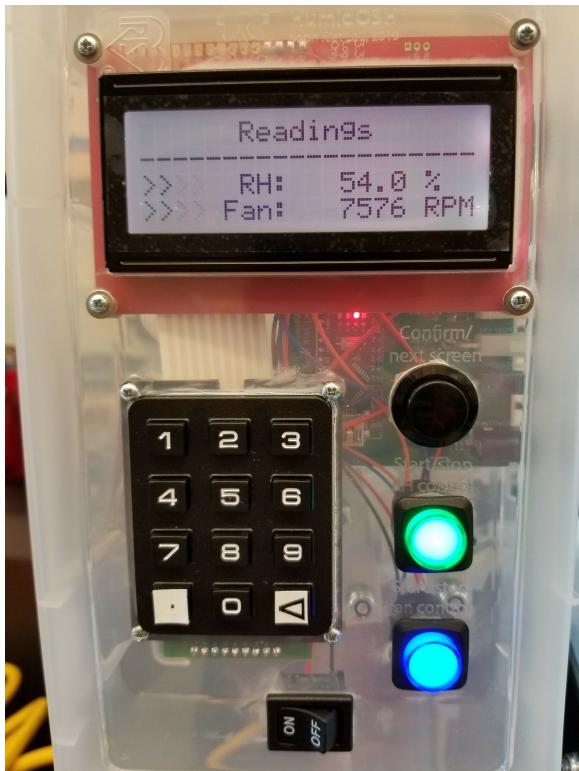


Connect the electronic parts to appropriate locations on the Control Box PCB.

- 59** The control box (A.B) is complete. It is recommended to provide power to the control box with A12 to test if it works properly.

In addition, it is recommended to replace the symbols on the bottom left and bottom right of the

keypad: the asterisk (*) symbol should be replaced with a dot (.) symbol, while the pound/hash (#) symbol should be replaced with something that indicates backspace/delete, such as a left-pointing arrow. These replacements could be done with a labelling tape or sticker.



Front view of the completed control box with power and with humidity and fan controls active.



Back view of the completed control box.

(A) Control assembly

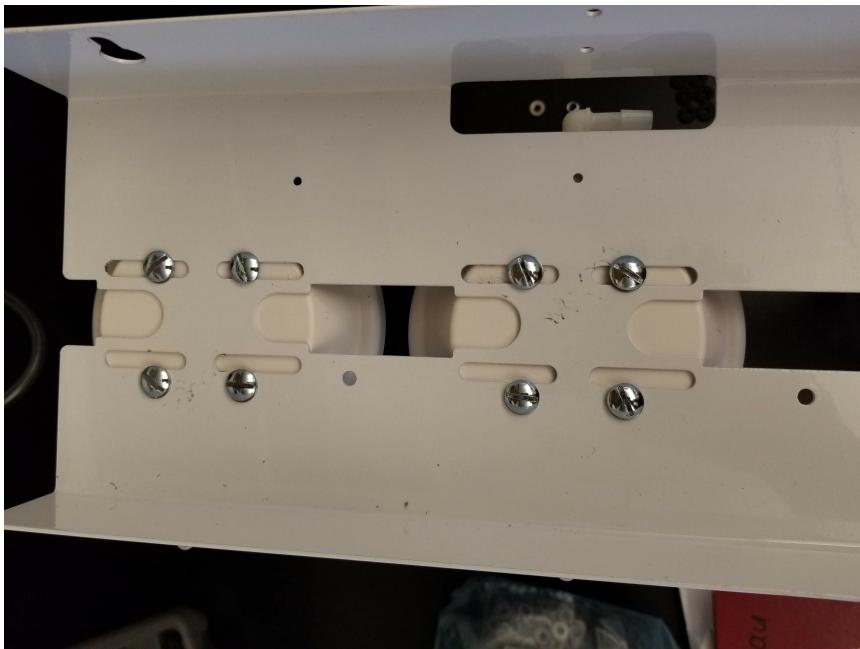
- 60 The control assembly (A) holds almost all of the components that are necessary for controlling the environment within the chamber. The parts required are:
- 1 set A.C (wet and dry columns)
 - 1 set A.S (solenoid valves)
 - 1 set A.P (pump power cable)
 - 1 set A.T (tubing assemblies)
 - 1 set A.B (control box)
 - 1 ea. A1
 - 10 ea. A2
 - 12 ea. A3
 - 2 ea. A4
 - 1 ea. A5
 - 6 ea. A6
 - 2 ea. A7
 - 2 ea. A8
 - 6 ea. A9
 - 6 ea. A10

- 6 ea. A11
- 1 ea. A12
- 2 ea. A13



Overview of the required parts. Not all parts are shown.

- 61 Install both of the A.C columns onto A1 using 8 pieces of A2, with 4 pieces per column. The orientation of the columns relative to A1 are important, so refer to the picture below.

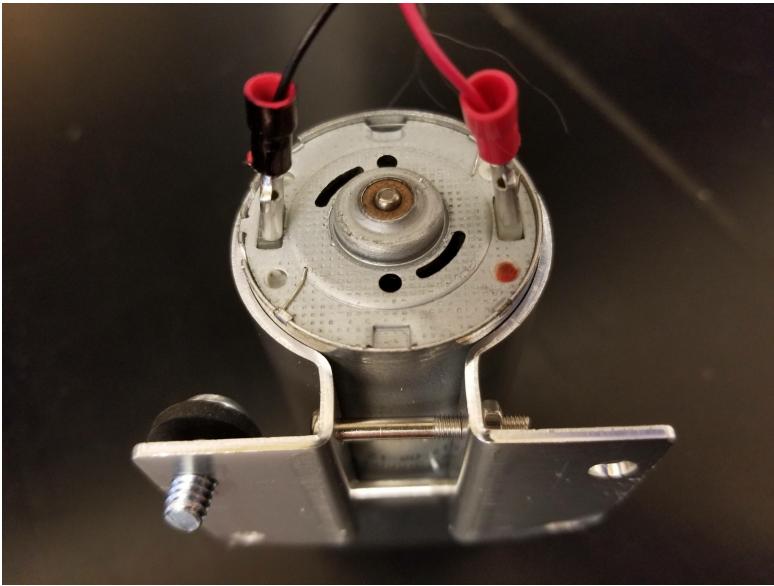


Location of the A.C columns on A1. Note the locations of the screw holes on A2 and the orientation of the tube fittings on A.C. Both A.C have the same orientation.

- 62 Install the solenoid valves (A.S) onto A1 using two pieces of A3 and two pieces of A4. Each solenoid valve only requires one A3 and one A4. Compare the picture below to the one in the previous step to determine the location of the mounting hole and the orientation of the solenoid valves, keeping in mind that the valves are mirror images of each other.



- 63 Attach the female terminal ends of A.P onto the male terminal ends on A5 by referring to the picture below. Note that the red wire of A.P attaches to the terminal of A5 that has a **red dot** beside it. **Connecting the wires in the opposite manner could damage the air pump.**

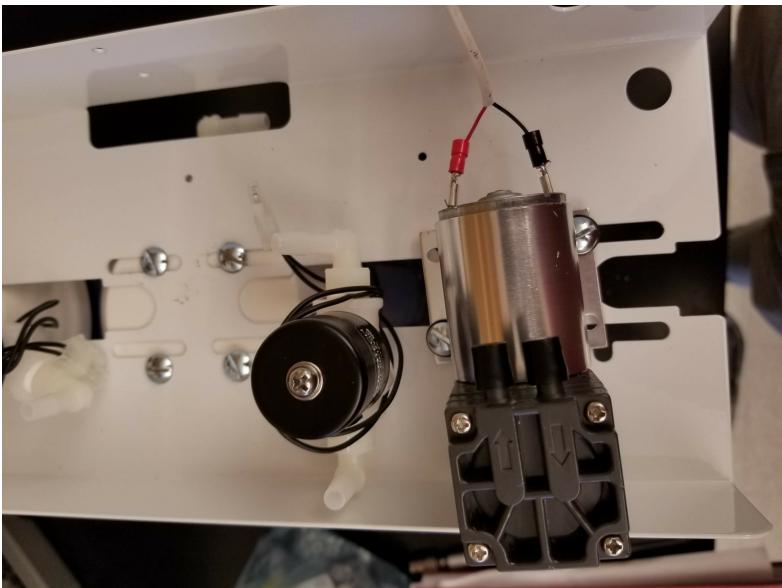


It may help to manually color the connector on the black wire with a black permanent marker.

- 64 Install the A5 assembly onto A1 using two pieces of A2, six pieces of A6, two pieces of A3, and two pieces of A7. The location of the air pump and the order of the fasteners are shown below.

Specifically, the fasteners on A5 follows this order, from top to bottom:

- A2
- A6
- Metal "leg" of A5
- A6
- A1
- A6
- A3
- A7



Location of A5 on A1

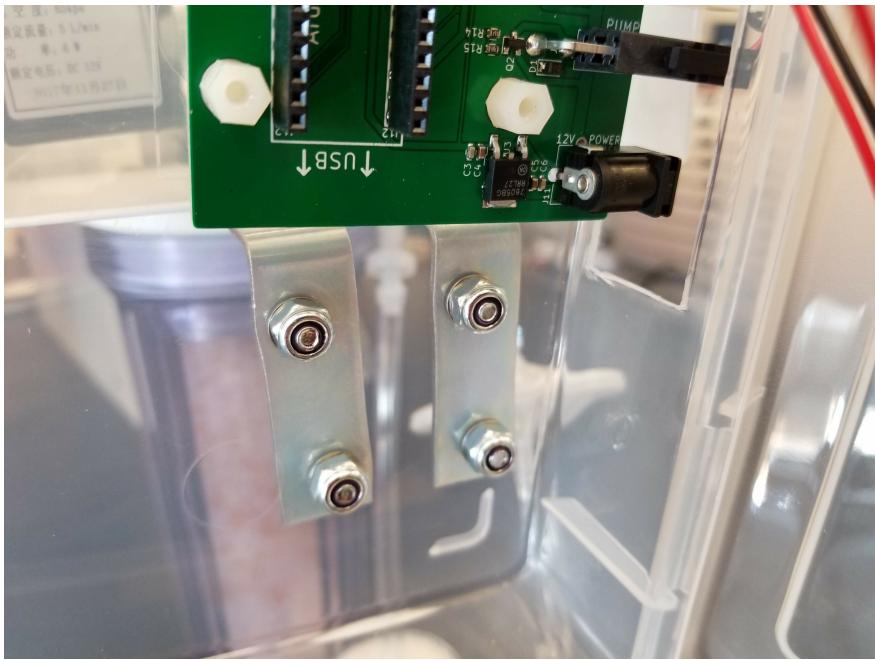


Close-up view of the order of the fasteners for A5.

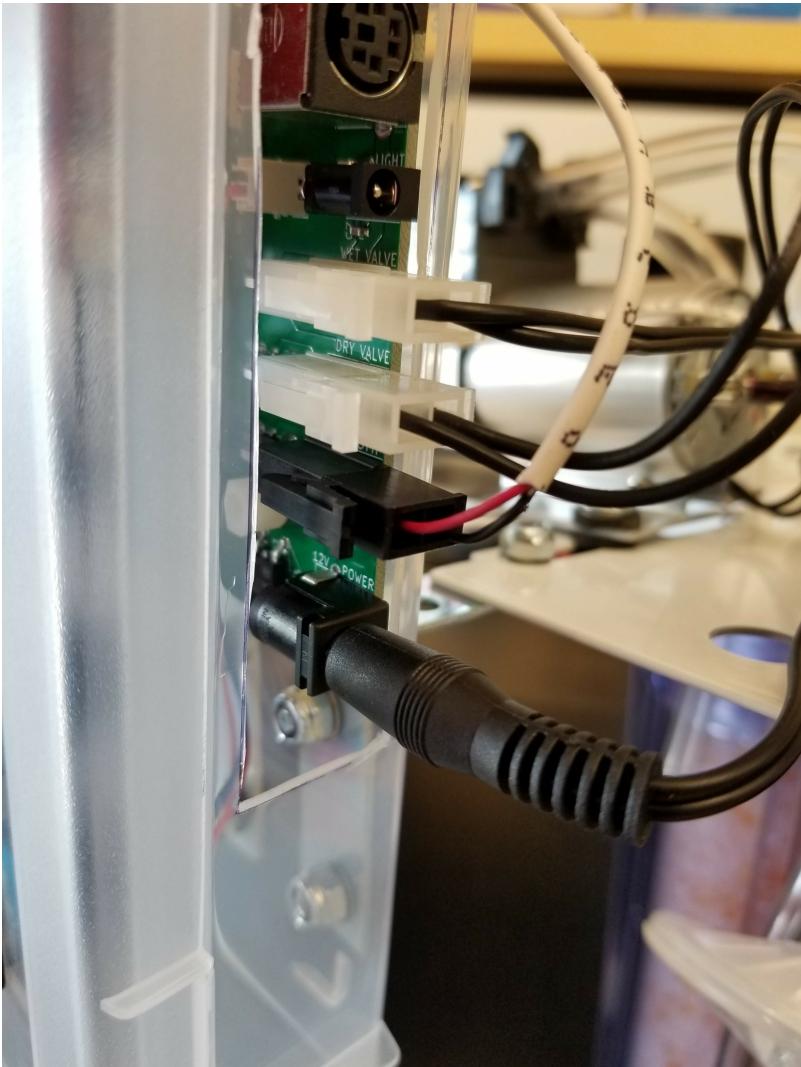
- 65 Install both pieces of A8 onto A1 near A5, using two pieces each of A9, A10, and A11. The screws (A9) should enter from below.



- 66** Mount the control box (A.B) onto the newly-installed A8 using four pieces each of A9, A10, and A11. The fasteners go into the four remaining holes pre-drilled into the back of A.B.

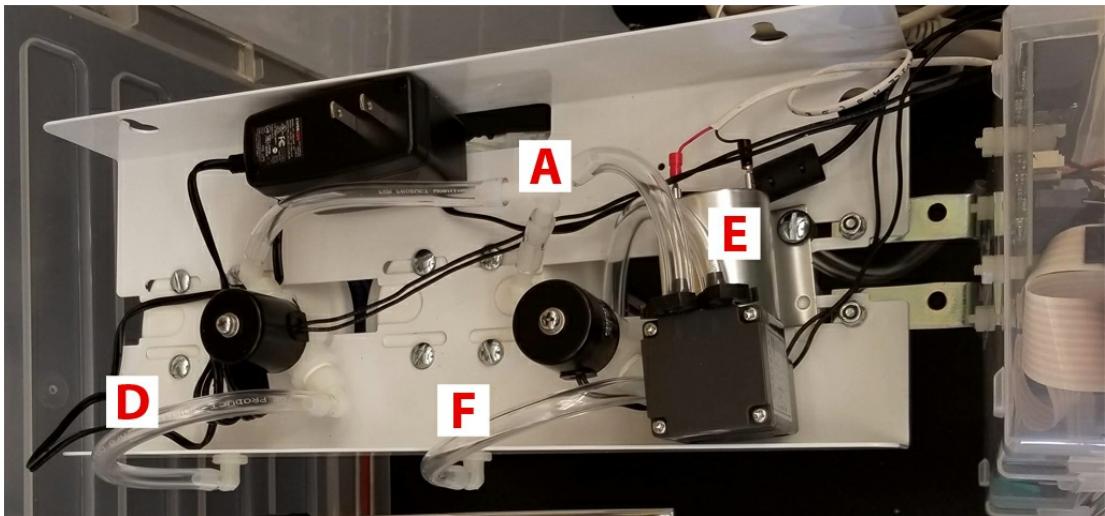


- 67 Connect the wires from the solenoid valves (A.S), the pump (A5), and from A12 into the jacks at the side of the control box (A.B). The solenoid valve furthest from A.B should connect to the "WET VALVE" jack while the solenoid valve closer to A.B connects to the "DRY VALVE" jack.



- 68 Connect the tubing assemblies (A.T) as shown in the picture below. The labels correspond to the ones shown in the steps for making A.T.

Once the tubing have been connected, the control assembly (A) is complete.



Tubing connections from top view of A1.



Tubing connections from side view of A1.

(G) Glove sleeves

- 69 The glove sleeves (G) serve as the attachment point for the disposable hand gloves. The parts required are:
- 1 pair G1
 - 1 pair G2



Overview of the parts required for the glove sleeves (G).

- 70 Use a pair of scissors to cut off the "hands" of G1. Discard the "hands"



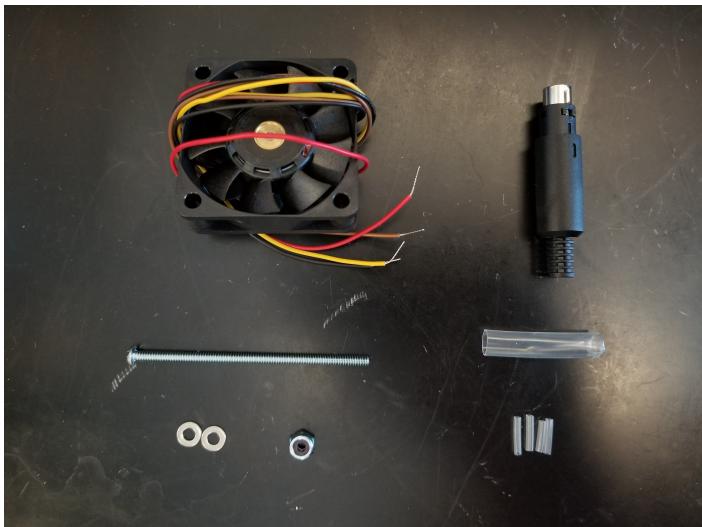
- 71 Insert the white ring of G2 into the "sleeves" of G1, ensuring that the tapering of both parts match. Reserve the black rings of G2 for later steps.



The tapering of G1 and G2 should match. In this and the previous picture, the left side of G1 was bigger than its right side before insertion of G2. Therefore, G2 should be inserted such that its left side is bigger than its right side.

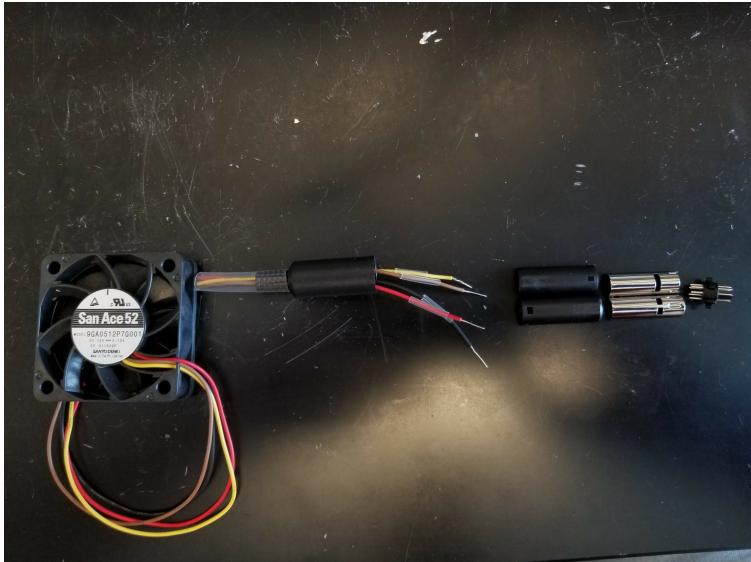
(T.F) Fan

- 72 The fan (T.F) circulates air inside the chamber to improve humidity distribution and to speed up equilibration of the sample. The parts required are:
- 1 ea. T.F1
 - 1 ea. T.F2
 - 1 ea. T.F3
 - 1 ea. T.F4
 - 2 ea. T.F5
 - 6 in. of T.F6, cut into four equal lengths (1.5 in. each)
 - 3 in. of T.F7



Overview of the parts required for assembling the fan (T.F).

- 73 Open up T.F2 and slide its individual parts along with T.F6 and T.F7 over the wires of T.F1 as shown in the picture below.

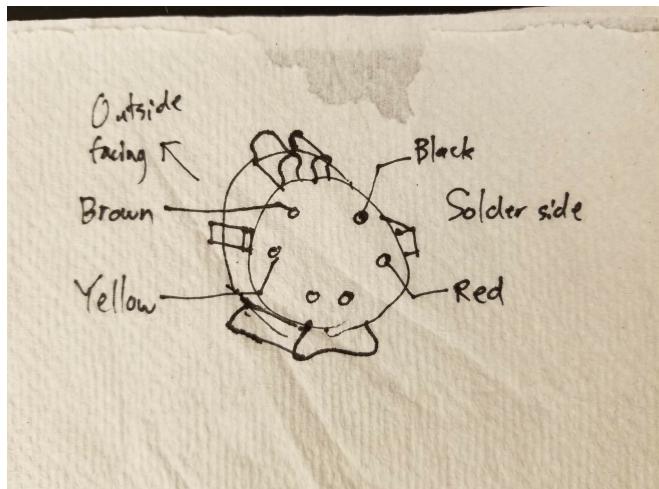
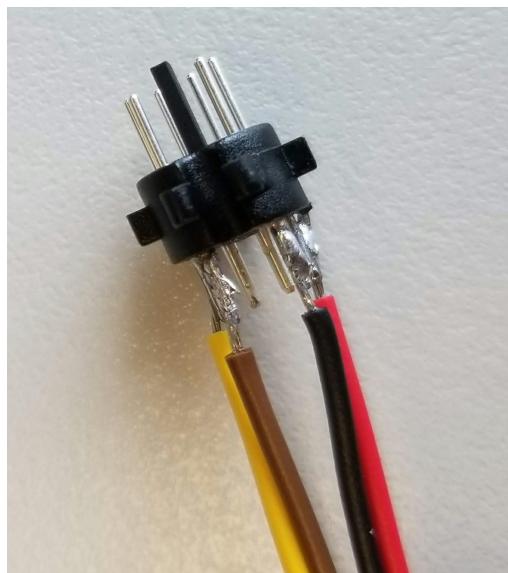


- 74 Solder the wires of T.F2 onto the part of T.F2 which has pins by referring to the pictures below.

One side of the pins has a long black plastic piece; that is the "outside facing" side in the second picture below.

Once the wires have been soldered on, slide the T.F6 pieces over the soldered wire and apply

heat (~80°C) using a heat gun or hair dryer to shrink T.F6 onto the wires.



75 Assemble the other pieces of T.F2 in sequence by following the pictures below.



1

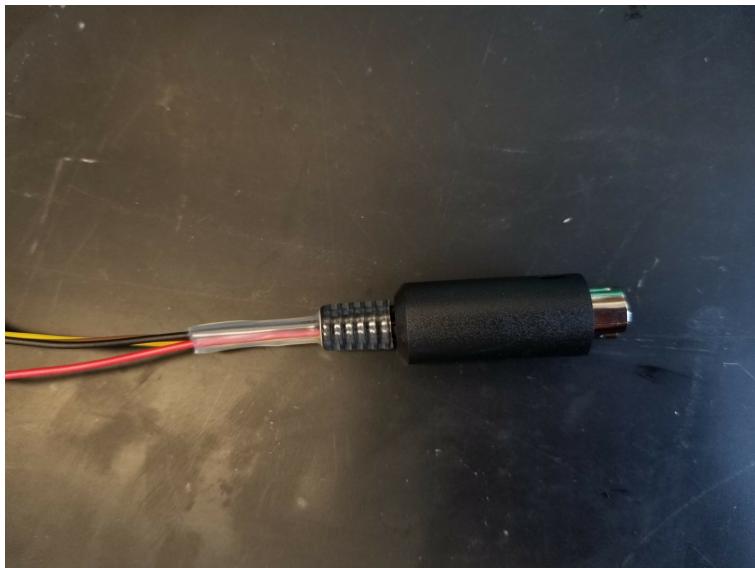


2



3

- 76** Slide the T.F7 piece over the strain relief of T.F2, then apply heat (~80°C) using a heat gun or hair dryer to shrink T.F7 onto T.F2.



- 77** Insert T.F3, T.F4, and T.F5 through the hole in the corner of T.F1 opposite to the wires. Tighten T.F4 and the fan (T.F) is complete.



Insertion of T.F3, T.F4, and T.F5.



Complete fan (T.F).

(T.R) Relative humidity sensor

- 78 The relative humidity sensor (T.R) consists of the "RH sensor PCB" which translates communication signals and the actual relative humidity sensor (T.R1). The parts required are:
- 1 ea. assembled RH sensor PCB
 - 1 ea. T.R1
 - 1 ea. T.R2



Overview of parts required for the relative humidity sensor (T.R)

- 79 T.R1 can actually be installed directly onto the assembled RH sensor PCB, but it will increase the

height profile of the entire sensor which makes it difficult to maneuver around inside the chamber.

T.R2 helps to bring T.R1 close to the PCB to prevent the aforementioned issue. To assemble, simply connect T.R1 to T.R2 according to the pictures below. Subsequently, connect the assembly onto the PCB and the sensor assembly is complete.



T.R1 connected to T.R2.



Complete relative humidity sensor (T.R.).

(T) Tray rack

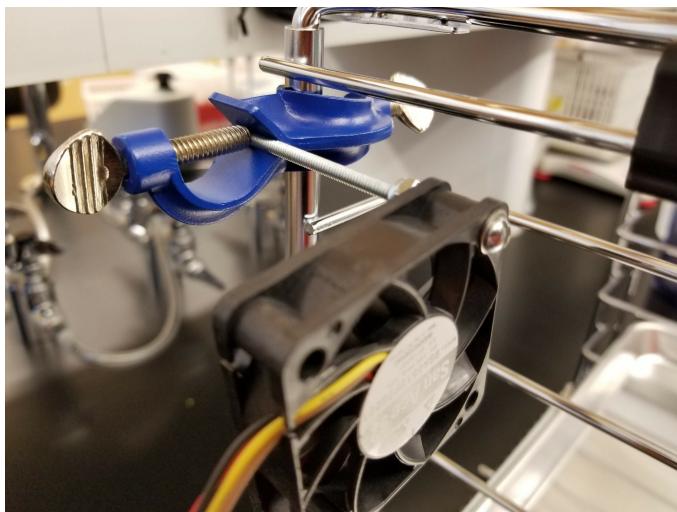
80 The tray rack (T) holds the trays containing samples, the relative humidity sensor (T.R), and the fan (T.F). The parts required are:

- 1 ea. assembled fan (T.F)
- 1 ea. assembled relative humidity sensor (T.R)
- 1 ea. T1, assembled per manufacturer instructions
- As many T2 as necessary
- 1 ea. T3
- 1 ea. T4



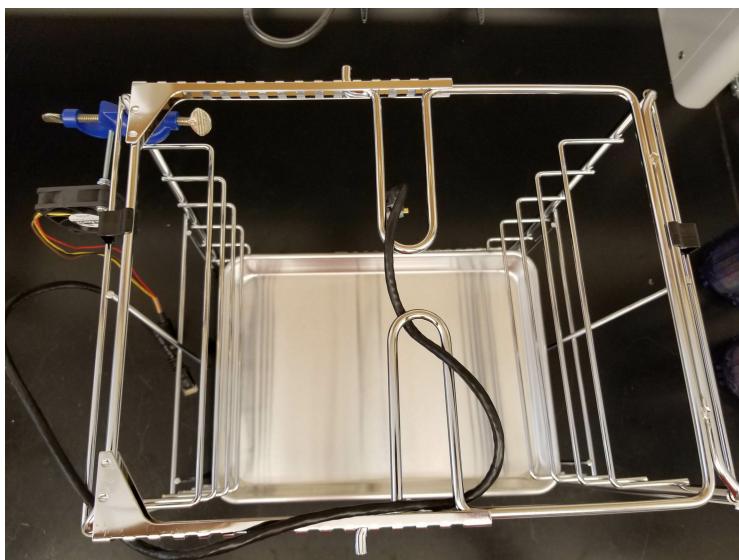
Overview of parts required for the tray rack (T)

81 Install the fan (T.F) onto T1 using T3.



- 82 Attach one end of T4 into T.R and wind T4 around the frame of T1 such that T.R hangs near the center. The goal is to provide support to T.R and prevent it from touching the samples. The tray rack (T) is now complete.

T1 can hold up to 6 units of T2. At this stage, it is not necessary to install T2; that can wait until the system is ready to be used.



Completed tray rack (T) with one T2 at the bottom.

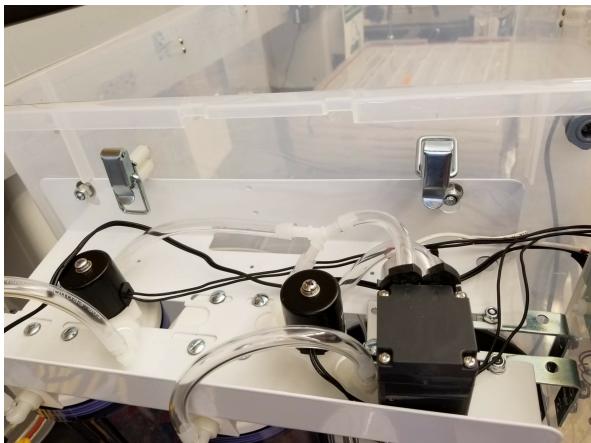
Final assembly

- 83 Congratulations on making it this far! The final step is to assemble all the individual assemblies into the final product, HumidOSH. The parts required are:
- 1 assembled chamber lid (L)
 - 1 assembled chamber (C)
 - 1 assembled control assembly (A)
 - 1 pair assembled glove sleeves (G)
 - 1 assembled tray rack (T)
 - 2 ea. C3
 - 2 ea. C4
 - 2 ea. C5
 - 1 pair G3
 - 2 ea. G4



Overview of the parts required for the final assembly. Not all parts are shown here.

- 84 Install the control assembly (A) onto the side of the chamber (C) using C3, C4, and C5 on the two holes pre-drilled onto the side wall of C.



Outside view of the control assembly (A) installed onto the side wall of the chamber (C).



Inside view of the control assembly (A) installed onto the side wall of the chamber (C).

- 85 Connect tubing assembly "E" (the one connected to the air pump) to the top left tube fitting at the side wall of the chamber.



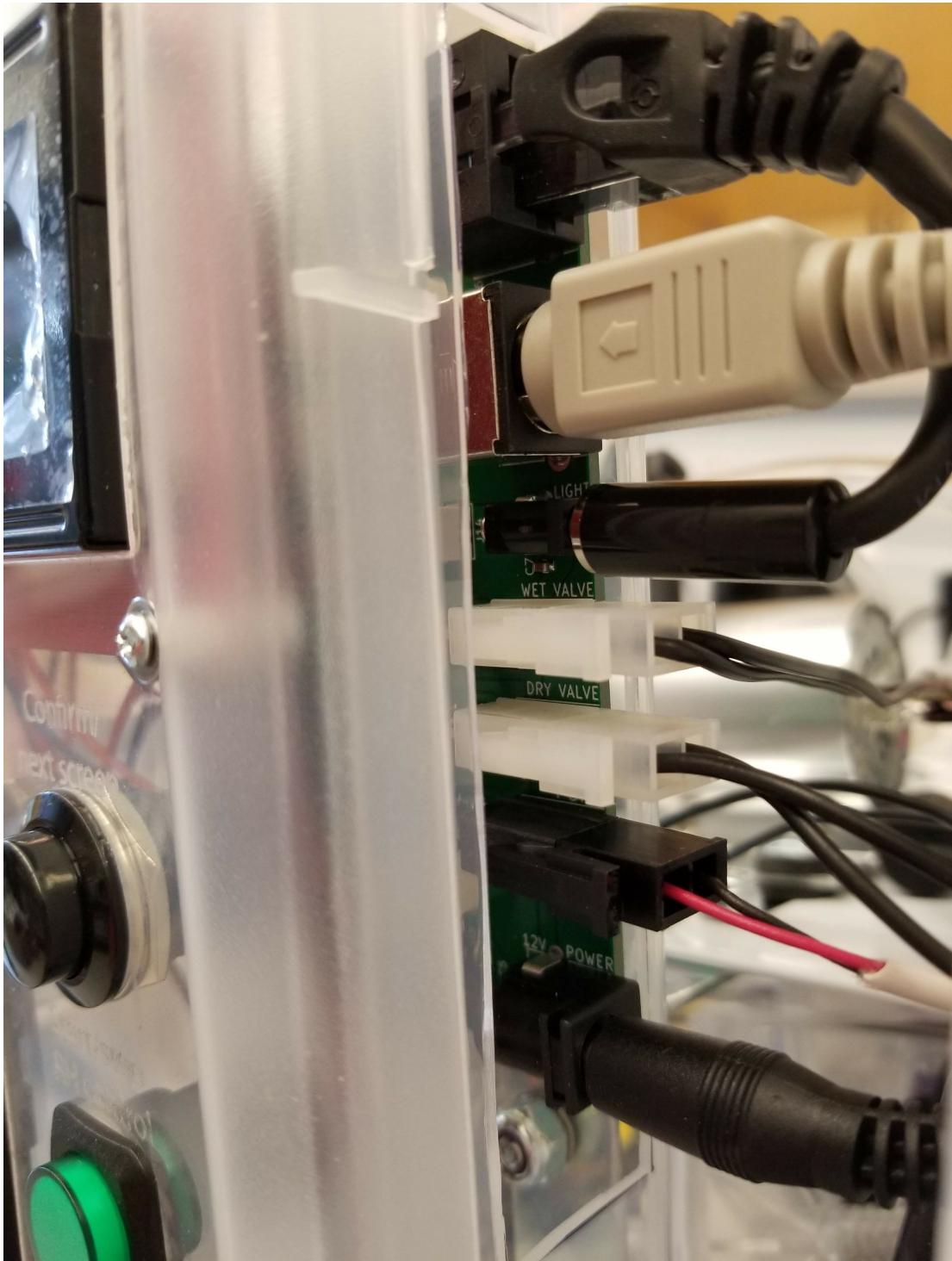
- 86** Connect tubing assembly "B" (the one connected to the closest column) to the top right tube fitting at the side wall of the chamber.



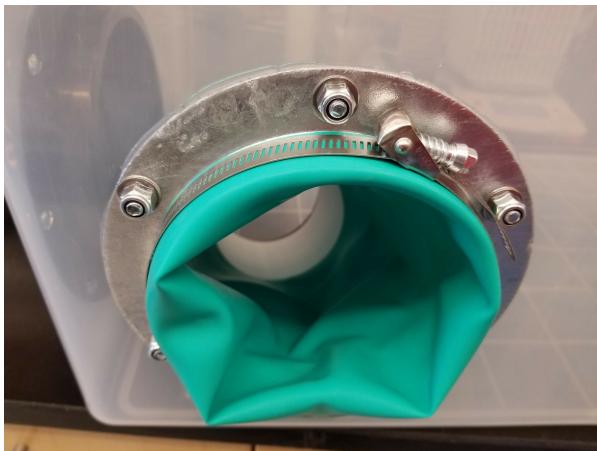
- 87** Connect tubing assembly "A" (the one connected to the furthest column) to the bottom right tube fitting at the side wall of the chamber.



- 88 Connect the cables C15, C17, and C.L that are hanging from the side wall of the chamber to the appropriate connectors on the side of the control box.



- 89 Install the glove sleeves (G) onto the glove ports at the front of the chamber using G4, as shown in the pictures below.



Outside view of the glove sleeves (G) installed onto the glove ports at the front of the chamber.



Inside view of the glove sleeves (G) installed onto the glove ports at the front of the chamber.

- 90** Install the pair of gloves (G3) onto the glove sleeves (G) using the black rings of G2. Wrap the lip of G3 on top of the end of G before sliding in the black ring of G2, ensuring that the tapering of the black ring and white ring of G2 match.



Install G3 onto G.



Secure G3 onto G with the black ring of G2.

- 91 Place the tray rack (T) at the center of the chamber. Connect the cables for the fan and relative humidity sensor to the connectors on the side wall of the chamber.



- 92 When closing the chamber with the lid (L), ensure that the LED strip (L.L) is connected to the LED power cable (C.L). **Remember to disconnect these two cables when removing the lid**, or they might be damaged from pulling off the lid.

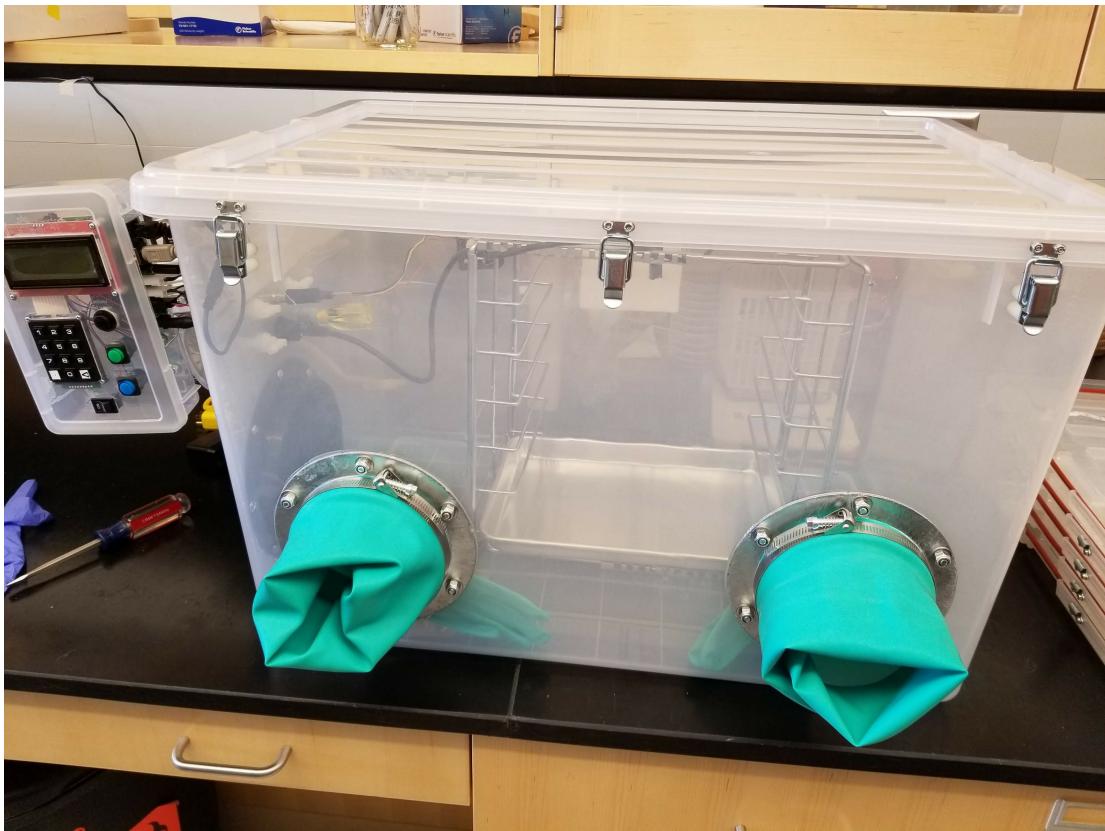


Connecting the power cable for the LED strip.

93 Close the latches on the lid and the HumidOSH system is ready for use!

Before first use, it is recommended to thoroughly clean the insides of the chambers with a cleaning solution such as 70% ethanol to remove any debris and contaminants. During this cleaning process, ensure that the relative humidity sensor is removed and placed away from the chamber to avoid contaminating the sensor. The chamber should then be left to dry for a few hours with its lid open and preferably with the fan in the chamber running at full speed.

Multiple HumidOSH units can be stacked on top of one another, but it will be better to organize them in a shelving unit for ease of maintenance. A typical 77" W x 72" H x 24" D 4-shelf metal shelving unit can house 6 HumidOSH units with an additional shelf for storing supplies.



Front view of a completed HumidOSH system.



Side view of a completed HumidOSH system.