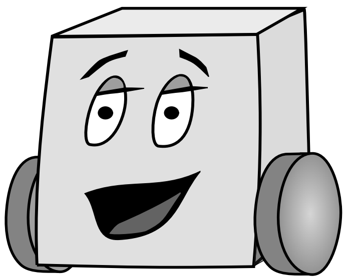


E11: Autonomous Vehicles

Fall 2010

Harris & Lape with Keeter & Ong

Lab 3: Fuel Cell Construction

The goal of the lab is to build a hydrogen-oxygen Proton Exchange Membrane Fuel Cell (PEMFC). This week you will construct all of the necessary components; in next week's lab, you will assemble and characterize your fuel cell.

Introduction

Learning to machine your own parts is extremely valuable. You'll be able to build prototypes for future classes and for your own projects, and you'll also gain intuition about physical limitations of what can be practically manufactured.

There are three student shops in the Libra Complex for wood, metal, and sheet metal. The Design Studio also has drill presses. For this lab, you will use the band saw in the woodshop, the mill in the metal shop, and the drill presses in the Design Studio and woodshop. Having completed the necessary safety training the first week of class, all E11 students are able to use the drill presses, band saw and mill during lab periods with proctors present.

Shop Safety

Don't underestimate the risk of having an accident in the machine shop. The machines can kill you or permanently alter your life. If you ever have any questions about what to or not to do, don't hesitate to ask the shop proctor or your instructor. Guessing what to do next may get you where you want to go, but might not be the best or safest way of going about it.

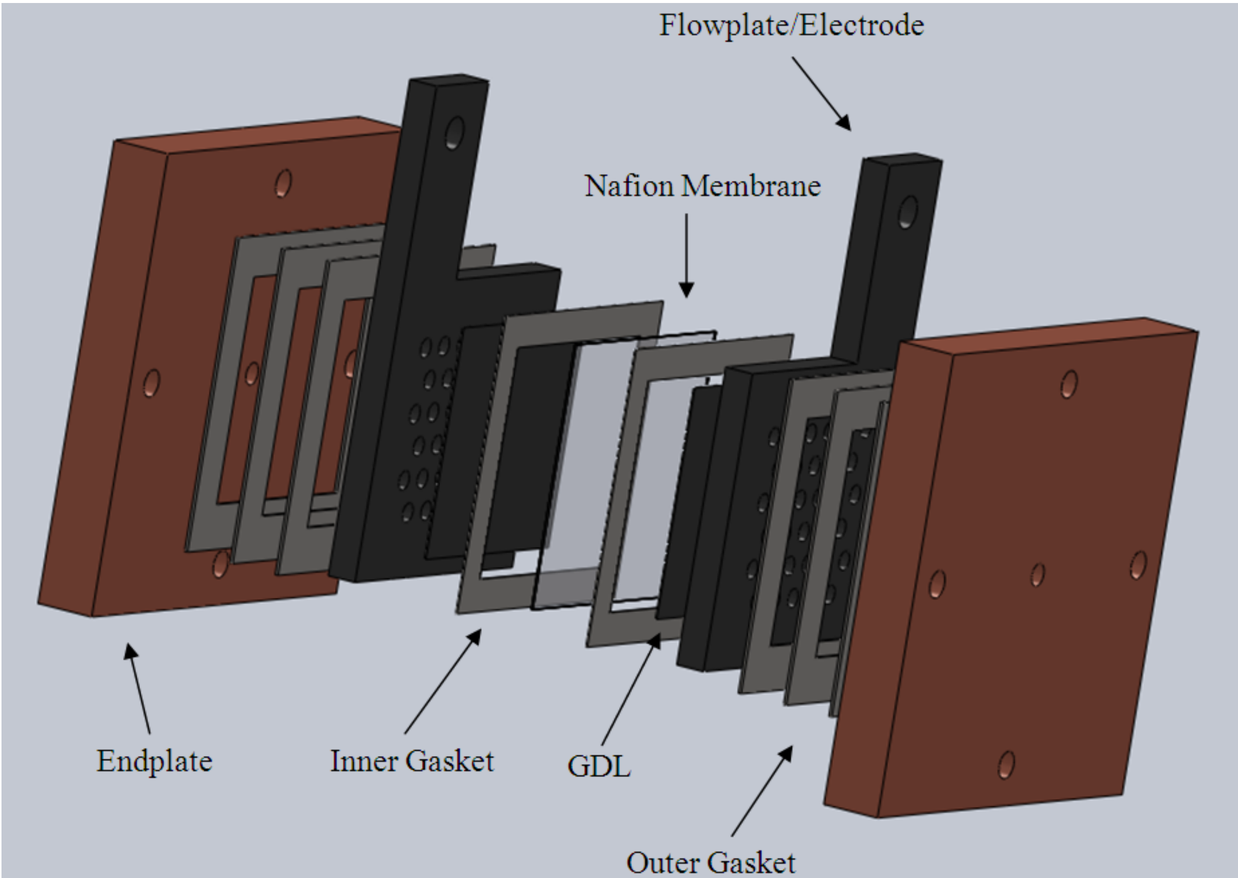
Things to always remember when in the shop:

1. **WEAR** safety goggles, closed toe shoes and at least knee-length bottoms.
2. **AVOID** loose jewelry, long sleeves, unbound long hair, and anything else that could be sucked into a machine.
3. **CLEAN UP** any messes you make. There are plenty of vacuums around the shop.
4. **KEEP AWAY** your hands from sharp blades and bits, preferably as far as is possible.

Additionally, when working with fiberglass you must **wear a dust mask** at all times.

Fuel Cell Overview

The fuel cell is a sandwich made of five types of components: endplates, flow plates, a 5-layer proton exchange membrane (PEM), and two thicknesses of gaskets, as shown below.



In your lab kit you should have:

- 1 rectangle of fiberglass
- 2 L-shaped pieces of graphite
- 1 strip of 20 mil super soft silicone rubber
- 1 strip of 10 mil super soft silicone rubber
- 6 #8 bolts and nuts
- 2 squares of carbon paper
- 4 double-barb double-ended tube connectors

You will need to sign out a pair of calipers from the Design Studio to make your measurements. Be sure to return the calipers at the end of the class.

In this lab, you will machine each of the components, and then assemble the complete fuel cell. You can build the components in any order, so if one machine is busy, consider working on a different component.

Scheduling

Because of the limited number of machines available, you will be put in one of four groups: A, B, C or D. Each group has a different workflow to maximize the three hours of lab time.

<table>
<tr><th>Time</th><th>Group A (3)</th><th>Group B (3)</th><th>Group C (2)</th><th>Group D (2)</th></tr>
<tr><td>0</td><td rowspan="4">Flowplates</td><td rowspan="2">Cut Endplates</td><td>GDL Prep</td><td>GDL Prep</td></tr>
<tr><td>10</td><td>Measurements</td><td rowspan="2">Gaskets</td></tr>
<tr><td>20</td><td rowspan="2">Drill Endplate Holes</td><td>Cut Endplates</td></tr>
<tr><td>30</td><td rowspan="3">Drill Endplate Holes</td><td rowspan="5">Flowplates</td></tr>
<tr><td>35</td><td rowspan="3">Cut Endplates</td><td>GDL Prep</td></tr>
<tr><td>45</td><td rowspan="2">Gaskets</td></tr>
<tr><td>50</td><td rowspan="7">Flowplates</td></tr>
<tr><td>55</td><td rowspan="2">Drill Endplate Holes</td><td rowspan="6">Flowplates</td></tr>
<tr><td>65</td><td rowspan="2">Cut Endplates</td></tr>
<tr><td>75</td><td>GDL Prep</td></tr>
<tr><td>85</td><td rowspan="2">Gaskets</td><td>Drill Endplate Holes</td></tr>
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Flowplate: Mill in Metal Machine Shop

Cut Endplates: Bandsaw in Wood Machine Shop

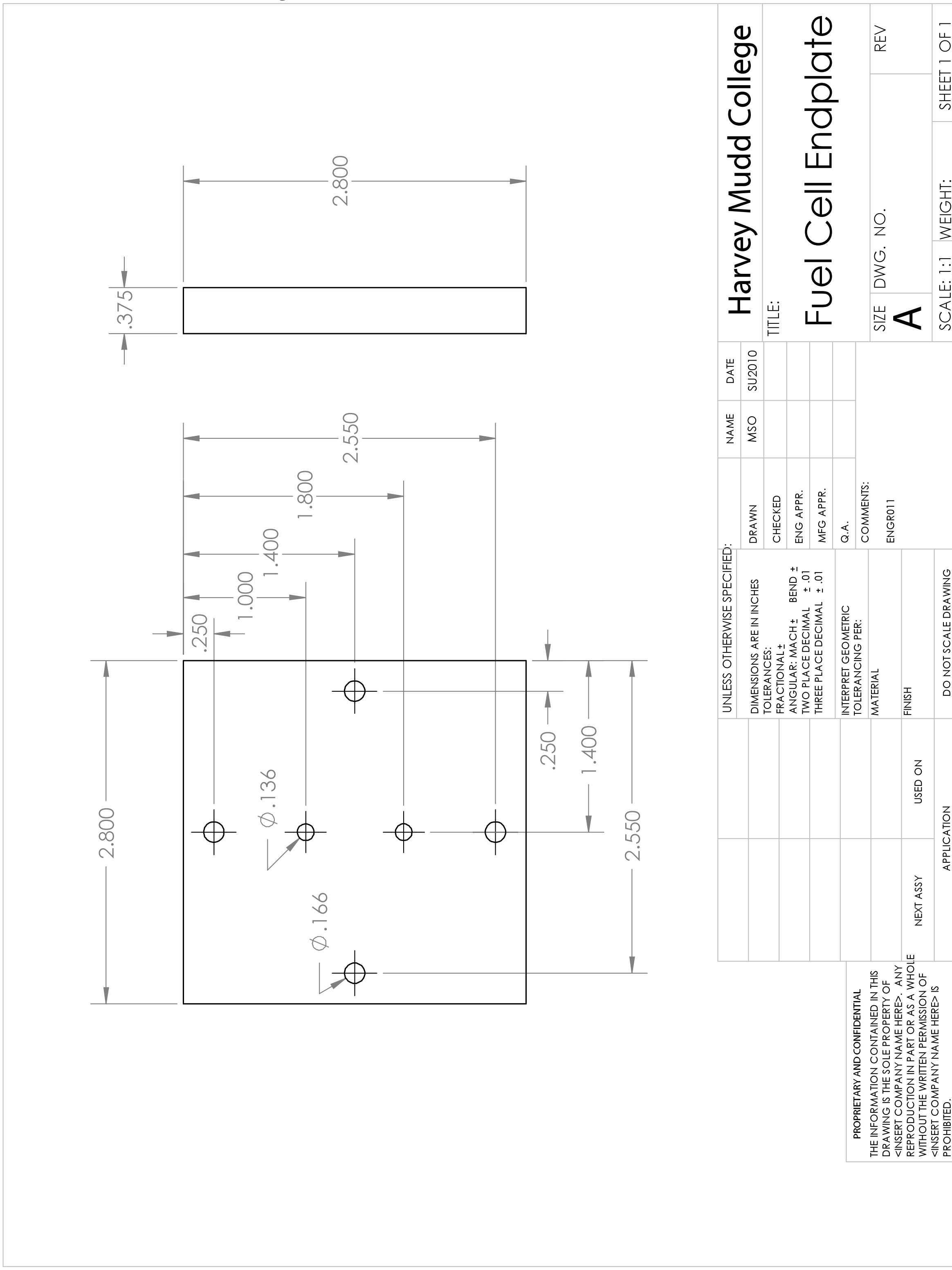
Drill Endplate Holes: Drill Presses in Design Studio and Wood Machine Shop

GDL Preparation: Table in Design Studio

Gaskets: Table in Design Studio

Endplates

The thick red fiberglass endplates hold the fuel cell together. They also contain holes for the inlet and outlet tubes. The draft drawings are shown below.



Cutting Endplates

Your fiberglass has already been cut to approximately 2.80" wide. Mark one side with a line to indicate the reference edge against which future measurements will be made. Remember to put on your dust mask before cutting the fiberglass.

In the woodshop, use the band saw to cut two 2.80" squares from the strip. Measure and mark each cut with calipers before you make it. Make sure the band saw blade guard is lowered to about ¼" above the plate you are trying to cut. Check that the cross-cut fence is square (perpendicular to the edge you intend to cut). Keep the reference edge against the fence. Be sure to account for the width of the blade's teeth. Cut one of the squares. Measure and mark the second and cut it. Now mark the right edge of each endplate using a different notation (such as RT). Note that your cuts are likely to be slightly inaccurate so the part will not be exactly square. This is why it is important to make measurements relative to the reference edges.

Drilling Endplate Holes

Next, mark the centers of the drill holes on one of the plates. Position the plate on the bench with the reference edge facing away from you. Measure all coordinates relative to the reference edge and the edge to the right of the reference edge.

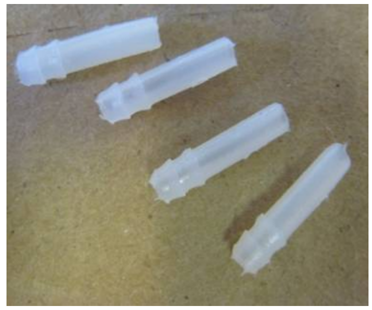
In the wood shop, use the drill presses to drill the holes. Again, make sure you are wearing your dust mask while drilling. Place a scrap of wood on the bottom of the vice so that you don't drill into the metal vice. Clamp the two endplates stacked on top of each other (and on top of the scrap wood) with the reference edge against one of the vice edges. This should hold both endplates securely even if one is slightly wider than the other in the perpendicular direction. Do not remove the plates from the vice until all six holes are drilled, lest you create a misalignment. Remember to keep your reference edges aligned.

Load a 0.165" drill bit in the drill press and tighten it with the chuck key. Drill the four bolt holes around the edges, making sure the bit is centered on your marks and goes all the way through both plates and part way into the scrap without hitting the vice.

Load a 0.136" bit into the drill press and drill the gas inlet and outlet holes in the middle of the endplates.

Before continuing, make sure you vacuum the fiberglass dust.

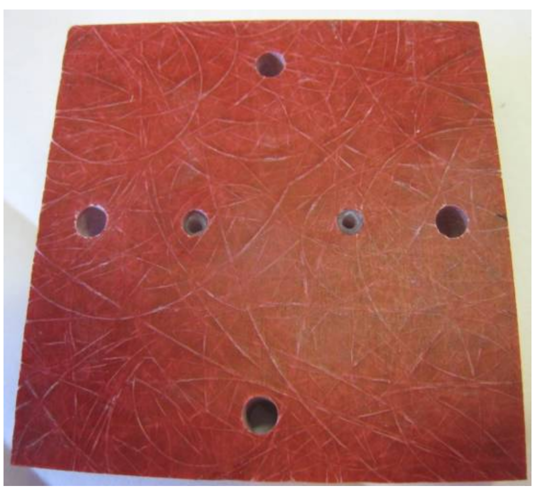
Return to a table in the Design Studio. Using a pair of scissors, cut the barbs off one end of each of the tube connectors, as shown below.

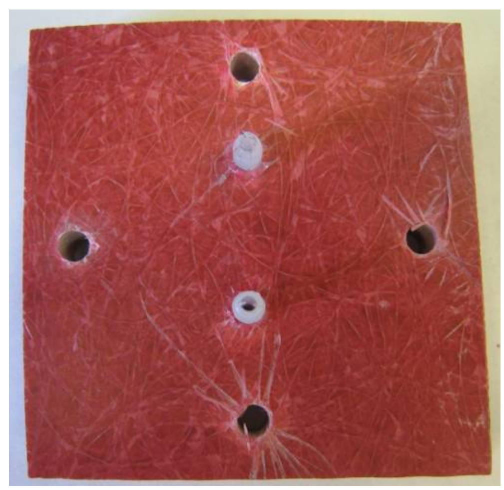


Apply sufficient 3M Silicone sealant around the edge of the newly cut end to prevent the gas from leaking out the gas inlet holes.

Note: Double check that you are putting the gas inlet barbs on the OUTER SIDES of your endplate stack. Otherwise your effort to keep your drill holes lined up will be for nought, and you will not be able to properly bolt your stack together next week.

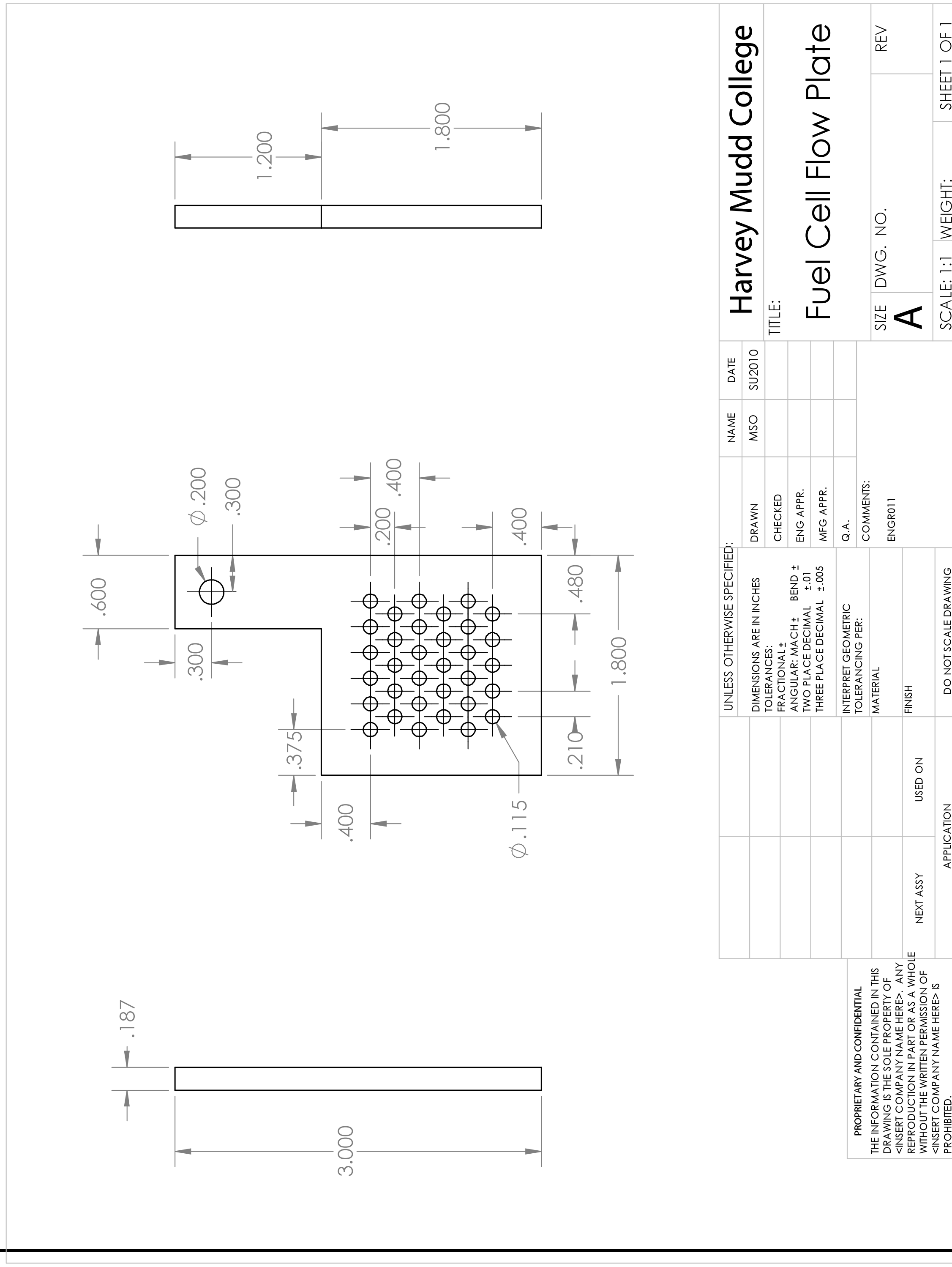
Twist and push the tube connector in until the cut end is just short of being flush with the inner side of the endplate.Both barbs should still be accessible on the outside to attach to tubing. The sealant should have been squeeze up to the side with the barbs, forming a solid seal between the tube connector and the endplate. Add more silicone if you note any gaps between the tube connector and the endplate to prevent leaks.





Flowplates [Graphite Electrode]

The conductive bipolar graphite plates serve as both the electrodes and flow plates of the fuel cell, while sandwiching the MEA layers. There is a hole for a bolt to make it easier to electrically connect to and smaller holes that help disperse the gas evenly across the MEA.



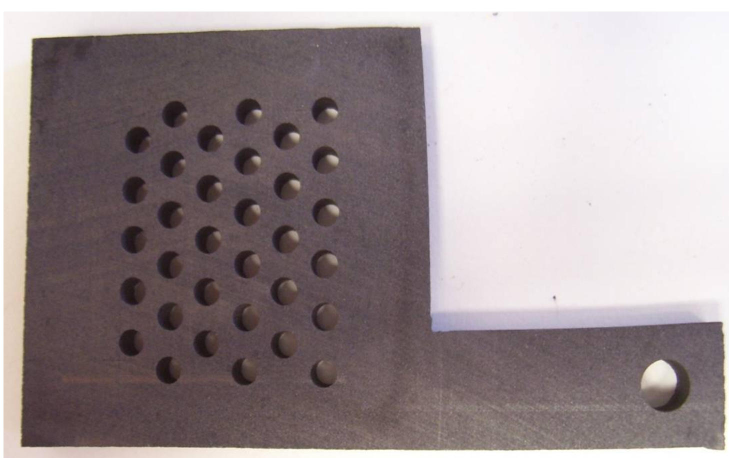
Graphite is delicate and messy to cut, so you will find two precut graphite flow pates in your lab it. Be careful while handling it, because it is breaks easily.

The mills in the metal shop are equipped with precise measurement boxes that are helpful for this job. Use the mills to drill the holes in the flowplate. Start with the larger hole for the terminal bolt. Mark the center of the bolt hole using calipers. Load a drill chuck into the mill's collet and ask the shop proctor for a 0.200" drill bit. Place one of your graphite plates on top of spacers, which raise and support the plates so that the bit will not cut into the clamp. Do not put the spacers exactly under the hole.The metal spacers are not sacrificial and will break the bit if you try to drill through them. Make sure the graphite piece, especially the long finger, is well supported to prevent unnecessary strain on the material. You may find it useful to have an additional spacer under the graphite at an angle, to support the tab as you drill through it. Although it it tempting to drill both plates at once, clamping both securely at once may be difficult so it is better to drill one at a time.

Next, drill the flowplate holes in two sets. The first will be the three rows of six holes, the second will be the three rows of five holes. This is for your sanity and to save time. Remove the piece from the mill vice and mark the location of the upper left and bottom right holes of the grid. These locations are indicated on the draft drawing.

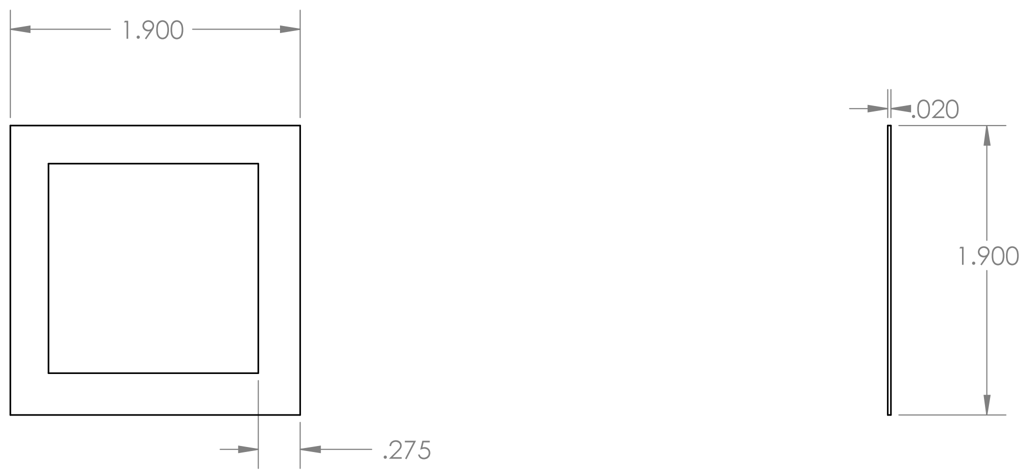
Load a 0.115" drill bit into the mill and center it over the mark you made for the upper left hole. Drill the first hole. Use the Sony measurement box attached to the mill to make your life much easier. Reset the X and Y coordinate measurements. Move the drill 0.210" in the Y direction, down the row. Drill the second hole. Repeat until you have a neat row of 6 holes. When you reach the end of the row, keep the Ydirection constant, and move your piece 0.4" in the X direction so the drill bit is situated to drill the next row of 6 holes. Repeat the aforementioned procedure to make the remaining two ros of 6 holes.

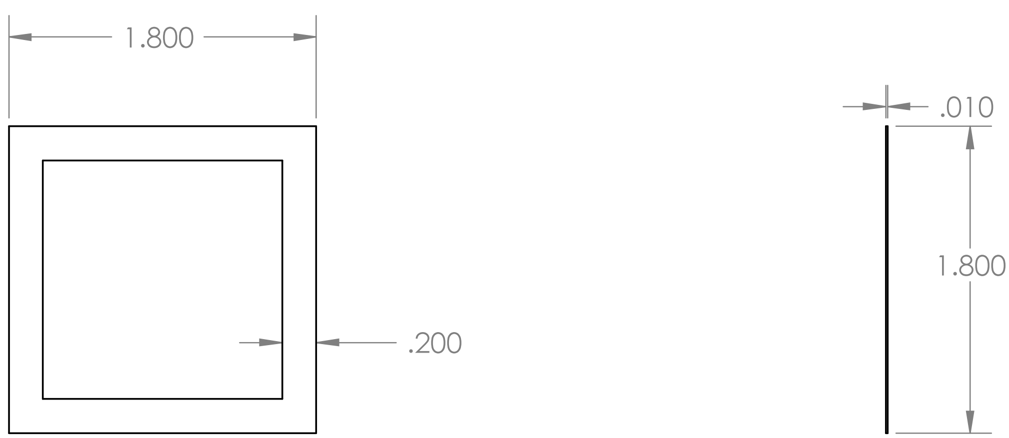
When you finish the 3x6 grid of holes, reposition the bit at the other mark you made for the lower right flow plate hole. Use the same methods as in the 3x6 grid to make the 3x5 grid. Your finished electrode should look like the picture below and adhere to the dimensions given in the drawing above.



Silicone Rubber Gaskets

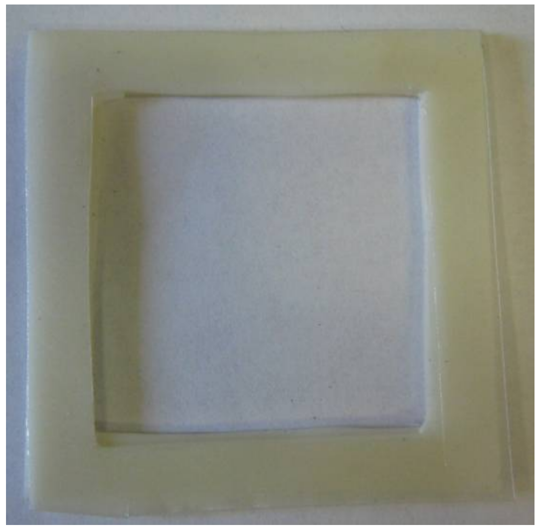
You have two strips of soft silicone sandwiched between harder plastic layers. The thicker one will serve as the outer gasket, while the thinner will serve as the inner gasket surrounding the MEA. In the below drawings, the upper one is dimensions for the outer gasket. The lower one depicts the inner gasket dimensions.





Use the calipers to measure and scissors to cut out appropriately sized silicone squares. You will need six squares of the thicker outer gasket and two squares of the thinner inner gasket. Each square has to be cut individually due to the plastic protection layers. These layers prevent the gasket from accumulating dirt, which will harm your fuel cell's functionality later.

Use the calipers to outline the inner edge of the gasket. The tips of the calipers are sharp enough to make a small groove in the plastic, which you can then follow with your exacto knife. **Get a piece of cardboard to cut on to protect the table's surface.** Use the exacto knife to cut out the inner square. It may be necessary to make multiple passes with the exacto to cut through both layers of plastic holding the rubber. Be careful as the exacto knife slips easily on the hard plastic cover layers. The finals squares should look similar to the picture below.



Make two stacks of three squares each to serve as the outer gaskets. Remove all the plastic from one square, and one side of plastic from the remaining two. Stack these such that the outside is covered in plastic and the inner exposed layers face each other. This will prevent dust from building up on the exposed side.

Leave the inner gaskets in the plastic for now.

Gas Diffusion Layer Preparation

Put on your safety goggles and get a pair of nitrile gloves. You will be handling materials that are easily contaminated by your skin oils. Get a Kimwipe to serve as your “lab station”. Label it with your name and section number.

Cut out two 1.4” x 1.4” squares from the Teflon-treated carbon paper. Be gentle with the carbon paper because it very brittle. Put these to the side, on your labeled Kimwipe.

Rinse your watercolor paintbrush in DI water. Do **NOT** use tap water. Small beakers and squirt bottles of DI water will be provided. Using your paintbrush, paint two thick coats of the Pt/C catalyst ink on one side of each of the carbon pieces. The platinum-based catalyst and carbon paper are very expensive so please do not waste material by painting the Kimwipe! Also, **please do not hog the catalyst ink, as it will be shared amongst all 10 students in your section.** The edge of the carbon paper will overlap slightly with the gasket, so it is not necessary to have the edges completely painted, but try to get as close to the edge as possible. These will be left to dry until next week on the back tables where you did your soldering.