

Scientific Glassblowing Class

The objective of this course is to acquaint the student with basic glassblowing hand operations and techniques. Each class period will begin with a brief demonstration of the particular glass seal to be accomplished, followed by “hands-on” practice of each seal by the student. Successful completion of the course will enable most students to accomplish routine glassblowing tasks encountered in the lab. It will also give you a solid background for preparing sketches and plans that are submitted to the Glass Shop for construction.

The following items will be discussed before we begin the glassblowing lessons:

Safety in the Glass Lab

Most of the safety procedures we will follow are similar to those of any chemistry lab. We will be working around open flames, hot glassware, and sharp edges on the glassware.

The following is a list of important rules for the glass lab:

1. Safety glasses are required at all times.
 - * Each student will be provided with a pair of Didymium glassblowing glasses. These glasses filter the bright sodium glare produced when the glass is heated.
 - * Welder’s goggles are required when working quartz or Vycor glass. These goggles filter harmful ultraviolet light produced as the quartz is heated.
2. Heat only clean, solvent free glassware.
 - * Never heat glass with volatile or toxic materials inside. If you must heat glassware under these conditions, do so in a hood with a safety shield. Also, attach a trapped blow hose to the glass so that you do not inhale vapors from inside the apparatus.
 - * After rinsing glassware with solvents, air dry the apparatus to make certain that no solvent remains. (Explosion could result.)
 - * Metal vapors must never be present in glass to be heated. The most common metal encountered in glassware is mercury. Remove all traces of mercury before heating and blowing on this glassware.
 - * Silicone stopcock grease is another source of contamination in heated glassware. A fine white powder (silica) is produced when heated to high temperatures. This silica will fire into the glass and, in turn, weaken it.
3. Protective clothing
 - * Sandals are not recommended footwear.
 - * Long hair should be tied back when working around open flames.
 - * Avoid wearing synthetic clothing that will burn and melt when exposed to flames or hot glass.
 - * Roll up long sleeves so they won’t catch on fire.
 - * Heat insulated gloves are available to handle hot glassware.

4. First Aid
 - * IMMEDIATELY tell instructor you are injured.
 - * For minor cuts, Band-Aids will be available.
 - * Severe cuts may require treatment at the Student Health Center.
 - * For burns, immediate immersion in ice water is the best treatment for minor burns to the hands. An ice bath will be available during all class periods.

5. Know location of each of the following:
 - * Fire blanket
 - * Fire extinguisher
 - * Fire alarm
 - * Safety shower
 - * Eye wash

6. General safety rules:
 - * Never hand the instructor a piece of hot glassware.
 - * No eating or drinking in the glass lab.
 - * Use common sense.
 - * Report all accidents to the instructor immediately.

Equipment

This section describes the tools and burners that we will be using during the class. Each student will be issued the following equipment:

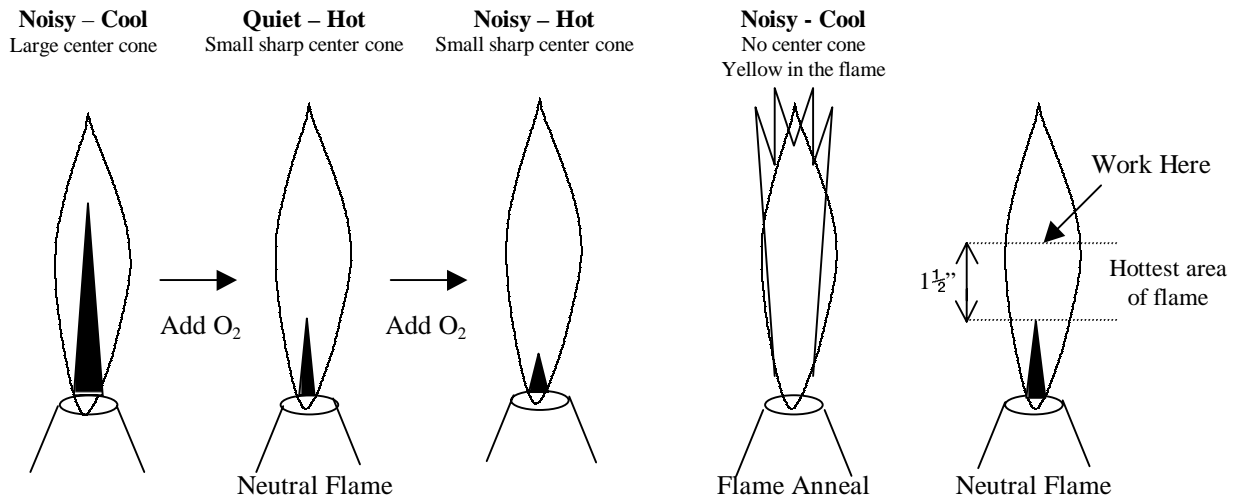
1. Bench mounted torch
2. File or glass knife
3. Flat graphite
4. Graphite rod
5. Tweezers
6. Corrugated cardboard
7. Cork stopper assortment
8. Cork stopper with tube assortment
9. Ruler
10. Blow hose
11. Didymium glassblowing glasses

Glassblowing Torch

The torch we will use is a National hand torch which operates with a fuel gas (natural gas, propane, or hydrogen) and compressed air or oxygen. To properly heat the Pyrex[®] glass used in the class, we will use natural gas (at line pressure, about 4 PSI) and oxygen (at about 7

PSI). This torch is a premix type and produces a flame temperature of about 2950° C. The hottest part of the flame is just beyond the small bright blue cone. For most glassblowing seals, we will work the glass about 1 1/2” from the end of the center cone. The mixture of gas and oxygen is very important in determining the temperature of the flame. The sound of the flame and the length of the center cone are useful observations to make when adjusting your burner. Typical flames are shown in figure 1.

Figure 1



This burner, when properly adjusted, is capable of working Pyrex® tubing up to a 35mm diameter. The procedure for turning on and off the torch is listed below:

1. Turn on supply lines from the bench.
2. Slowly open the gas valve on the torch. The gas lines are always marked with red valves. (When lighting the first time in each class you may have to bleed the air from the lines before the gas will light.)
3. Light the torch.
4. Slowly open the oxygen valve on the torch. The oxygen valves are always marked with green valves. If you open the oxygen too fast, the flame will blow out.
5. Adjust the flame to a neutral flame.
6. To turn off the torch, close the oxygen valve first.
7. Next, turn off the gas valve.
8. Turn off the main supply at the bench.

During the demonstration at the beginning of each class, proper burner adjustment will be described in detail.

Hand Tools

The tools used for forming the glass are made of graphite. The hot glass will stick to almost any other material. Each work area will have graphite rods and flat plates to be used for flaring and flattening the heated glass. These procedures will be demonstrated at the beginning of each class period.

Properties of Common Glasses

There are thousands of different glass types available on the market today. The most common glasses found in the laboratory are, borosilicates (trade names, Pyrex[®] and Kimble[®] KG33), soft glass (trade names: Exax[®], Kimax[®], Corex[®], etc.) and Quartz. Before 1920, the most common laboratory glass available was soft glass (commonly called soda glass, or soda lime glass). The following are the chemical and physical properties of the types of glasses.

Soda Glass

Chemical Properties of Soda Glass:

<u>Soda Glass:</u>	<u>Typical Composition (%):</u>
Silica	70.5
Alumina	2.6
Calcium oxide	5.7
Magnesium oxide	2.9
Sodium oxide	16.3
Potassium oxide	1.2
Boric oxide	0.5
Sulfur trioxide	0.2

Physical Properties of Soda Glass:

Linear Expansion Coefficient ($\times 10^{-7}$)	Strain Point (°C)	Annealing Point (°C)	Softening Point (°C)
92	475	510	696

Volumetric ware, television picture tubes, neon signs, household glassware and window glasses continue to be made from soda glass.

Pyrex®

Soft glass played an important role in early chemical development, but because it lacks good chemical and thermal shock resistance, other glasses were developed. In the 1920's a chemical and shock resistant glass was developed by Corning Glass Works called Pyrex®. This glass has made many additional chemical applications possible in today's laboratory.

Chemical Properties of Pyrex®:

<u>Pyrex®:</u>	<u>Typical Composition (%):</u>
Silica	74.3
Alumina	2.0
Calcium oxide	0.2
Sodium oxide	4.5
Potassium oxide	2.0
Boric oxide	17.0

Physical Properties of Pyrex®:

Linear Expansion Coefficient ($\times 10^{-7}$)	Strain Point (°C)	Annealing Point (°C)	Softening Point (°C)
32	510	553	819

Pyrex® has many advantages over soft glass. With a much lower coefficient of expansion, it can be constructed with a much greater wall thickness, and consequently greater mechanical strength, without affecting the thermal shock resistance. Pyrex® has a greater resistance to chemical attack, is harder and more resistant to surface abrasion, and complex glassware is fabricated and repaired much easier than with soft glasses.

Quartz

Chemical Properties of Quartz:

<u>Quartz:</u>	<u>Typical Composition (%):</u>
Silica	99.8
Misc.	0.2

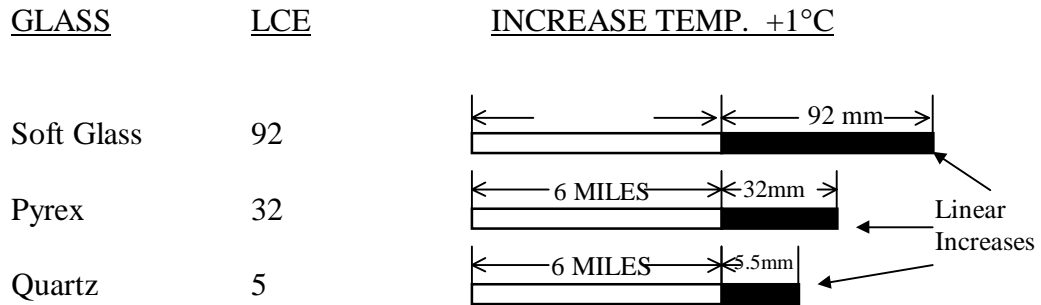
Physical Properties of Quartz:

Linear Expansion Coefficient (X 10 ⁻⁷)	Strain Point (°C)	Annealing Point (°C)	Softening Point (°C)
5	1070	1140	1650

Quartz glass is used when high temperature or high purity conditions exist for the particular chemical reaction. Making glassware from Quartz glass is very difficult, because of the extreme working temperatures needed (2400°C).

Linear Coefficient of Expansion

Glasses with different expansion rates may be sealed together only by using a graded seal. If the expansion rates are not similar, a seal between two different glasses will crack when it cools. A good illustration of the expansion rates of the three glasses discussed in the last section is as follows: (LCE = Linear Coefficient of Expansion)



Seals between any two of these glasses cannot be accomplished without a graded seal. If two glasses have similar expansion rates, they may be sealed together. The seal will have strain remaining after the seal is made, but not enough to crack the seal. By sealing successive graded glasses together, the two different glasses may be sealed. Example:

QUARTZ TO PYREX GRADED SEAL

Quartz	(LCE) =	5
Seal Glass #1	(LCE) =	12
Seal Glass #2	(LCE) =	21
Seal Glass #3	(LCE) =	27
Pyrex	(LCE) =	32

Identifying Unknown Glasses

Several methods will be discussed to identify an unknown type of glass. This will be helpful when trying to repair an existing apparatus of which the composition is unknown.

Glass Fiber Test

Take a sampling of the glass to be tested and form it into a 3-4mm rod. Take a known type of glass and do the same to it. Seal the two rods together and draw into a 12" fiber keeping tension on the fiber as it cools. Burn the fiber through in the flame 3/4 of the way up the fiber. If the fiber curves, the glasses are not similar. A straight fiber means similar glasses.

Index of Refraction Test

Preparing liquids with a similar refraction index to the glass to be tested can identify glasses. For soft glass, the liquid is chlorobenzene. The solution for Pyrex® is 16 parts methyl alcohol and 84 parts benzene. Label each container with the contents and the glass that matches the refractive index. Keep containers tightly closed.

When an unknown glass is immersed in the solution and "disappears", you have identified the glass by matching the refractive index. Dissimilar glasses and solutions will leave the glass visible in the container. A faint varicolored outline may be visible if the glass is viewed against a light background.

Physical Test

Glasses may be identified by visual observations of the glass. The following are characteristics of each glass:

SOFT GLASS -

1. When looking at the end of the tube, you will see a yellow/green color.
2. When heated, glass will give a strong sodium glare.
3. Fire polishes very rapidly when heated in a neutral flame.
4. Without preheating, the glass may crack easily when heated quickly.
5. The surface finish is smooth and free of bubbles and imperfections.

PYREX® -

1. When looking at the end of the tube, you will see a green color.
2. When heated, glass will give a strong sodium glare.
3. When fire polished, it takes a moderate time to flow.
4. The surface finish is smooth and free of bubbles and imperfections.

QUARTZ & VYCOR –

1. When looking at the end of the tube, a white to light blue color will be seen.
2. When heated, no sodium glare will be present.
3. When heated, a bright white light will be given off.
4. The surface finish may be rough or show tool marks. Vycor may look cloudy and have a rough texture.
5. Used or heated quartz may have sublimed silica (a white powder deposit) on part of the tubing.

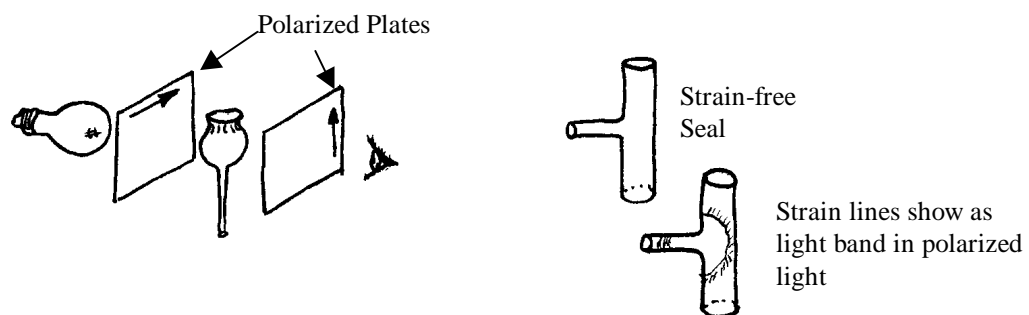
Annealing Glassware

The annealing of glass seals is important if durable equipment is desired. Internal thermal stress is introduced when the glass is heated above the strain point. (The strain point of Pyrex® is 510°C). Annealing is the process of heating the glassware to a temperature just below the softening point and then allowing it to cool slowly. This process may be accomplished by heating the glass in electric ovens or with annealing flames.

Locating Thermal Stress with Polarized Light

The presence of residual thermal strain in glass cannot be detected with the unaided eye. By viewing the glassware through a polarized light source, the strain can be easily located. It is known that light transmitted by strain free glass obeys the laws of refraction; and that a ray of light transmitted by strained glass is split into two rays. These rays follow slightly different paths through the glass, they're planes are polarized and their vibrations are at right angles to one another. If a beam of polarized light is passed through a piece of glassware, and the emergent light is viewed through the analyzer; the regions of glass that are strained will show a brighter light intensity. Areas of bright narrow light bands will cause cracking, and should be reannealed.

Figure 2



Oven Annealing

A large or complicated piece of apparatus may be assumed to be strained after it is blown. Each piece of glassware produced should be oven annealed to insure that it will not crack when it cools. The glass is annealed in a thermostatically controlled electric oven. The still-hot glass is placed in the oven and heated to a temperature at which the glass is rigid enough to keep its overall shape, but plastic enough to flow so as to relieve internal strain. It is then cooled slowly to room temperature. Even though strains develop after the glass cools, or “sets”, these strains are never severe enough to crack the glass.

Flame Annealing

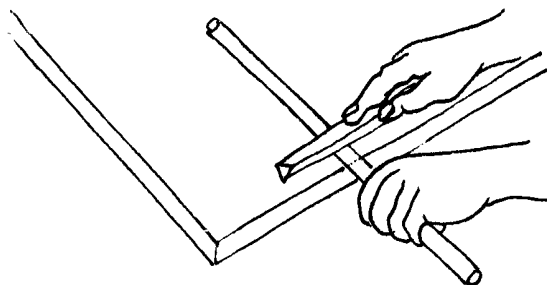
Most laboratories do not have an annealing oven, and hot glass must be annealed by judicious use of flames. After a piece of work has been blown, it is heated uniformly over a wide area surrounding the seal area, to a temperature just below the softening point, but above the strain point. For Pyrex[®], this corresponds to incipient red heat. Next, the work is rotated uniformly in a large, slightly yellow brushy flame. This flame will begin to deposit a layer of black carbon on the surface of the glassware. When a thin layer of carbon covers the annealed area, you have completed the flame annealing process.

Glassblowing Operations

Cutting Tubing and Rod

There are several methods of cutting tubing and rod. The procedures described below are the recommended methods for safe tubing cutting. Figure 3 shows the correct way to score the tubing for cutting. Place the tubing on the bench top and score the tubing once or twice. Do not “saw” the tubing, as this creates a wide notch in the glass. The best score mark is a narrow, deep file mark.

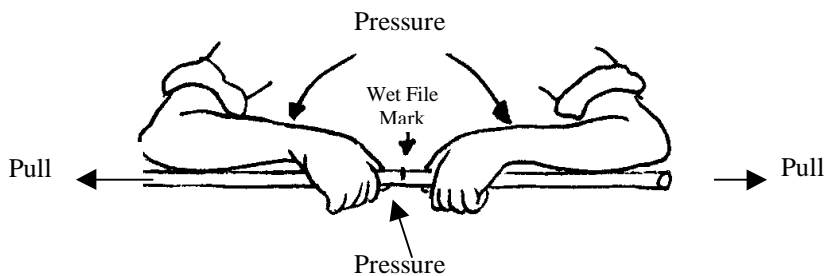
Figure 3



After scoring the tubing, wet the mark to further reduce the surface strength. Place the mark up and grasp the tube about 2” away from the mark with both hands. (See figure 4) Pulling

back and away with the arms, exerting a perpendicular force to the tubing then breaks the glass.

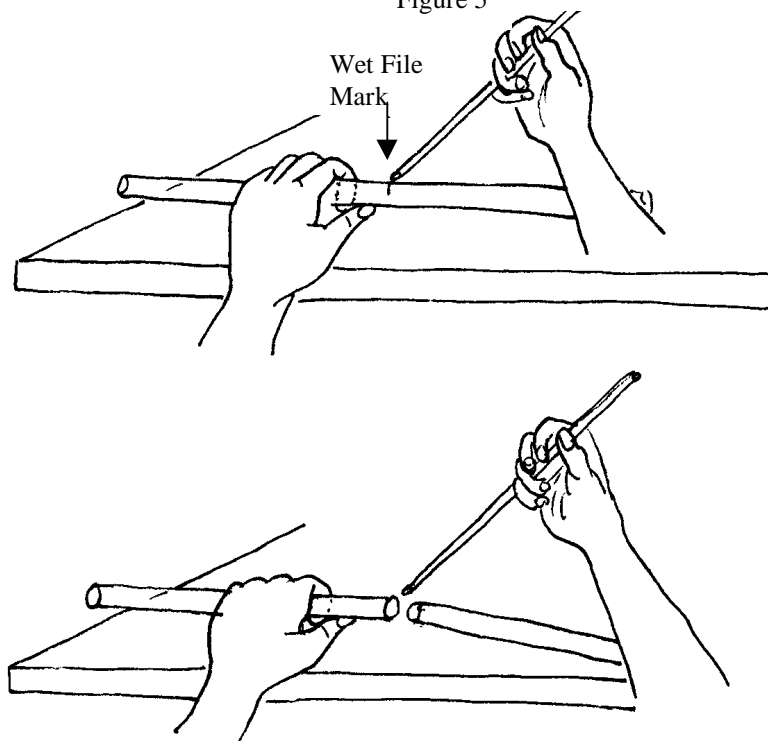
Figure 4



Another method of cutting glass is by applying a hot rod to the scored tube. This is done in the following manner:

Make a deep scratch on the tube as described above. Hold the tube in one hand and with the other hand, take a piece of 3mm rod and soften the end in the torch. When the end of the rod is molten, touch it to the scratch. If the scratch is straight, the tube will break cleanly. (See Figure 5) This method is convenient to use when the apparatus prevents you from grasping the tube in both hands.

Figure 5



Procedure for Rotating Tubing

Uniform rotation of glass during heating and blowing is essential for obtaining an evenly distributed wall thickness. The process of rotating cannot be overemphasized! If you stop rotating while your work is in the flame, it will sag or thicken on one side. Only by continuous, even rotation can you get smooth, even seals. You may rotate in any direction, but it is most common to have the top of the glass move away from the glassblower.

The tubing in the left hand should be supported by the last three fingers, which act as a bearing. The thumb and forefinger are then used to rotate the tubing.

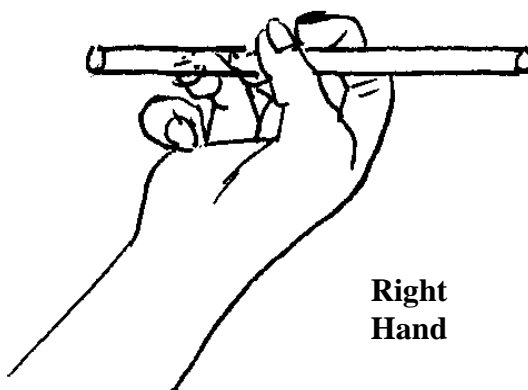
Figure 6



Left Hand

The tubing in the right hand is held differently. The right palm faces up and the tube is held between the forefinger and the thumb. The other fingers are arranged so that at least one is under the tube and is ready to support it when the finger and thumb release their hold and take a new hold on the tube. This is the hand that will give the beginning student the most trouble. Practice the right hand rotation as much as possible.

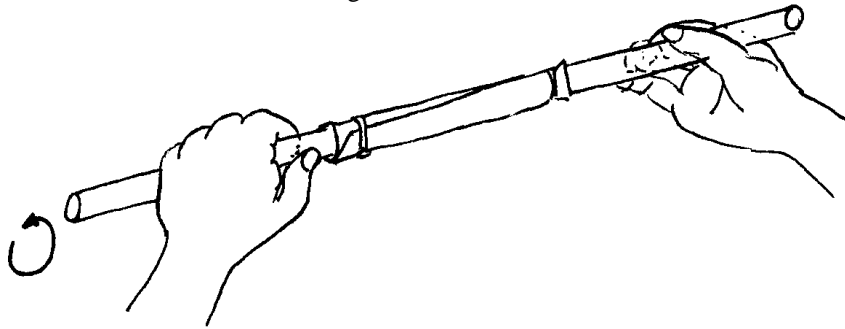
Figure 7



Right Hand

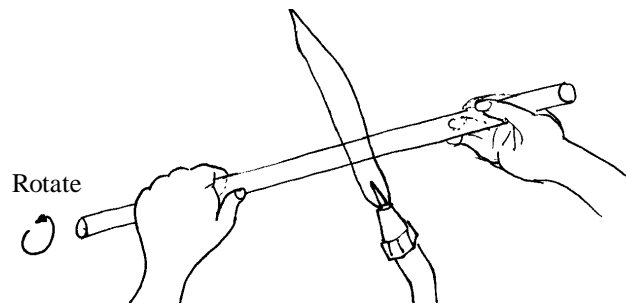
You must synchronize the right and left-hand movements to prevent twisting of the tubing in the heated zone. This may be practiced by joining a pair of tubes with a piece of cloth, and then rotating the tubes without twisting the cloth.

Figure 8



The following diagram shows the proper rotation method for both hands.

Figure 9



Basic Glassblowing Seals

The following seals will be discussed and practiced by each student:

1. Fire polish tube ends
2. Pull points
3. Round bottoms
4. Flat bottoms
5. Butt seals
6. Flare tubing
7. "T" seals
8. Tubing bends
9. Rod seals
10. Blind seals
11. Capillary seals
12. Blowing Bulbs

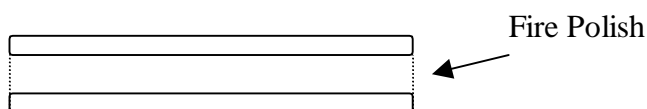
Included in the basic seals portion will be construction of the following:

1. Eye droppers
2. Volumetric pipettes
3. Glass flower
4. Graduated cylinder
5. Bulb to bulb distillation apparatus
6. Migratory fowl barometer

Lesson 1: Fire polish tube ends

Fire polishing the sharp ends of the glassware is a very important procedure. The glassblower is constantly blowing into the open ends of the apparatus and a sharp edge can cut the lips very severely. For your own safety, fire polish all sharp edges before beginning to heat the apparatus.

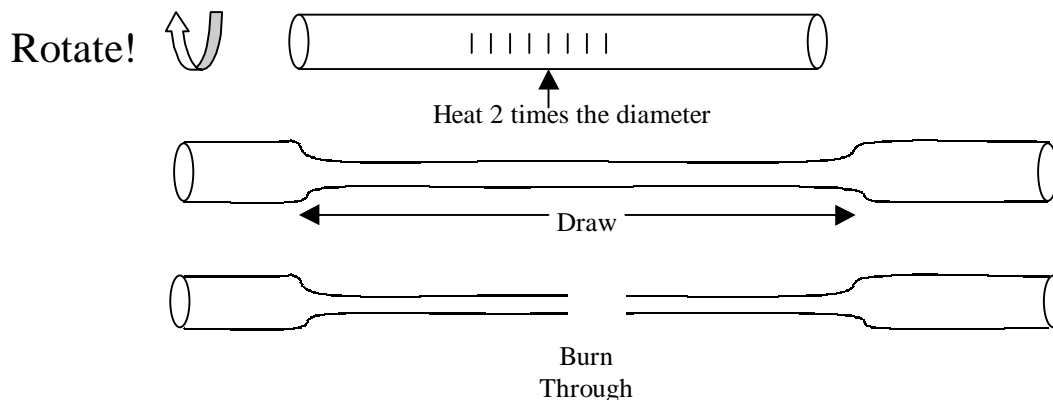
Fire polishing is accomplished by rotating the glass in the flame near the outer edge. Heat the glass until the edges flow into the hemisphere shape on the end. Do not heat to the point of constricting the diameter of the tube. Flame anneal each seal.



Lesson 2: Pulling points

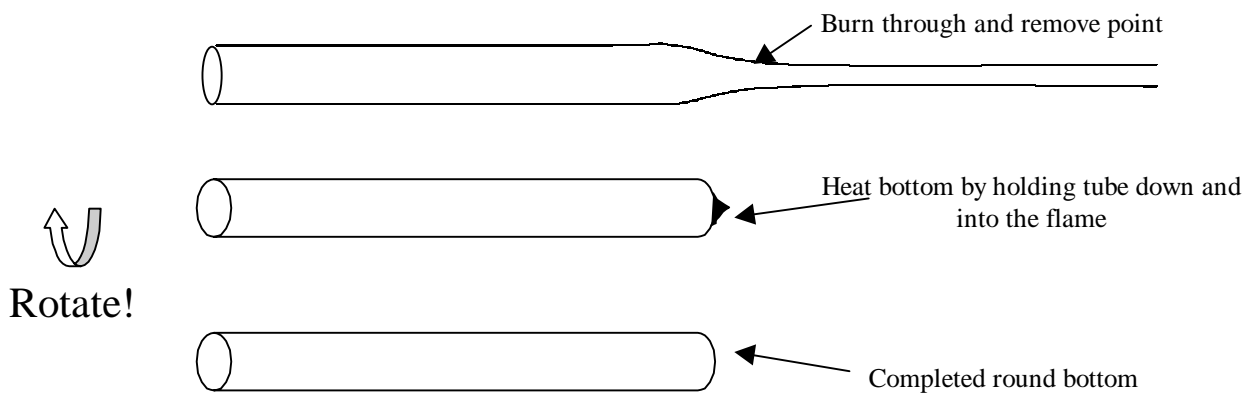
“Points”, as designated by glassblowers, are elongation’s on the ends of tubing, formed by pulling the tube to a small diameter. They form convenient handles for holding short pieces of tubing, as well as providing a means for closing the tube.

The correct procedure in pulling a “point” consists of rotating the tube in the flame so as to heat a length of about 2 times the diameter. When the glass has become pliable, remove it from the flame, and while still rotating, pull slowly to a length of about 4-5”. It is important that the resulting “points” have the same axis as the original tube. If the “points” are not in line, it will be necessary to heat at the junction with the tube to straighten them. Flame anneal each seal.



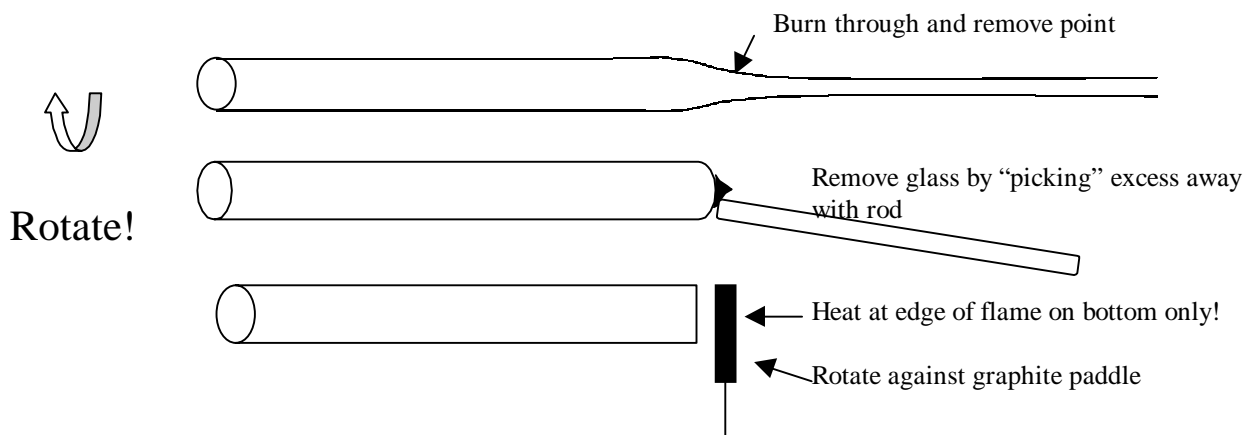
Lesson 3: Round Bottoms

The round bottom is made using one of the “points” that you have just made. Place the large diameter in your left hand and the “point” in your right hand. (Refer to tubing rotation section.) Next, heat the junction of the “point” in the flame and slowly draw it away. Burn the “point” through in the flame and remove it. Now, with the tube end sealed, rotate down and into the flame to gather the glass. The glass will thicken as you are heating. After sufficient heating, and while still rotating, remove it from the flame. Turn the end of the tube up and blow lightly into the open end of the tube. Blow just hard enough to shape the molten glass into a hemisphere on the end of the tube. Repeat this procedure until the round bottom is formed. The glass in the bottom of the seal should have the same wall thickness as the starting tube. If your round bottom is not uniform, your rotation in the flame was not even and smooth. Flame anneal each seal.



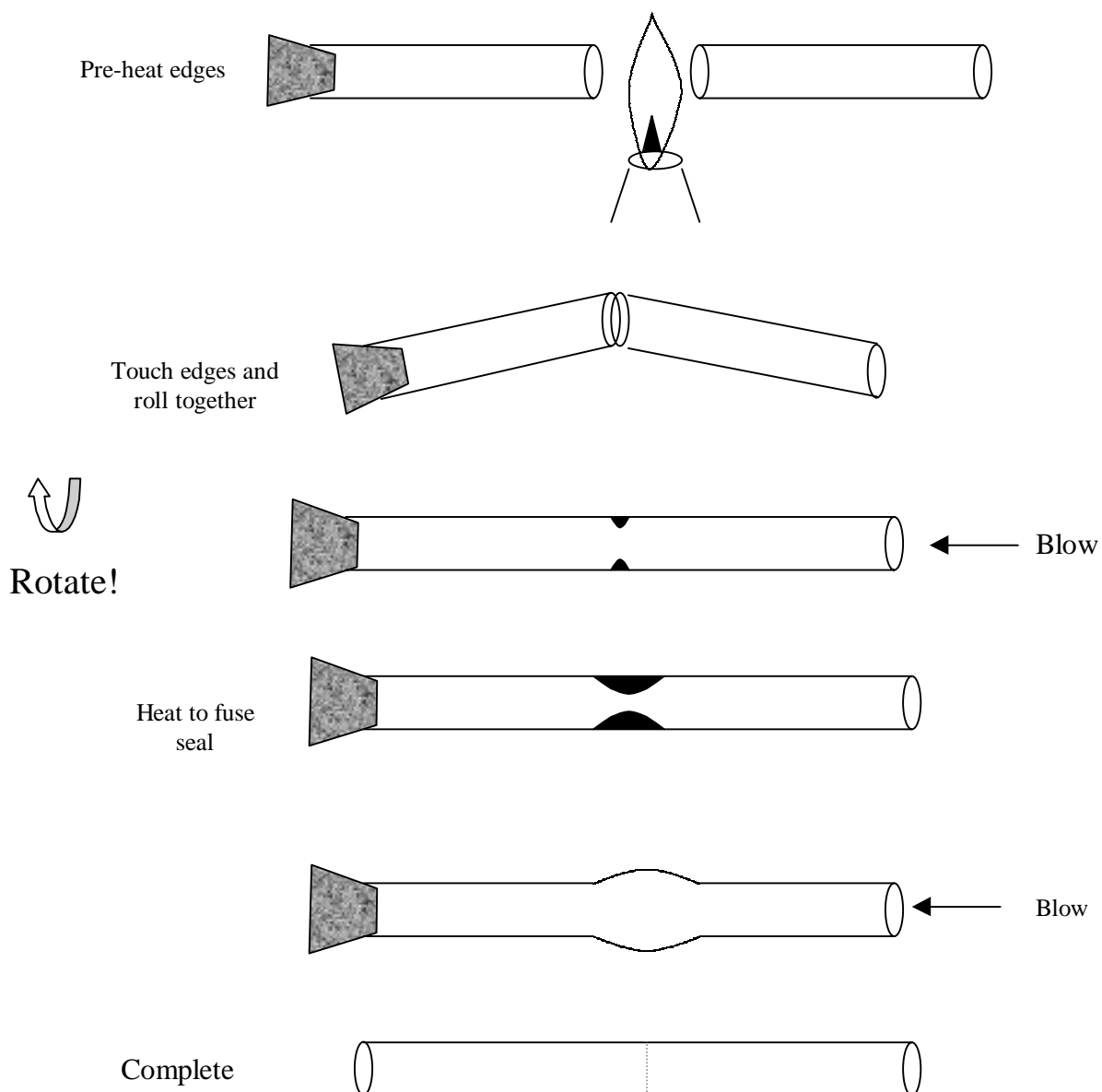
Lesson 4: Flat Bottoms

Flat bottoms are very similar to round bottoms in construction. Start with a “point” and while rotating in the flame, pull away and burn through the “point”. It is important to remove more glass from the bottom of the tube when making a flat bottom seal. You may want to use a small rod to “pick” away more glass from the end of the seal. When the seal is about half as thick as the wall thickness of the starting tube, rotate the tube in the edge of the flame. Make sure that the flame does not fire onto the shoulder too far. Keep the flame directed at the bottom of the seal only. As you fire the bottom, some glass will flow from the shoulder into the bottom. When you see that the bottom thickness equals the wall thickness, remove from the flame and rotate against a graphite paddle. Make sure you continue rotating as you touch the hot glass to the graphite. Flame anneal each seal.



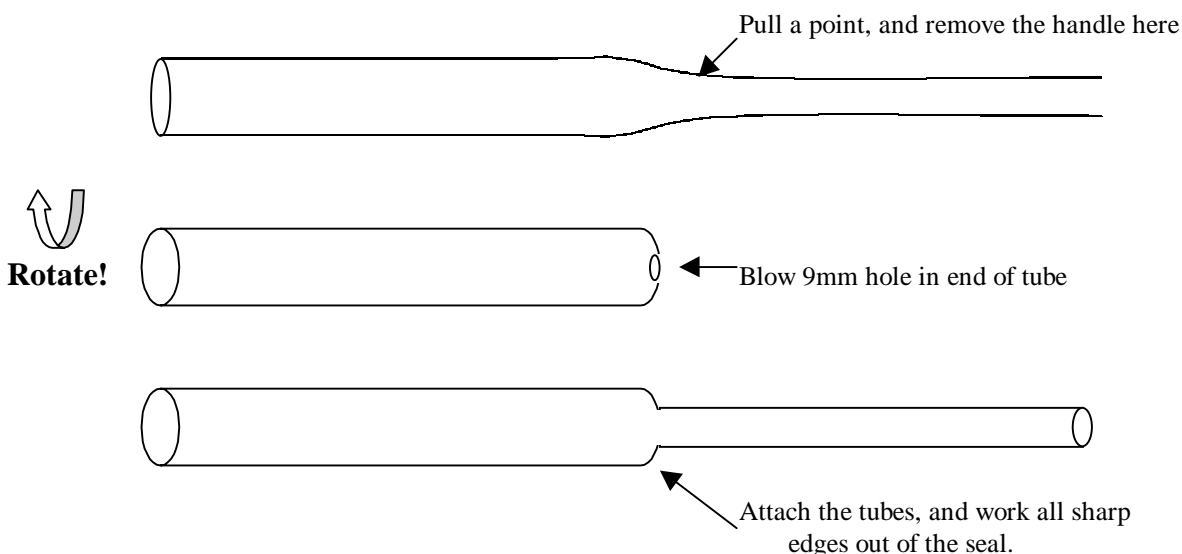
Lesson 5a: Butt Seals

Uniform butt seals require even rotation of the glass with both hands. (Refer to Tubing Rotation Section.) Cut two tubes of the same diameter to a 6" length and put a cork stopper in the end of one tube. Place the stoppered tube in the left hand and the open tube into the right hand. In a narrow flame, begin heating both edges until they begin to flow. While continuously rotating, remove the tubes from the flame and touch the back edges together and roll the tubes together. While the seal is still molten, blow lightly into the open end. Move back into the flame and reheat the seal until the edges begin to flow and gather thickness. Again, remove the glass from the flame while rotating, and blow into the open end. Blow the seal up slightly larger than the diameter of the starting tubes. Repeat the heating process, but this time blow the seal up to the same diameter as the starting tube. Rotate the seal to straighten. Flame anneal each seal.



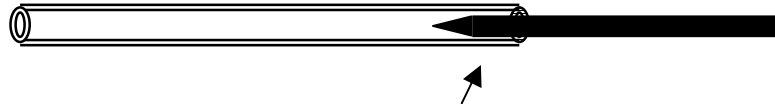
Lesson 5b: Butt Seals with Different Sized Tubes

Butt seals on large diameter to smaller diameter tubing is quite a bit trickier than same size seals. First, cut and fire polish a 4" piece of 9mm and an 8" piece of 22mm. Then, you start by pulling a point at the middle mark on a piece of larger tubing. Next, remove the handle as if you were making a round bottom. You then blow out a small hole in the end of the 22mm that is about 9mm around. (Just the same size as the small tube.) Cork the 22mm tubing and rotate it in your left hand, and rotate the 9mm in your right hand. Heat both edges so they begin to flow, bring the glass out of the flame, attach the tubes together, and blow lightly. You may have to go back in and rework the seal a few times. Each time, heat directly on the seal, remove glass from the flame, and blow. Always remember to ROTATE!! Flame anneal each seal.

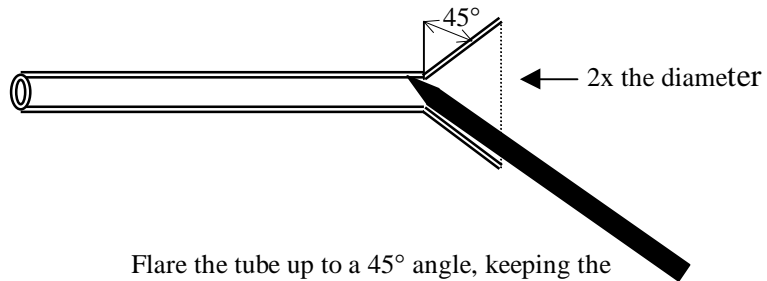


Lesson 6: Flare Tubing

To begin flaring tubes, cut and polish 9mm tubing into 6" lengths. Hold the 9mm tubing in your left hand, and in your right hand, hold the graphite rod (found in your toolbox). The first of the flares will be a 45° flare. With a large flame, begin rotating the tubing in the flame. You will want to heat about 2 times the diameter of the tubing in order for the flare to be thick enough. Once the glass is hot, remove the tube from the flame, and insert the graphite rod into the tube. You should insert the rod far enough into the tube so that the far edge of the rod is resting on the cool part of the glass. In order for the edge to stay hot enough, you will want to keep the outer edge of the flare in the flame. Continue to rotate the glass, while bringing the graphite rod to about 45° angle. Completely remove the glass from the flame. Continue to rotate the glass against the rod until it completely cools. Flame anneal.

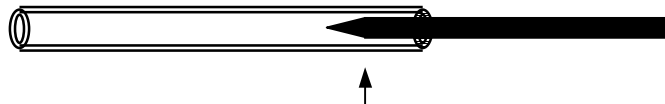


Heat about 2 times the diameter, and insert rod.
Remember to keep the rod on the cool area
of the tube.

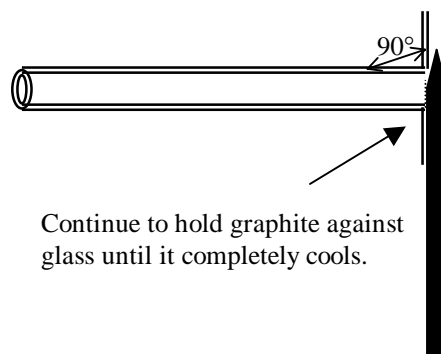


Flare the tube up to a 45° angle, keeping the
outer edge in the flame. Rotate until cool.

The next flare is similar to the 45° flare, except it is a 90° flare. The steps are the same, except when you hold the graphite rod, you will need to bring it perpendicular to the tube.



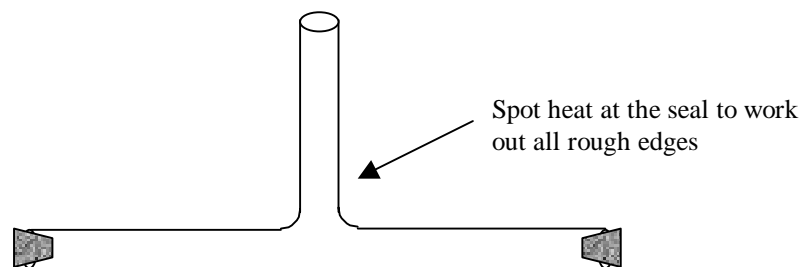
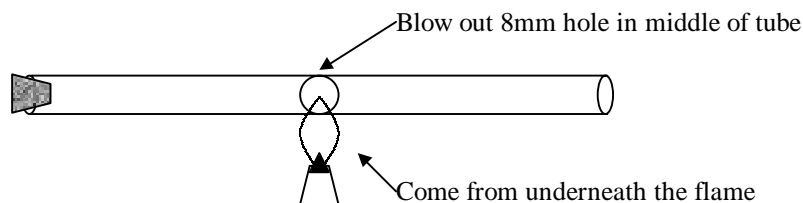
Heat 2 times the diameter of the tubing and
insert graphite rod.



Continue to hold graphite against
glass until it completely cools.

Lesson 7: “T” Seals

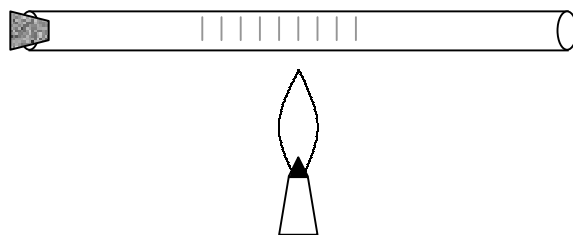
To begin the same size “T” Seals, cut and polish 9mm tubing into 8” (cut at 8”, and mark at 4”) and 4” lengths. With the corked 8” piece in your left hand, come up from underneath the small flame at the 4” mark. Heat a small area on the side of the tube until molten, and then blow lightly to form a small bump. This bump should be about 9mm. Heat the top of the bump in the flame until it becomes molten, and then blow out the glass. There now should be a hole about the size of the tube to attach to it (9mm). (If your hole is too small, you can use the graphite rod to push out a bigger hole.) Next, cork the other end of the 8” piece of tubing. Hold this in your left hand. You should come up from underneath of the flame with this tube, and hold the other tube in your right hand. Then, get all edges molten, come out of the flame, and stick them together. To get a good seal, you may want to stick the back edge together first and roll them together. Then, in order to get a nice, strong seal, the cold edges must be worked. At this point, you will want to get the smallest flame you can. You then can begin by picking one spot of the seal, and begin “spot heating” around until all of the sharp edges are gone. You can do the large to small “T” seals following all of the steps mentioned above, using an 8” piece of 22mm. Flame anneal each seal.



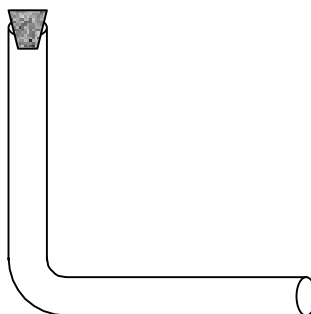
Complete

Lesson 8: Tubing Bends

To begin, cut and polish 9mm tubing into 8" (4x) and 12" (4x) pieces. When bending tubing, it is important that you get enough of the tubing hot enough, so you don't have to rework your bends. A good rule of thumb is to heat 3 times the diameter of the tubing for the 90° bends, and to heat about 4 times the diameter of the tubing for 180° bends. Begin by adjusting your flame to be the biggest, hottest flame you can get. Then, with the corked end of tubing in your left hand, begin rotating the tube in the flame, heating back and forth. Remember to heat about 3 times the diameter. So, for 9mm tubing, try to heat about 27mm (or just over 1"). Once you have the glass just to the softening point, you then want to sweep the backside of the tubing into the flame. (This will allow the outer side of the bend to be hot enough to blow out round.) In order to do this sweeping motion, you will need to move your left hand to hold the tube from the underneath (like the right hand holds the tube). This will also allow you to smoothly bring the tube up to your mouth to blow. After you sweep the backside, bring your right hand up to your mouth, bend the tube up 90° with your left hand, and blow. If the tube is heated correctly, you will not have to rework the bend. Sometimes, it may be necessary to use a small flame on the inside of the bend to work out any kinks. Flame anneal.

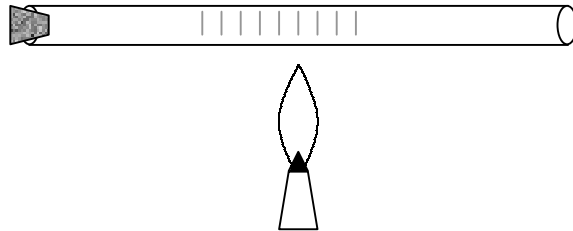


Heat 3 times the diameter of the tube
Swipe backside of tube into flame.

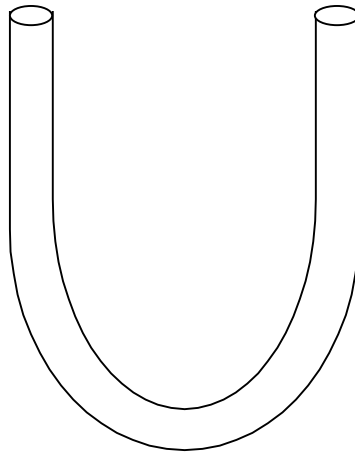


Bend at 90° angle, while blowing into the right side.
Work out any folds on inside of bend with small flame.
Flame anneal.

In order to bend the tubing 180°, you must heat about 4 times the diameter of the tube (about 36mm). The same techniques as the 90° bend are used, with one exception. After you sweep the backside of the tube in the flame, you will bring your right hand up to blow into it. While you are bringing your left hand up to the 180° point, you will then use a “scrubbing” motion. Your right and left hands will act as though you are actually scrubbing something between them. This allows any kinks to work out of the bend. It may be necessary to use a small flame to work out any kinks that might be on the inside of the bend. Flame anneal.



Heat 4 times the diameter of the tube.
Swipe backside of tube in the flame.

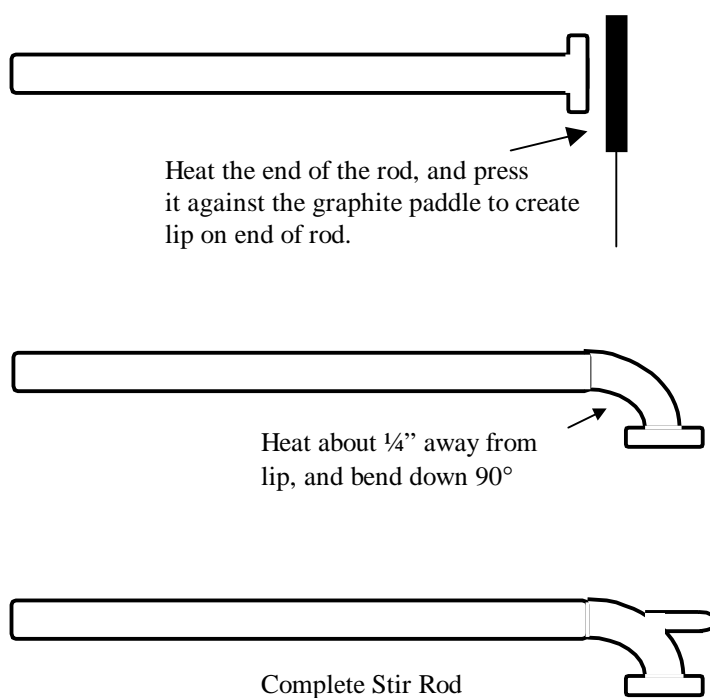


Use “scrubbing” action to complete
the 180° bend. Use a small flame
to
Work out any kinks on inside of
bend.

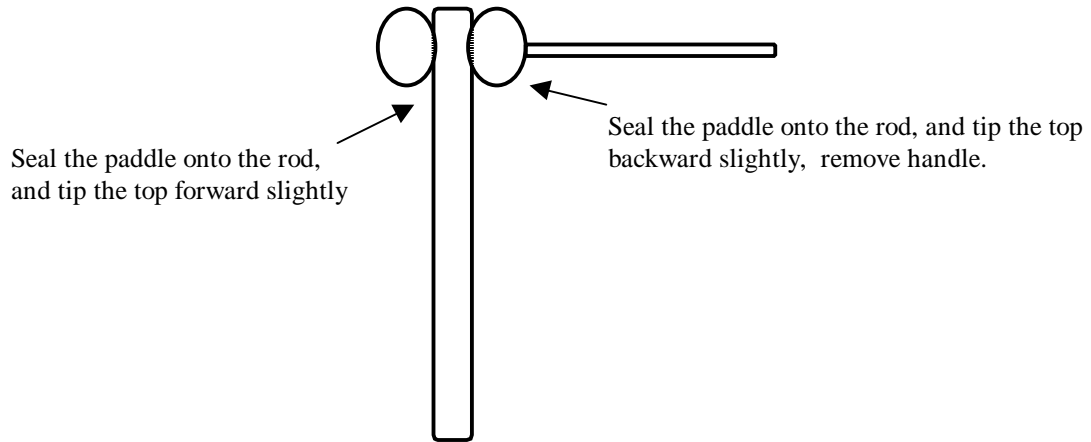
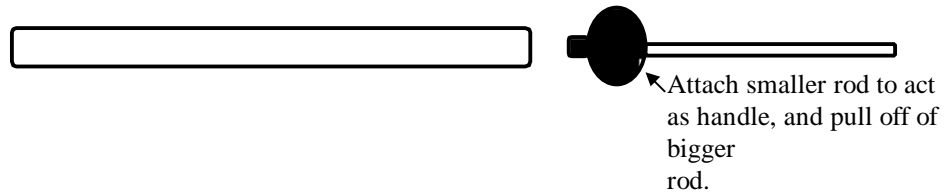
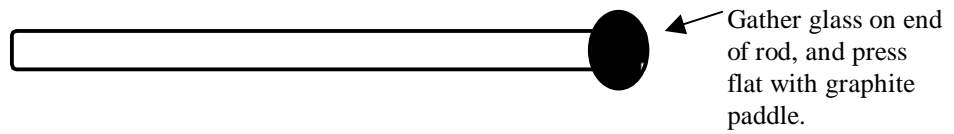
Flame anneal.

Lesson 9: Rod Seals

To begin your rod work, you will start by making a Teflon blade stir rod. This is quite simple to make. First, cut a piece of rod about 10". Hold the rod in your left hand, and rotate the right edge of it in the flame. You want to gather a section of glass (about $\frac{3}{4}$ ") that you can push flat. Next, come out of the flame, continue to rotate, and with your graphite paddle in your right hand, push the glass against the paddle to form a lip. Then, heat about $\frac{1}{4}$ " back from this lip with a fairly wide flame. Once the glass is just to the molten stage, you then want to use your paddle as a "finger", and push the tip down at a 90° angle. The last step to making this stir rod, is to add a small piece of glass to the end. This will keep the Teflon blade in place when on the rod. Flame anneal.

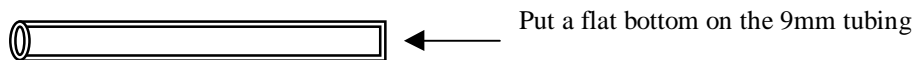


The next rod seal is a glass stir rod. To start the stir rod, first cut and polish a piece of rod about 10". To make the round stirring paddles, you need to gather a large amount of glass on the end of a rod, then press it flat with the graphite paddle. You will want to press the glass against another graphite piece. Attach the paddle to a smaller rod, which will act as the handle when attaching it to the rod shaft. Remove the paddle from the larger rod, leaving a small section of glass to attach to the rod shaft. You will need to make two of these paddles. Once these are made, you will then attach them to the rod. To do this, make sure you heat on both the rod and the paddle. Once both sides are glowing red, stick the paddle onto the rod at about a 30° angle from the rod. Repeat this process with the other paddle, attaching it 180° from the first. Flame anneal.



Lesson 10: Blind Seals

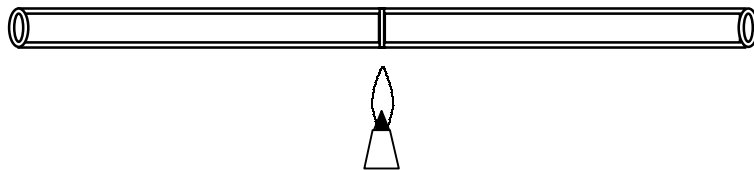
To make a blind seal, you must first start by putting a flat bottom onto a 4" piece of 9mm tubing. (Refer to Flat Bottoms page14) With this flat bottom in your left hand, and another open piece of 9mm in your right hand, begin rotating each end in the flame. Once the flat bottom and the other tubing edge are hot, stick the back edges together and roll. Blow into the right end, then the left end. Continue to rotate until completely cool. With a narrow flame, heat directly on the seal, to work out the rough edges. Bring the tube out of the flame and blow into the right, then left ends of the tube. Continue rotating while the tube cools. Flame anneal.



Rotate!



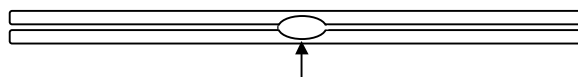
Hold the flat bottom in your left hand, & the open tube in your right hand.
Heat both edges, and stick them together.



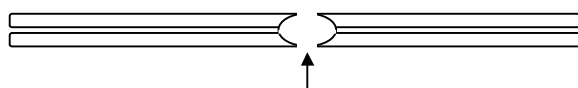
With a small flame, heat on the seal, come out of the flame and blow into both ends.

Lesson 11: Capillary Seals

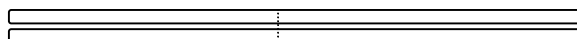
To begin with capillary butt seals, cut and polish an 8" piece of capillary tubing. At the center mark (4"), you are going to blow a small bulb. With the closed end of tubing in your left hand, rotate the tube in the flame at the center point, until it becomes molten. Once it becomes molten, bring your right hand up to your mouth, and blow gently into the tube. This now created an enlarged part of the capillary, which will allow you to more easily seal the tubes together. Next, rotate the tube in the flame, and pull the tube apart in the center of the bulb you just blew. You will then heat the end of the bulb in the flame to blow out the end of the tube. With your graphite rod, tool the edge of the tube into a nice, smooth surface. Repeat this step with the other tube. Then, you are going to close up the end of tube in your left hand, and do a butt seal (refer to Page 15). You must use a very small flame, in order for the capillary not to collapse. Flame anneal each seal.



Heat at the 4" point to blow a small bulb in the capillary tubing.



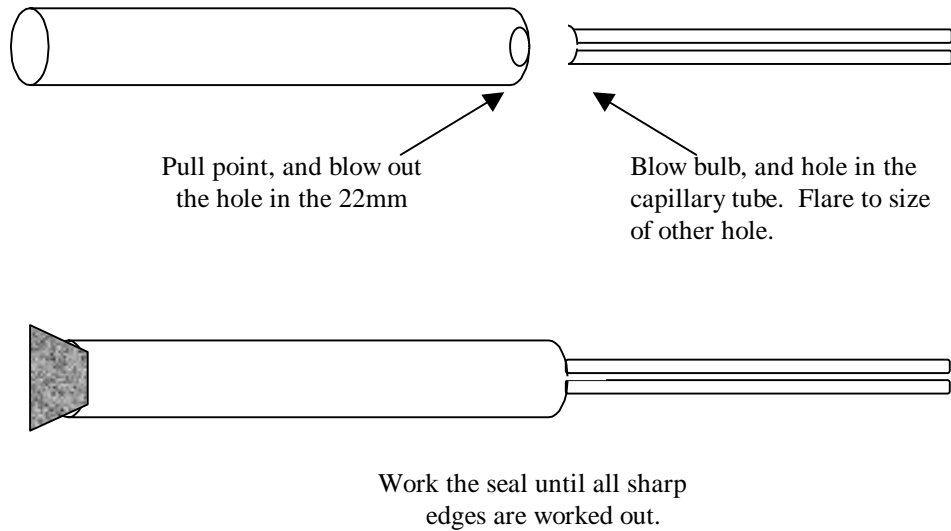
Blow the center of the bulb out to create smooth ends for your seal.
Heat both edges until hot, and touch the back edges together, roll towards you and blow.



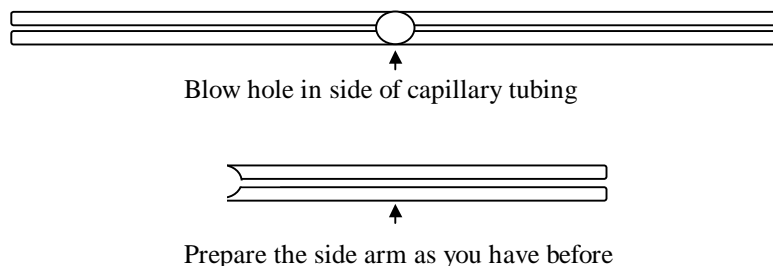
Continue to heat and blow to work out the seal.

Next, you will make capillary butt seals with two different size tubes. You will begin by blowing a small bulb in the center of the capillary tubing, as you did for the above example.

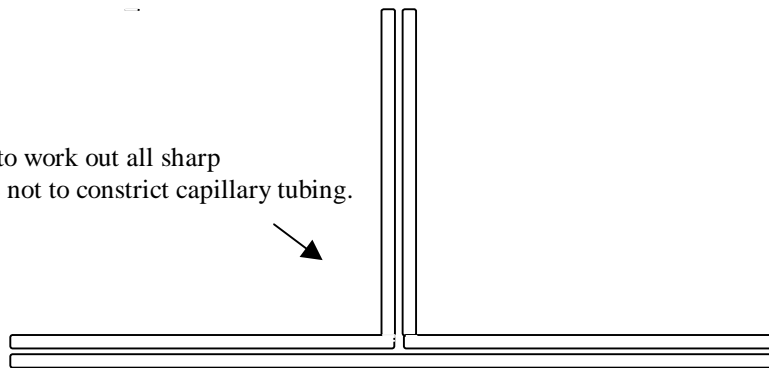
Blow the center of the bulb out to create a smooth end for your seal. You may want to slightly flare the blown end of the capillary tubing with your graphite rod. Next, you will need to pull a point on a piece of 22mm tubing. Then, pull off the point and blow out a hole the same size as the capillary tubing. You will then follow the same instructions for a normal butt seal with different sized tubing. (Refer to Page 16) EXCEPT, you must not allow the flame to heat back too far on the capillary tube, otherwise the inner diameter may constrict. Flame anneal each seal.



The last type of capillary seal is a capillary “T” seal. This is quite a bit trickier than the normal “T” seal because of the small inner diameter of the tubing. You will need to prepare a capillary tube as you have before, with a larger inner diameter at the end. Then, on an 8” piece of capillary, you will need to blow a hole in the center that is about the same diameter as the capillary tube you will be sealing on. It may be hard to blow the hole from the side of the tube, so you may need to blow slightly while the tube is still in the flame. If the hole does not blow out big enough, you may use the graphite rod to make it larger. You will then hold the longer tube in your left hand, and the smaller tube in your right hand. Come up from underneath the flame with the tube in your left hand, and heat all edges of both tubes. Then, just as with the other “T” seal, (refer to Page 17) you will want to touch the back edges and roll the tube forward. Lastly, gently spot heat all the way around the seal to work out all of the sharp edges. Flame anneal each seal.

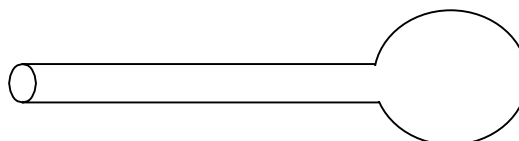
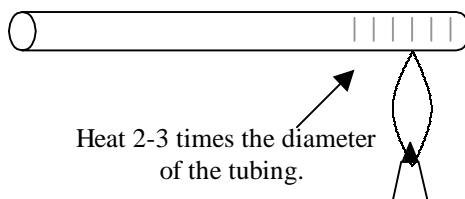


Spot heat the seal to work out all sharp edges. Make sure not to constrict capillary tubing.



Lesson 12: Blowing Bulbs

To begin blowing bulbs, you will need to cut and polish 12" sections of 9mm tubing and 22mm tubing. You will start by pulling a round bottom at the 6" mark of the tubing. (Refer to Page 13) With the tube in your left hand, you will begin rotating the end of the tube in a rather large flame. You will need to heat at least 2-3 times the diameter of the tubing to blow out a bulb. Smooth, even rotation is very important when blowing bulbs. If you heat one side longer than another, you will not get a nice, symmetrical bulb. You will have to tip the glass slightly upward, so that the tubing will fall back onto itself, which will thicken up the bulb. Once the glass is molten, you will then come out of the flame, continue rotating, and blow. Hold the tube upward while blowing into it. You should continue to rotate the tube until it is cool, to prevent the bulb from sagging. Flame anneal.

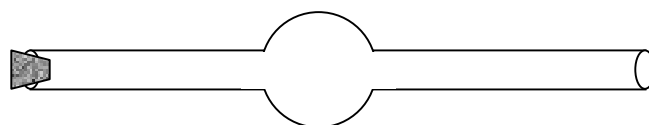


Continue rotating while the glass is hot! Flame anneal.

The next type of bulb is one that is in the middle of the tube. To begin, cut and polish the tubing into 12" sections. You are going to want a large flame in order to heat enough tubing. Begin rotating the tubing in the flame, with the tubing in the left hand corked. Heat a section of glass that is about 2-3 times the diameter of the tubing. You will need to move the glass back and forth in the flame to get it all hot. Then, once the tubing is molten, bring the tubing in your right hand up to your mouth and blow. You will need to rotate the tubing while you are blowing into it, to keep from sagging. Once the tubing is cool, flame anneal.

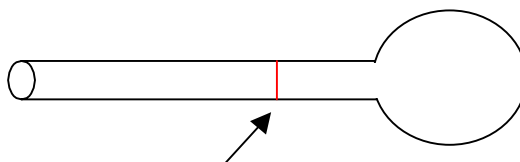


Heat 2-3 times the diameter of the tubing, using a sweeping motion.

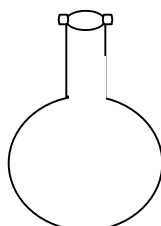


Continue rotating while blowing the bulb. Flame anneal

The last project for the bulb section is to make an actual round bottom flask. To do this, blow a bulb on the end of the tube, as described above. Once that bulb is cool, cut the neck of the flask off short, and bead the top. In order to bead the top, you will need to rotate the outer edge of the neck in the flame, insert your graphite rod, and slightly flare the tubing. This will create a tooled top for your flask. Flame anneal.



Cut the neck off here, and tool.



Complete flask

Advanced Seals

Lesson 1: Cold Trap – Ring Seals

Materials List:

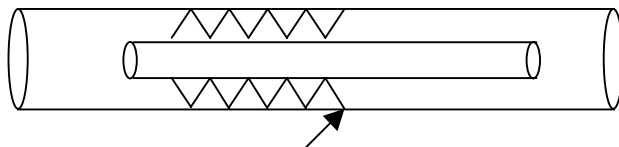
3 each 6" long 9mm tube (inner tube and side arms)

1 each 10" long 22mm tube (trap body)

Firepolish all tubes.

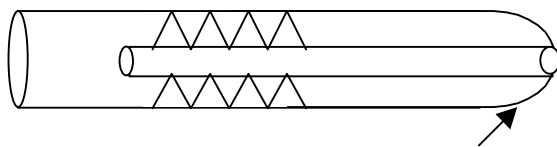
Construction Details:

During construction, the inner tube of the cold trap is held in the trap body using a corrugated cardboard spacer. The center tube is wrapped with a 2" wide strip of cardboard with the corrugations facing outward. An even number of complete wraps will ensure that the inner tube is properly centered. Slide the spacer and inner tube into the trap body and straighten as necessary.



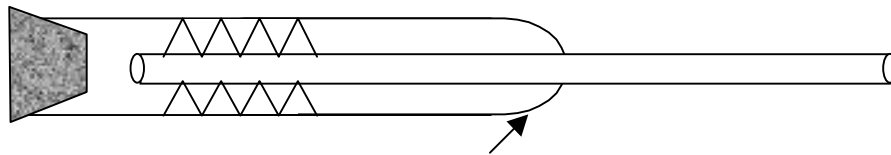
Insert cardboard spacers and center tube

Begin construction of the ring seal by preheating the trap body in the area directly over the end of the inner tube. Attach a glass tube to the open end of the trap body to use as a temporary handle. With the flame centered directly over the end of the inner tube, heat the trap body tubing in the same manner as you would to pull a "point". Let the glass flow onto the inner tube so that it forms a seal with the inner tube. Burn off the "point" handle. Heat the end of the trap body and inner seal using the same techniques as a round bottom seal. Rotate the tube down and into the flame while heating, and hold up when blowing. Form a hemisphere shape on the end of the trap body. Allow the seal to cool slightly. With a small sharp flame, heat the center of the ring seal to soften the glass. Blow out a bubble from the glass in the center of the ring seal.



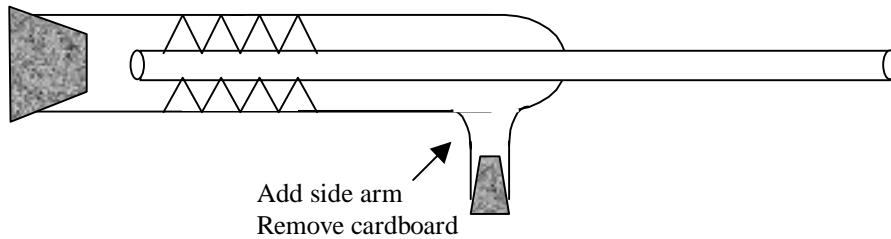
Pull the 20mm tube down over the 9mm tube, make a nice, smooth ring seal, and blow out the center hole

Extend the ring seal by attaching a 9mm tube to the opening at the ring seal. Flame anneal the seal for about 15 seconds.

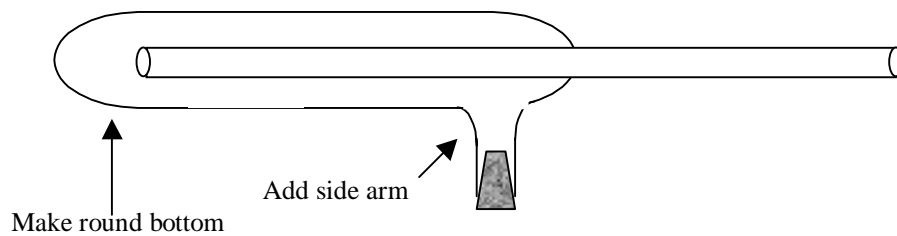


Extend the ring seal with another piece of 9mm

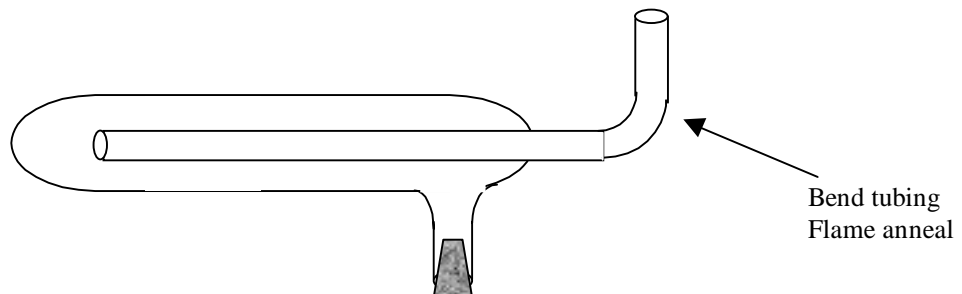
Attach a side tube to the trap body near the ring seal. Cut the side tube so that it is about 2" long. Fire polish the cut end. Completely flame anneal this end of the cold trap. Using a wire hook, remove the cardboard spacer.



Preheat the open end of the trap body and attach a glass handle to the open end of the trap body. Pull a "point" and continue making a round bottom seal. Flame anneal the round bottom. Allow to cool.



Complete the cold trap by making a 90° bend on the ring seal extension tube. Cut to about 2" length, fire polish and flame anneal.



Lesson 2: Condenser

Material List:

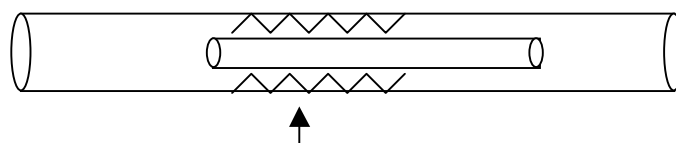
5 each 6" long 9mm tube (inner tube, side arms, and ring seal extensions)

1 each 10" long 22mm tube (condenser body)

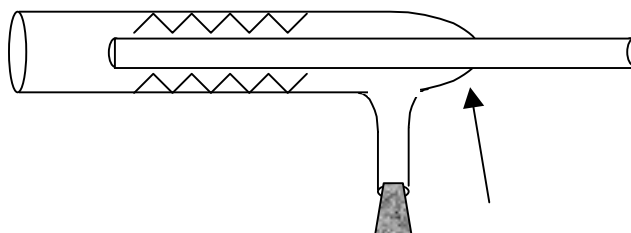
Fire polish all ends.

Construction Details:

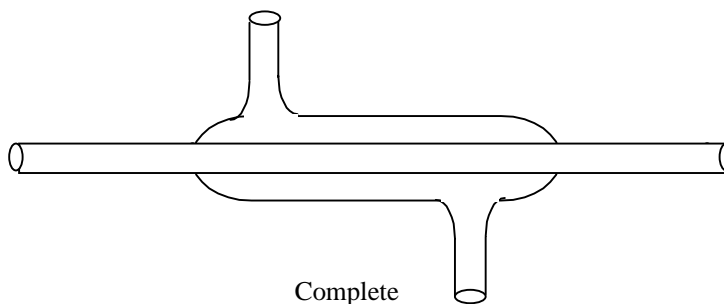
A water-cooled condenser is constructed using similar techniques to the cold trap. (Refer to Advanced Seals, Lesson 1, Cold Trap.) The second end of the condenser is slightly different than the first. As the condenser body is collapsed onto the inner tube, two separate air chambers are formed. Provision for blowing into each chamber is required. When the glass is heated sufficiently, alternate blowing into each chamber beginning with the water jacket chamber. The ring seal extension and sidearm are attached in the same manner as was accomplished on the cold trap assembly. Careful flame annealing will keep this double ring seal assembly from cracking. Cut side arms and ring seal extension tubes to approximately 2" lengths and fire polish all edges.



Support inner tube with cardboard



Make ring seal, extend ring seal,
add side arm, and remove cardboard.



Complete

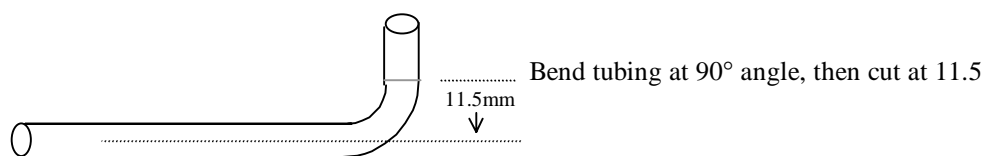
Lesson 3: Cold Trap – Side Ring Seal

Material List:

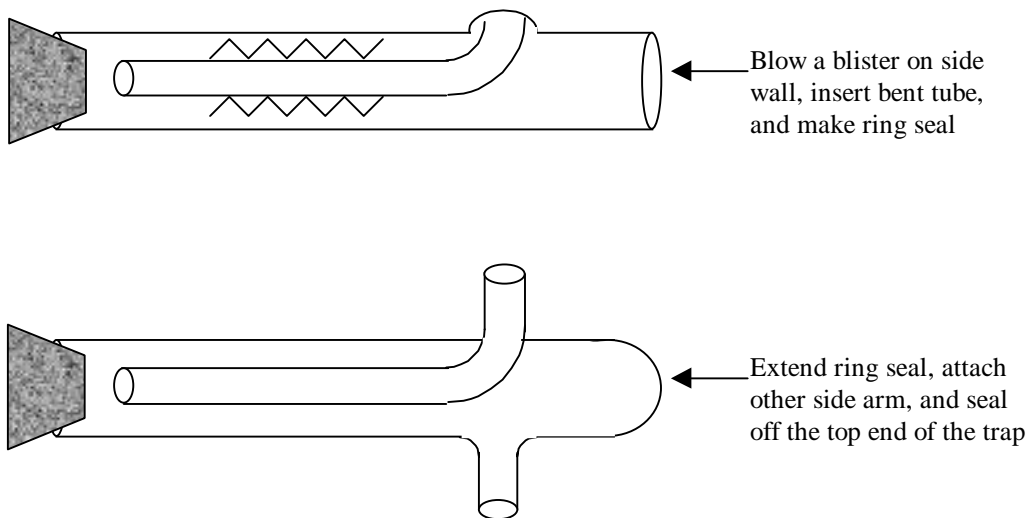
- 1 each 12” long 9mm tube (inner tube)
- 2 each 6” long 9mm tube (side arm and ring seal extension)
- 1 each 10” long 22mm tube (cold trap body)

Construction Details:

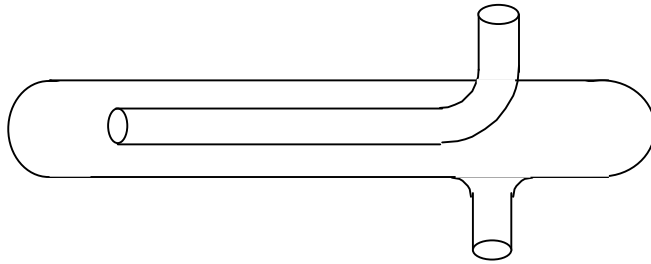
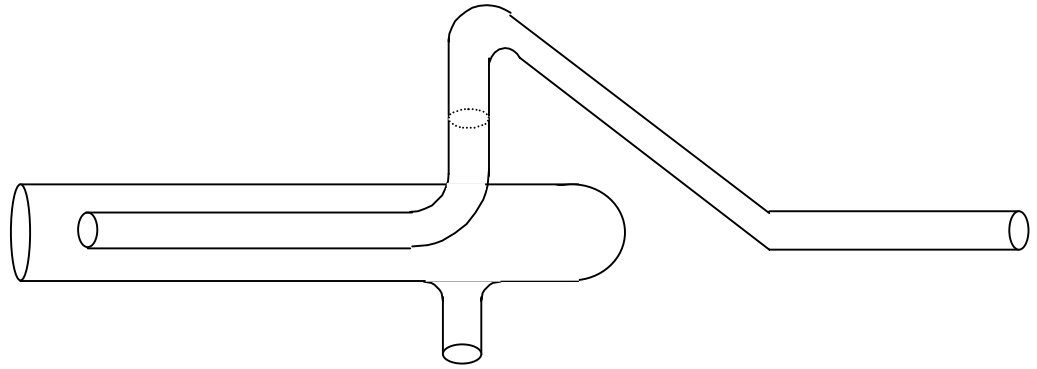
Begin construction of the cold trap by making a sharp radius 90° bend in the 12” long 9mm tube. Cut off one side of the bend such that the distance from the center of the tube is 2mm longer than the radius of the inside diameter of the cold trap body. (In this case, the radius is 9.5mm. Cut the tube at 11.5mm).



To facilitate construction of the side ring seal, a blister must be blown up on the side of the trap body where the ring seal will be located. This blister allows the inner tube to extend past the side wall. Support the inner tube with corrugated cardboard so that the inner tube is centered and extends into the blister on the trap body. Heat the glass blister so that it collapses onto the end of the inner tube. Make certain that the seal is well heated so that the seal is smooth and there are no sharp angles remaining. Blow out the center of the ring seal and extend the ring seal with a 6” long 9mm tube. While the ring seal is still hot, attach the opposing side arm. Attach a glass handle to the open end of the trap body and pull a “point” about 1” from the ring seal. Remove the “point” and complete the round bottom. Flame anneal completely.



Attach a temporary extension to one of the side tubes and form a “handle” as shown below. Center the “handle” to the axis of the trap body. Preheat the open end of the trap body and pull a “point” about 1” from the end of the inner tube. Complete a round bottom seal. Flame anneal completely. Cut and fire polish each side arm to about 2” long. Fire polish and anneal.



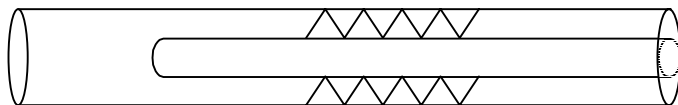
Lesson 4: Dewar Seal

Material List:

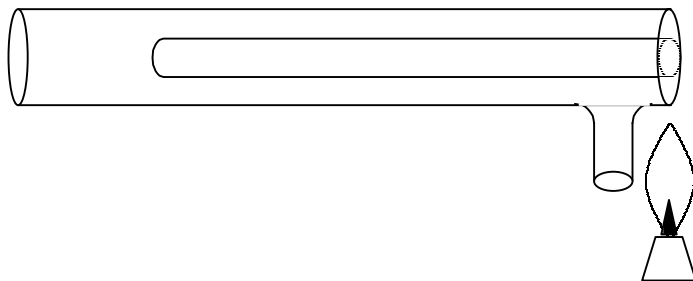
- 1 each 6" long 9mm tube (side arm)
- 1 each 8" long 15mm tube (Dewar inner tube)
- 1 each 8" long 22mm tube (Dewar outer tube)

Construction Details:

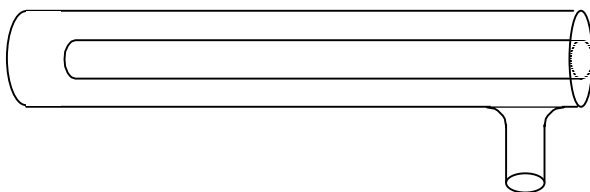
Place a 20mm diameter 90° flare on one end of the 15mm tube. Allow to cool. On the opposite end, form a round bottom so that the tube is 6" long. Allow to cool. Wrap this inner tube with corrugated cardboard and insert into the Dewar outer body. Center the tube.



Heat the edge of the flare and with the graphite paddle, push the glass together such that the seal is airtight. Continue heating the seal until it is smooth. Flame anneal briefly. While the Dewar seal is still hot, add the side arm. Anneal completely. Allow to cool and remove cardboard spacer.



The final step is to add a round bottom to the 22mm tubing. You will need to blow into the side arm to complete this round bottom. Flame anneal.



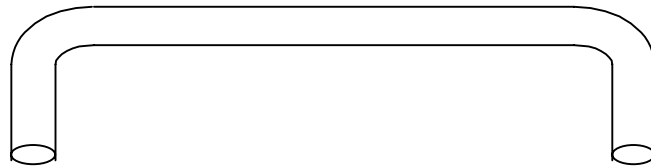
Lesson 5: Closed Circuit Seals

Materials List:

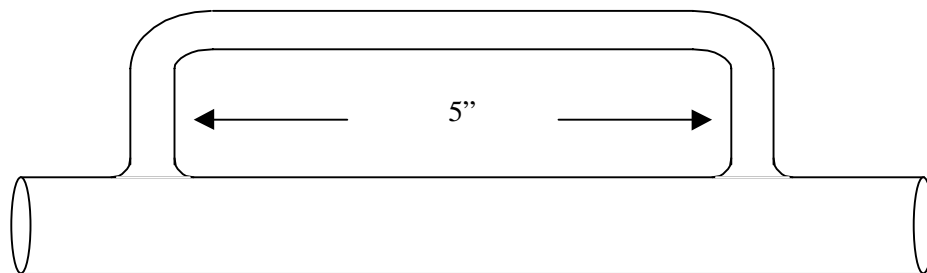
- 1 each 14" long 9mm tube (side tube)
- 1 each 12" long 22mm tube

Construction Details:

Closed circuit seals involve heating and sealing tubes at two locations simultaneously. Begin by bending the 9mm tube at 90° angles in two locations about 5" apart. Allow to cool. Cut each leg of the tube 2" long. Flame anneal and allow to cool. Measure the exact distance between the centerline of the two arms of the tube.



Based on the previous measurement, blow 2 holes in the 22mm tube so that the 9mm tube will align properly. Preheat each seal location and begin heating one seal location. When the glass is molten, join the tubes together. While the first seal is still hot, quickly heat the second seal. Join the second seal together. Additional heating may be required to get both seals hot at one time. Alternate heating seals until both are airtight. A 3mm patch rod will help fill holes that might be present. Quickly smooth one seal while keeping the other seal hot. Flame annealing both seal areas is very important throughout the entire sealing procedure.



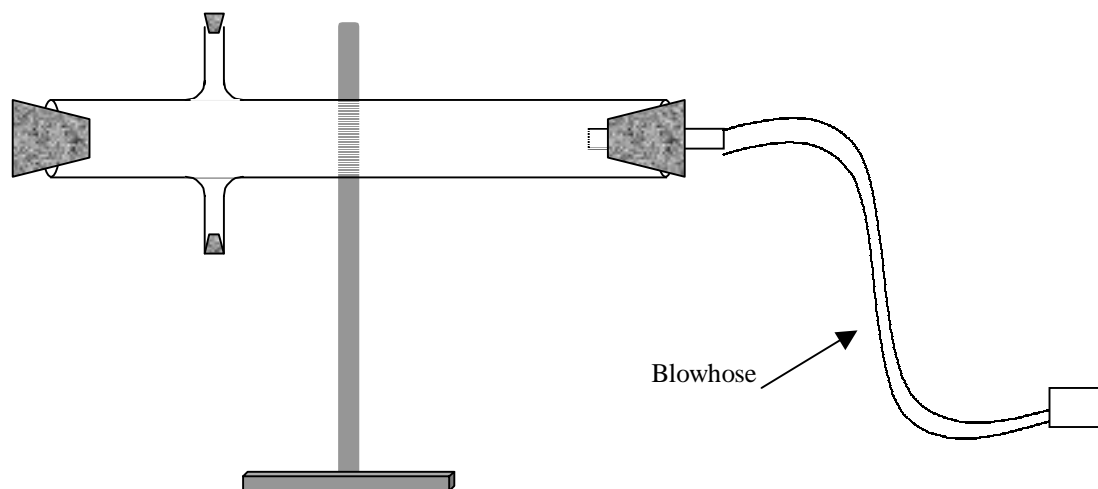
Lesson 6: In-place Manifold Work

Materials List:

- 1 each 16" long 22mm tube (manifold tube)
- 6 each 6" long 9mm tube with slight flare (side tubes)

Construction Details

Using a ring stand and clamp, secure the 22mm tube in a horizontal position. Cork one end of the tube and attach a blow hose to the other end. Begin this seal by preheating the seal location. Using a small, sharp flame, heat an area on the top of the 22mm tube and blow out an opening about 9mm in diameter. Care must be taken to assure that the blown opening closely matches the diameter of the tube to be added. With a slightly larger flame, heat both openings to a flowing temperature, and touch the edges together. While the glass is still molten, pull the seal out slightly while blowing into the tube. Adjust the flame to a very small pinpoint flame. Pick one section of the junction and spot heat the thickened areas of the seal. Continue working the junction area in small stages to assure a smooth seal. Avoid excessive heating that may warp the tubes. Flame anneal the seal area very carefully. Repeat this exercise on the bottom side of the manifold tube. Flame anneal completely.



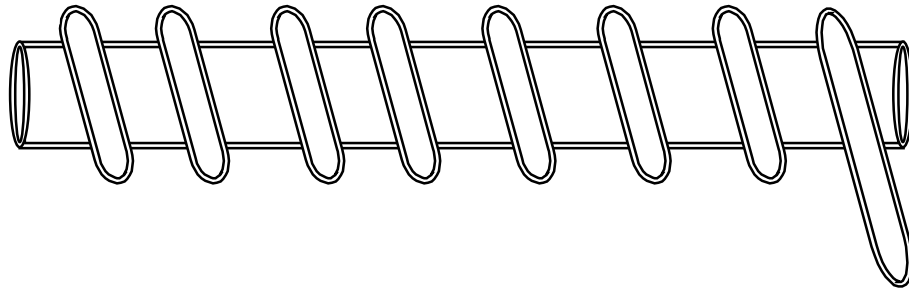
Lesson 7: Coil Winding

Materials List:

- 1 each 48" long 6mm tube
- 1 each coil mandrel covered with ceramic paper

Construction Details:

Preheat the coil mandrel slightly. Bend a hook on the end of the 6mm tube. Attach the hook to the rod attachment on the coil mandrel. In a large bushy flame, heat the 6mm tube such that it is soft enough to bend but not deform excessively. Keep tension on the tube as you rotate the mandrel and rotate the top of the mandrel towards you. The tubing will begin to coil onto the mandrel. Coordinate the flame temperature with the speed of rotation to accomplish smooth coils. On the bottom side of the mandrel, observe the spacing between the previous coil and the tubing to set the spacing of the coils. Raising your right hand during rotation will place the coils closer together. Lowering your right hand will increase the coil spacing. Constant adjustment may be required to accomplish uniform coil spacing. When the coil and mandrel have cooled, break the hook end of the coil away from the mandrel. While running under cool water rotate the coil and remove from the mandrel. Cut and fire polish the ends of the coil. Flame anneal.



Project Sketches

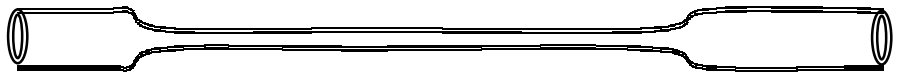
CHM 593

Basic Glass Blowing Seals

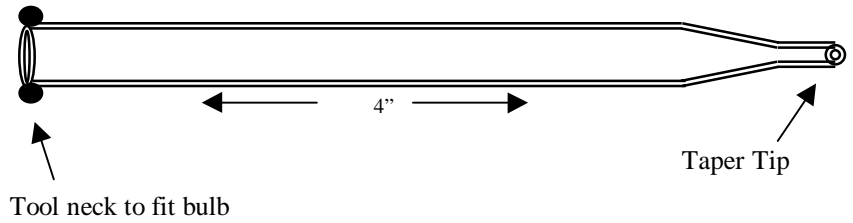
Lesson #1 –
Fire Polish
10 ea.



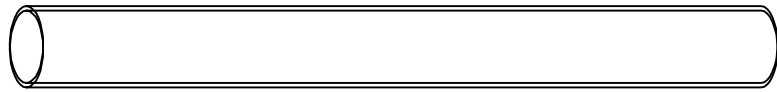
Lesson #2a –
Pull Points
6 ea.



Lesson #2b –
Droppers
9 mm tubing
8 ea.



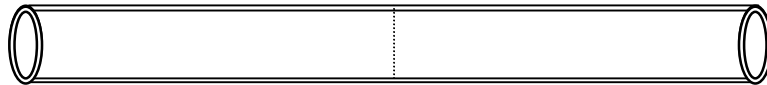
Lesson #3 –
Round Bottoms
4 ea.



Lesson #4 –
Flat Bottoms
4 ea.



Lesson #5a –
Butt Seals
(Same O.D.)
4 ea.



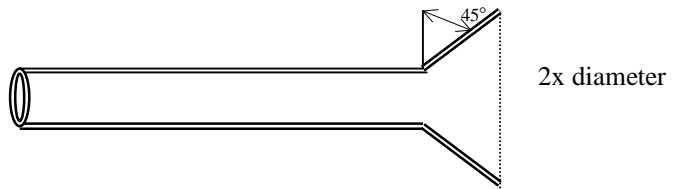
Lesson #5b –
Butt Seals
(Different O.D.)
4 ea.



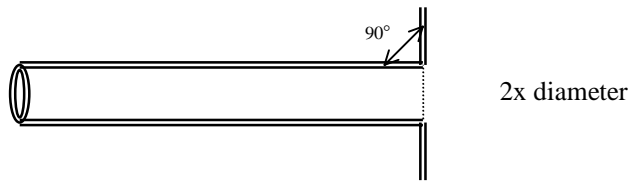
Lesson #5c –
Volumetric Pipettes
3 ea.



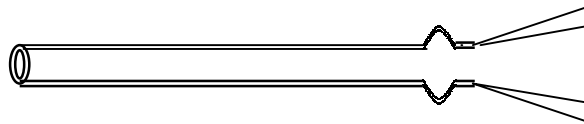
Lesson #6a –
Tubing Flare
(45°)
9mm Tubing
2 ea.



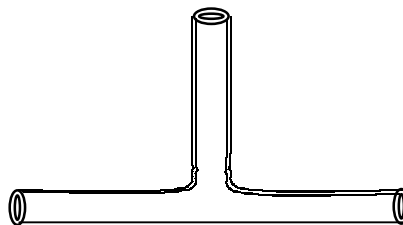
Lesson #6b –
Tubing Flare
(90°)
9mm Tubing
2 ea.



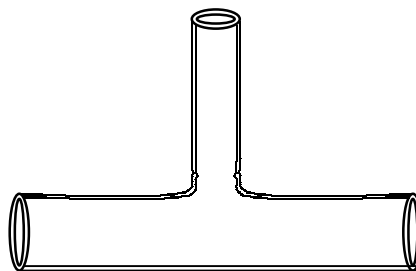
Lesson #6c –
Hose Connector
9mm Tubing
6 ea.



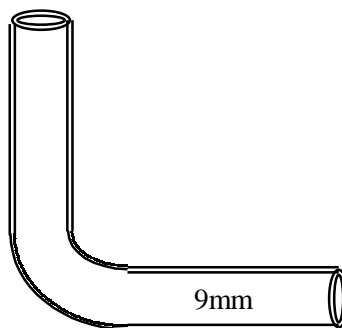
Lesson #7a –
“T” Seals
(Small Diameter)
3 ea.



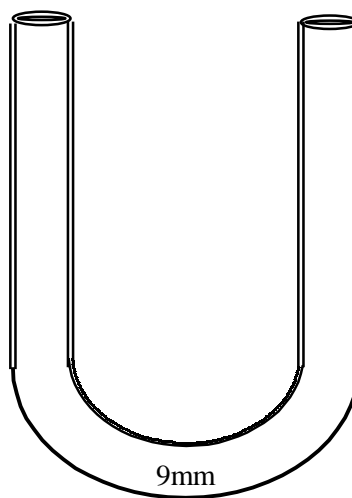
Lesson #7b –
“T” Seals
(Small to Large)
3 ea.



Lesson #8a–
Bends
(90°)
4 ea.

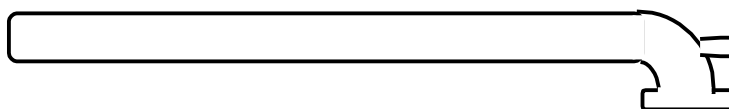


Lesson #8b –
Bends
(180°)
4 ea.

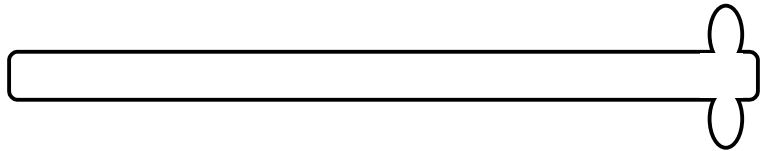


Lesson # 9–
Rod Work

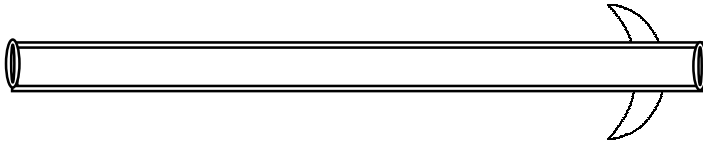
Teflon Blade/
Glass Stir Rod
1 ea.



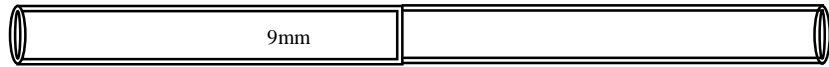
Glass Stir Rod
1 ea.



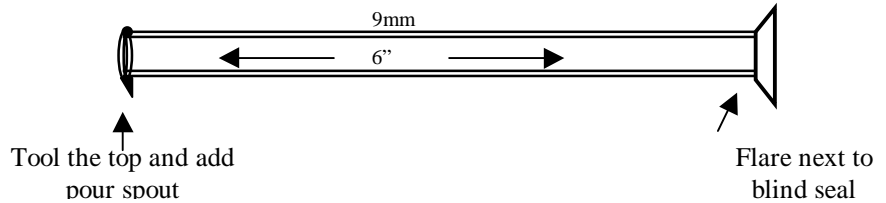
Glass Hooks
3 ea.



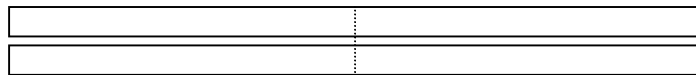
Lesson #10a –
Blind Seals
3 ea.



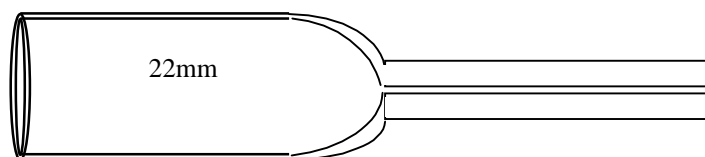
Lesson #10b –
Cylinder construction
2 ea.



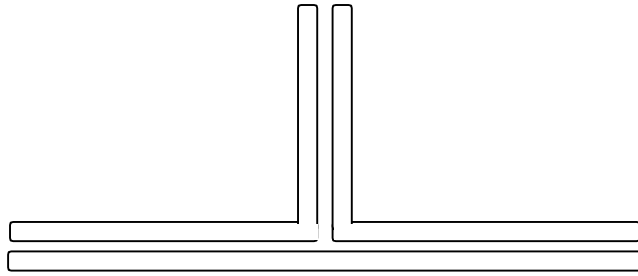
Lesson #11a –
Capillary Butt Seals
(Same O.D.)
1 ea.



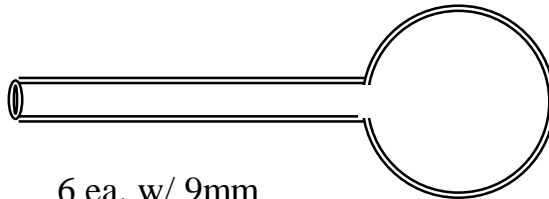
Lesson #11b –
Capillary Butt Seals
(Different O.D.)
1 ea.



Lesson #11c -
Capillary "T" Seals
1ea.

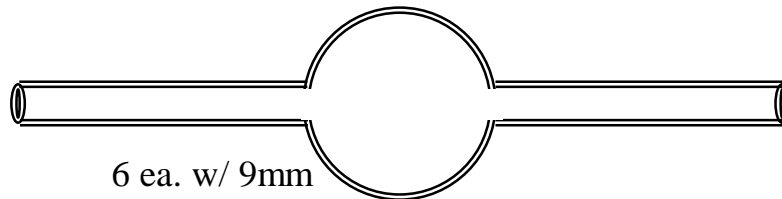


Lesson #12a -
Bulbs



6 ea. w/ 9mm

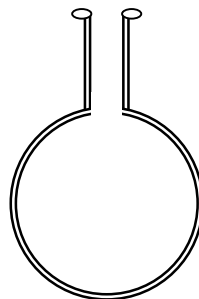
2 ea. w/ 22mm



6 ea. w/ 9mm

2 ea. w/ 22mm

Lesson #12b -
Flasks

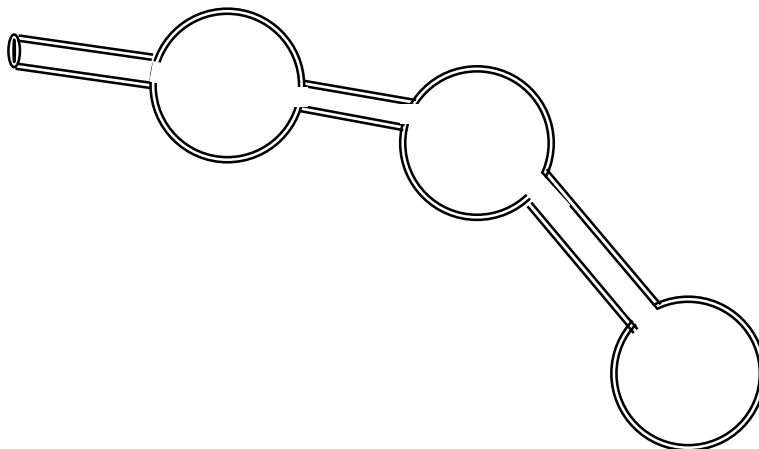


1 ea. w/ 9mm

1 ea. w/ 22mm

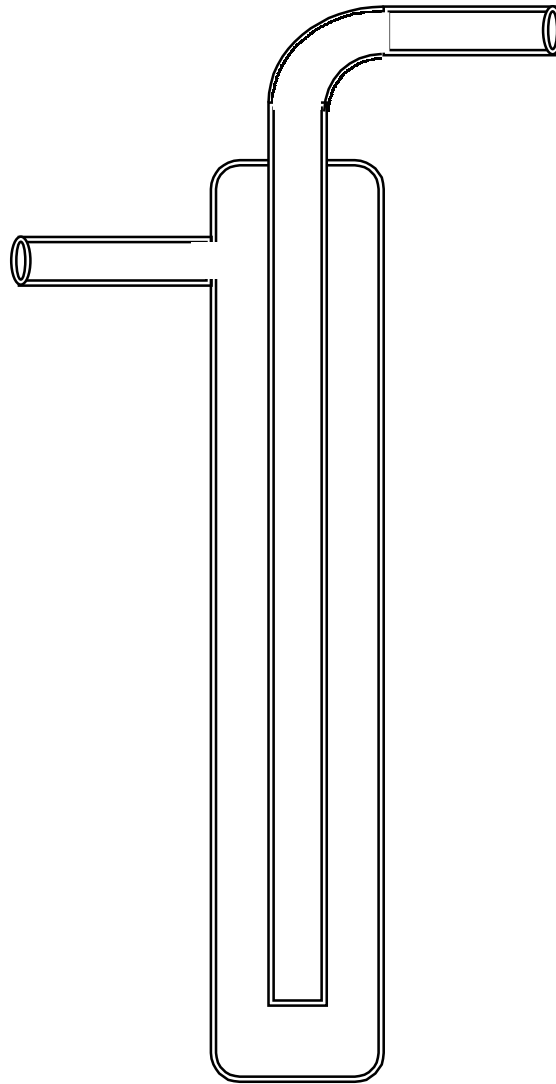
Lesson #12c –
Bulb to Bulb Distillation

1 ea.

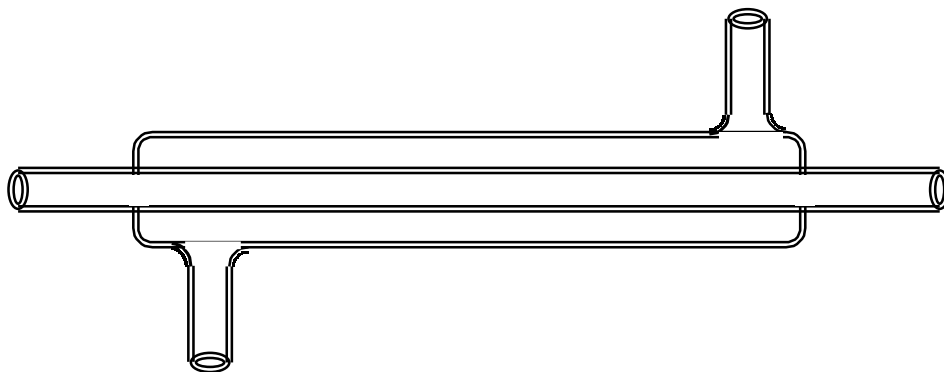


Advanced Seals

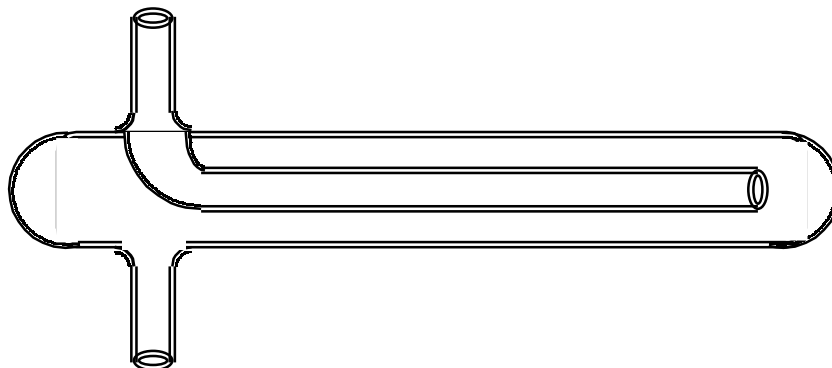
Lesson #1 –
Cold Trap
(9mm & 22mm)



Lesson #2 –
Condenser
9mm & 22mm
1 ea.



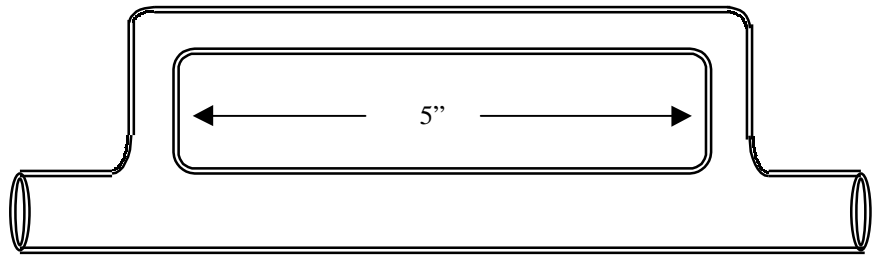
Lesson #3 –
Cold Trap -
Side Ring Seal
9mm & 22mm
1 ea.



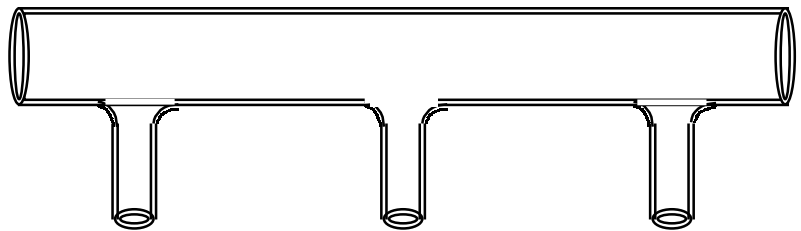
Lesson #4 –
Dewar Seal
15mm & 22mm
1 ea.



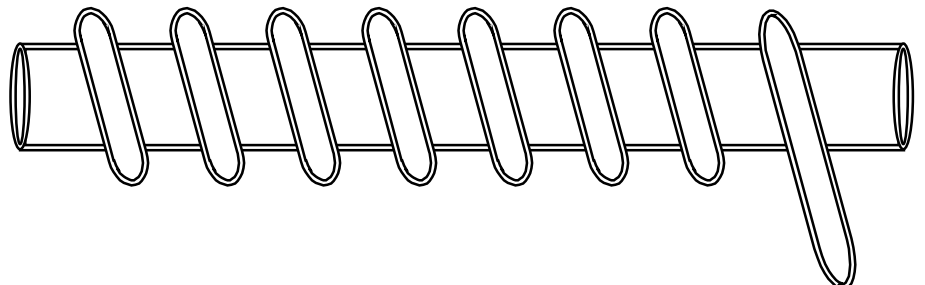
Lesson # 5 –
Closed Circuit
9mm & 22mm
1 ea.



Lesson #6 –
In place manifold work
9mm & 22mm



Lesson #7 –
Coil Winding
6mm Tubing
1 ea.



Final Project

Construction
Details

CHM 593