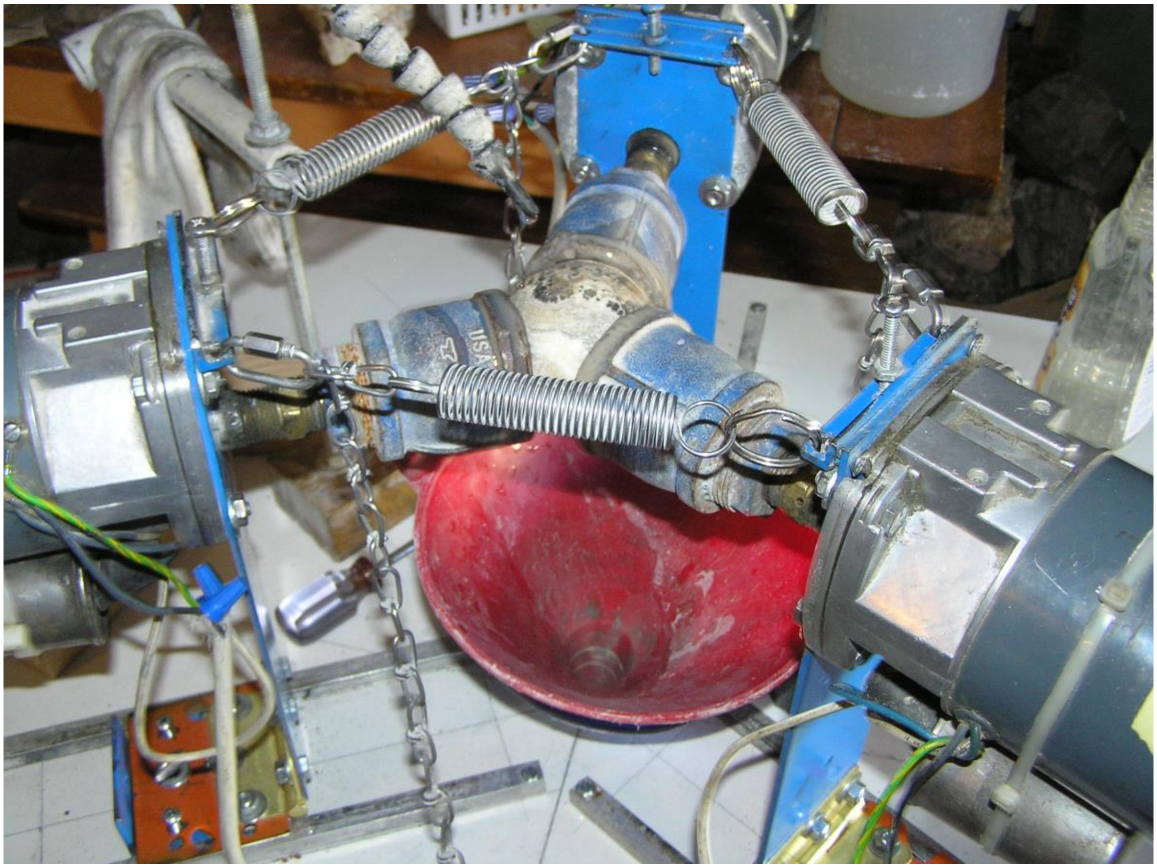
# SPHERE MACHINE

Motors: 3 single-phase AC 110V/60 cycle electric gearmotors, with starting capacitors TEFC (Totally Enclosed Fan Cooled), inline or angle.
150 rpm (geared down 10:1); 100 – 250 rpm OK – smaller cups should run faster, big ones slower
Continuous duty, at least 30 in-# of torque for turning larger rocks
Counterclockwise rotation (otherwise the grinding cups will unscrew themselves)
½" shaft with flat side is ideal;
Source: recycled from copier machine
www.blowerwheel.com or www.surpluscenter.com
Keep looking – they get the right motors once in a while then sell out. You should be paying $40-$80 per motor and you need three.

grinding cups are plumbing reducers with a metal/diamond mixture brazed on.
Use cast iron cups only!!! (galvanized cups when heated produce toxic fumes).
Diamond source: metal/diamond mixture (30/40 or 50/60 coarse grit) is available in form of brazing rods from www.sphereheaven.com. Look under the tab marked supplies.

Special tools needed to build machine: You will need a drill press and a thread tapping set; also the use of an oxy-acetylene torch for the brazing. A chop saw would give better results, but I used a hacksaw. Other than that, all that you need are standard tools like a screwdriver, wrenches, etc. All other materials are available at the hardware store, including the flat steel stock used to build the motor mounts.

Note: The following instructions are not meant to be the Bible for creating a sphere machine. They are one way of doing it, and there are many. However, the thing does work and has provided me many hours of absorbing and rewarding distraction.



**General instructions**:

Use a jig to build your metal parts so that all three motor assemblies are the same height. Otherwise your machine could grind rocks out of round. The smaller the spheres you want to make, the more accurate you need to be.

Cut metal parts to length. Use a chop saw to give a good straight cut, but a hacksaw works in a pinch. Make the vertical piece of flat stock about 8" long for small sphere-making and 12" long for large sphere-making.

**Drilling the flat stock**: Take a light piece of cardboard, cut a hole in it for the shaft of the motor to fit through, then get a rubbing of the bolt connections for the motor. Usually there are four. Press the cardboard against the bolt tips to get an impression. Then punch holes through the cardboard and see how well the holes fit over the bolts. When you get a good fit (no warping of the cardboard when the bolts go through the holes), transfer the pattern to a thin piece of hard plastic and drill out the holes. If that fits over the motor bolts, use it as a jig to drill holes in a piece of the flat stock. Then check that the flat stock fits over the holes. You will need to drill holes slightly larger than the bolts that will go through them.

Use a jig to make holes in the flat stock for the hinge attachment. Use the hinge itself as a template. Make sure that the hinge is mounted at right angles to the length of the piece, otherwise the piece will stand out of vertical when you put the machine together. Drill a hole to accommodate the motor shaft. This hole can be oversized as it is meant to allow the shaft to penetrate the stock, not to attach anything. Drill holes to attach the small crosspiece of angle iron at the top end of the bar stock. This crosspiece has a hole drilled at each corner to accommodate the spring attachments. I also put a hole in the middle of the crossbar, tap it, and thread in a bolt to attach rubber bands to (more on this later).

Once you have drilled all of the holes in one piece of the flat stock, use it as a template to drill holes in another, then a third. When you are done all three pieces should be identical.

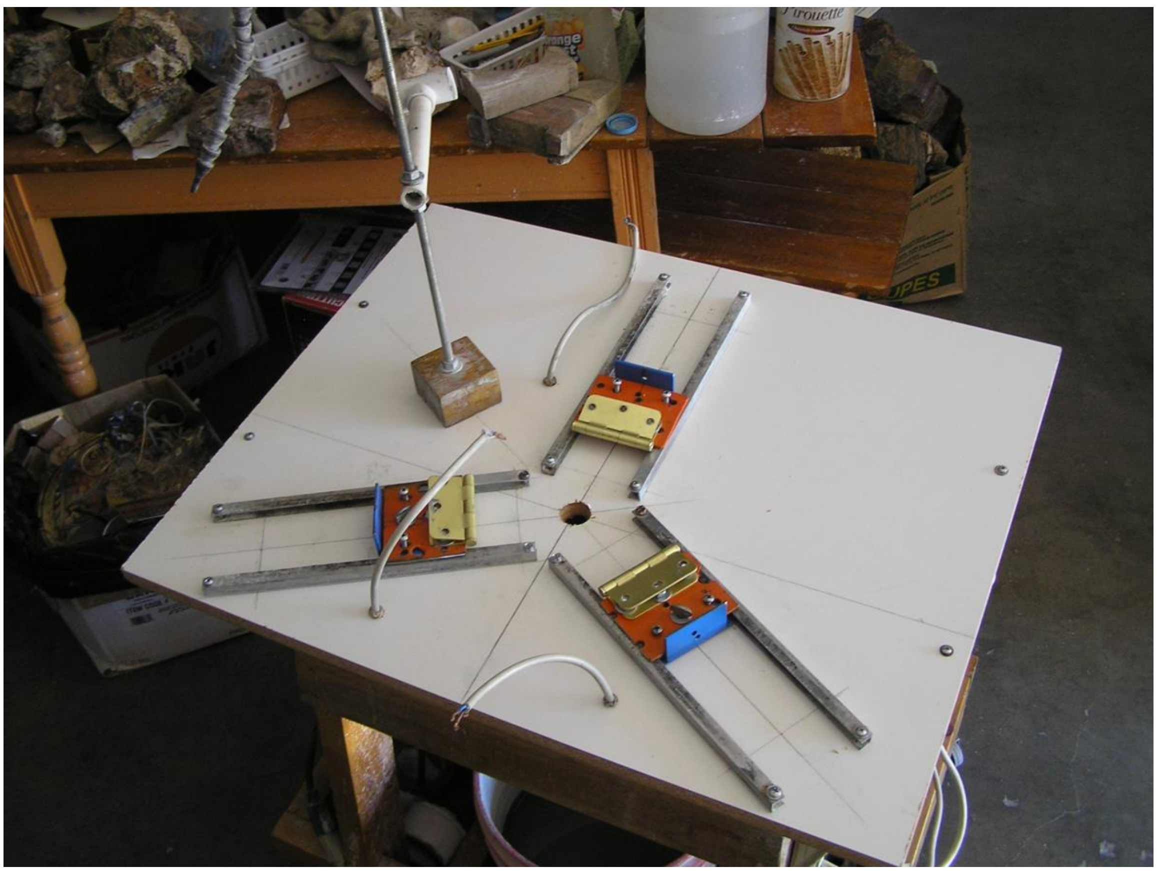
Now cut the pieces of the flat stock to form the base and clamping assembly. These do not have to be cut as accurately as the vertical piece was, because their size and shape do not affect the position of the motor. Drill holes to attach the hinge and the clamping bar.

The clamping bar is made of ¼" steel and has a threaded hole in it to receive a thumbscrew. The thumbscrew projects through the top plate through an oversized hole so that when the thumbscrew is tightened, it lifts the clamping bar and makes it clamp onto the rails of the aluminum sash material. You can't see the clamping bar in the picture below but it is slightly less wide than the inside of the u-shaped aluminum stuff.

Prime and paint all of the steel parts you have made.

**Mate the motor shaft to npt thread fittings**: Cut a 3/8" NPT threaded nipple in half crossways, drill two holes in it and tap them for set screws, then slide the nipple over the shaft (nipple is ½" on the inside). Attach nipple to flat on shaft with two allen set screws; then screw on a 3/8"/1/2" npt reducer/bushing to convert to ½" pipe thread.

**Build table**: This can be whatever height and size you want. Make top out of ½" or thicker plywood. Prime and paint at least the top. Using a protractor, draw three lines 120 degrees apart that meet in a center point. On a square or rectangular table, this center point will not actually be in the center of the table. Attach rails to the table so that when you are done, the center of the motor shafts will be directly over the lines you have drawn. Obviously, the rails will be parallel to your lines. Assemble the base of the motor mount assembly with the hinge and install it in the rails. Then attach the top part of the motor assembly, and next attach motors. They can be propped up by wooden blocks.



**Wire motors**: Run the power cords through the table surface from below for hookup to the motor wiring. Connect with wire nuts. The other end of the power cord should have a plug attached – yes, a <u>three prong plug</u>. You are working around water and all of your motors should be grounded. The motors should come with a wiring diagram and capacitors for easy starting. Plug all three motors into a plug-in strip with an on-off switch. This lets you turn all three motors on or off by throwing a single switch.

Needless to say, you should install a ground fault interruptor type plug receptacle in the wall plug you are using to power your machine.

**Water drip**: This can be a gravity feed using the oiler from a drill press, or you could use a very small pump. I use a 3/8" threaded rod attached to the table top to hold the oiler. Drill a hole for the rod, then secure to table top with a nut and washer top and bottom.

Drill a hole through the table top in the center point directly below where your rock will be when you are grinding it. Run a funnel through the hole to feed into a plastic bucket beneath the table.

**Miscellaneous parts**: You can attach springs between the grinding heads by drilling holes in the ends of the small angle iron cross bar that is fixed to the top of your vertical motor mount. Use small locking carabiner clips, light chain and key ring loops to make it easy to change spring tension. A small vertically mounted bolt that sticks up out of the top of the cross bar works well to attach rubber bands. These are used to adjust tension on the rock to change its rotation pattern when the machine is running.

**Tips on preparing the preform**

You start grinding on a **preform**. This is a rock that has been rounded enough for the machine to turn it into a sphere. The rounder the preform, the quicker the grinding steps will go. Take the time to make a good preform and everything else will be easy. Start with a lumpy, out-of-round preform and your machine will turn it into a misshapen, out of round egg or football.

A few rocks are naturally rounded enough to skip the preform steps – solid coconut geodes, for example, and some thundereggs. These you can pop into the machine after a couple of minutes of knocking off the bumps and lumps with a grinder.

There are two basic ways to make a preform - by cutting with a rock saw or by core drilling. I prefer to cut hard materials on a saw if they are over 3 inches or so, because my core drills are made to drill through concrete and not agate. The cutting teeth on concrete core drills are hard metal. This works fine on softer materials, because relatively soft concrete or rock (obsidian, for example) is very abrasive and wears away the metal that holds the diamonds fast enough to expose fresh diamonds to replace those that fall out. Hard agate is less abrasive; the diamonds eventually fall out but the agate does not wear away the metal fast enough. The drill stops cutting.

So I drill softer rocks (granite, thundereggs, marble, some petrified wood, moss agate), but cut with the rock saw on Brazilian agate, Canadian jade, harder petrified woods and other very hard, fine-grained material.

**Rock saw method**: To make a preform on a rock saw cut your rock into a cube. Then cut the corners off to make an octagon solid. Then cut away the top 8 edges and the bottom 8 edges. The result is a solid with 26 faces (26 saw cuts, 26 times to open the lid of the saw and breathe that wonderful saw oil smell, and 26 times to wash the oil off your hands). The catch is – you have to make all of the cuts at the right angles and the right distances out from the center. If even one face is cut too far in, your grinding time stretches out more hours and your sphere ends up smaller.

You can buy jigs that allow you to make the cuts quickly, or you can draw the guidelines for the saw on the faces of the cube that you made in the first step. I don't have a jig, so I do the latter. If you draw a circle on a piece of paper with a compass and then measure the sides of the cube that the circle would exactly fit in, you should be able to figure out where to make your lines proportionally on the face of the cube.

Or you can try to follow these directions. Make the cube as even as possible. Pick the side with the most regular edges to be the top. The top has four edges, right? Find the center of each edge and mark it with a pencil. You can do this by measuring the length of each edge, dividing by 2 and your dot should be the same number of millimeters from each side. Next, measure the diameter of your cube in millimeters from all three directions, take the smallest number, divide by 2 to get the radius, and multiply that number by 0.42. Add one millimeter and measure that number of millimeters out from the center mark on each edge and make a mark. Do this for all four edges, then draw a line across each corner connecting the marks. This line is where you will make your first cut.

Flip the cube over and do the same thing for the bottom side. Then draw lines on the side faces of the cube connecting the matching marks on each face. Cut the corners off the cube with your rock saw following the lines you have made. You should end up with a solid octagon and four triangular lengths that used to be the corners of the cube.

Clean up the rock to get the oil off. Make a mark in the center of each of the eight top edges. Draw lines on the top face connecting marks on opposite edges. There will be four lines and in a perfect cube (seldom happens) they will all intersect in the center of the top face. On each line, measure out from the intersection point the same distance you measured for the last cut (1/2 the minimum diameter of the rock times 0.42 plus 1) and make a mark. There will be eight marks. Draw a line through each mark at right angles to the line the point is on. There will be eight of these lines and they will form a grid pattern on the top face of your rock. Turn the rock over and repeat for the bottom side.

Next turn the rock on its side, measure inward from one of the ends along an edge a distance equal to ½ the diameter of the rock times 0.58 minus 1 millimeter. Make a mark with your pencil at this point. Repeat for the other seven edges, then connect all of these marks together with lines. Turn rock around and repeat for the other end.

You have now drawn the lines showing where to make the final 16 cuts on your preform. Put it into the saw and make them. To minimize the chances of the preform slipping in the vise and damaging your saw blade, make a wooden support with a v-notch cut out of the bottom to support the weight of the preform. I make every other cut on one end (4

large cuts), flip it over, do the same on the other end (4 more cuts), do the remaining 4 small cuts on that end, then flip it over again and do the last 4 cuts. It will be easier if the second set of four cuts is staggered 45 degrees to the first set because that will give you a flat surface to set the rock on for the last 8 cuts. Trust me. Your preform is now done – knock off some of the corners with a grinder and it is ready to put into the sphere machine.

The math summarized:

1. Measure the dimensions of your cube - let's say it is 108 mm X 106 mm X 105 mm.
2. Take smallest dimension, divide by 2, and add one. 105/2 X 0.42 + 1 = 23 mm.
3. Use this number to draw lines for cutting the first edge cuts and for making the grid pattern on the ends of the preform.
4. To make the lines on the sides of the preform for the final 16 cuts, use 105/2 X 0.58 -1 = 29.5 mm.

A perfect preform has 26 symmetrical faces. If it ground down perfectly, the centers of the 26 faces would be the only spots on the preform that would be on the surface of the sphere. As the sphere ground, each face would shrink to a round flat spot on the sphere and all 26 would disappear simultaneously. In reality, some of the faces will be misshapen due to mistakes in measuring and cutting the preform, so your sphere will take a little longer to grind and will end up a little smaller. Not to worry.

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Now that you have seen how much work it is to cut the preforms with a rock saw, the idea of core drilling begins to seem attractive.

**Core drill method**: If you want to core drill your preforms (this is quicker than the rock saw method on most rocks), you need not only the core drill bits (available on the internet) but some way to power them. You could buy a concrete core drill. They usually have two speeds – fast and very fast; both of them are too fast for lapidary applications, especially for making larger spheres. Remember, the core driller and the bits are designed to drill holes in concrete, a relatively soft and abrasive rock. What will happen is that the combination of high rim speeds and harder rocks will cause your bit to glaze over and stop cutting.

However, you can use a standing drill press to power the bit. These are tall enough to handle the long bits and the motors are powerful enough to turn the larger ones. You need a drill press with speeds in the range of 250 to 550 rpm and a motor of at least 1 HP. I bought a Harbor Freight 16 speed standing drill press and it has done the job. Parts will break because you are using the equipment for a more rugged purpose than it was designed for, so when you break a part – order two. It takes them about 3-5 months to get the new part made in China and shipped to you, but they are very cheap.

Diamond cutting works best at a moderate rim speed. Look on the internet for what those speeds are. The UKAM web site is a good source of information http://www.ukam.com/drilling_recommendations.htm . Generally, cut harder materials slower than the recommended speed, and cut softer materials faster than recommended. Also – I recommend using a water soluble cutting oil to prevent corrosion and extend the lifetime of your core bit.

To drill through rocks with water using the water soluble cutting oil, you need to recycle your water. Make a metal box and fasten it to the work table on the drill press. Mine is painted mild 1/8" thick steel, 14" X 20" X 8" deep, with a top lip. This serves the double purpose of holding the rock immobile and containing the drilling water, which I run through a Harbor Freight fountain pump. I irrigate the cut from the outside, but the preferred method is to irrigate from inside using a water swivel attached to the chuck on the drill press. If you do choose to use a water swivel, get the beefiest one you can afford. They are easy to bend if your rock moves during drilling operations. The fountain pump is designed to run clean water, not dirty sludge, so change your water when it gets too dirty and settle it in old milk jugs to conserve the cutting oil. When the fountain pump eventually dies, get another. They're cheap.

The rock is held in place using various shapes and sizes of wood blocks and wedges. Put a piece of plywood underneath the rock so that you don't accidentally drill through the metal box. Then fill the box with enough water to reach the intake of the fountain pump, add the cutting oil, and fix the outlet hose of the fountain pump to the side of the box with a C-clamp so that it wets the contact point between the bit and the rock.

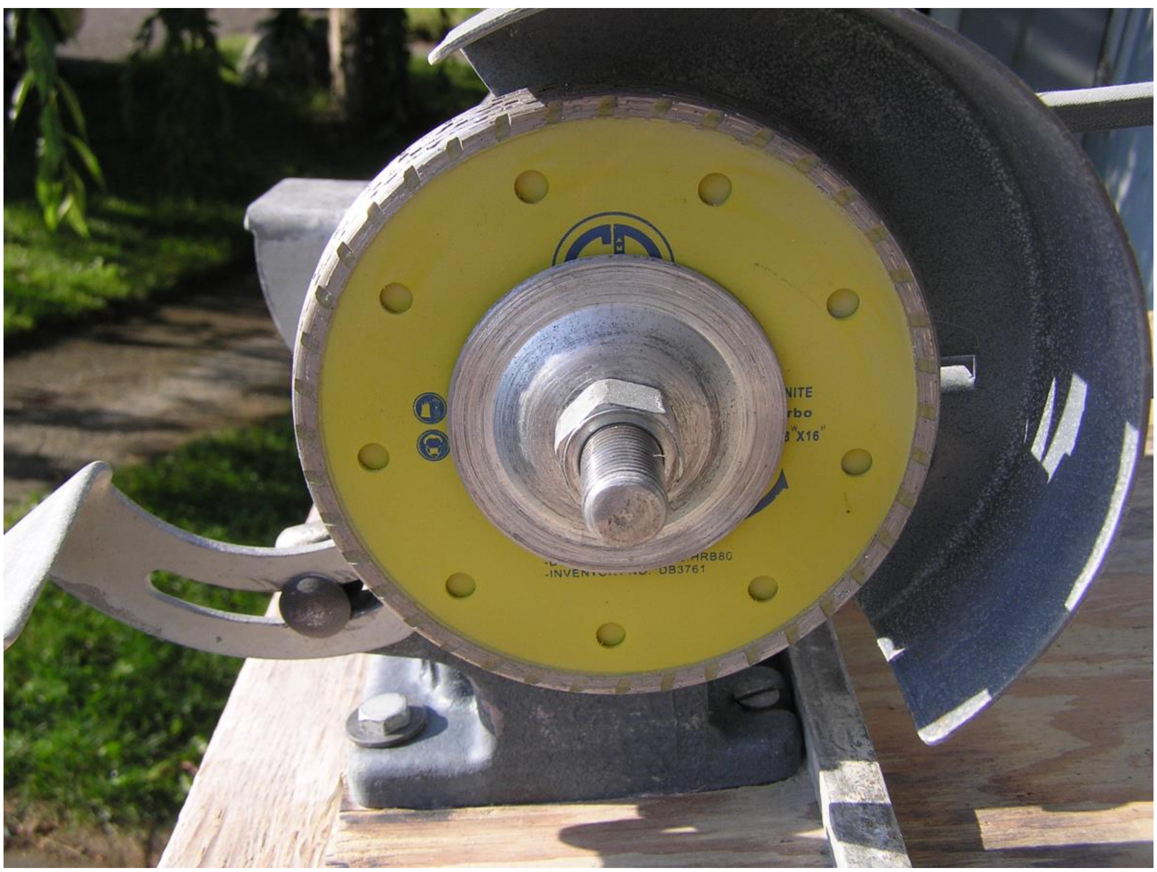
Raise the box until the rock is just below the bit, then support the box from beneath somehow. The drill press work table sits on a metal casting and you are putting a lot more weight on it than it was designed for. I stand a 2X4 upright under the work table/box. Start the drill press, adjust the position of the box so that the rock is centered beneath the bit, make sure that the rock is immobile and that both the clamp beneath the work table and the clamp on the the riser of the drill press are tight, then slowly lower the drill bit and gently start cutting into the rock, irrigating the cut constantly. Once a good groove has been set into the rock and the bit looks like it isn't going to come out of the groove, you can relax a little. I put a piece of PVC pipe on the handle of the drill press, run a cord through the pipe and hang a weight off the end. That way I don't have to stand there holding the stupid handle. That lets me do something else in the shop. Until you are totally comfortable with how your core drill functions and you trust it implicitly, **never, never, never leave the shop with the press running**! You need to be there to respond quickly if something goes wrong or you will break your equipment.


If your rock is more than three inches thick, you will need to raise the drill press work table (with your box, rock and water in it) after a while. Mine has a throw of about 80 millimeters. Do this while the press is running. Loosen the clamp on the riser of the press so that you can crank up the table. Support the table's weight with one hand while you crank it up with the other. The table will stay centered on the cut as the bit turns. Lock the table tight by retightening the clamp, make sure it is supported by the 2X4 again, and you are ready to go for another 80 millimeters.

As you approach the bottom of the cut, be there. What happens at the end of a cut is always unpredictable. Sometimes the bit gets unstable and vibrates wildly with the weight of the core inside it, sometimes it jams as the rock breaks up, and once I have broken a tooth off my bit. If this happens take it to your local welding ship and have them refasten it with silver solder. You can also drill through the bottom of your metal box. The drill bit will cut through metal as easily as it cuts through stone.

The second cut is made by laying your core on its side and drilling through it to make a squarish shape with four corners. To make the third cut, take the 4 cornered shape from the second cut, turn it 90 degrees and cut off the four corners.

You now have a roundish rock with 8 pointed corners or horns. Grind these off with a bench grinder or edge grinder. I make a grinding wheel by ganging together 5 cheap dry cut diamond blades on my grinder arbor. I get these from McGill's Warehouse online http://www.mcgillswarehouse.com.



**Using your sphere grinder**: Once you have assembled your machine, try it out. The best way to learn to use it is to make a preform of something other than primo rock and make the best sphere you can. I have run my machine for five years now and I am still learning new tricks, but then I am a slow learner.

Tips on how to use your sphere machine will be the subject of future writings.

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