

An Improved

ELECTRIC RADIANT SHOP FURNACE



by Dan Hartman

<http://www.dansworkshop.com>

***This book is dedicated
to my dear wife
and children
who put up with the
many hours I spent
at the computer
writing it***

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INTRODUCTION

Frequently Asked Questions

How hot will this furnace go?

Answer: With a heavy duty kanthal element for ceramic kilns, it will reach 2300°F. Cheaper elements may limit your furnace to 1800 degrees or less. However, extended operation at higher temperatures will shorten the life of any element.

What is the wattage?

Answer: The plan is for a 240 volt, 3600 watt unit. However, you can scale the furnace to any size you like, the most popular choice being 120 volt, 1800 watt.

What is the capacity?

Answer: It will melt close to two quarts of metal in a 5" crucible that is designed to fit the height of the furnace. My crucible is the 4" one I had made for the original Lil' Bertha style furnace, and it holds about a quart and a half.

Where did you find the elements?

Answer: At a local ceramic shop. You might have one near you, or you can certainly find them from ceramic kiln suppliers online. Another great source is www.budgetcastingsupply.com. They carry not only elements, but a variety of build-your-own furnace materials. Please see the *Online Suppliers Index* at the end of the book.

Can I make my own elements?

Yes, you can! I made elements of alloy 308 solid core MIG welding wire, .030" in diameter. This was too thin, however, and the elements did not last very long! If you must make your own elements, use .045" so that the elements will last longer.

I made mine by winding the wire over a length of 1/4"-20 threaded rod. The resulting coil was very nicely formed, being guided by the threads.

Where do I find high temp cement?

Answer: I got mine at a hardware store, but I had to shop around several places before I found the genuine black Worcester Brush brand cement. It was worth the effort. You may find that you have to shop around considerably to find this, and don't forget to tap the online sources. Another brand name to look for is Meeco.



How did you form the grooves in the firebrick?

I took 3 masonry cutting blades and mounted them in a stack on my table saw. Cutting with all three blades at once made a nice 3/8" wide groove just perfect for the element. This was quite time consuming, so when you tackle this, be patient. There are six bricks to be cut and 6 grooves in each! That's a lot of cutting, and wear a dust mask!

What kind of crucible do you use?

I had a local welding shop make me a crucible out of schedule 40 steel pipe. This resulted in a very durable crucible that I can lift out of the furnace with a large channel-lock type pliers. However, this crucible will only melt pot metal, aluminum, zinc, and other low melting alloys because of its own temperature limits.

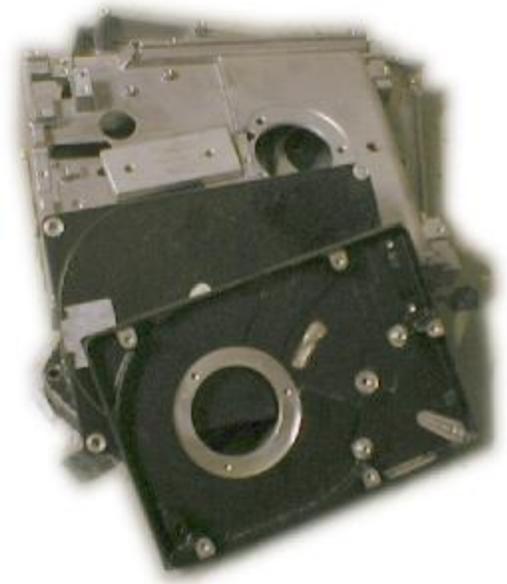
Will the furnace melt brass?

It will, but you need a clay graphite or silicon carbide crucible, a set of tongs to fit the crucible without breaking it, and elements in your furnace that will heat to the melting temperature of brass without ready failure.

What is your source of aluminum?

Extrusions (like old storm doors and ladders), castings such as pistons and lawnmower engine blocks, computer hard drive and floppy drive cases, and aluminum plate if it's more than 1/8" thick. I have tried melting soda cans, but the smoke and dross that is produced make this a very poor choice of aluminum source. Besides, here in Michigan, there is a 10 cent deposit on aluminum cans which also make it prohibitive.

If you can't find metal anywhere else, check with your local metals recycler in your area, and purchase some high grade aluminum scrap. It's worth it.



How long does it take to melt?

Two hours from a cold start, to melt a crucible full. Successive melts after the furnace is hot take much less time, between 30 minutes and an hour. The furnace can melt much faster, but the element will burn out faster, the harder you make it work.

Where do I find casting sand?

I got mine at a local foundry, as luck would have it. Not many folks have foundries local, and the one I obtained mine from is no longer in business. Because of the weight of the sand, you will find that purchasing online or through mail order can be quite expensive. You can get PetroBond sand at www.budgetcastingsupply.com. Or you could check state

directories to see if there's a foundry within driving distance. The cost of fuel may be manageable compared to UPS charges.

What's improved about this furnace?

I build my original furnace over Dave Gingery's Lil' Bertha plans. The furnace worked but needed some drastic improvements in the design. After working around the limitations in the original furnace, particularly the crumbling refractory, I decided to completely re-design the furnace using grooved firebrick and a more durable, available refractory. There were other improvements as well, and you can read more about them in the section "About the Title."



How long does it take to build the furnace?

From the time I started collecting materials to the first pour was about two weeks. I spent only evenings and a Saturday or two, working around a busy schedule with a family and full time job. See the next section, "Step by Step Construction at a Glance." Like any homebuilt project, it takes a little patience!

How much does it cost to build the furnace?

Between \$100 and \$200 depending on how far you have to reach for supplies (shipping costs or locally available materials), if you can wire the circuit yourself or hire an electrician, and other such factors. But even if you go a little over this suggestion, you will probably come nowhere close to a commercially available ceramic firing kiln of similar size. They start around \$600 last I priced one.

Step-by-Step Construction At a Glance

One question that I am asked frequently is “how long does it take, approximately, to build this furnace?” It is hard to estimate, because when I built mine, I had other duties calling and took breaks now and then, so I did not work on it for a continuous block of time.

Here is an amusing but realistic chart of the time and effort involved to build the Improved Electric Radiant Shop Furnace:

Step	Time to Complete
Collect the Materials	A trip to town, breakfast to lunch, maybe few minutes online to locate the hard-to-find stuff.
Assemble the Shell	Just before lunch (don't skip the most important meal of the day!)
Cut the firebrick	Lunch to dinner (this IS time consuming, don't give up!)
Assemble the furnace	After washing the dust out of your hair from cutting the firebrick. (Might have to wait a few days for ordered supplies to arrive)
Ram in the refractory	An evening (perfect way to end the day)
Air dry the refractory	A week (just forget about it for a while, patience, patience!)
Make temporary electrical connections	A cup of coffee (I prefer cappuccino)
Cure the refractory	16-20 hours on LOW heat
Make permanent electrical connections	Another cup of coffee while the electrician installs the circuit
Done, melt metal!	A lifetime of rewarding hobby!

Steps to Completion

In your particular circumstances, it may take longer to round up all the materials needed. (Print out the materials checklist to take along as your shopping list to help save some time!) As I hope you will understand, the time to build really isn't all that long, and then you will have a new capability in your shop!

About the Title

You may be wondering about my choice of a title for this book. There are several reasons I chose the title, "An Improved Electric Radiant Shop Furnace." Each and every part of the title deserves explanation, for those of you who wish! For the rest of you who simply don't care what goes into choosing a title, you may skip this part, but don't neglect to read the DISCLAIMER.

An vs. The

It's 'an' because it's not the only. If it were the only, the title would begin, 'The.' "Ok, such a minor detail," you might be thinking. It's important to consider the variations and further improvements you may make as you actually make a furnace for the heating jobs in your shop. My purpose in writing this book, in part, is to describe ONE way that such a furnace can be built, and particularly how I did it.

When you make your modifications to the design I present here, then the furnace is not 'a furnace' or 'the furnace' it's 'YOUR Improved Electric Radiant Shop Furnace.' Isn't life great?

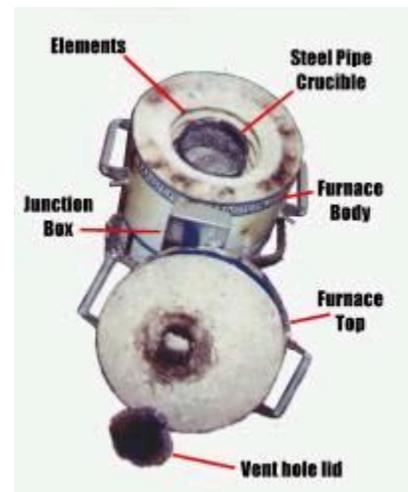
What's Improved

Here's where the story really begins. For my 25th birthday, my wife got me Dave Gingery's book "Lil Bertha, a Compact Electric Resistance Shop Furnace." So I started right off building by Dave's plans...

The main problem, in my opinion, that one encounters in making a resistance furnace is the structure that holds the elements in place. Dave's book describes one solution to the problem, and that is to form grooves in castable refractory.

My attempt at forming the grooves by Dave's designs failed miserably. The refractory that seemed to match Dave's description in his book was AP Green's "Kastolite" castable refractory, and after ordering and having shipped about a hundred pounds I got right to work. (Can you say 'UPS charges' 10 times really fast? Thank you. Now you feel my pain.)

Well, when I tried to pull the rubber hose out of the newly formed groove, the Kastolite chipped and broke out horribly. The element barely stayed in place in this malformed groove, but hey, I was following the instructions.



To make a long story short, I used the remaining Kastolite to make some 'donuts' with a little trough around the inside diameter, at the top. The inside of these donuts was the inside diameter of the furnace, and when stacked one on top of another, nice, well-formed element grooves resulted. However, the making of these 'donuts' required some styrofoam cutting to make forms, and that's another story. But this method of forming the element grooves worked well indeed, and the Lil' Bertha was up and running at last.

After a few melts, I discovered the great benefits of using electricity for melting. (I had indeed tried gas burners, but they were noisy, required close supervision, drank fuel like Coca-Cola on a hot day in the desert, and held the temperature about as steady as a roller coaster.)

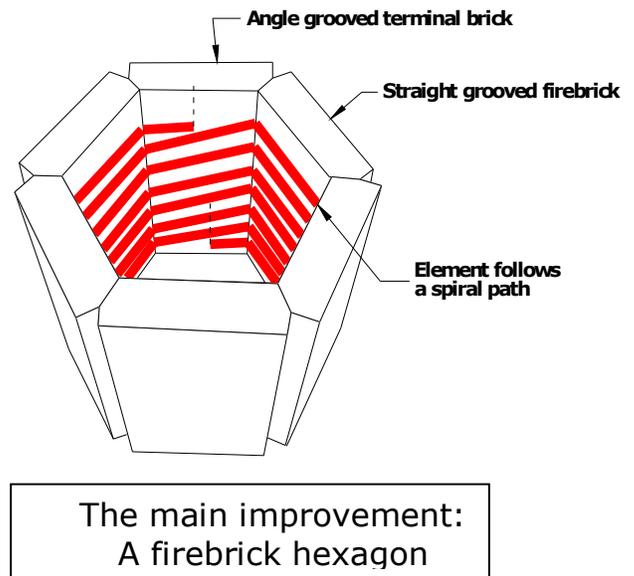
However great a success, the Lil' Bertha had her faults. The Kastolite began crumbling from the many heats. (An AP Green technical support rep told me that Kastolite was intended as a backup lining, and that I should have used Mizzou!) Well, the original Lil Bertha finally went south, so then the task of restoring/rebuilding (and improving!) the furnace became a foremost project, and I decided to keep a photo diary online of my progress. (That is likely where you found the link to purchase this book.)

So that's how '**Improved**' came to rest in the title of this book. I was not about to repeat the scenario of ordering more Kastolite, and paying the shipping cost, then reviving my old styrofoam forms and making more 'donuts.' I sought out the idea of making my own refractory, using firebricks, or whatever. After few hours of online research, I was ready to start experimenting.

It's Electric.

As mentioned earlier, I had tried building gas fired furnaces. I know it has been successfully done, and I don't criticize anyone who chooses to do their heating tasks with gas. But I can assure you from my own experience that electricity is an ideal form of energy to use for heating tasks such as metal melting and heat treating.

Another improvement that I made to the melting furnace is the controller. Instead of using a range control mounted right on the furnace body, I designed a beefed up version of a lamp dimmer and mounted it up away from the heat of the furnace. As you can see in this photo, the furnace and its controller are located in a corner of my shop next to the electrical panel.



Radiant vs. Induction vs. Ultrasonic

Not all furnaces heat their loads by radiant means. Some of them use electromagnetic induction with a pulsating magnetic field to induce currents in the workpiece or load. Others use ultrasonic radiation (sound) to heat with. I've even heard of special crucibles that can be used to melt metal in a microwave oven! However, this furnace uses the radiant glow of the element to transmit heat energy to the load.



It's a small-Shop Furnace.

This is called a shop furnace because it is intended for shall home shop use, in a variety of heating tasks. The term 'kiln' has reference to curing ceramics or drying wood, and the shop furnace can indeed be used for that. (I've used mine to distill methanol from wood!) But the 'furnace' is called on for metal heating and melting tasks, which is what I use it for mainly, and more than likely you will be using it that way as well.

So there you have it, the Improved Electric Radiant Shop Furnace!



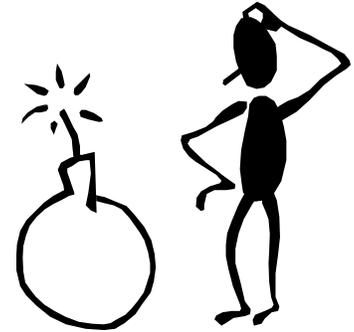
NOTICE OF DISCLAIMER

God gave you a head, use it

I use mine! I suggest you use yours. However, I am not a professional engineer, neither have I had training in design and operation of shop equipment. Even if I did, what good would it do you?

Even thus, I will try my best to inform you of potential dangers so that you can avoid them. But such warnings are not to be construed as my acceptance of any liability whatsoever for damages you incur to your property!

I myself am an amateur but I have successfully completed and regularly operate the project described in this book. My methods and designs are only intended as guidelines for other amateurs wishing to build their own machinery, and be warned that there may be dangers not mentioned!



Hereby, therefore, and heretofore...

I hereby disclaim liability for injury or other damage to persons or properties that may result from the use or misuse of the information contained herein. I cannot possibly warn you of all the dangers involved in making things attain unto red or other heat in your workshop.

That said, please do indeed read, understand, and enjoy this book and project of building and operating your own Improved Electric Radiant Shop Furnace!

PRINCIPLES OF HEATING

Using Electricity to Make Heat



Electricity is an excellent choice for a quiet, reliable source of energy to heat and melt metal. In most areas in the United States and other developed countries, a very reliable supply of electricity is available to you. You wouldn't be reading this if it weren't for a steady enough supply of electricity to reliably power a computer (and a printer if you have printed version).

It is also not very expensive in most areas. At the time of this writing, I pay about 9 cents a kilowatt in my area, and folks tell me this is high. If you build a furnace that takes 2 hours at 2000 watts to melt a quantity of aluminum for pouring, that represents a mere 36 cents worth of electricity cost!

An electric melting furnace is also quiet, and you can go about other tasks while the furnace silently does its job. I often work on patterns or molds for sand casting while my furnace is operating.

Resistance Losses of Various Materials

To make heat directly from electricity, the simplest method is to select a poor conductor of electricity. In other words, the conductor really does not do a very good job of conducting electricity, but instead 'loses' the power by heating up.

There are a number of materials including steel alloys that are ideal for this application.

Commercially available ceramic kiln elements are often nickel-iron-aluminum-chrome alloys that satisfy the requirements for high temperature and long lasting characteristics.

The Length of the Conductor and its resistance

You can match the conductor that you use for an element by choosing its length. If you can measure the resistance of an element, you can calculate its power drawing characteristics with the following formula:

$$\text{Volts} \times \text{Amps} = \text{Watts}$$

$$\text{Volts} / \text{Ohms} = \text{Amps}$$

- so -

$$\text{Volts} \times (\text{Volts} / \text{Ohms}) = \text{Watts power output}$$

$$240\text{volts} \times (240\text{volts} / 17\text{ohms}) = 3388 \text{ watts}$$

You can use the table below to find out what the resistance of the element should be for your furnace:

Amps	Watts Output	Volts	Resistance	Element Length
15	1800	120	8Ω	Shorter  Longer
12	1440	120	10Ω	
10	1200	120	12Ω	
9	1029	120	14Ω	
17	4114	240	14Ω	
16	3840	240	15Ω	
15	3600	240	16Ω	
14	3388	240	17Ω	

Element resistance table

To make your element draw more power, simply cut a few inches off. Measure the resistance with an ohmmeter that will go as low enough for these resistances. If you don't have one, purchase one! You should not be guessing this!

NOTE: Many digital ohmmeters have a base resistance that you need to subtract. For example, my ohmmeter reads about 3 ohms when the test leads are shorted, so I have to subtract 3 from a reading when I take a measurement. Just be aware of this.

I use half of an element for an EvenHeat ceramic kiln. I've saved the other half of the element for a replacement. It measures about 14 1/2 ohms resistance when cold.

How Temperature affects electrical characteristics of an element

The above formula uses cold starting temperature to compute target wattage for your furnace. You need to be aware that a cold element will draw more amps than a hot one, and as the element heats up, its resistance also goes up, drawing fewer amps. Your furnace might represent a 3600 watt load when it's cold, but that could a certain percentage as it heats up! This is unavoidable, and the control obviously must be able to handle the power draw when the elements are cool. However, I find that I must turn my furnace down when the aluminum melts, or the temperature will just continue to rise!

Using Refractory to Trap and Store Heat

A refractory is a material that acts as an insulator to keep the heat inside your furnace so that it may accumulate. Refractory materials are available commercially, and if you have a local source and know which formula works, good luck, go ahead and use it.

Can it take the heat?

Of course, the refractory's main job is to allow the furnace to get very hot on the inside, while limiting the flow of heat to the outside. This will make the inside accumulate enough heat to melt metal or perform whatever heat treating task you wish.

The refractories used in this design are twofold: A firebrick hexagon, surrounded by a backup lining of castable refractory.

Also needs to withstand mechanical shock

Many refractories may be excellent choices for their insulating properties, but they crumble when bumped. A good refractory sets up hard and is resistant to cracking. I hope you don't have to take your furnace down too many bumpy roads to your friends to show it off, but if you do, keep in mind that whatever you use for the refractory is going to suffer from too much vibration.

The hard firebrick in my design is very tough. It isn't the best choice for insulating, but it remains solid even when red (or orange) hot. When you put your tongs or pliers in to grab the crucible, you are likely to brush against the sides of the furnace. **(Always turn the furnace off to get anything out!!)** Or if you don't get perfectly center the crucible while you lower it into the furnace, it may bump the sides. A fragile castable refractory will disintegrate under these conditions. But the hard firebrick stays rock solid under this kind of minor abuse.

If you can find it, soft firebrick such as used in ceramic kilns has better insulating properties but is not quite as durable. Also, the soft firebrick will not be as hard to cut with the 3-stacked blade cutting arrangement, another benefit.

OBTAINING THE MATERIALS

Readily available refractory materials

The design in this book uses two refractories, one is simply 4"x9" common hard firebrick (again, if you can find local or other easy source, by all means use the soft firebrick, it's easier to cut).

The other is a homebrew mixture of perlite and high temperature stove mortar, like you would use to glue fiberglass rope to a woodstove door. The picture to the right is Perlite from the garden section at Wal-Mart, and the furnace cement is from a local hardware store that displays the 'Do It Best' logo.



Finding heating elements

I use an element from a local ceramics shop that is made by and for EvenHeat Kilns. It is the XL-1, a 'kanthal' wire rated at 2300°F. I recommend you look for something like this from ceramic kiln sources rather than making your own.

You can also order elements online at <http://www.budgetcastingsupply.com>. This company serves the build-it-yourself melting furnace crowd (that's us!) and they have many other foundry supplies as well.

Making your own elements

But you can also make your own elements if you can find a fairly thick stainless steel MIG welding wire, such as .045" solid core alloy 308. I used .030" in my first furnace, but it burned through after a dozen or so melts.

If you must make your own, I made mine with a homemade element winder. This winder used a piece of 1/4" threaded rod and wound up the strand of MIG wire using the threads as a guide. I also made a special guide nut out of a coupling nut to guide the wire from the spool onto the threads, while I turned the threaded rod with a variable speed drill.

Also keep in mind the calculations of ohms and watts, don't just wing it! You can and should apply your math to homemade elements, too. Use the table earlier in this book, *Element resistance table*. And purchase a digital multimeter that can test low ohms. I got mine at a flea market for \$6 and it works well.

The Shell Material and Hardware

The shell design makes very clever use of commonly available snap-together air duct. To get a 12" diameter, you simply snap together two 6" pieces.

You can get this in any good home improvement center, such as Home Depot, Lowes, Builder's Square, etc. You'll find it in the heating and cooling aisle, and there are many different sizes and guages.

By using the furnace duct, you can avoid a lot of sheet metal work. The duct snaps together and makes a beautiful seam that looks 'factory.' You can make many combinations of shell diameters by mixing and matching sizes. You could take a 6" and an 8" duct to make a 14" shell. Or, you could take a 4" and a 5" inch to make a 9" shell for a small melting furnace. The possibilities are many.

TOOL REQUIREMENTS

I'll just briefly list the tools I needed to complete the furnace:
Use this checklist to get your workshop equipped:

Tool Checklist

- Tin shears, lever action aircraft type.
- Table Saw, Radial Arm Saw, or other saw that can accommodate 3 blades on the arbor.
- 3 Masonry cutting blades.
- Electric or hand drill and standard selection of steel drill bits.
- 3/16 Masonry drill bit.
- Drill press. (Not absolutely necessary, but helps to get holes in firebrick square.)
- Screw drivers and obvious hand tools, such as crescent wrenches.
- Hammer, use the handle to ram refractory.
- Small trowels for refractory mixing.
- Carpenter's square or 'speed square' for marking perpendicular lines.
- A brain. Not available for purchase anywhere, but you've already got a good one if you've read this far.

Here is a complete parts list that you can print out and use as a shopping list.

MATERIALS LIST

From Garden Center or Superstore: (Wal-Mart, K-mart, etc)

- 4 Bags of Perlite, 8 quarts each

From Hardware Store or Fireplace Specialty Shop

- 8 quarts of Black Meeco or Rutland high temp cement
- 8 Firebricks, 4"x 9" (Six for chamber, and optionally, two for 'hot pads')

From Home Improvement Center:

- 1 Section of 6 inch air duct, galvanized (Shell, you only need 4' total)
- 2 Pairs of garage door handles (4 total handles, includes hardware)
- 24" Galvanized water pipe, 1/2" NPT (Furnace Legs)
- 1 Small roll of 18 guage galvanize wire (Base Reinforcement)
- Box Sheet metal screws, 2" (Fasteners for terminal cover)
- 2 Stainless steel screws, 3 1/2" x 10-24 (Terminals)
- 8 Screws, 1" x 10-24, zinc finish (Seam fasteners)
- 12 Nuts, 10-24, zinc finish (Seam fasteners, Terminal nuts)
- 4 Flat Washers, 10-24, zinc (Terminals)
- 6 Carriage Bolts, 2" x 1/4"-coarse thread (Leg hardware)
- 6 Nuts, 1/4"-coarse thread (Leg hardware)
- 1 Sheet Metal 2" x 4" Stud (Terminal cover, control box)

From Electrical Supply: (or Home Improvement Center)

- 3" Round or octagon electrical plate cover (Vent Hole Lid)
- 1 Infinite Range control (may need to purchase at appliance store)
- Spade connectors for infinite range control
- 10 feet of 12-2w/G heavy duty power cord, rubber coated
- 1 Romex clamp, 5/8" or to fit above cord
- 1 Plug, 240v, 20 amp
- 1 Receptacle, 240v, 20 amp
- 1 Breaker to fit your panel, 20 amp
- Length of 10-2w/G Romex wire (to run wire to receptacle)

From Ceramics Shop: (or online supplier)

- EvenHeat XL-1 or suitable element

CONSTRUCTING THE SHELL

Cutting the Sheet Metal

You can easily cut the galvanized air duct with a plain tin shears or the lever action 'aircraft' type. The air duct I used was the heavier 26 guage sheet metal, and the shears I happened to have was lever action 'aircraft' type shears which made cutting a breeze.

You will want to cut off the crimped end of the duct, where it is intended to slip inside another section of duct.

The Base and Lid

The base and lid are both 3½" thick. If you plan to roll the edges of these, you will have to cut the sheet metal an inch wider, so that you have a half an inch extra along each edge to roll. I completely skipped rolling (or folding, whatever) the edges. See the drawings.

A simple way to roll the edges is to take a 2"x 4" just a bit longer than the piece of sheet metal, and lay it with the desired width extending over the long edge, then use a hammer and pound the edge down. Then turn the sheet metal over and finish flattening.

If you don't have your own bending brake or don't want to use the crude methods outlined here, you may also take the shell pieces to a sheet metal shop and have them roll the edges to make them nice and smooth.

I didn't bother with the edges at all, but rather cut the sheet metal to exact dimension, and left the edges blunt. For extra safety, you can even take a file or coarse emery board and de-bur the edges if necessary.

The Heating Chamber

Cut two pieces of sheet metal 9 inches wide, or 10" if you want to roll the edges as described earlier.



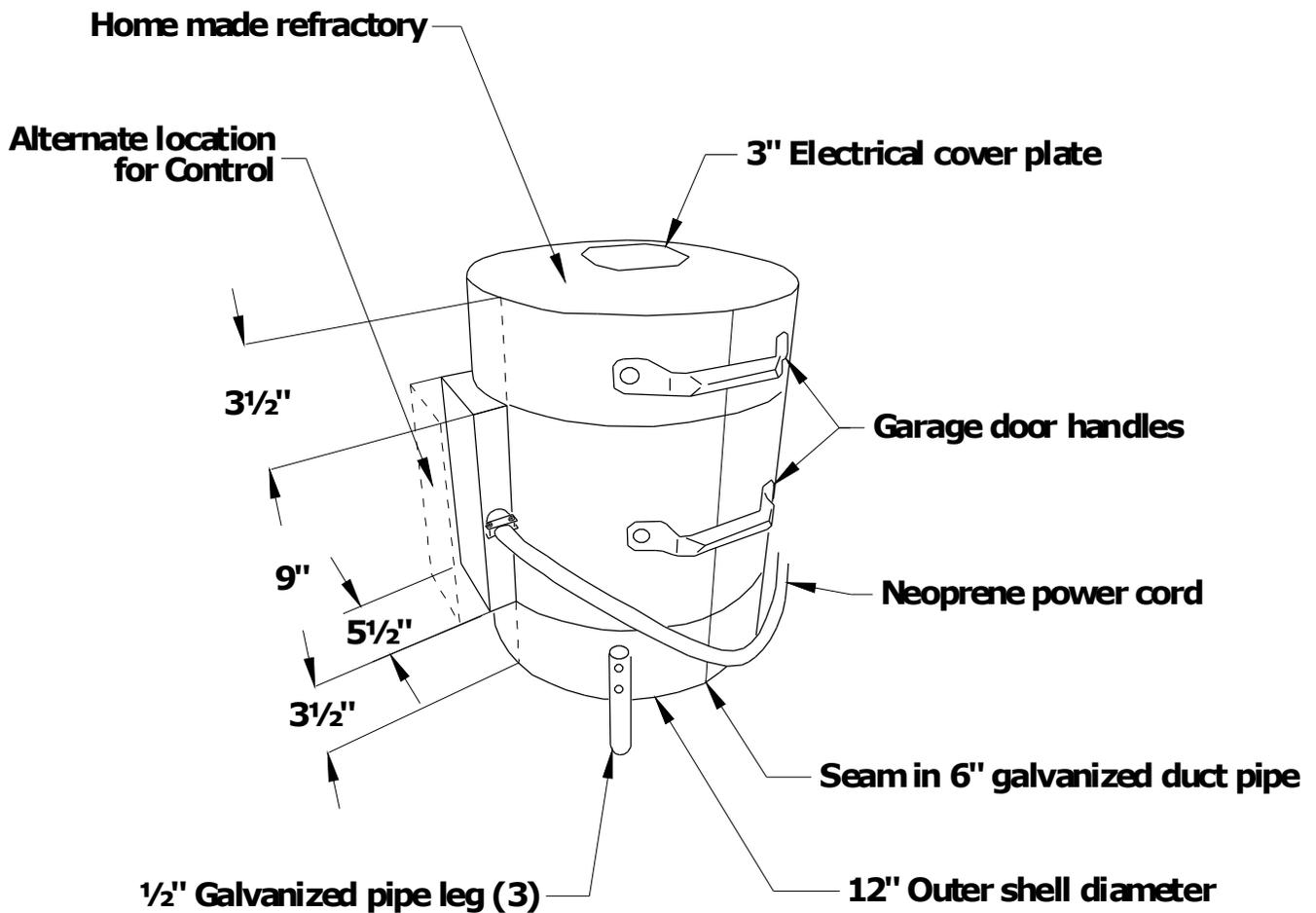


Diagram: Furnace Exterior

Shell Dimensions

The shell can be whatever dimensions you choose, but here is the size that I built. The furnace stands 18 inches high, and is 12 inches in diameter (excluding handles). The chamber will hold an object approximately 5 1/2 diameter x 9 inch tall.

The handles are commonly available Stanley or Clopay garage door handles that come 2 in a package and include hardware.

PREPARING THE FIREBRICK

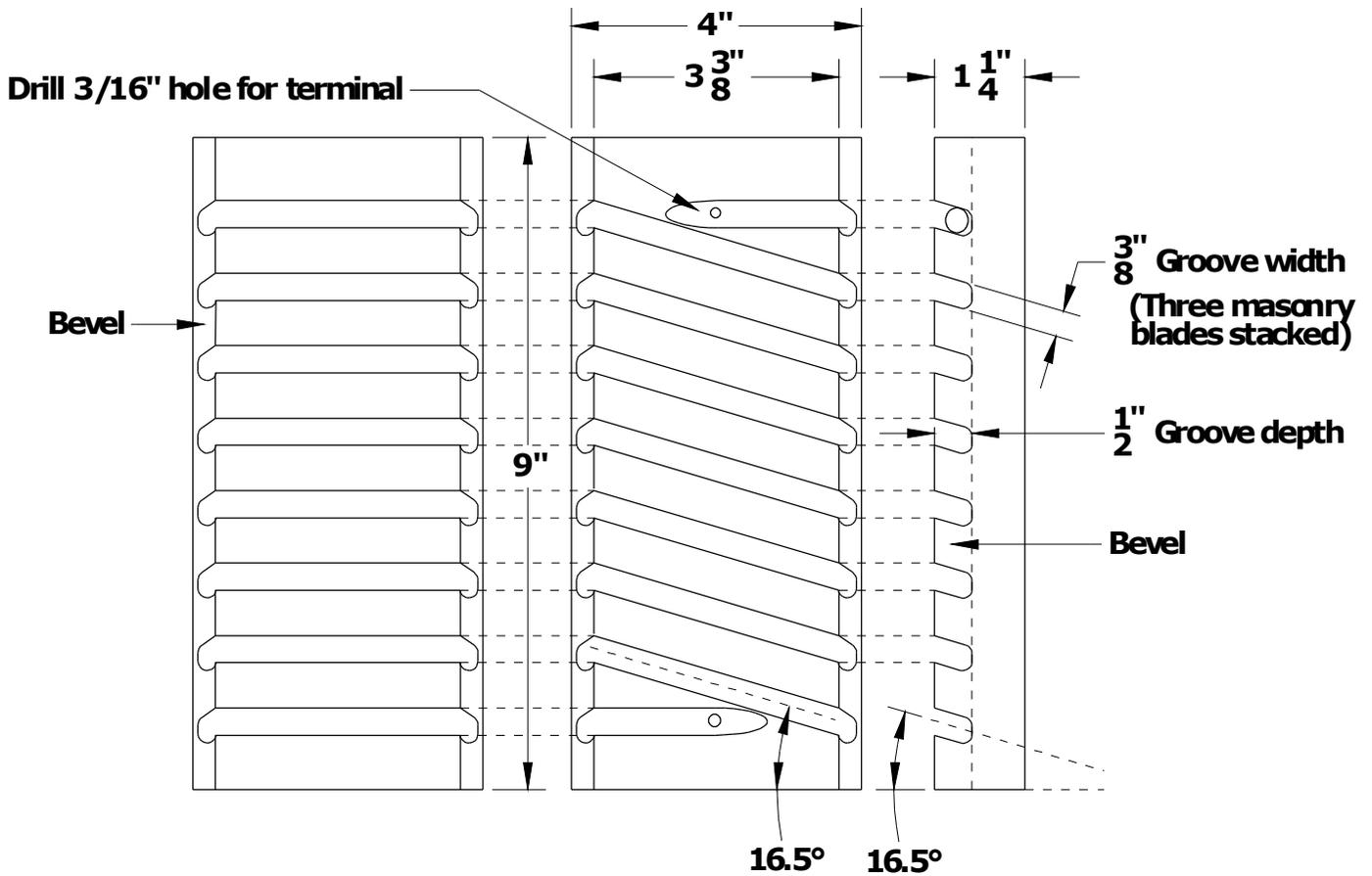


Diagram: Firebrick Grooving Dimensions Detail

*You will need five straight-grooved firebrick and one terminal brick.
Print this page out for a shop drawing.*

Using Abrasive Masonry Blades

At many home improvement centers and hardware stores, you can find abrasive cutting blades in a variety of sizes. I got 8 inch blades as a cost trade-off for my 10 inch table saw. They were about \$2.50 each. They are black and appear to have sort of a weave through them.

Stacking the 3 blades

I simply mounted all three blades on the arbor of my table saw. (One of my readers successfully used a radial arm saw as well.) Each blade is 1/8" thick, so the three together make a perfect 3/8" wide slot for your element.

Compensating Blade Wear

The blades wear down as the firebrick are cut, and the one cutting the deepest wears more than the others. As a result, you will need to rotate them periodically to help them to wear evenly. You will also need to measure the depth of the cut and adjust your saw accordingly.

Patience, patience, dust, sparks.

Cutting the firebrick is quite time consuming. It took me about 2 hours to cut the six firebrick. It is also very dusty, and I recommend you wear a dust mask and do the cutting outdoors if possible, because the dust is very fine and will get all over everything.

Also, some sparks may be emitted during cutting. It is up to you to protect your surroundings from this fire hazard. If your table saw or (whatever saw you use) has a pile of sawdust under it, clean it out! Once ignited, sawdust can smolder for hours or even days, then burst into flame unpredictably!

Marking and Making the Grooves

I made good use of the cutting fence and built in measuring line on my table saw, so I was able to avoid marking the bricks as I cut them. With a table saw, you won't even see your marks as you cut, anyway!

But if you use a hand held circular saw or radial arm saw, you will benefit from marking the bricks before you cut them, so you can see the marks as you cut.

The design calls for 5 straight bricks and one terminal brick.

The Straight Bricks

If you use a saw with a fence or other means of guaging the cut, I recommend you cut the first groove on all 5



straight bricks with one setting before adjusting to the next groove. It helps to make the grooves line up perfectly when each groove is cut the same on all bricks!

The Terminal Brick

This one is a bit trickier to cut. The top and bottom half-groove can be cut when you cut the top and bottom groove on each straight brick.

STOP!! The angled grooves must be cut so that they line up AFTER the bricks have been beveled! If you measure, mark and cut the grooves before cutting the bevel, you risk these grooves not lining up very well!!

Beveling the bricks

To make the bricks meet nicely and to keep refractory from spilling into the grooves at the brick edges, I beveled all the edges of my bricks. This also establishes the correct inside diameter of the furnace. Be sure to cut the bevel right so each brick's inside face is the proper measurement!

When cutting the bevels, I found that because of the slight flexing in the masonry blade, I needed to set the angle a few degrees steeper than the drawing calls for. Experiment and find what settings work best for you before cutting all the bricks.

Making the Terminal Brick Grooves

This is a compound angle cut, if you please. The saw needs to be tilted as in the other cuts, as well as being drawn across the brick at an angle. This guides the element to the next higher groove on the straight bricks, so that the element runs in somewhat a spiral fashion.

Of course, if you purchased 8 bricks as the materials list indicated, you have the ability to experiment and even mess up a brick or two, and you can still use the 'wrong' bricks for 'hot pads' to set the hot furnace lid or crucible on when needed.

Drilling the Terminal Holes

I used a 3/16" masonry bit to drill the holes in the terminal bricks. It drilled so easily, that I wondered why the grooves couldn't have been cut with a drill bit somehow!

Drill the holes as shown on the drawing, ensuring that they are precisely perpendicular to the brick. This ensures a proper alignment of the terminal holes in the furnace body. I drilled mine on my drill press rather than with a hand drill. One option here might be to secure the firebrick hexagon (in a later step) inside the furnace shell and run the masonry bit through the hole in the shell and through the brick.

Clamping the Firebrick Hexagon

The hexagon arrangement of the firebricks is the heart of the heating chamber design. They are held firmly together with hose clamps, and the precision (or lack thereof) in cutting the bevels on the firebrick will show here!

Arranging the bricks

Choose a solid, flat surface, free of dust and dirt, to set up the firebrick hexagon. The more squarely each brick can stand, the better you can get them to align! Make sure you have them with the correct end up on each, so that all the grooves line up, noting the terminal brick's orientation also. It's a masterpiece!

Clamping Together

Take the long hose clamps (you may need 4 of them to reach around) and position them around the bricks, making sure they don't cover the terminal holes! Give them at least a half an inch from the terminal holes.

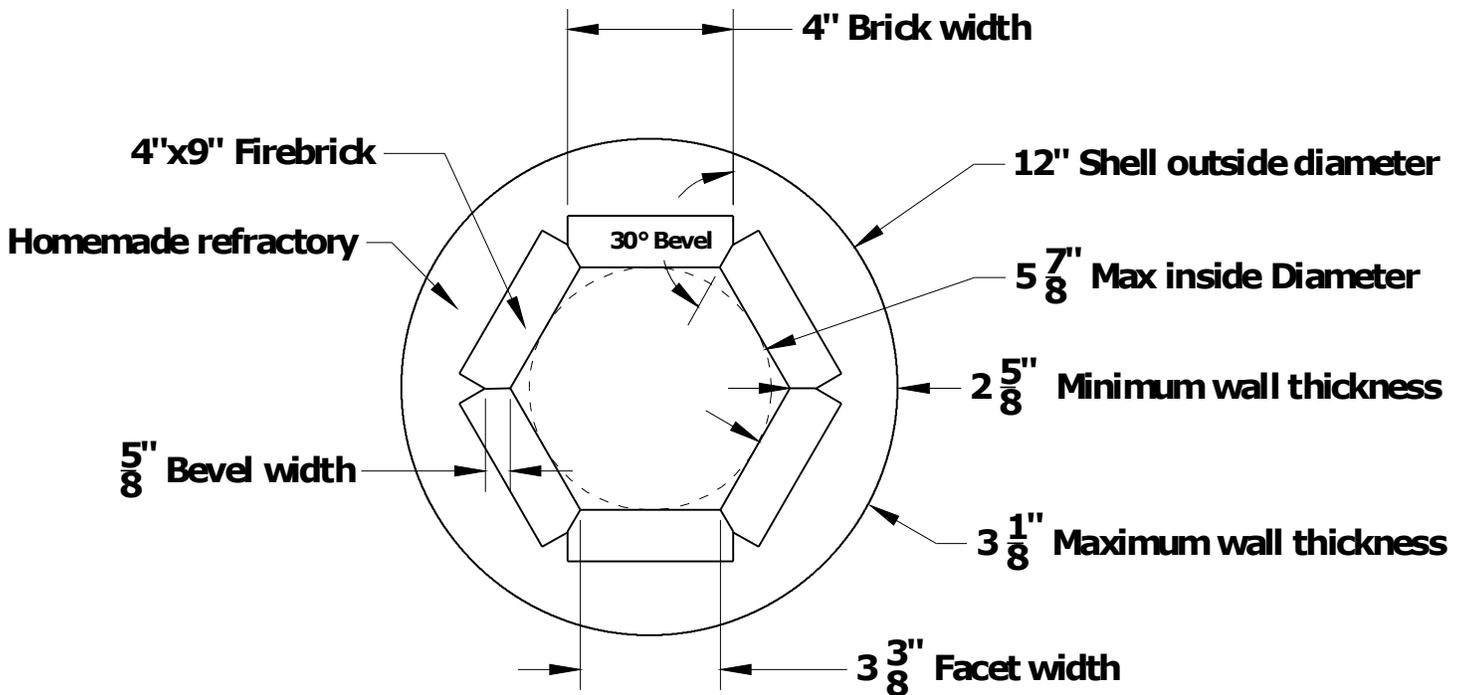
Tighten them firmly, and make sure the hexagon is not deformed from the pressure. You will then be able to pick up the entire assembly of six bricks.

At this point, if you did not drill the terminal holes yet, you could drill them now by carefully marking the back side of the brick so that the terminal will come out in the groove.



Refer to the drawing on the next page (*Inside Brick Layout*) for accurate detail of how the bricks should fit together. Your measurements may vary somewhat depending on how close you were able to get the bevels cut, but this is no problem. If the bricks don't fit together satisfactorily, you can always cut the bevels more.

Note that cutting the bevels deeper will result in a smaller inner face on each brick, and a smaller heating chamber. Cutting the bevels deeper will also result in a thicker wall and better insulating properties, so make your cuts carefully and with consideration to this!



**Diagram: Dimensions of
Brick Layout**

Print this page out for a shop drawing if you like. Use this diagram as a guide as you fit the firebrick together and verify the measurements. Note that you should have approximately 5 7/8" inches from brick face to opposing brick face.

MAKING YOUR OWN REFRACTORY

You can easily make your own refractory of commonly available materials. The recipe presented here was found on John Wasser's Coffee Can Foundry Site, although he mentioned a source which I could not confirm, so I can't give credit to a source for this!

The Recipe

...is very simple:

Ingredients

8-quart bag horticultural Perlite
2 quarts Meeco or Rutland Black high temp furnace cement
½ cup water, or to properly thin black cement

Mixing

Use a 1 gallon ice cream pail or similar to thin the black cement. Thin it to about the consistency of pudding. This may take more or less than the quantity of water specified, depending on the thickness of the black cement to begin with.

Use a 5 gallon plastic pail to mix the black cement into the perlite. Start with the 8 quarts of perlite, and stir in the black cement. This process should somewhat resemble the making of caramel popcorn; what you want to do is evenly coat the granules of perlite with the black cement. You'll end up with a black crumbly substance that seems rather dry.

You can experiment with the recipe if you like, but be warned that if there is too much or too little perlite for the quantity of cement, you will encounter certain problems. If there is too much perlite, for example, you use 9 or 10 quarts with the same quantity of cement, the insulating properties of the refractory will be better but at the sacrifice of strength. The opposite is true with too little perlite, and if the pores between the perlite beads is closed too tightly by too much black cement, you may have a problem curing the lining. The moisture in the cement will have no place to go and could crack or explode the lining.

Storing

Put a lid or a film of plastic on the pail of mixed refractory, and set aside. This will keep the refractory moist until you need it. Even if you don't use all of it, you can keep the remainder on hand indefinitely for repair or other use.

The big difference between this type of refractory and the concrete type is the setting. The black high temp furnace cement depends on the evaporation of moisture to set it solid rather than the chemical reaction in concrete products.

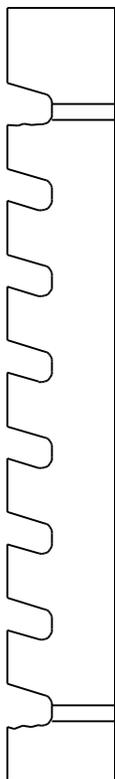
While the recommendation with concrete type castable refractories is to keep it moist during curing, the opposite is true with the Worcester Brush high temp cement. Keeping it moist in a sealed container will preserve it, and exposing it to dry air will set it.

ASSEMBLING THE FURNACE

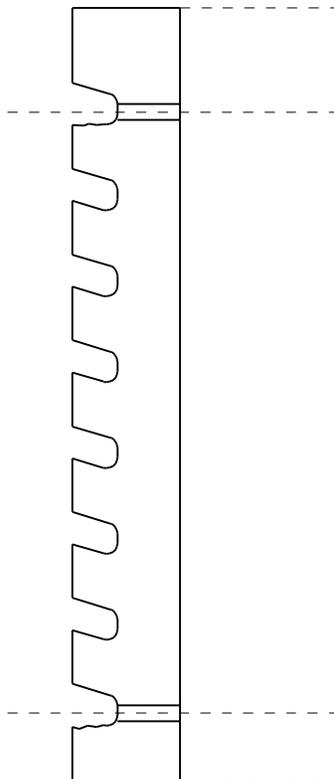
Now that you have the furnace shell assembled, the firebrick cut, and the refractory mixed, the next step is to put it all together.

Start by drilling the holes in the firebrick and furnace shell for the terminals:

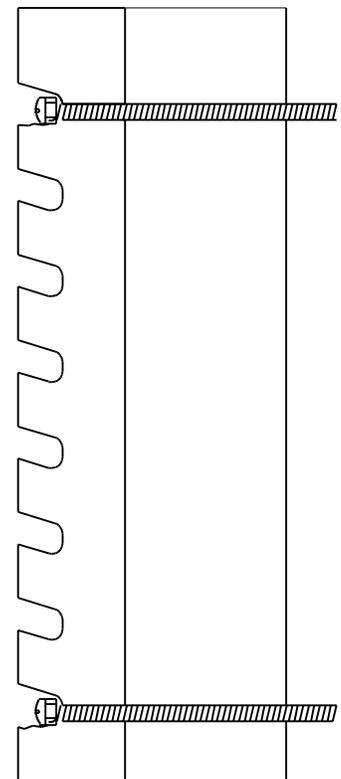
**Drill Terminal
holes in firebrick.**



**Align and drill
holes in shell.**



**Temporarily
mount terminals.**



**Diagram: Drilling the
Terminal Holes**

Ramming up the base

Starting with the base, you will build the furnace from the bottom up. Each section will be built in place upon the first, so that when you are finished, you can slowly cure the lining over a few days, then with the heat of the element, drive off the final moisture.

Start by selecting a covering a suitable flat spot on your workbench with a film of plastic, like a plastic shopping bag with a side and end cut open to lay it flat. Take the wooden former and lay it on the plastic, and insert the base shell upside down in it.

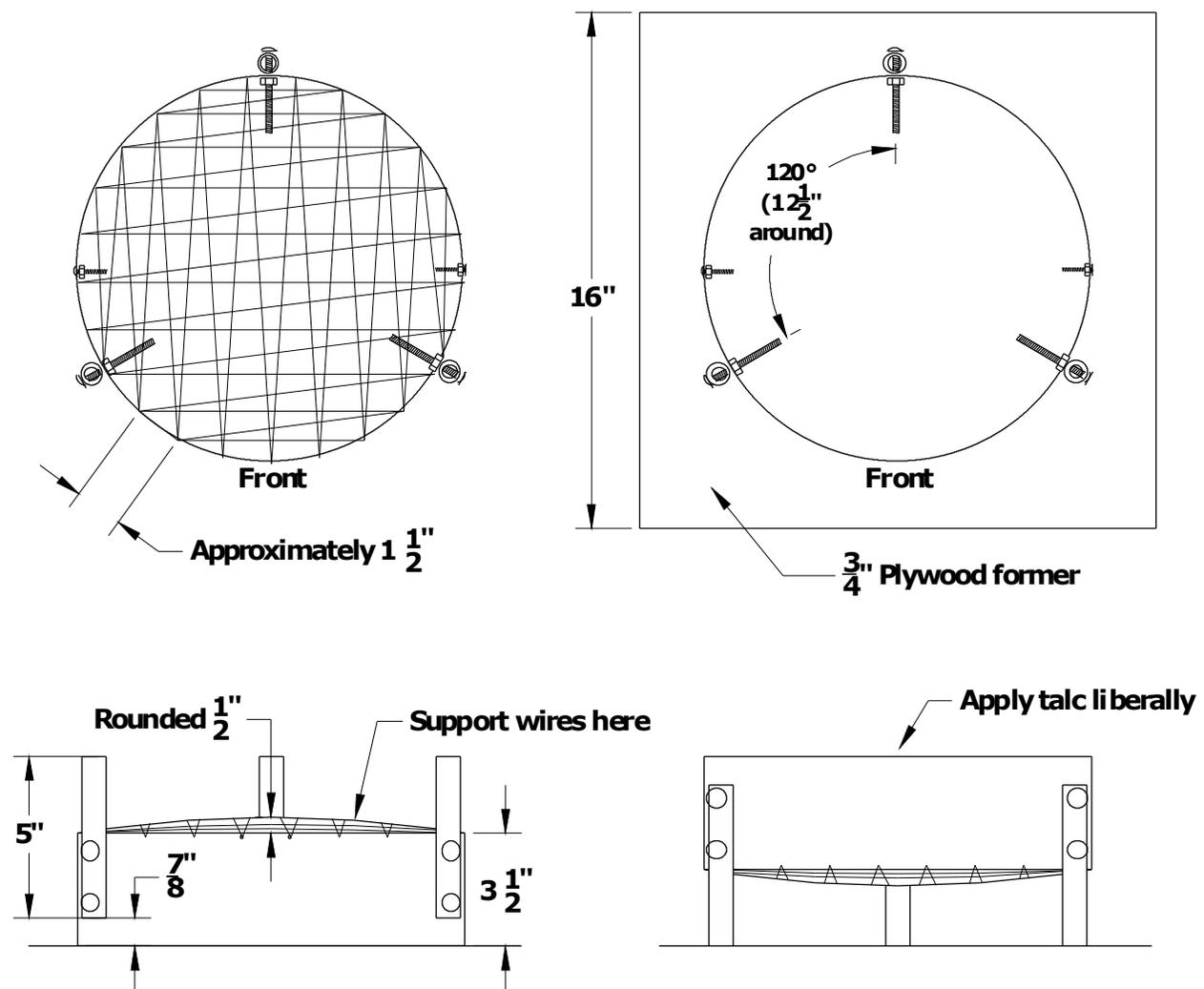
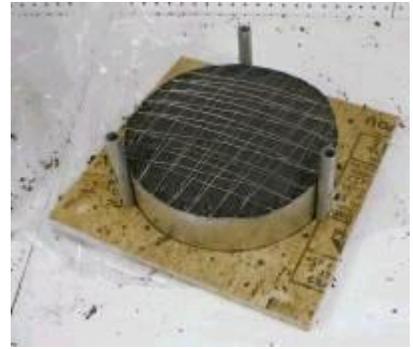


Diagram: Base Detail

Lightly pack in the refractory, taking care not to ram it too tight! Slightly round the refractory, smoothing down to the edges of the base shell. With a wet spatula or trowel, slick the perlite refractory to a nice smooth surface.

Then string the reinforcing wire in the holes you drilled. String them horizontally, then vertically, as shown.

Pull the wires as snug as possible, then once they are all strung, take a pliers and make little bends in the wire to pull them nice and tight.



Briefly cure the base

Give the base an hour or so to 'skin' over, then turn it upright onto its feet. Keep the wooden former in place around the base section. Carefully peel the plastic film off, and dust the base with a liberal but even amount of talc.



Set the heating chamber on the base

Carefully raise the wooden former up so it extends a quarter inch or so above the base. (If you made three formers instead of just two, you can set the second former on top of the first.)

To test the fit of the firebrick, set the firebrick hexagon down inside the heating chamber shell. The long carriage bolts from the garage door handles will nearly touch the firebrick. You may need to trim the bolts if they are too long.

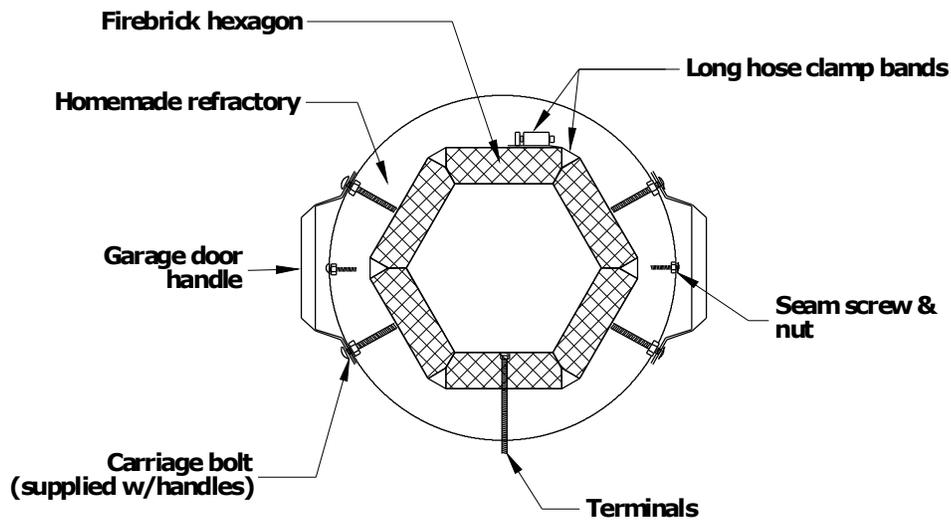


Diagram: Centering the Firebrick Hexagon within the Shell

You may need to cut off the long carriage bolts supplied with the garage door handles so that the firebrick hexagon will fit inside the shell.

Ramming up the Heating Chamber

Now place the top wooden former on top of the heating chamber shell, and set it into the former on the base, carefully aligning the seams. Then set the firebrick hexagon inside. Note the terminal locations, and ensure that you have them facing the holes in the shell!

Put the terminals in from the inside, through the firebrick and out the holes in the shell. This step insures alignment of the firebrick hexagon and the outer sheet metal shell. (If you wish, you can even mount the element on the terminals, and install it in the firebrick grooves.)



Now you are ready to ram in the refractory around the firebrick. Be careful not to ram it too tightly, or the insulating properties may be defeated. I like to use the a rubber hammer handle to tamp this in, as the weight of the hammer itself is just about right to sufficiently pack the refractory. **Level off and smoothly trowel the refractory at the top of the heating chamber.**

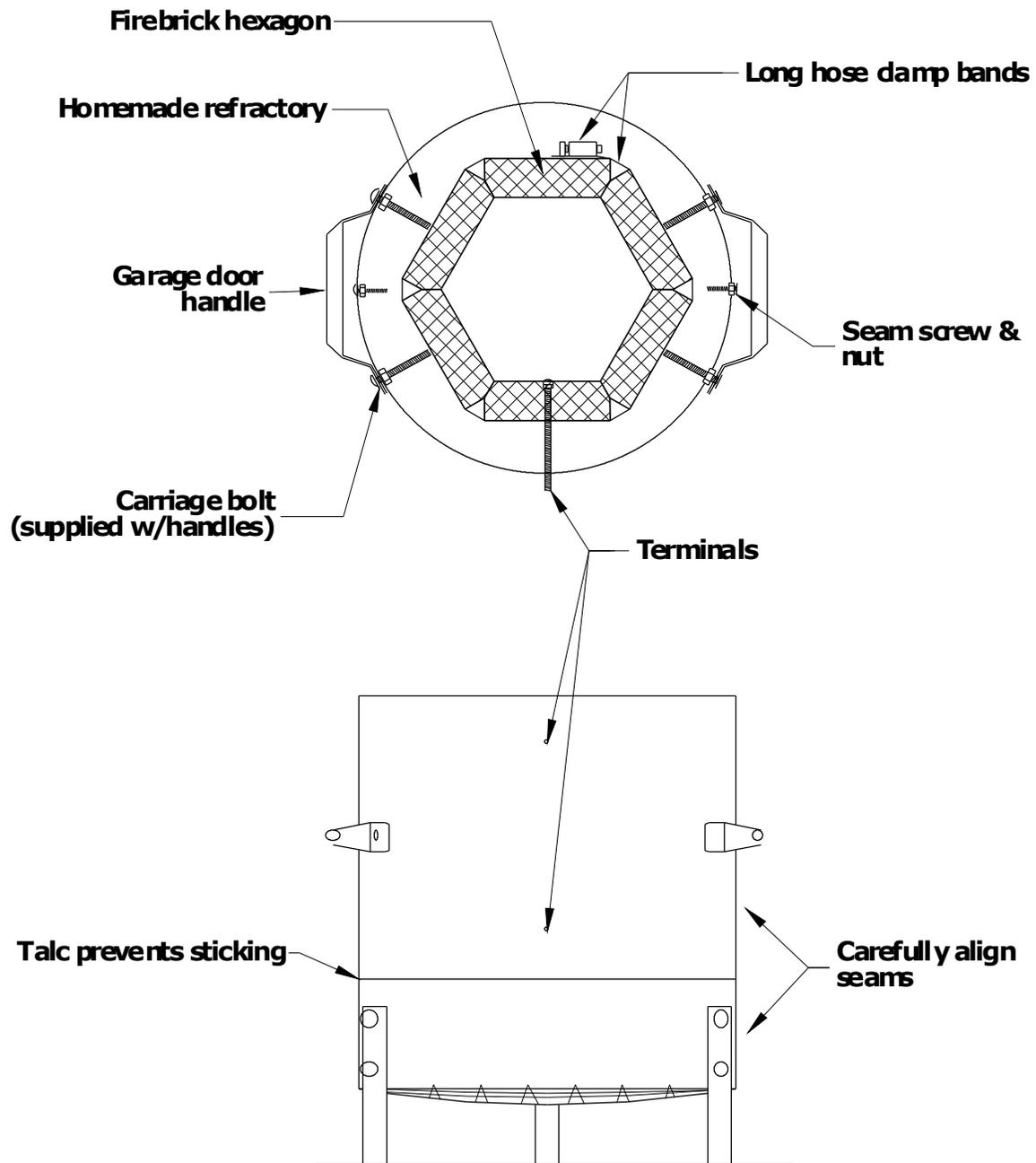


Diagram: Heating Chamber Detail

You may need to mix up more refractory. It will take as many as 4 batches of the homemade refractory mixture to complete the furnace. I used about 2 gallons of the high temperature cement, and (proportionately), 8 gallons of perlite!

Ram in refractory and allow air drying

Mount elements and terminals, nuts and washers

Make electrical connections as shown.

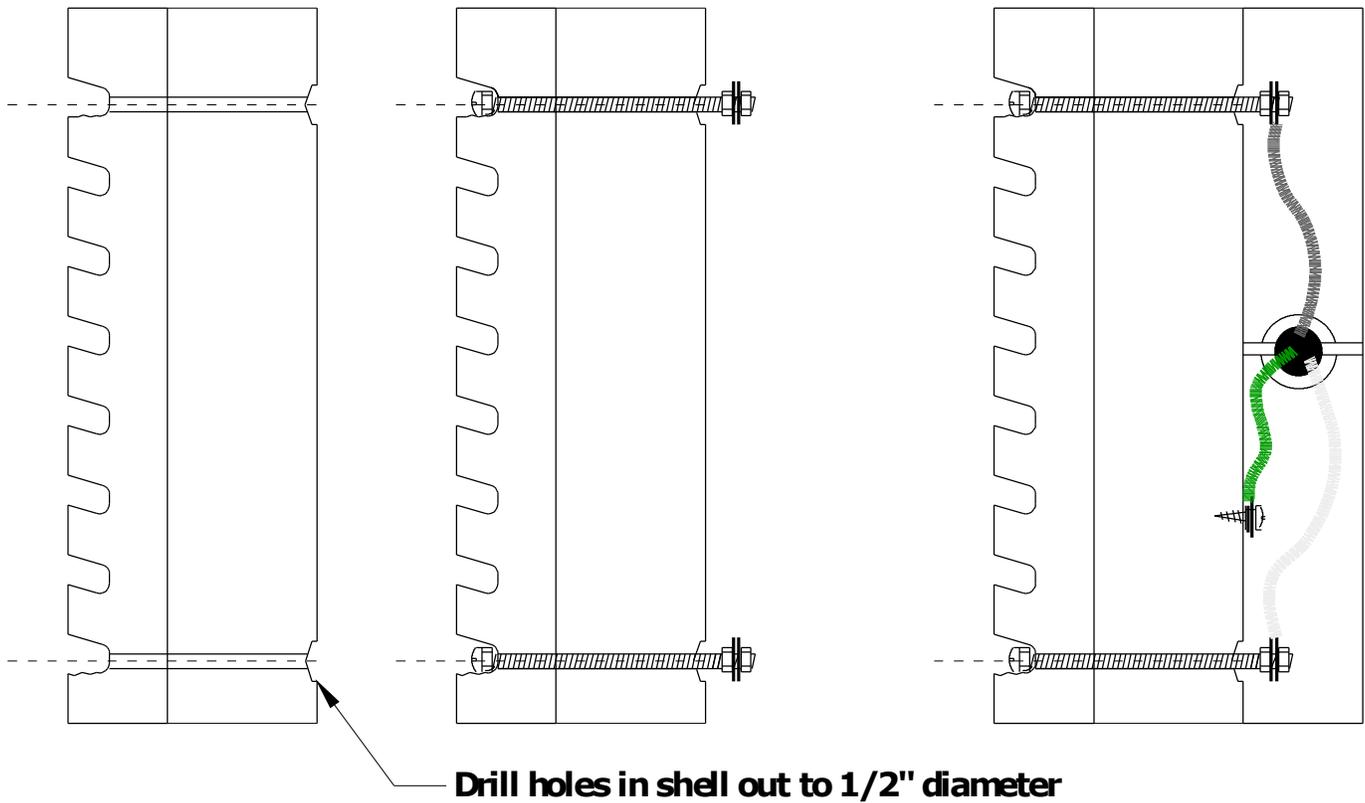


Diagram: Terminal Mounting Detail

To keep the elements from shorting out against the shell, enlarge the holes in the shell to 1/2" diameter. This will allow an insulating space which you can optionally pack with furnace cement to help keep the terminal centered. Be careful not to drill into the refractory when enlarging the hole.

The Hexagon Chamber Cover

Cut a plywood hexagon a quarter inch bigger than the heating chamber opening. This will set on top of the heating chamber to act as a form for the lid. Then cover the top of the heating chamber and its hexagon cover with the plastic film you used earlier.

This technique is provided to allow ramming up the lid right in place on top of the chamber, and the result is that you get a perfect fit of the lid against the heating chamber.

In my original furnace, the parts were all individually rammed up, and the result was ill fitting surfaces that leaked a lot of heat out. But the method described here will result in very precise fit, and a very nice seal to keep the heat from radiating out of the furnace.

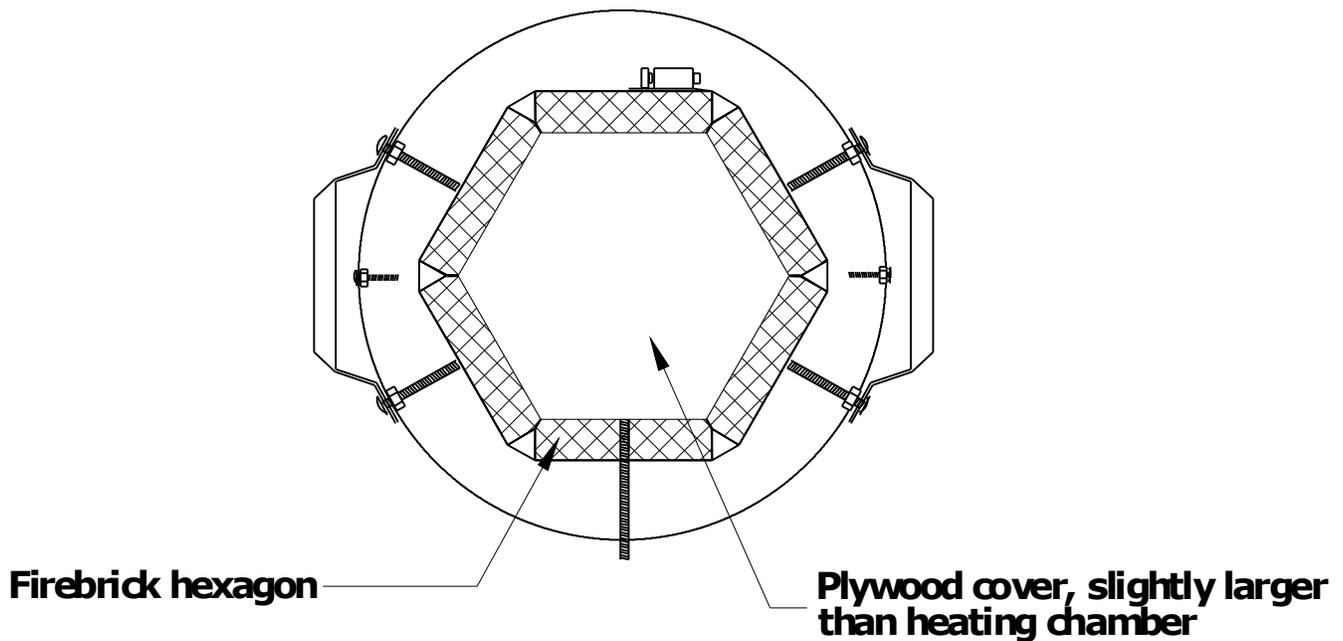


Diagram: Chamber cover

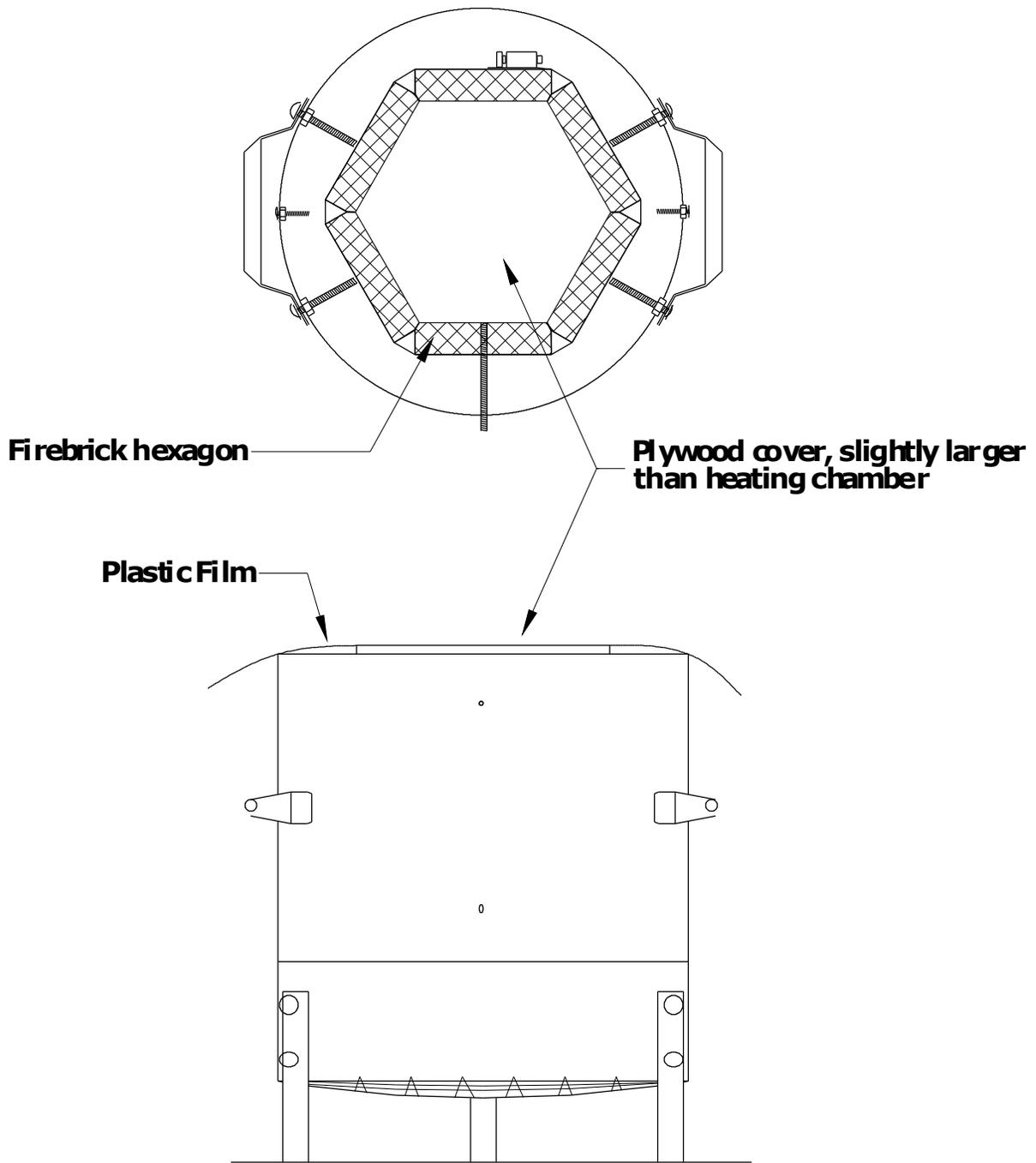


Diagram: Hexagon cover and plastic film

Lay the plastic film over the hexagon plywood cover. This will keep the refractory in the lid from sticking to the heating chamber below it.

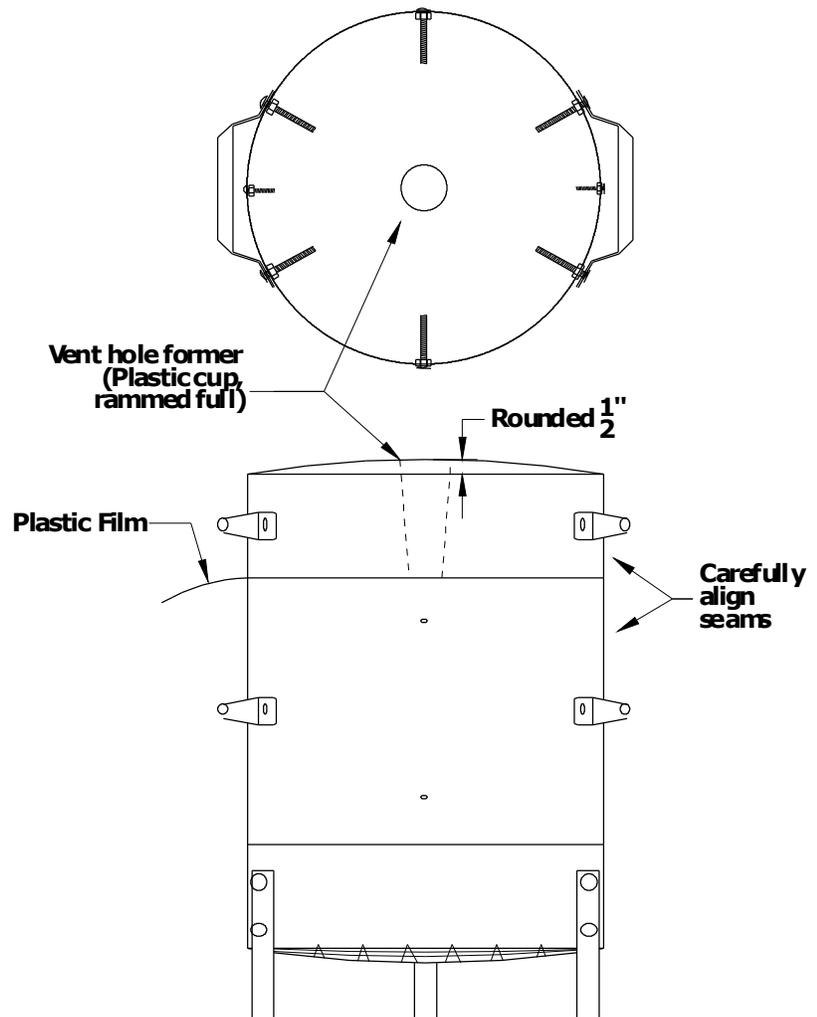
Ramming up the Lid

The vent hole former

Take a 6 oz dixie cup or similar, and trim it if necessary to a 3½" height. Ram it full of refractory. (You could actually use anything to make the cup hold its shape, such as clay or even foundry sand.) Set this in the center of the hexagon chamber cover.

Set the lid shell on top of the heating chamber, again carefully aligning the vertical seams in the shells. and wrap duct tape around the seam between the heating chamber and the lid to make the lid conform to the roundness of the heating chamber as constrained by the wooden former. The plastic film will be held in place by the duct tape.

Ram up the lid refractory, rounding smoothly up to the dixie cup vent hole former. You may even want to smooth off a flat spot around this hole to provide a flat surface for the vent cover to rest.



This technique forms a very precise match between the lid and heating chamber, with all the slight imperfections in the chamber top being copied in the lid. This provides a very nice heat seal between the lid and heating chamber!

Diagram: Lid and vent hole former

Air drying, more patience

You should give the furnace a 3 or 4 days, or even a week to air dry. The refractory in the base and lid will have good exposure to air, but the heating chamber will probably not lose much, if any of its moisture until you can separate the lid from it.

This was the most difficult step for me, waiting a few days while the furnace air dried before separating the lid from the heating chamber. I would go out every day, and poke the refractory, to check its progress!

If you can, find another project to work on while the furnace air dries a few days. This step really pays off. A decision to take things apart or heat the furnace too soon could result in disaster that ends up costing in terms of even more time to project completion.

After the lid has reached a suitable set, carefully remove it. The plastic film may come off with it, or it may stick to the heating chamber. Peel it off, and remove the hexagon cover from the heating chamber.

Then let the furnace air dry a few more days to allow some of the moisture to escape from the heating chamber and base. Oh, patience, patience.

INITIAL FIRING

After a few days of air drying, the refractory will be nicely set on the surface so that when you run your finger across it, no black color will readily transfer to your skin. The black high temp cement air sets quite firmly, almost like ceramic.

VERY CAREFULLY remove the heating chamber from the base. Remove the wooden formers, and repair any damage to the refractory with some of the left over home made refractory mixture. Re-dust the base if necessary, and set the heating chamber back on.

Drill the holes in the heating chamber shell out to $\frac{1}{2}$ " , using the $\frac{3}{16}$ " holes as pilots. Refer back to Diagram: Terminal mounting detail. This allows the terminals to pass through the sheet metal shell without shorting out on it.

Install the element in the heating chamber

The element will need to be stretched out from its original length in order to fit the groove path around the inside of the furnace. You must be careful not to stretch the element out too long, because it is next to impossible to 'shrink' it back if you get it too long!

A trick that you can use to measure the length of the 'groove path' is to take a piece of rope that is roughly the same width as the groove, and lay it in the groove. Mark it where it meets the terminal holes, and presto, you have a measurable length of rope to approximate the length the element should be! (This tip from one of my readers, Jim Morton, who also suggested a rolling cart to make the furnace more portable, which you can see in the chapter "Enhancements and Modifications." Thanks Jim!)

Heat slowly.

It is important to cure the lining slowly to avoid cracking problems and condensation problems. I heated my furnace with 110 voltage to the element, which at first barely warmed the firebrick.

A word about escaping steam. If you try to heat the furnace too soon or too quickly, heavy wet steam will pour out of the damp refractory. This will condense where it meets cool air, and specifically, where the furnace sections meet.

You can either operate the furnace on full voltage at its lowest heat setting, or use the method I did to apply a lower voltage (110v) in this manner:

Attach a 110v power cord to the terminals and grounding screw and plug in to a GFCI protected receptacle. With the lid off, heat the chamber 6-8 hours. You will notice a lot of steam escaping during this time. You will want to do this in a well ventilated area because of the smell from the refractory. It's not a real strong odor but more than you want cooped up in your house or garage with the door closed.

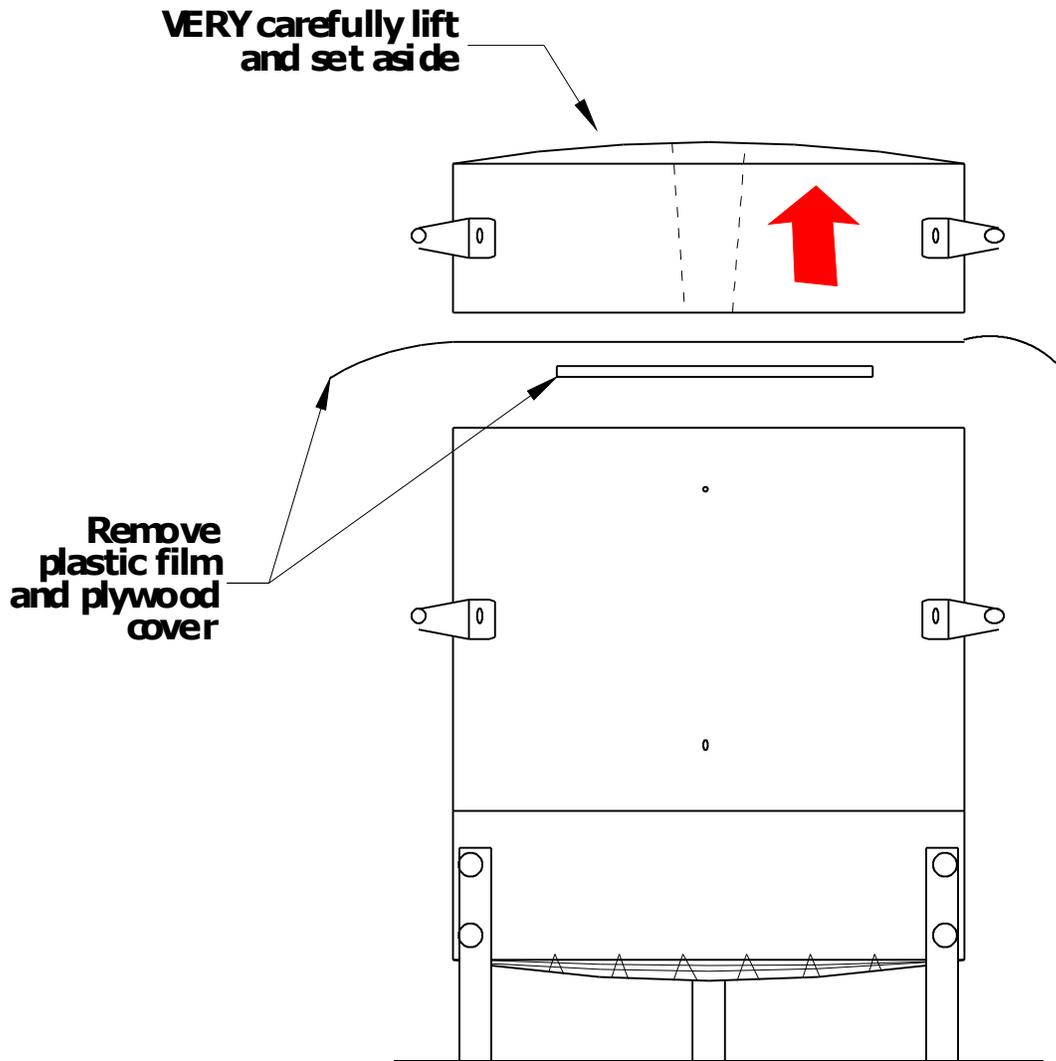


Diagram: Removing the plywood hexagon cover and plastic film

If you like, you can even use the plastic film as a 'handle' to assist in lifting the lid off after a few days of air drying. Set it aside where some air can get to the underside of the lid, but be careful not to let it stick to any surface.

Next, dust the heating chamber top with a liberal amount of talc. (This keeps the lid from sticking to the heating chamber during curing.) Then set the lid on, noting alignment again.

Fire again with 110 volts on the element for another 6-8 hours, with the vent hole open. Again, you will see a lot of steam escaping and even a bit of condensation may form around the vent hole.

After all visible steam stops, cover the vent hole with the octagon electrical cover plate, and fire another 6-8 hours, or until the interior of the furnace is red hot. At this point, all of the 'wet' moisture will be cooked out of the lining.

The refractory may develop small cracks, but this is normal and not to be concerned about. The refractory visible on the lid top and base bottom will gradually lose its deep black color and cure to a dark grey. Inside the furnace, the firebrick will lighten up some, and the refractory on the base and lid, where exposed to the heating chamber, will turn light gray or even white after many heats.

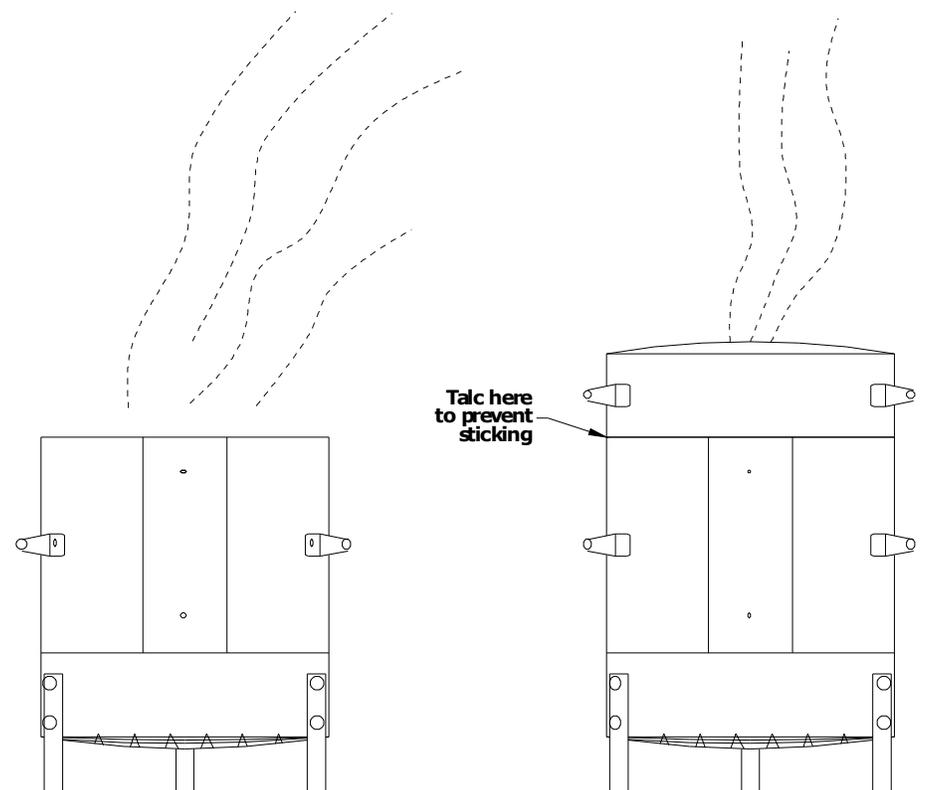


Diagram: Slowly drying the refractory

FURNACE OPERATION

Melting Metal

Note the picture at the right. This is how I laid out my foundry furnace area. There is an exit door to the right (not visible) and you can see the side of the garage door on the left. The length of cord I used allows me to operate the furnace just outside the garage if I need the extra ventilation for melting dirty scrap.

You built your electric radiant shop furnace, more than likely, to melt aluminum. With the right element, such as the recommended EvenHeat XL-1, you should be able to melt brass, although I have not done so.

The recommended steel crucible will obviously not work for melting brass, seeing that the brass will react with steel and erode it, possibly rapidly, and you don't want molten brass running about your garage or workshop.



If you do not wish to do it yourself, you can hire an electrician to do the wiring work in your shop for the furnace.



Note the use of firebrick to set hot objects on. You must do this to avoid damage to the floor of your workshop. Setting a red-hot crucible directly on a concrete floor could result in an explosion! It is also a good idea to put an inch or two of sand on the floor under your furnace to curb a leak of molten metal should it occur.

The Crucible

For melting aluminum, I had a local welding shop make several crucibles from schedule 40 steel pipe, 4" in diameter. This fit my original Lil' Bertha furnace, but there's plenty of room in the improved furnace for a 5" crucible. Have it made as tall as your furnace will allow, leaving a quarter of an inch or so for headroom.

Crucible Tongs

You can make a tongs with mild steel flat stock for gripping your crucible if you like, but I prefer to use one of those jumbo 'channel lock' pliers. With it I simply grip the rim of the steel pipe crucible and lift out. It gives me a reasonable distance from the intense heat of the crucible, and minimizes bumps and bruises to the firebrick lining in the furnace.

However, if you intend to melt brass, you **MUST** construct a set of tongs to very nicely fit around the curvature of a commercially available silicon carbide or clay graphite crucible. Gripping the rim of ceramic crucibles such as these will result in breaking and dropping the crucible! You don't want to do this with a quart of molten metal!

Other uses

You can even use the furnace to fire small ceramics or melt the wax out of and fire small plaster molds. Just put a piece of expanded sheet metal or hardware cloth under the furnace instead of the base, and a pan to catch the melted wax, and you can fire your plaster of paris molds!

I have even used mine to cook the methanol from wood in a specially modified distilling crucible. The result was methanol, a lot of tar, and little chunks of charcoal!

ENHANCEMENTS AND MODIFICATIONS

The Solid State Controller

Why build your own controller?

I chose to build a controller for a number of reasons. The first reason was that I saw how fragile the refractory was in my original furnace, and I didn't want the cycling of the current to the element to cause a contracting/expanding motion on the element to damage the furnace lining. The solid state controller does not cycle the element on and off like the intermittent controls, but rather makes a nice steady output even at its lowest settings.

Of course, the cycling is no concern in my present design using hard firebrick, but stay with me, there were other advantages readily evident. A simple test with an ammeter showed that under certain conditions, my furnace was drawing more than the 15 amps allowed by the contact rating on the intermittent heat controllers.

If you design your furnace larger than 15 amps of current draw, you will need to either find an intermittent range control (good luck) or build a solid state controller.

For example, suppose you want to build a larger 120 volt furnace, and want to push the 1800 watt limit, your furnace will draw more than 15 amps. You could build a solid state controller and operate on 20 amps for a 2400 watt furnace. Keep in mind that the electric codes require 20-amp wiring and a special plug and receptacle for such configuration. A 20-amp, 120 volt receptacle is designed so that both the flat prong 20-amp plug and the regular plug will both fit. But your 20-amp plug will not fit a 15-amp receptacle!

Or another scenario is a 240 volt furnace that draws more than 15 amps, and exceeds the 3600 watt limitation. Furnaces bigger than this, however, will soon exceed the safe limits of crucible size for one person to handle, so it is important to keep in mind the other design considerations in scaling the furnace up beyond the sizes mentioned in this book.

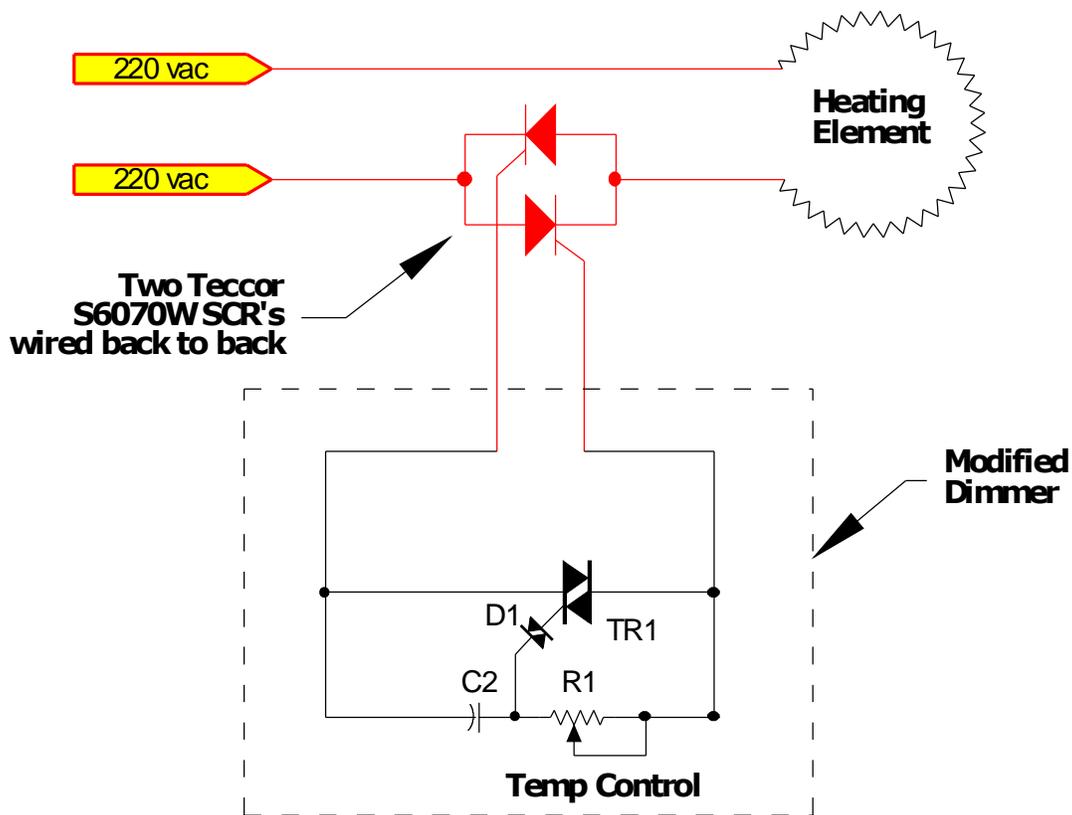


Diagram: Solid State Controller Schematic

The solid state controller is not much more complicated than an ordinary triac based lamp dimmer. However, a basic knowledge of electronics and soldering is required so I don't recommend you tackle this unless you are confident in reading schematics and building electronic circuits.

Modifying the lamp dimmer

The solid state controller is actually based on an ordinary triac lamp dimmer. You will need to purchase two Teccor S6070W SCR's (rated at least 400v) from an electronics supplier. I got mine from www.digikey.com. You will also need to replace the triac (TR1) in the lamp dimmer with a 400v rated one, also from DigiKey, or you can get it at Radio Shack. I got my replacement 400v triac at Radio Shack.

Something to note about the modified lamp dimmer is that the RC network and the VR are designed for 120 volts, so the amount of variation is not as wide. Instead of varying from

0% to 100%, it is more like 50% to 100%. This is of no consequence to me, because I never need the furnace to operate below 50%.

To remedy this, two things could be done. One would be to replace the 500k ohm VR with a 1M ohm one. In many of the available lamp dimmers, this would be a real pain! The resistor is often built into the printed circuit board, making this modification next to impossible.

The other thing would be to increase the value of C2. I don't know what the value is to begin with, so it could be a matter of trial and error to find a value that extends the range to what you want.

In any case, this is only necessary if you intend to use your furnace to roast possums or other things that require operating your furnace on less than 50.

If you are desperate to extend the range of the dimmer, you may experiment with the values of R1 and C1 in the RC network. But you're on your own!

Building an enclosure for the controller

Your controller circuit will need a house. My design incorporates a large heat sink and cooling fan, but I think it's overkill. The air that blows out is always stone cold, so I don't really think it needs it. You can build yours without a fan, but be sure to use a heatsink to mount the SCR's.

I used sheet metal studs to make a box for my controller. These are available at most lumberyards or home improvement centers that carry drywall supplies. I like to use them because they have nicely formed bends and require a minimum of fuss to make nice enclosures. They are also made of nice thin gauge galvanized steel that you can cut with a scissors.

Different Sizes: Scaling the furnace larger or smaller

The previous plans detail a two quart capacity furnace using an 8 3/4" tall by 5" diameter steel pipe crucible, intended to run on 220 volt current. This is plenty large enough for a small shop, and I do not recommend you build larger unless you truly do have a justifiable need.

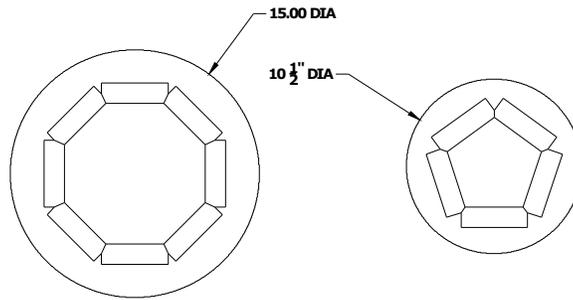


Diagram: Octagon or pentagon configuration

You can scale this furnace up or down to different sizes for smaller or larger applications.

Control considerations

As previously mentioned, if you are going to use intermittent style range controls, one limitation you need to be aware of in scaling the furnace up, is the 15 amp contact rating in the intermittent style range controls.

The solid state controller that I detail in these plans doesn't have this limitation, you simply get bigger SCR's and match the ratings of the components to the voltage and amperage you intend to use.

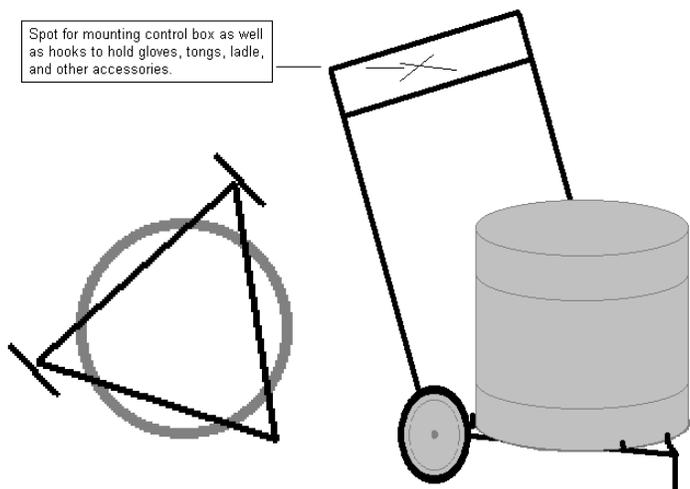
Crucible weight considerations

Ok, so you built a furnace that can melt a gallon of brass. How are you going to lift it out of your furnace? It will weigh more than you can safely lift by yourself with a tongs, so you will need to figure out a two man tongs arrangement, or hoist or something. Just be careful!

Making the furnace more portable

This suggestion came from one of my readers, and with permission I publish it here. Thanks goes to Jim Morton III.

Please note that it is not a good idea to try to move the furnace while in operation, you may spill molten metal!



The Mini-Melter: Foundry on 120v

Scaling the furnace down, you can make a cute little furnace to take with you wherever you go, melting little pint sized shots of metal for the smaller castings. You can use the same hexagon design, or a pentagon if you wish.

Off the shelf solid state controls

I've seen up to 1200 watt solid state lamp dimmers at my local home improvement center, and this would serve as an excellent control for a small furnace. I consider the solid state controls superior because of their continuous operating characteristic rather than a cycling on and off like the cheaper intermittent range burner control. It's your preference.

At the time of this writing, Home Depot's website listed a 1000W dimmer at \$35.00, with these specifications:

Lutron Electronics Heavy Duty Lamp Dimmer Features:

- Contractor's choice in rotary dimmers for demanding applications
- Just turn to dim or brighten; positive click on/off
- For incandescent or halogen(120V) light bulbs
- 1000 Watts maximum capacity (UL; CSA; NOM listed)
- Single pole for a light controlled by one switch or dimmer only

This dimmer would be ideal for small 120volt furnaces with resistance elements not less than 14 ohms. In other words, a 14 ohm element or a 15 ohm, but not a 13 ohm. Refer to the ohms table earlier in this book. DO NOT attempt to operate this dimmer on 240v!

ONLINE SUPPLIERS INDEX

Black High Temperature Cement and Firebrick

Corner Hardware:

www.cornerhardware.com

(Seems to be the only one that has 3000 degree cement anymore!)

Do It Best:

www.doitbest.com

Many local hardware stores carry Do It Best's line of products including Worcester Brush high temp cement.

Heating Elements and Intermittent Heat controls

Budget Casting Supply

www.budgetcastingsupply.com

This is a very good website dedicated to home shop foundrymen!

EvenHeat Kilns

www.evenheat-kiln.com

Doesn't sell direct, but gives local distributor information.

I used EvenHeat elements from a local supplier.

Paragon Industries

www.paragonweb.com

Doesn't sell direct, but gives local distributor information.

Electronics Suppliers

Digi-Key

www.digikey.com

I purchased my Teccor S6070W SCR's from Digi-key!

Newark Electronics

www.newark.com

Another source for larger semiconductors.

Radio Shack

www.radioshack.com

There may be a store near you! Save the shipping!