

CASTING METAL PARTS

CASTING METAL PARTS

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We have many good Mini and other books on Gunsmithing, Knife making, History, Out of date, and Crafts books. The purpose is to give you the basic information on subject that is covered here. I hope you enjoy and learn from these books. H. Hoffman

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Zaibatsu Release

I am the alpha, the omega,
the beginning and the end

CASTING METAL PARTS

GETTING STARTED

The first item we will talk about is a way to melt metal. You can use a gas furnace or an electric furnace, which is easy to make.

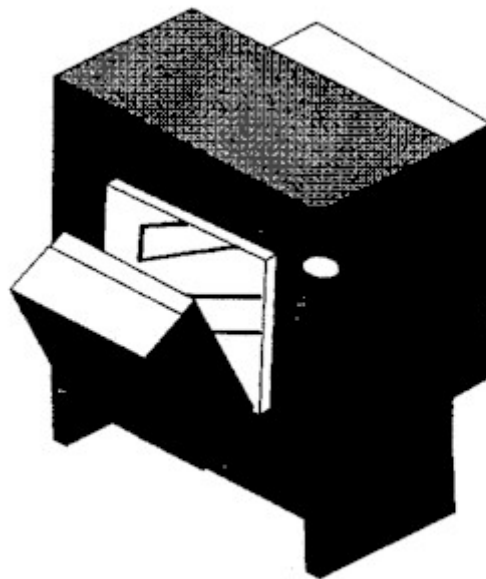
MAKING A ELECTRIC OVEN

The tools required for making an electric oven usually are found in your shop or garage. At a cost of about twenty to thirty dollars and in a few evenings you can own an oven of which you can be proud.

The oven that you can make is capable of temperatures up to 1900° and, if equipped with both a pyrometer and power control, it can maintain near constant temperatures over this range.

Once you have established the power setting that you need for a given temperature, it is simple to set up a time/power, ratio you can duplicate the temperatures.

The power ratings for this oven, is based on the availability of heating elements, which we will use the electric elements for a 1000 watt oven.



THE ELECTRIC HEATTREAT FURNACE

The heating element used is the type normally sold in appliance and electric supply stores. The element for appliances such as the clothes drier is already coiled and need only be stretched to the required length for use with this oven. It is made of Nichrome wire, which offers resistance to current flow, thus producing the necessary heat. If the element does burn

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out, replacement is simple and a fraction of the cost of a commercial unit.

The oven can be used as for a heat-treating and tempering oven for steel tools, enameling and other similar applications. With Imagination, you can find many other applications and uses for this piece of equipment.

MATERIALS

Galvanized iron sheet, 26 gauge

1 Pc. 7 ½" x 32" (top & sides)

1 PC. 7 ½" x 8 ½" (door)

1 PC. 6 ½" x 12" (bottom)

IPC. 11" x 15" (back cover) (light gauge)

2 PC. 2" x 3 ¼"

5 insulating fire brick, 2300° F, 9" x 2 ½" x 4 ½"

24 round head sheet metal screws, #6 x 3/8"

1 PC. Asbestos shingle or sheet asbestos, approx. 2" x 6"

2 Pcs. flat steel, 1/8" x ½" x 6"

1-pint high temperature furnace cement

1 heating element, Nichrome, coiled, 1000 watts at 110 volts

1 Pc. round steel, 1 ¼" x 18"

4 brass machine screws, round head, 10-24 x ¾"

8 hex nuts, brass, 10-24

1 PC. Round metal stock, any material, 1 ½" x 4" (for the counterweight)

1 heavy-duty line cord (type used on electric irons)

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4 machine screws, round head, 6-32 x 1 ¼"

4 hex nuts, 6-32

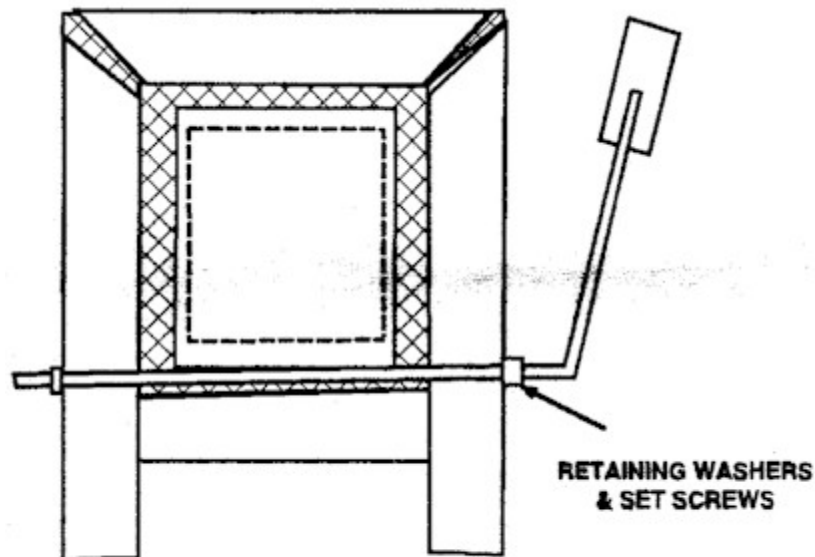
1 power control, Type C.R.S., rated 1000 watts (minimum)

1 pyrometer

1 can, heat resistant lacquer or enamel

STARTING CONSTRUCTION

You can begin construction by cutting the galvanized sheet, to the required dimensions given. The individual pieces should now be laid out for further cutting, folding and bending. You will note from the drawing details that the areas that have been shaded out are to be removed. For neater looking corners, ¼ Inch holes have been drilled on centers at the Intersections of the areas to be removed. These holes permit much easier bending and allow for the slight miscutting of angles. Look at the metal layout details for dimensions and areas to be removed.



FRONT VIEW OF FURNACE

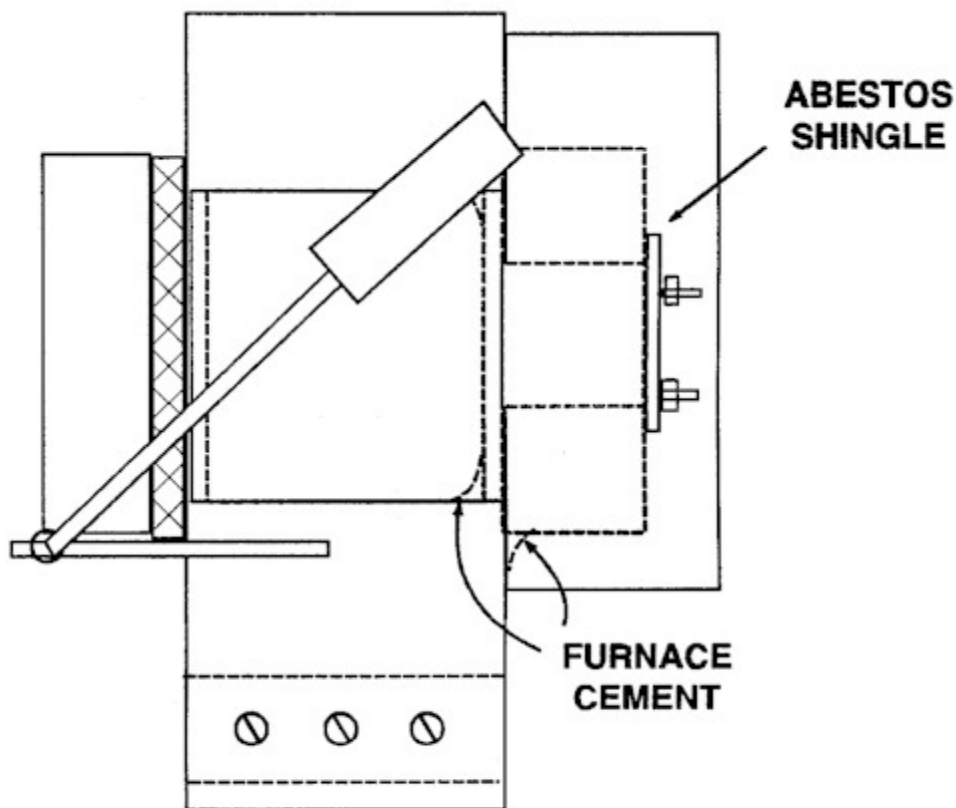
All pieces must be bent to 90° as shown by an X on the metal layout detail sketch. If you have a sheet metal shop in your town, it is better that it is taken to the shop and let them do the bending. If there is not a sheet metal shop in your town, the bending can be done by clamping the pieces in a vise between two boards that is cut to the length needed. Bending the pieces with the above method is slightly more difficult; a neat bend can be achieved with a little care.

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The bending sequence should be well thought out before starting of any bends to avoid interference of one bend with another. This is all there is to the metal portion of the oven.

FIREBRICKS

Next refer to the sketch titled, "Furnace Layout." Two firebricks are left whole; two bricks are cut to 5 ½ inches long and one brick is cut exactly in half. You can make all cuts with a thin bladed back saw. The two full-length bricks will be the top and bottom of the oven. The brick cut in half will furnish the two sides that have the heating element. The 5-½ inch bricks will be the door and the back of the oven.



SIDE VIEW OF ELECTRIC FURNACE

This type of insulating firebrick is very soft and should be handled with care. A fingernail has sufficient hardness to gouge the brick. For this reason and its high temperature properties it was chosen for making this furnace. This type of insulating brick is normally used in some commercially made ovens. This brick is made by several suppliers and can be bought to withstand various temperatures. The 2300° F brick is sufficient for this type of furnace and should be specified as the type you want.

Take the two half bricks and looking at the coil layout, route the bricks so the heating elements will fit. The routed width should be slightly under the outside diameter of the

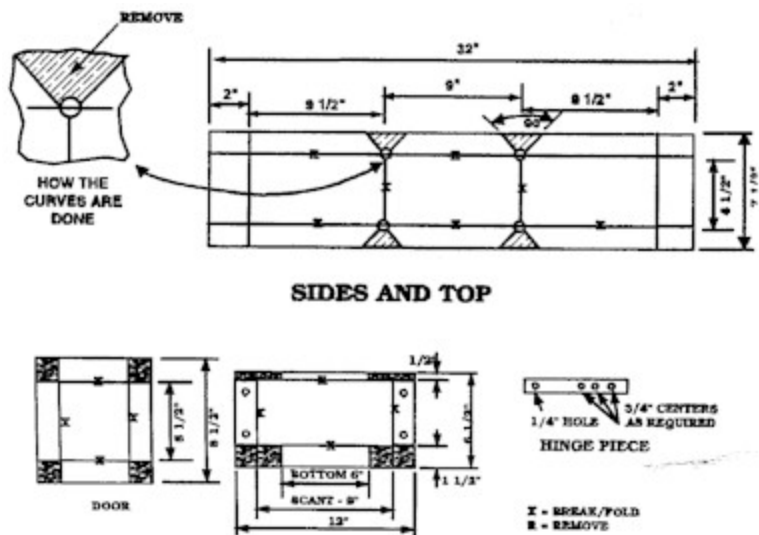
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Nichrome coil and sufficiently deep to contain the coil below the surface of the brick. Heating coil placement is not critical but should be close to the placement shown in the drawings.

DOOR

The door and back brick also must be routed to a depth of 1/4 inch along all four sides so a portion of the brick protrudes into the oven openings for better heat retention.

This also can be done on a drill press using a flat-ended bit as a router or by carefully cutting and scraping away the excess material with a knife. Refer to the brick and coil drawing for the width of these cuts.

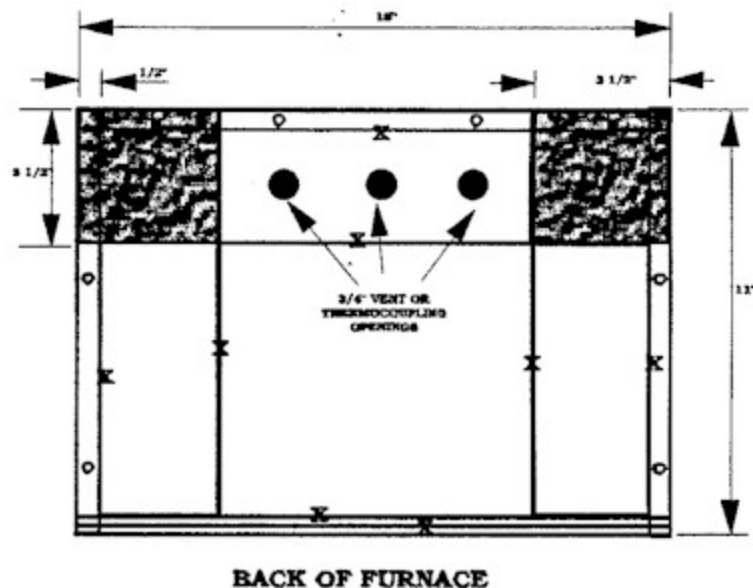


If you have a drill press or milling machine, the routing can be done by simply using a drill or router bit of the required diameter. The coil layout can be carefully outlined on the brick in soft pencil, the drill or router bit set to the required depth and the brick pushed into the revolving bit, following the pencil outline. If you do not have a drill press, the routing can be done with a piece of round steel stock by pressing the end of the steel into the brick and using die rod as a scraper. This may seem difficult, but the brick is relatively soft and can be cut easily.

HEATING COIL

Setting up the heating coil is next. Cut the coil exactly in half, this can be done by simply counting the number of coil loops and cutting it at the midpoint. At both ends of each coil half, if the coil must be straightened by stretching the coil loops so there is a 4 inch length of straight wire.

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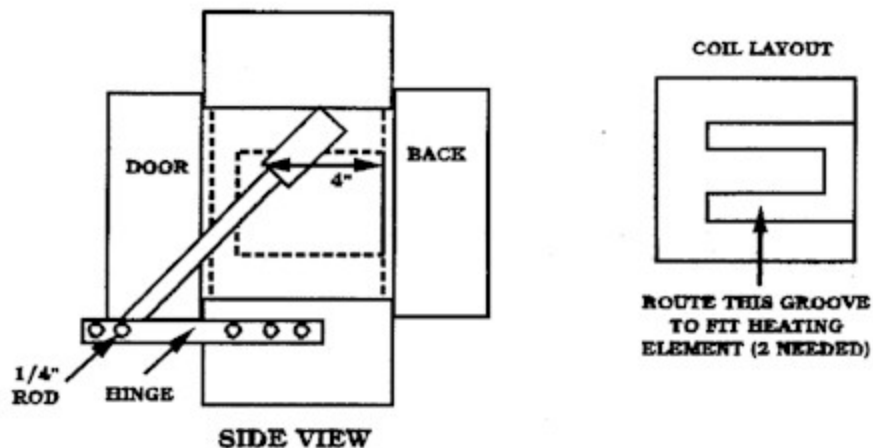
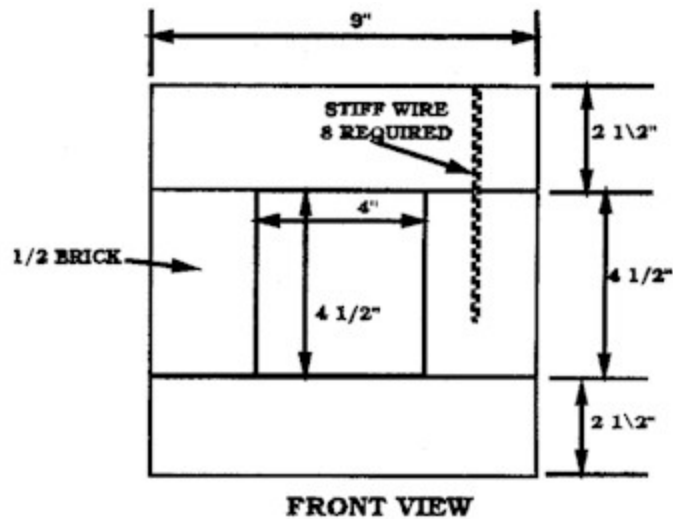
The straightened ends will be fastened to the terminal screws at the back of the oven; About 6 to 8 straightened coils is sufficient to produce the above length. The total length of the routing should now be determined and each coil stretched about one inch short of this length. Lay a yardstick on a flat tabletop, grasp both ends of one coil and stretch the coil using the yardstick as a guide.

The amount to which the coils return should be the length needed as determined above. Starting $\frac{1}{4}$ inch from the edge of the routed firebrick, press the coil into place. Get some staples $\frac{1}{2}$ inch long with a radius of $\frac{1}{16}$ inch and push these staples into the brick along the length of the Nichrome coil at points to hold the coil in place. In locating the staples, be sure they are pressed between the individual coils so as not to short out any adjacent coils. Once the Nichrome wire has been heated, it will take a permanent set. The use of the staples is to aid assembly.

THE BOTTOM

Assemble the bottom, top and sides of the brick portion of the oven. Put one full brick on a solid flat surface and then position the two side bricks containing the heating elements flush with the front and side edges of the full brick and place the remaining full brick on the top of this assembly. Get some light, 4 inch pieces of stiff $\frac{1}{8}$ inch diameter wire and sharpened one end of each piece to a point and drive two of these wires, as you would a nail, through each full brick into each side brick, both top and bottom.

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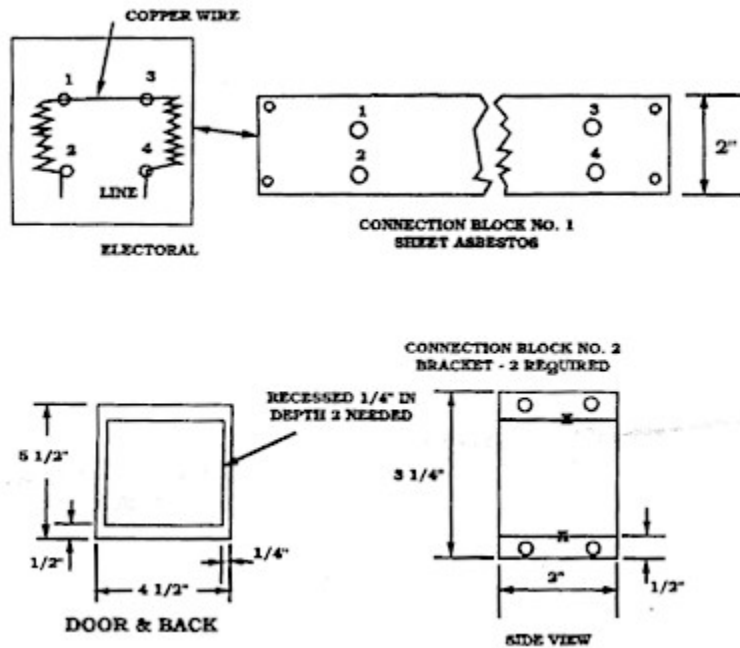


The wires should be located through the full brick so they will be driven into the middle of the side brick one inch from both the front and back edges of the assembly. The reinforcement of the bricks is needed to hold them together for the assembly into the metal case. Drill pilot holes a little under the diameter of the wire used is drilled into the full brick. This will help in driving the wire into the side brick. When you predrill the holes the wire is less apt to be driven into the sides at an angle. The firebrick is soft enough to accept the wires without breaking, if drive them in carefully.

FITTING

When ready slip the completed brick assembly into the formed metal case. Turn the case containing the assembled bricks over so it rests on its top. Next, locate and drill two holes through the outside the metal case one inch from the front and back edges of the oven and centered with relation to the flange of the bottom piece.

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The bottom piece should be put in position to check the locations where the holes should be drilled. The holes should be the same size as the outside diameter of the sheet metal screws used. Now place the bottom piece in position again and locate the drilled holes on the side flanges of the bottom piece.

When located, remove the bottom piece and drill holes the root diameter of the screws at where you marked them. Assemble the bottom piece to the case using sheet metal screws.

ASSEMBLING

Sheet metal screws are self tapping so to fasten two pieces of light gauge metal, the outer piece of metal is drilled to the outside diameter of the sheet metal screw and the inner piece drilled to the root diameter of the screw. By drilling the holes this way the sheet metal screw will bring the two pieces together and hold them tightly.

Take the two pieces of 2 x 3 ½ inch sheet metal and bend them into a bracket for the terminal board. Bend a ½ inch flange on each 2 Inch end in the directions indicated by the side view of the sketch. Drill the foot of the flanges for sheet metal screws and the tops to take 632 machine screws.

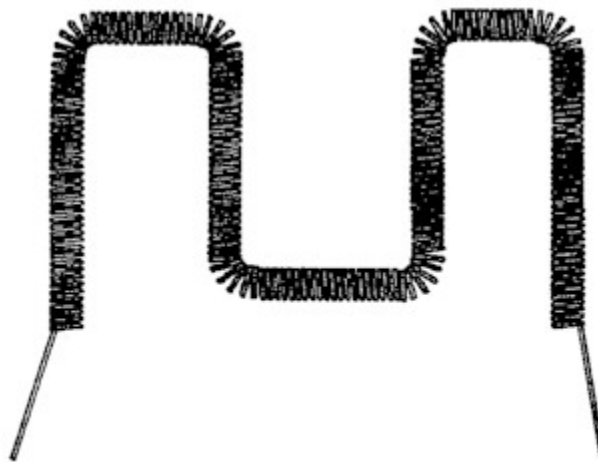
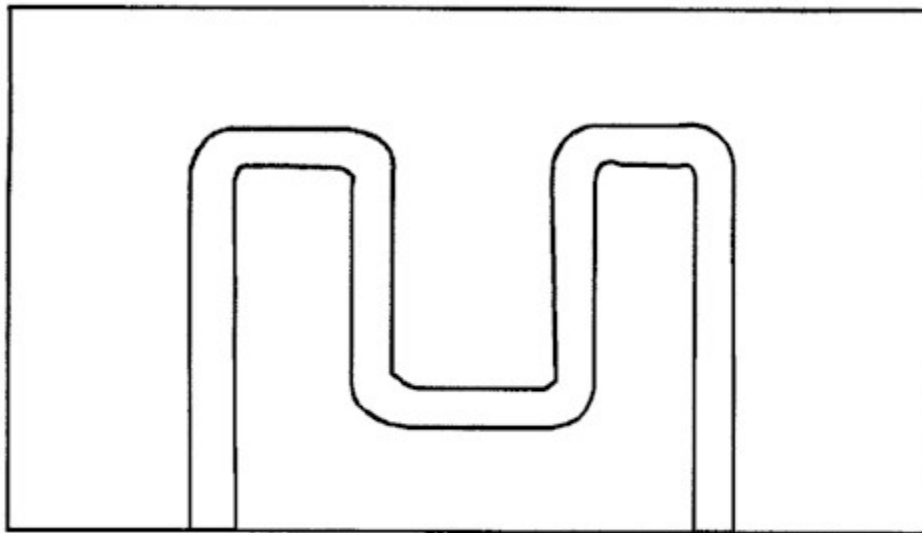
Locate the foot holes on the sheet metal on the back of the oven so the bracket will just clear the back brick. These brackets and the terminal board form the clamp to hold the brick in place. Fasten the brackets in place with sheet metal screws.

Cut and prepare the asbestos shingle and attach it to the brackets using the four, 6-32 machine screws. The asbestos can be broken successfully if it is first scored deeply with a

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scratch awl, and then snapped over a sharp edge. The asbestos sheet is the type normally used as siding to protect wooden structures. Before assembling the asbestos to the bracket pieces, drill four holes into the asbestos to accept the brass machine screws that will be the electrical terminal posts for both the Nichrome wire elements and the line cord. (See illustration.)

The brass machine screws should now be inserted and the hex nuts tightened. Next, remove this assembly, place the back brick into position and reassemble. Be careful so you do not disturb the Nichrome wire leads, as each Nichrome wire lead should reach one of the brass terminal posts.



THE HALF BRICKS (TOP) ARE WHAT FORMS THE SIDES OF THE OVEN. THE BRICK IS ROUTED OUT TO TAKE THE HEATING COIL. THE HEATING COIL SHAPED TO FIT THE ROUTED AREA.

FILLETING THE BRICK

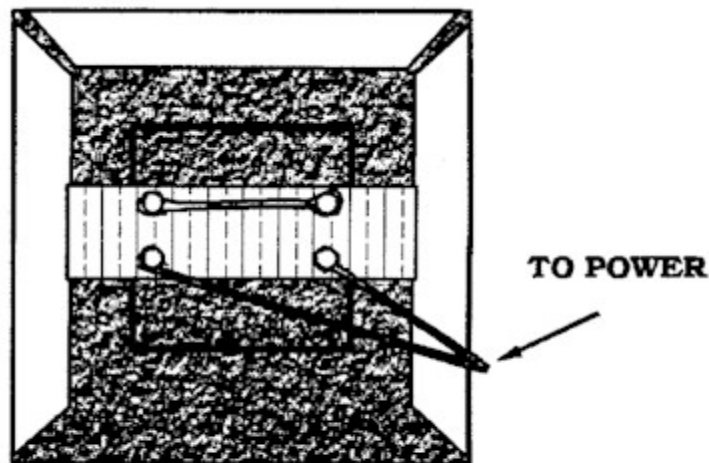
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All the firebrick on the Inside should be filleted with a high temperature furnace cement. This is done by spreading a fillet of cement with the tip of the finger to form a $\frac{1}{4}$ inch fillet radius.

Place the metal door piece face down on an insulated surface; the $\frac{1}{4}$ inch steel rod can be positioned and welded or brassed in the correct position. The end of the rod should extend three inches beyond the width of the door and should be flush with the face of the door.

Use clamps to hold the door piece down against the insulated surface to prevent warping during welding or brassing. About 1 inch area at each edge of the door and rod contact points, are all that is necessary to hold the door securely to the rod. It is not necessary to bend the rod now, but when ready the door handle can be either to the left or the right of the oven.

Position the oven between two bricks placed at the top and bottom of the oven so the oven is level and the back bracket is held above the working, surface of a workbench.



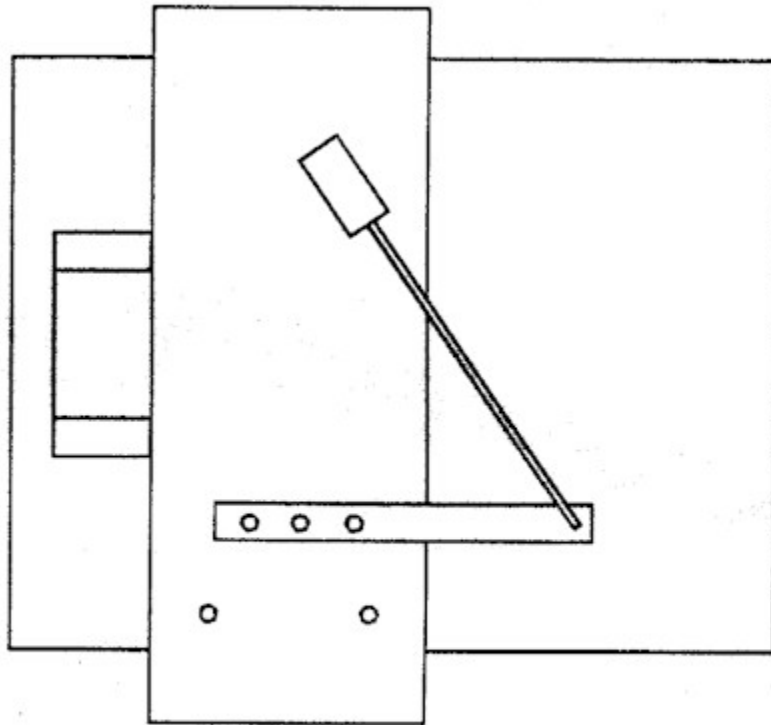
**REAR OF OVEN WITH
BACKCOVER REMOVED**

MOUNTING THE DOOR

Take the front door firebrick and place it into the metal door piece and center this assembly on the oven with relation to the oven opening. Now drill $\frac{1}{4}$ inch holes into the hinge bracket piece. This hole should be centered and $\frac{1}{2}$ inch from the end of each piece, and from the opposite end, drill three holes on $\frac{3}{4}$ inch centers to accept sheet metal screws.

Set the two bracket pieces on the positioned door rod and locate the three screw holes on the sides of the metal case. Drill holes in the case to the root diameter of the sheet metal screws and assemble. The door can be opened and closed now to check any points of binding. If you have binding points they can be relieved by further cutting away the firebrick.

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SIDE VIEW DOOR HINGE

MAKING THE HANDLE

Take two $\frac{1}{4}$ inch retaining collars should be used to keep the hinge rod from sliding back and forth. The retaining collars can be $\frac{1}{4}$ x 20 hex nuts drilled to a full $\frac{1}{4}$ inch opening. Take one of the hex nut faces on each nut and drill and tap them to accept a setscrew. Put the retaining collars on the rod, with one on each side of the hinge bracket, and center the door, position and tighten the collars in place.

Using a gas torch with a small flame to bend the rod, so at a point, 2 inches from the hinge bracket, heat the hinge rod to a cherry red and bend the rod up toward the top of the oven at an angle slightly less than 90° . This rod also should be bent back about 35° in relation to the front face of the oven.

Finish the counterweight by drilling a $\frac{1}{4}$ inch diameter hole to a depth of about 2 inches. The counterweight can be made of any round stock with sufficient weight to hold the door tightly closed. The counter weight can be secured to the end of the rod by epoxy glue or a setscrew.

FINISHING UP

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Now to the back of the oven, attach one Nichrome wire lead to each of the four brass terminal screws. Attached across the two upper screws a piece of heavy gauge copper wire that acts as a jumper, to give continuity to the two heating element.

On the bottom two brass terminals, attach the heavy-duty line cord. Position and fasten the back cover using the remaining sheet metal screws. This will complete the oven assembly except for painting. Use aerosol wrinkled finish paint in either black or gray to give the oven a professional finish.

In mounting a pyrometer, the vent holes in the back cover can be used to pass the thermocouples through to the backfire brick and into the oven chamber. Mount the pyrometer on top the oven, and a silicone controlled power rectifier of the proper wattage can be used with this oven. By controlling the Input of current, an infinite range of heat adjustment can be achieved over the range of the 1000-watt model.

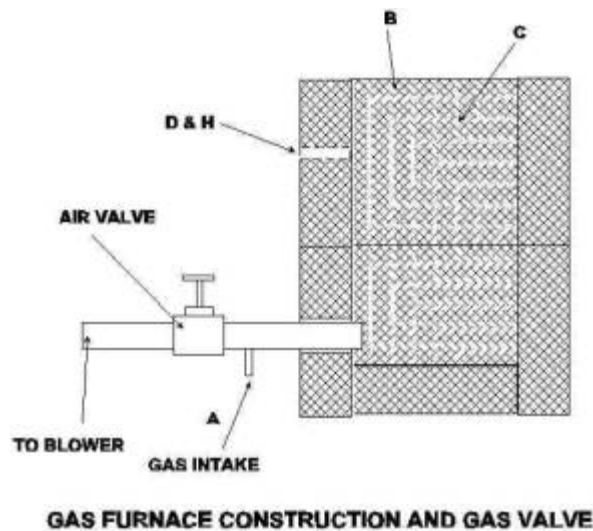
Leftover firebrick pieces can be cut into slices $\frac{1}{2}$ inch thick and used to set your tools on.

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BUILDING A GAS HEAT TREAT FURNACE

Building a small heat-treat furnace for the shop. This furnace is made from standard firebrick, 2 1/2 x 4 1/2 x 8 inches. Firebrick does vary in size, so the size shown in the drawing may have to be changed to fit your needs. Another style of furnace is where the main opening is at the top, and the part hangs down on the inside. This seems to give a more uniform heating.

A-Gas/Air outlet; B-Furnace opening; C-Side view; D-Opening for temperature sensor; E-Blower; F-Gas intake; G-Heat sensor pipe; H-Heat sensor opening; <D>



You will need eight firebricks to make this. When completed you will have a furnace with an inside size of 4 1/2 x 3 x 8 inches. This size will handle just about any job in the shop.

The firebrick is mortared together with the cement used in fireplaces, and it should not be any problem to get from any business that sells fireplaces or wood burning stoves. The brick is placed 2, flat side by side, mortared, and then one brick on each side is stood on edge, (see drawing) mortared to the two laying flat.

Two more are then placed on top of the first two. To finish it off, two more are mortared and set on edge on one end, as per drawing.

Let it set for 24 hours before starting any more work on it"

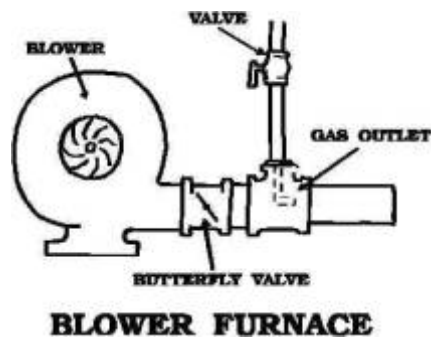
Next you will have to get a cement drill 1 1/2 inch, and drill one hole 1/4 inch above the base in the center on the side. This is where the 1-inch pipe from the blower will be inserted.

You will need to get your pipe cut and threaded to the correct length. Connect a 2-inch pipe to the 1-inch pipe; this will go to the blower.

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Next, you will need to cover the firebrick on the outside. Cut 1/8 inch metal to fit to the outside and top and weld this together, to form a box for the firebrick. Be sure to have a metal bottom already cut out to put under the brick so the sides can be welded to it.

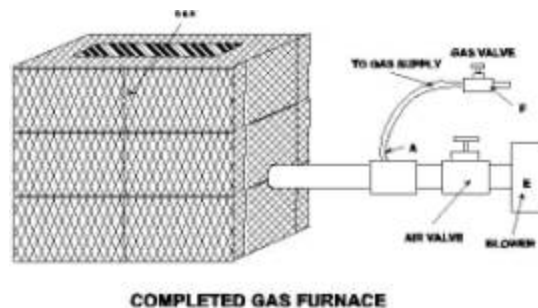
You can when building this go with the opening in the top, and then you need not make a door for the front. This is the simplest way to go and I believe the best. You hang the part down through the opening in the top. At the front, there is a small opening for the temperature probe. This is a 1/4 or 3/8 inch hole.



If you decide to build a front-loading furnace, you will need a 2-inch opening in the top of the furnace for the gas. In addition, you will have to build a metal door for the front and line it firebrick.

You now will need to find a used Kirby vacuum cleaner blower, or any other type of high-speed blower to provide the air for the furnace.

A shop Vacuum blower also works great. You will need to find an adjustable rheostat to control the speed of the blower. The speed that it runs would make it impossible to light the oven. The final step is to tap into the airline with a line from your gas supply.



The basic tools for heat-treating are the gas torch. The torch is a simple apparatus consisting of a mixing tube into which fuel gas and a blast of air are introduced to be mixed and burned at the end of the tube. An old vacuum cleaner can be used for the air blast.

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The hose used for the various attachments for the cleaner can be used to deliver the blast of air to the torch. You will have to make a fitting for attaching the hose at the dust-bag outlet and arrange the cleaner so that air can enter at the suction end.

At the torch, a gate of sheet metal is arranged to regulate the amount of air entering the mixing tube. You can also reduce the airflow by reducing the speed of the blower. A simple light dimmer found at any hardware store would do the job very well, if you have a DC blower motor.

The fuel is supplied through a rubber tube of a size to fit the supply pipe and the fitting on the torch. You should have a 1/4 inch needle valve to adjust the gas to air mixture. Using Butane or Propane from a 5-gallon bottle works better as there may not be enough pressure from natural gas. If you use butane, make sure all your fittings, and hose are for high pressure.

It has rubber ends that will fit on the gas nipples at each end. Any other good rubber tube can be used, such as a 3/8-inch garden hose. The mixing tube must be long enough so that the gas and air are thoroughly mixed by the time it gets to the burner end.

Artificial gas will burn at the end of a plain mixing tube, but for natural gas there must be a special tip on the burner end to maintain the flame, or else the air blast will snuff it out. This special tip consists of a jacket fitted around the end of the mixing tube with several small holes drilled into the mixing tube. This gives a low-velocity supply of gas and air to the jacket.

This will maintain a small circular flame around the end of the mixing tube, which will keep the mixture ignited as it comes out of the end of the main burner tube.

The air blast tends to blow the main flame so far away from the end of the mixing tube that it will mix with so much outside air that it will no longer be a combustible mixture and will be snuffed out. This annular ring of low velocity flame surrounding the outlet of the mixing tube will keep the main flame ignited unless so strong an air blast is used that the entire flame is blown away from the end of the mixing tube.

When you start up the burner, shut off the gas until you have the air adjusted, and then slowly turn on the gas, while holding a lit Butane torch over the opening of the furnace. It is best to reduce the air blast until the gas is ignited and then slowly open it until the desired flame is obtained. The flame should burn with a firm blue center cone, and the hottest spot will be at the tip of the blue cone. A yellow flame is not as hot and is very sooty. After the bricks of the furnace have become well heated, the air blast may be opened a little farther, and the blast will thus be increased.

The flame from this torch is very hot and will heat steel to a white heat for forging, but it is not hot enough for welding, however a supply of oxygen for the air intake will increase the temperature.

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Get large enough cement drill to drill a hole through the firebrick about 2 inches from the top. The heat sensor will fit in there. I find a short length of iron pipe that is large enough on the ID to allow the sensor to fit inside. This pipe is then mortared in place. See Drawing.

A High Temperature gauge can be purchase from an industrial supply dealer. If you can find one, a 2000-degree gauge is best.

In the air intake pipe, (A) you will need some kind of manually controlled valve. You will have to be able to shut the air down quite a bit. If you tried to use the full amount of air, it would blow out the flame.

When you are ready to start the furnace, hook up the gas, check for leaks with soap, and if OK, you are ready to fire up.

NOTE - It is important to do things at first very carefully to prevent an accident. This is the way I have my furnace set up, and have had no problems. I have no control over what is done by other people, and cannot accept responsibility for what some other person does. If you build a gas furnace, you are on your own. Check it outside of the building for safety's sake.

Turn on the air, and close down the valve until there is almost no flow through the pipe. Now take a butane torch and light it. Open the main valve on the gas tank.

BE SURE THAT THE SMALL ADJUSTING VALVE IS CLOSED ALL THE WAY.

Holding the lit torch over the opening, slowly turn on the gas. In a few seconds it should light. There probably wont be much flame, so slowly open the air valve/gas valve until the furnace has a "roar" to it. Don't open the air valve to much as you need a slow heat. Adjust the fuel so that you get 3 to 4 inches of flame from the top. Let it heat up for a few minutes to dry out, and then it is ready to use.

Once it has cooled down, it can be moved back in the shop. This furnace can be changed to where it is front loading, made larger or altered for what ever is needed.

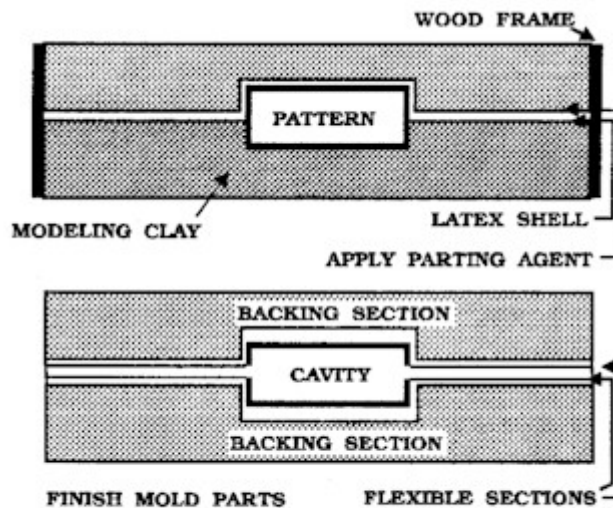
This furnace is very fast. Normally it takes only 10 to 15 minutes to get to operating temperature. I find that hanging the knife parts down from the top will cause even heating. You can use two bricks to close down the opening more to confine the heat better. When through heat-treating, close the top up with the bricks, and let cool down to tempering temperature.

This furnace works great with O1 and other tool steels. It can be used for forging steel as well.

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RUBBER MOLDS & WAX PATTERNS

If you need to cast several objects that are the same, it is best to take the time to make molds for the repetitive wax patterns that are made out of rubber. With the use of this media, it is only necessary to execute one metal pattern. You can use soft metals such as lead, pewter or tin-lead solders as the master pattern material. They are all relatively easy to carve, file and engrave to create the first design. A rubber mold made with the master pattern can then produce wax patterns that can be used to cast additional pieces in more durable metals such as bronze, silver, gold, brass, and aluminum.



LATEX MOLD

Use rubber to make the molds that is unvulcanized gum rubber. It can be purchased by the pound in sheets 1/8-inch thick. The rubber normally has a cloth backing that must be removed before use. In addition, the rubber should be dipped into naphtha or benzene to remove any residue of oils. Lately, I have been using rubber latex that is specially made for making molds.

All that is needed to produce a rubber mold is the pattern, the unvulcanized rubber, a flask to contain the unvulcanized rubber and a means to apply pressure and heat, The Latex rubber is brushed on and allowed to dry between coats, and doesn't require heat.

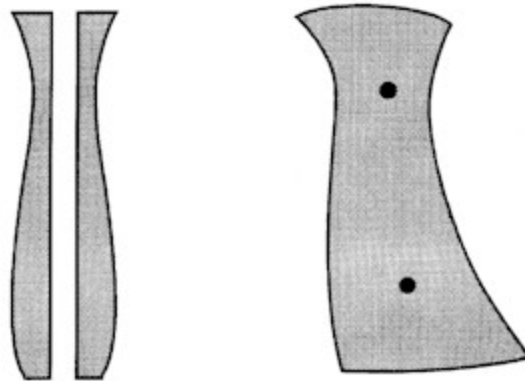
HEAT

Commercial mold makers use a device that applies both pressure and controlled heat to the rubber filled flask to achieve vulcanization. This device is costly and unless you intend to make large numbers of rubber molds, your kitchen oven can be used satisfactorily. The heat required to attain vulcanization is 300° F. for about 30 to 40 minutes, depending on the size of the mold. A mold 1 x 1 ½ x 2 Inches is about the right size for small jewelry pieces, takes

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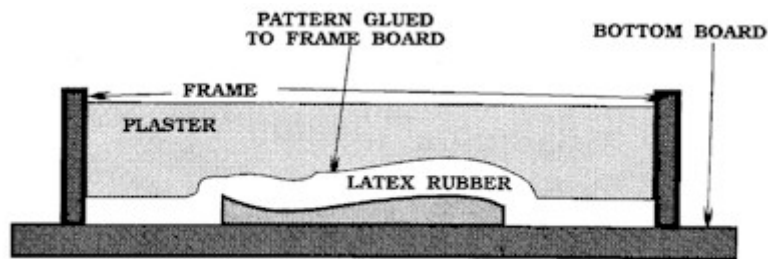
30 minutes at 300 degrees to cure, but larger molds will take relatively more time.

The Internal temperature of the kitchen oven does not always agree with the oven dial setting. The heat required to produce vulcanization is critical within plus or minus 5° F. Preheat your oven for about 15 minutes before curing the rubber mold, then check and adjust the temperature accordingly. An oven thermometer can be purchased at a local hardware store will be sufficient for temperature checking. If your rubber mold is not completely vulcanized, increase the time of curing. If the mold has a burnt appearance around the pattern, decrease the curing time. After working on a few molds, establish the time necessary with your mold size to attain vulcanization and use this time in relation to other sizes.



STEP 1--PREPARING THE PATTERN

After curing process, the rubber mold must be cooled in water to room temperature before you start the cutting or parting of it. Remove the mold assembly from the oven after the proper time and plunge the entire assembly into a container of tap water and permit it to remain submerged until completely cooled.



STEP 2--APPLYING LATEX TO PATTERN WITH PLASTER BACKING

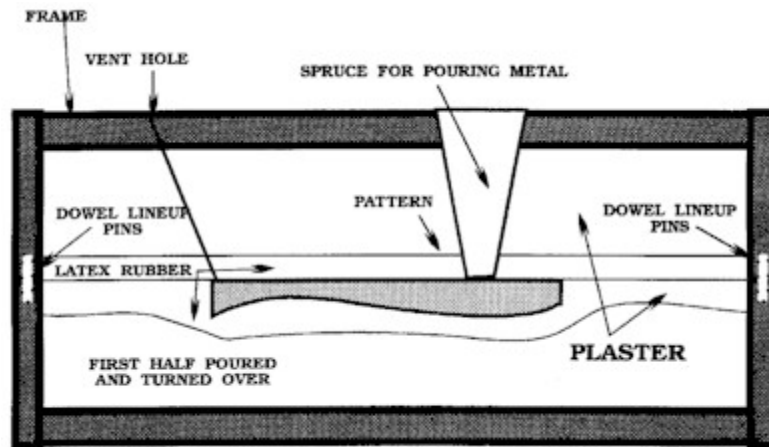
About a half hour will be a sufficient length of time to produce complete cooling. Do not part or cut a hot mold as this will result in shrinkage and an unusable wax pattern.

A fixture must be made to contain the pattern and the rubber, plus a means to apply pressure during the heating cycle. The drawing is a simple way to vulcanize the molds.

RUBBER MOLD FLASK

CASTING METAL PARTS

The rubber mold flask is a length of extruded, rectangular, aluminum tube stock cut and squared to the correct height. This material can be gotten from aluminum supply houses as cutoffs or aluminum storm door and screen suppliers. The drawing of the flask measures 1 inch high by 1 ½ x 2 inches in width and length inside, and a 1/8-inch hole must be drilled into one end of the flask to hold a sprue piece.



STEP 3--POUR THE PLASTER IN THE SECOND FRAME

This hole should be centered to both the height and width of the flask. A line should be scribed around the inside perimeter of the flask centered about to the height. This line will be duplicated in the finished rubber mold and will act as a centered cutting line when the mold is parted.

PRESSURE SETUP

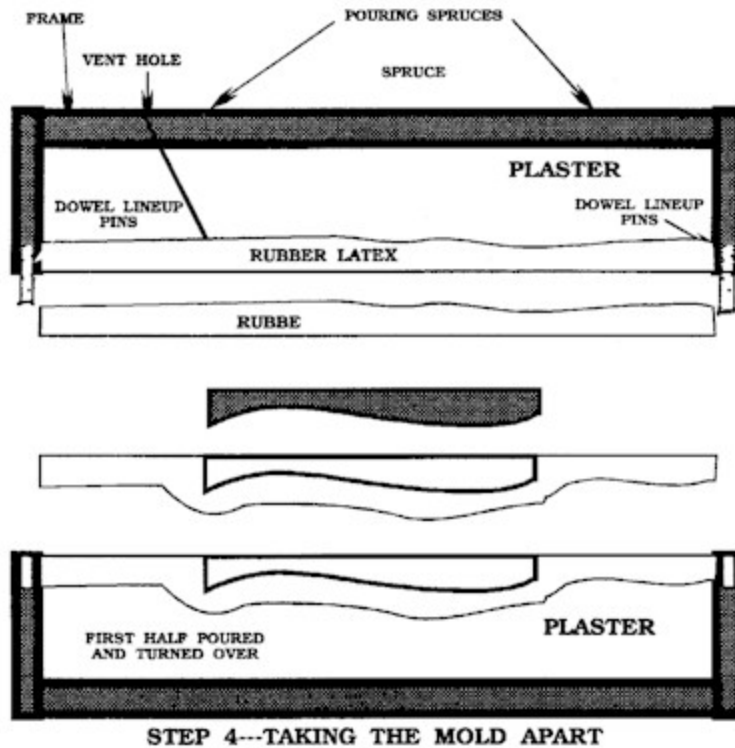
You need now to arrange to apply pressure to the rubber filled flask also must be made. This is two ¼-inch flat brass or aluminum plates, cut to size, with pressure applied by C clamps.

Get two pieces of 1/4 inch brass or aluminum flat stock, ¾-inch larger in length and width than the outside the flask. With both pieces clamped together, drill four holes 3/8-inch from each outside edge and centered to the length and width of the pieces. Use a No. 7 drill so one set of holes can be tapped with a ¼-20 (N.C.) standard screw thread. Mark one of these pieces as the bottom, the other as the top and separate them.

Next, thread the four holes in the top piece with ¼-20 threads. Get and cut four 2 ½-inch lengths of ¼-20 threaded rod and screw these into the threaded holes in the top piece. With one end of each threaded rod flush with the face of the top piece, then with a center punch, punch it around its perimeter to anchor the rod in place. Lock nuts can be used if desired to anchor the threaded rod to the pressure plate.

Now the holes in the bottom plate must be redrilled to ¼ inch to accept the threaded rod as a sliding fit. Get four ¼-20 wing nuts and assemble the pressure device as in the drawing.

CASTING METAL PARTS



MAKING A MOLD

The actual making of a rubber mold consists of cutting several pieces of the sheet rubber to the inside dimensions of the flask. The exact number can be figured out by; if 1/8-inch sheet rubber is used, divide 1/8 into the flask height, so a flask one inch high will require 8 pieces of sheet rubber cut to dimension.

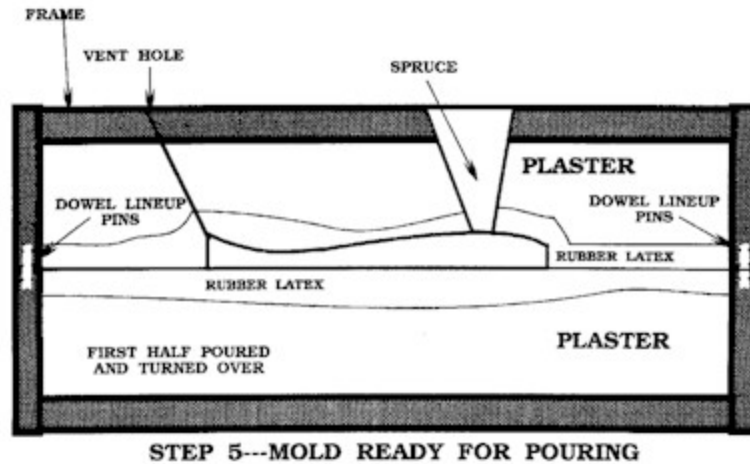
Now sprue the pattern to a short length of 1/8-inch brass or copper tubing, fastening the sprue piece to the pattern with soft solder. When this is done, assemble the spruced pattern with the sprue button in place through the 1/8-inch hole in the flask. The pattern should be centered about to the width and length of the flask and centering with respect to height will be automatic when the flask is packed with rubber.

Next, place the flask on a flat surface and pack half of the pre-cut rubber pieces into one side of the flask, and then place the pressure plate on top of the packed rubber and then turn the assembly over. Pack the remaining half of the flask with rubber and put the other pressure plate into position. Screw on and tighten the wing nuts to compress the rubber into the flask. Place the entire assembly in a preheated oven and cure as outlined above. In about 5 minutes in the heated oven, the rubber will soften and begin to flow. Now, again tighten the wing nuts until the pressure plates are in intimate contact with the rubber-filled flask. Now remove and cool when curing is complete as described above.

PARTING

CASTING METAL PARTS

The most important thing of making the rubber mold is the actual cutting or parting of the mold. The mold must be parted so the wax pattern can be extracted with a minimum of effort. Studying the actual pattern and deciding where the mold should be cut, will help you when the mold cutting begins.



Hold one corner of the rubber mold in a bench vise. Place the rubber mold into the vise so let will be held along its entire width at the bottom edge. With a sharp knife, cut across one corner, at the parting line, to a depth of 1/8 inch then cut up ward at a 45° angle and back down to the parting line, again at a 45° angle. The resulting triangular mounds and recesses in the rubber will act as locks to align the mold when completely cut. When the four corner locks have been cut, go to cut around the parting line of the mold down to the pattern. When the pattern has been reached at one point, cut from the pattern to the outside the mold. Try to cut from the centerline of the pattern to the outside centerline of the rubber mold. As the cutting progresses, continually pull the mold apart and proceed with further and deeper cuts. To cut the rubber easily, the rubber must be stretched before the application of the knife-edge and the actual cutting of the rubber.

After the entire pattern has been cut around its outside perimeter, again stretch the rubber and cut the center of the rubber mold. This area would correspond to the center or finger portion of the ring. The mold should now be dusted with baby talc and the excess talc blown away. Be sure that the talc comes in contact with all cut and pattern surfaces of the mold to help removal of the wax pattern.

Rubber molds need not be restricted to jewelry alone, as small, non-replaceable parts of almost anything can be duplicated in rubber and the wax patterns cast in brass or aluminum. If the part is broken, it need only be temporarily soldered together and a rubber mold made, and the new casting will be as good as an old one.

CASTING METAL PARTS

DUPLICATE PATTERNS

When duplicates of a design are needed, the easiest way to do this is to make a rubber mold, using the original casting as a pattern. From this mold any number of duplicate wax patterns can be made. Once made, the duplicate patterns are used the same as an original to make an Investment casting.

Making the rubber mold starts with getting a short length of brass or copper tubing, 1/8-inch in diameter. Also a sprue button must be made. Soft solder the 1/8-inch brass tubing to the finished casting to form a sprue. Place the sprue into the opening of sprue button.

Select a rubber mold flask that will contain the metal, and there should be a minimum of 1/4-Inch around all sides of the metal pattern. Less than 1/4-Inch of rubber around the pattern may result in a deformed wax pattern in later wax Injection.

Now cut several pieces of unvulcanized gum rubber the exact inside dimensions of the flask. Be sure to remove the protective covering from the pieces of rubber. Dip each piece of rubber into a beaker of either naphtha or carbon tetrachloride. Drain the excess solvent by tapping the piece of rubber against the edge of the beaker. You must include the solvent dip, as it is necessary to remove any traces of oil or dirt from the unvulcanized rubber. Do not handle the rubber after dipping, as this will deposit oil from the fingers. Unvulcanized rubber normally comes 1/8-inch thick. It is a simple matter to measure the height of the flask and determine the number of pieces needed, so if the flask height is one Inch, eight pieces of rubber will be needed, four on each side of the pattern.

As the wing nuts are tightened, the unvulcanized rubber will be compressed within the flask. Be sure to tighten the wing nuts securely. Now preheat your kitchen oven to a temperature of 300° F. Place the entire assembly into the oven and bake for 30 minutes.

The size of the rubber mold will determine the length of time necessary to get complete curing of the rubber, and the temperature is constant at 300° F. If the rubber mold is over baked there will be a tendency for the rubber to char or darken in the area of the pattern. If you under-cure the rubber mold, the rubber will have a putty-like texture after cooling. Trial and error will show the correct time for baking. If the rubber mold is under-baked, it can again be reheated to finish curing.

Remove the vulcanized rubber mold from the oven and cool in a container of cold water, The entire assembly should be placed into the water, and allow sufficient time to get complete cooling throughout the bulk of the rubber Mold. Cooling will take from twenty to forty minutes,

Clamp one edge of the rubber mold in a vise. With a very sharp knife, cut diagonally across one corner, at the centerline of the mold, to a depth of about 1/8 Inch. Cut upward at a 45° angle, again for about 1/8 Inch, and back down to the centerline.

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Repeat this cutting at all four corners of the mold. When the rubber mold is completely parted, the mounds of rubber thus formed will act as locks to align the two halves.

After the locks have been cut, cut deeper into the rubber mold, starting from the sprue button and work down along the sprue until the pattern has been reached. Cut around the centerline of the pattern for 180° or to the side of the rubber mold opposite the sprue. Always cut from the pattern to the outside the mold. When the side opposite the sprue has been reached, again start cutting down the sprue on the other side of the mold. All cuts should be made with a slicing, continuous stroke, and each cut will result in a small irregularity in the surface of the rubber, which will act as additional locks to align the two halves.

After parting the rubber mold, the half molds should be completely dusted with baby talcum powder. The best means of applying the talc is by using a plastic squeeze bottle, the opening of which has been covered with one or two layers of muslin cloth. Fill the squeeze bottle about half full of talc and apply muslin over the opening, and screw the top in place. Holding the plastic bottle at a slight downward angle, squeeze the sides gently but quickly, and the escaping air will carry a quantity of baby talc to the mold.

You must cover all cut surfaces of the rubber mold with a fine layer of talc. Flex the mold to expose all pattern surfaces and cover these with talc. Remove the excess powder by tapping the mold sharply against a solid object.

Again flex the mold to be sure that no undue amount of talc is being kept in the crevices or details of the rubber impression.

LATEX RUBBER MOLDS

The method of making vulcanized rubber molds is usually too complicated for the average person. The Latex mold is not as durable as vulcanized molds, but it can be used for a reasonable number of duplicate wax patterns.

This method of making molds for duplicate wax patterns is simple and does not require any elaborate equipment, processing or heat treating (vulcanizing). The original pattern may be made of any convenient material such as wood, or plastic, but not wax. The pattern must have a sprue attached so a pouring orifice is molded into the mold.

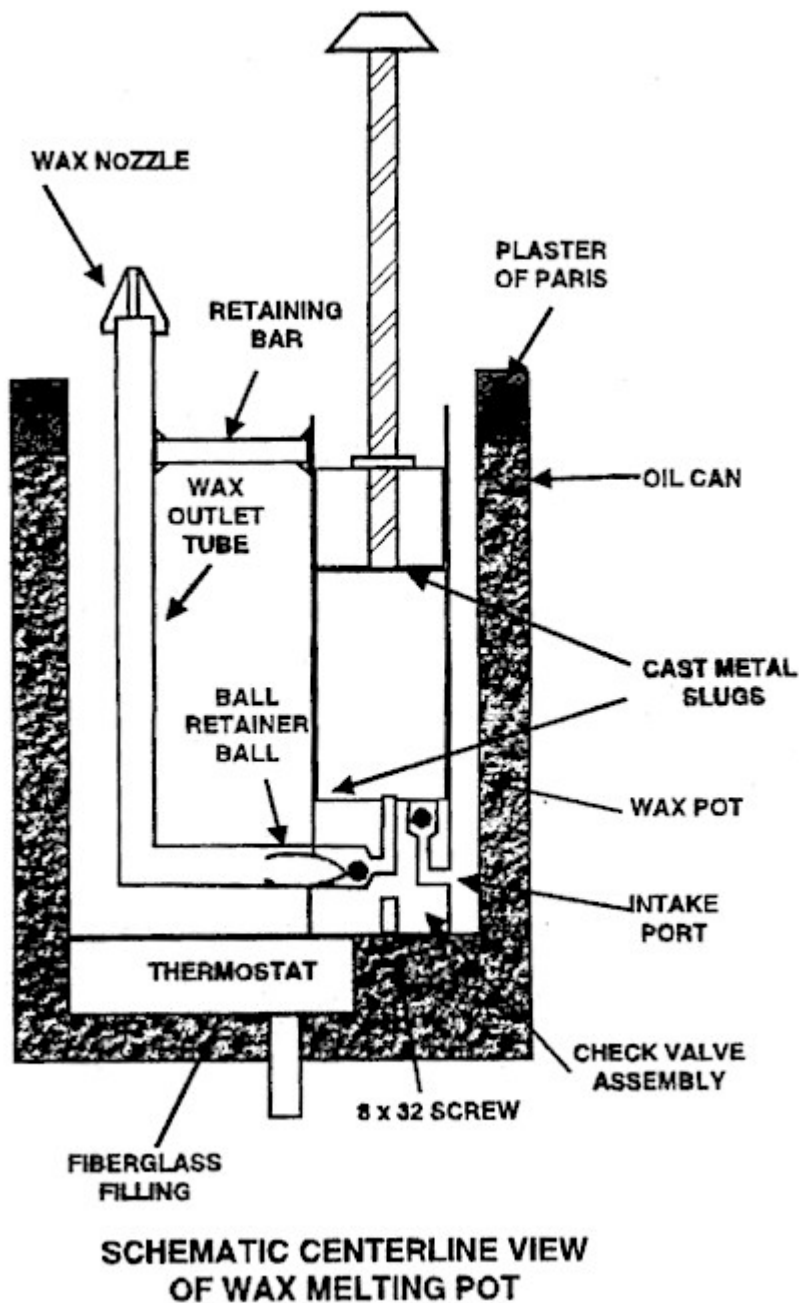
The mold material is known as Pure Rubber Brushing Latex and is obtainable in many art supply, hobby, and plastic supply shops, such as Douglas and Sturgiss, 730 Bryant Street, San Francisco, California.

MAKING THE FIRST HALF

Imbed the pattern to its halfway point in a block of modeling clay having a flat surface. This

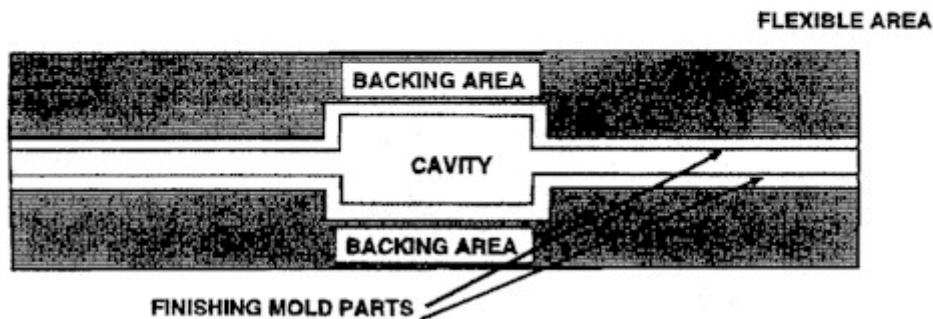
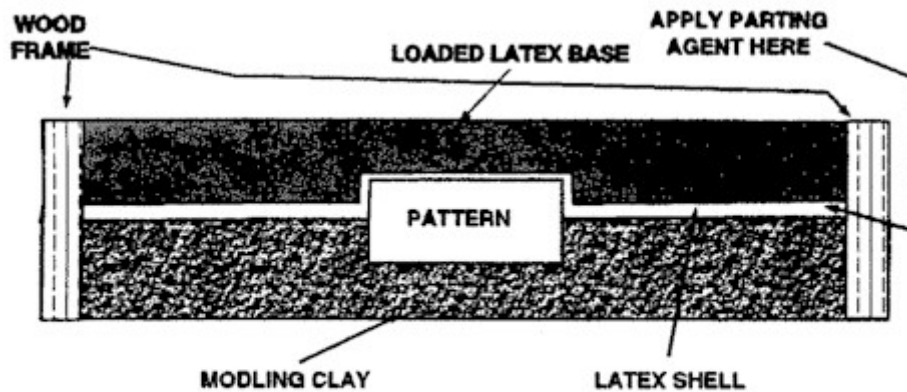
CASTING METAL PARTS

block of clay should be about three Inches Square, larger for larger patterns.



Make a wooden form that surrounds it extending about 3/8-Inch above the pattern. Grease the Inner surfaces of the wood form with Vaseline. Coat the entire surface of the pattern and the block of clay with four or five coats of the latex. Apply it with a brush. Drying time for each coat ranges from a half hour at elevated temperature (about 100° F.) to two hours at room temperature. Build up with another couple coats to get a good thickness for easier handling of the mold.

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When all coats are set and tack-free, brush on two coats of a parting agent, such as silicone, and let it dry. Fill the area within the wood frame with latex, which has a very fine sawdust or some similar filler, mixed in it, brushing in successive coats that are no thicker than 1/8-inch. The thicker coats will take too long to cure. Do not mix anymore than necessary, as any left over will cure before you are ready for the next coat. The brush will wash out readily if washed immediately after each coat in running water. The latex may be mixed in any cup or glass, as it will not adhere.

MAKING THE SECOND HALF

When the first half is completely cured, remove the modeling clay, invert the whole in the wood frame so the filled latex section is now at the bottom. The upper surface, now exposed, is that which was against the florist's clay, with half of the pattern exposed. Now coat this entire surface with parting agent. Repeat with the several coats of pure latex and, the coats of filled latex. Be sure to apply the coats of parting agent between the two operations. The mold will usually part easily for the removal of the pattern, and the filled sections will part from the thinner, pure latex, mold sections.

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The wooden frame will serve as a guide for reassembling the mold parts.

You now have a four-part mold. The two thin sections are sufficiently flexible to allow the removal of the wax patterns regardless of any undercuts, while the firmer sections, made of filled latex, will be sufficiently firm to back up the thinner sections and hold them in place. The thin sections may be made thicker or thinner as experience dictates, depending on the intricacies of the original pattern.

You must make provision in the wood frame to match the sprue opening for pouring the wax. This mold will stand warming to the temperature necessary to allow the wax to flow freely, but it is advisable to make provision for clamping the mold with "C" clamps.

PLEASE NOTE- Latex is not a rubber cement, although for many applications it does a good job, especially for temporary bonding to glass, such as wooden frames to contain plaster for intarsia. It is a liquid latex formulated for air curing, and it is most used for ceramic molds. Molds made with Latex lack the durability of vulcanized rubber, they are sufficiently durable for most purposes, but the Latex molds have a shelf life of about two years before they start to deteriorate.

Working out the best thickness of the shell section in relation to the particular pattern to be reproduced. The more intricate the pattern as regards to undercuts, the thinner the shell should be, but the thinner the shell, the more difficult it is to assemble the mold.

Any type of parting agent-containing silicone can be used to coat the sections. This can be supplied by ceramic shops or through the source listed above. Do not use talc since the latex must be brushed on and this could disturb the powder and cause problems.

The Latex will loosen when it comes in contact with moisture and IT IS NOT OIL RESISTANT. It is completely soluble in gasoline, naphtha, benzene, xylol and similar solvents.

WAX INJECTOR

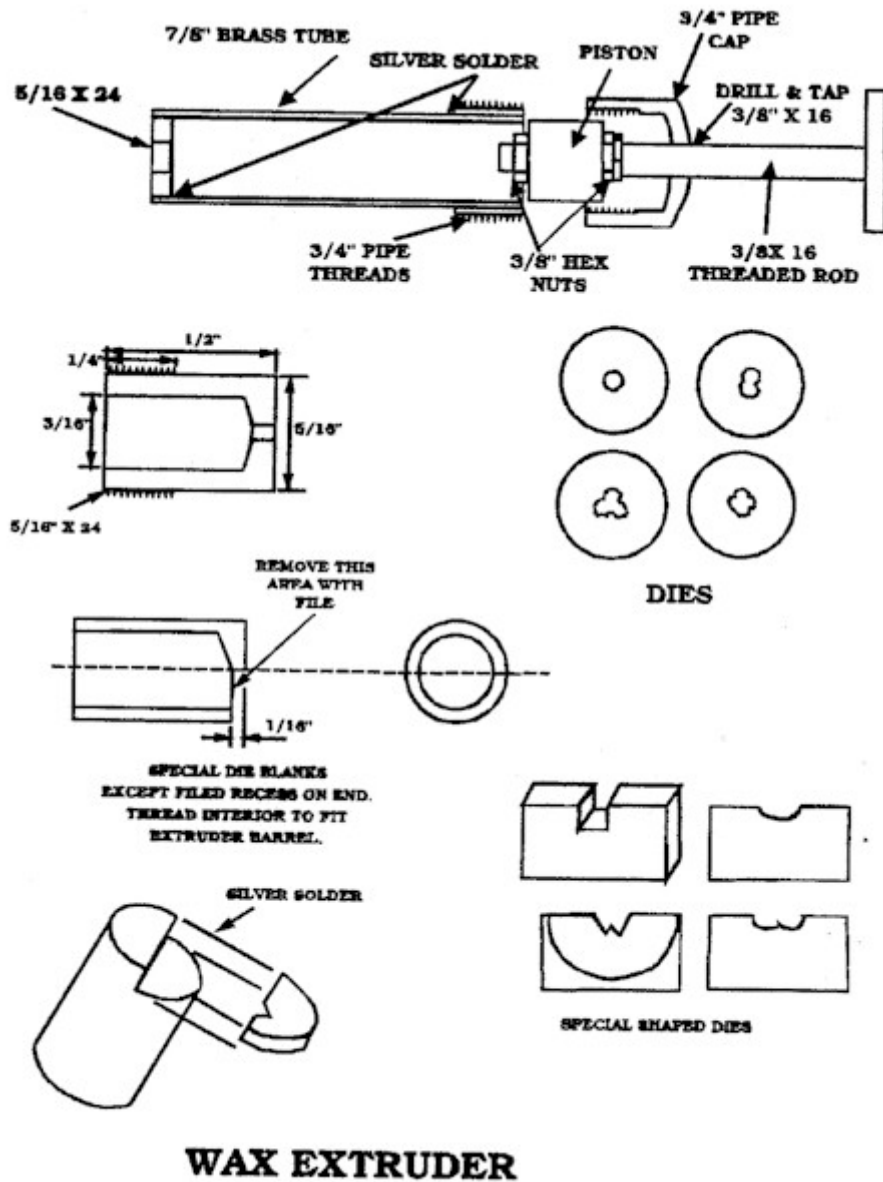
After a design has been executed in metal and a rubber mold is made, it becomes a simple matter to reproduce this design in wax. Although wax can be poured into the mold, a better, quicker method is to use a wax injector. A wax injector consists of a heated pot to hold the liquid wax and a means to transport the wax, under pressure, to a rubber mold. Commercial models are available utilizing both air and hydraulic pressure with heat that is thermostatically controlled.

The wax injector shown here is, quite similar to the commercial models. The molten wax is transported to the rubber mold by hydraulic pressure produced by a piston and cylinder arrangement. The temperature of the wax is controlled thermostatically, using a self-contained flat iron thermostat.

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The heat is produced electrically by using resistance wire (Nichrome).

Fill the wax melting pot three quarters full of broken pieces of wax, set the thermostat completely counterclockwise. Plug in the line cord. Using a double receptacle, one for the wax Injector and another for a lamp, move the thermostat setting slightly clockwise. When the lamp flickers, the heating coil of the melting pot has been energized. Turn the adjustment 10 to 15 degrees further clockwise. Observe the wax after about 15 minutes. If the wax has melted,



Insert a thermometer to obtain the wax temperature. If the wax has not begun to melt, advance the thermostat slightly clockwise. The thermostat setting must be set where the wax will be held at approximately 1 58°F. Be sure to allow sufficient time between each

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adjustment of the thermostat to permit the entire contents to become heated. When the correct temperature has been found, mark this point for future reference.

The actual making of a wax pattern is relatively simple. First the rubber mold must be powdered with baby talc to prevent the solidified wax pattern from sticking. Hold the rubber mold together with two 1 / 16 Inch metal plates slightly larger than the mold.

Press the opening of the rubber mood against the wax nozzle and, at the same time, apply pressure to the piston through the piston rod. Very little pressure is needed to force the wax into the rubber mold. Apply pressure for approximately 15 to 20 seconds, then remove the pressure from the pump, turn the rubber mold so the orifice is facing up, and permit the wax to solidify. Part the rubber mold carefully and remove the wax pattern.

The wax used for Injecting is especially compounded for this purpose. Normally the working temperature of the wax is 158°F., but check with your supplier for the correct temperature.

The wax injector shown here will have a slight tendency to over shoot the normal temperature setting when the wax first melts. The temperature of the wax will become stable when the entire mass of wax is molten. When it reaches this point, the wax injector is capable of a nearly stable temperature within plus or minus 2° F. for extended periods of time.

You may have difficulty with the first few wax patterns, but after as you become more experience at powdering the rubber mold and applying the correct amount of wax pressure, no further difficulty should be encountered. Wax pattern sizes ranging from very small parts to large parts and are within the scope of this wax Injector.

WAX WIRE EXTRUDER

With the wax extruder shown, you can make your own wire forms. The wax extruding dies can be made just about any shape, so the wire shapes extruded can be limitless.

USING THE EXTRUDER

The extrusion of the bulk wax into the various wire shapes is a relatively simple operation. Having charged the extruder with a length of bulk wax, select the die and assemble the extruder. Using a Propane torch, and heat the extruder over its full length by rotating it over the flame for sufficient time between each heating to allow the heat to penetrate the entire mass. This is a point just below the temperature where the extruder becomes uncomfortable to hold, and then the wax can be extruded. Point the extruded wax toward the floor to permit gravity to straighten the wax wire. The beginning length of extruded wire will tend to curl. When a sufficient length has been extruded the weight will straighten the remainder. Permit the extruded wax to form a large coil, on the floor, allow time for the wax to harden, and then cut it into desired lengths.

The temperature required for wax extrusions is a matter of trial and error. After a few tries you

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will be able to extrude without difficulty. The extruder can also be used to fill the molds.

INJECTING THE WAX

When the thermostat of the wax Injector has been stabilized to give 160°F wax temperature, it need only be switched on to again attain this temperature. Normally, the attainment of the proper temperature takes about one-half to three-quarters of an hour. If the wax that is too low in temperature will freeze before the rubber mold cavity is completely filled. Wax, which is too high in temperature, will result in undue shrinkage of the wax pattern.

Place the rubber mold between two metal plates. Place the sprue opening over the wax discharge nozzle of the wax Injector. Next apply pressure to the piston rod with the finger. A gentle pressure is sufficient to force molten wax into the rubber mold cavity, and when full remove the finger pressure and lift the rubber mold away. While still applying pressure with the fingers to the metal plates, turn the rubber mold so the sprue opening face up. Hold the mold under pressure for about one to two minutes to permit the wax to solidify and do not relieve the pressure from the mold as this will tend to increase the size of the cavity and result in a malformed wax pattern.

Now part the mold carefully, starting from the sprue end, be careful, as the parting should be done slowly to permit the rubber to flow or to have time to release from the undercuts.

If the casting is pitted, this is the result of either dirty or unclean metal or not enough burnout, and an incomplete casting may be the result of not enough heat to completely melt the metal or not enough amount of air pressure to quickly force the metal into the cavity.

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BRONZE CASTING

This begins with making a clay core roughly approximating the desired form. Wax is rolled out on a board and parts are cut off with a knife, applied to the core, and modeled with the fingers.

New wax that is added is joined by applying a heated knife.

Forms are modeled with wood spatulas and after wax runners and a pouring cup are formed, the completed model is covered with a very smooth clay coating. The model is dried and another layer of clay is added. Bands of thin sheet iron are tied around the mold for reinforcement and then the bands are enclosed by additional layers of clay.

The dry mold is placed (if size permits) in a kiln, or if too big over a hole in the ground, with the pouring cup down. If in the hole, a fire is made over the mold and the wax is allowed to run out into the earth. The wax-free mold is removed from the pit and rubbed with wet earth to seal possible cracks. It is then returned to the hole, again with the opening down, and heated with a slow fire to insure complete penetration of the heat in preparation for casting.

Also, the metal for the casting is placed in a crucible and heated in a charcoal forge fire. When mold and metal are judged ready for pouring, the mold is removed from the fire with tongs and stood upright in soft earth. The crucible is removed from the forge fire with tongs, and the metal is poured until the mold is filled. Any remains of metal in the crucible are poured off on the earth and salvaged for future casting.

After a short cooling period, the molds are placed on their side. When trying to shake out the casting, the mold is sprinkled with water, which also helps to cool. If the outer layers up to the metal bands are removed by knocking them off with a hammer and then the bands are pried off. The rest of the mold is removed carefully, until the softer, black inner layer is reached. The final mold remains are scraped away with an old saw blade. The spruces are cut away, any fins are filed off, and the surface is chiseled, chased, and polished.

PLASTER MOLDS (See Plaster Castings)

The finished model, made in wax, is ready for casting. It must then be spruced with wax tubes or rods no smaller in diameter than $\frac{1}{4}$ inch, in vertical channels that in the mold will become the openings or runners through which the molten metal will flow. The runners lead to all the necessary points in the mold cavity that are going to receive the metal, especially to the heavier parts of the model and the extremes. All runners join and meet above the model. A cup or pouring basin is formed in wax to help in the later pouring of the metal, and a few risers are also made in wax.

This is tubes not connected with the runners, starting from the model, they lead from the heaviest sections of the model and generally join before appearing at one or two points

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above the model at one or both sides of the sprue cup. On the finished mold they are level with the sprue cup at the top. The risers are meant to carry off the air and gases from the hollow of the mold when the molten metal is poured. At any points that they are needed, additional wax balls are added to the risers to provide an extra reservoir of metal that may be drawn into the casting as it shrinks on cooling. Without these wax balls, on large castings cavities might form on the surface of the casting.

While pouring the metal, it first appears at the openings at the top of the mold that are the outlets of the risers. When this occurs, it will just be before the metal fills the sprue cup and is a sign that the metal has filled the mold cavity and that the pouring is nearly completed. Vents are also made leading from heavier parts and joining the risers where necessary. The whole assembly the pouring basin, spruces, runners, vents, and risers are called the gate assembly.

MAKING THE MOLD

There are several ways to make a mold. You can start by spreading a thick layer (four to six inches) of plaster on a board large enough to accommodate the model and a wall of plaster about four inches thick that will be built up around it. The luto plaster for this wall is made by mixing two parts of new plaster of Paris with one part of used plaster ground up coarsely from old molds.

The two plasters are combined and added slowly into a pan containing the necessary amount of water when the mixture is stirred with the hand, breaking up lumps, till it thickens into a slurry. With handfuls of thick slurry, the wall is slowly built up; making sure that the space that it surrounds is large enough to accommodate the wax model with its gate assembly that is to be placed later. You may have to wait to allow the lower parts to harden depending upon the height of the walls so the upper levels can be supported. The wall is built to the height of the sprue cup and riser ends.

A finer mixture of plaster of Paris (two parts), silica (one and a half parts), and water is now prepared after the second layer is added. This mixture is finer because it is intended to create an accurate copy of the surface texture of the model. The plaster acts as a binder medium for the silica, which by itself would not stay suspended or set. Just before the mixture is poured, the completed model is placed into the center of the walled plaster enclosure and held in place. The plaster is then poured over the model being careful to avoid doing it any damage. Enough plaster should be made to fill the wall to the sprue cup (or top) in one pouring as joining of hardened plaster and new added plaster might become actual cracks on the metal surface. You also can pour the necessary plaster into the wail and then slowly immerse the model till it reaches the bottom. Whatever method used, the model is held erect for three or four minutes till the plaster sets enough for it to remain in place without support.

After setting completely, the complete outside the mold is then wound with steel wire. The wire, wound from top to bottom in one continuous length, serves to reinforce the mold, If the castings are heavy, Iron pipe is joined for reinforcement to the outside of the mold and covered with plaster. Additional rough plaster slurry is added in handfuls, with a backhand

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flipping motion, over the entire mold, covering the wire. While it is still in a semi soft state, it is smoothed with the palm of the hand to its final, smooth shape.

On large models, they are sometimes made without the Initial thick coating of the board with a layer of plaster. The wax model sets on the board directly, and it is then turned upside down and additional wax spruces and runners are added to what will be below the model to insure the filling of the bottom of the mold. The wall is extended and plaster added to enclose the added spruces, and an opening is left at the bottom. This type of mold has two openings, and is placed upright in the burnout kiln when the wax is drained.

This is done to insure complete drainage of the wax on large pieces. After the burnout is completed, this bottom opening is plugged with a mixture of clay and sand, so that only the sprue cup opening at the top remains.

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PREPARING THE INVESTMENT

When weighing waxes, remember that some waxes are denser than others, and it is therefore better to allow one quarter to one-half pennyweight of extra metal to compensate for the difference. A little extra metal can always be used in the next casting: also it gives the extra push, in casting, to fill the mold.

The proportion of water and cristobalite powder is 2.2 parts of cristobalite to one part water. This is a good sample ratio, depending on flask capacity.

Cristobalite (cup)	Water (cc.)
1/3	25
2/3	50
1 ½	110
3 ½	255

Water drawn from the faucet should work OK, but RO water would be better. It is left to stand one hour some air will dissipate, and the temperature will stabilize at the acceptable range of 70 - 80° F. If the water is cold, it will hold back the setting time of the investment and warmer water will accelerate it. The investment material also should be within this temperature range. The setting time is roughly eight to fifteen minutes depending on the mixture.

MIXING THE INVESTMENT

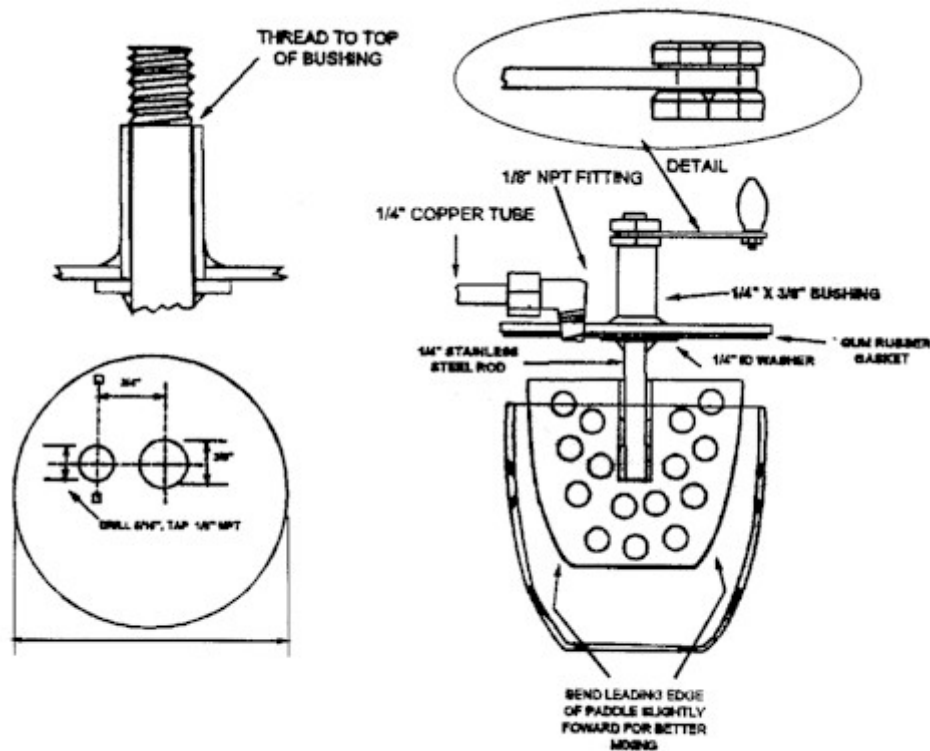
Small amounts can be mixed in a small rubber-mixing bowl, and large bowls will accommodate mixtures intended for large-flask capacity. More investment material should be mixed than necessary, to make sure there is enough to fill the flask completely. The water is measured and placed in the bowl, and the measured amount of cristobalite is added gradually while the mixture is stirred with the spatula or large spoon. The investment material mixes easily and smoothly, without lumps, into a creamy slurry; this should be spatulated for one to four minutes. Further removal of air bubbles is done by placing and holding down the rubber-mixing bowl, with its contents, on the vibrator.

VIBRATOR

This is an electrically operated machine that can be regulated to variable speeds. It has a platform that vibrates, and air bubbles rise to the surface of the slurry, where they can easily

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be broken with the spatula. After this treatment, the Investment Is ready to be used for application with a brush or to be poured.



VACUUM MIXING BOWL

An otherwise good casting is often made unusable because air bubbles are present in the investment when the wax pattern is invested. When this happens, small globules appear on the surface of the casting. Though these can be removed, sometimes, they normally detract from the detail of the piece and make finishing difficult.

Various methods have been used to eliminate bubbles, including "debubblers." These are essentially detergents that lower the surface tension of the mixture and allow air to escape more easily.

Vibrators have also been used to "shake" the bubbles loose. But, by far, the most satisfactory method of eliminating bubbles is by mixing the Investment in a vacuum. The problem is to obtain a vacuum in a suitable container while still being able to stir the mixture inside.

By lowering the pressure in a closed container to approximately 24 to 28 inches of vacuum and mixing the investment in this medium a bubble free mixture can be obtained. In order to attain the vacuum, one does not necessarily need an expensive vacuum pump. Most supply houses carry hydro aspirators, which will produce the necessary vacuum from normal city water pressure of 30 pounds or more.

An automotive air conditioner pump can be used also to produce a vacuum. An aspirator of

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this type can be obtained with adapters for direct attachment to a utility sink faucet.

With the aspirator illustrated the necessary vacuum can be attained in 20 to 30 seconds provided the container is well sealed and of moderate size. For the casting of rings and other jewelry mountings, a container or mixing bowl with a capacity of one to two cupfuls will be ample. The container should be sufficiently rigid to withstand the exterior atmospheric pressure, and should be a nonoxidizing metal or plastic. The vacuum mixer illustrated was made from a plastic bowl purchased at local store.

Use the recommendations of the manufacturers about the ratio of water to investment powder for the most efficient results. If the proportion of water is increased, the investment slurry becomes thin and weak; it may separate on standing and become porous on setting, thus producing a rough surface in the casting. Water separation due to the settling of particles will not occur if the time between pouring the investment and setting is kept as short as possible. If globules of dry powder remain because of incomplete mixture they will show up later as bubbles with dents in them. Humidity is a factor that can affect the water-investment ratio, but if the investment container, once opened, is stored tightly closed in a dry place, this problem is minimal under normal conditions.

ASBESTOS FLASK LINER

Reducing the surface tension on the wax pattern and sprue, a debubbler must be painted over all surfaces. Commercial debubblers are available from supply houses. Equal parts of tincture of green soap and hydrogen peroxide make a very good debubbler. Flow on an ample coat of debubbler, making sure it wets all corners and undercuts, and then set the spruced pattern aside and permit the debubbler to dry thoroughly.

As the debubbler dries, the flask can be prepared by measuring its circumference with a string and allowing 1/8 inch extra. When the debubbler has dried, rinse the pattern in a beaker of clean water. Observe the pattern to be sure the water wets all surfaces. If the water for small globules on the surface of the pattern, repeat the debubbling procedure. Again permit the pattern to dry thoroughly, rinse, and inspect. If most of the debubbler is not rinsed from the pattern, a heavy oxide will result on the finished casting.

This added measurement allows for the 1/16-inch thick sheet asbestos used as a liner in the flask. The height or width of the asbestos should be one-half inch less than the height of the flask, allowing one-quarter inch shortness at top and bottom. The liner acts as a cushion on to the expansion of the investment material during burnout and casting.

During heating the investment expands twice as much as the flask metal, and the asbestos, which compresses easily, takes up this extra expansion. Dipping the asbestos liner once quickly into water will allow it to be pressed tightly against the inner flask wall. Also the small amount of water prevents it from absorbing too much of the moisture in the investment mixture when this is poured.

CASTING METAL PARTS

APPLYING THE INVESTMENT, POURING

Several flasks can be prepared for the various patterns that may be cast. The flasks can be made from either brass or stainless steel tubing. Cut several tubes varying about $\frac{1}{4}$ inch in height. A good supply of flasks would range from $1\frac{1}{2}$ to 3 inches in height. The diameter of the flasks should vary according to the size of the castings to be made.

After the debubbler has been applied and is dry, the investment is applied with a small soft brush to precoat all parts of the wax model that has already been mounted on the sprue former. Select a flask at least $\frac{1}{4}$ to $\frac{1}{2}$ inch larger in diameter than the overall width of the wax pattern. The flask should be from $\frac{3}{16}$ to $\frac{5}{16}$ inch higher than the spruced pattern. A sufficient number of investments should cover the pattern to prevent the molten metal from breaking through the bottom when the metal is cast. This thickness should not be so large, as to prevent the free passage of gasses through the bottom of the invested flask.

Cover the model and spruces completely and to avoid trapping air bubbles, if these are allowed to remain, they will become a part of the casting in solid form. Now cut strips of sheet asbestos about $\frac{1}{4}$ inch less than the height of the flask. Form these pieces over the outside the flask to give them curvature. Insert enough pieces into the flask to cover the inside. A small amount of overlapping is OK. The asbestos is needed to absorb expansion of the investment during burnout. The pieces should be centered about the height of the flask.

The exposed areas, both top and bottom, with no asbestos covering, will act as locks to keep the investment within the flask when the flask is removed from the burnout oven and transported to the casting machine. Sufficient investment is applied to make a solid cover over the entire model and spruces, and about twenty minutes is allowed for drying. The model is placed into the flask with the sprue former in contact with a sheet of plate glass. A coil of plasticene can be placed around the outside the flask and pressed into place to cover the joint between the sides of the flask and the sprue former, so that no investment material leaks out after pouring.

APPLYING THE ASBESTOS

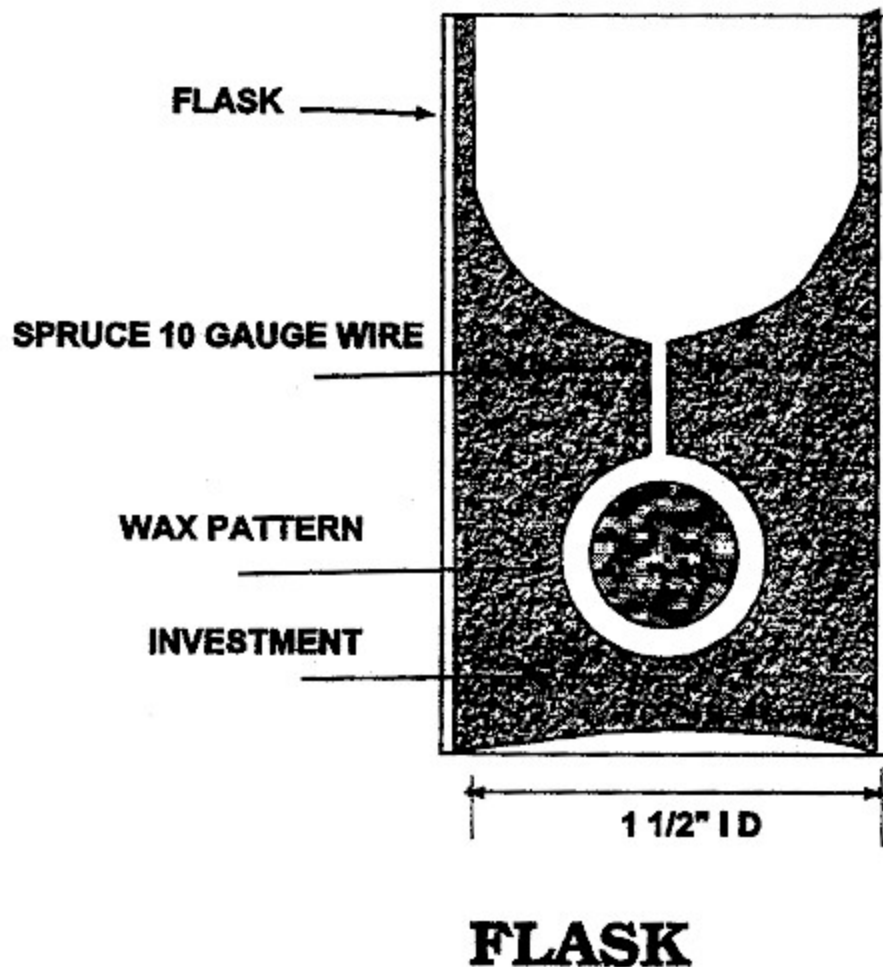
Dip the asbestos-lined flask into a beaker of water. Wetting the asbestos is necessary to prevent excessive absorption of water from the investment. After the flask has been dipped, iron out with the index finger any air bubbles under the asbestos. Set the flask aside and permit any excess water to drain.

Place the asbestos lined flask over the spruced pattern. Center it with relation to the wax pattern. The flask can be held in place with a small quantity of sticky wax around the bottom at the junction of the flask and base.

The supporting flask can then be safely tilted as the investment slurry is poured into the side of the flask. The slurry should be almost level with the top. The tilted position allows the air to escape and not become trapped under the model. The glass is then made level again and

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investment is added to completely fill the flask.



MIXING THE INVESTMENT

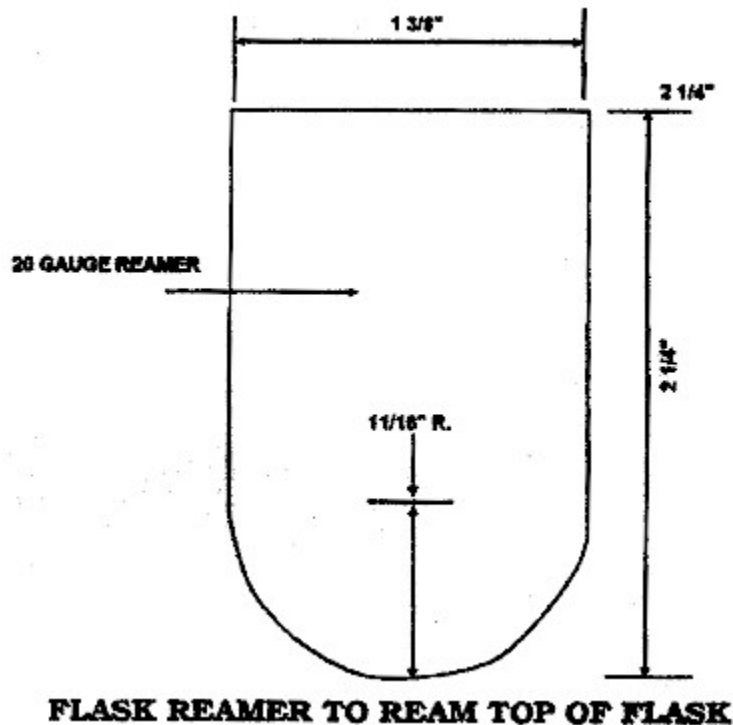
If your flask is 1- $\frac{3}{4}$ inches high and 1- $\frac{1}{2}$ inches in diameter, measure out about one ounce of water at room temperature. Place the water into the mixing bowl. With a spatula, sprinkle the dry investment on the water. Sprinkle on only small amounts of the investment at a time. At first, the water will absorb the investment and it will sink to the bottom. Eventually, the dry investment will begin to build on top of the water.

If the pattern is intricate and detailed, a thin mixture of investment will be needed. If the pattern is bulky, a thicker Investment will be required. Although a thinner Investment will more readily conform to an intricate pattern, it is inherently weaker.

There is no hard-and-fast rule that can be used to determine the consistency. Begin with a consistency about that of a pancake mixture.

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Mix the dry investment by hand to produce a homogeneous mixture. The dry investment will tend to stick to the mixing paddle of the vacuum mixer if not completely mixed and this can result in a non - uniform Investment.



It has been found that about $1 \frac{1}{4}$ ounces of water will produce sufficient investment to fill a casting ring 3 inches high and $1 \frac{5}{8}$ inches in diameter. Using the above ratio as a starting point, a water/investment ratio can be compiled which will result in a minimum of wasted material. If thinner investment is needed for an intricate casting, the pile of dry investment should be small. A heavy casting of simple design may require a thicker mixture.

VIBRATOR

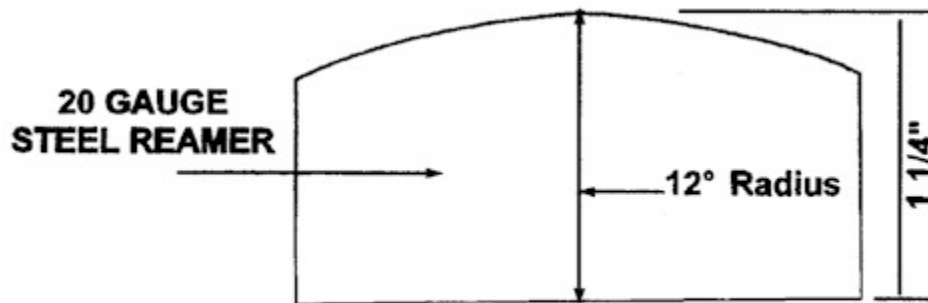
The whole assembly is then placed on the vibrator, which is set to a low cycle to avoid breaking off the model at the sprue opening joint. With the vacuum mixer attached as shown, the hydro aspirator to a spigot. If a vacuum mixer is not available, the hand mixed investment can be vibrated to dislodge air bubbles. The vibrator can be made from a foot massager that can be bought various stores.

The purpose of vacuum mixing or vibrating is to remove all air bubbles captured in the mixed investment. After casting, air bubbles against the pattern will appear as nodules of metal. These can usually be removed with pliers but sometimes they are so firmly attached that an otherwise good casting is ruined.

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VACUUM

If the pattern is extremely intricate, it is often a good idea to paint the investment on with a small brush. In this manner the investment can be flowed into the most intricate cavities. The painting of the pattern is an added safety measure and can be used with either of the two investment methods outlined before. Turn the water on full and press the top cover of the mixer against the bowl to create a vacuum inside. Place a thumb against the top and push upward, trying to raise the top. If the top cannot be raised when reasonable pressure is applied, it is assurance that the vacuum is being made.



REAMER FOR REAMING BOTTOM OF FLASK

On the mixer shown, mix the investment for at least 40-50 turns of the handle. Occasionally tap the bowl assembly against a solid, flat surface to dislodge any dry investment sticking to the sides. When mixing is finished, pull the tube away from the aspirator. Do not simply turn off the water before pulling the tube away as residual vacuum in the bowl will tend to draw water into the mixture.

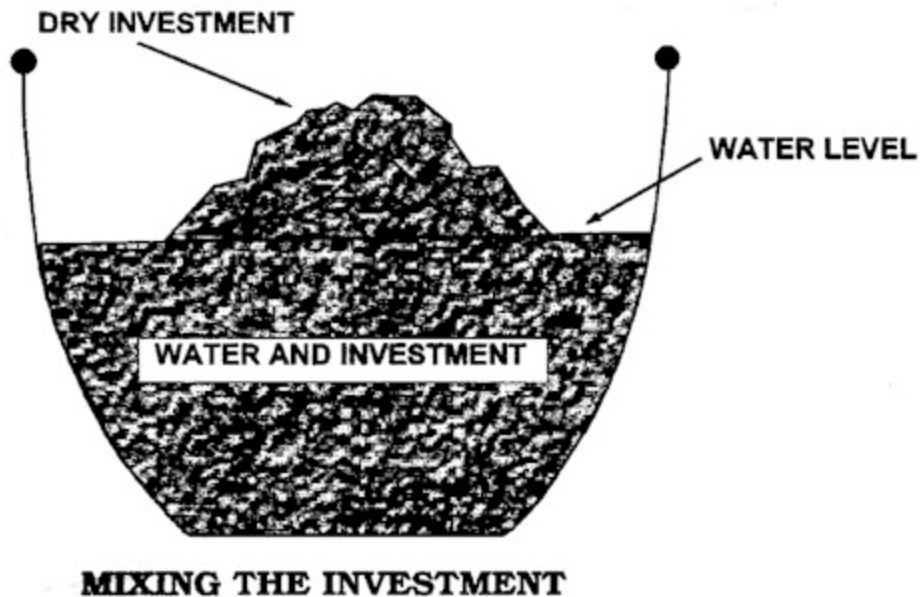
Vibration removes the residual bubbles and packs the investment around the precoated model. If additional investment is needed to bring the level to the top of the flask again, it can be added before the initial set begins. Hold the flask containing the pattern and vibrate the investment into the flask, Note that the thumb of the left hand is in intimate contact with the vibrator. The thumb acts as a dampening device for vibrations sent to the flask and prevents breaking the sprue or wax pattern.

The cup containing the investment is placed directly on the vibrator and tilted forward until a steady stream of investment flows into the flask. When the flask is completely full of investment it should again be vibrated directly on top of the vibrator with the little finger acting as a cushion. This additional vibration is an added safety measure to be sure that no air bubbles have been captured in the investing process. Naturally, if a vibrator is not available, the investment can be poured directly into the flask.

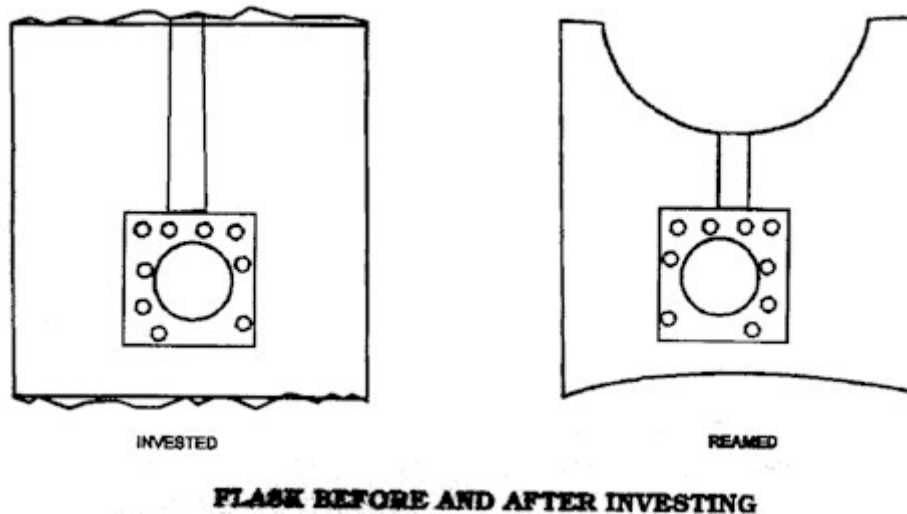
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investment methods outlined before.



Set the Invested flask containing the pattern to one side for about one-half hour, as this is necessary to give the investment sufficient time to absorb any free water. If free water is present when the burnout schedule begins, the water will form steam that will break down or distort the investment.



Remove the bottom plate from the flask with a twisting motion. The point at which the sprue attaches to the bottom plate will normally detach from the plate and be kept in the Investment.

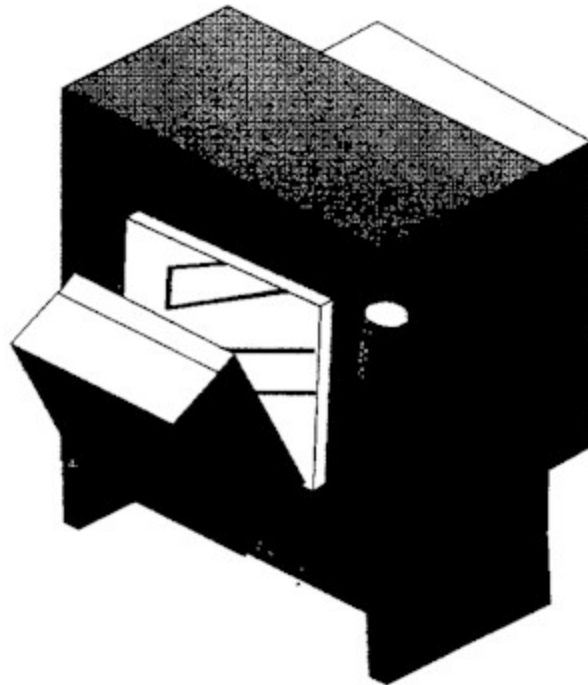
When the investment has set for at least one-half hour, it should be hard to the touch. With a sheet metal reamer about 1/8 inch in diameter smaller than the inside diameter of the flask. Ream a cavity into the Investment. Use the wax sprue wire to guide the center the reamer. Clean off the buildup of investment on the reamer every so often. The reamed cavity will hold

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the casting metal after burnout.

Ream the bottom of the investment in the flask with a tool like that shown in the drawings. The reamer should have a large radius so it will not cut too deeply into the investment. Reaming the top

is necessary to provide a cavity in which to melt the metal. The bottom is reamed to assure that none of the investment projects below the flask so the rim will present a flat surface to the casting machine. The drawing shows the flask before and after reaming.



THE ELECTRIC HEAT TREAT FURNACE

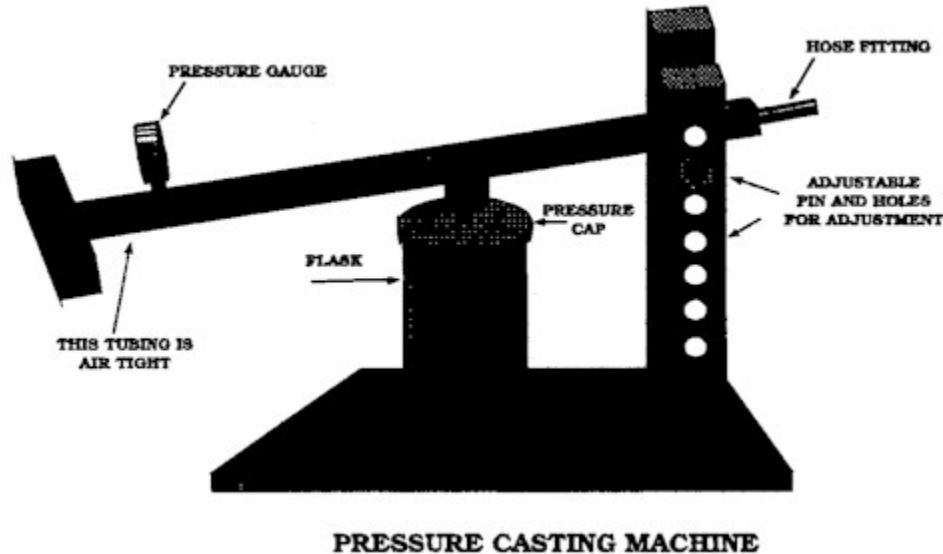
THE BURNOUT KILN

The mold can then be allowed to cure to reduce some of its moisture, or it can be placed directly into the wax-melting kiln. This process is known as the burnout. A specially constructed temporary, oil heated, beehive kiln made of refractory brick covered with clay and topped with corrugated metal covered with still more clay is used. The kiln is built around a group of molds (or one large one) and encloses them completely. The molds are placed upside down, that is, with the sprue cup pointing down (except for those having a bottom opening as mentioned), so that the wax of the model can drain out easily as the kiln is heated and run into a metal trough; this leads it to a pan placed outside the kiln.

The purpose of the burnout is to remove all traces of wax in the mold, to eliminate gradually the chemical moisture in the investment material (which might otherwise cause a porous casting), and to bring the temperature of the investment up to the proper degree to receive

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the molten metal. When doing a burnout, the heat attacks the wax and the investment material, and the outer layer of the wax penetrates the investment pores, aided by steam from the moisture in the investment.



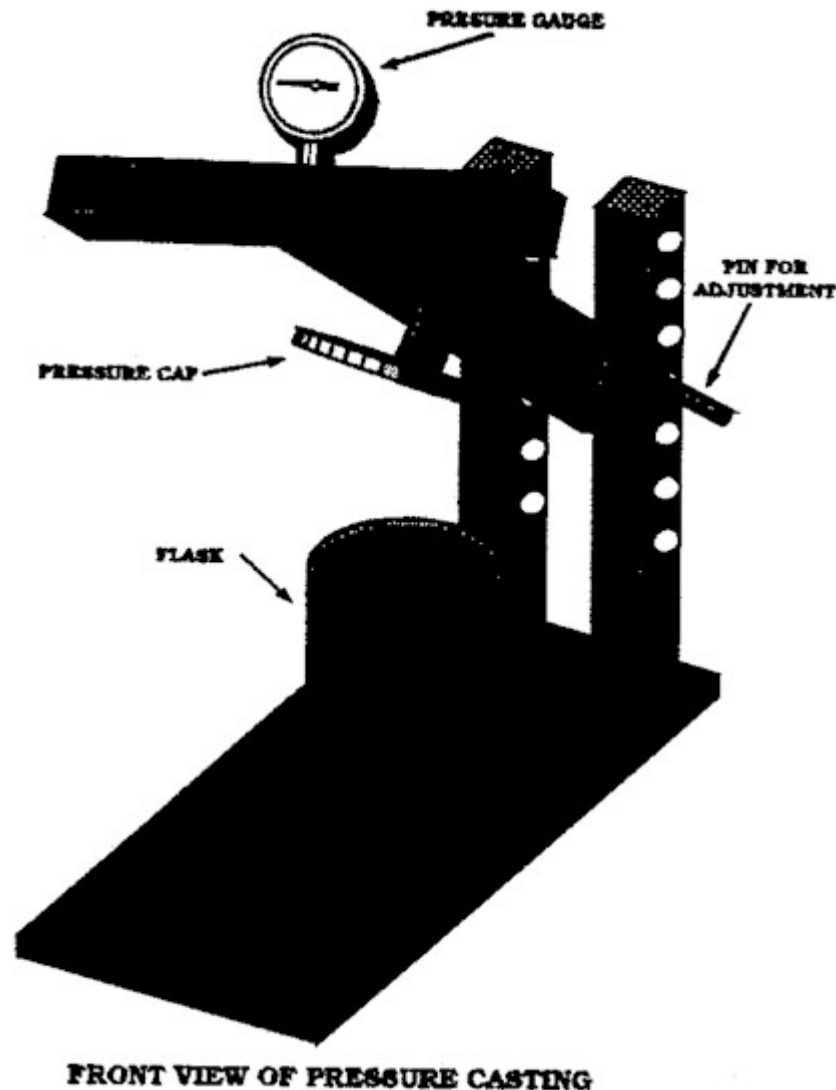
The Ideal burnout condition allows the flask to be heated from the bottom, the wax then drains through the sprue first (the flask has been placed with sprue opening down) and progressively upward, allowing the pattern wax to follow and so reduce the pressure quickly. The best burnout kiln is of the gas-heated muffle type, heated from below and vented to allow gases to escape. Electric burnout kilns with a bottom element are good, but the element should be protected with a refractory shelf to avoid direct contact with the wax.

The wax melts out, sizzles, burns, and smokes all of which affects the longevity of the element. If neither kiln is available, a ceramic or enameling kiln that has heat control is satisfactory. In this case, it might be advisable to reverse the position of the flask after the first hour (during which it has been in the kiln with the sprue opening down), set the flask on a Nichrome wire trivet, and, an hour later, reverse it again. Metal tongs should be used to handle the hot flask, and asbestos gloves worn.

The time for burnout varies with the size of the flask and the amount of pattern wax in the model. Small flasks with delicate models may take only two hours, while larger flasks require from three to six hours and sometimes more.

The color of the Investment is a good Indicator of burnout completion.

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The gathered wax can be used again for gates and risers, but new wax is preferred for model construction. The kiln is heated to about 1000° F till all the wax is either drained or vaporized by burning out. The length of time needed to accomplish this depends on the size and thickness of the mold; small pieces take at least twenty four to forty-eight hours, and large pieces of perhaps seven feet may take up to one week of continuous heating to do the job.

The casting machine must now be set to the correct height. Center the invested flask with respect to the base and the pressure plate. Remove the fulcrum pin and select the correct hole so that the lever arm of the casting machine will be as nearly parallel to the base as possible. Replace the pin.

Press the lever arm down so that the pressure plate firmly contacts the flask. Release the pressure and repeat the pressure application to the flask a number of times. The pressure plate is attached to a swivel and may not completely seat with the first application of

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pressure. The casting machine is now adjusted to receive the first flask.

Place the invested flask into the burnout oven sprue opening down. Close the door of the oven and turn on the switch. Normally, the burnout sequence takes in the neighborhood of one hour.

If your oven is equipped with a pyrometer, it is a simple matter to gradually bring the temperature to 1200°. Hold the temperature at 1200° for a period of 10 to 20 minutes. The initial heating of the flask should be with the sprue hole facing down. As the heat penetrates, the wax will become molten and flow through the sprue hole onto the floor of the oven. When the sprue opening is completely devoid of wax, the flask should be turned over so that the sprue opening is facing up. In this position the gasses from the remaining wax can escape more readily. A completely burned out flask is indicated by the white, clean appearance of the investment or by looking down through the sprue into the cavity for the presence of visible red light (glow).

Once all the wax is “lost,” the oven is partially opened and the molds are allowed to cool to an above room temperature so that they may be handled with gloves. They are then removed from the kiln and brought to the pouring room near the melting furnace. Here they are placed upright that is, with the interior of the furnace contains a crucible with a pouring spout. It is used repeatedly for the same metal till replacement is necessary.

In pouring a large piece, several melting furnaces can be used to make the required amount of metal, which is all poured into one crucible. When the metal is ready, the furnace is opened and the metal is poured at specific temperatures (1950°F for bronze) into the crucible that will contain all the metal needed for filling the mold completely. The mold must be filled in one continuous pouring.

MEASURING THE METAL

During the burnout operation for the wax, the metal for casting can be prepared for small castings. If new or virgin metal is to be used, go on to the next step. If you are using used or otherwise unclean gold or silver, the metal must be cleaned. This can be done by heating small quantities of metal on a charcoal block to the melting point. Flux the metal thoroughly with borax and permit it to cool. Pickle the metal in a sulfuric acid or Sparex solution. The metal used for casting must be absolutely clean or pits will result in the finished casting. A pinch of saltpeter added to the borax will help purify the molten metal.

Before the model wax has been mounted on the sprue former, it must be weighed, with the spruces attached, to arrive at a wax-metal ratio. If sterling silver is used, the wax is weighed and the weight multiplied by 10 to arrive at the weight of metal needed for casting. To this, one-quarter to one-half ounce is added, depending on the size of the button needed for the model. The button is the extra metal that acts as a reservoir from which metal can be drawn during cooling into the cavity of the mold if it is needed. For rings, one-quarter ounce is sufficient, and for larger pieces, add one half ounce.

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Weigh out sufficient metal for the casting as previously described, this will be nine times the weight of the wax pattern for silver, and 14 to 16 times the weight of the wax for gold. If a balance is not available, the amount can be determined volumetrically. Take a beaker with enough water in it to submerge the pattern. Note the height of the Water, and then submerge the pattern and note the point to which the water rises. Remove the pattern. Now add small quantities of metal until the water again rises to the same position it attained when the pattern was submerged. This amount of metal will contain the same volume as the pattern. A tall, thin container will be more accurate than a wide, flat one.

Use the tongs to remove the flask from oven and immediately place it on the base of the casting machine. Be sure the flask is centered with respect to pressure plate. The sprue opening should be facing up. Next place the preweighed metal into the cavity. Immediately begin heating the metal with a torch adjusted to a nonoxidizing flame.

You will notice that when the metal melts, it will form a molten ball in the center of the cavity. Remove the heat at this point.

Now, quickly place a small amount of borax on top of the molten metal. This is done by using a plastic bottle that is half filled with borax. Squeeze the bottle to put a small amount of borax to the metal; a large quantity of borax is not needed. About a $\frac{1}{4}$ teaspoon of borax is sufficient to cleanse the oxides and Impurities from the molten metal. Preheating, applying borax and reheating the metal should be done as quickly as possible to prevent excessive loss of heat from both the metal and the invested flask.

Again apply heat until the metal is completely molten, or when the metal has a shiny, glasslike appearance. Grasp the handle of the lever arm on the pressure-casting machine with your free hand. Remove the torch and apply the pressure plate to the top of the flask. If you are using the pressure-casting machine in the drawing, be sure to place your thumb over the hole in the handle.

Use the foot pump to bring the pressure to approximately five to ten pounds. Hold this pressure for approximately two to three seconds and then bring the pressure to twenty and then to forty pounds. The higher pressure should be maintained for approximately two or three minutes. The initial pressure will force the metal through the sprue opening into the cavity. The higher pressure is necessary to attain a good density in the finished casting and fill all the cavities. Remove both the air pressure and the lever arm pressure from the flask. Permit the flask to cool for about five to ten minutes. At this point the casting operation has been completed.

Plunge the flask into a bucket of water at room temperature. As the water contacts the hot investment, steam will be generated and the investment will disintegrate into the water. Permit the flask to remain submerged until completely cooled.

The casting should have dropped from the flask, but if it hasn't by the time the flask is removed from the water, carefully force the casting from the investment. Sometimes

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investment will adhere to the finished casting.

With a stiff bristled brush and a good laundry soap, scrub the casting thoroughly to remove all traces of investment. Difficult areas can be cleaned with a sharp nail to help remove the investment.

The casting is then pickled to remove the oxide from the metal. The pickling solution can be a 10 percent solution of sulfuric acid in water. The acid-water solution is a little more dangerous, it does a better job.

Always pour the acid into the water to prevent splattering of the solution.

Pickle the casting until all traces of oxide have been removed, remove and rinse and remove the sprue with either a saw or a suitable pair of nippers.

LARGE CASTINGS

On large castings, once all the wax is “lost,” the oven is partially opened and the molds are allowed to cool to an above room temperature so that they may be handled with gloves. They are then removed from the kiln and brought to the pouring room near the melting furnace. They are placed upright that is, with the interior of the furnace contains a crucible with a pouring spout. It is used repeatedly for the same metal till replacement is necessary. In the case of pouring a large piece, several melting furnaces can be used to make the amount of metal needed and then poured into one crucible. When the metal is ready, the furnace is opened and tilted, and the metal is poured at specific temperatures (1950°F for bronze) into the crucible that will contain all the metal needed for filling the mold completely. The mold must be filled in one continuous pouring.

Prior to this time, the metal has been made ready for pouring so that the mold will not cool off too much. Once started, the pour is continued till it slightly overflows the sprue cup. The gases escape from the mold through the risers, and to some extent through the plaster itself. Good ventilation is needed to draw off possibly harmful fumes and gases. Metal should not be poured too hot as an undesirable surface will result, and neither too cold or it will not run properly and if the mold, resulting in an imperfect casting which is then a total loss. There is a leeway of about 150° F in which a pouring can be successfully completed.

The metal is allowed to cool sufficiently for the mold to be handled. The one-piece plaster mold can be used only once. In the shaking out operation, the casting is removed and the mold is destroyed with a hammer and tools.

FINISHING THE CASTING

The waste metal such as runners, risers, is removed with clippers, and hacksaws. Remaining projections are cleaned away with abrasive discs and the waste metal is saved to be used in

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future castings.

The casting can then be cleaned using sand blasting and then an acid bath. Should any cracks or openings have developed in the casting, they can be repaired by welding with a welding rod of metal similar to the metal of the casting.

NOTE - Do not drop or shock the investment material.

This would cause visible cracks in the finished casting and perhaps destroy it. Burnout should not begin too early, for the too rapid evaporation of moisture at elevated temperatures might cause the investment material to expand too fast, crack, or be destroyed completely. Cracks in the investment appear in the casting as “fins” or as finlike metal projections on the surface.

These can be removed, but they might appear in an unexpected location and blemish a design or surface. Splintering of the inner mold surface that is called “spalling,” is another danger in too rapid a burnout at the beginning stages. The splinters, chips, or crumbs that might break away from the inner mold cavity become unwanted objects in the molten metal after it solidifies. Erosion of detail by too rapid wax movement is also possible.

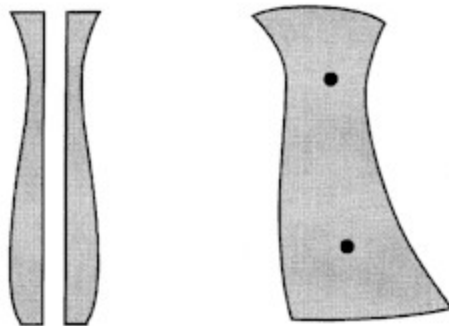
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PLASTER CASTING

If you decide to make a few pistol frames, you will find it much easier to cast the frame, and then finish it to proper size. Machining a frame takes many hours, and a cast frame will serve fine for small calibers.

When you needed special parts for a rifle, knife, etc. you may be able to make them out of brass or aluminum? I have had to restore old rifles; mostly muzzleloaders that had broken trigger guards or butt plates. On making pistol frames, the pattern can be made in two pieces from wood. It would take to much time to machine or file out the needed parts.

When a special part was needed, I found some soft pine and whittled out the pattern that I needed to have. I then got some gypsum plaster and made a mold. The wood pattern was sanded smooth, and a coat of lacquer was put on it to seal the wood.



STEP 1--MAKE THE PATTERN OR USE A ORIGINAL

When the pattern was ready to use, I added a good coat of paste floor wax to it to guarantee it not sticking to the plaster. I poured some fine sand in a box, and smooth it off. The pattern was pressed one half of its thickness into the sand. The patterns and parting surfaces are first sprayed with a suitable parting agent.

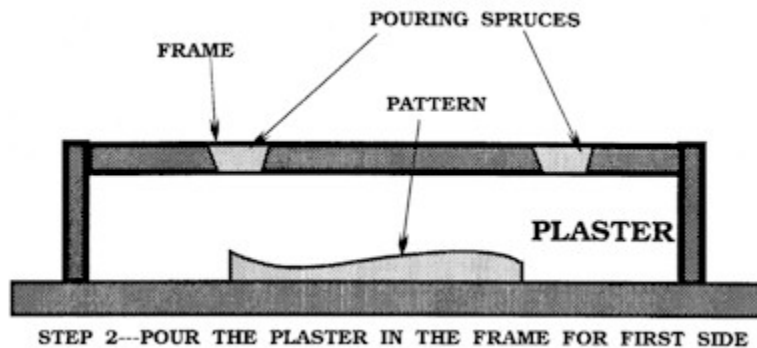
After mixing the powder with about 60 per cent water by weight, the plaster slurry is poured into the flask, or surrounding frame, over the pattern. This should be done carefully to avoid the entrapment of air. Be sure that the pattern is just at $\frac{1}{2}$ of its depth, as if it is too deep, or not deep enough, you will stick it in the mold. The plaster was then poured over the pattern, and in 10 to 30 minutes, the plaster will become hardened. Then the patterns must be carefully removed with lateral rapping.

After it was set up, I removed it from the sand and removed all the sand. I carefully removed the pattern from the mold, taking care that the pattern is not nicked. One method for removing a pattern is to blow compressed air through a small hole that leads to the separation surface between the plaster mold and the pattern. Later during pouring, the hole may serve as a vent for the escape of air.

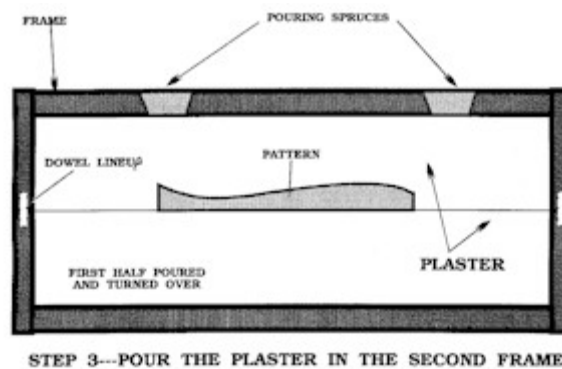
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The mold halves must then be heated in an oven at or about 400 degrees F (this temperature may range from 300 to 1500 degrees F to drive off all free water and convert the gypsum again to CaSo. This may require 20 or more hours.

While the mold halves are still hot from the drying oven, they are quickly assembled, plaster cores are set if required, and the mold is poured. This is done without any delay to minimize the absorption of moisture from the surrounding air. Moisture must be kept at a minimum, because ordinary plaster molds have practically no permeability.



With plaster casting it is possible to produce castings with smoother surfaces and closer dimensional tolerance. Small dimensions on one side of its parting line can be held, if required, to within tolerance of + 0.005 inch. The molds are made of gypsum plaster, and they also contain silica flour, silica sand, and other desired ingredients. Since the patterns must not be affected by water, I usually made them out of metal (Aluminum) when I had several parts to make.



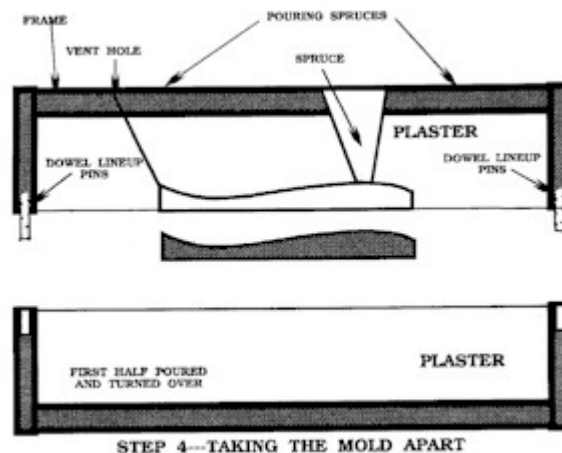
There is a metal casting plaster available, which can be made permeable by whipping or mixing small air bubbles into the slurry with the use of a rapidly rotating, partially submerged disk or blade. Many of the small air bubbles thus formed become interconnected when the mold is dried, providing sufficient permeability. Small castings in nonferrous metals (aluminum, brass, bronze) can be produced in plaster molds with a surface finish as fine as 90 inches to 125 inches. An accuracy as close as 0.005 inches on small dimensions with an additional 0.002 inches per inch on larger dimensions. From 0.005 inches to 0.015 inches

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more is usually required across the parting line. Molds are made of a special plaster.

Cores, for holes and recesses, also can be made of the plaster composition. The sizes of parts usually made in plaster molds ranges from a small fraction of an ounce to 10 lb. The plaster causes slower cooling of the casting than would occur in sand molds. This slowness has a tendency to improve the characteristics of bronze castings, but it is a disadvantage with aluminum, giving properties that are somewhat lower than those with sand or shell mold castings.

The pattern and the piece cost are considerably higher than for sand castings, but this cost is often justifiable because of the better finish and the elimination of machining. Thin wall sections and fine details can be produced.

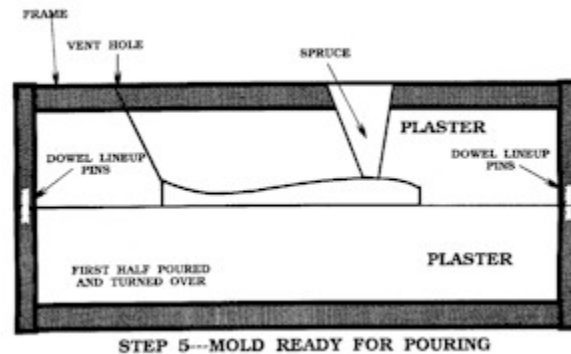


With these permeable plaster molds, it is not necessary to eliminate the chemically combined water from the gypsum, so drying requires less time.

PRESSURE CAST

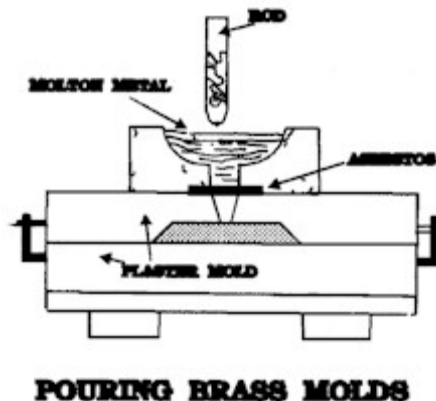
One important application of plaster casting is the making of pressure cast fancy brass handles for pistols or knives, as well as frames for guns. In this particular application, the molten aluminum is first poured into a plaster lined, cylindrical metal receiver above the gate spruce.

CASTING METAL PARTS



A soft asbestos disk about 1/16 inch, thick placed at the bottom prevents the metal from entering the sprue. When the metal is just beginning to solidify, the metal receiver is covered, and compressed air at or about 5 psi is admitted above it. This breaks the asbestos disk and forces the solidifying metal quickly into the mold cavity.

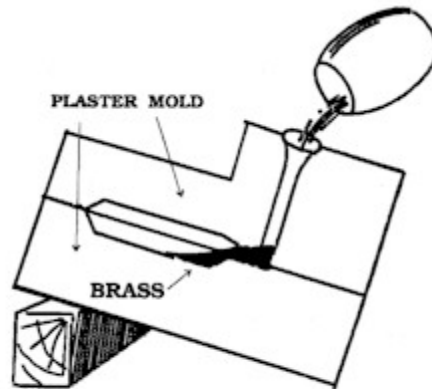
This casting procedure produces smooth surfaces, excellent detail, and a minimum of shrinkage. Because of the limited refractoriness of gypsum, plaster casting is limited to metals with pouring temperatures below 2150 degrees F. Since the heat conductivity of plaster is lower than that of molding sand, solidification of the castings will be slower.



This is accomplished without altering mold-cavity surface smoothness. Additional drying time may be necessary to drive off free water. The use of metal patterns is recommended, especially if more than one part is made. This process is well suited for intricately shaped castings, especially of aluminum, where dimensional accuracy and surface smoothness are the main concern.

A plumber's propane lead metal melting pot can be used to melt most alloys. If higher temperature is required, you will need to make up a forge to melt the metal inches if much casting is needed, a forge will speed up the casting. A split metal pattern is used, mounted on plates and so designed that it can be removed in two halves from the mold. The plaster is poured around this pattern and allowed to harden.

CASTING METAL PARTS



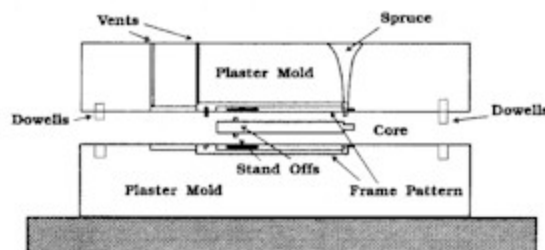
USING BRASS MOLD

Then the pattern is removed, and the two halves of the mold are baked in an oven to harden them further and to dry out all moisture.

The nonferrous metals predominantly used for casting are alloys of copper, brass and bronze. Brass is generally identified by its color, and is said to be either red or yellow; color can serve as an indication of the temperature required for the melt.

FLUXES

When a copper-based metal is melted in a crucible, some of the metal will combine with oxygen to form cuprous oxide. To convert the cuprous oxide back to metallic copper, something has to be added to the melt to draw the oxygen. The one most commonly used for red metal is phosphor-copper: an alloy of copper and phosphorous. Phosphorous has such an affinity for oxygen that it will ignite upon exposure to air; to make it stable enough to use, it is alloyed with copper in the form of "shot." When introduced into the molten metal, the copper melts and releases the phosphorous, which deoxidizes the cuprous oxide in the melt.

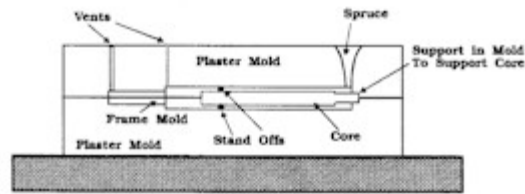


PLASTER MOLD SPLIT SHOWING PATTERNS AND CORE

Oxygen can be carried out of a melt by nitrogen. The nitrogen gas (dry) is introduced through a hollow tube called a lance, which is connected to the gas cylinder by a rubber hose. For red metals, the lance is carbon; for aluminum, it is iron or steel. The tube is inserted into the molten metal to within an inch or so of the bottom of the crucible. A very good deoxidizer for

CASTING METAL PARTS

copper is 5 ounces of black calcium boride powder sealed in a copper tube 2 inches long, with the ends crimped closed. The best flux for melting down extremely fine scrap pieces such as buffing or grindings is plaster of Paris.



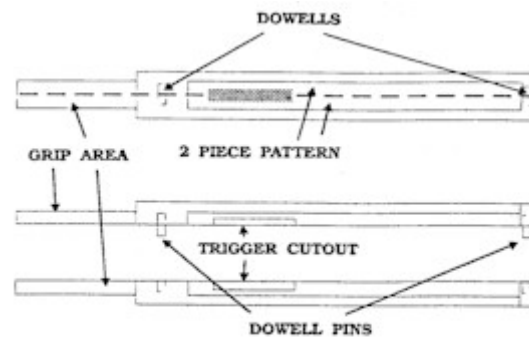
PLASTER MOLD READY FOR CASTING WITH CORE IN PLACE

There is another group of fluxes that are used to prevent the products of combustion in the furnace from coming into contact with the molten metal and oxidizing it. Because they are used as a protective cover, they are called cover fluxes. Such a flux can be made by mixing 5 parts ground marble with 3 parts sharp sand, 1 part borax, 1 part salt and 10 parts charcoal. Another one, Mix equal parts of charcoal and zinc oxide, add enough molasses water to form a thick paste; roll the paste into 2 inch balls and let them dry. When the alloy starts to melt, drop in enough balls to cover the surface.

Some fluxes are very detrimental to refractory linings, often eating away a ring around the inside of a crucible during a single heating. Check with your crucible and flux supplier to find out what is compatible before using a particular flux.

RED BRASS

Leaded red brass can be used with a simple gating system but it must be choked because these alloys flow quite freely. Risers are required for heavy casting sections, and the melt must be fast (under oxidizing temperatures). No cover flux is necessary for these alloys, especially when clean materials are used; deoxidize with 1 ounce of, 15 percent phosphor-copper, for each 100 pounds of melt. Too much deoxidizer will make the metal too fluid, and can result in dirty castings.



TWO PIECE WOOD PATTERN

CASTING METAL PARTS

The average composition of red brass is: 85 percent copper, 5 percent tin, 5 percent zinc, and 5 percent lead; this alloy is commonly called eighty-five and three fives or “ounce metal.” Semi-red brass is handled like red brass. Its composition is normally; 78 percent copper, 2.5 percent tin, 6 percent Lead, and 7 percent zinc. The pouring temperature range for this alloy is 1950 degrees Fahrenheit for very heavy sections, to 2250 degrees Fahrenheit for very thin sections. Generally, 2150 degrees Fahrenheit can be considered as an average pouring temperature.

Using leaded yellow brass necessitates gating similar to that used for red brass, with the exception that the sprue, gates, and runners must be somewhat larger. The mold cavity must be filled as rapidly as possible. If filled too slowly, the zinc in the alloy will produce a “wormy” surface on the casting if melted in an open flame furnace, such as a rotary or reverberatory type, high zinc loss will result. Crucible melting is best for yellow brass. The general pouring temperature is 2050 degrees Fahrenheit. No cover flux is required. The metal should be deoxidized with 2 ounces of aluminum per 100 pounds of melt. (Never use aluminum and phosphor-copper together).

ZINC CONDENSING

To prevent zinc from condensing in the mold cavity, the cause of the surface condition described, tip the mold so the sprue is at the low end of the mold.

The normal composition of yellow brass is 74 percent copper, 2 percent tin, 3.5 percent lead, and 20.5 percent zinc. “High-strength leaded yellow brass (manganese-bronze) is characterized by high shrinkage, and the tendency to form dross (oxides) during pouring, or when agitated. Bottom horn gating is preferred, and large risers and chills must be used. It's a tough metal to cast, and requires considerable experience. It is best melted in crucibles and poured at the highest possible temperature to prevent the excessive production of zinc fumes. High temperatures are also recommended to reduce the risk of flaring flames shooting up from the surface of the molten metal. Yellow brass will flare at about 185 degrees Fahrenheit. Approximately 1% pounds of zinc will be lost for every 100 pounds of alloy melted; this must be replaced.

ALUMINUM ALLOYS

Aluminum alloys are melted and handled much the same as copper based alloys; melt under oxidizing conditions, and gate for progressive solidification with a minimum of turbulence. They have, however, a fairly high rate of shrinkage during solidification; attention must be paid to correct rising to prevent this. It is common to increase the strength of an aluminum casting by as much as 50 to 100 percent by redesigning or relocating the gates and risers. Cores must be low in dry strength and high in permeability. The pouring temperature range is usually between 1250 to 1500 degrees Fahrenheit. Deoxidizing is done with solid fluxes, or by bubbling nitrogen through the molten metal. Aluminum is melted in crucibles, cast iron pots, and in open flame furnaces.

CASTING METAL PARTS

CASTING A PATTERN IN PLASTER

This is a simple method to cast a few small parts in plaster. We will use a simple project like a grip on a revolver as a starting point, but a pistol frame is done the same way. The frame must measure 5 ½" x 3 ½" x 2" high. It is mounted on a piece of glass that has first been rubbed with liquid soap or Vaseline; it is then filled slightly less than half-full with a thick paste of plaster of Paris.

To make the plaster harder, add a pinch of alum or some water glass. Use cold water for mixing, warm plaster hardens too quickly. After the paste has been thoroughly smoothed with a spatula, wait two minutes until the plaster has started to dry. Press the grip, sideways on, halfway into the plaster, having previously coated it thinly with Vaseline or salad oil.

Be careful not to coat the fine detail too thickly, otherwise this detail will be missing from the mold. Make sure the model is pressed in only as far as the halfway marks to get no undercut forms in either half of the mold. Bits of plaster forced up around the edges or into the hollow parts of the model as it is pressed in, must be carefully scraped away with a small knife, after the plaster has hardened.

At the same time as the grip is introduced, a piece of doweling is pressed into the plaster to form a pouring channel leading to the mold. This should run obliquely from the top of the frame to the base of the figure so the mouth of the channel lies as low as possible. A second, thinner piece of doweling should run vertically upwards from the top of the grip.

Later, during casting, air will be able to escape through this outlet. These two pieces of doweling must also be coated with grease so the plaster does not stick to them. Before the plaster has completely dried, make four conical holes in the surface of the half-mold with a blunt pencil.

When these are quite dry, carefully rub them smooth with a pumice stone. The lower half of the mold is now complete. Its surface and the four holes are brushed with graphite or wiped with Vaseline to separate them from the plaster of the upper half. For the latter, we use much thinner plaster that should be poured on gently from the side and allowed to cover the grip slowly and gradually.

Be careful to prevent the smallest air bubble from forming in the plaster. Once the grip is covered with a thin layer of plaster, stop pouring for a moment and then fill the frame to the top. Let the whole thing stand overnight so that the plaster can set properly, remove the surrounding frame, and separate the two halves of the mold, making careful use of a knife blade to remove the pieces of doweling.

It is now clear why we made the four conical holes in the lower half of the mold. The upper half has pegs that fit into these holes and ensure the exact matching of the two halves. After taking out the model, remove any surplus plaster from the mold, clean out the mouths of the

CASTING METAL PARTS

two channels, and develop the upper opening of the pouring channel into a funnel shape.

After a week of drying (we won't use heat on the first one), the mold is ready for use. It is sufficient to smear it lightly with soot before casting and to press both halves firmly together while pouring in the molten metal. The metal is heated, but not overheated, in a cast iron ladle. The mold may break at the first or second casting because of cavities due to small air bubbles just beneath the surface, the walls of which are burst by the hot metal. However, a carefully made mold can give some 20 castings before the edges begin to crumble, rendering the mold unusable.

CASTING METAL PARTS

SAND CASTING

This is the earliest, and still the most commonly used, of all casting processes. It can be used with brass, aluminum, bronze, copper, and magnesium. The pattern cost is low, wood and metal patterns are used.

The piece cost is fairly low, and pieces of almost any size can be cast. Although, it is adapted primarily too small or medium quantity production sand casting.

The principal advantages of sand casting are low cost of pattern and low piece cost also, intricate pieces with elaborate interior cavities can be made with sand cores.

The chief disadvantages are the rough surface and the low accuracy of the castings. These disadvantages often involve expensive finishing and machining operations that might be eliminated by some of the other casting processes.

The following description for making a mold is given so the beginner will have first hand information on how molding is done. Even in small shops with simple equipment, small castings can be made from the softer metals, since these metals can be melted in the average shop. The processes encountered are duplicates of the methods applied in the regular foundry. Any person would show extreme interest in making a mold, pouring it with molten metal, and finally viewing his first casting.

The pattern is made of wood or metal in the form of the piece desired. Allowance must be made in the dimensions for the shrinkage of the metal, but this step usually is done by the pattern maker, the drawings showing the dimensions of the desired casting.

For beginners, the soft metals may be used for pouring. They can be melted in a forge, a gas furnace, or with a gasoline torch. Lead is easily melted and it pours a mold readily. Lead, however, will not give a sharp casting since it shrinks greatly at the time of setting. Type metal makes splendid castings, since it expands to give sharp impressions.

Aluminum offers opportunity for an easy melting metal. It alloys readily with tin, antimony, zinc, and, under proper circumstances, lead. An alloy of 95 parts aluminum and 5 parts zinc is easily melted and can be used to make small castings.

Metallic molds offer opportunity to pour castings without making molds of sand. Lead usually is used to pour such molds, to make toys, fishing sinkers, and many other small castings.

Usually the pattern and the mold are made in two parts to allow for removal of the pattern from the mold, which is made of a special mixture of moist sand and clay. It is packed firmly around the pattern in a wood or metal box called a flask. The upper mold is called the cope, the lower, and the drag. For more accurate work, the two halves of the pattern may be, mounted on match plates, which provide for exact alignment of the two halves. In this case,

CASTING METAL PARTS

the pattern and the plates usually are made of metal.

The mold material may be moist “green” sand, or may be held together by a binder and dried or baked (dry sand). Dry-sand molds cost more, but they give a better finish, sharper detail, and greater accuracy. Holes or cavities are formed by cores that are molded separately of special sand mixed with a binder and baked for added strength, and are located in recesses in the mold before the metal is poured.

One or more openings, called gates, are provided into which the metal is poured. Sometimes additional passages, called risers, are required to let the metal flow properly to all parts of the mold.

The excess metals that harden in these gates and risers are called spruces. The location of the gates and the risers is usually determined by the foundry. Proper design at this stage contributes materially to the soundness of the final casting.

Since tolerances in sand castings have to be very large, any surfaces requiring a smooth finish or a close fit require machining. Usually 1/8 inch to 1/4 in, excess material is allowed, to be removed by the machine operations. If too little is allowed, the cutting tools wear very fast, because of abrasive particles in the surface layer of the casting.

Sand molding is done by the green sand and dry sand processes and may be classified as:

(1) Bench molding,

(2) Machine molding.

Bench molding is for small work done on the bench, floor molding is done when castings become too large to handle on a bench. The work is done on the foundry floor.

Machine molding is done on machines that are capable of performing a large part of all molding that is done in the foundry today. The machine replaces many hand operations such as ramming the sand in the mold, rolling the mold over, lifting and drawing the pattern from the mold, and other operations.

Bench and machine molding will be the two types of molding described in detail in this text.

TOOLS

Shovel or trowel, screen, draw screw, rapping bar, bellows, bulb and brush, rammer, gate cutter, sprue pin, slicks and lifters, flask, moldboards, bottom boards, pattern, furnace, meting pot, and ladle materials. Molding sand, parting sand, water, and metal.

CASTING METAL PARTS

MAKING A MOLD OF A ONE PIECE PATTERN

The first step in making a mold on the bench is to place the pattern with the parting surface downward on the molding board. Tempering the sand means to add moisture so it will pack.

Sprinkle the sand uniformly with water, and thoroughly mix with a shovel or trowel. Test for the proper moisture content as follows:

Make a lump of sand by squeezing a handful together in the hand. Break the lump into parts with the fingers, and if the edges at the breaks are firm and sharp, the sand is ready for use.

The pattern is checked to see that the draft is pointing upward so, when the flask is turned, the pattern may be removed without breaking the mold.

The drag half of the flask is placed on the molding board with the pins pointing downward. Place the pattern centrally on the moldboard with the largest dimensions down.

A pattern must have draft (be tapered) so it can be withdrawn from the sand.

SET UP THE DRAG

The drag is the half of the flask that is used for the bottom half of the mold. Select either half of the flask for this purpose. In either case, place the drag down on the moldboard and over the pattern with the pins or the sockets down.

Parting compound is dusted over the pattern and molding board. Riddle (screen) the sand into the drag to cover the pattern about 1 inch. Fine facing sand is riddled to a depth of about 1 inch over the pattern.

Pack the sand around the edges of the pattern, using the fingers to press it firmly in place. Take special care to pack the sand next to the moldboard and pattern. Then fill the drag-heaping full of unriddled sand and start ramming. Peen ram around the sides of the drag first and then over the entire surface. Fill the drag-heaping full of sand again, and use the butt ram to pack the sand down over the entire surface. Finally, with a straightedge, strike off the excess sand to make it level with the edges of the drag.

The flask is filled level full with unriddled, tempered sand from the bin or floor. The sand is peen rammed around the outer edge of the pattern and the inside edge of the flask.

After peen ramming is completed, the flask is filled heaping with sand. Correct ramming is important if sand packed too hard will have insufficient openings to permit steam and gases to escape.

CASTING METAL PARTS

The surplus sand is removed. The sand is leveled even with the top of the flask using a strike-off bar.

Loose sand of about $\frac{1}{4}$ - inch is placed on top of the flask to form a bed for the bottom board. Venting should be next. Venting allows the gases generated by hot metal to escape from the mold so they cannot cause damage. For making small castings of soft metal, venting is unnecessary. Regular venting for large castings is accomplished as follows: Use a wire $\frac{1}{16}$ inches inch diameter, and punch holes in the sand directly above the pattern. A knitting needle also serves well for this purpose. Space the vent holes about 1 inch apart, and make them reach to within about $\frac{1}{2}$ inches of the pattern.

The bottom board is then placed on the sand and rubbed firm to the bed.

Next, the mold is turned over so the cope may be placed in position.

Throw a thin layer of fine, loose sand over the level sand surface of the drag.

Lay or the bottom board and rub it back and forth so it rests solidly on the drag.

The molding board is removed and the surface of the mold around the pattern is smoothed with a trowel. Hold the drag firmly between the moldboard and the bottom board, and turn the drag over so the bottom board will rest on the bench. Try to keep the boards from slipping as the drag is turned over. Remove the moldboard, and slick down any rough sand on the surface with a trowel. A smooth surface will make a good parting.

Blow off any loose sand with the bellows. Dust the pattern and the surface of the sand with a layer of parting sand. This is easily dusted on through a cotton bag. Blow off all excess parting sand from the pattern.

The cope part of the flask is placed in position with the pins on either side holding it. Place the cope on the drag, seating the pins firmly in the sockets. Test to see if the cope slides up and down readily. Never oil or wax to aid sliding.

To provide a place for the molten metal to enter the mold, a sprue pin is placed as close to the pattern as practical. Then a riser is placed in the drag near the heaviest section of the pattern front about the same distance as the spruce pinches

The surface of the pattern and of the sand surrounding covered with a fine coating of parting compound.

The parting prevents the tempered sand from sticking to the pattern when the cope is rammed and will also enable the cope to be lifted from the drag without the two sticking together.

CASTING METAL PARTS

Next sand is riddled over the pattern and the cope is filled with sand from the benches. The sand is rammed and the excess sand is removed with the strike off bar. To insure the escape of gases when the molten metal is poured, small vent holes are made through the sand to within $\frac{1}{2}$ to $\frac{1}{4}$ inch of the pattern.

The sprue pin, which should be slightly longer than the depth of the cope, makes the hole in the sand through which the molten metal is poured. Set the pin into the molding sand of the drag about $\frac{1}{4}$ inches to hold it upright, and at least 1 inch away from the pattern.

Fill and ram the cope as you did the drag above. The sprue and riser pins are removed from the cope. A funnel shaped pouring basin is formed around the sprue opening. Twist or jar the sprue pin, and pull it carefully from the sand. With the forefinger, cut the sprue hole to a funnel shape. Pack the sand firmly around the sprue hole.

The cope half of the mold is carefully lifted off and set to one side. Lift the cope straight up, by taking hold of the guides (pins or sockets) or handles, and carefully lift the cope straight up and free from, the drag. Set the cope on its side, out of the way, so it will not be disturbed or upset.

Before the pattern is withdrawn, the sand is moistened with a water brush (molder's bulb) or swab so the edges will not break off when the pattern is withdrawn. With a rubber bulb swabber, or other device, carefully wet the sand just next to the pattern, being careful not to get it too wet. Wetting will help to hold the sand firmly in place when the pattern is drawn. Turn a draw screw into the pattern. Now, gently rap the draw screw from all sides to loosen the pattern in the sand, and give a slight clearance.

Tap gently with one hand, and lift the pattern straight up, at the same time trying to leave the sand undisturbed. If the sand is cracked or broken while lifting, allow the pattern to settle back into place and repair cracks or breaks by slicking down the sand around the pattern. Finally, lift out the pattern and remove any loose sand.

A draw screw or spike is inserted into the pattern and rapped slightly from all angles, loosening the pattern slightly. The pattern then can be withdrawn by lifting with the draw screw or spike.

Any repair work on the mold can then be done with a trowel or slick. The gate is a channel, cut in the sand, from the pattern to the sprue hole. The gate is cut with a gate cutter, from the mold cavity to the spruce opening.

The cross section area of the gate should be less than that of the sprue to flow clean metal to the hole. Gates can be cut before the pattern is withdrawn.

This channel allows the molten metal to run into the mold. With a gate cutter or other tool, cut the gate about $\frac{1}{4}$ inches deep and $\frac{3}{4}$ inches wide, making it slightly deeper at the sprue hole.

CASTING METAL PARTS

Remove any loose sand.

Then, with bellows or an air hose, all loose sand is blown from the sprue, riser, and the mold cavity. The sprue hole should be entirely open and that the sand surfaces in both the cope and the drag are in good condition. Grasp the cope, as before at the guides, and turn it right side up to allow any loose sand to fall away and not fall on the drag. Now place it on the drag, carefully guiding the sockets and pins together. If the mold is not to be poured immediately, cover the sprue hole to keep out loose sand or dirt.

The cope is replaced on the drag. The mold is ready to receive the molten metal. If the mold is to remain in the original flask for pouring, clamps are useful to hold the parts together or the bottom board. A weight placed on top of the mold will keep the molten metal from lifting the sand in the cope.

POURING THE MOLD

The actual pouring of molten metal into molds is a very important phase of the casting operation. More castings are lost due to faulty pouring than to any other single cause.

NON-FERROUS METALS

In most cases if you do castings of frames, you will probably use aluminum or brass to do so. Nonferrous metals are melted in numerous types of furnaces. The crucible furnace is the most common, and lowest in initial cost.

The furnace is essentially a refractory-lined cylinder with a refractory cover, equipped with a burner and blower for the intense combustion of oil or gas. The metal is melted in a crucible or pot made of clay and graphite, or silica carbide, which is placed in the furnace. When the melting is complete, the furnace is turned off, the furnace cover is opened, and the crucible removed with tongs and placed in a pouring shank. Then the liquid metal is poured into prepared molds.

CASTING METAL PARTS

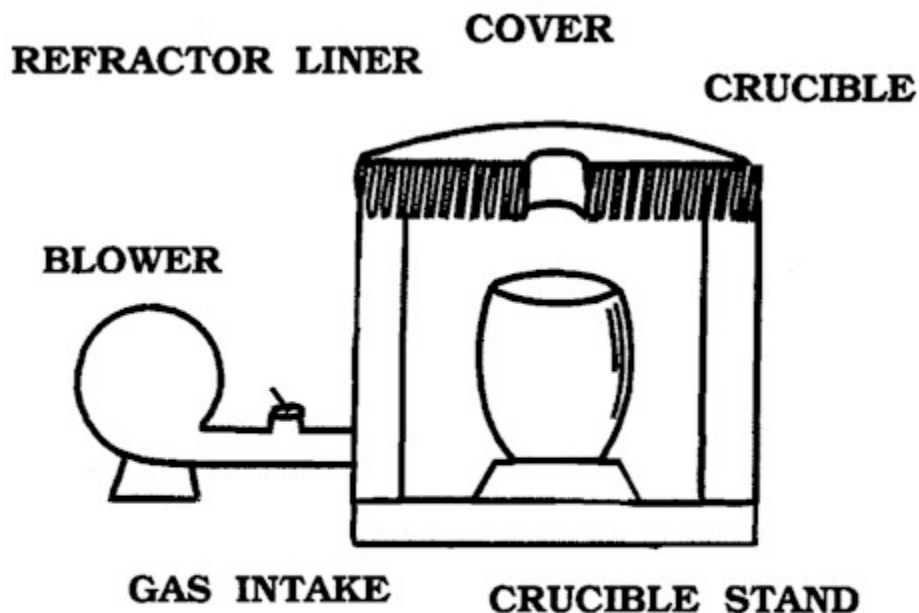
CRUCIBLE

FURNACE CONSTRUCTION

A crucible furnace can be made from an old metal drum, a few pipefittings, the blower from an old vacuum cleaner, and twenty to sixty dollars worth of castable refractory material. The refractory suppliers can also furnish you with complete advice on what to buy for your particular purpose, along with tips and how to handle the material. Crucibles come in sizes from as small as a cup to several hundred pounds.

Homemade melting furnaces are simple to construct, and are easy to build and operate. A furnace for a No. 20 crucible, which has a single pour capacity of 60 pounds for bronze, or 20 pounds for aluminum, would be considered average in size.

By weight, crucibles will hold three times as much bronze as aluminum. Always allow some clearance below the top of the crucible for safety-it is dangerous to melt a brimming pot full.



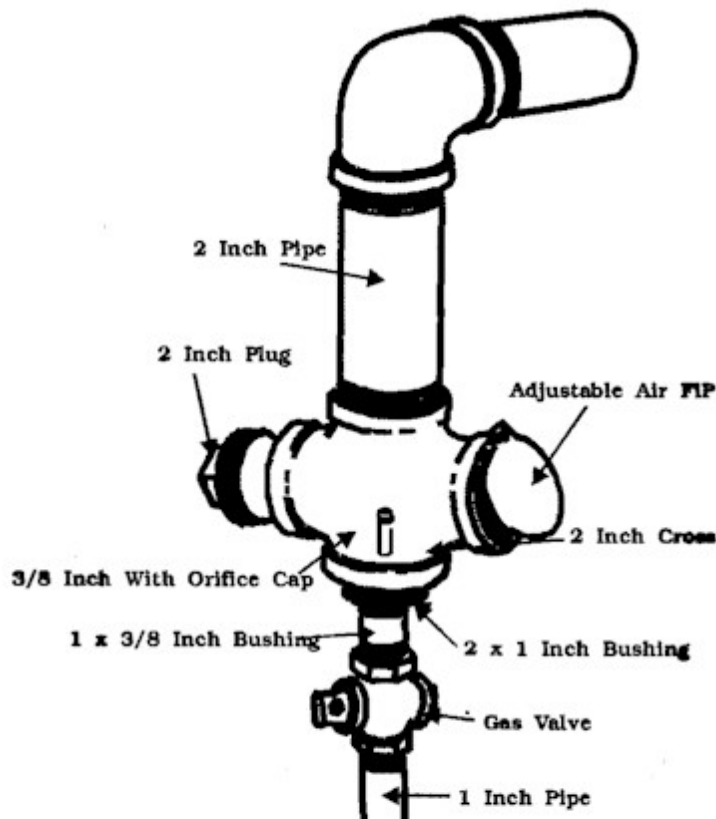
MELTING FURNACE

You have chosen a No. 20 crucible: 10 ½ inches high, 7 13/16 inches across the top and bottom, and 8 ½ inches at its bilge, or widest point (its shape resembles that of a barrel). This crucible requires a base in the form of a truncated cone 6 inches across the top, 7 inches across the bottom and 5 inches high. We have 15 inches of high and 8 inches in diameter to go in the flame.

CASTING METAL PARTS

There must be sufficient distance between the crucible and furnace lining for correct combustion, and for room to fit open tongs around the crucible. Also, enough space between the furnace bottom and the covers is needed for correct combustion and exhaust through the cover opening. A good rule here is to allow 2 ½ to 3 inches of clearance between the furnace wall and the bilge, and 3 inches between the top of the crucible and the cover and above the furnace bottom. The lining should be a minimum of 4 inches thick to insure good insulation.

With this we need a shell for our furnace 22-½ inches (inside diameter) by 22 1/8 inches high, with a cover band 22 ½ inches (inside diameter) by 4 inches in height. A safety hole directly in the front of the furnace, flush with the bottom and 3 inch's square, is needed. Should the crucible break, the metal would run out of the furnace through the hole



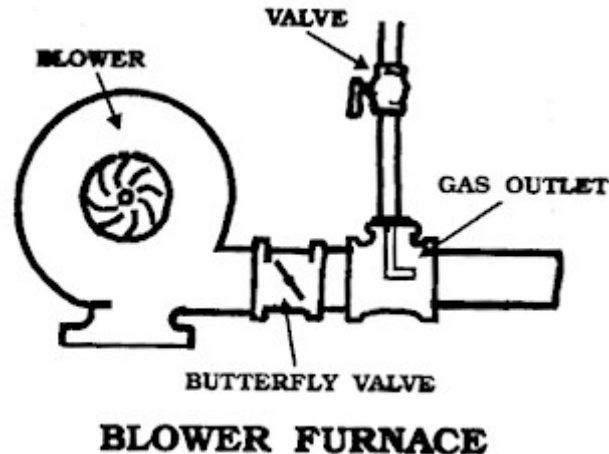
BURNER FOR FURNACE

Without a safety hole, metal could run into the burner pipe, or simply fill up the bottom of the furnace and solidify there, leaving you with a block of metal next to impossible to remove without taking everything apart.

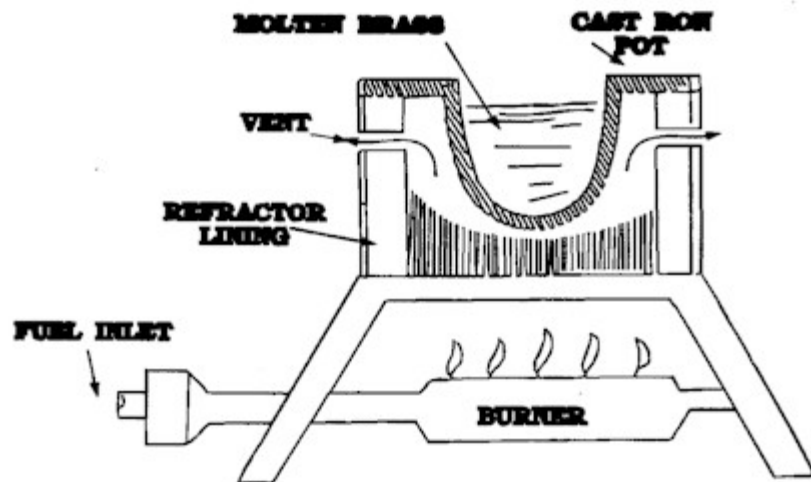
The shell is completed by making a 3-inch hole 6 inches above the bottom of the shell, a third of the shell's circumference away from the safety hole. This is where the burner pipe enters. The burner pipe is brought in 2 inches above the refractory lining of the bottom, and off center

CASTING METAL PARTS

from the diameter of the shell so that the flame coming will circle the space between the crucible and the lining, spiral around the crucible, and out of the vent hole, this gives the highest and most even heat.



The cover consists of a metal band formed into a ring 22 ½ inches in diameter, but tapered slightly; lifting ears must be riveted on directly across from each other on the cover "ring." They should be drilled with holes to clear a ½ inch pipe, which will be used to remove the cover.



GAS BURNER FOR MELTING BRASS

The cover ring is placed on a smooth floor covered with newspaper in preparation for making the exhaust hole.

Within the center of the cover ring, place a 6-inch tin can or jar as a form for the exhaust vent. The castable refractory is now mixed according to the manufacturers directions, tamped firmly in place around the vent form, and leveled off smoothly with the top of the ring, and left

CASTING METAL PARTS

to set overnight.

Now you can to line the furnace body. Place a heavy cardboard sleeve 14 1/2 inches in diameter and long enough to extend slightly above the top of the shell in the center of the furnace, 22 or 23 inches tall should do.

Once the sleeve is centered, fill the inside of the sleeve with dry sand to give it added strength, and hold it in place while tamping in the lining all the way to the top. Two plugs will be needed for the furnace shell while the lining is being installed, one to fit through the safety hole and against the cardboard sleeve, and another to fit the burner port; dimensions for the plugs are given inches

Coat each plug with heavy oil or grease, and fit both into their respective places. Use small wooden wedges to get a snug fit. With both plugs securely in place, start tamping in the lining, making sure the castable refractory is well compressed. Do not place too much material between the sleeve and the shell at a time; doing so will produce spaces. When the top of the shell is reached, trowel and smooth the refractory. The furnace is now complete.

Now we must have a suitable burner and blower, a blower that will deliver 30 cubic -feet of air per minute. A good blower, particularly one from an industrial vacuum cleaner, will deliver enough air at the right pressure.

The simplest type of gas burner can be made easily in the shop. There are many types, and the drawings will give you some ideas. The intake of the blower must be provided with a shutter or damper to regulate air going to the burner.

A butterfly valve will fit within the burner pipe. Whether you decide to control the air in the burner pipe or at the blower intake doesn't matter, but it must be constructed in a manner that provides positive action without moving of its own accord.

The newly lined furnace should be slowly dried by building a wood fire inside and letting the wood burn down to coals. It takes about two days of this treatment to be safe.

For the first heat, put two thicknesses of cardboard on the crucible support block and place the crucible on the cardboard. With the furnace cover off, place the metal charge loosely in the crucible. Do not wedge the metal in; it must have room to expand without restriction. Wedging metal in a crucible can cause it to split.

Now place a wad of burlap material dampened with fuel oil, or charcoal lighting fuel, about a foot from the burner port, in line with the firing direction. The lighter wad should be jammed snugly between the support block and the furnace wall. This will prevent it from being blown out of the furnace or away from the burner. The wad has to remain in place, burning until the furnace wall reaches ignition temperature. Prepare to fire the burner by opening the blower's air control valve halfway. Light the wad and allow it to burn briskly. The blower is started up. Check to see if the wad is still burning briskly. Should it blow out, turn off the blower and start

CASTING METAL PARTS

over. Once you have determined that the lighter wad will burn with the blower on, open the gas valve until you get ignition.

Adjust the gas to the point that produces maximum ignition, the loudest roar in the furnace. At this point, you have maximum combustion for the blower's output. Allow the furnace to run for 5 minutes at this setting. After 5 minutes have elapsed, the furnace wall should be hot enough to maintain combustion. Place the cover on the furnace, and advance gas intake and blower output to the point where the gas is wide open and the air is adjusted for maximum roar. Now advance the blower output slightly. This will give you a slight oxidation in the furnace, the best condition for melting.

During the lighting up and the 5-minute period with the cover off, keep your hand on the gas valve. Should you lose ignition during this period, close the gas valve at once, let the blower run a minute or two to clear the gas - air mixtures, then close down the blower and start over.

Never relight a furnace using a hot wall; always use a lighter wad.

Never light a furnace without the blower delivering at least half its capacity; too low a setting can result in a backfire into the blower. The blower has to be blowing strong enough to overcome backpressure so that the ignition takes place in the furnace. Do not light a furnace with the cover on for the same reason. Should the power fail, and the blower stop, immediately turn off the gas? Never leave a furnace unattended during the melting process. To shut down the furnace, close off the gas first, then the blower.

POURING THE MOLD

The actual pouring of molten metal into molds is a very important phase of the casting operation. More castings are lost due to faulty pouring than to any other single cause. Some basic rules for "gravity casting" a mold poured from a crucible or ladles are:

1. Pour with the lip of the ladle or crucible as close to the pouring basin as possible.
2. Keep the pouring basin full (choked) during the entire pour. Keep
3. Keep the pouring lip clean to avoid dirt or a double stream
4. Use slightly more metal than you think you'll need.
5. Pour on the hot side - more castings are lost by pouring too cold rather than too hot.
6. Once a choke is started, do not reduce the stream of metal.
7. Do not dribble metal into the mold or interrupt the stream of metal.

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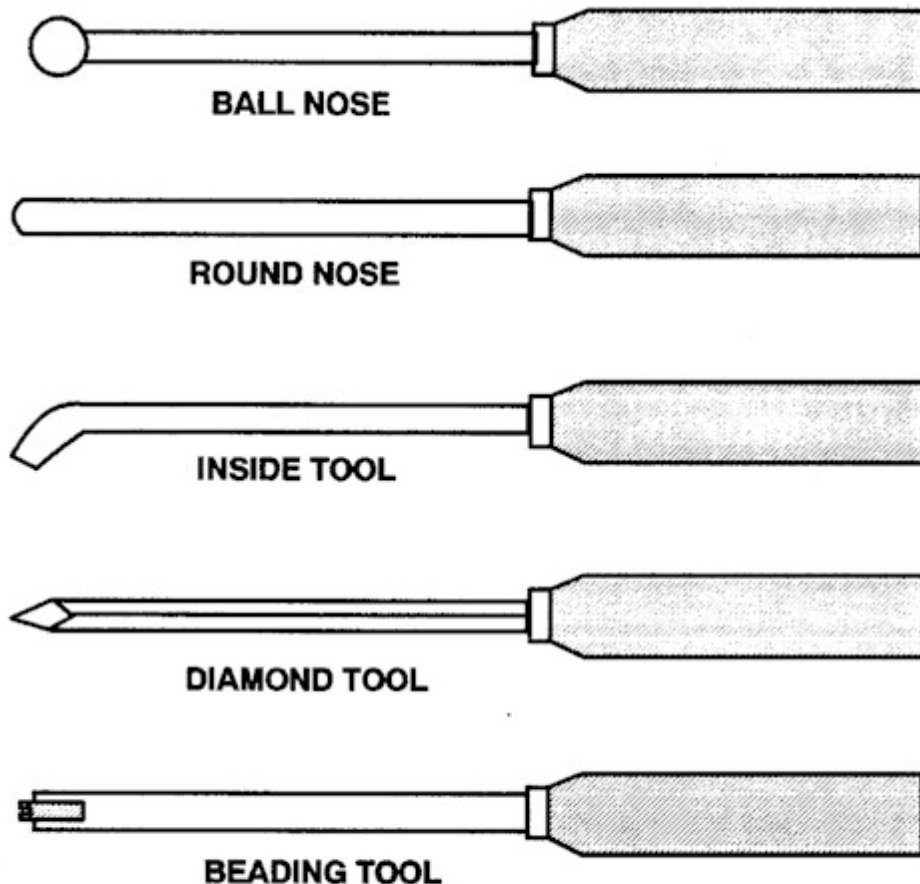
8. If a mold cracks and the metal starts to run out, don't try to save it.
9. If a mold starts to spit metal from the pouring basin or vents, stop pouring.
10. Don't use weak or faulty tongs.
11. Keep the pouring area clean and allow plenty of room for sure footing and maneuvering.
12. Do not pour with weak crucibles.
13. Wear a face shield and leggings.
14. When pouring several molds in a row with a hand shank, start at one end and backup as you go. Going forward to pour brings the knuckles of the hand closest to the ladle over the mold just poured.
15. When pouring several molds from a single ladle or crucible, pour light, thin casting's first (the metal is getting colder by the minute).
16. Don't try to pour too many molds at a single heating.

CASTING METAL PARTS

FORMING METAL

When a metalworker wishes to construct a project having a depressed or a raised surface, from a flat piece, he resorts to the process of raising the metal. Raising is a method of stretching the metal by hammering it in a depression or over a pattern to produce the desired shape. The resulting hammer marks often add to the beauty of all objects formed by raising.

The softer and more ductile metals are used by the craftsman for raising purposes.



METAL SPINNING TOOLS

Ductility means the ability to be drawn out or stretched. Silver, pewter, copper, brass, and aluminum lend themselves well to raising. Sheet iron and steel plate, while not so soft and ductile, may also be shaped by this process. Wood stakes or forms like and, are not difficult to make, the design of the cutout portion can be made almost any shape desired.

EQUIPMENT FOR METAL WORK

The craftsman, whose home workshop includes equipment for woodworking, will not require many additional tools when he begins his work in metal. He will doubtless have a workbench

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or table of the proper height, if not, a heavy, strong kitchen table will answer. A vise is necessary for holding mandrels, stakes for hammering and a bench pin for sawing, and should be at least three inches across the top. An anvil is required for many processes.

Wooden and rawhide-tipped mallets are required in the processes of mold forming metal shapes and for flattening surfaces without marking them. A hand drill with sizes of points for drilling different holes is needed in the process of sawing, and a steel plate, with shaped grooves for forming and stamping shapes and a smooth surface for other types of stampings.

Metal cutting shears with blades shaped or straight or curved cutting are now available. The jeweler's or fret saw frame is the same as that used for inlay and marquetry work in wood but is equipped for metal sawing with blades numbered from No. 1, the finest, to No.5, the coarsest. The difference is in the size of the teeth that are set on a slant as appears in the enlarged sketch of a blade. The Nos. 2 and 3 blades are commonly used for silver and copper sawing.

Hammers for metal work have two faces or ends. The chasing hammer with one flat face and a round or "ball peen" will be needed for many processes. A raising and planishing hammer with oblong and round face and, smoothly polished, and like the ball peen hammer used only for contact with the metal and never used to pound the chasing tools or dies.

Also needed are: Soldering equipment, 1 pair of dividers, scribe, pliers (flat and round nose), tongs and tweezers, also a set of jeweler's files that include round, half round, flat and triangular files in different sizes or cuts.

A scraper and burnishing tool is necessary for finishing and other finishing supplies include fine steel wool, emery cloth, pumice powder and rouge. A pottery or porcelain crucible, charcoal block and pieces of asbestos is needed for any casting. The use of a pitch pot or bowl, pickle pan and containers for etching fluids will be described under special projects.

For raising metal forms, hardwood molds and stakes of required size may be turned with the woodworking lathe.

FIRST CUT THE METAL TO DESIRED SIZE

The size and shape of the project will determine the size to cut. It is usually desirable to cut the metal 1/8 to 1/4 in. larger all around, and finally re-cut after it has been raised.

OUTLINE THE PORTION TO BE RAISED

Guidelines for any raised portions are conveniently added when the metal is in the flat. Lay out any circles, ellipses, or special curves at this time, with either pencil or chalk that will not scratch the metal. If the front surface is to be raised, marking maybe unnecessary.

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MAKE THE PATTERN

The end of close grain hardwood block is well suited for raising metal. A log is set on end for this purpose. A block of lead with hollows or depressions can also be use. Depressions of different shapes can be made to suit the particular needs. Shallow depressions generally are used by the craftsman. These depressions can be made by striking the block with a raising hammer. A heavy canvas bag filled with sand is used for backing in place of a solid block. For making small, flanged trays, forms of the exact shape and depth are convenient, wooden forms, are made by turning a maple block on a lathe.

If a number of raised pieces are to be made the same shape, a more permanent mold can be made from metal. Metal forms of standard shapes are furnished by firms specializing in metalworking tools, or they can be made in a machine shop.

MOLD FORMED METAL

Trays, plates and bowls may be formed from a suitable gauge of almost any metal in hardwood molds that may be turned on a wood working lathe, or obtained from dealers.

The disc of metal is centered over the mold and gradually depressed into the contour with the wooden hammer applied as indicated in slightly overlapping rotation.

A wood stake is used for straightening the edge. Which may become buckled in the forming process. After the bowl has been formed the shape may be trued to a perfect outline by the process of "planishing," which is done with a smooth planishing hammer applied lightly to the entire surface as it is held over a metal stake.

Finish the bowl in side and out with very fine steel wool followed by fine pumice and water for a matte surface. Wash with soap and water and apply a protective lacquer.

A fluted edge decoration is formed on a fluting stake that must be held in the vise. The tapered grooves may vary according to the diameter and depth of the bowl, and should be equally spaced on the rim. The flutes may be inward or outward and the stake shaped accordingly, concave or convex.

The grooves may be filled 1/8" to 3/16" deep and tapered about 1/8, then smoothed with sandpaper. A fluting hammer, or the narrow end of a riveting hammer is used on the harder metals. On pewter a wooden fluting hammer is required.

Occasional annealing, restore malleability will be necessary on all metal, except pewter.

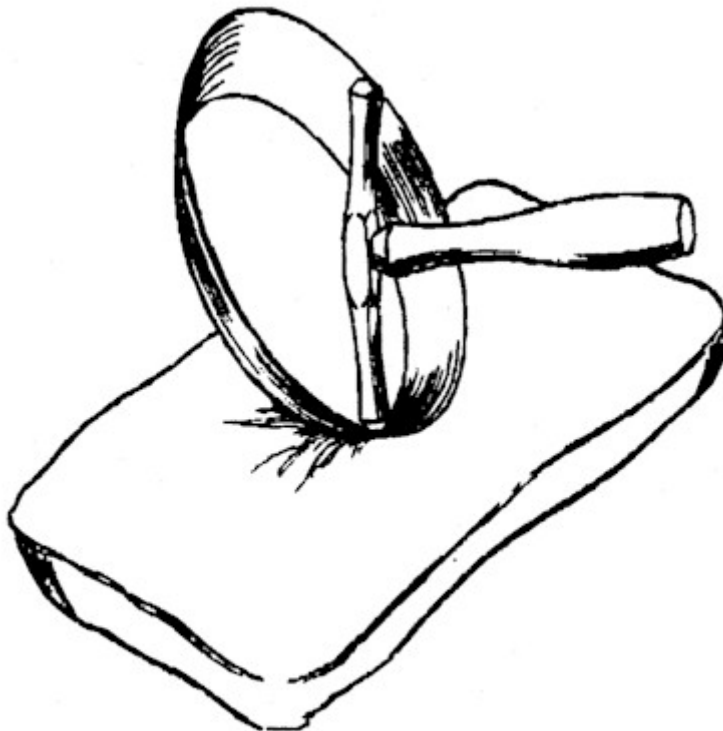
Select a raising hammer whose curvature corresponds most nearly to the curve desired. Raising hammers are made with faces of different shapes and sizes. A ball-peen hammer

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may be used for a great variety of raising work if you can't find a source.

ANNEALING COPPER, BRASS AND SILVER

Hammering, especially with a metal surface, will make all metals except pewter; tin and the soft Titian aluminum become hard and lose their malleability so that shaping cannot be continued. Annealing means to soften the metal. To anneal copper or silver, heat it to a dull red and plunge it into cold water. If 1 part of nitric acid is added to 10 parts of water the metal is not only annealed but also left clean.



FORMING THE METAL

The softening process or annealing consists of treating the metal as in the first stage of tempering. Place the article, on an asbestos mat with surrounding baffle of asbestos or firebricks to concentrate the heat.

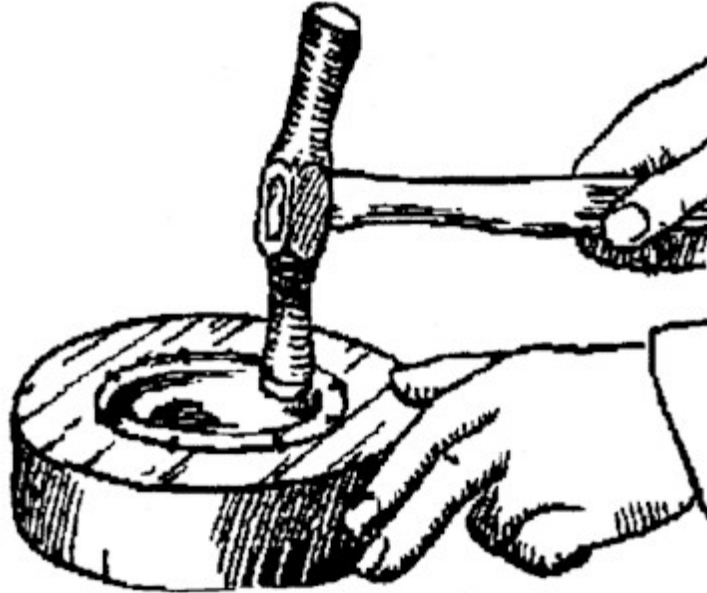
Apply a soft bushy flame of the butane torch, until the annealing temperature is reached and the area glows with a dull red color. This is best noted in a darkened corner and will require but a few minutes. Permit to cool gradually and do not hammer again until entirely cold.

Metal stretched with raising becomes hard, and cracks easily when struck with a hammer. To avoid this cracking, anneal the metal often. Metal to be raised is best worked if it is soft and ductile. Copper, brass, and iron must be softened if they are raised to any great extent. Raise the entire surface a small amount after each annealing.

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PICKLING

Dipping into the water and acid is called "pickling." Heat aluminum to a dull pink and anneal it in a subdued light, and the Aluminum need not be pickled.



FORMING INSIDE A MOLD

When the annealed metal has cooled it will be discolored and the surface may appear blistered, as the upper the metal loosens and forms a scale. This must be cleaned off or it will be hammered into the metal and make it rough. A black oxide forms on copper that also must removed.

The pickling solution is made of 15 parts water and one part sulfuric acid. As in mixing the etching solution, always put the water in the container that must be of glass, porcelain or glazed earthenware, and then add the acid very slowly.

Never permit any steel or iron tool to come in contact with the solution, as it will change the acid. Handle pieces to be annealed with copper or wooden tongs, or wear rubber gloves. Immerse the annealed or soldered article in the pickling solution and leave for five or ten minutes. Remove and wash thoroughly in clear water. Dry with a soft cloth.

Iron must be heated and allowed to cool slowly to make it soft. It is not necessary to anneal pewter if the raising is not forced.

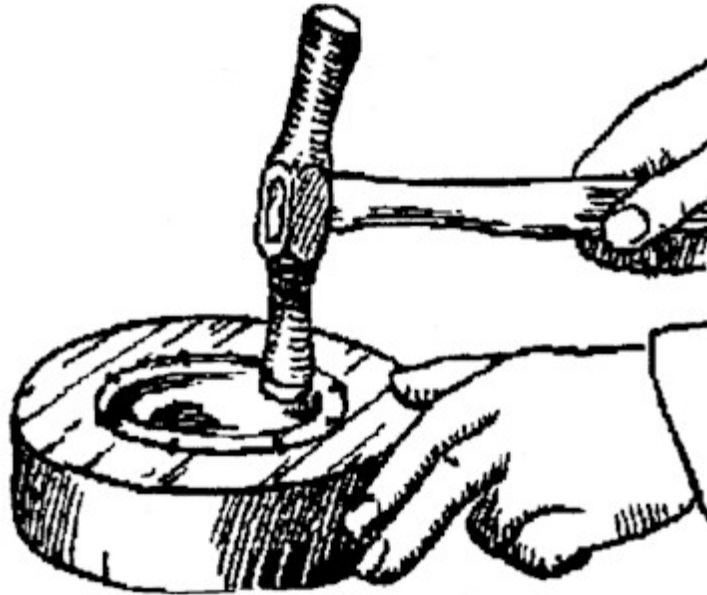
RAISING THE METAL

For bowls and the like, begin at the center or inner edge of the portion to be raised. Hold the

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metal over the depression and with a raising hammer strike it with light blows. Turn the metal slowly and continue to strike it, hammering in concentric circles.

Gradually work toward the outer edge of the bowl. The blows should be close together, evenly placed, and not too heavy.



FORMING INSIDE A MOLD

For raising a plate or tray with a rim, the blows are confined more to the outer edge of the depression or bulge. Strike the metal gently until the depression is formed.

Do not use too heavy blows or the rim will buckle. Do not hammer the center of a bulge that is to remain flat, but confine the hammering to the outer edge. Stop the hammering before the bulge becomes larger than the depression in the form.

Raising can be done without the use of a block with depressors. Trays, plates, etc., with a rim can be successfully fashioned on the flat surface of a wood or metal block. Raising of a pewter plate with a raising hammer over the edges of a wooden block. Using two nails serve as guides to give a uniform rim around the plate.

Copper and silver surfaces on both horizontal and curved planes are often decorated by hammering either alone or in combination with embossed designs. It is particularly effective on copper for plain or for pierced projects.

Lay the piece of metal, thoroughly cleaned with steel wool (000) and cut slightly larger than the pattern (outside the design outline) on the smooth metal block or flat surface of the anvil. Use the round or oval ball peen or chasing hammer, which must be perfectly smooth and heavy enough to produce the desired stippled effect by weight when dropped about 2 or 3

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inches.

On an oblong shape such as the sides of a tray, follow the margin in parallel lines. On a circle start at the center and work to the edge in concentric circles to cover the area. The knack is in developing a rhythm of a light grip on the handle that allows the hammerhead to rebound after each stroke.

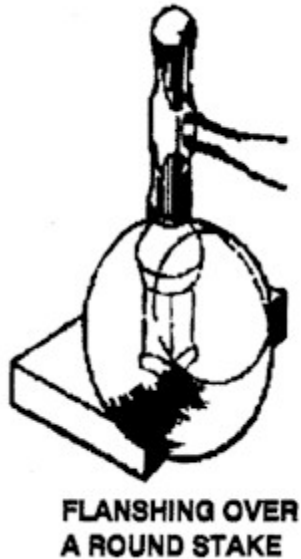
Force should not be used as each row of hammer marks should touch but not overlap the preceding row and be of uniform size and depth. The metal is hardened by this process and must be annealed to soften before any shaping can be done,

If a textured rim is desired, grip the metal between 2 pieces of wood held in a vice, with the edge extending about 1/16." Hammer with ball peen hammer.

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FINISH THE SURFACES

Sometimes the metalworker finishes the raised surface by placing it on a round wood stake and, with a fiber hammer, pounds out the irregularities from the opposite side. The best-shaped fiber hammer is one with flat or rounded faces, used to give a finished surface to the project after it has been shaped.



RAISING A METAL BOWL

The equipment required and procedure in raising a small bowl. Silver, copper or brass is hardened by the hammering and should be annealed as necessary to restore softness or malleability.

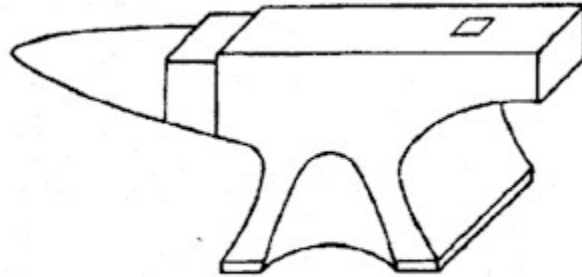
Mark a circle on a 7" disc of metal as a guideline to be followed in raising or shaping a bowl over a metal stake.

Place the stake on its pedestal, and hold the disc against the stake with the guideline in contact with the curve of the stake.

Strike the disc with the blocking hammer just outside the guide circle. The experienced craftsman maintains a rhythm count of three concurrent slightly overlapping blows at a time. The disc is rotated with the left hand between the series of rhythm blows and the process continued until the curve is established. At intervals the tendency of the bowl to cup at the bottom may be corrected by placing it on a flat surface where it may be hammered with flat surface of the ball-peen hammer.

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When the desired curve is formed, place the bowl on the stake, and with the planishing hammer reduce or smooth out the hammer marks.



ANVIL

The inner surface is planished with the bowl held against a sand filled bag. Carefully planished surfaces resemble rolled sheet metal in texture with only faint traces of the hammer marks.

METAL SPINNING

Sheet metal can be formed into various shapes by spinning it in a lathe. This requires a lathe with ample power and a wooden form, called a chuck, over which the metal is worked. The chuck has the exact shape and size as the inside of the finished work and is fastened to the faceplate of the lathe. This chuck can be made from a suitable hard wood, but if many pieces are to be spun on the same chuck, it should be made of metal, usually of cast iron. The sheet metal is cut into a circle large enough for the finished size. The center is marked, and a circle is drawn, to be used to center it on.

Cup-shaped parts having rotational stability can be made by spinning. Stainless steels with thickness ranging from 0.012 to 0.12 inch are readily spun cold, and the diameters of parts that are spun cold range from a few inches up to a few feet. Due to its low tooling cost, spinning is normally used for producing small quantities.

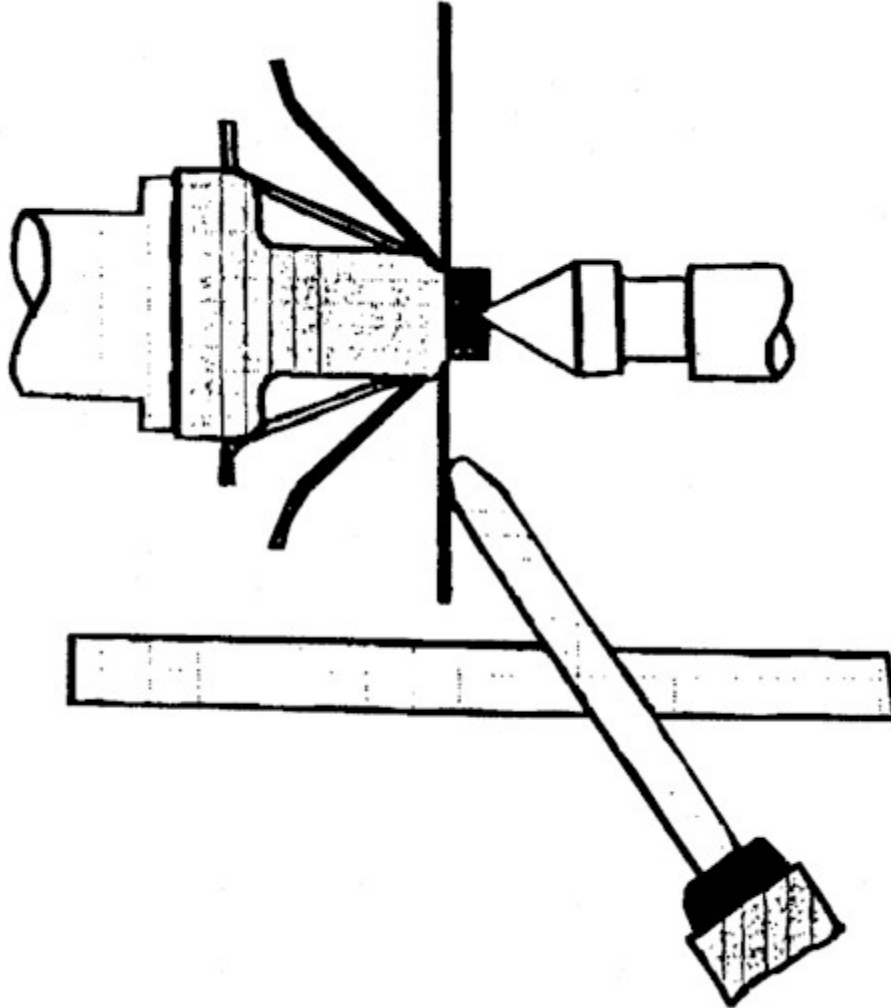
Round disks of thin metal may be shaped over a form as the metal and form revolve in a lathe. The disk is made to conform to the shape of the form by pressing it against the form with various-shaped tools. This process is known as metal spinning. Trays, bowls, plates, and pitchers may be formed in this manner

Spinning may be done on a metal-turning lathe or woodturning lathe, although there are special lathes for this work. The spinning lathe has a wide gap that allows larger pieces of metal to be spun than can be spun on the conventional lathe.

If not a gap lathe, the spinning lathe is usually one of large capacity or swing.

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Spinning is ordinarily done on a rigidly built lathe, similar to an engine lathe, with suitable rotational speeds and sufficient room to rotate the desired blank diameters.

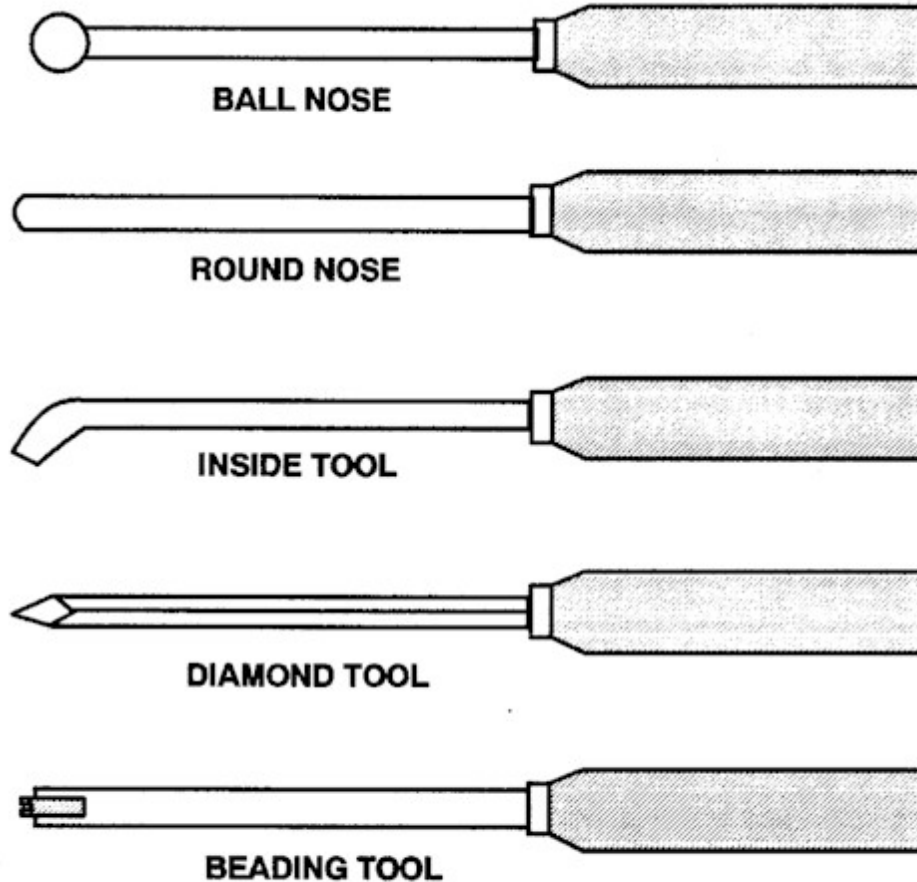


A SPINING SETUP ON A LATHE

Essentially, it involves shaping a circular disc over a mandrel. The mandrel is mounted on the headstock of a heavy-duty lathe. The disc is clamped to the mandrel by tail stock pressure, and forming is done by manipulating a blunt tool or an anti-friction roller to shape the metal tightly against the mandrel. Spinning tools include forming, trimming, and beading tools. A forming tool may consist of a well-rounded bar of hardwood or of metal.

Other forming tools have a small roller mounted at the end of a suitable handle. The tool bit is ground to have a sharp point so it can enter the metal like a lathe parting tool; also cutting edges are provided on each side of the point. Beading tools are designed to roll over a small amount of metal at the edge through about 60 degrees and thus form a bead. Tools are usually made from low-cost hardwood or metal.

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METAL SPINING TOOLS

They have fewer components than draw dies. When several sizes of a similar item are required for prototype samples, tools may be re-cut at a considerable savings.

A circular disk is properly centered with a tool such as a hardwood stick. The blank rotates and is lightly held against the chuck by the pressure of a freely rotating pad on the tailstock.

As the disk is rotated rapidly about its axis of rotation, pressure is applied to the metal surface by bar type or roller type tools, flowing the metal progressively over the chuck.

A trimming tool has a cutting tool bit mounted on a suitable handle so it can be held by hand. The spinning is started with a ballpoint tool and gradually worked down to the shape of the chuck; Different tools are used to finish it tight against the chuck. The final edge is trimmed to size with the diamond point tool, beads are formed with a formed wheel tool, and the amount of stock to make the bead must be allowed for when making the final trimming to size. Spinning, which is cold working of the metal, tends to harden it very quickly.

The main requirement is that the lathe has a substantial headstock with end thrust bearings

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to withstand the unusual end thrust as pressure is applied with the spinning tools.

Spinning is useful where only a limited number of pieces of one kind or design are required. The common metals used for spinning are pewter, aluminum, copper, and brass. Copper and brass becomes hard and brittle during the spinning process and must be softened by being heated to a dull red. They are then dipped in cold water or allowed to cool in the air.

The form over which the metal is formed can be of wood or metal and is called a chuck. Chucks are made of hardwood reinforced with steel, or of hardened steel, depending upon the quantity of parts to be produced.

Chucks should be smooth and polished. One-piece chucks are used for parts that have sufficient draft and can be removed from the chuck.

Chuck sections must fit together smoothly at the joints, because slight irregularities will be reproduced on the spun parts. The spinning speeds used are comparatively high and are determined by the metal, blank diameter, and blank thickness. During spinning, a hardwood bar is commonly used as a backup support opposite the spinning tool to avoid wrinkling at the outer edge. As its diameter is reduced, the metal becomes thicker, and this compensates somewhat for the thinning caused by the forward flow of the metal.

When wood is used it should be a close hard grain wood such as cherry, birch, or maple. If a large number of parts of the same shape are to be spun the metal form will be the most serviceable. The chuck must be the same size and contour as the inside of the finished article after it is spun. If any part of the article to be spun is smaller than the open end, the chuck must be sectional or collapsible so it can be withdrawn after the article is spun.

When pressure is applied to the spinning metal with the tool, the friction produces heat, which softens the surface of the metal and produces small grooves or ridges in the surface. To reduce the friction and thus reduce the heat, a lubricant is applied to the metal as it is spun. An easily obtained lubricant that works well is ordinary yellow laundry soap. A tallow candle works well. Cup wheel bearing grease will produce good results or a wax stick is very good.

The metal disk is placed in the lathe between the chuck, and the follow block. The chuck should be larger than the depth of the article to be spun. When the disk has been mounted and centered accurately in the lathe, lock it securely in place and lubricate the metal.

The tool is held close to the body for good leverage. Turn the lathe on at low speed and check that the disk is turning true and does not wobble. Make the necessary adjustments by sliding to one side and holding a flat tool against the edge of the metal. Then loosen the tailstock spindle very slightly until the disk runs true and then retighten the spindle.

The spinning of the metal should be done slowly and with care to avoid damaging the metal. Use a slight but firm and steady pressure on the metal working from the center toward the outside of the disk with a slight back and forth motion. Too much pressure or heat will cause

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the metal to thin out or crack.

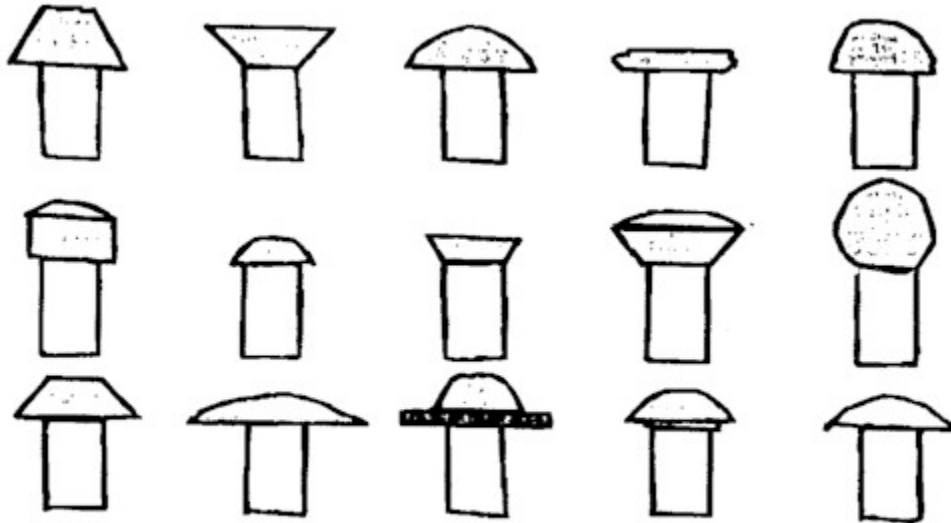
The work must be removed from the chuck and annealed at frequent intervals or it will become so hard that the metal will refuse to flow under the tool and will warp and crack. Before the work is removed for annealing, it must be worked tight against some part of the chuck, to center it and assure that it will run true when replaced on the chuck.

For deep spinning, it is to your advantage to make a series of chucks, each one being nearer the final shape, so that work can be finished down tight to a solid chuck before it is removed for annealing.

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RIVETING METAL

Many times I have made different items that were needed to be fastened together securely. Most of these could have been welded, but in many cases I found that riveting made almost as strong a joint as welding. Riveting is a fast way of joining two or more pieces of metal. All that needs to be done is to clean up the parts, drill the holes and rivet them.



DIFFERENT TYPES OF RIVETS

Rivets can be the tiny pins that hold the hinges on your eyeglass frames. They may also be solid, tubular, or split, according to the application and the load carried.

Solid rivets are used in heavily loaded parts such as structural steel work. A solid rivet has a head on one end and a straight, solid shank. It is inserted through holes in the parts to be joined and held in place by a solid block or anvil held against the head. The opposite end is formed into a second head on the other side of the work by a series of hammer blows.

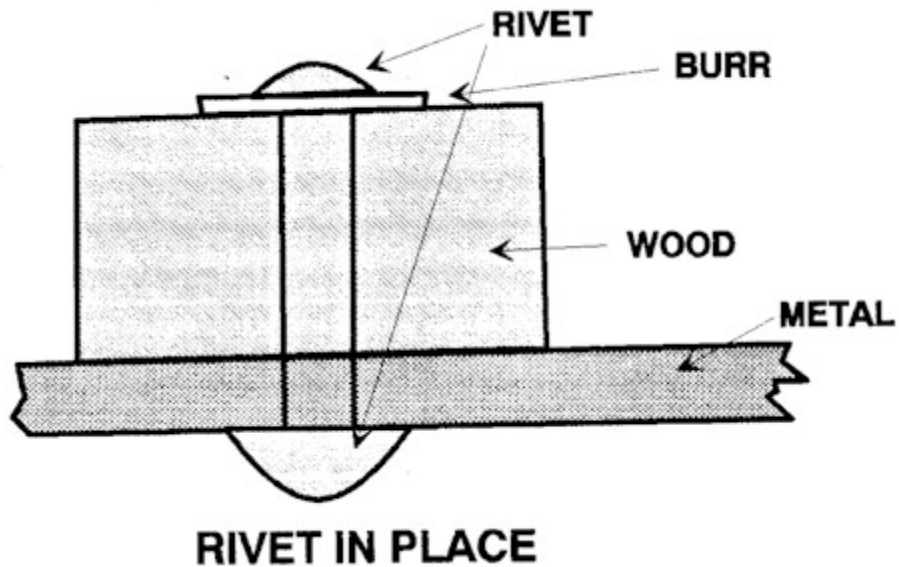
The parts are held tightly together under considerable tension and a very strong joint is formed. Aluminum solid rivets are widely used in the aircraft industry, but they are now meeting some competition from resistance-welded joints.

Where the load is not so great and faster assembly is required, tubular rivets or eyelets are used. Tubular rivets have a head on one end and a shank that is drilled part way through to form a tubular section that is rolled over to form the holding member.

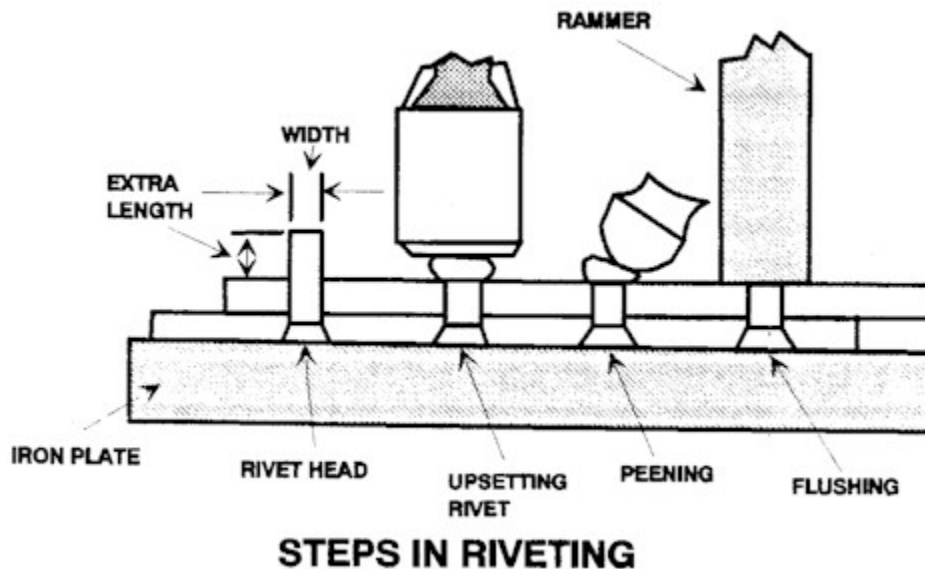
Eyelet rivets cost less than rivets and are quite satisfactory where their appearance is not objectionable and where the somewhat greater shear strength of the rivets is not needed.

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Split rivets have a wedge-shaped slot in the end opposite the head. They are used in leatherwork or in assembling hardware of luggage, where they are driven through the leather or wood without the need for drilling a hole.



The prongs strike a shaped anvil on the backside of the work, and this anvil rolls them outward and clinches them tightly in place.

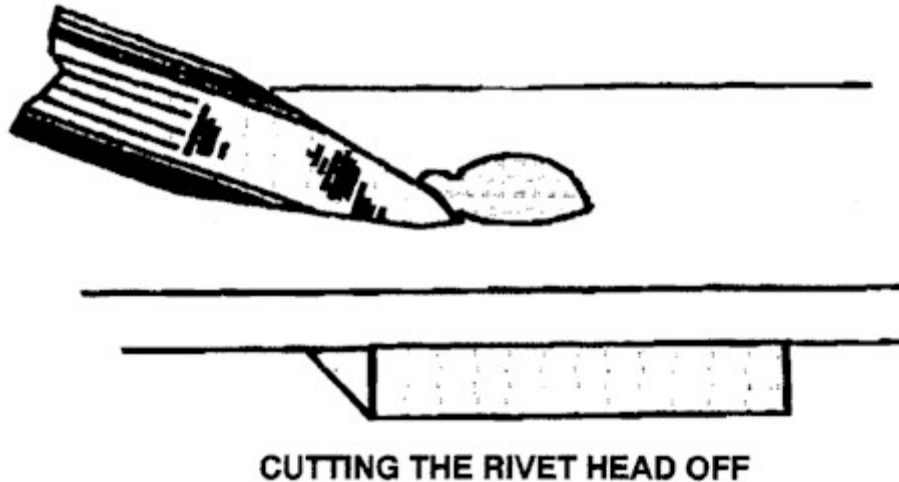


The ordinary types of rivets require access to both sides of the work to drive and cinch them. Many times this requirement limits their usefulness, and various types of blind rivets have been developed for use under these conditions.

CASTING METAL PARTS

SOME OF THE NUMEROUS RIVET-HEAD TYPES.

Several of these types are used for thin metal as well as for heavy materials. Cooking utensils that are made of thin metal may have handles, ears, and hinges riveted on with a flat, or oval headed rivets. The round head and the countersunk head are the ones used for heavy metal.



The round head is used for strength and appearance and the countersunk to make a flat surface. The other types shown are, available for special purposes.

Rivets are manufactured in the common soft metals, as iron, copper, brass, and aluminum. For average work the small rivets are headed cold.

The size of rivets includes the diameter and the length. The length is taken from the underside of the head to the point in all rivets except the countersink. The length here includes the head.

The diameters of small rivets sometimes are made scant so they will readily enter the hole of the diameter given.

The washer like disks used on the ends of rivets is called burrs. They are necessary when riveting soft material such as leather, wood, and certain plastics that may fracture easily, or when fastening these materials to metal.

When ordering burrs, indicate the exact size of the rivet for which they are intended as burrs, and are not just plain washers.

Tools: Punch or drilling tools; rivet set; riveting hammer; anvil or back plate.

Select the type of head suitable for the job. Iron rivets are usually used in ironwork, but

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sometimes copper or brass rivets are selected with iron for decorative purposes. The projecting length necessary for heading a rivet should be from one to one and one-half times the diameter of the rivet. Select a diameter strong enough for the joint but not too large, since the necessary hole might weaken the pieces to be fastened.

Lay out the position of the holes accurately, in heavy metals the holes the holes must be drilled or punched. The diameter of the hole should be such that the rivet will slip easily in place.

Place the rivet in the hole, and check for proper diameter and length. If too long, the surplus can be removed conveniently with a nipper or bolt clipper.

Place the head on an anvil or any convenient solid plate of metal. If a round head is to be protected, place it in the hollow of a rivet set or special metal block. Strike the point of the rivet heavily to fill the hole and upset the end. This spreads the rivet into a flattened head. The head can be formed round by shaping with the ball of a hammer, or better with a rivet set.

A badly set or headed rivet can be removed as follows, cut off the head with a chisel, and drive out the rivet with a punch.

To remove a rivet by drilling, which is recommended for sheet metal. Use a drill slightly smaller than the diameter of the rivet and drill as near the center of the rivet as possible. Removal by drilling reduces the tendency to mar the surrounding surface with a chisel.