Sawing Equipment

Silversmiths consider both saw blades and files to be sawing equipment. One of the most basic skills of a silversmith or jeweler, sawing is used to cut openings in decorative shapes along the edges of objects. The equipment needed for sawing is minimal: a saw frame, a saw blade, a *bench pin* to hold the metal still during sawing, and a C-clamp to hold the bench pin to the workbench.

While saws are used for cutting larger pieces, small files are used to refine the shape of silversmiths' designs. Small, straight files called needle files are commonly used, and curved files called riffler files come in handy for specialty pieces.

Bench pin

Be sure to purchase the proper saw blades for the project. Saw blades can be inexpensive, but cheap, flimsy blades are no bargain. At the least, buy blades of good enough quality to avoid frustration. Match the thickness of the blade to the thickness of the piece being cut. Make sure that at least three teeth touch the metal at all times.

Pickling Solution

Silversmiths use an acid bath called pickling solution to remove residue left after soldering and oxidation caused by heating during the annealing process. A solution of 10 percent sulfuric acid and 90 percent water is often used. Commercial pickling products are available in a granular form to be mixed with water as needed.

Never use a steel item to reach into the pickling solution. If you do, everything in the solution will become copper-plated. This is because the pickling solution removes some of the copper found in sterling silver. Once the steel item is removed, the solution will be fine again, but the plated objects must be polished heavily to remove the copper layer.

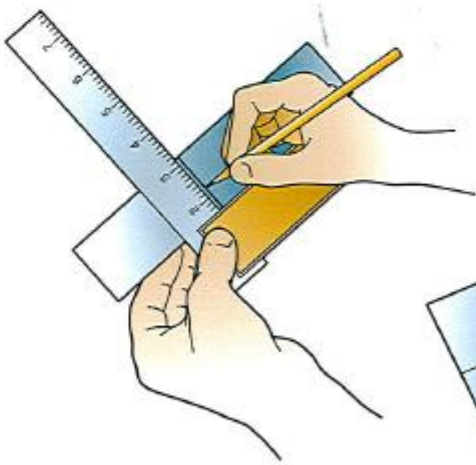
To remove items from the solution, always use sticks or tongs made of wood or copper. Rinse the pickled object in fresh water and dry it completely. Also, never leave soldered work in the solution for more than a couple of hours—it will weaken solder joints.

Basic Silversmithing Skills

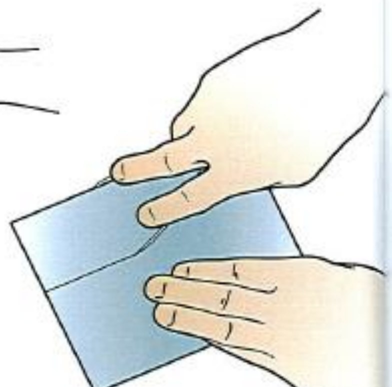
While they know the basic techniques of metalworking, silversmiths must know some techniques that are specialized for the types of materials and tools they use.

Laying Out Lines

One old saying, "Measure twice, cut once," is good advice when it comes to laying out lines. When using dividers, loosen the setscrew and place the tips against a steel rule. Holding one tip firmly at the zero point, spread the dividers until the second tip has reached the desired measurement. Lock the setscrew in place to hold the legs securely and use the tips to mark off the line.



Use a square to establish a 90-degree corner, checking from both sides to be certain the angle is correct.

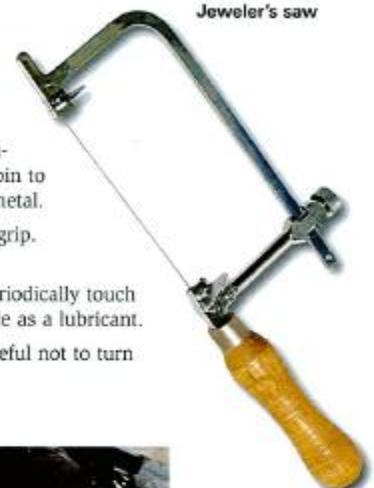


To lay out a strip with parallel sides, drag one leg of a divider along a prepared edge. Scrub the metal with a scrub sponge in a circular motion so the scratch line shows clearly.

Sawing

While sawing might seem to be a fairly basic and easy skill to master, care must be taken when it is used as a metalworking technique. The jeweler's saw is a common sawing tool used by silversmiths, and it must be handled with care to prevent injury and ensure proper use.

Jeweler's saw



To use the jeweler's saw:

Step 1—Make sure the blade is firmly attached to the saw frame, with the teeth pointing toward the handle.

Step 2—Hold the saw so the blade is perpendicular to the work. Reach under the bench pin to do this properly. Take care not to jab at the metal.

Step 3—When preparing to saw, relax your grip. Let the saw blade do the work.

Step 4—Use long, relaxed strokes to saw. Periodically touch a piece of beeswax or candle wax to the blade as a lubricant.

Step 5—Turn the work while sawing. Be careful not to turn the saw.

Sinking

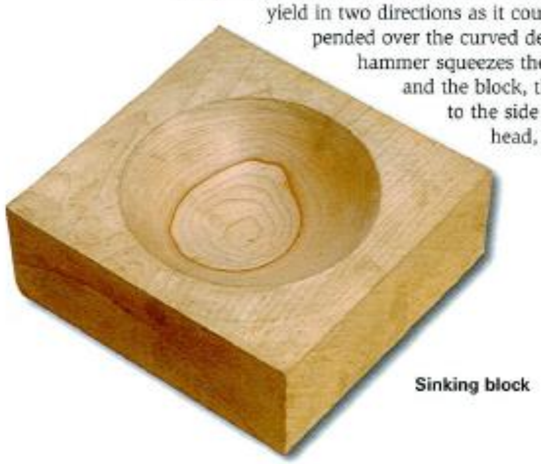
To a silversmith, sinking means hammering a depression into a piece of flat metal. This technique, which stretches the metal, is used to make bowls, plates, and serving trays. Most objects that use the sinking technique consist of three parts:

- The rim—the flat part used to pick up the object
- The *bouge*—the curved sides of the depression
- The *platewell*—the horizontal bottom of the piece into which the bouge transitions

Sinking very shallow forms can be accomplished by using a sandbag and a hammer, but it takes considerable time to achieve the desired depth. Because the sand shifts under each blow, the metal does not move a great deal.

Using a sinking block yields faster results. Hammering the metal over a depression carved into a block of hardwood such as beech or maple allows for greater stretching with each blow, with the sides of the wooden block supporting the metal as it is stretched to the desired depth and shape.

However, the final form should not conform to the depression. That is, don't hammer the metal until it is driven to the bottom of the depression (called "bottoming out")—this ruins both the surface of the sinking block and the work. Bottoming out puts dents in both items because the metal can no longer yield in two directions as it could when it was suspended over the curved depression. When the hammer squeezes the metal between itself and the block, the metal will push out to the side around the hammerhead, forming a dent.



Sinking block

One way to create a sinking block is to cut a hole in a thick piece of hardboard or plywood (1). Drive roofing nails along the edges and attach the metal to the board by holding the work in place with the nail heads (2). Using a silversmith's hammer with a head that has a radius that matches the desired curve of the bouge, tap the metal along the inside perimeter of the hole, driving the material into the gap between the surface of the workbench and the top of the board (3). Work the metal until it almost touches the bottom surface—remember that you are stretching the metal when you are using the sinking technique.

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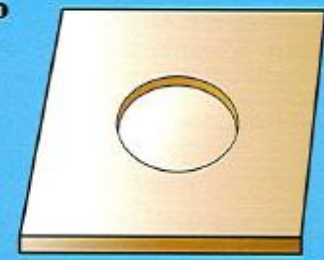

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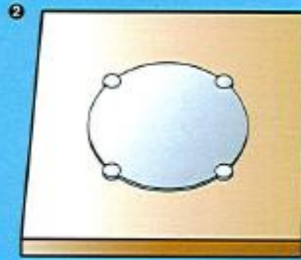

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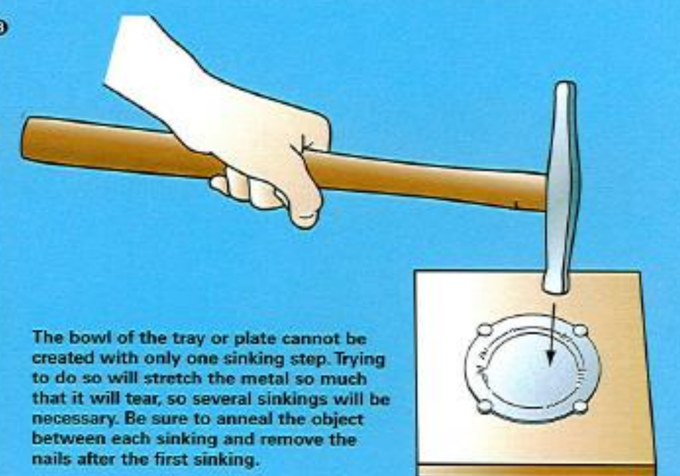


The bowl of the tray or plate cannot be created with only one sinking step. Trying to do so will stretch the metal so much that it will tear, so several sinkings will be necessary. Be sure to anneal the object between each sinking and remove the nails after the first sinking.

Soldering

Soldering is a basic skill used often by silversmiths. As with most skills, practice at soldering will help you achieve better results.

SWEAT SOLDERING

At times you may wish to apply a special piece to the surface of another. Perhaps you have fashioned a small fleur-de-lis that you would like to attach to a flat disk that will become the front of a neckerchief slide. To attach that fleur-de-lis without obvious signs of soldering, use the sweat soldering technique.

Step 1—Turn the fleur-de-lis on its back and melt on a couple of small pieces of silver solder. Do not let them flow away; just heat them until they have attached themselves—they should still be small blobs of silver solder at this point. Set the piece aside.

Step 2—Place a small amount of flux on the disk where you want to attach the fleur-de-lis.

Step 3—Carefully position the back of the fleur-de-lis onto the flat disk. Play the torch flame over the fleur-de-lis until the silver solder flows. Be careful not to let the silver solder flow out from under the fleur-de-lis. The attachment should look as if you carved it in place.

Preserving Your Work

Silver, copper, and brass must be polished regularly to prevent oxidation from dulling and pitting the finish. Apply a liberal amount of a good-grade polish to a lint-free cotton cloth, and take your time as you polish. Working on small sections and using a circular motion, rub the pumice into the metal until it is polished to a high luster.

Silversmithing Projects

Listed below are the basic tools and materials needed to make the projects shown in this pamphlet. You don't have to buy specialty tools from catalogs; many of these tools can be made from things found in scrap yards.

Basic Tools Needed

- ❑ Raising hammer
- ❑ Planishing hammer
- ❑ 16-ounce forging hammer
- ❑ Flat-faced wooden mallet
- ❑ Peen-ended wooden mallet
- ❑ Raising stake
- ❑ Bottom stake (optional)
- ❑ Ball stake
- ❑ Stake holder (optional)
- ❑ Stump (used to mount the stake holder)
- ❑ Flat files
- ❑ Riffler files
- ❑ Jeweler's saw
- ❑ Jeweler's saw blades
- ❑ Bench pin
- ❑ Sturdy wooden bench
- ❑ Sheet metal snips
- ❑ Try square
- ❑ Metal straightedge
- ❑ Ruler
- ❑ Scriber
- ❑ Steel dividers
- ❑ Center punch
- ❑ Silver solder (at least three types, of different melting temperatures)
- ❑ Flux (borax paste)
- ❑ Brazing station (several hearth bricks or pea gravel in a heavy pan; avoid using aquarium gravel coated with epoxy)
- ❑ Pin-flame propane torch
- ❑ Sinking block (your choice of hole diameter)
- ❑ 10-gallon or larger pickling tank with close-fitting lid

Materials

- ❑ 10 percent sulfuric acid solution
- ❑ Sheet copper of varying gauges
- ❑ ⅜-inch hardboard
- ❑ Cotton shop cloth
- ❑ Crocus cloth
- ❑ Machine oil
- ❑ Wooden tongs
- ❑ Jeweler's pumice of various grits
- ❑ Cotton cloth
- ❑ Silver polish (or type of polish appropriate to the metal being used)

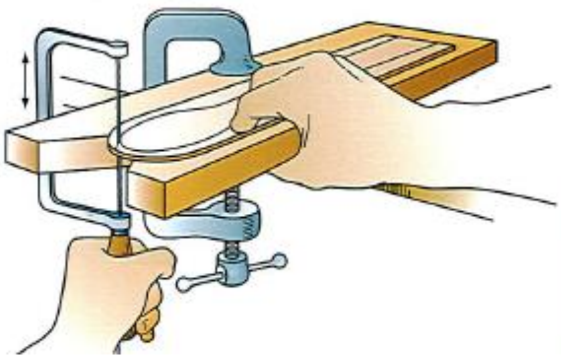
Copper has the same properties as silver and is less expensive.

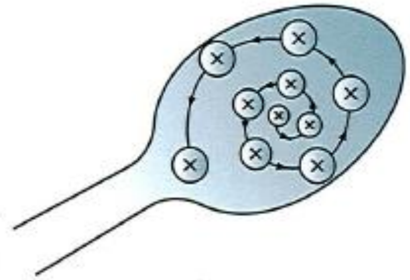
Forging a Spoon

The spoon project is hammered cold using a piece of 18- or 20-gauge sheet copper. As you forge the bowl of the spoon, you may find that you need to soften the metal. Remember that nonferrous metals are annealed by heating them to a red heat and then quenching them in water. To meet the requirement for a soldered joint, you may wish to fashion a small Boy Scout fleur-de-lis and apply it to the handle of the spoon by using the sweat soldering technique.

Step 1—Use a marking pen to draw the pattern onto the metal. Be sure to mark out the dotted line—this gives you sufficient material to make a fairly deep bowl.

Step 2—Using a jeweler's saw and a bench pin, saw out the basic shape of the spoon.





Step 3—Using a forging hammer to thin the metal in the bowl of the spoon, strike a series of blows beginning in the center of the bowl and working out to the edge.

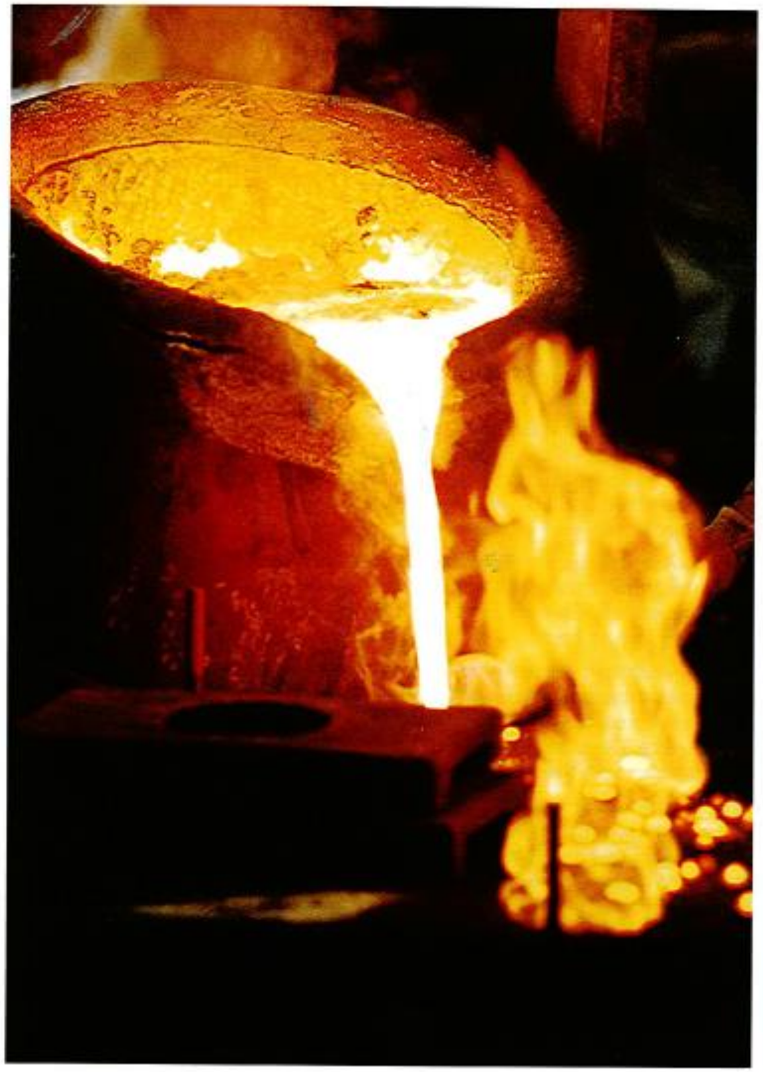
Step 4—Using a bouge and a curve-faced hammer, sink the spoon's bowl. Place the bowl of the spoon over the cavity and stretch the bowl using a silversmith's hammer that has a radius that corresponds to the radius of the bouge. Remember to stop hammering before the metal touches the bottom of the bouge to help prevent denting the bouge. If the edge of the bowl warps, place it upside down on the anvil and tap it back into line with a wooden mallet. Anneal after each sinking.

Step 5—Once the bowl has been drawn out to the proper width and thickness, forge the spoon handle. Working along the spine of the handle, strike from the center outward. Flare the end of the handle and keep it narrow near the bowl. Use a kitchen spoon as a guide. Anneal as often as necessary.

Step 6—File the edges of the spoon smooth. Be careful not to scrub the file back and forth. Push the file away from you to remove metal, and lift it up on the return stroke. This keeps the file's teeth sharper longer.

Step 7—Soak the finished spoon in the pickle bath for about 20 minutes to remove oxides and fire scale. Use wooden tongs to retrieve it from the pickling tank to avoid accidentally staining the piece. Flush the piece with plenty of water to neutralize the remaining acid, then dry it with a clean cloth.

Step 8—Polish your work. Remove the swirls and manufacturing marks by rubbing the piece with pumice. Start with a coarse grit and gradually move to finer and finer grits as the desired degree of shine appears.



The Founder

A person who pours molten metal into molds is called a founder. Ancient humans began melting metal and pouring it into molds almost as soon as they discovered how to hammer it into shape.

Numerous industrial companies cast metal, and most city telephone books will contain a listing for at least one *foundry*. Not all foundries are huge factories employing scores of people. Some smaller foundries specialize in producing hard-to-cast shapes using hard-to-cast metals and cater to artists whose sculptures will become patterns for limited-edition castings. In some cases, the artists operate their own foundries and make their own castings. Increasingly, hobbyists are casting metal on a small scale in their garages and workshops.

Basic Tools and Skills

Founders use skills and techniques that are different from other metal workers. Their craft includes making and working with molds to create pieces from molten metal. While some founders use premade molds to cast the metal shapes, many founders are involved in every step of the creation process, including carving or sculpting their own patterns to shape the molds.

Keep in mind that working with molten metal is dangerous. Always have adult supervision when working with any of these techniques.

Making a Pattern

The *pattern* must be created before the mold can be made. The first step is to draw a full-size sketch of the object. This two-dimensional drawing will have to translate into a three-dimensional object, so limit the depth of the object to about ½ inch.

Sketch the pattern with the finished piece in mind. Pieces designed with projecting elements such as extended arms or legs modeled in running poses cannot be cast in one piece because the arm or leg will stick in the mold and prevent the piece from being released. Keep the design simple and within your capabilities to create a model.

Designs with slightly beveled sides (called "draft") rather than perfectly straight sides are more easily removed from the mold. Only three or four degrees of draft are necessary, so you can still give the illusion of perfectly straight sides. Avoid undercuts (sometimes called "ledges") that will jam in the mold, making it impossible to remove the finished piece.

If you wish to whittle your pattern rather than sculpt it, use a softer hardwood such as basswood or tupelo, or use reusable sculptor's wax.

The next step in pattern making is to sculpt the model using sulfur-free polymer clay. Use a variety of tools to creatively carve the details of the piece. Follow the clay manufacturer's instructions to bake the model until it is hard.

Making a Mold

When the pattern is complete, it can be used to make a mold, which will hold the molten metal until it is hard. Mold makers can choose from at least four different types of molds for casting metal:

- **Lost-wax mold,** in which the wax pattern is eventually burned out of the mold, forming a highly detailed cavity
- **Rammed-sand mold,** which is made by compressing a box of fine-grained sand around a pattern
- **Metal molds,** which became popular during the industrial revolution and are the most expensive type of mold

- **Rubber molds,** which are durable and reusable molds most often made from room-temperature vulcanizing (RTV) silicone rubber

No matter which mold-making method is chosen, remember to include *vents* and a *sprue*—the opening in the mold through which the molten metal will be poured.

Casting Molten Metal

In metal casting, the metal is heated to its melting point and poured into a clean mold. Using an electric melting pot with a thermostat and a bottom-pour spout will help control the temperature of the metal and help prevent impurities from entering the mold when the molten metal is poured.

Mold lubricants, such as finely powdered graphite, help the molten metal flow into the mold and prevent the metal from sticking to the mold when it is being removed. The lubricant should be smeared into a fine coating that thoroughly covers the piece like grease. Use a stiff-bristled brush to work the lubricant into the crevices of the mold.

The process of applying lubricants to a mold is called *blackening,* because early silversmiths would hold their molds over a candle flame, letting the soot coat the mold.

A metal mold should be preheated by making two trial runs before the final cast is poured. This is another secret to making high-quality castings. The castings made with the trial runs will be flawed, but mistakes can be melted down for another try. Save these pieces for later, because adding them to the pot will add wait time while the metal completely melts again.

For your health and safety, use lead-free pewter. Lead ingots leave lead particles on the skin and can get into your food and your body. Molten lead produces dangerous fumes. Lead poisoning causes brain damage. Using lead-free pewter will prevent all these problems.

Always place the mold as close to the melting pot as possible. Some melting pots allow the mold to be filled directly from the bottom of the pot to prevent the *dross*—impurities that float to the surface of molten metal—from being poured. If a transfer ladle is used to fill the mold, the dross must be skimmed off before the mold is filled. Once the transfer ladle is full of molten metal, move quickly to minimize heat loss. Pour the molten metal at a rapid and steady rate.

The piece should be allowed to cool completely before disassembling the mold and removing the piece from it. Any scars in the metal left as evidence of gates, vents, and *parting line* flash can be filed and polished until they are no longer detectable.

Always apply thin coats of paint so that you do not obscure the figure's details and so that the paint does not sag and drool.

Preserving Your Work

Pewter does not need to be covered with a finish to preserve it from oxidation. However, some people like to paint their cast metal figures. If you do so, paint the piece with a metal primer before applying color. White primer works best because white makes a better color base for the finished colors. If you can't find white primer, use gray metal primer, but cover the figure with a thin base coat of white paint before applying the colors.

Casting Projects

Use the following checklist to gather the tools and materials necessary to complete the founder option requirements for this merit badge.

Basic Tools Needed

For creating the RTV silicone mold:

- ❑ Four spring clamps
- ❑ Two disposable paint brushes (one for applying the RTV silicone and one for applying the graphite to the mold)
- ❑ Disposable rubber gloves

For creating the pattern:

- ❑ Sculpting tools
- ❑ Hobby knife
- ❑ Toaster oven

For casting the molten metal:

- ❑ Electric melting pot with thermostat
- ❑ Pyrometer
- ❑ Heavy aluminum baking tray for use as a pouring station
- ❑ At least one premade metal or silicone rubber mold
- ❑ Scout-made silicone rubber mold
- ❑ Riffler, needle, or jeweler's files
- ❑ Standard screwdriver
- ❑ Spring clamps
- ❑ Hobby knife
- ❑ Shop apron
- ❑ Insulated leather gloves
- ❑ Safety glasses

Materials

For creating the pattern and mold:

- ❑ 12 panels of thin plywood or hardboard cut into 4-by-6-inch rectangles
- ❑ Two 4-by-6 pieces of fiberboard
- ❑ Four small wooden pegs, each about an inch long
- ❑ One pound of sulfur-free polymer modeling clay
- ❑ Plastic wrap or aluminum foil
- ❑ Approximately 16 ounces of two-part RTV silicone rubber for one figure that is 2½ inches tall by 1 inch wide by ½ inch deep
- ❑ Four disposable mixing cups. Two of the cups must be large enough to hold the contents of each rubber pour.
- ❑ Two disposable mixing sticks
- ❑ Approximately 1 ounce of mold release cream (petroleum jelly is effective)

For casting the molten metal:

- ❑ A Scout-made pattern
- ❑ An instructor-provided mold
- ❑ Fine graphite powder
- ❑ Lead-free pewter (approximately 2 ounces per each 54-millimeter figure)
- ❑ Tempered hardboard, ¼ inch thick, cut in pairs to the size of each rubber mold
- ❑ Soap and water to clean graphite from hands
- ❑ Paper towels

Preparations

- ❑ Collect all materials before starting.
- ❑ Choose a well-ventilated spot.
- ❑ Determine where to place the sprue and vents on the pattern.
- ❑ Make the sprue and vents from wax, wood, or sulfur-free clay before mixing the RTV silicone rubber.
- ❑ Make locator pins before mixing the RTV silicone rubber.
- ❑ Measure the pattern against the stock of box-making panels and select those large enough for the necessary clearance.

Making a Silicone Rubber Mold

Step 1—Study the pattern and decide where the parting line should be and where to place the sprue and vents. When deciding where to place the sprue, choose a location such as the bottom of the piece where no one will see where the sprue is attached. In this example, the sprue will be attached to the bottom of the truck-shaped pattern. Use some of the polymer clay to make a cone-shaped sprue and one or more vents.

The dotted lines drawn on the pattern above indicate where the parting line will be.

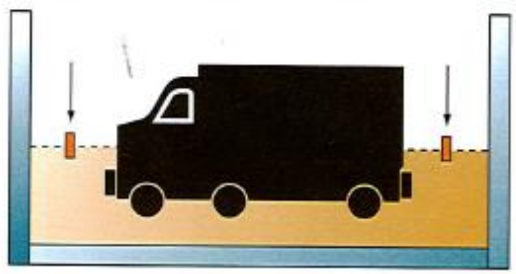
Step 2—Make a molding flask out of pieces of plywood or hardboard. Use some of the sulfur-free clay to hold the pieces together. Make sure there is a minimum clearance of ½ inch all around the model. If the pattern will be embedded in a layer of clay, estimate how thick the clay will be. Holding the pattern in the box to simulate for the clay layer, check for at least ½-inch clearance from the top of the embedded pattern to the top of the box.

As the box is built, place the pattern in it and check it for fit.

Step 3—If the flask is made of loose panels, make sure that there is a good seal with the polymer clay to prevent the RTV silicone rubber from leaking. Wrap a rubber band around the panels to hold them together.

Step 4—Spread a layer of polymer clay in the bottom of the flask. Make it deep enough to prevent any part of the pattern from touching the bottom of the box as it is pushed into the clay down to the parting line in step 6.

Step 5—Wrap the portion of the pattern that is to be embedded in clay with aluminum foil or plastic wrap. This will prevent it from picking up any clay residue that will obscure the details when making the second half of the two-piece mold.



Step 6—Embed the wrapped half of the pattern up to the established parting line. Make sure that no part of the pattern touches the bottom board.

Step 7—Insert the two alignment pegs into the clay. Putting the pegs in opposite corners (about ¼ inch from the corner) will locate the two halves correctly. Attach the pouring gate and vents to the model.

Step 8—Using disposable mixing sticks, prepare the RTV silicone rubber according to the manufacturer's instructions. Be sure to wear rubber gloves when working with the liquid silicone rubber mixture.

Step 9—Brush a thin layer of mixed RTV silicone rubber over the pattern. This will discourage the formation of air bubbles in the small crevices.

Step 10—Holding the container as close as possible to the flask, slowly pour the mixture over the pattern, allowing it to fill all the crevices and to level off. Continue pouring until the top of the RTV silicone rubber is a minimum of ½ inch above the highest point of the model. Lift an edge of the tile about a half inch and let it fall quickly, lightly rapping the piece on the table a few times to drive the bubbles to the surface.

Step 11—Place the top board on the flask.

Step 12—*Cure.* Allow the chemical reaction to progress by letting the piece rest until the RTV silicone rubber has hardened to its maximum amount. This will take eight hours at room temperature.

Step 13—Invert the flask and disassemble it. Remove the clay, the foil or plastic wrap, and the alignment pegs.

Step 14—Reassemble the flask and attach the pouring sprue and vents. Use clay to hold the flask together.

Step 15—Apply mold release cream to all of the exposed areas of the cured silicone rubber. The silicone rubber only sticks to itself.

Step 16—Repeat steps 8 through 12 to create the second half of the mold.

Step 17—Disassemble the box and separate both parts of the mold from the original. Remove the pattern.

Step 18—Check the sprue and the vents to make sure they are not constricted. If they are, use a hobby knife to cut the RTV silicone rubber. The molten metal will be poured into the mold cavity through the sprue, and the air will escape through the vents.

Step 19—Reunite the two halves of the mold, making sure that the silicone alignment pins drop into the holes. Place a piece of thin plywood or a tempered hardboard panel on the front and back of the mold to reinforce the rubber. Use two spring clamps and press two panels together opposite the sprue. This will help prevent the molten metal from leaking out.

Tips for Casting Lead-Free Pewter

Lead-free pewter is composed of 91 percent tin. The remaining percentage is made up of copper, antimony, and bismuth. Metals with a high tin content have excellent flow characteristics and work well with highly detailed figures. Pure tin is the best material for pouring figures, and figures made from pure tin can easily bend without breaking. Following these tips will yield the best results.

- Tin fumes are toxic, so be sure to do your melting and pouring in a well-ventilated area, and keep your head away from the melting pot.
- Heat the metal to between 550 and 650 degrees. Use a thermometer to obtain the correct temperature. Use the lowest temperature you can that produces good castings.
- Wait at least 15 minutes after the metal has melted before pouring the mold.

Using a Silicone Rubber Mold

Use a thermometer to discover the best temperature for use with your particular molds, and write that temperature on the mold with a permanent marker for future reference.

Step 1—Use graphite powder to lubricate the rubber mold. This will help prevent the cast metal from sticking to the rubber and will help the molten metal to flow freely through the smaller parts of the mold. With an applicator brush, dust a small amount of finely powdered graphite over the mold and then smear the graphite into a greasy coating with your fingertips. Clap the molds together to remove any excess powder.

Step 2—Position the tempered hardboard mold supports on the outside of each mold half. The mold should be clamped in at least two positions with spring clamps for best results.

Step 3—Heat the lead-free pewter to between 550 and 650 degrees. Use the coolest temperature that you can to obtain good quality castings. Experiment with the melting pot's heat settings to discover where the coolest temperature is.

Step 4—Pour the metal quickly into the mold, filling it to the top. If the mold fills too slowly, widen the throat of the sprue a little bit. A slow-filling mold will let the metal solidify prematurely, preventing the figure's extremities such as hands and hand-held objects from filling with metal. Use a sharp hobby knife, a small file, or a rotary burr to remove a small amount of the rubber from both halves of the mold.

Step 5—Using gloved hands, squeeze the sides of the mold together after pouring. Tap the mold gently on the work surface at the same time to help improve the detail and reduce the flashing (the small amount of metal that leaks around the parting line) around the figure. Always wear insulated leather gloves when pouring and holding the mold. Allow the mold to set for at least one minute before opening it. When the figure is being released from the mold, the mold can be bent slightly, if necessary.

Properly handled, the rubber molds will give you long and continuous use. Allow rubber molds to cool after each use. Because rubber is not as good a conductor of heat as is metal, the rubber molds retain the heat of the hot metal longer than a metal mold. Continuous rapid pouring can overheat and burn a rubber mold.

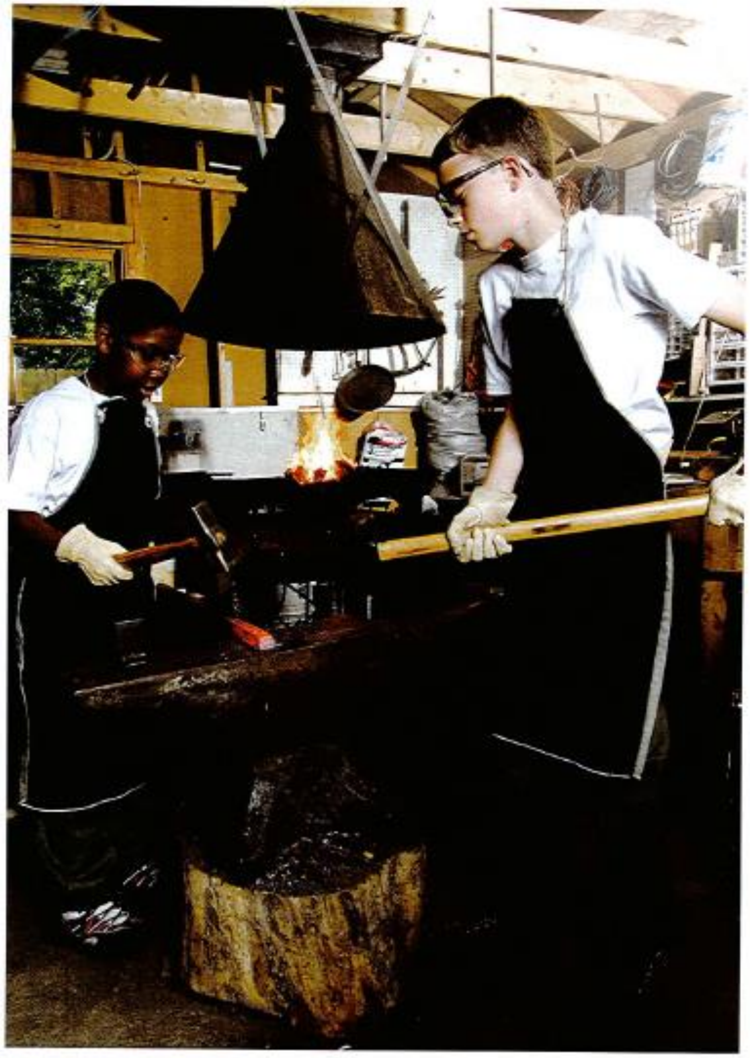
Using Multipart Molds

Complex figures must be cast in a slightly different way. For example, you might have created a figure of a man holding a flag in front of his body with his right hand. This figure cannot be cast as it was sculpted because the out-thrust arms cannot be released from the mold without destroying the mold. To avoid this, the right arm is carefully sawn off the sculpture and cast as a separate piece. Here is how.

Step 1—Center the figure's body in the mold, with the right arm placed nearby and off to one side and a connector called a "gate" dug between the two pieces. This permits the molten metal to flow from the body, along the gate, and into the component.

Step 2—Since you know that the figure's arm must be assembled onto the body, put a dab of clay on the inside of the arm at the shoulder joint and fashion it into a small pin. Place a small depression, the size of the pin, in the figure where the arm will attach. Once the mold is cast, file the arm into its finished shape and attach it to the torso using two-part epoxy glue.

The flagpole is cast as a separate item and attached to the figure later. Use paper to make the flag, and paint it using acrylic or enamel hobby paint.



The Blacksmith

When the Worshipful Company of Blacksmiths, a craft guild, was formed in London during the 12th century, its motto was "By hammer and hand, all arts do stand." This was not an idle boast. Before the availability of less-expensive machine-made products drove them out of business during the industrial revolution, blacksmiths were truly important craftsmen because they made the iron and steel tools that were used by other craftsmen. They also made all the iron hardware and kitchen equipment that was used by people from all walks of life.

Some blacksmiths in large cities concentrated upon making artistic items for use by architects and builders, specializing in making ornamental ironwork such as fences, gates, railings, balconies, and elegant sign frames.

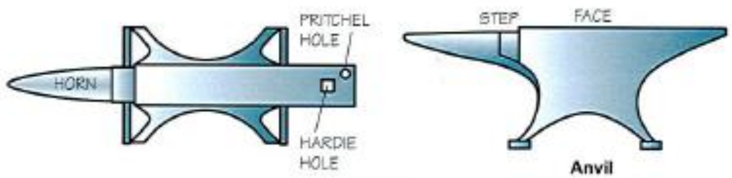
Today there is a tremendous interest in preserving this craft. In addition to the smiths who are working to rediscover the techniques of the old masters, today's blacksmiths are also artists, making all sorts of imaginative things from hot steel.

Because of the high temperatures generated by the *forge,* Scouts who select this option must work under direct adult supervision.

Basic Blacksmithing Tools

The blacksmith's tools have remained unchanged for thousands of years, and the blacksmith still uses the most basic elements—fire, water, and iron—to fashion both practical objects and objects of art.

Although an anvil is a sturdy chunk of metal, it is not a tool that can be abused with arbitrary or purposeless hammer blows. Doing so will leave pits and marks on the working surfaces that will show up on worked objects. Never strike the anvil directly with a hammer. Always have a piece of metal between the hammer and the anvil to avoid making dents and dings.



Anvil

The anvil's step is used for cutting metal, so it most likely will have dings and chisel marks. The face is where most of the work is done, so it must be kept free of any marks and imperfections. The heel has a square hole called the hardie hole and a round hole called the pritchel hole.

A hardie is a chisel-shaped tool with a square shank that sits in the hardie hole and is used with a hammer to cut iron and steel. A pritchel is a round punch; therefore, the pritchel hole is used to punch holes in hot iron and steel. The horn of the anvil is used to create scrolls and bend curves in bar stock.

Hardie

The leg vise is used to bend and twist hot iron and steel. The long leg sits in a cup attached to the shop floor. This gives the leg vise extra power to resist hard blows when a person is bending large pieces of metal with a sledgehammer.

The modern blacksmith's forge has an electric bellows attached to the firepot by a short length of sheet steel pipe. By burning soft coal with a steady stream of air from the bellows, the forge fire can reach 3000 degrees. When forging, keep the steel between 1400 degrees and 1800 degrees. Low-carbon steel burns at about 2200 degrees. Because the forge fire generates such high temperatures, always be alert to avoid burning the steel.

Cross peen hammer

Forge

The *cross peen hammer* is the blacksmith's heavy forging hammer. Large ball peen hammers are also used to forge out items on the anvil.

If work is not planned properly and stock is cut too short to be hand-held while forging, tongs will be necessary. The tongs used most often have flat jaws to hold flat or square stock or curved jaws to hold round stock. Some tongs have a square groove to make it possible to grasp small-diameter square or round bars. Blacksmiths often make their own tongs to hold objects with unusual shapes such as ax heads.

Tongs

Basic Blacksmithing Skills

Naturally, there are some fundamental techniques that must be learned before making anything at the anvil. Because there is not room in this pamphlet for a complete treatment of the subject, only the most basic information and techniques are presented here.

Think, "hit, rotate 90 degrees, hit, rotate 90 degrees," and so on until the taper is completed.

Forging a Taper

To forge a taper, hammer the end of a hot bar into a tapered point like that of a center punch. To avoid having to use tongs, cut a length of bar long enough to permit holding the cool end in your gloved hand when forging. To make the taper, tilt the hammerhead and hit the hot bar with angled blows.

Hit the hot end once and then rotate the bar 90 degrees and hit it again. Repeat this process of hitting and rotating the bar back and forth, forcing the hot steel into a taper. This action is called *tumbling*. Think, "hit, rotate 90 degrees, hit, rotate 90 degrees," and so on until the taper is completed.

Hot steel can be bent over the horn of an anvil.

Using the Horn of the Anvil

Position the hot steel on the horn so that the hot portion juts outward past the horn. Strike the hot section a soft blow, forcing it to bend over the curve of the horn. To keep from flattening the metal, hit it at an angle, and avoid hitting it straight down on the horn. Always hit the metal beyond where it touches the horn.

Using the Edge of the Anvil

Use the edge of the anvil to make L-shaped bends in objects. Heat the spot to be bent to an orange heat. Position the hot spot on the outside edge of the anvil, letting the cooler tip project over the anvil. Tap the end of the bar straight on with a hammer, forcing the hot spot to bend over the edge. To square up the bend, tap the bend at the front of the anvil, where you can be sure to get a 90-degree bend. Be careful not to strike the bend at the corner of the anvil or you will squash the material there, weakening the piece.

Bending steel over the edge of the anvil creates L-shaped bends.

Twisting Steel

Twisting is used to put a decorative element in square and flat stock. Heat a bar to an even orange color where the twist should appear. Clamp one end of the hot steel bar in the vise, grab the other end near the hot section with tongs or a bar twister, and rotate the bar 360 degrees. An even heat means an even spiral.

Preserving Your Work

Paraffin wax makes a fine preservative. Be sure that you are wearing gloves because the metal will still be quite warm. Rub a candle stub over your work while it is still warm, letting the liquid wax flow into all the crevices. Be careful not to overheat your work because the wax will evaporate or burn off, which is ineffective. Just before the wax hardens, rub off the excess wax with a shop rag.

Basic Tools Needed

- ❑ 125-pound anvil (minimum)
- ❑ Stumps (one for the anvil; one much taller one for the vise)
- ❑ Two turnbuckles for securing anvil to stump
- ❑ Two 12-inch lengths of welded-link chain to pass over the anvil's feet and connect to the turnbuckles
- ❑ Two eye screws to secure the turnbuckles to the stump
- ❑ Leg vise or large machinist's vise
- ❑ Firepot
- ❑ Metal forge top with legs
- ❑ Mechanical bellows
- ❑ Bellows pipe
- ❑ Measuring tape or folding rule
- ❑ Soapstone pencils (for marking steel)
- ❑ 24-ounce cross peen hammer
- ❑ 12-ounce ball peen hammer
- ❑ Hot hardie
- ❑ Cold hardie
- ❑ Flat-jawed tongs
- ❑ ¼-inch and ⅜-inch bolt tongs
- ❑ Pea-sized soft coal, approximately 50 pounds per eight-hour day
- ❑ C-clamp or locking-grip pliers
- ❑ Center punch
- ❑ Drill press
- ❑ Drill, sized to match the diameter of the nails used as rivets
- ❑ Shop apron
- ❑ Leather gloves
- ❑ Safety glasses

Materials

- ❑ ¼-inch by ½-inch flat, mild steel (C1020, A36, or equivalent)
- ❑ ¼-inch diameter mild steel (C1020, A36, or equivalent)
- ❑ ¼-inch or ⅜-inch square mild steel (C1020, A36, or equivalent)
- ❑ ⅝-inch round or square medium-carbon steel (C1065, W1, or equivalent)
- ❑ ¼-inch square, or ¼-inch by ½-inch flat, medium carbon steel
- ❑ Tenpenny or larger nails
- ❑ Candle stubs
- ❑ Cooking oil

Blacksmithing Projects

The following projects are practical objects that a Scout can use while camping. Because the creation of art is personal to each artist, no art objects are illustrated. If you prefer to be artistic rather than practical, use your imagination and remember to apply the basic metalworking techniques.

Forging a Dutch Oven Lid Lifter

Step 1—Sketch the Dutch oven lid lifter to use as a pattern. The length of the lifter from the hook all the way around the handle should be about 16 inches.

Step 2—Using a hacksaw, cut a 16-inch length from a piece of ¼-inch square mild steel.

Step 3—Place the metal in the forge, and bring the end of the shaft to an orange heat.

Step 4—Using tongs, remove the piece from the fire and forge a taper in the end of the shaft (A). Flatten the taper (B).

Step 5—Carefully reheat the flared taper and bend it about 30 degrees by tapping it over the edge of the anvil (A). Bend the tip back (B).

Step 6—Reheat the hook end, then create the J-hook by bending it over the anvil horn. Bring the hook to the face of the anvil to "true it up," or straighten the bar, leave the J slightly open to make grabbing the oven handle easier. Plunge the piece in water to cool it.

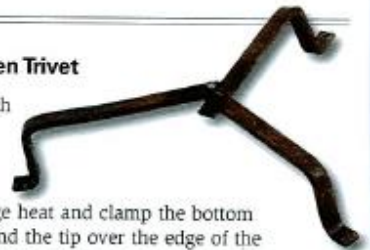
Step 7—Place the handle end of the bar in the forge, and heat the center of the bar to an orange heat. Using tongs, transfer the piece from the fire to the workbench and clamp it in the vise. Place a 90-degree bend in the center.

Step 8—Grasp the piece with tongs and reheat it. Without touching the hot metal, forge a T-handle in one end by bending the bar over the horn of the anvil. Make sure the handle is big enough for all of your fingers to fit comfortably inside without touching or grazing the hot Dutch oven.

Step 9—Reheat the shaft and apply a decorative twist, then true up the shaft again, if needed.

Step 10—Wearing gloves to protect your hands from the still-warm metal, rub a candle stub over the finished piece to preserve your work. Just before the wax cools, remove the excess with a rag.

Forging a Dutch Oven Trivet



Step 1—Cut three 7-inch pieces of ½-inch by ¼-inch mild steel.

Step 2—Heat the tip of one piece to an orange heat and clamp the bottom half inch in the vise. Bend the tip over the edge of the vise in a 90-degree angle. Cool the piece.

Step 3—Reheat the piece, then hook the bends under the vise jaw and bend them upward like an elephant with a raised trunk to form the foot of the trivet.

Step 4—Repeat steps 2 and 3 with the other two pieces. Be careful to make all three pieces the same shape and size so the legs of the finish piece will nest correctly. Allow the pieces *air-cool* for at least an hour. (Cooling in water will make the metal too hard to drill.)

Step 5—Stack the pieces and clamp them firmly together. Use the center punch to place a mark in the center of the bar, about a half inch from the unbent ends. Use vise grips to hold the punch steady, then make a dimple in the top piece by giving the punch a solid blow with a mallet.

Step 6—Lubricate the dimple with a drop of oil and, using the mark as a guide to keep the drill bit from wandering, drill a hole through the first piece. To ensure that the holes in all three pieces will line up, stack the second piece under the first and use a nail to make a tiny mark to guide drilling the second piece. Stack those two pieces on the third piece and mark it. Then drill a hole in piece three. This method ensures that all three holes line up and that the legs will nest correctly.

Step 7—Stack the three pieces and slide a nail through the hole. Use a file or another nail to mark the shaft about 3/16 inch above the top of the hole.

Step 8—Clamp the shank of the nail in a vise and use a hacksaw to cut it at the mark.

Step 9—Take the trivet pieces to the anvil and slide the nail into place. Using the peen end of a ball peen hammer, strike in a circle around the protruding shaft of the nail, creating a mushroom shape. This is called "upsetting" the metal because the metal is thickened and shortened on the end. Gradually increase the size of the mushroom until the rivet has thickened enough to keep the legs firmly attached without any wobbling.

Step 10—Heat the trivet a little in the forge, and then lubricate the trivet with wax to prevent it from rusting.

Don't overdo it here—you don't want to thicken the rivet's shank so much that the legs are locked in place, making it impossible to pivot the legs around the rivet. You want the legs free to rotate so that the three legs of the trivet can be nested together and stored inside a Dutch oven.

Spread the trivet's legs to use the lid of the Dutch oven as a frying pan. Fold the legs and place the trivet in the Dutch oven for storage.

Careers in Metalworking

Master metalworkers have their choice of many interesting hands-on careers, including gunsmiths, welders, founders, and sheet metal mechanics. Other metalworking careers, while not as hands-on, require a background and extensive knowledge in metalworking, including structural engineers and architects.

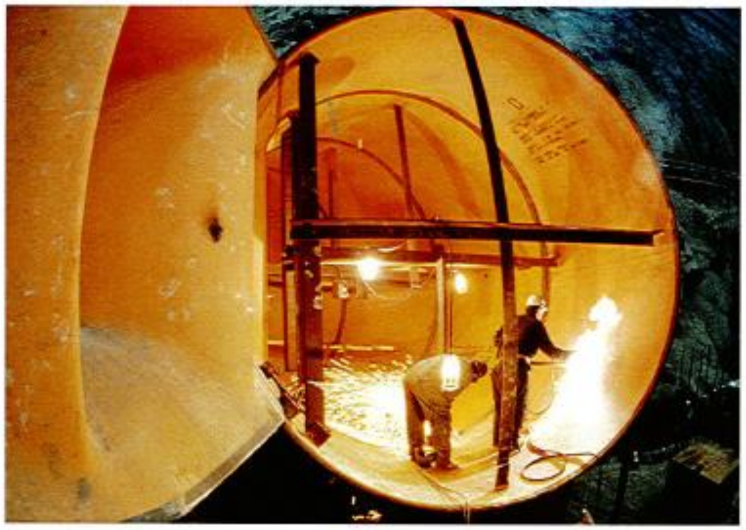
Basic Skills of a Metalworker

While the four metalworking disciplines described in this pamphlet—tinsmith, silversmith, founder, and blacksmith—are quite diverse, the basic skills a worker in each specialty needs are the same.

Metalworkers should be strong in basic math skills, including geometry, and they should have good verbal and written communication skills. The hands-on nature of the work requires good hand-eye coordination, attention to detail, and an interest in precision. A metalworker's logic skills should be sharp, because he needs to be able to break down a complex task into a logical sequence of steps. Creativity and a good eye for balance, conceptualization, composition, and other qualities of an artist are positives for metalworkers, too.

Education and Career Paths

Many metalworkers need a high school education, followed by vocational school or an apprenticeship, to become professional hands-on metalworkers. Some may choose to work for a shipyard, an automobile-parts manufacturing plant, or an aircraft manufacturing plant. Others may decide to work for large machine shops that specialize in rebuilding engines or manufacturing specialty parts for other companies. Still others may decide to become sheet metal workers, who manufacture heating and air conditioning items used in the construction of private homes, manufacturing plants, and office buildings.

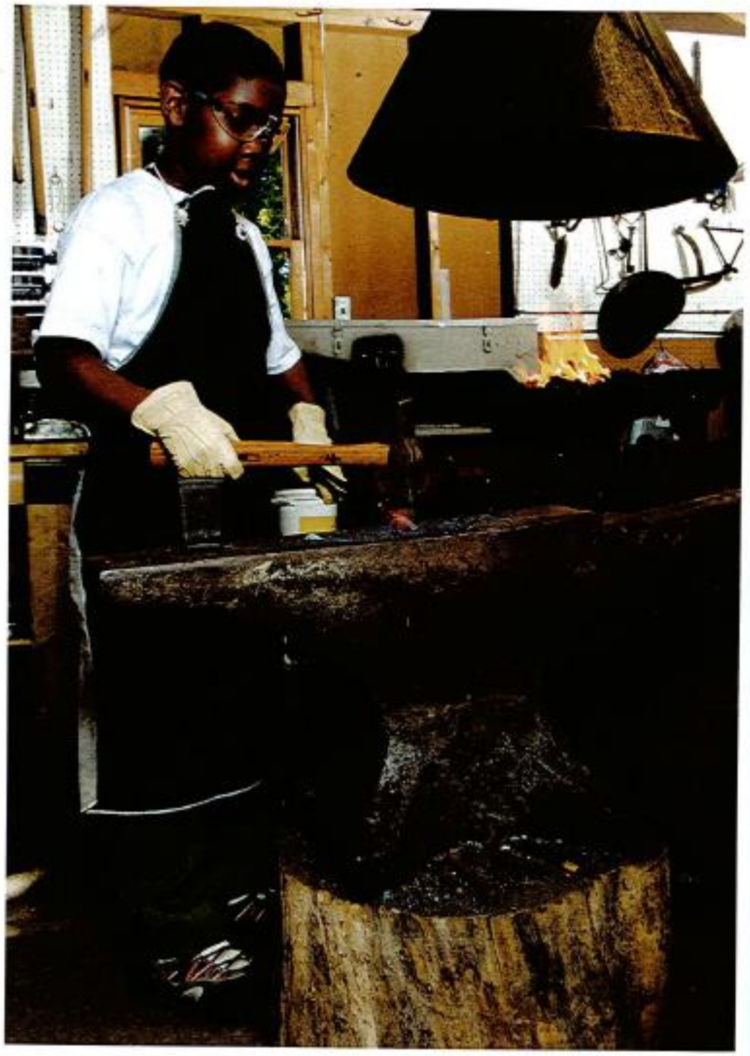


Some professionals with interests in metalworking earn college degrees in mechanical, structural, or metallurgical engineering. They will tackle such projects as designing bridges or creating specialty metals in a steel mill or an aluminum-producing facility. An engineer who is familiar with the properties of metals might find a good career in the automobile, shipbuilding, aircraft, petroleum, defense, or parts-manufacturing industry.

High school courses that will help prepare a future metal-worker include art, math, and science. Perhaps the most basic knowledge a metalworker can acquire is an understanding of the strengths, limitations, and metallurgical properties of typical metals used in the craft.

Any metalworker can go into business for himself after learning the trade as an apprentice. Successful metalworking entrepreneurs are those who learn to balance their creative side with their practical business side. Some of these successful entrepreneurs make and sell architectural hardware to construction companies, or create fanciful and imaginative sculptures and décor for banks, law offices, and other professional buildings.

Many professional associations, such as the Artist Blacksmith's Association of North America and the Society of American Silversmiths, can give you advice on pursuing a metalworking career. If you are considering such fields as sheet metal mechanic, machinist, or welder, visit a local metalwork shop or workers' union and ask about apprenticeships or on-the-job training opportunities.



Glossary

alloy. A substance having metallic properties and being composed of two or more chemical elements of which at least one is an elemental metal.

annealing. A treatment consisting of heating to and holding at a suitable temperature followed by cooling at a suitable rate, used primarily to soften metals but also to simultaneously produce desired changes in other properties.

anvil. A heavy iron block with a steel face upon which metal is shaped with a hammer.

bench pin. A rectangular wooden board clamped to a workbench used by jewelers to control a piece when using a jeweler's saw or needle file.

blackening. The act of applying carbon such as candle soot to a metal mold or applying graphite dust to a rubber mold. The carbon acts as a releasing agent, making it easier to extract the cooled casting from the smaller recesses of the mold.

bouge. The curved portion of a plate or a tray from the edge of the rim to the bottom of the plate or tray.

brazing. Joining metals by flowing a thin layer (capillary thickness) of nonferrous filler metal into the space between them. Bonding results from the contact produced by the dissolution of a small amount of base metal in the molten filler metal without fusion of the base metal. Sometimes the filler metal is put in place as a thin solid sheet or as a clad layer, and the composite is heated, as in furnace brazing. The term brazing is used where the temperature exceeds some arbitrary value, such as 800 degrees; the term soldering is used when the temperature is lower than the arbitrary value.

casting. (1) An object at or near finished shape obtained by solidification of a substance in a mold. (2) Pouring molten metal into a mold to produce an object of a desired shape.

corrosion. The deterioration of a metal by a chemical or an electrochemical reaction to oxygen present in its environment.

cross peen hammer. A hammer where the peen (the end that comes to a blunt taper) runs from left to right with reference to the face. Also called a blacksmith's hammer or an engineer's hammer.

Crucible

crucible. A vessel made of a material such as porcelain that can withstand high temperatures without cracking, used for melting a substance that requires a high degree of heat.

crystal. A solid composed of atoms, ions, or molecules arranged in a pattern that is repetitive and three-dimensional.

cure. To allow the hardening process to run its course by letting the piece rest for a period of time.

dross. The impurities that form on the surface of molten metal.

ductility. The ability of a metal to deform plastically without fracturing, being measured by elongation or reduction of area in a tensile test or by other means.

ferrous. Of, relating to, or containing iron.

flux. A substance used to clean away impurities caused by oxidation during soldering or brazing. Solder will only adhere to the metal where flux has been applied.

forced-draft fire. A fire where air is deliberately introduced through some mechanical means (such as a bellows) to significantly increase the rate of combustion.

forge. A furnace where bars of metal are heated prior to being hammered on an anvil. The shop that houses this furnace is also called a forge.

foundry. A furnace where metals are heated to the liquid state prior to being poured into a mold (casting). The shop that houses this furnace is also called a foundry.

hardie. A blacksmith's chisel-like tool that fits in an anvil's square hole (the hardie hole) and used to part bars of metal. To part a bar of metal with a hardie, a smith lays the metal over the hardie's chisel-shaped end and strikes the metal with a hammer.

hardness. Resistance of metal to plastic deformation, usually by indentation. However, the term may also refer to stiffness or temper, or to resistance to scratching, abrasion, or cutting.

Hem

hem. To fold a small portion (between $\frac{3}{16}$ inch and $\frac{3}{8}$ inch) of the edge of a piece of sheet metal back upon itself. Hemming acts to both stiffen the sheet metal and to create a safe edge, preventing cuts.

malleability. The characteristic of metals that permits plastic deformation in compression without rupture.

mallet. A hammer with a barrel-shaped head made of wood.

Melting pot

melting point. The temperature at which a solid begins the transformation into a liquid.

melting pot. A sturdy vessel (usually metal) used to melt metal.

metal. An opaque lustrous elemental chemical substance that is a good conductor of heat and electricity and, when polished, a good reflector of light. Most elemental metals are malleable and ductile, and generally heavier than the other elemental substances.

metallurgy. The science and technology of metals. Process metallurgy is concerned with the extraction of metals from their ores and with the refining of metals. Physical metallurgy deals with the physical and mechanical properties of metals as affected by composition, mechanical working, and heat treatment.

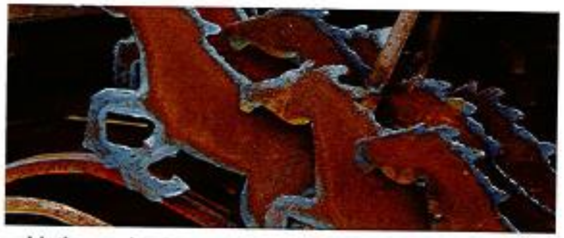
Mold

mold. A cavity in which a substance is shaped. It is used in the casting of molten metal.

native metal. A metal that occurs naturally in a nearly pure form. Gold nuggets are an example of a native metal.

nonferrous. Of, or relating to, metals other than iron.

ore. A natural mineral that may be mined and treated for the extraction of any of its components, metallic or otherwise.



oxidation. A thin layer of rust or corrosion that forms on the surface of unprotected metal because of the metal's interaction with oxygen in the atmosphere.

parting line. The horizontal line formed where the two halves of a two-piece mold meet. A parting line is often placed at an object's halfway point when viewing the object from the side.

pattern. (1) A three-dimensional model used for making the cavity in a mold into which molten metal is to be poured to form a casting. (2) A piece of stiff paper or light-gauge sheet metal that has been cut to conform to the outlines of a component part of a sheet metal project. The craftsperson then traces the paper or metal pattern's outline onto the sheet metal from which the component part is to be constructed.

pickling solution. Any of various baths used to clean metal. One of the pickles used by silversmiths is a 10 percent sulfuric acid, 90 percent water solution. A pickling solution is most often used to remove the metal oxide that has formed on the surface of silver. Pickling solutions also will remove the flux used to solder seams.

planishing. The process of hammering or refining a metal surface.

platewell. The flat bottom of a tray or plate into which the bouge runs.

quench. To cool (as in heated metal) by immersion (as in oil or water).

raising. The process of creating a hollow form from a flat sheet of metal by forming it over a cast-iron stake.

rivet. A mechanical fastener that is hammered in place.

rolling. The technique of creating rounded shapes, performed either using an anvil or a slip-form roller.

seaming. Connecting two pieces of sheet metal without welding. Seams are soldered or brazed to ensure that the joint remains together.

sinking. The process of creating a concave shape from a flat piece of metal by hammering the metal over the top of a shaped form (sinking block).

smelting. A metalworker's term for exposing ore-bearing rocks to high temperature to separate the metal from the rock.

sprue. The hole through which metal is poured into the mold during the casting process.

soldering. Similar to brazing, but the filler metal has a melting temperature range below an arbitrary 800 degrees. Soft solders (low melting point) are usually lead-tin alloys, although pure-tin solders are available and are recommended.

stake anvil. A polished cast-iron or steel tool placed in a vise and used during the forming and planishing of metal.

steel. Commercial iron that contains carbon in any amount up to about 1.7 percent as an essential alloying constituent, is malleable under suitable conditions, and is distinguished from cast iron by its malleability and lower carbon content.

tempering. The process of relaxing the brittleness of a water- or oil-hardened steel by reheating it at a lower temperature.

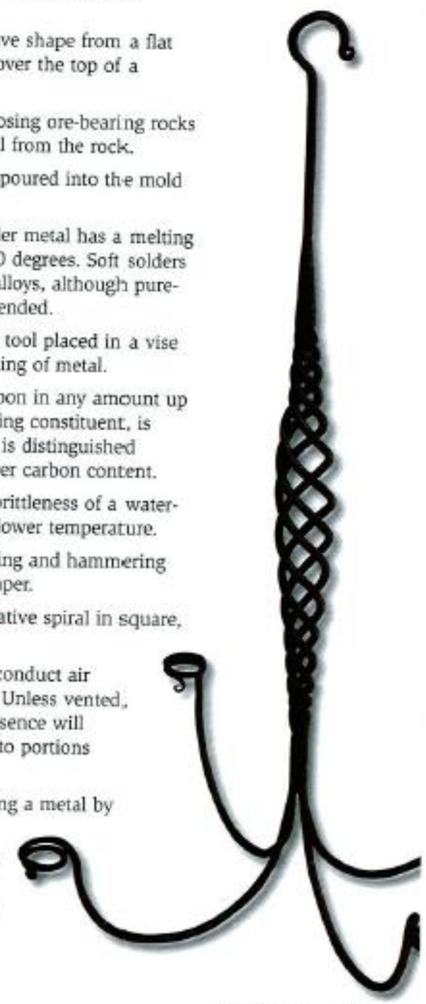
tumbling. The process of alternately rolling and hammering the end of a bar of hot metal to forge a taper.

twisting. The process of making a decorative spiral in square, hexagonal, or octagonal metal.

vents. Small tunnels placed in molds to conduct air out of a mold during the casting process. Unless vented, trapped air has nowhere to go and its presence will prevent the molten metal from flowing into portions of the mold.

work hardening. The process of hardening a metal by hammering it.

yield point. The point at which a crystal under pressure has been transformed to such a state that, when the transforming pressure is released, the crystal cannot return to its original condition.



Metalwork Resources

The resources listed below represent only a fraction of those available to the hobby metalworker. Check the local library and bookstores for additional titles, and don't be afraid to purchase out-of-print titles or titles with older copyright dates—the majority of metalworking techniques are timeless.

Visit the Boy Scouts of America's official retail Web site at *http://www.scoutstuff.org* for a complete listing of all merit badge pamphlets and other helpful Scouting materials and supplies.

Books

Metalworking

Almeida, Oscar. *Metalworking.* Drake Publishers Inc., 1971.

McCreight, Tim. *The Complete Metalsmith: An Illustrated Handbook.* Davis Publications, 1991.

Walker, John R. *Modern Metalworking.* Goodheart-Wilcox Company Inc., 1993.

Metal Can Craft

Elliot, Marion, and Peter Williams. *Tinwork.* Laurent Books, 1996.

Hansson, Bobby. *The Fine Art of the Tin Can.* Lark Books, 1996.

Maguire, Mary. *Tin Crafts: Over 20 Projects for the Home.* Lorenz Books, 1999.

Tinsmithing/Tinware

DeVoe, Shirley Spaulding. *The Art of the Tinsmith—English and American.* Schiffer Publishing Ltd., 1981.

Handsberg, Ejner. *Shop Drawings of Shaker Iron and Tinware.* Berkshire House Publishing, 1993.

Silversmithing

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——. *The Metalsmith's Book of Boxes and Lockets.* Hand Books Press, 1999.

Metal Casting

Ammen, C. W. *The Complete Book of Bronze Casting.* Tab Books Inc., 1983.

McCreight, Tim. *Practical Casting.* Brynmorgan Press, 1994.

Blacksmithing

Andrews, Jack. *The New Edge of the Anvil.* Skipjack Press, 1994.

Blandford, Percy. *The Practical Handbook of Blacksmithing and Metalworking.* Tabb Books Inc., 1980.

Weygers, Alexander G. *The Complete Modern Blacksmith.* Ten Speed Press, 1997.

Organizations and Web Sites

Artist-Blacksmith's Association of North America
Web site: *http://www.abana.org*

The ArtMetal Resource to Metalworking
Web site: *http://www.artmetal.com*

National Ornamental Metal Museum
Web site: *http://www.metalmuseum.org*

Society of American Silversmiths
Web site: *http://www.silversmithing.com*

Materials and Supplies

Covell Creative Metalworking
106 Airport Blvd.
Freedom, CA 95019
Toll-free telephone: 800-747-4631

Rio Grande
4516 Anaheim Ave. NE
Albuquerque, NM 87109
Toll-free telephone: 800-545-6566
Web site: *http://www.riogrande.com*

Shor International Corporation
20 Parkway West
Mount Vernon, NY 10552
Telephone: 914-667-1100
Web site:
http://www.shorinternational.com

Stebgo Metals
P.O. Box 65368
St. Paul, MN 55165
Toll-free telephone: 800-289-0138

Widget Supply
P.O. Box 3282
Albany, OR 97321
Telephone: 541-924-8882
Web site: *http://www.widgetsupply.com*

Casting Metal, RTV Silicone, Premade Molds Castings
P.O. Box 298
Eastsound, WA 98245-0298
Toll-free telephone: 800-346-0567
Web site:
http://www.miniaturemolds.com

The Dunken Company Inc.
P.O. Box 526
Willis, TX 77378
Toll-free telephone: 800-544-6653
Web site: *http://www.dunken.com*

Centaur Forge
117 N. Spring St.
P.O. Box 340
Burlington, WI 53105-0340
Toll-free telephone: 800-666-9175
Web site: *http://www.centaurforge.com*

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Andrew G. Hagemann, courtesy—cover *(anvil)*; pages 10 *(top)* and 49 *(bottom)*

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Wikipedia.org, courtesy—page 11

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John McDearmon—pages 25–27 *(illustrations)*, 38 *(patterns)*, 42–45 *(all patterns and illustrations)*, 52 *(illustrations)*, 55 *(all)*, 58–59 *(illustrations)*, 67–68 *(all)*, 74 *(center, both)*, and 80–81 *(all illustrations)*

Brian Payne—pages 56 *(bottom)* and 87 *(bottom)*