

PRACTICAL CASTING
A Studio Reference



Tim McCreight

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My wife Jay has played a vital part in this book; her advice, good judgement and moral support are reflected on every page. Our children, Jobie and Jeff, are a boundless source of enthusiasm to us both.

Thank you, thank you.



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INTRODUCTION

When I wrote *The Complete Metalsmith* in 1982 I envisioned a series of books that would share the same format. This is the second step toward that idea. I hope it retains the popular aspects of the first book and introduces some improvements. One of the ideas behind this series is to divide information into easily assimilated pieces that are arranged in a straightforward practical sequence. The format is largely visual, and has a bias toward the simplest, cheapest way to achieve a specific result.

This volume, like its predecessor, is printed on heavy paper and uses a plasticized cover. The spiral binding will allow the book to lay flat on a workbench. Optional index tabs are provided at the back of the book so you can create your own chapter dividers if you would find them helpful.

The first five chapters deal with lost wax investment casting, the method most commonly used in jewelrymaking. The process is divided into its several aspects, and each is discussed fully. The remaining chapters describe alternate casting techniques; some are simpler than investment casting and some are more complex. A glossary is provided at the end of the book for quick reference. This book makes no attempt to cover related aspects of metalworking such as soldering and finishing. It is because of this singleness of purpose that *Practical Casting* can offer the complete coverage it does.

While most of the information in this book can apply to casting on any scale, bear in mind that it is written as a classroom text for situations where an instructor is present and volume is limited. It is not intended as a resource for industry, where other safety requirements may exist. For help in this area, contact your state office of Occupational Safety and Health Administration (OSHA) or the Industrial Safety Division of your state Labor Department. It is your responsibility to protect yourself and those around you.

OVERVIEW

Considered historically, casting is not a specific technique but a logical extension of the process of refining ore and consolidating nuggets. We can imagine that when the first metalsmiths found their material in the ashes of a fire, they discovered that it retained the shape of the ground on which it was spilled. All subsequent technology in casting has developed from this beginning.

When a worker pours an ingot as the starting point for fabrication, it is logical to cast a shape that is close to the desired end product. When making wire we cast a rod, and so on. Somewhere in ancient history, a metalsmith realized that the ingot could be poured to an almost finished shape. With this discovery the ingot mold became the object mold, and casting as an art form was born.

It appears that this revolutionary discovery was made independently by several cultures. We know of highly sophisticated bronze castings made in China about 7000 years ago. Not long after that, the ancient Egyptians evolved highly developed casting skills, creating stunning work that has inspired generations of metalsmiths. Around 500 BC, Greek smiths developed the blast furnace, in which a jet of forced air was directed at iron ore. This important development produced consistently better metal at a relatively low cost. In one sense, this marked the beginning of the Industrial Revolution.

Compared with most enterprises, casting has changed very little in the last 4000 years. The materials have been improved and the scale has

grown, but the process is virtually intact. Also intact over the years is the terminology.

Mold (or, in England, *mould*) is the negative impression into which a softened or fluid material is pressed, poured or injected to achieve a pre-determined shape.

A mold is an intermediary step between two objects: the original pattern and the finished casting. The material and complexity of the mold depends on each of these elements. A complex pattern will dictate certain kinds of molds and rule out others. The melting point of the material being cast also restricts the choice of mold material.

Some molds can be separated for removal of the casting. These are called *piece molds*. They may be made of only two pieces, or may be very complicated and involve a dozen or more parts. Some piece molds use flexible materials to provide increased versatility. Others are made in one piece which must be broken apart after being filled to retrieve the cast piece. These are called waste molds, because the mold must be destroyed, (i.e., *wasted*) with each use.

The pattern or model is an exact image of the object being produced. The model material is chosen to suit the mold, the casting method and the intentions of the modelmaker.

In manufacturing, casting is one of many processes used to duplicate a shape. Casting takes its place among other processes such as blanking, drawing, stamping, spinning and so on. The manufacturer selects a

production method that will create the highest yield of the best product at the minimum expense. Casting often fills these requirements, with new applications being found every day. Techniques originally developed for dental work were taken up in the 1940s by the jewelry trade, and today, in addition to jewelry, hundreds of thousands of small parts such as valves and machine components are being cast. As the manufacturing community turns its attention to casting, developments and refinements occur with great speed. More research is being done on casting each year now than was done in the whole decade of the 1950s.

Without meaning to diminish the importance and excitement of mold-making and casting, it must be noted that the peak of creativity is in making the model. Most of the characteristics of the final piece—its shape, proportion, contours, and usually its surface—are resolved here. The success or failure of moldmaking and casting is defined as the degree of similarity between the original model and the finished casting. Every artisan is open to the value of “spontaneous design” (happy accidents) but control of technique is important to good design.

To borrow a concept from the noted craft author David Pye, the model is a “storehouse of the time and talent” of its creator. Through the technical expertise of the moldmaker and the caster, the skills of the designer and modelmaker can be realized. In fact with a reusable mold, they can be realized in great number. Technical skill, no matter how great, cannot improve deficiencies in the original model. The best efforts in casting a mediocre model will result in a mediocre duplicate.

Division of labor is almost as old as metalsmithing itself. Ancient Egyptian paintings show apprentices doing the busywork of their accomplished masters. In that and most other cultures it was generally true that a master achieved skills and status by working through the levels of the workshop. Though the master no longer performed the menial tasks of the shop, knowledge of them came from personal and usually long experience. In later cultures, and most especially since the 19th century industrial revolution, roles within a large casting shop have been hired out as needed. It is possible therefore to find a modelmaker who is only vaguely informed of the subsequent processes needed to convert that model into a finished work.

If there is a premise to this book it is that these subdivisions have little value, and are perhaps detrimental, to the artisan. For the jeweler working on limited production or one-of-a-kind pieces, it is common to work a piece under one’s own hands from start to finish. In a highly specialized world, this has an emotional appeal and a psychological reward.

The shape, scale and imagery of a model have more to do with design (an aesthetic topic) than with casting (a technical concern). A study of design is as fascinating as it is important but it is outside the scope of this book.

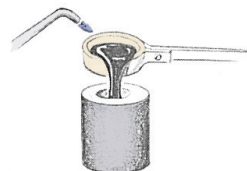
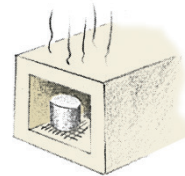
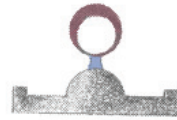
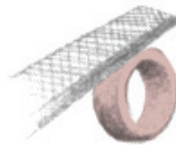
A sense of design—knowing of what shape to make—is both vital and elusive. Good design is a rare alchemy of perception, inspiration, diligence, and response to materials. For our purposes, we must be content to encourage diligence, reward perception, hope for inspiration and turn our attention to technique.

The technique most widely used to cast jewelry today is the lost wax investment mold process. The ability of this process to produce consistently clean castings with a minimum of equipment accounts for its wide popularity. The next five chapters describe this process in detail.

With a relatively small investment of time and money, any metalsmith will be able to master the process of lost wax casting. It should be noted, however, that not everyone has the space, temperament or need to set up a full-scale casting studio. An online search will quickly link companies that are in the business of casting the models of independent jewelers. For metalsmiths whose limited volume does not justify a large casting, setup these companies provide a valuable service.

The Lost Wax Process

- 1 A model is made of wax or another completely combustible material.
- 2 The model is mounted on a wax rod, called a sprue.
- 3 The sprued model is mounted onto a base and fitted with a watertight open-ended cylinder called a flask.
- 4 A plaster-like material called investment is mixed to a creamy consistency and poured over the model, filling the flask. Steps are taken to remove bubbles from the mix.
- 5 The investment is dried and then burned out (heated in a kiln) to remove all traces of the model. Lost wax, get it?
- 6 While the mold is still warm from burn-out, molten metal is poured or forced into the mold, where it assumes the shape of the original model.
- 7 After brief cooling, the mold is quenched in water, which breaks it open and releases the casting.



Making a Model

The first step in making an investment casting is to create a model or pattern, that is an exact image of the object to be cast. The aesthetics of a piece—its shape, thickness, surface, and texture—are intimately bound up with the material being used. Experimentation and experience are the best teachers of these important factors.

Wax is the most popular material for modelmaking because it can be formulated to achieve a range of properties and it burns out cleanly.

WAXES

Because wax is a familiar material, it's easy to take it for granted. Don't. It can be dangerous. Wax at the dangerous, overheated temperature of 500° F looks the same as wax at 150°F/65°C. Spilled wax can adhere to skin and cause severe burns. Always keep a bucket of cold water handy as first aid for such spills.

Melt wax only in a double boiler arrangement. This can be as crude as a tin can set into a bucket of water, but it is very important. As long as there is water in the larger vessel, the wax won't be heated much above the boiling point of water. If you melt wax directly on a burner or in a flame, there is the possibility that it will reach its flash point and explode. This can spray burning wax great distances and cause serious injury.

Most waxes expand as they melt. Because of this, it is unsafe to set a pot of solid wax onto a burner. The lower section will melt and expand but the still solid cap will seal the pot, allowing pressure to build up. At some point the cap will be weak enough and the pressure great enough to cause the wax

to erupt, again with potentially disastrous results. Tip the pot like this, either when allowing the wax to harden in the pot, or when remelting.



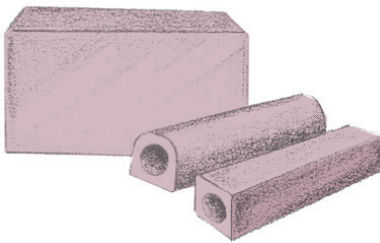
Waxes are made of three kinds of ingredients, selected, purified, and blended to achieve specific properties.

1. WAXES - white beeswax, carnuba, candelilla (from palm trees), ceresin, ozenite (earth waxes), and synthetics are all used.
2. RESINS - These are tree saps like damar, balsam, kauri copal (gum), shellac, and rosin from pine trees.
3. FILLERS - Talc, starch, chalk, soapstone, pumice, and wood flour are fillers.

Every wax has its liquidus and solidus points. The former is the temperature at which the wax melts, the latter is the point at which it hardens. In between there is a temperature spread, called the *plastic range*, in which the wax is easily worked. It will be beneficial to know these points and the range between them. A sense of the temperatures can suffice, but for really accurate work it's worth the effort of making a test to determine the exact range of the wax you are using.

Melt a small quantity of wax in a tin can, set in a double boiler arrangement. With a candy thermometer, measure the temperature of the wax when it has melted into a puddle. When all the wax has melted, remove the can from the double boiler. Watch the thermometer and note when a skin forms on the wax. These two points are the liquidus and solidus temperatures.

Carving Waxes



These waxes are worked reductively (also called subtractively). They are whittled or filed away to create a shape, similar to the process of a sculptor working in stone or wood. Carving waxes are available in blocks, tubes, rods, and sheets of varying thickness and are made in several degrees of hardness. Most are too tough to be bent or molded in the fingers. Because each manufacturer uses its own color code, don't assume that a blue wax from one source will behave like a blue wax from another company. Experiment to choose a wax that suits your personal work style.

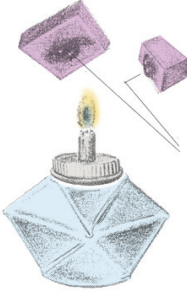
Blending Waxes

Waxes are purified, refined and blended to create materials with specific toughness, flexibility, viscosity and melting points. They are dyed to color code the various types and to prevent eyestrain when carving. Any wax, from candles to household paraffin, can be used for modelmaking, but most modelmakers prefer to buy a ready-to-use product.

Unique waxes can be created by blending two or three casting waxes. Because these are clean when purchased, mixing them almost always yields a workable wax as long as you take care that the wax is kept clean and is not overheated as it is being prepared. Burning out some of the ingredients will change a wax, usually for the worse, leaving it pale, brittle, and sometimes full of air bubbles.

PREPARING A BLOCK

Any shape can be cut down from a single block, but there are cases where this is time consuming and wasteful.



Often it's more efficient to weld blocks of wax together to create a generalized outline of a design.

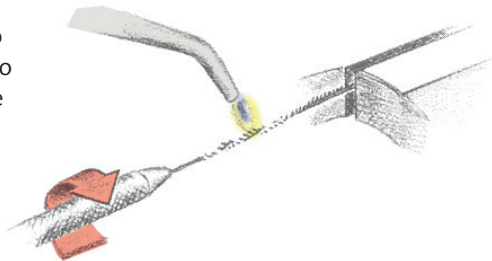
To fully bond two blocks of wax, both pieces must be molten at the point of contact. This can be achieved in the flame of an alcohol lamp or with an electric soldering pencil. Press the fluid surfaces together with a slight twisting motion and allow the wax to harden completely (about a minute, or until the original color returns) before beginning to carve. Be careful not to touch the molten wax: it will stick to skin and can cause a nasty burn.

CUTTING

Any sawblade can be used to cut wax, but some are better than others. A jeweler's blade will cut, but the friction heat it generates melts the wax along the kerf, or line just cut. If the blade halts for even a few seconds, the wax hardens (freezes) along the blade and locks it into place. A bandsaw, hacksaw, or coping saw will avoid this problem, but cannot cut around tight corners.

A spiral sawblade is a jeweler's blade that has been twisted during manufacture so its teeth project outward in all directions. This cuts a wide swath that does not seal up on itself. It can be a little difficult to guide with accuracy, so cut outside the intended design.

Spiral blades can be bought from most suppliers of jewelry tools, but if one is needed in a hurry, you can make your own. Grip the blade in a vise at one end and a pair of pliers or a pin vise at the other. Heat it to a bright red with a torch flame and twist. You'll probably find you can keep only about a half inch red at a time. Twist this, then move down the blade to twist the next section. Because this blade will be used only on soft materials, it's not necessary to harden and temper it.



FILING

Most carving of hard wax is done with files. Coarse-toothed files will cut quickly and resist clogging. Those sold for use on soft materials such as wood, plastic, or white metal will be good choices and can be bought at hardware stores or jewelry supply companies. This kind of file is typically large and heavy, which can be awkward on a jewelry scale, especially when working on a lightweight piece of wax.

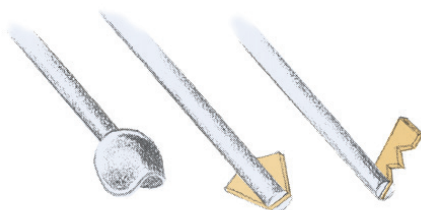
For more delicate work, jewelry and casting supply companies sell small coarse-toothed files made for wax work. These are not cheap, but they are the right tool for the job. If they are reserved only for wax, as they should be, they will last a lifetime. Any of the files found on the metalsmith's workbench can be used on wax. Fine teeth cut slowly and are likely to clog, but these are matters of inconvenience and can be overcome. A light coating of talc, cornstarch, chalk dust or silicone mold release will help files resist clogging. Use a file card or fine brass or steel brush to clean files as needed, but don't try to burn off wax that is stuck to a file. This will only make it stick harder.

It's especially important to clean files before using them on metal again because small bits of wax can play havoc with soldering. Also, small bits of metal can be transferred from files to waxes, where they become inclusions in a final casting. The ideal arrangement has separate files, burs and work areas for metal and wax.

Burs

Rotary files and burs used in a flexible shaft machine offer a quick and fluid way to carve wax. Again, coarse-toothed tools are preferred. A steel bur that as only three blades and looks like a propeller is made especially for wax carving. These are available in a spherical shape from most jewelry suppliers.

Rotary tools (i.e. flex shaft burs) heat up quickly, and even the best can clog. This is a nuisance and slows down the creative flow of carving. To avoid this, use a stroke that touches the wax with the tool spinning, then lifts up for a second before touching down again. This touch-and-go method allows heat to dissipate without altering the position of the hands. This fluidity of movement is important in achieving continuity of the form.



The enterprising modelmaker should consider the possibility of making or modifying tools as needed. The time spent will be well repaid in efficient carving. Solder on bits of brass, nickel silver or steel to an old mandrel or a nail.

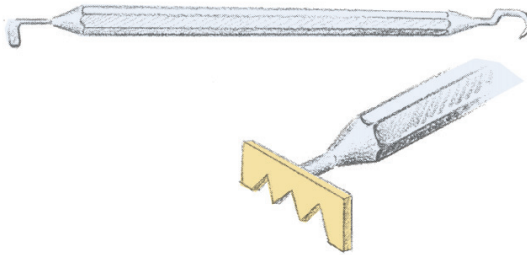
Scraping

A sharp edge held at right angles to the wax can be pulled along to shave off a small curl of wax. This leaves a smooth finish and can offer a lot of control. Scraping is done with a knife blade, a razor, a triangular scraper, or an improvised tool that has been shaped to create the contours needed for a particular job.

Scraping, or any other kind of cutting with a blade, is usually difficult at the early stages of a model. Note that scraping tends to modify an existing shape. It's awkward to scrape a square block into a ring shank, for example. In this case it is better to first use a saw and then a file to achieve the general contours of the piece. Once the shape has been roughed out, scraping can be an effective way to sharpen a design.

Dental tools make terrific scrapers. They can be purchased through jewelry suppliers, and are sometimes available through a dentist, whose broken tools still have great potential for the modelmaker. They are usually made of unhardened stainless steel and can be shaped with files and sandpaper.

To make a radical bend, heat the tool in a torch flame and bend it at red heat. Forging must also be done at red heat, and even then it is hard to control. Special shapes can be made up from brass or steel and silver soldered onto the tool. These tools suffer no wear in regular use, so the time spent in making them will be repaid over many years of use.



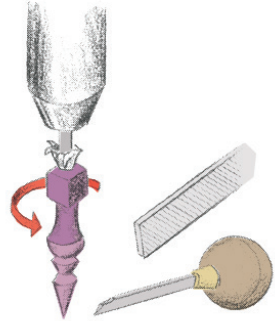
TEXTURE TRANSFERS

Carving wax can pick up textures from any surface that is free of undercuts and able to withstand about 325°F/165°C. Hold a block in a gloved hand or vise grip pliers and warm one surface with a torch flame or an electric pencil. If working “in the field,” a cigarette lighter will do. When the wax is uniformly shiny, press the block firmly onto the surface. In most cases, no release agent is needed.

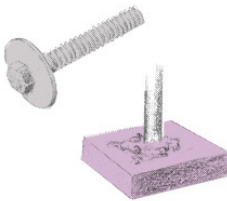
Machine Tools

Carving wax can be shaped on a lathe, with a vertical mill, or in any similar power tool. Specific applications will vary with the scale of the project, the tools at hand and the imagination of the modelmaker. Here are a few suggestions:

Small scale spindle turnings can be worked on a drill press or a flexible shaft held in a vise. Drill a hole through a piece of wax, then wrap the drill bit with tissue paper. Slide/twist the wax firmly in place. Run the machine slowly, scraping away wax as it turns. Use a knife blade, gravers, files or scrapers to remove the wax. Wear goggles and a dust mask. The trick here is to work slowly, being careful not to dig too deeply in a single pass. This might cause the wax to slip on the drill bit, making it necessary to refit the bit.



Face Plate Turning

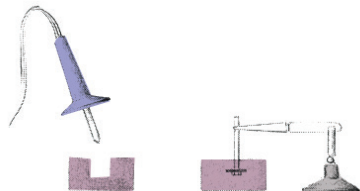


Face plate turning can be improvised as shown. The spindle is a bolt and the plate is a washer. Of course the disk can also be cut from a sheet of brass or nickel silver, or a coin can be used. Be careful to make all sharp edges blunt by filing them.

Heat the wax until its skin is molten, then warm the spindle and press the two pieces together. Small holes in the disk will increase the grip between the two pieces. When cool, tighten the spindle into a drill press or flex shaft and begin turning. Wear goggles and a dust mask to protect against airborne particles.

It is again important to proceed slowly, because too deep a gouge will tear the wax loose. Because it's difficult to recenter the wax on the spindle, caution is more efficient than repair.

Another method uses a preheated soldering pencil to create a cavity of molten wax in a block. Quickly slide a warm bur or nail into the cavity and hold it there while the wax hardens around it. Use a third-hand device to keep the piece steady as the wax cools. Any of these methods, or variations on them, can be used to fix wax in place for milling on other machines.



Gauging the Weight

A typical problem among people learning to use carving wax is the tendency to create heavy pieces. By understanding the reasons for these pitfalls it is possible to avoid them.

Carving wax is brittle, especially compared to metal, the material familiar to most jewelers. After several breaks, beginners become wary of the fragility of wax and hesitate to make it thin. Also, the wax is between ten and twenty times lighter than the metal of which the final piece will be made. A proper model for a jewelry piece will probably weigh so little that it can hardly be felt in the hand. This is a foreign sensation to most metalworkers, and one we are not ready to accept instinctively. It's important to remember that the final object will be made of metal, and will have metal's strength, weight and cost.

Metalsmiths familiar with fabrication should think in terms of familiar points of reference. Is that section as thick as most ring shanks? How thick is this section in B&S gauge? What

thickness would you use in this situation if you were fabricating instead of casting?

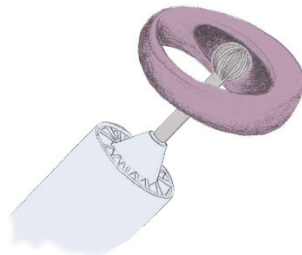
Thickness can be observed by holding the wax model up to the light, where pale shades will indicate thin sections. As a guide, file a wedge of wax that can be measured and use this as an index of color-to-thickness relationships. A stone gauge or similar measuring device is useful here.



REDUCING THE MASS

First concerns about thickness are taken up in the overall shape and proportions of the piece. If the wax is too heavy when the shape is completed, it is sometimes possible to hollow out sections of the model from the back. This can be done with a variety of tools, but scraping or rotary files are the most frequent choices.

Consult Chapter 2 for information on weighing the model to determine the weight of the finished piece.



Finishing Hard Waxes

After shaping, carved wax is smoothed with fine files, a nylon stocking or a paper towel. These materials are preferred over sandpaper or steel wool which can leave grit or fibers stuck to the wax.

The final surface should duplicate as nearly as possible the finish intended for the metal. Remember that a few light touch-up strokes on the wax will save minutes of work on the metal. Besides taking time, neglecting finishing touches on the wax wastes metal and diminishes details on the piece. Make the wax just right.



Soft abrasives such as a wad of nylon stocking tend to follow a surface, accentuating its characteristics. If a surface is slightly wavy, the wad wears down the hollows and increases the waviness. Soft abrasives are used for rounded, organic shapes.

When the shape calls for a flat facet, use a stiff tool like a file or coarse paper glued to a board (or popsicle stick). For final finishing, use a stiff fabric like denim or twill stretched over a flat stick.

Scrapers can create a subtle linear effect. To make the lines more obvious, file serrations in a scraper blade. These can be used in a crosshatch to make a matte area. This is recommended for areas that will get a lot of wear, that will be difficult to polish, or that will be colored (oxidized). Where a matte area is too confined to allow scraping, use the point of a needle to create a stippled surface.

Repairs

To repair breaks or make design changes in a wax model, heat a pin tool in a lamp or torch flame and touch it to the break. Be certain that all wax surfaces being joined are molten or they will not bond securely. When the pieces have been joined in this way, a bit of molten wax can be dripped onto the heated area to replenish any gap that may have formed. In this way a design or texture can be “erased.” Beginning modelmakers should take note of this, and experiment freely as they create a form.

Whenever melting wax, avoid breathing the fumes. They may contain petroleum distillates and can cause sore eyes and nausea.

Scraps

Pieces of carving wax can be recycled as long as they are kept free from contamination. This is important, because even tiny particles of contaminants can become a nuisance if they happen to fall at critical places in a model. Bits of foreign metal can create major havoc in casting, especially if white metals are involved.

Sort through scrap wax pieces and discard any that are unclean. Set the rest in a steel container and warm it slowly in an oven. Take care that the wax doesn't get so hot that it smokes. Heat just until the wax begins to melt, then stabilize the heat at this level. Smelly and noxious fumes may be produced so the room should be ventilated.

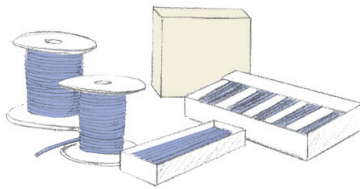
It's possible to let the wax cool in this container, but you'll have better results if you pour the wax into a

different container. Use heavy gauge aluminum foil to create forms, worked up freehand or formed over cans and boxes. To facilitate release of the wax, coat the foil with liquid soap or silicone spray release.

If you suspect foreign matter in the wax, pour through a piece of wire mesh (something you can throw away later) or a piece of cheesecloth. Allow the wax to cool slowly.

To make sheets of wax, pour the molten mix onto a clean flat surface such as a piece of glass or Plexiglas, or into flat pan that has at least a half inch of boiling water.

Modeling Wax



Soft waxes are used to create forms through the build up of successive layers of wax. Both soft and hard waxes are used to create models for jewelry, but the two families of wax are as different, from a designer's point of view, as wood and clay.

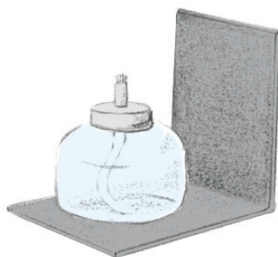
Like carving wax, modeling wax is made of a blend of resins, waxes, and fillers. These ingredients are

mixed to yield a wax that is soft enough to be bent, cut, molded and pinched into shape.

Modeling wax is sold in bars, sheets and wires of almost any cross-section. It is sold in a rainbow of colors, but as in carving wax, these do not conform to any universal system and are introduced at the manufacturer's whim.

HEAT SOURCES

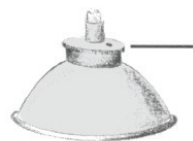
Heat is essential when working with modeling wax. It is usually provided by an alcohol lamp, but a torch flame or a candle can be substituted. A candle flame colors the wax with soot, and should only be used in a pinch. Whatever heat source you use, reduce eyestrain by arranging a matte black surface behind the flame. This should be a fireproof material such as painted metal.



Lamps

Modelmakers' alcohol lamps are simply glass jars with a tight-fitting metal cap that has a short tube soldered through it. This tube holds a cotton wick, which draws fuel upward by osmosis. A handy feature is a knob on the tube that allows the wick to be raised. As the wick burns it must be extended, and without this feature it is necessary to pull the wick up with tweezers.

An alcohol lamp can be improvised from a small glass jar (e.g. baby food) as shown. An even better solution, because it won't break if dropped, is



made from an oilcan. Saw off most of the spout and drill a small air hole as shown. Over the course of several years this may rust through, in which case it should be discarded and replaced.

FUELS

Denatured alcohol is available from paint stores, where it is sold as a solvent. Lamp fuel is available from department stores where it is sold for use in ornamental lamps. This is often scented, which is unnecessary but will do no harm to the wax. Avoid using substitutes. They are likely to be more volatile than is safe. Under no circumstances use gasoline, or expose the container of fuel to open flame.

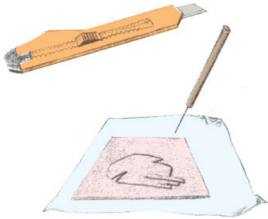
It's a good idea to keep a plastic funnel with the alcohol for refilling the lamp. In case of a spill, allow the puddle to evaporate completely before striking a match.



Cutting Sheet Wax

Drafting templates and patterns cut from thin Plexiglas make useful tools. Plastic letter templates can be used with a needle to imprint or cut out letters. Paper punches can also be used to good effect on sheet wax.

Especially in cold weather, wax can splinter when cut. To avoid this problem, dip the wax in a bowl of warm tap water before starting to work. To keep your drawing dry, set a piece of glass or Plexiglas on the drawing.



Models in soft wax grow in the same way a snow drift or an icicle forms, through an evolution of layers. In some cases the first step is to cut out sheet wax with a razor knife or with several passes of a needle point. Because sheet wax is transparent, it can be set directly upon a drawing to copy it.

To type a pattern or message onto sheet wax, warm the wax and shake it dry. Working quickly, sandwich the wax between sheets of plastic wrap and roll it into a typewriter (remember those?). With the typewriter set to "stencil," type the message. To keep the wax soft, position a light directly over the work. With care a hairdryer can be used to keep wax at an appropriately warm temperature.

Tools



Tools in wax working are a direct extension of the hand, and must be comfortable in every sense of the word. Tool length is usually about 6" but this can vary with each person. A basic tool is a needle shape and I prefer a lightweight wooden-handled needle to anything else I've tried. These are available from clay suppliers (sometimes called a cut-off needle) or from a school bookstore where they are called biology needles. I like the lightweight

and I often flip the tool over as I'm working to use the dowel handle to smooth or bend the wax. Other modeling tools can be made from a piece of coathanger, from scraps of brass, or from dental tools. Handles should be insulated with wood or tape.

Modeling tools have a great deal to do with the final character of a piece. Experiment with tools and invent some of your own as you evolve a personal style.

To make a delicate and handy snips for cutting wax wires, grind a thin cutting edge on the tips of a pair of fine-pointed tweezers. The beauty of this tool lies in its light weight, quick action, and in its ability to reach into tight spaces.

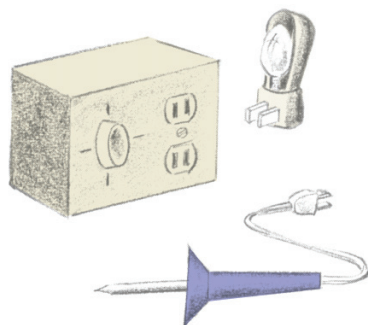
Electric Wax Pens

These popular tools offer an alternative to the heat-and-work, back-and-forth motion of modeling with a flame-heated tool. The pen is constantly heated from within, saving time and allowing more concentration on the modeling itself. Inexpensive electric pens must be occasionally switched off (or unplugged) to prevent overheating, but the better quality tools are regulated to maintain a constant temperature. When using these, it's a good idea to experiment to find a temperature that suits the wax being used. Once this is established, it's possible to dial the correct temperature and focus attention on the process of modeling.

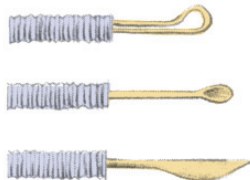
Do It Yourself Wax Pen

Soldering irons and wood burning tools can be used for wax work, but they get too hot. Mount a standard outlet into a 2-gang electrical box. In the space beside it, install a dimmer switch to control the heat. Make a short electrical cord with a plug on one end (I use an extension cord with the socket end cut off), and wire this to the outlet.

Use a nightlight in the extra socket to indicate when the tool is on. Follow the manufacturer's instructions regarding the wattage that can be passed through the switch. You might want to write numbers on the box so you can calibrate your work. With a little experimentation you'll be able to dial the correct heat for each of your waxes. The total cost, including the soldering iron, was \$40.

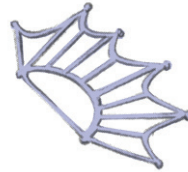


Most soldering irons make it easy to improvise your own tips. Use a bolt that matches the screw threads on the soldering tip and silver solder pieces of needles, paper clips, or brass wires to them.



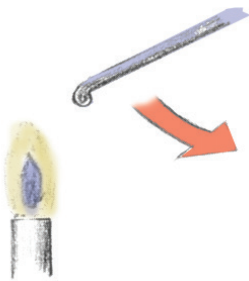
Working with Modeling Wax

In some designs it is easiest to start with an armature of wax wires. These are cut to shape and welded by touching the joints with the tip of a hot needle. An armature can be filled in with drips from a wire or with panels of sheet wax. Properly used, an armature not only provides a system for making the model, but a network to assist in filling the mold. It can also be an important structural device to provide strength in the final piece.



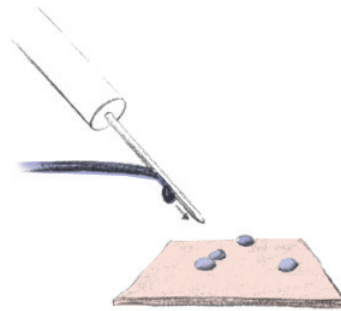
METHOD ONE

Hold the tip of a wax wire in the flame of an alcohol lamp. It will melt and form a drop. This can be quickly carried to the sheet and deposited. Timing is critical. If the wire is held for more than a split second, the drop falls off, into the flame. If the wire is not sufficiently heated it will not adhere to the sheet. Practice and patience will soon teach the proper pace.



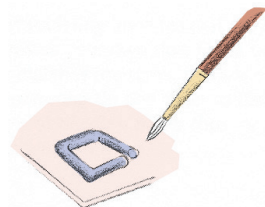
METHOD TWO

Heat a needle tool and point it at the spot where the wax is to be deposited, keeping it just above the surface of the wax sheet. Touch the wax wire to the tool about a half inch from the tip—the wax will melt, slide down the needle, and fall into place. At least it's supposed to. It is important to control the temperature of the needle.



For large deposits, a wax wire can be laid into position and flooded with additional wax to create a ridge. This wire can be formed from soft wax and can be rolled along the tabletop under the palm to create a "snake" of irregular contours. These can be built up in many layers to quickly establish a thick section.

It is also possible to brush molten wax into place with a paintbrush. Heat a can of wax in a double boiler and use a disposable soft bristle brush.

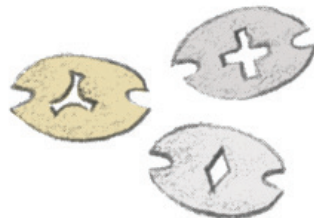
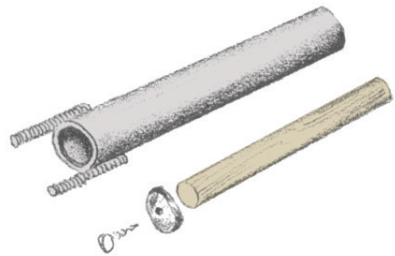


Sheet wax can be molded in the fingers to make a substructure. Soften the wax by dipping it in warm water or by breathing on it. In very warm weather it might be necessary to “lock” the wax into position by dipping it in cold water. This is especially important when the model will be handled. If handling causes difficulties, the model should be mounted on a stand so it can be worked without distorting it.

A Homemade Extruder

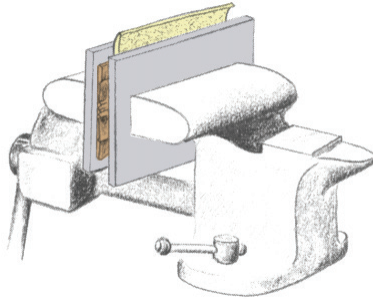
There is almost no limit to the shape of the wires to be created with this tool. Conventional soft wax can be extruded to create wires with unusual cross sections. By mixing a very soft wax, the extruder can be used like a cake decorator’s frosting cone to build up interesting shapes.

1. Buy a piece of metal pipe about a foot long and an inch in diameter. You will also need a dowel to fit inside this. If a tight fit cannot be found, use a smaller dowel fixed with a rubber washer at the tip to make a tight seal.
2. Cut the heads off two bolts and solder these threaded rods onto the sides of the pipe so about $\frac{1}{2}$ ” projects below the bottom edge.
3. Use brass sheet (about 18 gauge) to cut out design panels as shown. The space between the lugs must be measured against the two bolts to ensure a close fit.
4. Use heavy gloves when extruding. Pour molten wax into the extruder and slide the piston into place, using slow even pressure to squeeze a rod of wax out the end of the tube. If the wax hardens, work over a small flame or in the warm blast of a hair dryer, rotating the extruder for even heat. Allow the wax to fall into a dish of cool water.

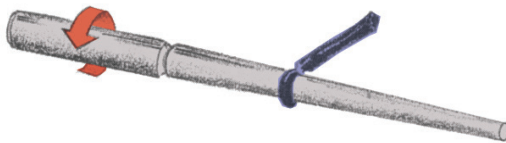


Using a Press Die

Dies may be made of copper or brass through fabrication or etching. These will be the reverse (negative) image of the desired casting. Set the die plate into a vise, supported by sheets of steel and cushioned with a piece of wetted leather or rubber. Warm a sheet of wax and protect it between sheets of plastic wrap. By tightening the jaws of the vise, the die will press into the wax and make an impression. This has many applications for production work.

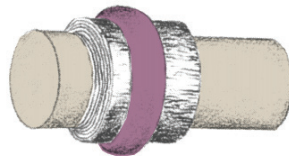


Making Ring Shanks



Warm a steel or aluminum mandrel and smear a layer of wax around it. Before applying the wax, coat the mandrel with a thin film of a parting compound like microfilm, talc, or a spray cooking oil. This technique requires control over the temperature of the rod, and will take some practice, but it's possible to create a band of consistent thickness in a single swipe around the mandrel. Slide this off and invert it on the mandrel to even out the taper. If the wax sticks, cool the rod by holding it under cold tap water for a few minutes before attempting to slide off the wax.

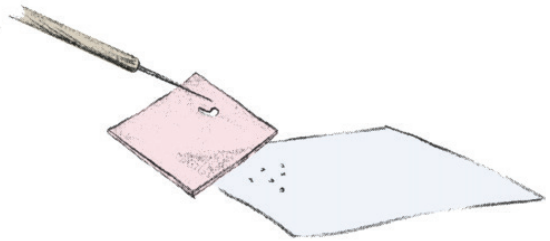
Another way to prepare a ring blank involves building up an armature of sheet or wire. This can be done on a tapered mandrel, but I prefer to work on a dowel with parallel sides. Jewelry suppliers sell a set of stepped aluminum rods with full and half sizes that attach to a stand for a convenient work position.



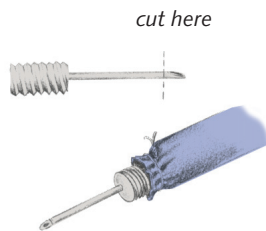
An alternative is a 6" length of wooden dowel adjusted as needed. To establish the correct ring size, build up layers of masking tape, adding to or removing tape as needed to create a mandrel of the correct ring size. Lubricate the tape to prevent wax patterns from sticking to it, or cover it with a sheet of plastic wrap. Periodically rotate the model as you work to keep it free.

After the basic form has been established, the model is refined by adding or removing wax. Wax can be scraped away with a tool shaped like a miniature spoon made from a brass or nickel silver wire, or from a dental tool. For some waxes (and especially in cold weather) it may be desirable to warm the tool in a flame, but in many cases the wax can be scraped away at room temperature. When warming the tool, avoid using too much heat. Even a slight miscalculation can make a hot tool do a lot of damage. Hold a tissue or rag close at hand and wipe off the excess wax after each stroke.

Remember that heating alone does not make wax go away. It will cool and harden in more or less the same place it was originally. To pull molten wax away, touch it with a hot needle and either allow it to slide down the needle or blot it with a paper towel. To make holes, poke a hot needle through the wax and pull it back out. Lightly blow at the spot of molten wax and a hole will open up. Droplets will splatter onto whatever surface is below the piece so I suggest setting a piece of scrap paper into position like this.



Finishing



Files are almost never used with modeling wax. They will rip the form, fill with wax and be totally useless. Sandpaper and steel wool are also inappropriate for modeling wax. Steel wool is especially bad since it will leave fibers of steel that will contaminate the mold and show up in the final casting.

To create a smooth finish on soft wax, heat a needle and draw its tip lightly across the surface of the wax. Some modelmakers slide the model through the lamp flame to smooth its surface, but this is risky. Practice with some scraps before trying it, and then try it only if you are confident of your reflexes. A second too long and your modelmaking efforts will have been wasted.

A pump tip (the kind used to inflate sports equipment) can be modified to make a dollhouse-size Bunsen burner. Attach this to a rubber hose running from a propane or natural gas line and run the flame lightly over the surface of a model to smooth it.

SPONTANEOUS EFFECTS

Some interesting textures and shapes can be created by dripping melted wax into or over a range of materials. Resulting shapes can be worked in any of the methods mentioned above. Never heat wax to its flashpoint! At this temperature (which differs with each wax combination), the wax will suddenly ignite. This is very dangerous. Watch the melting procedure and remove the wax from heat as soon as it is fluid. Always use a double boiler arrangement to melt wax, setting the wax pot into a larger container that has about an inch of water in it. As the water boils away, add more.

Drip wax onto:

- water
(the temperature changes the effects)
- weathered wood
(soaked with water)
- a steel slab
- concrete
- leaves
- wood shavings
- plastic wrap

Clay Relief



You can get rich and unexpected results by making a wax impression of forms and textures pressed into clay. Use a potter's clay, or any other clay mixed with water. Plasticine (children's modeling clay) won't work because it melts when hot wax is poured into it.

Roll or pat the clay into a slab and create patterns by (for instance) pressing, dragging, or cutting. Remember

that the results in the wax impression will be the reverse (negative) of the shape in clay.

Pour or brush molten wax onto the clay. When pouring, it might be necessary to build up a wall of clay to contain the pour. When using a brush, "throw" the melted wax onto the clay, using a sharp flick of the wrist to fling the wax into small recesses. Modeling or inlay waxes are preferred for clay relief because they are especially fluid when molten.

The hardening of the wax is usually interpreted by observing a change of color as it cools. After a minute or two, pull the wax from the clay and rinse it off under cool water. A soft brush can be used to clean away the mud that results. Wax sections can be cut with a knife or scissors, and can be bent, formed, modeled and added to as with any other wax model.

ORGANIC MATERIALS

Many organic materials can be burned out and cast. Note that because each material has its unique characteristics, you'll need to experiment. Here are a few of the factors to keep in mind.

- The volume of water in a model will effect its ability to hold its shape during investing and burn out. Plant materials collected in the autumn will be drier than those collected in the spring, and in some cases this can make the difference between the success and failure of a casting.
- "Leafy" materials generally burn out; "woody" materials generally don't. This can be confusing because the difference between these two types of materials is vague. I've found that some pine cones, for instance, burn out cleanly, while others leave a residue of charcoal that prevents the mold cavity from filling. Experimentation is the best way to tell which materials will yield a clean casting.
- The weight and moisture of the plaster-like investment can greatly

deform a natural model. A flower in bloom will crumple when covered with investment, so even a complete cast will yield a sorry, bedraggled bud. To strengthen a model against this, coat one side with wax, usually by dripping or painting molten wax carefully into place. A flower could also be sprayed with lacquer or paint. Beware of especially nasty fumes during burnout. Turn on ventilation and leave the room.

- Very thin areas will not cast because surface tension of the molten metal prohibits it from entering a small crevice. Thin sections such as the wings of insects should be thickened with wax, lacquer, paint or glue.
- Bony structures and shells do not usually burn out completely. If you want to try them, build ash traps into the sprue system to collect the unburned residue and use an especially long burn out.

Found Plastic Parts

Most plastics burn out completely and offer a wide range of possibilities for modelmakers. The fumes produced as plastics melt can be toxic, and must be properly vented. Work with plastic models in a large, well-ventilated space. When burning out plastic models, it is especially important to vent the exhaust gases. Failure to observe these safety rules can be risky to your health.

Plastic parts abound in our society: pieces from model kits, machines and household gadgets are all sources for raw material. The huge supply of interesting shapes makes the job of using plastics difficult because there is a temptation simply to transform a plastic article into a metal one. This is a technical exercise, and has little value beyond that. The challenge of found object casting is to make creative use of found objects, giving them a new and innovative meaning.

Hard Plastics

Some plastic items will be too thick to be cast in metal. They can be thinned by filing, sawing, or grinding with burs. Do not use heat, unless you want to distort the object.

It's a good idea to test a sample before devoting much time to a model that might not cast well. If you have several pieces of the found object, it is easiest to test by investing and casting a piece. Any metal can be used for this sample casting.

After casting, examine the work for completeness and surface quality. Missing details or large voids indicate that a residue of the model was left in the mold and prohibited the metal from completely filling the cavity. Perhaps a longer or hotter burnout is needed. Or perhaps that item simply can't be burned out.

For a simpler, less conclusive test, set a piece of the model material in a small can and cover the lid with a scrap of metal (brass, steel, etc). Heat the can in a kiln up to about 1200°F/650°C, then check it to see if there is residue left in the can. If not, there is a good chance the material will burn out cleanly. If there is a gummy residue, there is little hope of getting a good casting. In this case it might be necessary to make a rubber model of the original object and create a wax model from that.

Expanded Plastic

Soft plastics such as styrene and Styrofoam can be used to make models. Refer to the safety warning above, because the fumes from working with these materials can be hazardous.

We are surrounded by many kinds of soft plastics, from food wrapping to packing materials; from coffee cups to building insulation and each of these offers unique possibilities for the modelmaker.

Plastic can be cut with a saw or a knife, can be worked with hot or cold tools, and can be used by itself or in conjunction with waxes. Pieces can be heated in a flame to create rich textures and spontaneous shapes. Remember that because small pieces of Styrofoam are practically weightless, it's easy to get carried away and create models that will be heavy when cast. Experimentation and experience are the best guards against this problem. Pieces of plastic can be assembled with hot wax or with a light glue such as airplane glue or rubber cement. Very frail pieces of plastic can be stiffened by adding a layer of wax or by spraying with a lacquer or plastic spray.