After his death I was given custody of an extensive collection of manuscript material-mostly on the technical issues of metalworking.

This text represents the first effort to organize the material—an attempt merely to group the files by topic. None of this is finished, and the text makes reference to illustrations that were never done—illustrations which were stored separately in any case, making it extremely difficult to bring the parts together.

It is unlikely that I will ever be able to spend the time to sort this all out. But it seemed a shame to let these articles languish unread by those who might benefit from them in some small way. So I have decided to release them in their roughly sorted form in the hopes that someone may find them useful.

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HOT MELT

This particular section illustrates a technique that I really haven't used much but it should be a good one to experiment with. The ring shown was done by my daughter Chris. She helps me around the shop with general organizational things and also does some jewelry work. One afternoon we were looking at advertisements for various wax or plastic extrusion devices. She thought that it might be fun to work with a material that was flexible but tougher than conventional wax wire. I had just finished gluing some parts together with hot melt glue which is really tough and flexible. Why not give that a try? The results were a success, and a hot melt glue gun is a very modest investment so I would like to share the results with you.

Most hardware stores carry hot melt glue guns. These are available with two kinds of material. The first is a white caulk and the second is a translucent ivory colored glue. The glue is what you want for this project.

For those of you that have never used a glue gun a couple of words of caution are in order. The molten glue sticks to everything very well (including your skin) and it is hot enough to cause painful second degree burns. Be very careful. The sticky nature of the glue was the first characteristic to be overcome. If you hold the gun in the air you can extrude a string of glue, however, it will stick to the first thing it touches.
MODELING
JOINING SHELL SECTIONS

As we have discussed elsewhere, the viscosity of molten waxes varies widely. However, even the thinnest of them is relatively viscous. This means that they will not flow freely into tightly fitting joints. When you're using rotational turning methods or assembling from plastic it's possible to make parts that fit together so well that you can't flow wax into their joints to join them into larger forms. You'll actually be confronted with the need to up or bevel the juncture to make the wax flow in.

There are two simple approaches to solving this problem. One is to put a deep bevel on both halves of the part. This approach is indicated in the sketch on Figure 62. This is rather like welding together thick metal plates. The plates have to be beveled back so that you can flow weld metal all the way to the back of the joint. Another way to achieve the same effect (with wax) is to hold the two parts together, and touch the joint with a hot spatula in a couple of spots. Then you can take a very hot spatula and slowly go around the edge, welding your way into the joint. This will carry away some of the hard wax, and leave a groove. You must apply enough heat to melt all the way through the section, and create a fillet on the inner side as indicated in the
next Figure. After you've fused the parts together you can fill in the joint with inlay wax. There are really two approaches to filling in the joint depending on how you intend to finish the part. If the part is going to be polished, you can use blue inlay wax, or any other convenient material to fill in the gap. However, if you're going to use heat to develop texture on the surface of the model you should use the same kind of wax. If you blend two different waxes in the joint, and then try and texture the material, it will usually show up in the texture, and ultimately in the final work.
ZINC PLATE ENGRAVING

The traditional jewelry maker has a number of techniques at his disposal for embellishing the surface of metal forms. Engraving chasing, reticulation provide the metal worker with the ability to add detail and interest to the surface of a fabrication. This detail may be highly structured in a case such as ornamental engraving, uniform in the case of chasing, or random with reticulation.

Many of the same surface treatments can be applied to cast parts. However, the casting process used in conjunction with other model making techniques, provides the opportunity to do some unique surface effects which would be difficult to achieve by other means. It also allows the jewelry maker to accomplish the results at a much lower cost.

One of the very useful techniques is the process of photo engraving as it is applied in the printing industry. This method can be to make jewelry models in several different ways. The two most common ways are to use the process to make dies and to actually photo engrave a positive master for mold making.

Since the photo process can easily be reversed, this provides an excellent way to achieve highly developed and detailed reversal images. They may be either positive or
negative and/or mirror images.

The simplest way to apply this technique is to work with a maker of printing plates who prepares zinc or magnesium plates. Almost any small printing shop should be able to accommodate you. In my experience, they will have a minimum charge in the range of $15. Almost all of my jewelry projects are accomplished for the minimum fee.

The best way to proceed is to illustrate some examples of specific applications of the process. Based on these, you should be able to create your own concepts of how this technique might be applied.

The first one is a small tie tack which I made up for the Chicago Chapter of the IDSA. They wanted a limited production item for their members and they had no concept of how many they might actually sell. Since sales were pretty much uncertain, they didn't want to spend a great deal on tooling. Various estimates for the tooling bill alone were in the range of $150. Since I knew some of the members of the group, I volunteered to try coming up with something more economical. Figure 36 illustrates the basic logotype used by their group. This was obtained in a variety of sizes, the smallest being about 1/4" by 3/8" in size.

You will notice that this design has a very fine network of
lines. This is about as fine a pattern as you can expect this technique to reproduce. The master was taken to a local printer and a zinc plate was prepared. In this case, since there was a minimum charge, we had a plate made up with eight repeats of the same logo. That provided insurance in a couple of ways. Number one, if one or two of them didn't etch well it wouldn't matter, and second, if I damaged one in preparing the mold there would be no great loss. The overall thickness of the original plate was about 0.14 inches and the etching was roughly half of that thickness. The first step was to saw around the part and remove it from the plate. Next, jewelers files and sandpaper were used to clean up the edges. They were left with a slight draft or taper and were highly polished. At this point the part was a little too thick so the thickness was removed by grinding off the back and polishing the part smooth. At this point, the part could have been put directly into a vulcanized rubber mold. However, since it was to have a flat back and we didn't know how many parts would sell, I simply made an open silicone rubber mold. This was done by adhering the master to a plate of glass, putting a small paper dike around it, and filling the space with room temperature vulcanizing silicone rubber. I use silicone rubber in my own shop because I've never put together the equipment to do vulcanized molds. However, this part could easily be sent out for mold making. In the photograph you can see that this part was made in the same
mold with some other components. This helps minimize the mold cost and larger molds are a little easier to prepare.

Another version of this technique is taught in a number of college metalsmithing programs. The engraved image is used for tooling rather than to make the model itself. In this case, I have chosen a simple band ring as an example. A line drawing is prepared of the pattern for a ring. The raised areas of the ring are indicated by the dark lines. This is taken to the printer and the raised areas are engraved or etched into the plate. The next step is to use this as a master to prepare a model. The procedure is simple. Sheet wax is pressed into the zinc plate to provide the impression.

In this case we need some kind of mold release. A piece of Saran Wrap is carefully stretched over the mold and then a piece of slightly warmed thick sheet wax is placed against the Saran Wrap. Finally, the whole sandwich is placed between a couple of metal plates in a vice or hydraulic press and some pressure is applied. Basically the pressure extrudes the wax into the impression into the plate. When the pressure is released, the plate is removed, and then the Saran Wrap is withdrawn. At this point, you should have a crisp image of the jewelry impression. Figures 30-34 illustrate an example of this process.
One further application which you might consider is the preparation of large texture sheets by engraving. These can be reproduced to provide texture elements for portions of larger projects. As the size of the piece becomes appreciably larger, the impression technique becomes more difficult. Doubling the size increased the surface area by four times. This means you need four times as much pressure to get an equivalent effect. The impression technique is best suited for smaller pieces with relatively little detail, while the molding technique is more suitable for highly detailed parts or larger areas.
ORGANIC MODELING

DRYING

When you are working with natural leaves and flowers all of these techniques may not be enough to capture the beauty of their shape or texture. When other methods fail, consider drying the materials artificially. Many leaves will wither away to almost nothing if they are simply laid out to dry. However, if they can be supported during the drying process they will hold their shape and texture.

The craft of flower drying is an old one but modern materials have made it much easier. If a flower is packed in borax power it will dry rather nicely but silica gel works even better. Silica Gel is available in many craft shops. It often comes in a flower drying kit. The general procedure is as follows:

1. The leaves or flowers should be picked fresh and should be free from any excess moisture.
2. Place a 1" to 2" layer of the Silica Gel in an air tight container. Plastic refrigerator containers are perfect. Gently sprinkle the gel over and around the object until it is completely covered and then add an additional 1" to 2".
3. Put the lid on the container and seal with masking tape. Set the container aside at room temperature of 2-3 days.
The actual drying time will vary with the size of the object. Avoid overdrying since this tends to make the material more fragile.

Pour off the silica gel and remove your object. It will probably be a little dusty but she can usually be removed by gently blowing the dust away.

5. The silica gel seems to last almost forever but it has to be reactivated from time to time. Many of the commercial formulations contain a color indicator (cobalt chloride?) which changes from blue to pink as the material absorbs water. In any case the gel is restored by heating it in a metal container in a 250 F. oven.
ORGANIC MODELING

DESIGN PROBLEMS

The perfection of nature is both a myth and a fact. A leaf or flower is a thing of beautiful design viewed from close or far. Unfortunately the perfect leaf is a rare thing in nature. You will find that you have to go through dozens of leaves to find a reasonably good sample. Generally, plants grown in the wild or outdoor gardens will be more imperfect than those grown indoors. Commercially grown plants and cut flowers tend to be much more perfect. Houseplants and hothouse flowers are your best chance for perfection.

If you examine leaves carefully you will often find that the texture and veining is more pronounced on the back than on the front. Some of my best cast leaves have been cast "backward" with the back side outward.

Many leaves (such as holly) have a lot of sharp points which make them unsatisfactory for jewelry purposes. You can deal with this by trimming the leaf or the finished cast part. I generally try to work on the leaf itself. An ordinary finger nail clipper is a great tool for this trimming. It works with both fresh and dried leaves.

When you are working with leaves there are really two separate problems. These are fresh versus dried leaves.
In most respect the problem of dealing with a dried leaf is simpler and more straightforward than working with fresh material.
ORGANIC MODELING

PREPARATION OF MATERIALS

There are a number of problems associated with using organic materials. The first is porosity. If you try and invest a material which is very porous or water absorbent you'll have more difficulty getting an accurate reproduction of the surface on a quality casting. For this reason, some type of surface treatment is usually required for organic materials. Some of the ones which I have used from time to time include:

- **Lacquer or model airplane dope** - Most of the clear, fast drying spray or brushable lacquers which are used in the hobby model or craft fields are suitable for this purpose. If the materials are brushed on, they should probably be diluted so they do not build up and obscure the detail of the surface. I've had very good luck with the fast drying, clear model sprays and craft finishes.

- **White Glues** - Most of the various water soluble white glues can be used for this purpose. Generally, they must be diluted extensively with water to provide a thin enough material to prevent obscuring the detail. This approach is best when it's used with large or massive parts. You'll find if you used this on a very thin, fragile piece of organic material, the water may soften it and actually
. change its shape. I would use this approach for heavier, woody materials.

. Waxes - The use of white glues of even lacquers requires that the material have a certain drying time after the finish is applied. If the material is sturdy, such as wood, acorns, or other sturdy materials I simply flow on melted dental inlay wax and brush off the excess with a toothbrush. This way the model building process can proceed immediately.

The second generic problem is that nature didn't plan most of these materials for casting models so they may contain shapes or configurations which are unsuitable. Probably the most common would be to have very narrow, then openings or convolutions. The surface of the holly berry shown on page 26 would be a good example. The tiny puckers and folds are lovely and the investment will follow every detail. However, this would create very find, thin webs of investment which are too fragile to withstand the casting process. During casting these break free and end up somewhere in the metal. Quite often this results in a serious flaw in the casting surface. For this reason you should examine all your organic masters very carefully and use wax to fill in fine holes or other weak areas which may not survive the casting process.
Both the shells and the nuts themselves of almost all of the common varieties can make very handsome ornamental or jewelry pieces when cast in metal. Generally, those with very dense, hard shells, such as walnuts, do not tend to burn out quite as well as the softer more porous materials such as peanut shells or almonds. In cases where burn out is difficult, a good alternate is simply to make a rubber mold off the nut and work from wax instead of the original shell. In either case, the results can be very intriguing.

The small peanut pendant, shown in the photograph, was cast directly from a peanut shell. If you want to try this particular technique, you'll need some peanuts which have not been salted in the shell. Generally, the salting process tends to scuff up the surface and make them less attractive. In addition, peanuts don't burn out as cleanly after they've been salted. The peanut pendant was a joint project between my daughter and myself which was made as a humorous item shortly after President Carter was elected. If you'd like to try something like this, simply take the whole peanut and split it carefully with a jewelers saw. Next flood both the inside and the outside with a blue dental inlay wax. While the wax is still warm, take an old toothbrush and brush away all the excess. This will prevent moisture absorption by the nut and wipe out some of the fine, difficult detail which actually gets in the way of the casting. The two halves of the shell were invested with one large sprue on the inside at one end and cast in a single flask. After sprue removal, the shell joint was very carefully filed and fitted and both halves were soldered together with medium silver solder. Be sure to remember that you must leave a small opening at one end to allow the gases to escape during the heating process.
ORGANIC MODELING

BANANAS

The first time someone suggested to me that you could make jewelry models out of banana peels, I thought he was kidding. Frankly, I didn't even try it for some years after I first heard the suggestion. Then later I saw an article about using banana peels for jewelry models in a magazine and I decided I had to try it. Frankly, I was surprised at how effective the result is. It is a good combination of the random event but there is some control over the final result. Having examined carefully the dried remains of a couple of dozen banana peels, I think I can describe what happens and help you put some direction on your efforts. When you remove a banana peel, you'll find that it's about an eighth of an inch thick and is distinctly different on the inside and the outside. The outer covering is a fairly hard fibrous material and the inside is a very soft pulp. When you dry the peel, you will find that it shrinks dramatically in thickness as the soft pulp dries and collapses. At the same time there is some shrinkage in the crosswise direction. That is, across the grain of the fibers running down the length of a banana. There is almost no shrinkage in the lengthwise direction.

If you take all of these factors into control you can exercise a reasonable amount of control over the final product. However, there is a considerable amount of curl and uncontrolled shrinkage that it lends a little extra character to each and every piece. When the peels are fully dried you will find the outside of the skin has a strong, linear, almost woodgrained type texture, while the inside is a little softer and more general texture. You'll also find that the peels are really quite thin and fairly fragile. This means that in most cases you will have to reinforce them on one side or the other with a little extra wax both for structural strength and modelling and to provide sufficient bulk of metal in the final cast. The best way to begin with your experiments, is simply
to take a banana peel or two and a sharp knife and cut out a large selection of
shapes. It's not a bad idea to sketch or record the shapes you cut and then
examine them against the dried results later. Anyway, cut out a number of pieces
and lay them on a piece of wax paper and allow them to dry for a few days at
room temperature. This drying process works very well indoors in the Midwest in
the wintertime. In a more humid climate, I suspect there might be a problem with
mold or mildew and you might have to use an oven or some other approach. However,
all of mine were simply dried in the air. This process turned out to be so much fun
that I've done a number of pieces this way. Several of which, are illustrated here.
WAX MODEL BUILDING

The use of wax models is the origin of all the varied techniques which have evolved into the contemporary investment casting process. This is also the most appropriate place to begin to develop your model building skills. When you have begun to master wax modeling you can move on to other areas. Like so many complex processes there are several alternate methods which can be pursued. These include fabrication, carving and buildup. However, before considering the detailed processes some general background information would be useful.

Waxes - When I started to write this particular chapter my original thought was to begin by carefully defining what a wax is. I quickly learned that this is not a very good way to approach the subject. The whole question of waxes is complex and in many respects remains more an art than a science. Webster's dictionary defines waxes as "any of numerous substances of plant or animal origin that differ from fats in being less greasy, harder, and more brittle and in containing principally esters of higher fatty acids and higher alcohols, and saturated hydrocarbons" or as "any of various substances resembling beeswax." The latter definition is adequate for our purposes. Waxes are generally assumed to be soft, impressionable, or moldable. For our discussion let's include all of the waxy substances which are:

1. Impressionable or moldable
2. Burn out cleanly
3. Have low melting points
The best way to classify the waxy materials is by origin:

1. Animal
2. Vegetable
3. Mineral
4. Synthetic

For the most part these distinctions are of academic rather than practical interest. For the time being, as long as you are working with the commercially prepared materials you needn't concern yourself with the origin of the wax. The most useful description of the waxes is one which deals with their physical properties. These physical properties would include:

1. Melting point
2. Hardness
3. Flexibility (brittleness)
4. Viscosity
5. Shrinkage

Each of these properties may influence the way that the wax will be used.

Melting Point - Many waxes (and particularly wax blends) do not exhibit a sharp specific melting point such as you would see for a pure metal. They will soften and melt over a range of temperatures in a fashion similar to many metal alloys. This melting point (or range) will have some influence on the use and application of the material. For example, it would be desirable to have a wax with a sharp, low melting point for injection molding of wax parts. If you wish to use the wax to take an impression by pressing it against some other substance, it would be better to have a broad melting point.
If you are constructing a wax model that will be handled a lot during construction, you would not want a material which is soft at room or body temperatures. Melting point is important in various wax joining operations. In many respects this is like silver soldering. The wax joining needs to be done with a wax formulation which has a melting point significantly below the melting point of the parts to be joined. If the reverse is true, a lot of problems can be encountered. For example, many commercial wax models have melting points as low as 140 degrees F. If you try to weld these to a sprue with inlay wax with a melting point in the range of 160 degrees F, you will often melt or damage the master model. However, this same material is very satisfactory for welding or joining parts made of hard carving wax with a 250 degree F melting point. They can be joined with little risk of damage to the higher melting parts.

**Hardness** - Wax hardness is another characteristic which influences the application of a wax. A high degree of hardness is desirable in carving and the construction of complex rigid shapes. Softness may be much more desirable for molding or adhesive purposes. There is no really simple measure or standard for wax hardness and the hardness may vary widely with temperature. From a practical viewpoint all that's required is a relative measure. Like the Moh's standard for gems the real question is whether any given material is softer or harder than another. Since this is all a matter of relativity, your primary interest is simply whether or not a wax is hard enough for the application being considered.

**Flexibility** - Flexibility or its opposite characteristics, brittleness, can be of considerable importance in the model building process.
For example, a certain degree of brittleness may be required for good machining or filing. This brittleness will allow chips to break away cleanly as the material is worked. Conversely, a good deal of flexibility will be desirable in materials used for injection molding. A degree of flexibility will prevent breakage during removal from the mold. Generally, a slight degree of flexibility is desired in all model waxes to keep the material from breaking too easily in handling. A good measure of flexibility is how far the material can be bent around a sharp corner without breaking. For example, blue dental inlay wax can hardly be bent at all before it will break. Most of the commercial wax wires will easily bend 90 degrees at room temperature. Most waxes are very sensitive to temperature; a modest increase in temperature will dramatically increase the flexibility of the wax. By the same token most of the common waxes are quite brittle at temperatures of around 40 degrees F. This means that some care will be needed in removing wax models from any type of background by the use of chilling.

Viscosity - The physical characteristics of a molten wax have a great deal of influence on its application. One of the best ways to express the difference between various melted waxes is in terms of viscosity. Expressed simply, the viscosity of a liquid is its resistance to flow. For example, honey which flows much more slowly out of a jar than water, would have a higher viscosity than water. The various kinds of modeling waxes exhibit a broad range of viscosities when they are melted. The differences are at least as dramatic as those between water and honey. At one extreme are the hard carving waxes composed of polymers such as polyethylene.
These exhibit a very high viscosity when molten. This means that they are much more able to hold a high degree of texture when treated with a heated spatula or other hot tools. Conversely, waxes such as dental inlay wax have a very low melting viscosity. They tend to texture rather poorly when worked with a hot spatula. In essence, the low viscosity wax just forms a molten puddle that levels itself out before the wax hardens. Viscosity is also important when casting the wax into a rubber mold. In this case you want a very low viscosity. This tends to keep air from being entrapped in the melted wax and allows it to flow quickly under minimum pressure into all the details of the mold.

Shrinkage - Waxes tend to shrink significantly during solidification and/or cooling. If molten wax is poured around a stone to form a close fitting seat the seat will actually be too small after the wax hardens. Shrinkage is only a problem in a few areas. Precision parts are obviously one area. Uneven cooling can lead to warping or internal strain. In large cast blocks of carving wax this means that parts may distort during carving as the internal forces operate on thinner pieces of material. Shrinkage may also cause porosity or surface texture defects under certain conditions.

Color - Some people attribute specific characteristics to the waxes according to their color. In their raw state the color of the wax may relate to its purity or composition. However, in the refined materials used in model construction, the color of the modeling wax has no effect on its physical properties. The color is present for two basic reasons. First it helps identify the material, and second it makes it far easier to work on. From time to time I have tried to carve natural white waxes. It is extremely difficult to see the
detail when working with a white wax. When I blend my own materials I always use some dark dye to make the material easier to see. If you are doing your own blends, I have found that ordinary candle dyes are quite satisfactory for this purpose. Purple, blue, brown and green are all excellent colors to use.

**Basic Materials** - As I proceed with this book I will describe a number of tools and materials. If you would like to work along with the descriptions and duplicate the various techniques, some tools and materials will be required. For those of you who are just getting started in wax modeling, you can begin with a very simple collection of materials. If you would purchase the following items you could make a wide range of models and get a good feel for the various techniques and materials available. These would be:

1. Hard Carving Wax
2. Blue Inlay Wax
3. Sticky Wax
4. Assorted round wax wire (10, 12, 14, 16, & 18 gauge)
5. Sheet wax (assorted or 20 gauge)

**Basic Tools** - One of the principle advantages to wax modeling is the low investment in tools that you need to get started. To begin with you need:

1. Three Wax Modeling Tools
   a. Pointed (awl)
   b. Round
   c. Spatula (oval flat)
2. Alcohol Lamp
3. Hacksaw
4. Files
   a. Combination Rasp
   b. Rat Tail Rasp

5. Small Knife

There are all kinds, sizes and shapes of wax modeling tools but the three shapes listed are the most useful in getting started. These are illustrated in the photo. You can buy your tools from a supply house or make your own. The examples in the photograph were made from piano wire with dowel handles. Each of these tools has somewhat different characteristics. The spatula is the most versatile. The flat area on the tip will pick up and hold wax. This means that you can use the spatula for wax build up or to remove unwanted wax from the model. Inlay wax works well for this kind of process. Neither the pointed or round tip tools will carry wax in quite this manner. The pointed tool is useful for welding, texture and sculpture and the round tip for smoothing and texturing. Each of these techniques will be illustrated by specific examples.

The hacksaw and coarse files are used exclusively for hard carving wax. They will speed up the sculpting process considerably. The hacksaw is used with the teeth pointing downward like a jeweler's saw. For many years I just used a saw blade with a little masking tape wrapped around one end. Recently, I purchased the small hack-saw blade holder shown in the photo.

One of the annoying things that happens during the wax modeling operation is the gradual build up of the wax on the tools. If you don't remove this it ends up in the wrong place. I used to keep a rag around my bench to wipe off the warm wax when it got in the way.
When I was really in a hurry, I would often wipe the wax off on my blue jeans. However, this got to be a pretty unpopular approach, and finally one day I made a simple cloth wiping pillow. This little pillow is illustrated in the photo. Just take a small rectangle of wood (3 or 4" square) and tack on a pad of clean cotton rag. You can leave this on your bench and wipe off your tools as you are working. As the surface becomes loaded with wax you can turn it over and refold it and give yourself a new surface whenever you desire. This device will clean up your work area considerably.

There are a couple of different approaches to the question of knives for wax modeling. I have illustrated two of my favorites. These are an old fashioned pocket knife and a small shop knife with a replaceable blade. In the long run the pocket knife is most economical if you have the patience to keep it sharp.
BLANKING AS A MODEL BUILDING PROCESS

The development of a casting model for a ring proceeds through a number of steps. However, if the project is to be carved from hard carving was the first step is usually the preparation of a wax blank of the proper ring size and appropriate configuration. One common place to begin is with the use of various carving wax ring tubes, such as those illustrated in Figure 1.

These tubes provide an excellent base material but still suffer from certain weaknesses or problems. Obviously, the tubes come in one basic ring size and this must be filed or scrape to achieve the proper size in the blank. While this is not a particularly time consuming process there is a faster more precise way for preparation of these blanks. This is to drill them from carving wax blocks.

The technique which will be described below allows the small production jewelry shop to make a series of special drills which can be used to prepare the basic ring blank in a single drilling operation, which can produce a blank of the proper size in approximately 30 seconds. The key to the success of this approach is to have a proper drilling apparatus and specially prepared drills.

The place to begin is to purchase a series of so-called spade bits or speed bits from a hardware or wood supply company.
These will look like the bits illustrated in Figure 2. The next step is to regrind these to drill the appropriate size holes for the ring blanks. Figure 3, is a table of the size bits which you will have to purchase to prepare blanking drills for the indicated ring sizes. The basic process is to purchase a drill slightly larger than diameter required and to grind it down to the appropriate size.

If you're going to make this a practical job operation, you will need a small drill press to ensure that you get a steady straight b. Although the holes can be drilled freehand they tend to wobble, enlarge or not go through the sheet straight. A small light-weight table top drill press can be purchased for something well under a hundred dollars. I find this technique so useful that I have a single drill shop in my shop totally dedicated to this type of work.

I fine the most practical approach is to prepare a series of drills in half step sizes from about size 5 to size 11. This covers the vast majority of the requirements which we encounter in our custom work. It's interesting to note that because of the softness of the wax and perhaps a little wobble in the drill press, it's difficult to translate precisely from the diameter of the drill to the size hole in which it will make. For this reason, I would suggest that you develop the drill shanks by grinding them to size on a trial and error basis.
Grinding is relatively straightforward. The key is to keep the work symmetrical and cut an equivalent amount on both sides off both sides of the blade, while maintaining a slight relief or undercut on the back side. Simply grind a bit off, put it in the drill press and drill a hole. Put the wax on your ring mandrill and see what size you've achieved. Keep doing this slowly and gently and you shouldn't have too much difficulty arriving at the appropriate size. I use a pair of vaneer calipers to make sure that the two sides remain parallel. If you have to grind very much off the drill will tend to become unsymmetrical. One way to check this, is to put the drill bit in the drill press, set the speed on low and slowly bring a pencil into contact with the rotating blade. The moment it touches stop an examine to see which blade is scraping the blade first. This will tell you wear you need to emphasize you're grinding and remove a little more material. After you have prepared a drill be sure and mark it clearly so you won't have any confusion in the future. Some comments are in order if you're going to use this process. First of all, always put a flat wooden block on the drill press table and drill into the block. This will ensure a clean breakout on the backside of the wax. Set the drill press at low speed and don't force the operation. Finally, you should clamp the wax block in some kind of a clamp which gives you an opportunity to control the operation and keep you're fingers well out of the way of the whole process.
Over the years, I've had a number of women work in my shop who had long hair. It's vitally important to wear a hairnet or at least keep the lady's hair tied well back when working around a drill press. Getting a lock of hair caught in the rotating bit is an unpleasant an unnecessary experience which should be avoided.
Since every detail of the wax model will reappear in the final casting, it's important to achieve a good finish on the final wax model. Although in some situations the charm or character of the investment casting is obtained by texturing the wax, there are cases where the jewelry requires a highly polished final finish. In these cases a wax polish is very useful. For many years, I used Eucalyptol in my own shop. This material seems to work for almost all kinds of the waxes used in jewelry modeling. However, it requires that you not apply it too liberally as it can actually damage or soften the surface of the waxes to a great depth. Generally Eucalyptol is applied with a soft cotton cloth which has been moistened but not saturated with the material. The softening action can be stopped by wiping the wax model with acetone after polishing is complete. There are also a number of commercial wax polishing compounds. I've tried several of these and they all seem to give a reasonably satisfactory results. In all cases you will find that the polishes have various effects on different waxes. That is, essentially some waxes seem to be more soluble than others.

Another good technique can be borrowed from the candle makers. Lightly buff the work with a women's nylon stocking. This can be used to bring the wax to a very high lustre. A plain cotton cloth can also be used to polish many waxes. If the material tends to soften and smear try doing the polishing under a flow of cold running water.
One problem is worth enumerating. If you wish to structure a surface which is going to be flat and highly polished, it's very difficult to build such a surface from wax. First of all, it's hard to bring the wax to a smooth surface, and if you do succeed in filing it or sanding it to a flat plane, the use of the wax polishing agents will tend to cause slight ripples or dulling of the edges. In cases where I'm trying to achieve a large smooth polished surface in a casting I generally go to a material such as acrylic or polystyrene. This can actually be buffed if you desire and it can be maintained in a very flat plane. The complete model can be made from plastic or plastic sheet may be used for the flat areas.
WAX MOLD RELEASE

A number of the various model building processes require that molten wax be built up against various base materials such as ring mandrels, flat plates or gem stones. Many of the waxes adhere rather well to these clean, smooth surfaces so their removal becomes a problem when the models are complete. All kinds of material are recommended for wax release agents. These include Pam cooking spray, glycerine, oil, handle mold release and most of the debubblers used in wax investment. Almost all of these materials work to varying degrees on different surfaces. However, it's worthwhile to stop a moment and try to break these down into at least major groups of materials. Many of the release compounds which work the best contain varying amounts of silicone fluid or greases. Essentially all of these silicone fluids or greases are excellent release materials. They are so excellent that they may cause almost problems in other parts of the process since they are also impossible to remove completely without vigorous chemical action. Therefore, if you treated a Baroque stone with silicone grease, built up wax around it and tried later to epoxy the stone into a mounting, the chances of achieving a good epoxy bond are pretty poor unless you go through all kinds of cleaning or griding to prepare the surface of the stone. If you use silicone type materials in your shop, you should make some effort to keep them completely separate from surfaces which will be later glued or painted. Most of these compounds will also interfere with ever getting a good paint job on a metallic surface. If you want to use silicones as release materials, I would suggest that you get a tube of silicone Stopcock grease from a laboratory supply house. A tiny amount of this put on a rag and rubbed on a ring mandrel will provide good wax release. As a matter of fact, one tube of the silicone grease is probably a lifetime supply for the average hobbyist. If you can't find a lab supply house to pick up this material,
most automotive departments will carry spray cans of silicone lubricant. This same material can be sprayed into a rag and rubbed on to the surfaces where release is required. In cases where you don't wish to use silicone materials, light household oil is probably as good a bet as any for a release agent. A film of this wiped on most surfaces will provide adequate release and it can be removed from most non-porous surfaces. The best approach for removal is a hot, soapy ammonia solution followed by wiping with acetone if you're going to try to epoxy bond something which has been oil coated.

No matter what release agent you use, sooner or later you're going to have some problems with a wax model sticking to a mandrel or a stone that won't pop out of the master. The best approach here is to simply slip the piece of work in a deepfreeze and let it chill. The differences in thermal expansion between metal and wax or metal and stone are generally enough to pop the material free. The only caution here would be to be careful about the thermal shock on some stones such as opal. Another thing that will help is to always be sure when you're waxing up around a stone to provide at least a small hole in the back where you can put just a little pressure from the rear to help the stone out of the wax. This is much better than prying around the edge of the stone or trying to pop it out from the front surface.
WAX MOLD RELEASES

There are many cases which were handy to build up or construct a wax model on a smooth surface such as glass or metal. However, at the end of the build-up you may experience some difficulty in moving the wax from the base unless you have used a wax lubricant or release of some kind. There are all kinds of such materials available. Within the dental and jewelry industry there are a number of dilubricants and wax releases which all seem to work reasonably well. There are also the candle mold releases which can be purchased in many craft hobby shops. Glycerine made a very acceptable release for many operations. Sylacone ______ are also excellent releases, but they should be used with some care or caution. These greases are developed as lubricants and vacuum seals for various industrial or laboratory applications. In fact the cheapest and best way to purchase sylaccone and grease is to purchase ______ grease from a laboratory supply house. Some of the manufacturers of wax build-up ______ supply small tubes of sylaccone grease with their product. This stuff works very very well, but a couple of cautions should be used. The sylaccone materials excellent release for almost everything, that includes ________ and paint, even tiny traces of these materials can contaminate tumbled stones or metal parts which are to be glued with a poxy. This material will significantly lower the bond strings of such joints. Also traces of this material on a metal surface which was to be painted or finished will seriously effect the ability of the paint to stick. Last but ______ not least, it is practically impossible to get water or investment to wet out surfaces which are contaminated with significant amounts of this type of material. I have never encountered too much problem if the backs of wax models or the inside of rings shanks were contaminated with material, but
you will experience some breaking of the surface fill during investing. For those of you who don't wish to do a lot of this kind of work or invest a great deal money in getting started, you can use aluminum foil to release, for example, if you wish to build up the ring simple wrap aluminum foil very carefully around an ordinary ring mandrel. You find that you can build up the ring then slide it off the mandred, carefully peeling the aluminum foil off the inside. By the same token you can tape a piece of aluminum foil over a flat surface and build up your model on the aluminium foil. When you are done you can usually peel the foil off quite easily. This may not provide quite as smooth surface as glass, but for most purposes it is more than adequate.
GEMSTONE SETTING

There is one curious characteristic which you should understand when picking the girdle thickness for faceted gemstones. Although the stones with relatively thick girdles are much less prone to chip, when they do the chips tend to be much larger. Anyone who has ever reproduced stone Indian artifacts has experience in this area. As the blade is worked down it’s necessary to actually braid the edges slightly flat before flaking, if you want to remove large massive flakes from the object. As the the stone becomes more and more knife edged it requires less pressure to remove a flake, but the flakes removed will be much smaller. As long as you do not add enough pressure the thicker girdle sounds obviously are less prone to damage. However, if you succeed in applying enough pressure in the stone to chip it, the thick girdle stones will usually provide very large fractures. These often proceed all the way from the girdle completely to the culet on even a large stone.

Conventional gemcutting practice suggests that the girdle should be approximately 2% of the overall depth of the stone. However, in practice this varies widely. If the girdle is left unpolished the wider girdle tends to detract from the brilliance of the stone. If the girdle is fully faceted this effect is somewhat less noticeable. If the girdle is 2% or more of the stone height, you will typically have relatively
little problem in stone setting. The worst culprits are the knife edge girdles, and probably the second are the girdles of varying dimension. Not only does the narrow portion tend to break but it is more difficult to achieve a level of uniform mounting with this kind of stone.

Another problem can arise when the bevel varies around the cabochon stones. Good cutting practice suggests that the bevel is uniform all the way around. With 15° being a typical bevel angle. Unfortunately, many elongated stones such as the navette tend to break this rule. They often end up with an appropriate bevel in the middle of the long sides, and are much shallower cut and/or deeper angle on the two ends. As we have discussed elsewhere the height and angle of the beveled area determine the thickness and height of the bezel. This may mean that the bezel height should vary around the circumference of the stone. This general situation is illustrated in Figure 6.

There is always some temptation to assume that a very thin bezel is the safest to set, because at least in theory it requires the least pressure. As a practical matter this isn't really true. Since, some compression of the metal is required to bring the bezel down around the stone, too thin a metal may tend to buckle rather than compress in thickness. Generally speaking, you'll achieve the best results when the
bezel is as thick as practical for the bevel stone height and structural qualities of the gemstone material.

It is worth noting the difference between the faceted stone and cabachon as it regards the bevel angle. If the girdle is essentially cut vertical then this means that the bevel angle basically becomes the crown angles of a gemstone. For most material this ranges from about 35 to 50°. This means that the effective bevel of the top of a faceted stone is much greater than the case with the cabachon. Basically it suggest that the prong will have to be bent roughly 45° rather than 15° would be typical for a cabochon stone. This is one of the reasons that it's far easier to set a faceted stone with prongs than it is with a tube setting or bezel. Basically, this severe angle requires a good deal of compression of the material around the stone. The problem is minimized by having a very narrow bezel which barely rolls over the edge of the faceted stone. However, if it is too high or too thin it's extremely difficult to achieve a smooth bezel setting on a faceted stone. Certainly if you're going to try and bezel mount a faceted stone the bezel material should be as malleable as possible.

The jewelry literature spends a great deal of time describing various techniques for preparing bezels, stone seats, and prong mountings. However, very little space is devoted to describing the way that the shape or configuration of the
stone influences the mounting process. Gemstones come in a wide variety of materials and a enormous range of cuts. If you understand the relationship between the stone shape and the mounting process, it will be easier for you to cut gemstones which are easy to set and it will make you a much more careful and selective buyer of gemstones. Even among a lot of faceted stones which superficially appear identical there will be significant variations in dimension, girdle thickness, etc. Knowing how to sort through these and pick the easiest stones to mount will save you a good deal of grief in finishing your jewelry. I would like to make one comment about stone selection and the larger issue of making jewelry. When I teach a class I always insist that my students wear binocular loops. I always get a certain amount of resistance to this from the folks who say that I just can't see well because of my age. Let me assure you that I've been using a loop for about as long as I've been making jewelry. I defy anyone to be able to sort out a batch of 4 milimeter gemstones without some kind of optical assistance. When you go to a show, when you're cutting or mounting your stones use a loop. There's nothing to be embarrassed about and it will dramatically improve your selection, and the work process itself.
HOLLOW FORMS

The process of making hollow shell jewelry may be difficult to master, but the results are well worth the effort. Hollow shell forms are an excellent design solution for a number of applications. If the shell thickness can be minimized it is a very effective use of karat gold materials for fabrication. It lends a sense of mass without the attended wait and cost and the forms tend to be structurally sound.

The style of construction also provides an excellent opportunity to combine various modeling materials and techniques to provide the highest quality model with the least amount of time invested. There are other design considerations in this process.
INTRODUCTION

TEXTURE

I've always found it curious that most jewelry design books do not dwell on the specific details of how texture can be achieved in modeling. The use of texture can be very important from a design and practical viewpoint. The texture itself can be a major factor in the design character of the work. At the same time, property applied texture can make the finishing problems of a piece of jewelry much simpler.

In order to deal with this discussion on a common basis, I have developed a collection of texture samples. These samples are simply cast rectangles of silver which are 20 x 30mm square. Each of these has a different texture. They have been photographed and enlarged for publication. The texture samples illustrated throughout this book are about three times life size. Those of you who are involved in photography will appreciate the difficulty in trying to reproduce or illustrate these kinds of textures in printing. However, this enlarged new view should give you a sense of the character of the materials. As you will note, many of the textures are linear in nature. These linear patterns can obviously be combined in many ways. It would be impossible to illustrate the infinite range of variations. However, some of these have been included to help you think of your own work.
Many of the small tools for jewelry making can be made as needed. Since some highly specialized tools are rarely needed and the general level of usage in a craft workers shop is seldom high industrial quality (especially with regard to hardness) is often not necessary. Some of the easiest tools to make are small dapping punches, chasing tools, and wax working tools. A brief explanation of the methods used to treat steel to improve it's properties will be followed by a few specific examples.
ROTATIONAL FORMS FOR
INVESTMENT CASTING MODELS

By: Richard D. Austin

The technique described here is a freehand turning procedure for preparing component parts for investment casting models. The components may be cast individually and assembled into fabrications, or they may be used as elements of complete investment casting models. In many respects, this technique is a bridge between traditional fabrication and investment casting. It allows you to overcome many of the common technical problems of investment casting, and it provides a degree of detail and crispness of design which is usually associated with fabrication. The real objective is to provide a high level of quality at optimum cost. This is not a universal technique, but its application has its place among the alternative approaches to jewelry fabrication.

The basic technique is simple. A rectangular block of hard carving wax is fused to a turning plate. The assembly is chucked in the handpiece of a flexible shaft machine. Parts are turned freehand, using gravers and small hand tools. Although the concept of turning parts is certainly not unique, the freehand method described is not widely used. There are few literature references to the method, and I rarely encounter it in commercial shops. This is unfortunate, since it is a versatile technique which requires no special equipment. The
technique is skill oriented, rather than equipment oriented.

I have taught this technique to a number of students and have found that like so many other skills, it takes some practice. This means that there will be a frustrating learning period, when you have to invest some time practicing. However, after a short learning period, your skills will improve rapidly. Eventually you should be able to produce a prong type setting in 5-10 minutes.

**BASIC TECHNIQUE**

I am going to begin by discussing the general technique and then present the details of a specific example. Figure 1 illustrates a set of five turning plates which you can make in your own shop. The plates illustrated were made from #16 common nails and washers. Five nails were cut off about 3/4" below the head. The nailhead will have a diameter of approximately 5/16". This can be used directly for the smallest plate. The other plates were made by soldering 7/16", 1/2", 3/4" and 1" washers to the cut off nails with easy silver solder. After soldering, the plates can be spun in the hand piece and trued up with a smooth mill file.

I have had the best success with this technique using Kerr Master Pattern Wax (Blue) or Kerr Smoooth-Carv Wax. Both waxes machine freely and have enough strength and flexibility to withstand the stress of this method. Begin with a wax
blank with a square cross section about 50% greater than the girdle diameter of your stone. The wax blank should be 2-3 times as long as it is thick.

The wax blank and turning plate are both heated with an alcohol lamp (Figure 2) and fused together. The joint may be reinforced by flowing on Blue Inlay Casting Wax. When the wax is cool, the plate is chucked in the handpiece.

The first step is to turn a slightly tapered form (Figure 3). This is done with round and/or flat gravers. The edge of the tool is used to develop smooth straight sides. The gravers can also be used to cut into the end of the form (Figure 4). Round cutting burrs can be used to carve a hemispherical depression (Figure 5) or setting burrs can be used to cut a bearing for a stone (Figure 6).

Tool chatter can present a problem for freehand turning. The wax is quite soft. It's easy to gouge the tool into the work, or to take too deep a cut. Because both the tool and the work are not held rigidly, it's easy to set up a vibration pattern. A few basic precautions will eliminate chatter. First of all, the blank which you are working on should not be more than about three times as long as its diameter. As you develop very long, thin shapes, they tend to whip. You can turn very thin parts if they're made from a thick blank and you work from the tip. You can turn a 1/8" diameter rod an inch long, but you must start with a thick blank and cut from the tip toward the base. The point where the cutting tool meets the surface of
the part is important. The contact point should be behind the centerline of the part. See Figure 7.

It's been my policy to reserve a set of stone setting burrs and rotary files just for working in wax. Since the wax is soft, it has little tendency to dull the tools, which means that the tools remain sharp. This makes for a much smoother cut and less clogging.

Please note! You will find that you will be working close to your face. Eye protection is a must!

FORM AND CROSS SECTION

Many people experience difficulty with cast-in-place prongs. This often seems to be caused by porosity at the prong base. In my own experience, this can be avoided if the cross-sectional areas of the parts are properly developed. What is required is a form which constantly increases in cross-sectional area from the tip of the prong to the base and through the structural part of the stone bearing and mounting. Figure 8 illustrates a general shape for the prong model. This will yield a good casting and an appropriate shape in the finishing process. The rather blocky, rectangular corners will be slightly rounded with whatever finishing process you use. Figure 9 illustrates how the cross section should constantly increase as the prong blends into the mounting. Figure 10 shows how this same principle is applied to a cup for a pearl.
The small depression in the base of the cup provides a convenient location device for adding a post.

**CARVING STEPS**

The best way to understand the details of the technique is to work through a practical example. Figure 11 illustrates four shapes developed by this technique.

The illustrations in Figure 12 and the following text will describe how to carve the shape on the left in Figure 11.

**A.** A rectangular wax blank is fused to the turning plate as indicated in Figure 12: The next step is to rough out a slightly tapered cylindrical shape with a slight depression in the top. The tapered shape will ensure good structural strength and minimize chatter. All the cutting can be done with round or flat gravers.

**B.** The next step is to rough out the inside of the form. Begin by using a small round burr; simply press it against the middle of the blank. As it works its way in, it will form a round hole. A larger tapered area can be removed with a flat graver. The diameter of the cone-shaped depression should be as large as the girdle diameter of the stone you're working with.

**C.** The next step is to use a setting burr to cut a bearing for the stone. There should be a little play in the stone when
it's dropped into the hole. It should not be a force fit. It's all right if the bearing is cut too deep at this point. It's easy to turn down the rim to adjust the prong height.

D. When the bearing is cut, the outside can be turned down to the appropriate thickness for the prongs. At this point, if you err, it should be in the direction of making the prongs too thick rather than too thin. The prongs can be thinned out after the side grooves are cut in the model. Note that the taper is carried well below the top of the stone bearing.

El At this point, you can go in two directions with the stone seat. Step El is to remove material from the outside to form the shape for a tall prong mount. The taper should be adjusted to provide appropriate thickness, and a tapering cross-section as indicated in Figure 9. Beyond this, aesthetics should determine the degree of taper and height of the top. Note the slight bevel on the rim.

Fl Using a four-corner file, cut away the material in four quadrants. This should be done with the turning plate still firmly chucked in the handpiece. If you leave it chucked up, you can continue to turn the form for any final adjustments in shape without having it unbalanced. Work a little at a time to cut away four quadrant sections from the outside. Again, the depth of the cut is largely a matter of aesthetic judgement. Alternately, you can use a round file to develop
a different shape at this point. This would yield a form like the example on the right side in Figure 11. I use the round-bottom form in much of my commercial work. Note that if the prongs are too thick after the quadrants are cut away, you can still turn down the outside. Simply spin the part, and approach it gently with an engraving tool.

Drawings E2 and F2 in Figure 13 illustrate how the form can be developed for a plate-type mounting.

**E2** Bevel the rim and cut the sides in more sharply.

**F2** Working with a small shop knife and/or jeweler's files, remove the wall section between the prongs and cut off the form. I have indicated a slight bevel on the area outside the girdle of the stone. This area can also be finished flat, or tapered even more. You may also wish to add a decorative texture to this area. Alternately, cut the material away, so nothing shows outside the girdle except the prongs.

The photograph at the beginning of this article shows three rings with tops carved using this technique. Stone sizes range from a 1/4 carat diamond to a 2.5 carat amethyst. The rings were cast in one piece. The shanks on these models were carved from acrylic plastic.
CAPTIONS

Figure 1 - Turning plate sizes range from 5/16" to 1" in diameter.

Figure 2 - The turning plate and wax carving blank are heated in the flame of an alcohol lamp before joining.

Figure 3 - The side edge of a flat engraving tool is used to develop smooth straight edges on the blank. A round graver can be used for more rapid material removal.

Figure 4 - The engraving tool can also be used to cut a cone-shaped depression in the wax.

Figure 5 - A ball shaped rotary file is used to cut a hemispherical depression in the wax. The tool is held free-hand against the rotating wax.

Figure 6 - A conventional stone seating tool is used to cut a bearing in the wax.

Figure 7 - The cutting tool should be presented to the work slightly behind the center line rather than ahead of it. This will help minimize tool chatter during cutting.

Figure 8 - This form will yield a solid casting and buff into a well shaped prong.
**Figure 9** - This illustrates the proper cross-section for the prong and support to ensure a sturdy, solid casting.

**Figure 10** - This is a good cross-section for a pearl cup. Notice the increasing thickness toward the base or attachment point.

**Figure 11** - The models for all four of the components illustrated were constructed by turning.

**Figure 12** - Carving steps A through F1 illustrate the steps in preparing a prong mounting model.

**Figure 13** - Alternates E2 and F2 show how to finish the turning as a plate-type seat.
ROTATIONAL FORMS

When I suggest this technique to commercial goldsmiths, they usually reject it out of hand. The first response is that it's easier to use small commercial setting heads. This is true under certain circumstances, but I think that for many of you in this audience, the situation is quite different. If I were to receive an order that would require me to set 200, 3mm round brilliants, I would probably consider commercial parts. However, if I had a custom order for a top quality, one of a kind, that required a half dozen small brilliants in combination with a quality piece of metalwork, I certainly would cast the parts myself. The benefits of this technique can be segmented into a number of different areas. These include:

1. Inventory Investment
2. Time (Delay + Administrative)
3. Part Cost
4. Quality (Weight + Material Match)
5. Design Freedom

Each of these is worth at least a brief comment.

Inventory Investment - If I were to stock a full range of various gemstone heads, the investment would be very large. Since I never know what my next job will be, stocking a
full range of parts would be impractical and expensive. This problem really then becomes one of time.

**Time** - There is both an administrative time waste and a delay involved in ordering commercial parts. Even though I work in the suburbs of Chicago, there's a certain amount of grief associated with picking up parts from one of the findings companies in the jewelry district. I've also found that the quicker I can produce the work, the happier my customers are. So the simple delay of locating and buying the findings is a problem. Even worse, if I'm buying only a few findings, the administrative cost is very large. Even if I order them through the mail, I must sit down, fill out an order, and so on. At the very least, I must pick up the phone and make an order. Even then, I'm not done since the order has to be logged into the shop and all the appropriate records kept. I think those of you who are in the commercial area of metalsmithing will appreciate how annoying and time-consuming all this administrative nonsense really is. Worse yet, the first company you call may be out of stock in the particular item you need or they may have six when you need seven, and so on. All I'm suggesting is that there is considerable time delay and grief involved in picking up a few small heads. Frankly, I can turn six 2mm diamond heads in less time than I'll spend buying them.
Part Cost - I don't have to tell you that the cost of findings can be very high. During the recent rise in gold prices, the cost premiums for gold findings were nothing short of astronomical, and even now, with lower gold prices, there is still a big premium over the actual gold content in the item. This means that as long as I can keep my labor relatively low, the cost savings go a long way toward covering the labor required to make the part. Besides, I get paid for labor and someone else gets paid for a commercial part.

Quality - Quality means many things to different people, but certainly this approach provides quality in a number of ways. First of all, it's economical to make the parts more massive. This means they're less subject to damage, and the overall feeling of the work is more solid than when you use standard commercial parts. One of the key quality benefits I've found is the fact that you're able to get good material matches, since a whole piece can be made out of the same gold alloy. In many cases, you can make a project using special alloys (for example, colored gold). Finally, the parts can be tailored to the precise application required. You aren't in the position of having to bend the prongs out a little bit on a commercial head because one size is too small and the next is too big.

Design Freedom - The ultimate benefit in this technique is
a tremendous range of design freedom. The design does not need to be forced in any direction to accommodate a commercially styled part. If a rotational form is needed, you can make it any shape, weight or material that you desire. I am also pleased with the ability to quickly create small sculptural forms with the same feeling or quality that raising can create. I've found that it's frustrating to generate hard, crisp shapes and forms in wax. Even when the overall form can be developed, it's often difficult to take enough material out to create thin sections which are practical to cast in precious metals. For me, the real appeal of this technique is the ability to create geometric thin-shell forms.
PART 3

MODEL MAKING - MATERIAL FOR INVESTMENT CASTING

ACCESSORY MATERIALS AND TOOLS

By: Richard D. Austin

To date we have discussed wax properties and specific wax formulations. In addition to the waxes there are a number of other accessory materials and tools which are useful in the model building process.

**Lubricants and Release Agents** - Melted wax may stick tenaciously to metal work surfaces. A number of release agents may be used to minimize sticking. In some cases a film of glycerin or fine machine oil may be sufficient to coat metal surfaces and prevent adhesion. Special materials such as Kerr's Microfilm are also available for this application. The most effective release agents are the silicone compounds which are found in high temperature lubricants and water proofing compounds. If you want to use silicones, they are available in two forms which are useful for shop application. The first would be the aerosol cans of silicone spray lubricant which can be found in a hardware store or automotive shop. These can be sprayed onto the surface and the excess wiped off. If you want concentrated material, silicone laboratory grease is the best. This is available in tooth paste size tubes. Although it's relatively expensive, a $5 or $10 tube of the grease is a lifetime supply. Jewelry trade shops also offer silicone grease in syringe applicators.
Some cautions about the silicone are in order. They work so well that they can be annoying. If other surfaces in your shop become contaminated, they can cause problems. It's difficult to paint over the surfaces which have been contaminated with silicone grease and it can cause poor adhesion on components which are assembled with glue. If you do use silicone, use it sparingly, keep it under control and clean up well when you are done.

Solvents and Polishing Agents - For practical purposes wax solvents and polishing agents are the same material. The solvent property is used to smooth the surface by rubbing with a soft cloth and the solvent. The solvents are also useful for cleaning up shop tools. Commercial material such as Kerr's Laboratory Solutine work very well. One popular material is eucalyptol. It has a very pleasant odor and works well as a wax or polish. Xylene is also an effective wax solvent. Although no major hazard is present you should remember that many wax solvents are flammable and may also be toxic in quantity. They should be used in a well ventilated area and careful hygiene is appropriate.

Mold Releases - There is a different class of release materials which may be used in vulcanized rubber molds. Not all combinations waxes and mold materials require a release agent. I would recommend that you follow the manufacturer's direction with regard to wax releases for rubber molds. It should be noted that the release properties of the injection waxes vary widely from compound to compound.
ZINC PLATE ENGRAVING

The traditional jewelry maker has a number of techniques at his disposal for embellishing the surface of metal forms. Engraving chasing, reticulation provide the metal worker with the ability to add detail and interest to the surface of a fabrication. This detail may be highly structured in a case such as ornamental engraving, uniform in the case of chasing, or random with reticulation.

Many of the same surface treatments can be applied to cast parts. However, the casting process used in conjunction with other model making techniques, provides the opportunity to do some unique surface effects which would be difficult to achieve by other means. It also allows the jewelry maker to accomplish the results at a much lower cost.

One of the very useful techniques is the process of photo engraving as it is applied in the printing industry. This method can be to make jewelry models in several different ways. The two most common ways are to use the process to make dies and to actually photo engrave a positive master for mold making.

Since the photo process can easily be reversed, this provides an excellent way to achieve highly developed and detailed reversal images. They may be either positive or
negative and/or mirror images.

The simplest way to apply this technique is to work with a maker of printing plates who prepares zinc or magnesium plates. Almost any small printing shop should be able to accommodate you. In my experience, they will have a minimum charge in the range of $15. Almost all of my jewelry projects are accomplished for the minimum fee.

The best way to proceed is to illustrate some examples of specific applications of the process. Based on these, you should be able to create your own concepts of how this technique might be applied.

The first one is a small tie tack which I made up for the Chicago Chapter of the IDSA. They wanted a limited production item for their members and they had no concept of how many they might actually sell. Since sales were pretty much uncertain, they didn't want to spend a great deal on tooling. Various estimates for the tooling bill alone were in the range of $150. Since I knew some of the members of the group, I volunteered to try coming up with something more economical. Figure 36 illustrates the basic logotype used by their group. This was obtained in a variety of sizes, the smallest being about 1/4" by 3/8" in size.

You will notice that this design has a very fine network of
lines. This is about as fine a pattern as you can expect this technique to reproduce. The master was taken to a local printer and a zinc plate was prepared. In this case, since there was a minimum charge, we had a plate made up with eight repeats of the same logo. That provided insurance in a couple of ways. Number one, if one or two of them didn't etch well it wouldn't matter, and second, if I damaged one in preparing the mold there would be no great loss. The overall thickness of the original plate was about 0.14 inches and the etching was roughly half of that thickness. The first step was to saw around the part and remove it from the plate. Next, jewelers files and sandpaper were used to clean up the edges. They were left with a slight draft or taper and were highly polished. At this point the part was a little too thick so the thickness was removed by grinding off the back and polishing the part smooth. At this point, the part could have been put directly into a vulcanized rubber mold. However, since it was to have a flat back and we didn't know how many parts would sell, I simply made an open silicone rubber mold. This was done by adhering the master to a plate of glass, putting a small paper dike around it, and filling the space with room temperature vulcanizing silicone rubber. I use silicone rubber in my own shop because I've never put together the equipment to do vulcanized molds. However, this part could easily be sent out for mold making. In the photograph you can see that this part was made in the same
mold with some other components. This helps minimize the mold cost and larger molds are a little easier to prepare.

Another version of this technique is taught in a number of college metalsmithing programs. The engraved image is used for tooling rather than to make the model itself. In this case, I have chosen a simple band ring as an example. A line drawing is prepared of the pattern for a ring. The raised areas of the ring are indicated by the dark lines. This is taken to the printer and the raised areas are engraved or etched into the plate. The next step is to use this as a master to prepare a model. The procedure is simple. Sheet wax is pressed into the zinc plate to provide the impression.

In this case we need some kind of mold release. A piece of Saran Wrap is carefully stretched over the mold and then a piece of slightly warmed thick sheet wax is placed against the Saran Wrap. Finally, the whole sandwich is placed between a couple of metal plates in a vice or hydraulic press and some pressure is applied. Basically the pressure extrudes the wax into the impression into the plate. When the pressure is released, the plate is removed, and then the Saran Wrap is withdrawn. At this point, you should have a crisp image of the jewelry impression. Figures 30-34 illustrate an example of this process.
One further application which you might consider is the preparation of large texture sheets by engraving. These can be reproduced to provide texture elements for portions of larger projects. As the size of the piece becomes appreciably larger, the impression technique becomes more difficult. Doubling the size increased the surface area by four times. This means you need four times as much pressure to get an equivalent effect. The impression technique is best suited for smaller pieces with relatively little detail, while the molding technique is more suitable for highly detailed parts or larger areas.
Almost every text written on jewelry fabrication warns of the hazards of soldering hollow, totally closed forms. There are really a couple of different problems involved. First, even if you are able to solder the closed form together, the tremendous vacuum created by the cooling gases will tend to suck the solder out of the joint and create porosity. In thinner sections the shell may even crumple on cooling.

The problem is readily solved by placing even the smallest hole in the shell. If the opening can be hidden in the design there is no problem. However, subsequent cleanings may introduce pickle, water or cleaning solutions into the shell. This tends to dribble out and stain the area around the opening.

In some cases it's more useful to close the opening with a threaded plug. This can be done in two different ways. It can be hidden in the attachment of a bail or an eye. Alternately they can be fully plugged and finished.

The first situation can be illustrated by a simple example. The sterling peanut in Figure 1 was cast in two halves and soldered together with a small opening where the eye was to be placed. This was accomplished by filing a vee notch in both sides of the shell as illustrated in Figure 2. After
soldering and pickling the hole was finished with a #26
 drill and tapped with a 14-26 tap. A small eye was soldered
 onto a length of 18 ga wire which was threaded with a
 matching die.

A little epoxy was applied to the threads and the eye was
 screwed into the hole. It should be screwed in firmly but
 be careful not to twist the eye off.

If you wish to close the hole off and finish the piece to
 a high polish this can also be accomplished by mechanical
 means.

Whether the shell is fabricated or cast it should be built
 up to an extra thickness at the closure. The same proce-
dure is used to prepare the hole in the shell. However, in
 this case the plug is a piece of wire threaded for only part
 of it's length. File a pair of flats on the rod just above
 the threads. This will allow you to grip the rod with a
 pair of pliers to thread it into the opening.
SPRUING

FLASK SIZE

There are various rules of thumb about how close a model can be to the wall of a flask. To some degree, a number of elements vary according to the absolute size of the flask. Burnout cycle would be an excellent example. As the flask is put in the oven and the temperature is raised, the insulating effect of the investment itself means that the temperature at the core of the flask will lag behind the oven furnace temperature. The larger the flask the more that lag will be. Also, the larger the flask is, the more complex the spruing will probably be and the more difficult it is for air to enter the cavity and burn the carbon residue. This means that the larger flask will heat more slowly and have a longer burnout cycle. All of the factors in the cycle, such as the time you dry the moisture out, tend to increase with increasing size.
\[ \frac{L_1 - L_2}{L_1} \times 100 = \% \text{ Shrinkage} \]

0.968 -
Cooling is a contact area surface phenomenon. More pressure means more cooling.

Idea of supercooling & nucleation. Generally speaking, a pure crystal is very strong however a few large ones are bad.

Lots of easy paths to break. A complex breaking can concentrate force when a boundary yields.
<table>
<thead>
<tr>
<th>B&amp;S Wire Gauge</th>
<th>Diameter Millimeters</th>
<th>Area Millimeters Square</th>
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<td>20</td>
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5) **Spruing** - In my own consulting work with casters as well as my general experience with students, I find that probably more casting defects can be traced to bad spruing than almost any other single defect. Although there always seems to be a little mystery attached to the spruing operation, certain principles or rules can be stated which dramatically increase the likelihood of sound, complete castings.
Large Mass
Flat Plate
Long Wire
Mass con Mass
Ring suit Ups
Self Error.
SPRUING
VENTING

Although the basic premise of investment casting is the elimination of air from the cavity through the investment you may wish to vent the cavity in certain situations. For example if you have a fill problem on a thin section, venting may improve the reliability of the process. If you consider the hydrostatic characteristics of the system it is obvious that the vent must emerge "above" the level of the casting metal. Although vents will often chill the metal before it reaches the surface this is not a reliable approach. The direct approach is to lead an 18 or 20 gauge wax wire from the mold cavity back to the base of the sprue former. A vented sprue system is illustrated in figure 63.
SPRUING

I. Equal Areas of Branching

II. Cross Sectional Rules
   A. Area Great er than Section
   B. Constantly diminishing Area

III. Radius Effect
   A. Cut In
   B. Over Fill

IV. Commercial Vs. Art/Craftsman

V. Carry Over - Size Limitations - Reservoir

VI. Spruing Situations
   A. Massive Sections
   B. Remote Mass
   C. Flowback
   D. Thin Section

VII. Difference for Different Forms of Casting
<table>
<thead>
<tr>
<th>U.S. Ring Size</th>
<th>Diameter in Inches</th>
<th>Circumference in Inches</th>
<th>Diameter in Centimeters</th>
<th>Circumference in Centimeters</th>
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The shape or form of a piece of metalwork has a great deal of impact on the ease of finishing. Deep recesses with sharp corners are much more difficult to finish while shallow recesses and radiused corners are much easier to deal with. An understanding of the relationship between the finishing process and the model building process will speed construction considerably.

The selection of the appropriate cutting tool is very important. The radius of a file face or a rotary burr should match the curve of the work as closely as possible. It's difficult to freehand carve broad curves with small radiused tools.

In some respects, carving with rotary tools will work to your advantage. There will always be some radius at the bottom of any recesses. Model assembly methods may create sharp corners. These corners can be given a radius with wax if desired.
The quality of an investment casting is influenced by every step, from the original design sketch to final buffing. In the case of production items cast from injected waxes, a modest level of reject castings is not a serious problem. However, failures are extremely frustrating if you produce one-of-a-kind objects. In this case, all of the labor invested in model construction is lost if a casting fails. A clear understanding of investment properties and application can significantly decrease the risk of casting failure. Extra care will produce results that more than justify the extra effort.