Richard Austin (1936-1990) was a metalsmith and author, with several hundred articles to his credit.

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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WAX DATA

The following comments should be used in conjunction with the injection wax data presented at the June, 1986, Kerr meeting. First it should be noted that Kerr aqua wax is the standard for these tests. For purposes of analysis, you may assume that the viscosity of the wax must be four hundred or less at the injection temperature. Put the opposite way, injection temperature may be considered to occur at a viscosity of fourhundred. In order to be injectable as a paste, the wax must have a flow of eighty-plus percent. When working with the percent flow charts, keep in mind that a dash or a blank space represents essentially a one hundred percent liquid condition.

Surface Discoloration - Gross overheating the investment will free sulphur compounds which are available to react with the metal surface during the casting process. This kind of discoloration is very deep and persistent. It will be very difficult to remove by pickling and may require extended abrasion. Unfortunately, there is a more subtle problem which occurs. At any temperature, when the mold is placed in the flask, the contact area on the surface of the investment will be heated to the temperature of the metal. This heat transfer doesn't last very long. As the metal cools, the investment
drops below the critical temperature and everything is under control. However, note that the higher the temperature of the investment at the time of casting, the deeper this affected surface area will become and the slower the metal will drop in temperature. This means that if you cast into a very hot mold, even though it's below the critical temperature of the investment, a significant depth of the investment will be affected. This kind of effect can be observed if you carefully section the investment or trim it away after casting. There will be a discolored zone near the metal.

**Wetting Agents** - Traditional casting practice calls for the use of a wetting agent to insure good contact between the investment and the model. Classical literature reference suggests the use of material such as peroxide and green soap. More recently, a number of commercial materials have become available. These are basically sold in two types, one for vacuum casting and one for vibratory investment, the primary difference being that the material sold for vacuum investment applications have less tendency to foam. The use and application of the wetting agents is an area of enormous controversy among casters. Which agent is best, how it should be applied and how long it should sit before investment are all issues of debate. Fortunately, this is gradually becoming a non-issue. Companies such as Kerr Manufacturing have begun
to add wetting agents directly to their investment. These wetting agents work well enough to eliminate the need for material to be applied to the model. As a practical matter, at this point using a wetting agent may actually decrease surface quality if it's improperly applied. I would strongly suggest that you use an investment material containing a wetting agent and do not use any material on the models. There are some other benefits which accrue from this approach. First of all, it eliminates a whole area of uncertainty and, second, it means that you can invest very quickly after spruing. There is really nothing to wait for.

It should be noted that the use of silicone rubber molds or silicone mold releases make the surface of the model considerably more hydrophobic. This can be seen if you attempt to apply wetting agents to the surface. Silicone-contaminated surfaces do not wet out even with the wetting agents. Although it may not at first seem obvious, the use of wetting agents with silicones is probably counterproductive since it does tend to bead up and concentrate in a heavier layer in certain areas of the casting. This is precisely the situation which we do not wish to encounter. Even in the case of highly hydrophobic surfaces, it's better to let the wetting agent in the investment do its work.
In addition to being hydrophobic, wax models often tend to develop a significant static charge, particularly in lower humidity conditions. This static attracts all kinds of contaminants, the most serious probably being wax dust from fabricating operations. It's not too hard to believe that having this contamination in the casting system is a bad idea. If you encounter situations where you seem to be getting various kinds of surface contamination, this can be eliminated by a quick rinse in a strong detergent solution followed by cold water. After the model is dried, you may proceed normally.

**Silica** - There is a strong tendency for metal casters to underestimate the possibility of developing silicosis from handling the investment. It is important to understand that there already are identified instances of silicosis associated with workers in the manufacturing environment exposed to investment. Good personal hygiene and shop habits are an important part of any preventative health program.

**Burnout** - The optimum burnout cycle is a subject of considerable debate and practices vary widely. It is important to understand that many of the defects or phenomenon which are observed in the burnout process are both subtle and
intermittent. A particular burnout cycle may work for ten batches of castings and in the eleventh batch there will be a bad flask. When you examine this more carefully, it becomes obvious that there are a number of variables which are relatively difficult to account for and yet may influence the result. Some of these less obvious variables are:

. Position in the oven;
. The number of flasks in the oven;
. The amount of residual moisture in the investment.

All of this means that subtle differences in the burnout cycle may produce unexpected results. A classic example of this case would be the decision whether or not to wet the investment and whether to begin with a cold furnace or a heated furnace. Let's examine this second issue in further detail. As the temperature in the flask rises, the wax melts and finds its way into the pores of the investment. It now appears that a somewhat faster rate of rise allows the wax to clear the mold more quickly. Obviously, this rate of rise can't be too fast since it would damage the flask. However, all other things being equal, a rapid rise seems to help. This suggests that the flask be put in an oven which is somewhat above the burnout temperature of the wax. In essence, this procedure is intended to minimize the penetration of the wax into the investment. As it turns out,
this process helps to minimize fine scale surface spalling which is observed from time to time.

This also suggests the use of a de-waxing system since this insures that the mold will quickly be brought to a temperature above the melting point of the wax without undue thermal shock.
The preparation of master patterns for production generally proceeds by one of two methods. The master part may be fabricated directly in metal by conventional goldsmithing techniques. Alternately, the master model may be prepared in wax, cast and finished. Each method has certain advantages and disadvantages. Metal fabrication allows the preparation of highly detailed models of modest weight. Additionally, it may be easier to achieve the desired level of internal finishing in a fabricated piece. Finally, craftsmen with the required fabricating skills may be more readily available. Wax modeling also has its attendant advantages and disadvantages. Generally speaking, an experienced wax carver can construct a simple model more rapidly than it can be fabricated. On the negative side, it may be more difficult to achieve a high level of detail in a wax model.

The use of plastics in conjunction with wax can decrease or eliminate many of the disadvantages. In actual practice, complete models can be prepared from appropriate plastics. However, special skills and materials will be required. When plastics are used for detailing, most of the potential problems are minimized or eliminated.
Although there are many potential applications of plastics, we have selected a few examples which should be the most useful:

- Prong Construction
- Bezels
- Thin Sections
WAXES

CUTTING TOOLS

Waxes are easily removed by a scraping action. This can be observed in the use of two or three flute wax burrs or by cutting the material with an engraver. However, the low melting point of the wax means that the material will soften or melt and clog the teeth of conventional files or rotary burrs. The wax data illustrated in chapter 7 indicates that a considerable softening occurs even before the material actually melts.

If you intend to use conventional cutting tools, they must be extremely sharp. There are three principle factors to consider when you machine plastics or waxes:

1. The Cut Of The Tools
2. Sharpness
3. Cutting Speed

The Cut of the Tools - The pattern and size of the teeth both influence the way in which the tools cut the material. Generally speaking, plastics require a finer tooth pattern and waxes a larger, more open pattern.

Sharpness - Because these materials have low melting points,
tools must be extremely sharp to lift chips of the cut material rather than melt the surface. As soon as the tools become clogged, the friction between the two wax surfaces aggravates this problem considerably. In effect, clogging the tool destroys its cutting action.

**Cutting Speed** - The velocity of the surface of the cutting tool is directly related to the rotational speed of the tool and its diameter. Obviously, a large diameter tool will have higher surface speed at any given rpm.

For most applications, I have found that small tungsten carbide burrs work extremely well on plastic. Because they usually have a double-cut surface, they tend to minimize chatter. Because they are carbide, they remain very sharp for a long period of time, and the tendency to melt the plastic is minimized.
WAXES

INTRODUCTION

The lost wax casting process has been used for thousands of years. However, until recently there were only a few waxes available for model making. Early goldsmiths were limited to natural materials such as bees' wax and bayberry wax. When the petroleum industry began to refine natural crude oil, a number of new materials became available. Paraffin wax is the most obvious example. Subsequently, the development of the petrochemical industry added synthetic waxlike substances (plastics) to the list of materials which might be suitable for "wax" model making.

At the present time, there are hundreds of different types and forms of wax available for jewelry making. These are various combinations of natural organic waxes, refined petroleum materials and synthetics created by polymer chemistry. A growing market has encouraged the introduction of materials with a wide range of properties. This has expanded to the point where it is sometimes confusing to select from the alternates available.

The following is a non-technical discussion of various waxlike materials, their properties and application. However, I would
like to remind you that there is no "right way". Within the parameters of the process, whatever works is all right.
WAXES

APPLICATION

Many commercial jewelry waxes are formulated for specific applications. This usually results in a unique set of product characteristics and/or form. Often, one or more properties may be emphasized to make the material more suitable for a particular use. Some specialized waxes are discussed individually below.

Carving Wax - The term carving wax is sometimes confusing. Almost any wax can be carved. I have even seen people trying to carve red sticky wax. However, when most people describe carving waxes, they mean ones that can be cleanly carved with sharp tools. I would like to introduce my own definition of a "carving wax". It's my personal opinion carving wax is an expression which should be limited to materials which are suitable for carving with power tools such as rotary files. By my definition, carving waxes would have two key properties. First, they must be free machining. Second, they would have a high melting point. Free machining materials are ones which form clean chips or cut away with minimum chatter and don't stick to the tools. If you look at the various wax formulations, you will encounter a group of waxes which have melting points of $200^\circ$ or higher. When you find a material
such as this, it is almost always a blend of polyethylene wax. The polyethylene provides the high melting point which is not normally available in any of the petroleum or natural organic waxes. These are the materials which generally have the kind of properties which I have described. If you are going to do any kind of machining or working with power tools, look for materials with a melting point over 200°F.

**Injection Wax** - Multiple copies of a piece of jewelry can be made by preparing a rubber or metal mold and injecting melted wax into the mold under pressure. For limited production, the molds are commonly made of vulcanized rubber. However, molds may also be made of various cold cure materials such as silicone rubber or in some cases metal. In any event, the wax is blended with special properties. Because of differences in injection pressure, there may be differences in both material and application between rubber and metal molds.

Since shrinkage is related to temperature spread between solidification and room temperature, a low melting point is preferred. The smaller the difference between the melting point and room temperature, the less shrinkage will occur. Most injection waxes have melting points in the range of 140°F to 155°F. Injection waxes are often characterized by their injection temperature rather than melting point. This
represents the optimum temperature for the molten wax at the pressure it is to be introduced to the mold.

Another preferred characteristic is a sharp melting point. Solidification should occur over a narrow range of temperatures. A low melt viscosity is also important to make sure that the material flows freely into all parts of the mold, and it also helps minimize air entrainment in the wax mixture. Flexibility is also a very useful property since it helps remove the model from undercut areas with a minimum of breakage.

It's difficult to build up or modify injected patterns with many conventional waxes. For example, if you put a large drop of blue inlay wax (melting point about 163°F) on a thin portion of a low melting model, the whole thing will simply collapse into a puddle. If you're going to modify these patterns, the best results will generally be achieved if you use a scrap of the same wax.

Whether you make your own waxes or buy commercial prepared waxes, you will often encounter very small air bubbles in the surface of the pattern. Note that subsurface bubbles may be present which will burst during vacuuming. These can be a great annoyance when you try to fill them in, since it's
difficult to get a smooth job. There is one product on the market which can make this easier.

**Disclosing Wax** - Kerr makes a material called Disclosing Wax. The Disclosing Wax has a consistency about like shortening or cold cream. You wipe it into small bubbles or pits and remove the excess with a soft cloth. This can be a great help if you have a lot of touchups or repairs to do.

**Sprue Wax** - Sprue waxes are special wires or rods which are used to build up the sprue arrangements for casting. Usually, the sprue waxes will have relatively low melting points and in many cases a slight degree of tack or adhesion. The low melting point allows the wax to melt out of the sprue arrangement first, clearing the way for the model wax to flow out. In very large castings, this may be important. Also, in cases where you wish to minimize smoking by recovering the wax before proceeding with the burnout, this may be handy. It is particularly useful in industrial applications where ceramic molds are used and the mold is introduced directly into a very hot furnace.

**Wax Pen Wax** - There are a number of commercial wax pens available on the market. It is usually recommended that they use special waxes. These are usually waxes which have a low
melt viscosity and some flexibility. In my experience, the wax pens do work best with the specified wax. There seems to be a lot less problem with plugging or other malfunctions of the pen.

I have found one other use for wax pen waxes. I make simple open molds from silicone rubber for small jewelry parts. I usually melt a little wax in a teaspoon and pour it into these molds. Wax pen wax is very good for this application. It fills all the corners very well and it doesn't tend to develop bubbles.

**Inlay and Build-Up Wax** - These materials typically have melting points in the range of 160°F to 165°F. They are used to build-up or add to patterns. Most formulations are hard enough to conveniently carve with hand tools after they have cooled. The waxes are traditionally added with a heated spatula, but build-ups can also be made with an artist's brush and a small container of melted wax.

**Sticky Wax** - This material is used for repairing wax models and for joining wax components in larger, more complex assemblies. With melting points as low as 136°F, sticky wax can be used to repair or modify injection wax patterns. Other materials such as Utility Wax or Boxing Wax are also slightly
tacky but they have higher melting points (approximately 1760°F).
WAXES

ACCESSORY MATERIAL

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 sticks to metal work surfaces. A number of release agents may be used to minimize sticking. A film of glycerin or fine machine oil may be sufficient to coat metal surfaces and prevent adhesion. Special release agents are available in the dental trade. These may be referred to as dip lubricants. 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 available in hardware stores or automotive shops. 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 silicones 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 is 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 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** - Not all combination 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.
WAX FORMULATIONS

There seems to be a tremendous temptation on "do it yourself" in wax formulation. Since the wax may cost several dollars a pound or more, this isn't too surprising. In the commercial market many suppliers provide compatible materials systems the user can blend. The hobbyist or craftsman may also decide he can save a little money or develop special properties by blending his own wax. I must confess that I went through this phase about fifteen or twenty years ago. At that time, I purchased samples of about fifty different grades of plastic wax. I blended all kinds of things and quite frankly, I never came up with anything any better than what I could buy through commercial sources. If you place any value on your personal time, I believe that blending your own waxes probably isn't worth it. However, if you are bound and determined to try, I would recommend a few things which may make your life a little simplier.

First of all, don't try to be too complex. The best formulations will typically be mixtures of two or three materials. More complex mixtures usually have poor physical properties. Be extremely careful about the fire hazard. Most waxes will burst into flame at relatively low temperatures. I did most of my melting in an aluminum sauce pan, which I placed in an electric frying pan. This eliminated open flame and provided good temperature control. The frying pan also contained most of the little dribbles that seem inevitable working in wax.
If you are bound and determined to try your own blends, you can begin by using white polyethylene can lids and blending them with conventional paraffin wax or other common waxes. These are the replaceable lids which you normally find on coffee cans. These will yield a very hard, high melting carving wax when properly blended. The only other suggestion I would make, is to keep meticulous records. The formulations seem to be surprisingly sensitive. If you haven't weighed your ingredients carefully and kept good records, you will find that sooner or later you will get a great batch of material which is difficult to reproduce.

Next month we will be considering the tools and accessory materials offered in the wax modeling process.
PART 2
MODEL MAKING - MATERIALS FOR INVESTMENT CASTING

WAX APPLICATIONS

By: Richard D. Austin

In the first article of this series we discussed a series of physical properties which characterize modeling waxes. Many commercial jewelry waxes are formulated for specific applications. This usually results in a unique set of product characteristics. Often, one or more properties may be emphasized to make the material more suitable for a particular use. Some specialized waxes are discussed individually below:

Carving Wax - The term carving wax is sometimes confusing. Almost any wax can be carved. I have even seen people trying to carve red sticky wax. However, when most people describe carving waxes, they mean ones that can be cleanly carved with sharp tools. I would like to introduce my own definition of a "carving wax". It's my personal opinion carving wax is an expression which should be limited to materials which are suitable for carving with power tools such as rotary files. By my definition, carving waxes would have two key properties. First, they be free machining. Second, they would have a high melting point. Free machining materials are ones which form clean chips or cut away with minimum chatter and don't stick to the tools. If you look at the various wax formulations, you will encounter a group of waxes which have melting points of 2000 or higher. When you find a material such as this, it is almost always a blend of polyethylene wax. The polyethylene provides the high melting point which is not normally available in any of the petroleum or natural organic waxes. These are the materials which
generally have the kind of properties which I have described. Medium and hard Kerr Master Pattern Carving Wax are excellent examples of waxes which have these kind of properties. If you are going to do any kind of machining, or working with power tools, look for materials with a melting point over 200°.

**Injection Wax** - Multiple copies of a piece of jewelry can be made by preparing a rubber or metal mold and injecting melted wax into the mold under pressure. For limited production the molds are commonly made of vulcanized rubber. However, molds may also be made of various cold cure materials such as silicone rubber or in some cases metal. In any event, the wax is blended with special properties.

First, since shrinkage is related to temperature spread between solidification and room temperature, a low melting point is preferred. The smaller the difference between the melting point and room temperature, the less shrinkage will occur. Most injection waxes have melting points in the range of 140° to 155° F. Injection waxes are often characterized by their injection temperature rather than melting point. This represents the optimum temperature for the molten wax at the moment it is to be introduced to the mold.

Another preferred characteristic is a sharp melting point. Solidification should occur over a narrow range of temperatures. A low melt viscosity is also important to make sure that the material flows freely into all parts of the mold and it also helps minimize air entrainment in the wax mixture. These particular properties of the wax suggests certain
cautions when you are modifying or working molded wax patterns. Flexibility is also a very useful property since it helps remove the model from undercut areas with a minimum of breakage.

It's difficult to build up or modify the patterns with many conventional waxes. For example, if you put a large drop of blue inlay wax (melting point about 163°F) on a thin portion of a low melting model, the whole thing will simply collapse into a puddle. If you're going to modify these patterns use a scrap of the same wax.

Whether you make your own waxes or buy commercial prepared waxes, you will often encounter very small air bubbles in the surface of the pattern. These can be a great annoyance when you try to fill them in, since it's difficult to get a smooth job. There is one product on the market which can make this easier.

**Disclosing Wax** - Kerr makes a material called Disclosing Wax. The Disclosing Wax has a consistency about like shortening or cold cream. You wipe it into small bubbles or pits and remove the excess with a soft cloth. This can be a great help if you have a lot of touch ups or repairs to do.

**Sprue Wax** - Sprue waxes are special wires or rods which are used to build up the sprue arrangements for casting. Usually, the sprue waxes will have relatively low melting points and in many cases a slight degree of tack or adhesion. I have mixed feelings about the need to differentiate the sprue waxes. With the burnout cycle which I use, I find that any wax
wire or rod works well. In theory sprue wires are special, since they have lower melting points than the model. This allows the wax to melt out of the sprue arrangement first and clear the way for the model wax to flow out. In very large castings, this may be important. Also, in cases where you wish to minimize smoking by recovering the wax before proceeding with the burnout this may be handy. It is particularly useful in industrial applications where ceramic molds are used and the mold is introduced directly into a very hot furnace. In this case, the wax can actual build up pressure if the sprue channels don't clear quickly. Obviously, there is no harm in using the sprue wax but unless you're trying to recover the wax or eliminate the wax before burnout, sprue waxes are of marginal value.

Wax Pen Wax There are a number of commercial wax pens available on the market. It is usually recommended that they use special waxes. These are usually waxes which have a low melt viscosity and some flexibility. In my experience, the wax pens do work best with the specified wax. There seems to be a lot less problem with plugging or other malfunctions of the pen.

I have found one other use for wax pen waxes. The Kerr wax pen wax has a low melt viscosity and clears itself of bubbles very quickly. I do a lot of two dimensional rubber mold work. I make simple open molds from silicone rubber for small jewelry parts. I usually melt a little wax in a teaspoon and pour it into these molds. I find that the Kerr wax pen wax is very good for this application since it fills all the corners very well and it doesn't tend to develop bubbles.
Inlay And Buildup Wax - These materials typically have melting points in the range of 160° F to 165° F. They are used to buildup or add to patterns. Most formulations are hard enough to conveniently carve with hand tools after they have cooled. Kerr Blue Inlay Wax and Perfect Purple Wax are typical examples. The waxes are traditionally added with a heated scoopula but buildups can also be made with an artist's brush and a small container of melted wax.

Sticky Wax - This material is used for repairing wax models and for joining wax components in larger more complex assemblies. With a low melting point of 136° F the Kerr Sticky Wax can even be used to repair or modify injection wax patterns. Other materials such as Utility Wax or Boxing Wax are also slightly tacky but they have higher melting points (approximately 176° F).
PHYSICAL PROPERTIES

The goldsmith is primarily interested in two aspects of the material: physical properties and form. The physical properties of the wax establish its working characteristics and its form is largely a matter of convenience. A wax blend is like an alloy, in that its properties represent some combination of the properties of its constituents. However, just as in the case of alloys, the result of combining two materials may or may not be predictable. The important physical properties of modeling waxes are described below:

Melting Point - The melting point (or solidification point) is a key characteristic of model building waxes. Most waxes are blends of various materials and they behave more like alloys of metal (which melt over a range of temperatures) than they do like pure materials such as water which has a very sharp characteristic melting point. Although the distinction is arbitrary, I usually think of waxes as having three ranges of melting points: Low (below 160°F), Medium (160°F to 200°F) and High (200°F +). The materials in these ranges usually have specific applications, characteristic properties and common constituents.

Flexibility - Waxes vary widely in their degree of flexibility. The degree of flexibility desired is strongly related to the application. Many waxes vary widely in flexibility depending on the temperature. A material which is brittle at 55°F Fahrenheit might be very flexible by the time its temperature reaches 85°F Fahrenheit.
Specific Gravity - In commercial applications the specific gravity of a wax can be quite important. Probably the best example is in the case of injection waxes. A simple example illustrates how important this can be. If an injection retails for a dollar a pound and has a 1.1 specific gravity, this would translate into a certain number of models or wax castings per pound or per dollar. Obviously, if another wax has a lower specific gravity (a lower weight for any given unit volume) it will go farther. You can cast more models per pound. If the 1.1 specific gravity wax sells for $1.00 per pound, the 0.9 specific gravity wax can sell for a $1.22 per pound and be just as good a bargain. You will get just as many castings per dollar with one wax as the other. Since the weight confusion method of calculating the metal required for a casting is widely used, specific gravity is also important for this application.

Color - Wax color has nothing to do with the properties of the material. Most jewelry modeling waxes would range from translucent white to opaque light tan if they weren't treated with various coloring agents. The coloring agents are used for two key reasons. First, they help to identify brands and grades of wax. From the manufacturer's viewpoint this has both a practical and their aesthetic value. Second, dark colors create a characteristic called readability. Simply put, it is easier to see what you are doing in dark wax than it is in white. If you don't believe this, try preparing a wax model out of paraffin. You will find that usually that it's extremely difficult to work. You will lack depth perception.
Burnout - Obviously, the waxes are only suited for their intended purpose if they burn clean in a normal cycle. I have never had a burnout problem with any commercial jewelry wax. On rare occasions I have had some difficulties with blends that I made from industrial grade materials. Companies which make both jewelry waxes and dental waxes usually adhere to the dental industry's standards for these materials, which specify an extremely low ash content. If you use plastics for model making an extended burnout may be required with some materials. With plastics there may be some reaction between the investment and the combustion products. This may be confused with poor burnout.

Tack - Tack or stickiness may be annoying or very useful, depending on the application. Obviously, red utility wax or sticky wax can be handy for assembly where the adhesion of the material is very useful. On the other hand, if you're trying to carve the wax and it sticks to the tools adhesion is not a functional property. This property will tend to vary considerably over a range of temperatures. Many waxes become quite sticky before they are fully melted.

Wetability - Most waxy substances tend to reject water. This property is exactly like what you see on the surface of a freshly waxed car. The water doesn't form a continuous film. Wetability is important when the material is being invested. The investment is water based and it must come into good contact with the model. This is generally taken care of by the use of wetting agents. However, you should realize that some waxes work better than others even with these agents. In any given situation you may achieve slightly better casting quality with a more wetable wax. This characteristic also shows up in waxes cast in silicone rubber molds. Silicone rubber is highly hydrophobic. It rejects water.
This property (through traces of the silicone materials) is transferred to the surface of the wax. You will find that waxes prepared in silicone rubber molds are much more difficult to wet out than those prepared in rubber molds.

**Water Solubility** - Several suppliers provide water soluble waxes. Generally, these are used as cores or bases for wax build up. The materials are rather grainy and not quite as easy to work with as conventional model building waxes but they can be extremely useful. Usually, these waxes will dissolve slowly in water but this can be speeded up if a small amount of hydrochloric acid or vinegar are added to the water.

**Flexibility** - Flexibility may be important in the modeling process or to improve handling of finished models. Wax sheet and wire are commonly made from relatively flexible waxes. Inlay waxes and carving waxes tend to be more ridged. Flexibility is a particularly important property in injection waxes since it minimizes breakage when parts are removed from the molds.

**Melt Viscosity** - The viscosity of the molten wax can vary widely. Synthetic waxes (polyethylene) are often very viscous. Petroleum or natural waxes may be very waterlike when melted. In materials with a wide melting range the viscosity may vary widely in a range of 5° to 10° Fahrenheit near the melting point. Many waxes display a crumbly cheese like consistency in this same temperature range.

In subsequent articles we will be discussing specific wax applications, forms accessory materials and tools for the model building process.
WAX VISCOSITY

The physical characteristics of 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 it's resistance to flow. For example, honey would have a much higher viscosity than water. Therefore, the honey flows much more slowly out of a jar 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 various types of carving waxes which are composed of polymers such as polyethylene. These exhibit a very high viscosity when molten. This also means that they are much more able to hold a high degree of texture when treated with a heated spatula or other tools. Conversely, waxes such as dental inlay wax have a very low melt viscosity. They tend to texture rather poorly when worked with a hot spatula. In essence, the wax just forms a molten puddle that levels itself out before the wax really 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.
Although not particularly suitable for jewelry models, it is far easier to use if a little dye is added. It's particularly important that you understand that one company's blue wax has absolutely nothing to do with another brand which might be the same or similar color.

**Do It Yourself Wax Blending**

In almost every class which I teach on wax modeling, somebody suggests the idea of blending their own waxes. Quite frankly, I advise against it even though I've done a lot of experimenting in this area myself, or perhaps it's because I have done the experiments. Over the years I've collected samples of at least of fifty different kinds of natural and synthetic waxes. I've blended these into all kinds of formulation, about 90% of which were worthless. If your time has any value at all, I would suggest you stick to commercial wax. However, if you'd like to experiment, let me make a few suggestions.

First, try to keep your formulation simple. Combined two different materials, certainly no more than three different materials, to achieve the properties you're looking for. As you combined more and more ingredients, most wax formulations tend to get rather cheesy and has strange melting point properties. One of the most fruitful areas to experiment with is in the preparation of a very hard covering waxes. As was stated elsewhere, the covering waxes tend to be some combination of polyethylene wax and other waxing materials. As a jumping off point, you might try some plastic polyethylene reusable can lids as illustrated in the photo. These can be melted and blended with a little parafin wax to create some
extremely hard brittle carving waxes which do have rather interesting properties. Some of these can be drawn into fine filaments and used in ways which are a little bit different than most commercial waxes. In addition to using the jar lids or commercial polyethylene, you might consider picking up some steric acide from a candle supply house or chemical company. This material can also be used to create wax blends, which tend to have a hard glossy characteristic. However, at the present time, I tend to enjoy making jewelry more than I do making wax. If you're going to experiment in this area, please use caution. It's very easy to start a fire working with melted wax and perhaps even worse the material burns very seriously if you spill it on yourself. If you're going to try melting wax I would suggest you pick up an old electric frying pan and use this as a heater. When I want to melt wax, I put an aluminum frying pan and set it into the electric frying pan. This tends to keep the worst of the mess off the bench top and although the frying pan gets pretty burnt and carbonized, it seems to be about the safest and easiest method to control.
WAXES
FORMULATION/COMPATIBILITY

There seems to be a tremendous temptation toward "do it yourself" wax formulation. There are probably two reasons for this. First, the modeling wax seems relatively expensive compared to the cost of raw materials. Second, there is a dangerous temptation to assume that results might improve dramatically if only you could find "the perfect wax". People seeking improved properties often take the approach of blending various commercial waxes. Those intent on achieving a lower price usually try to develop their own blends of bulk commercial waxes.

In either case, the constraints and limitations on the system are the same. Most important, don't try to be too complex. The best formulations will usually be mixtures of two or three materials. More complex mixtures tend to have two principle drawbacks:

- They exhibit a broad melting point range.
- They show poor strength when warm.

There is one useful and effective approach to wax blending. Some manufacturers of injection wax offer compatible systems. This might consist of a hard ridged wax and a very soft flexible wax. The two can be blended to provide a continuous range of properties.
If you construct individual models it is more effective to use the appropriate material in each portion of the model rather than search for the ultimate wax. I typically stock over fifty different kinds of commercial modeling wax in addition to an extensive supply of plastics. These can be joined together in complex models so that each material provides the proper properties for its portion of the model.

If you do wish to experiment a few suggestions may be helpful. First, weigh all of your ingredients very carefully and keep meticulous records. Formulations are sometimes surprisingly sensitive to small changes and proportions. If you don't keep good records, sooner or later you will get a batch of material which you will like and can't seem to reproduce. It's also important to emphasize the safety problems involved. First melted wax is a fire hazard. Waxes can create very intense fire when they are overheated. Also the polyethylene waxes cause very severe burns if dropped on the skin. They adhere and transfer heat at a very high rate.

For most of my experiments I melted the wax in an aluminum sauce pan, which is placed in an electric drying pan. This eliminates open flames and provides good temperature control. The frying pan also contains most of the dribbles and wax spills that seem to be inevitable.

If you would like to experiment with wax blending there is one simple way to begin. The polyethylene plastic in transparent can lids can be blended with conventional paraffin wax or other common waxes. These are the replaceable lids
which you often find on coffee cans. They will yield a hard, high melting carving wax when properly blended. See figure 96. (Photo in modeling section)
PART 1

MODEL MAKING - MATERIALS FOR INVESTMENT CASTING

By: Richard D. Austin

The lost wax casting process has been used for thousands of years. However, until recently there were only a few waxes available for model making. Early goldsmiths were limited to materials such as bee's wax and bayberry wax. When the petroleum industry began to refine natural crude oil, a number of new materials became available. Paraffin is probably the most obvious example. Subsequently, the development of the petrochemical industry added synthetic waxlike substances (plastics) to the list of materials which might be suitable for "wax" model making.

At the present time, there are hundreds of different types and forms of wax available for jewelry making. These are various combinations of natural organic waxes, refined petroleum based materials and synthetic materials based on polymer chemistry. A growing market has encouraged the introduction of materials with a wide range of properties. This has expanded to the point where it is sometimes confusing to select from the alternates available.

What I intend to do in this series of articles is to present a non-technical discussion of various materials, their properties and application. However, I would like to remind you that there is no "right way". Within the parameters of the process, whatever works is all right. I have seen craftsmen produce beautiful results with unlikely materials. What works for you is what you should use.
When I started out to prepare this article, I thought it might be interesting to segment the commercial waxes by their constituents. This turned out to be difficult for two reasons. First, commercial manufacturers are not willing to disclose what materials they use in various wax blends. Second, knowing that a wax blend contains a particular ingredient isn't much help. I concluded that the best way to discuss the waxes is to talk in terms of their physical properties and intended applications.
PHYSICAL PROPERTIES

The goldsmith is primarily interested in two aspects of the material: physical properties and form. The physical properties of the wax establish its working characteristics and its form is largely a matter of convenience. A wax blend is like an alloy, in that its properties represent some combination of the properties of its constituents. However, just as in the case of alloys, the result of combining two materials may or may not be predictable. The important physical properties of modeling waxes are described below:

Melting Point - The melting point (or solidification point) is a key characteristic of model building waxes. Most waxes are blends of various materials and they behave more like alloys of metal (which melt over a range of temperatures) than they do like pure materials such as water which has a very sharp characteristic melting point. Although the distinction is arbitrary, I usually think of waxes as having three ranges of melting points: Low (below 160° F), Medium (160° F to 200° F) and High (200° F +). The materials in these ranges usually have specific applications, characteristic properties and common constituents.

Flexibility - Waxes vary widely in their degree of flexibility. The degree of flexibility desired is strongly related to the application. Many waxes vary widely in flexibility depending on the temperature. A material which is brittle at 55° Fahrenheit might be very flexible by the time its temperature reaches 85° Fahrenheit.
Specific Gravity - In commercial applications the specific gravity of a wax can be quite important. Probably the best example is in the case of injection waxes. A simple example illustrates how important this can be. If an injection retails for a dollar a pound and has a 1.1 specific gravity, this would translate into a certain number of models or wax castings per pound or per dollar. Obviously, if another wax has a lower specific gravity (a lower weight for any given unit volume) it will go farther. You can cast more models per pound. If the 1.1 specific gravity wax sells for $1.00 per pound, the 0.9 specific gravity wax can sell for a $1.22 per pound and be just as good a bargain. You will get just as many castings per dollar with one wax as the other. Since the weight confusion method of calculating the metal required for a casting is widely used, specific gravity is also important for this application.

Color - Wax color has nothing to do with the properties of the material. Most jewelry modeling waxes would range from translucent white to opaque light tan if they weren't treated with various coloring agents. The coloring agents are used for two key reasons. First, they help to identify brands and grades of wax. From the manufacturer's viewpoint this has both a practical and their aesthetic value. Second, dark colors create a characteristic called readability. Simply put, it is easier to see what you are doing in dark wax than it is in white. If you don't believe this, try preparing a wax model out of paraffin. You will find that usually that it's extremely difficult to work. You will lack depth perception.
Burnout - Obviously, the waxes are only suited for their intended purpose if they burn clean in a normal cycle. I have never had a burnout problem with any commercial jewelry wax. On rare occasions I have had some difficulties with blends that I made from industrial grade materials. Companies which make both jewelry waxes and dental waxes usually adhere to the dental industry's standards for these materials, which specify an extremely low ash content. If you use plastics for model making an extended burnout may be required with some materials. With plastics there may be some reaction between the investment and the combustion products. This may be confused with poor burnout.

Tack - Tack or stickiness may be annoying or very useful, depending on the application. Obviously, red utility wax or sticky wax can be handy for assembly where the adhesion of the material is very useful. On the other hand, if you're trying to carve the wax and it sticks to the tools adhesion is not a functional property. This property will tend to vary considerably over a range of temperatures. Many waxes become quite sticky before they are fully melted.

Wetability - Most waxy substances tend to reject water. This property is exactly like what you see on the surface of a freshly waxed car. The water doesn't form a continuous film. Wetability is important when the material is being invested. The investment is water based and it must come into good contact with the model. This is generally taken care of by the use of wetting agents. However, you should realize that some waxes work better than others even with these agents. In any given situation you may achieve slightly better casting quality with a more wetable wax. This characteristic also shows up in waxes cast in silicone rubber molds. Silicone rubber is highly hydrophobic. It rejects water.
This property (through traces of the silicone materials) is transferred to the surface of the wax. You will find that waxes prepared in silicone rubber molds are much more difficult to wet out than those prepared in rubber molds.

**Water Solubility** - Several suppliers provide water soluble waxes. Generally, these are used as cores or bases for wax build up. The materials are rather grainy and not quite as easy to work with as conventional model building waxes but they can be extremely useful. Usually, these waxes will dissolve slowly in water but this can be speeded up if a small amount of hydrochloric acid or vinegar are added to the water.

**Flexibility** - Flexibility may be important in the modeling process or to improve handling of finished models. Wax sheet and wire are commonly made from relatively flexible waxes. Inlay waxes and carving waxes tend to be more ridged. Flexibility is a particularly important property in injection waxes since it minimizes breakage when parts are removed from the molds.

**Melt Viscosity** - The viscosity of the molten wax can vary widely. Synthetic waxes (polyethylene) are often very viscous. Petroleum or natural waxes may be very waterlike when melted. In materials with a wide melting range the viscosity may vary widely in a range of 50° to 100° Fahrenheit near the melting point. Many waxes display a crumbly cheese like consistency in this same temperature range.

In subsequent articles we will be discussing specific wax applications, forms accessory materials and tools for the model building process.
PART 2

MODEL MAKING - MATERIALS FOR INVESTMENT CASTING

WAX APPLICATIONS

By: Richard D. Austin

In the first article of this series we discussed a number of physical properties which characterize modeling waxes. Many commercial jewelry waxes are formulated for specific applications. This usually results in a unique set of product characteristics. Often, one or more properties may be emphasized to make the material more suitable for a particular use. Some specialized waxes are discussed individually below:

Carving Wax - The term carving wax is sometimes confusing. Almost any wax can be carved. I have even seen people trying to carve red sticky wax. However, when most people describe carving waxes, they mean ones that can be cleanly carved with sharp tools. I would like to introduce my own definition of a "carving wax". It's my personal opinion carving wax is an expression which should be limited to materials which are suitable for carving with power tools such as rotary files. By my definition, carving wax would have two key properties. First, they be free machining. Second, they would have a high melting point. Free machining materials are ones which form clean chips or cut away with minimum chatter and don't stick to the tools. If you look at the various wax formulations, you will encounter a group of waxes which have melting points of 200° or higher. When you find a material such as this, it is almost always a blend of polyethylene wax. The polyethylene provides the high melting point which is not normally available in any of the petroleum or natural organic waxes. These are the materials which
have the kind of properties which I have described. Medium
and hard Kerr Master Pattern Carving Wax are excellent examples of waxes
with these properties. If you are going to do any kind of
machining or working with power tools, look for materials with a melting
point over 200º.

Injection Wax - Multiple copies of a piece of jewelry can be made by
preparing a rubber or metal mold and injecting melted wax into the mold
under pressure. For limited production the molds are commonly made of
vulcanized rubber. However, molds may also be made of various cold cure
materials such as silicone rubber or in some cases metal. In any event,
the wax is blended with special properties.

First, since shrinkage is related to temperature spread between
solidification and room temperature, a low melting point is preferred.
The smaller the difference between the melting point and room
temperature, the less shrinkage will occur. Most injection waxes have
melting points in the range of 140º to 155º F. Injection waxes are often
categorized by their injection temperature rather than melting point.
This represents the optimum temperature for the molten wax at the moment
it is to be introduced to the mold.

Another preferred characteristic is a sharp melting point. Solidifi-
cation should occur over a narrow range of temperatures. A low melt
viscosity is also important to make sure that the material flows freely
into all parts of the mold and it also helps minimize air entrainment in
the wax mixture. These particular properties of the wax suggests certain
cautions when you are modifying or working molded wax patterns.

It's difficult to build up or modify the patterns with many conventional waxes. For example, if you put a large drop of blue inlay wax (melting point about 163°C) on a thin portion of a low melting model, the whole thing will simply collapse into a puddle. If you're going to modify these patterns use a scrap of the same wax.

Flexibility is also a very useful property since it helps remove the model from undercut areas with a minimum of breakage.

**Disclosing Wax** — Whether you make your own waxes or buy commercial prepared waxes, you will often encounter very small air bubbles in the surface of the pattern. These can be a great annoyance when you try to fill them in, since it's difficult to get a smooth job. There is one product on the market which can make this easier.

Kerr makes a material called Disclosing Wax. The Disclosing Wax has a consistency about like shortening or cold cream. You wipe it into small bubbles or pits and remove the excess with a soft cloth. This can be a great help if you have a lot of touch ups or repairs to do.

**Sprue Wax** — Sprue waxes are special wires or rods which are used to build up the sprue arrangements for casting. Usually, the sprue waxes will have relatively low melting points and in many cases a slight degree of tack or adhesion. I have mixed feelings about the need to differentiate the sprue waxes. With the burnout cycle which I use, I find that any wax
wire or rod works well. In theory sprue wires are special, since they have lower melting points than the model. This allows the wax to melt out of the sprue arrangement first and clear the way for the model wax to flow out. In very large castings, this may be important. Also, in cases where you wish to minimize smoking by recovering the wax before preceding with the burnout this may be handy. It's particularly useful in industrial applications where ceramic molds are used and the mold is introduced directly into a very hot furnace. In this case, the wax can actual build up pressure if the sprue channels don't clear quickly. Obviously, there is no harm in using the sprue wax but unless you're trying to recover the wax or eliminate the wax before burnout, sprue waxes are of marginal value.

Wax Pen Wax There are a number of commercial wax pens available on the market. It is usually recommended that they use special waxes. These are usually waxes which have a low melt viscosity and some flexibility. In my experience, the wax pens do work best with the specified wax. There seems to be a lot less problem with clogging or other malfunctions of the pen.

I have found one other use for wax pen waxes. The Kerr Wax Pen wax has a low melt viscosity and clears itself of bubbles very quickly. I do a lot of two dimensional rubber mold work. I make simple open molds from silicone rubber for small jewelry parts. I usually melt a little wax in a teaspoon and pour it into these molds. I find that the Kerr Wax Pen wax is very good for this application since it fills all the corners very well and it doesn't tend to develop bubbles.
Inlay And Buildup Wax – These materials typically have melting points in
the range of 160°F to 165°F. They are used to buildup or add to
patterns. Most formulations are hard enough to conveniently carve with
hand tools after they have cooled. Kerr Blue Inlay Wax and Perfect Purple
Wax are typical examples. The waxes are traditionally added with a
heated spatula but buildups can also be made with an artist’s brush and a
small container of melted wax.

Sticky Wax – This material is used for repairing wax models and for
joining wax components in larger more complex assemblies. With a low
melting point of 136°F the Kerr Sticky Wax can even be used to repair
or modify injection wax patterns. Other materials such as Utility Wax
or Boxing Wax are also slightly tacky but they have higher melting points
(approximately 176°F).

The wide variety of specialized jewelry waxes is a great convenience to
the jewelry maker. However, the fact that a jewelry wax has an intended
"special purpose" should never become a limitation. You should constantly
explore the working characteristics of the various materials. For example,
the melting point and melt viscosity of a given material will strongly
influence the way in which the material responds to a heated spatula.
This response will establish the kind of texture which will result.
You must constantly explore the working properties of the material.

FORM

Although it seems self evident it is useful to briefly review the forms
in which the material is available.
Sheet - Wax sheet is most typically available in thicknesses from about 23 gauge up to about 8 gauge. Material such as utility wax may be available as thick as 3/16" to 1/4". The material is usually packaged with a separator sheet. It's important to keep these sheets in place to preserve the finish of the wax and to keep the sheets from sticking together.

Wire/Rod - Wax wire is available with a number of cross sections including round, half-round, square, rectangle, triangle, bezel and several "fancy" sections. Round wire is usually available in the range of 6 to 20 gauge. Other round sections such as sprue rod may be available in 3/8" diameters or larger.

Block/Bulk - Carving waxes are commonly sold in blocks about 1-1/2" thick. This dimension is obviously suited to carving even the largest ring. A one pound block would be about 3" x 7" x 1-1/2". Sliced blocks are also available. If you don't need the finished rectangular form it is also possible to buy some carving waxes in bulk chunks.

Prefoms - Carving waxes may also be available in a number of semi-finished shapes. Ring tubes or rods can be used to shorten the carving operation and individual ring blanks may simplify the operation even further.

 Flake - Injection molding waxes are often available in flake form. This serves largely for ease of use. The material loads easily into a
melting pot and melts readily in this form.
WAX FORMULATIONS

There seems to be a tremendous temptation on "do it yourself" in wax commercial wax blends formulation. Since may cost several dollars a pound or more, this isn't too surprising. In the commercial market many suppliers provide compatible materials systems the user can blend. The hobbyist or craftsman may also decide he can save a little money or develop special properties by blending his own wax. I must confess that I went through this phase about fifteen or twenty years ago. At that time, I purchased and samples of about fifty different grades of plastic wax. I blended all kinds of things and quite frankly, I never came up with anything any better than what I could buy through commercial sources. If you place any value on your personal time, I believe that blending your own waxes probably isn't worth However, if you are bound and determined to try, I would recommend a few things which may make your life a little simpler.

First of all, don't try to be too complex. The best formulations will typically be mixtures of two or three materials. More complex mixtures usually have poor physical properties. Be extremely careful about the fire hazard. Most waxes will burst into flame at relatively low temperatures. I did most of my melting in an aluminum sauce pan, which I placed in an electric frying pan. This eliminated open flame and provided good temperature control. The frying pan also contained most of the little dripples that seem inevitable working in wax.
You can begin by using white polyethylene can lids and blending them with conventional paraffin wax or other common waxes. These are the replaceable lids which you normally find on coffee cans. These will yield a very hard, high melting carving wax when properly blended. The only other suggestion I would make, is to keep meticulous records. The formulations seem to be surprisingly sensitive. If you haven't weighed your ingredients carefully and kept good records, you will find that sooner or later you will get a great batch of material which is difficult to reproduce.

In addition to the waxes themselves, there are a number of accessory materials and special tools used in the model building process. Next month we will be considering these in the third part of this series.
To date we have discussed wax properties and specific wax formulations and forms. A number of accessory materials and tools are useful in the model building process.

**Lubricants and Release Agents** - Melted wax may stick tenaciously to metal work surfaces. A release agent may be used to minimize sticking. A film of glycerin or 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 the silicones, two forms are particularly useful for shop application. The first are the aerosol cans of silicone spray lubricant available in hardware stores or automotive shops. This 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 work surfaces in your shop become contaminated, this can be a problem. 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 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. Polishing with a solvent will proceed more rapidly if you use tissue paper saturated with the solvent.

**Mold Releases** - Mold releases may be needed when wax is injected into vulcanized rubber molds. Not all combinations
of 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.

WAX TOOLS

In addition to the wax materials and special compounds for working the wax, there are also a number of tools designed to speed up or enhance the model building process.

There are several ways to think about wax working tools but the simplest is to first divide them into tools which are used heated and tools which are used cold or at room temperature. Spatulas are probably the commonest tool.

There must be thousands of possible shapes for wax working tools but there are probably only three fundamental tool shapes which are important.

- Pointed
- Bell Shaped
- Flat

These tools vary from each other in only one major consideration; that is their surface to column relationship. As you progress down the list the tools develop more and more surface
area relative to their volume. This characteristic relates to how they transfer heat to the wax and also how they remove or add material to the model. As the surface area increases they tend to pick up and carry wax. This means that the pointed or low area tools are more suitable for texturing and welding and the flat shapes are more suitable for high levels of heat transfer and adding or removing wax. In essence, the flat shapes provide surface area which is covered with wax and can be transferred to the model.

The effect of the tools when applied to the work relates to both their shape and the characteristics of the wax being used. The melt viscosity of the wax is the key characteristic. If a wax has a very low melt viscosity (that is it is very fluid when molten) it will tend to make level puddles when it's melted with a tool. That means that low melt viscosity waxes are difficult to texture with heated tools. On the other hand, the hard carving waxes have a very high melt viscosity and therefore are relatively easy to form with a very deep texture.

The use of the tools for surface texturing can be particularly beneficial since it enhances the appearance of the finish and provides detail without a great deal of labor. This is useful for finishing parts of the model where you can't come back
and polish later. I very often use the ball shape tool to provide a stripped or dimpled kind of texture on the recessed areas of a ring model. This can be given a light brush finish and provides a very attractive alternate to the time and difficulty required to provide a high polish on the inside areas of a model.

Much of the literature suggests some mystique about using spatulas. This is probably somewhat overstated. There are a few simple rules. It is probably best to use a clean heat source, such as an alcohol lamp. If you try to use a candle the smoke or soot from the wax will quickly contaminate the tips. On the other hand, it's not necessary to baby the tools. Some of the literature and instructions I've seen suggest that it's important not to heat the tools too hot since it may ruin the temper of the steel and/or burn carbon onto the metal. Frankly, I find that neither of these are much of a problem. Since you are not trying to maintain a cutting edge or do any operations which require a very strong tool, it doesn't much matter whether you preserve the temper in the steel tools or not. I don't worry about keeping the temperature low on my spatulas. By the same token, there may be some carbon build-up if you overheat wax on the spatulas, but again, this isn't a serious problem. A quick sanding with 600 grit water-dry sandpaper will usually remove any carbon.
The only time it really seems to get in the way is when you are doing very careful detailed texturing. In this case you might want to polish your tools before starting.

Wax Pens - The wax pens are electrically heated devices which deliver controlled amounts of molten wax to the work surface for building up models. At one point in time, there were a number of manufacturers of these devices. There are relatively few on the market at the present time. Kerr remains a widely distributed manufacturer. The Kerr Jewlers Miniwax Pen allows you to build up wax in a controlled manner. This speeds the process and provides better control. I use a combination of techniques and seldom use the wax pen by itself. It is very useful in many cases but it doesn't replace a good selection of conventional tools.

Electric Spatulas - Another useful device is the electric spatula or welder. These are small electrically heated tools which function exactly like the tools held in the flame of an alcohol lamp for heat. In my personal opinion these are a real benefit if you intend to do any relatively large amount of wax buildup. These are particularly useful in production work for spruing where you need to set up and do large numbers of pieces over a period of time. With both the wax pen and the wax spatulas there are several techniques which will make
them more effective or useful. First of all, they need a little time to stabilize and come to a consistent temperature. Many of the units that I have worked with require one-half hour to an hour to come to equilibrium and maintain a precise temperature. Once you achieve this point they will function all day and never vary more than a degree or two. As a practical matter, it is possible to construct an electric spatula from a conventional electric soldering iron and a dimmer switch. Wax pens are a somewhat different matter and are considerably more difficult to prepare on your own. If you would like to try a wax pen you will probably have to purchase a commercial unit.

**Matt Gun** - The Matt Gun is a second cousin to the conventional hot-melt glue gun. Instead of ejecting melted glue, it extrudes filaments of hard carving wax. It is worth noting that you can extrude filaments from a hot melt glue gun and use the material for model building. The glue strands are very tough, flexible and burn out satisfactorily.

**Glaze** - There are some commercial compounds available which can be used to dip or paint the finished wax models to put a higher polish or finish on their surface. Although they won't cover major defects, they may improve the surface quality of the models. There is a trade-off of time and quality involved in the use of these glazes or in the use of
polishing agents and solvents. There is not much use putting a better finish on the wax than your casting process can manage or reproduce. If you put an impeccable finish on the model and then have difficulty with your investment from bubbles or other surface texture problems such as channeling, you will put a lot of work into the model which is not translated into the finished casting. In my experience, improvements in the finish quality of the waxes must go hand-in-hand with improvements in the overall casting process.

There are obviously a wide range of specialized tools which are useful in a wax building operation. However, most of these relate to specific operations or particular wax materials. I would suggest that you look through your past issues of *Gems and Minerals* and the various craft and trade books for further ideas on how to get the most out of your wax and associated shop tools.
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 alchols, 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 purposes of 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
WAX PROPERTIES

Kerr Sol-U-Carv 200°F
* Sierra Red 162°F (72°C)
* Non Shrink Red 140°F (60°C)
  Kerr Sprue 145°F (63°C) 6, 8, 10, 12, ga.
  Kerr Wax Pen 162°F (72.2°C) 8 ga.
  Kerr Boxing-Slightly Tacky 176°F
  Kerr Sticky 136° (58°C)
* Injectoleather 160°F (71°C)
* Tuf Guy Wax 165°-175°F (74°-79°C)
  Kerr Blue Inlay 163°F (73°C)
  Baseplate Wax
  Kerr Max-E-Wax 156°F (69°C) 8-23 ga.
  Ferris File-A-Wax 250°F (121°C)
  Kerr Master Pattern
    Carving Wax
  Kerr Utility Wax 173°F
  Water Sol Wax 180°-200°F

Carnuba 180°-187°F Hard, brittle, lustrous
  Carnuba Palm
Beeswax 149°F Widely Compatible
Ceresine 125°-185°F Mineral Wax Derived
  From Ozokerite
Microcrystalline 140°-200°F Petroleum Based
Bayberry 108°-118°F Bayberry Shrub

Sheet Wax - Generally 28 - 16 ga.
Paraffin 105°-155°F
118°-132°F  Most Common
You may occasionally have difficulty preparing small, precise carving wax parts because they seem to warp during processing. There are several factors which might contribute to this, but the most likely source of the problem lies in how the wax is prepared. The hard polyethylene carving waxes are relatively strong. They are also characterized by a significant amount of shrinkage on cooling. If you were to pour a small pool of melting carving wax onto a sheet of metal, you'll find that it may warp as it cools. This kind of stress may remain in the wax bars, which are cooled cut into blocks. The uneven cooling builds internal stresses into the wax. When you cut a piece out of the wax, you relieve the restraints, and the piece assumes a more "relaxed" form. Unfortunately, that form may be different from the one which you carved out. I have found the best way to prepare high precision parts is to use acrylic plastic rather than hard carving wax for areas where I need to hold close tolerances. I've found that if I store the hard carving wax someplace warm, (about 100°F for awhile) that it seems to diminish this problem. I suspect that this "annealing" tends to relieve the internal strain. I don't consider this a serious problem, but it may at least explain to you an occasional difficulty which crops up in precision model making.
WAX

WATER SOLUBLE WAX

The use of water soluable wax allows the craftsman to create a number of forms which are both useful and decorative. What we are dealing with is material that can be worked like wax, but which will dissolve in water. This can be used in several ways.

The most obvious use for such a material is the construction of hollow shapes which would not be practical or easy by other means. For example, you can make a ball of water soluable wax and build-up a conventional wax shape on the outside. The material is soaked in water. When the water soluable wax is gone you have a light thin form. In many cases this build-up can proceed much more quickly than any kind of carving or construction without the use of the core.

The water soluable wax can also be used as a one time mold for transferring patterns or texture. As long as the surface to be copied has no undercuts you coat the material to be copied with wax release and pour melted soluable wax over the pattern. The pattern is removed and conventional wax is poured into the cavity in the soluable wax. Next, the combined waxes are placed in water and the soluable wax is dissolved away. This leaves the conventional wax as a precise reproduction of the original surface or texture. For
single copies of simple surfaces this may be quicker and less expensive than most of the conventional mold making techniques. The use of the soluable wax can also make the process of casting bezzles much simpler. If you take a cabochon and the top with water soluable wax you can then carve away the edges back down to the outline of the stone. Actually you should leave a very slight flair so that the top of the wax is slightly bigger than the griddle of the stone. Next this combination of the stone and the soluable wax can be placed on the basic model. Dental inlay wax or other build-up wax can be used to construct a bezzle around the soluable block in the stone. When the model is complete you can place it in water and dissolve the soluable wax allowing the stone to pop out. This leaves a precise bezzle. In many cases this is simpler than trying to carve a bezzle or build it up from wax sheet.

The use of soluable wax core can also allow you to construct rings which appear very heavy but which have thin sections. One of the best ways to do this is to carve a core of water soluable wax, which is attached to the mandrel. The model is built up over this core. When modeling is complete, it is slipped off the mandrel and the core is dissolved. This can allow you to cast very thin and delicate shell. Often you can save as much as 2/3's of the normal weight of the casting by using this technique. This makes it especially valuable for the construction of Karat gold castings.
WAX FORMULATION

Almost every time I teach a class or seminar someone brings up the idea of formulating his own modeling waxes. Personally, I would rather spend my time making jewelry than I would making wax blends. However, I must confess that I went through a phase of experimenting with my own formulations. These experiments did a good deal to mold my attitude about homemade wax products. I ended up with samples of 30 or 40 different waxes and modifiers, and I must have tried hundreds of different formulations. Although I could duplicate the general characteristics of a number of commercial waxes, I never created anything that was in any way superior to the materials already available. Since I was consuming a great deal of time, I gradually drifted away from this whole area of experimentation. There is another factor which works against the do it yourself approach. If you wish to purchase the raw materials for your own formulations at bulk prices, you will find that you have to buy in large quantities. I still have the remains of a couple of 50 pound bags of material that are left over from these experiments. If you wish to purchase material in small quantities, you will find that they are either difficult to obtain, or about as expensive as commercially formulated material.

For those of you who would like to experiment with your own formulations, I would like to make a few suggestions.
Essentially all of the wax materials will burst into flame if they are heated above some temperature. This temperature is known as the flash point. More than one home has been burned down when a housewife heated her canning paraffin above the flash point of material. This creates a very violent fire that is difficult to put out. For this reason, you need a special heating arrangement to prevent the wax from ever approaching this temperature. For waxes or blends which have melting points below 212 degrees F. (100 degrees C.) a double boiler is probably the best bet. The synthetic polyethylene waxes usually have melting points well above the boiling point of water. In these cases I use an electric frying pan. You can place the container for melting the wax in the frying pan. This has two advantages. Any slight spilage will stay in the frying pan, and it tends to keep the container from tipping over. The electrical controls on a frying pan are not too precise, but they are sufficiently accurate and reliable for this purpose. Your wax melting should be done in a well ventilated area. Although the fumes are not too toxic, they are unpleasant. If you want to be super safe, it's a good idea to keep a dry chemical fire extinguisher around during these experiments. If you start a wax fire, pouring water on it could produce some very spectacular and dangerous results.

You need to be able to measure your ingredients quite precisely
since a small change in formulation will often have a large effect on the end product. For this reason I would suggest you work with a small laboratory-type scale, and weigh your materials in grams. It's also very important to keep a good record of your various experiments. It is very frustrating to prepare a formulation that you like and then discover that you can't precisely remember how you made it. Several other things are useful in this kind of work. One is a wax thermometer to keep track of the temperature of the materials you are working in. This will help keep you from raising the temperatures too high and encountering the fire danger. I have used small aluminum weighting dishes (sold by a laboratory supply house) to formulate my materials. They make a small disc of wax weighing an ounce or two. Scribe an identification number in the bottom of the pan before you melt the ingredients. This number will be molded into the wax as it cools and you will be able to keep track of which block is which.

One of the most fruitful areas for experimentation would be to use polyethylene waxes, and modify them with various amounts of conventional wax. This tends to produce hard brittle material. Re-sealable polyethylene container lids can be blended with parafin to form a very tough, hard blend. This type of formulation will usually make good carving wax for working with machine tools. The trick is to modify
efficiently to keep it from being too brittle. I really
don't have any other suggestions, but persurverence may
yield a formulation that you like to work with.
COMMERCIAL WAX

A custom jewelry maker is seldom interested in making more than one piece of jewelry of any given design. However, the professional manufacturer may wish to make hundreds or thousands of any given design. In this case he must mechanize the model making process. For many years, commercial jewelry manufacturers have made multiple wax models by injecting molten wax into various kinds of molds. In recent years a wide variety of molded wax jewelry models have become available on the retail market. When you consider the time that these models can save they are an excellent buy. The major criticism of them is the fact that they represent a non creative approach to jewelry making. I use the prepared models in several different situations:

1. **Casting Experiments** - When I want to test a new casting technique. I usually begin with a prepared model. That way if it doesn't work out I haven't wasted a lot of time.

2. **Modification** - The models can be modified in various ways. Stones or other parts can be added, portions of the model can be cut away, or parts from various models can be combined.

3. **Design Element** - The model or casting can be used as part of a larger total project such as the bear bola illustrated.

Before trying to work with commercial models it will help if you understand their properties. The waxes used are selected to work best in the molding process rather than any subsequent operations. The best molding waxes would have the following properties:

1. **Melting Point** - A low melting point is desired. Commercial materials are often in the melting point range of 140° to 150° F.
2. **Shrinkage** - In order to minimize distortion a low shrinkage rate and sharp solidification point are desired.

3. **Flexibility** - The material should be flexible at mold removal temperatures to minimize breakage. Mold removal temperatures are usually above room temperature. Many of the waxes are quite brittle at lower temperatures.

4. **Melt Viscosity** - A low melt viscosity is desirable to insure that the wax will fill all the detail in the mold.

This collection of characteristics establishes the working properties of the models. Generally speaking, the models are fragile at lower temperatures. The low melt viscosity, low melting point, and sharp melting point demand a little extra care if you are modifying a model. If you flow molten inlay wax (160° F melting point) onto the fine detail of a model made from a molding wax with a 142° F melting point it will simply destroy the spot that it hits. Any wax joining should be done with low melting wax. If you are in doubt, simply use scraps of wax from the same brand of models so that the melting points will at least be the same. Because of the low melting point power tools generally don't work well on the commercial models. A rotary, powered file will clog almost instantly.

My favorite use for commercial models has always been to cut them up and use the parts to add detail to my own designs. Recently the Van Lightner Company of Irvine, California made that far easier. The Van Lightner Company is a commercial jewelry manufacturer. They have created a wax model system to serve the retail jewelry trade. The basis of the system is a large assortment of wax components.
There are leaves, branches, scrolls, bails, shanks and many other parts. These are accompanied by a very interesting design system. Each component is represented by a design similar to the transfer lettering used in the graphics industry. Their kits also include special pens to color the transfers and other design support materials. The Van Lightener waxes are well molded and quite strong. The variety of design materials is good and many of the parts are light enough to make sensible gold castings. This system would be an excellent choice for anyone getting started in commercial jewelry work.

**SPRUE WAX**

Directions for spruing often indicate that the model should be sprued on a special sprue wax. Generally this is a wax which has a lower melting point than the waxes used in the construction of the model. In the case of industrial casting, there are some good reasons for this approach. In the industrial case the molds are made of ceramic materials and the first stage of burnout is to heat the mold very rapidly to melt out the wax rather than burn it clear. This early melt out requires that the sprue opening be cleared as quickly as possible. This leads to the need for a low melting sprue wax. In case of hobby jewelry casting, this is not particularly important. I have never had any difficulty which I can attribute to spruing models on other types of materials. In a few experiments I have intentionally sprued patterns with a high melting sprue attached to a low melting pattern. None of this has ever caused a noticeable problem. Sprue wax certainly won't cause any harm. If you do a lot
of casting it may be worth the trouble to stock the special wax. For the average shop I would suggest that you not bother.

WAX FORMULATION

In every class that I teach, someone brings up the idea of formulating his own modeling waxes. Personally, I would rather spend my time making jewelry than I would making wax. However, I must confess that I went through a phase of experimenting with my own wax formulations. These experiments did a good deal to mold my attitude about homemade waxes. I ended up with samples of 30 or 40 different waxes and modifiers, and I must have made a thousand different experimental formulations. Although I could duplicate the general characteristics of a number of commercial waxes, I never created anything that was in any way superior to the materials already available on the market. Since I was consuming a great deal of time, I gradually drifted away from this whole area of experimentation. There is another factor which works against the do-it-yourself approach. If you wish to purchase the raw materials for your own formulations at bulk prices, you will find that you have to buy in large quantities. I still have the remains of a couple of 50 pound bags of material that are left over from these experiments. If you wish to purchase material in small quantities you will find that they are either difficult to obtain, or about as expensive as commercially formulated material.

For those of you who would like to experiment with your own formulations, I will make a few suggestions. First of all, I would like to mention the safety aspect of experiments with wax. Essentially all of the waxes will burst into flame if they are heated above some
temperature. This temperature is known as the flash point. More than one home has been burned down when a housewife heated her canning paraffin above the flash point. This creates a very violent fire that is difficult to put out. For this reason, you need a special heating arrangement to prevent the wax from ever approaching this temperature. For waxes or blends which have melting points below 212° F (100° C) a double boiler is the best bet. The synthetic polyethylene waxes usually have melting points well above the boiling point of water. In these cases I use an old electric frying pan. You can place the container for melting the wax in the frying pan. This has two advantages. First of all, any slight spillage will stay in the pan, and it tends to keep the container from tipping over. The electrical controls on a frying pan are not too precise, but they are sufficiently accurate and reliable for this purpose. Your wax melting should be done in a well ventilated area. Although the fumes are not too toxic, they are unpleasant. It's a good idea to keep a dry chemical fire extinguisher around during these experiments. If you should start a wax fire, pouring water on it will produce some very spectacular and dangerous results.

You need to be able to measure your ingredients quite precisely since a small change in formulation will often have a large effect on the end product. For this reason I would suggest you work with a small, laboratory-type scale, and weigh your materials in grams. It's also very important to keep a good record of your various experiments. It is very frustrating to prepare a formulation that you like and then discover that you can't remember precisely how you made it.
Several other things are useful in this kind of work. One is a wax thermometer to keep track of the temperature of the materials you are melting. This will help keep you from raising the temperature too high and encountering the fire danger. I use small aluminum weighing dishes (sold by a laboratory supply house) to formulate my test materials. They make a small disc of wax of an ounce or two. They are formed from aluminum foil and it is easy to scribe a control number in the bottom of the pan before you melt the ingredients. This number will be molded into the wax as it cools and you will be able to keep track of which block is which.

One of the most fruitful areas for experimentation would be to work with the polyethylene waxes, and modify them with various amounts of conventional wax. This tends to produce a hard brittle material. This type of formulation will usually make good carving wax for working with machine tools. The trick is to modify sufficiently to keep it from being too brittle. Stearic acid can also improve wax properties. Stearic acid is a chemical compound which is commonly used in the candle making hobby. Generally, steric acid imparts gloss and hardness when blended with paraffin waxes.
Figure 71 Commercial wax models are easy to incorporate into projects such as this bolo.
Figure 70. Commercial waxes often present subjects which would be difficult or time consuming to model.
Figure 72 An ornate commercial wax model is ideal for modification. Add or remove parts or include stone or pearl seats.
Figure 73 These are just a few of the many Van hightower wax components available.
Figure 24. Many of the Van Brightner parts are available in right and left hand sets. These sets allow the construction of symmetrical designs.
WAXES

Clean scraps of carving wax can be remelted to cast special wax shapes. I would commonly use this approach to cast large thin sheets for applications such as pendants. If you are going to use this approach some cautions are in order. First be extremely careful to avoid contamination. Even the smallest particles of wood, metal or investment will cause problems. I use only blocks of scrap and discard my shavings or filings.

There are a number of references in the literature which suggest that you catch and reuse wax which flows from the mold cavity during preliminary heating. This is an excellent way to minimize burnout fumes but I do not recommend trying to reuse the wax. Except in very carefully controlled situations the chance of contamination is too high. There may be a place for this technique in commercial/industrial situations but not with the art metalworker. The investment in time in a original model is far too great to risk with salvaged materials.
WAXES

In practical matter, you needn't concern yourself about the origin of the wax materials as long as you are working with the commercially prepared forms. This only becomes important if you wish to prepare your own wax blends and operate any more scientific or basic level of the preparation of wax. The best useful description of the waxes one which deals with its physical properties. These physical properties would include:

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

Each of these properties in some latter degree influences the way 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 by will soften and melt over a range of temperatures in a fashion similar to many complex metal alloys. This melting point range will have some influence on the use or properties in application of material. For example, it would generally be desirable to have wax with a sharp and low melting point for injection molding wax parts. If you wish to use the wax to take an impression, pressing it against some other substance, it might be useful for to have a broad melting point. In addition to the characteristic actual melting, most waxes soften considerably below their melting point. Again, in some cases that can be a problem in other cases can be a benefit. In the case of constructing the wax model
here you will need a handle during the construction, you would not want a material which had a high degree of softness at room or body temperatures. Again, in the case where you wish to mold the material such as sheet wax over a form or develop complex shapes it might be very desirable for the material to soften the temperatures slightly above room temperature. Also in some cases in understanding the melting point can be useful in various kinds of wax joining operations. In many respects this is like silver, that is 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 and weld these to the sprue with large amounts of wax with the melting point in the range of 165 degrees F, you will often melt or damage the master model. This melting point relationship means that a material such as blue inlay wax with a melting point in the range of 160 degrees F. It is very suitable for welding or joining parts made of hard carving wax with a 250 degree F melting point. They can be easily joined without any risk or damage to the higher melting parts.

Hardness - Wax hardness is also another characteristic and or measure of the application of wax. A high degree of hardness is desirable in carving and the construction of complex rigid shapes. Softness maybe much more desirable for molding or adhesive purposes. The commercial test for hardness are relatively complex and are not normally applied to these materials. Although they may be applied at the laboratory level the hardness data is generally not
Flexibility - Flexibility or its opposite characteristics bittleness can be of considerable importance in the model building process. For example, a certain degree of bittleness maybe required for good machining or filing. This bittleness will allow chips to break away cleanly as the material is worked. Conversely, a good deal of flexibility will be desirable in materials which were going to be used for injection molding and the _____ molds. A certain degree of flexibility will prevent breakage during _____ molds. Generally a degree of flexibility is desired to keep the material from breaking too easily in handling. A good measure of flexibility of how far the material can be bent around a short corner without breaking. For example, blue dental inlay wax can hardly be bent at all before it will break. However most of the commercial wax wires can be bend to 90 degrees. At this kind of bend they may show some defermation _______ they will not break in room temperature. Almost all the waxes are very sensitive to temperature which regard to this characteristic. Usually modest increases in gesture 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 shelling.

Viscosity -

Shrinkage -
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 _____ composition, however in the refined materials used in model construction the color has little or nothing to do with the physical properties of the material.
WAX FORMS

Specific forms available in wax products are a matter of convenience. The best form for a given project is the one with a configuration which is as close as possible to the actual form of the final model. The form minimizes the effort required to bring the model to completion as quickly as possible. The wax forms are analogous to the various forms of precious metal used in jewelry fabrication. Most silversmiths today, are not interested in making a wire object by melting with bulk silver. Although it is practical to cast and then roll and draw it to size, the labor cost would probably be prohibitive. It is much simpler and quicker to purchase drawn wire. The same situation exists in wax. Many years ago model builders were confronted with extruding their own wax wire, pouring sheet wax and so on. None of these is considered very practical given the wide range of materials available. I would like to discuss some of the common forms available. The size and form of most of the wax products is established by, and limited to, the sizes of configurations useful in jewelry making. For example, ring wax blocks are about the thickness needed to fabricate the largest man's ring. Generally speaking, the sizes available are tailored to the specific application.

Sheet - Sheet waxes are available in a number of grades or hardnesses and thicknesses ranging from about 22 gauge to 12
Wax is usually sold with a stick resistant separator between the layers. Be sure that you keep this sheet so the wax may stick together in a useless blob if they are removed. Most of the waxes can be cut with a sharp razor. Although, in the case of hard wax sheet it may be necessary to warm them slightly to prevent cracking during handling.

- Wax wires are typically available from about 22 gauge to 12 gauge or even larger in the case of sprue rod. The vast majority of wax wire sold is round in cross section, though a number of other shapes are available. Half round, bezel wire, and triangular wire are fairly common. Many companies also offer various ornate sections which are similar to flower petals and other geometric forms. Most wax is prepared from a relatively flexible material and therefore will not withstand too vigorous handling. This means that complex or thin sections such as wax bezel wire can be hard to manage. In many areas where the material is simply too fragile to be practical I substitute plastic materials for the wax. Although, we have not expanded this discussion to include plastic model building materials they are analogous to the wax and have many of the same uses with improved physical properties.

Serving Wax -

Since it is to be sculpted it is simply providing in masses large enough for the intended application. Strictly speaking,
The blocks are not always rectangular and may be warped or slightly variable in cross section depending on the manufacturing process used.

Ring Tubes - Ring tubes provide a convenient wax form since one of the most time-consuming (and not particularly creative) parts model building process is blanking out a ring shank with a hole in place this is speeded up considerably. Obviously, you pay a premium price but the time saved may be worth it. An alternate approach is to use a carpenter's type spade wood bit to prepare the hole in the blanks. These can be reground to standard ring sizes to speed up the process considerably.

Flake Wax - Wax flakes are easiest to handle in situations where the material needs to be melted. Obviously, the common case here would be in the use of injection wax.