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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METALLURGY - INTRODUCTION

There is an unfortunate tendency on the part of many art metal workers to avoid the study of the basic metallurgy of the materials used. Granted, this may be a difficult subject and never fully mastered by the artist/craftsman. Some overview is vitally important. The reason for this really relates to other inputs which you will receive in the course of your life-long education. People will give you various pieces of advice. For example: "Always quench after a kneeling" or "Never quench after a kneeling." The world is full of rules of thumb which are passed on as pearls of wisdom. As a practical matter, the impact of quenching after a kneeling is very sensitive to the material used. Fairest metals are quite different than the precious metals, and even more significant various precious metal alloys behave differently. If you have some idea of the basic metallurgy involved, you will be able to make judgments about the advice which you hear or which you receive in print. A great deal of the misinformation in this field comes from the well-meaning attempt to translate concepts suitable for one technique into another area. Perhaps even more important, if you have some overall understanding of the metallurgical principles involved, you will be able to interpret the results or problems in your work. For example, if you are preparing a
piece of reppouse and the outer surface develops a pebbly texture, what does this mean? In practice, it means that the material has been overknocked and metal grains are too large. If you don't understand the basic metallurgy, I suggest that it would be very difficult to interpret this and many other phenomenon which you will observe. Elsewhere, we are alluded to the fact that it is vitally important to minimize the impediment to artistic expression. Nowhere is this truer than in the metallurgical area. If you do not understand how to treat the material, you will be totally frustrated in your attempts to make it behave in the desired manner.
METALLURGY

PHASE CONSTITUTION DIAGRAM

It should be obvious from the tertiary phase constitution diagram for silver, copper and gold that adding additional alloying elements complicates the problem of understanding what's happening in any given alloy. Adding a fourth or fifth component tends to create even more complex situations, which may yield surprising or unexpected results. This complexity is one of the key problems in using scrap gold. Many of our customers bring in items of gold jewelry and ask that for financial or sentimental reasons we use the material in their work. Generally speaking, this is a bad practice since different items of jewelry may be made from different alloys. We generally suggest that we will purchase their gold jewelry at some discounted market value. We scrap the material and do our casting with new material. Obviously, if there are sentimental reasons for using the gold, you just have to take your chances.

As we have mentioned elsewhere, the surface-to-volume ratio of the casting affects the rate of cooling. Some of the same general principles apply to oxidation and gas absorption. Very small melts of metal have a much higher surface area for any given volume. This means that they will be somewhat more
subject to various atmospheric effects. Larger melts should be somewhat less sensitive.
METALLURGY

ZINC

Relatively high proportions of zinc are often used in white
golds. However, the addition of zinc in small quantities can
also provide a very beneficial effect in yellow golds.
Typically, the percentages used would be two percent or less.
The addition of the zinc has a number of benefits. If you
would wish to see one of these for yourself, it's very simple.
Prepare an alloy of copper, silver and gold and cast any
object. When the casting is removed from the investment, it
will tend to be dark and discolored. Although this
discoloration can be removed by pickling, it is an obvious
characteristic of these alloys. If you take the same alloy
and add one or two percent of zinc nd cast it, the castings
will tend to be much brighter and cleaner. In addition to
this deoxidizing effect, zinc also has an influence on the
fluidity of the metal and other casting characteristics.

This characteristic of zinc (or other low level additives)
does a good deal to explain the problems with re-melt or
scrap. Zinc will tend to burn or form a slag at relatively
low temperatures. This means that repeated heatings will tend
to decrease the zinc content of the alloy.
### Metal Characteristics

#### Unit Cell Dimensions

<table>
<thead>
<tr>
<th>Metal</th>
<th>Lattice Structure</th>
<th>Dimension (nm)</th>
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</tr>
<tr>
<td>Platinum</td>
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#### Atomic Radii

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</tr>
<tr>
<td>Silver</td>
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<tr>
<td>Copper</td>
<td>0.1270</td>
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#### Melting Point

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<th>Temperature (°C)</th>
</tr>
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<tr>
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<tr>
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<td>Copper</td>
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<td>Aluminum</td>
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</table>
METALLURGY

ALLOYS

The most common yellow gold alloys are composed primarily of gold, silver and copper. In addition, there may be small quantities of other materials added to modify the final properties of the alloy and/or its behavior during the casting process. Let's begin with some general statements about this class of alloys. Obviously, the amount of gold relates directly to the final carat value required. Fourteen carat gold must contain 58.5% gold, and eighteen carat must contain 75.0% gold. The balance of the material is some combination of silver and copper which will provide a pleasing color and a good balance of properties. Generally speaking, there is somewhat more silver than copper in these alloys. Typical fourteen carat alloys might contain roughly three times as much silver as copper. In higher carats, the balance might be one-and-a-half to two times as much silver as copper.

If you remember from our previous discussion, the molecular size of copper is somewhat different than silver and gold. Silver and gold are so similar in composition that they form solid solutions at essentially all combinations. However, the significantly different size of copper means that separate phases may occur with larger percentages of copper.
Experience has suggested that fourteen carat yellow gold alloys with equal amounts of copper and silver will probably be excessively brittle and, therefore, difficult to work with. For example, prongs made of this composition would tend to break during closing.
METALLURGY

ALLOYS

Any alloy is a combination of two or more metallic elements while a pure metal is a single metallic element. There are a number of physical differences between a pure metal and an alloy. Generally speaking, the pure metal will exhibit less complex behavior than an alloy. For example, the pure metal will melt at one precise temperature while an alloy may melt over a range of temperatures.

For many applications, an alloy would be preferred to the pure metal. Various alloy combinations can:

- Lower Material Cost
- Change Metal Color
- Improve Physical Properties

As pure metals, both gold and silver are too soft for practical application to jewelry. The addition of other metal such as copper will significantly increase the hardness of the combination. In the case of gold, there is an obvious cost saving to be had by adding base metals to the alloy. The base metal may also impart color to the mixture. Nickle can produce "white" gold and additions of copper will darken or add a rose tint to silver and gold. The preparations of
alloys is a complex science, and the results are not always too predictable. Gold and aluminum can be combined to create an alloy that is violet in color. Unfortunately, this material is brittle and porous. Small amounts of the proper additives can:

- Modify Grain Size
- Increase Fluidity
METALLURGY

PHASE CONSTITUTION DIAGRAM

It is my personal opinion that it is impossible to become technically proficient in the investment casting field without a general understanding of the physical nature of the materials involved in the process. Basically, the two key materials are the investment or mold material and the metal being cast. The manipulation of these materials and the design of the system for their application spell the difference between success and failure. We have discussed the nature of the investment material in some detail in other portions of this work. At this point, I would like to go into some detail concerning the basic metallurgy of the non-ferrous jewelry alloys and, in particular, the phase constitution diagram.

Gold, silver, platinum and copper are all pure elements. Each of these elements has different physical and chemical characteristics which relate to its basic atomic nature and to the way the fundamental atomic building blocks have been arranged. Although the physical properties of pure materials can be modified to some degree by changes in their physical structures (such as crystal structure), pure materials tend to have specific physical characteristics. These characteristics
can best be modified by combining groups of materials into alloys. For purposes of our discussion, an alloy can simply be defined as some combination of two or more metals. The purpose of alloying metals is to improve their basic physical properties and/or to decrease their cost. A simple example would be copper. Copper was one of the first metals available in primitive societies. It can be found in pure metallic form in nature and can be produced from ores by relatively simple reduction processes. This impure metallic copper can be modified by processes such as cold work to improve its properties to a limited degree. However, one of the great triumphs of early technology was the understanding of alloying and the production of bronze. In simplest terms, bronze is an alloy of tin and copper. This combination has an appreciable lower melting point and a much higher hardness and physical strength than either of its individual constituent materials.

The art metal field employs a broad range of alloys for many different purposes. However, in the majority of cases, these are aimed at enhancing the physical properties of the material. For example, pure platinum, pure gold and pure silver are all too soft to make durable coinage or jewelry. For this reason, anything from a few percent to a major amount of alloy may be added to enhance their properties.
There are relatively few situations where the jewelry craftsman will work with pure metals. The majority of jewelry applications are made with various alloys. Although it is not the intent of this text to provide an in-depth understanding of metallurgy, some basic insights will be very useful in helping you understand the casting process.

There are several concepts or elements of the alloying process which need to be better understood. The most fundamental tool for dealing with alloys is the phase constitution diagram.

The phase constitution diagram is a graphic or diagramatic approach to illustrating the melt properties of alloys prepared from various combinations of metal. The same kind of diagrams are used in all areas of metallurgy. For example, the phase constitution diagram of carbon steel is useful in understanding the metallurgical processes involved with forming, hardening, tempering and alloying ferrous metals. In our case, we will focus the discussion on the phase constitution diagrams of various combinations of metal used in the jewelry process. Probably the most commonly taught and easiest to understand is the phase constitution diagram for combinations of copper and silver.
METALLURGY

METAL CHARACTERISTICS

Any comprehensive understanding of the spruing process must take into account the characteristics of the molten metal. The situation is complicated by the fact that the various jewelry alloys do not behave in identical fashion. Generally speaking, the white gold alloys are far more difficult to work with and less forgiving than the other precious metal alloys. Many of the precious metal substitutes are also difficult to work with. Some of the factors influencing the overall problem are:

1. Incompressible fluid characteristics
2. Melt viscosity
3. Expansion/solidification

Incompressible Fluid Characteristics - From an engineering viewpoint, the design of any piping network for the flow of fluids must take into account whether or not the fluids are compressible. There are large classes of materials which do not change their physical volume to any measurable degree under a wide range of pressure. Water would be a good example. At room temperature, there is no significant difference in the weight of a given volume of water under a wide range of pressure. Conversely, a given weight of air can
occupy a widely varying volume depending upon the pressure applied. Air is a compressible material where water is essentially incompressible. Some of the textbooks on jewelry craft have tried to explain the spruing problem based on the flow characteristics of air. Since air is a compressible material, this is an improper analogy. Molten metal behaves as an incompressible fluid during the casting process.

**Viscosity** - The viscosity of a molten metal is also a significant factor in sprue design. Fortunately, in the range of sizes and shapes used in jewelry casting, this is not a dominating element in sprue design. However, in marginal pressure situations (such as steam casting and poured castings), the viscosity of the metal has a strong influence on the minimum size sprue which can be used and the minimum section thickness which can be cast. As a practical matter, a combination of viscosity and surface tension are what prevents the metal from flowing into the sprue system during melting when a sprue melted casting is made.

**Expansion/Solidification** - One of the key problems in casting quality relates to the contraction which the metal undergoes during cooling. Improper sprue and model design can have a very bad effect on casting quality. This effect is most pronounced or evident in material such as white gold, which
undergoes dramatic transformations during solidification.
The expansion or contraction of solids is generally expressed as a Coefficient of Thermal Expansion. Typically, this is measured in units per degree centigrade. The unit of measurement is immaterial since the coefficient is proportional. It is important to note that the rate of expansion varies with temperature. The coefficient at room temperature may be different than the rate at 800°C. However, for purposes of this discussion, the change in the coefficient at different temperatures is insignificant. An understanding of the approximate amount of expansion or contraction is sufficient for this discussion. Three of the common jewelry metals have the following coefficients of expansion.

Gold \(13.20 \times 10^{-6}\)

Copper \(14.09 \times 10^{-6}\)

Silver \(17.04 \times 10^{-6}\)

These materials are in the mid-range of most of the common metals and alloys. Some metals, such as platinum, will display less expansion while some of the bronze alloys will have considerably more. However, almost all of the common alloys will have a Coefficient of Thermal Expansion in the range of 8 and \(22 \times 10^{-6}\).
What this means is that a one-inch bar of silver (Coefficient of Thermal Expansion of 17.04 x 10^{-6}) will expand 0.00001704 inches for each degree centigrade its temperature rises. The expansion effect is obviously rather small. However, it occurs over a wide range of temperature during the solidification process. If we assume that the average craft metal has a Coefficient of Thermal Expansion of approximately 15 x 10^{-6} and a melting point of about 900°C, the consequences are interesting. This means that our hypothetical metal will contract by a total of 875 x 15 x 10^{-6} inches per inch going from its solidification point to room temperature. This equals about 0.013 inches per inch, or a contraction of about 1.3%. You will note on the attached graph that cristobalite investment contract about 1.25% in the range of temperatures being considered. In essence, this means that the cristobalite investments will almost exactly offset the contraction of most of the common jewelry metals and alloys.

Most stainless steel (flask material) has a Coefficient of Thermal Expansion in the range of 10-12 x 10^{-6}. This means that during heating the flask will expand about 0.96% while the investment is trying to expand 1.25%. The difference of 0.29% represents a compressive load or restraint on the system. This is consistent with literature references.
suggesting differences in casting dimensional tolerances related to orientation in the flask.
METALLURGY

SPECIFIC GRAVITY KARAT GOLD

If you buy and sell scrap gold, sooner or later you will encounter pieces which have been deeply scratched. This usually means that an acid test has been applied. This is done by applying strong acid to the jewelry and comparing the rate of reaction to that of a known gold standard. This method can give surprisingly good results in experienced hands. However, for the average amateur it's really not too good a system. For those of you with a good balance or scales, you can get a reasonable idea of gold content from specific gravity. Specific gravity of gold alloys can vary somewhat for any given karat since the proportion and content of other materials may vary. However, specific gravity values are generally in the following range.

<table>
<thead>
<tr>
<th>Karat</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>19.3</td>
</tr>
<tr>
<td>18</td>
<td>15.6</td>
</tr>
<tr>
<td>14</td>
<td>13.1</td>
</tr>
<tr>
<td>10</td>
<td>11.6</td>
</tr>
</tbody>
</table>
METALLURGY

METAL MEASUREMENT

One of the most frustrating things that can happen during the casting process is to melt too little metal and have the casting come up incomplete. There are two widely recommended methods which can be used to prevent this problem. The amount of melt metal can be determined by:

- Displacement
- Specific Gravity

In theory, one of the simplest ways to measure the volume of metal required for casting is the displacement method. All that is required is a graduated cylinder. The model is submerged in water and you note the increase in the level of water in the cylinder. For example, if there were 20 ml of water in the cylinder and you submerge a ring model and the miniscus rises to 21 ml, this means the ring itself displaced one milliliter, or one cubic centimeter of volume. The ring can be removed and metal added to return the volume to 21 ml. In theory, at this point the metal would precisely fill the cavity of the model. With a little addition for a sprue button, your measurement would be complete. In practice, this is an unhandy method. If you think about it for a moment, the most precise way to measure displacement would be a very, very
tall, narrow cylinder. That means that the graduations would be widely spaced and a small increase in the volume of material in the flask would make a large change (easy to read) in the total volume.

In my experience, the displacement method is awkward and not very precise. To yield an accurate reading, the cylinder needs to be narrow so that changes in the water height will be fairly large of any given volume change. Unfortunately, jewelry shapes are usually contrary to the optimum for measurement by displacement. For example, a large medallion requires a cylinder which is as large in diameter as the medallion. Since the volume of metal required for the medallion (compared to its diameter) is small, the method becomes quite inaccurate.

In my experience, I vastly prefer to use the specific gravity method for measurement of casting metal. An inexpensive scale is at least as accurate as the displacement method in most instances. I simply weigh the wax model and apply the appropriate specific gravity. These weight factors are listed in Table 9. This technique is based on a simple principle. There are a number of rather obtuse explanations of specific gravity, but these won't add much to our discussion. Consider the problem this way: two measuring cups of water weigh
exactly 1 pound. If we fill the two cups with lead, the weight would be 11.34 pounds. Therefore, a given volume of lead weighs 11.34 times as much as the same volume of water. The relationship between the weight of a substance per unit volume and the weight of water for the same volume is called the "specific gravity". There are some other interesting implications to the specific gravity table. If 18 KYG has a specific gravity of 15.58 and 10 KYG has a specific gravity of 11.57, then it takes nearly 35% more 18 KYG by weight. This makes higher Karat gold work doubly expensive since it requires more weight of a more expensive material.

Metalsmiths often find the concept of specific gravity something of a mystery. However, it is really quite straightforward. If you weigh an object in the air, it has a measurable weight. If that object is measured in water, the apparent weight will change depending on its volume. Basically, it is a matter if displacement. If an object displaces exactly one cubic centimeter and weighs exactly one gram in the air, it will have absolutely no weight in the water. It displaces one gram of water or has one gram of buoyancy, which exactly compensates for its weight. Any object which displaces one cubic centimeter and weighs less than one gram will float. This is because it does not need to displace its full volume to come to neutral buoyancy.
On the other hand, any one cubic centimeter object which weighs more than one gram, will yellow gold weighs about 14 grams. It will still only displace one gram of water, so it weighs 13 grams when weighed under water. Basically, the specific gravity process is simply one of measuring the weight of an object in the air and in the water and making the calculations accordingly. The specific gravity calculation is shown below. The details of how to set up a specific gravity measurement are indicated in the sketches in Figure 64. It should be noted that this is exactly the same process used to measure the specific gravity of gemstones. As a practical matter, if you have access to a high quality analytical balance, this determination can be made with a great deal of precision. It can also be used to evaluate the Karat quality of solid gold objects.
<table>
<thead>
<tr>
<th>Specific Gravity</th>
<th></th>
<th>Specific Gravity</th>
<th></th>
<th>Specific Gravity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>19.32</td>
<td>18 KYG</td>
<td>15.58</td>
<td>18 KWG</td>
<td>14.64</td>
</tr>
<tr>
<td>18 KYG</td>
<td>13.07</td>
<td>14 KYG</td>
<td>14 KHG</td>
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<td></td>
</tr>
<tr>
<td>10 KYG</td>
<td>11.57</td>
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<tr>
<td>Sterling Silver</td>
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<tr>
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<td>Lead</td>
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</table>
METALLURGY

METAL SOLIDIFICATION

When reduced to its simplest elements, the process of metal casting appears easy. Molten metal is poured into a cavity of the desired shape and allowed to cool. In actual practice, the problem is more complex. For the designer-craftsman, the problem is often compounded by the lack of sophisticated equipment. Working with a limited range of tools and equipment presents a challenge, but it does not preclude professional results if care and technical understanding are applied to the problem.

The physical changes which a metal undergoes on solidification are of utmost importance to the caster. The potential influence of these characteristics can effect the work from preliminary design to the final polishing step. Since this is not intended to be a technical work on metallurgy, certain elements of the technical aspects of the problem will be vastly oversimplified. However, I will attempt to convey the nature of the physical process.

All of the common craft metals have the characteristic of expanding on heating and contracting on cooling. This phenomenon occurs in both the solid and liquid state for the
pure metals and their alloys. Dimensional changes are also associated with the change from liquid to solid at temperature \( T \). The material will shrink on solidification and expand on melting without change in temperature. The precise effects of this shrinkage on cooling manifest themselves in several ways. One of the most critical problems with porosity caused by shrinkage \( T \).

Pure metals freeze at a specific temperature but alloys freeze over a range of temperatures. As the metal cools to its freezing point, tiny metal crystals form and grow. These are often in the form of dendrites similar to the illustration in Figure 62. As cooling proceeds, the dendrites continue to grow until they meet. Growth proceeds as smaller and smaller arms are formed from the solidifying metal. The domain or body of each dendrite is a crystalline area within the solid mass of metal. It should be noted that all of the accompanying dimensional changes which were previously discussed accompany this solidification process.

If you want to visualize the way dendrites form, there is a good example which you may have encountered in your everyday life. If you watch the surface of a puddle of water as it freezes, or a window pane as frost begins to form, you may see
a good example of dendrite formation. Christmas tree-like structures of ice begin to form on the surface and spread out. They may become very long before they develop any width. If you look closely, you'll see the smaller branches grow out of the sides of the main crystal. This is precisely what occurs in a three-dimensional form as metal cools from the molten state and begins to solidify.

When molten metal is cast, the mold is at a lower temperature than the molten metal. Since heat loss occurs at the surface, an outer shell of metal freezes and forms a shell while the core remains molten. During the solidification and cooling process, the casting is slowly shrinking. As each area solidifies and shrinks, it draws molten metal from an adjacent area of the casting that has not solidified. If no metal is available to make up for the shrinkage, a porous casting will be the result.

The effects of the dimensional change can be illustrated by visualizing the sequence of events which occurs when molten metal solidifies within a mold. See Figure 68.

In commercial foundry practice, a number of techniques are used to control the metal cooling process. Wherever possible, the thinnest sections are farthest from a riser. Where it is
necessary to encourage a particular part of the casting to cool first, a metal chill plate can be embedded within the mold. This mass of metal quickly removes the heat from an area of the casting to initiate the solidification process. In some cases, a blowtorch can be played over the surface of the riser to delay solidification in this area. Alternately, an insulating material can be placed over the molten metal in the riser. This also slows cooling in the area.

In the case of investment casting, chill plates are not practical since the mold is at a rather high temperature. In the centrifugal casting process, the solidification of the metal is well advanced by the time the machine stops spinning (60-120 seconds). In the vacuum casting process, heat can be applied to the sprue button.
METALLURGY

CASTING POROSITY

Probably no area of the investment casting process is as frustrating to deal with as the problem of porosity. This is so persistent and pervasive that many people (even professional jewelers) feel that a certain degree of casting porosity is inevitable. My personal opinion is that even with modest equipment, a very high quality level can be achieved. Casting porosity does not have to be a universal problem. One of the difficulties in dealing with casting porosity is the fact that it probably can be attributed to at least ten different causes, and in any given project you would need the services of a metallurgical laboratory to identify which factor was the primary cause of your difficulty. Even worse, poor quality castings are often caused by a combination of more than one of the problems. There are probably other causes of porous castings, but it's reasonable to assume that most failures are caused by one of the following:

- Gas Absorption
- Metal Oxidation
- Contamination
- Mold Reaction
- Turbulence
- Improper Model Design
. Improper Spruing
. Incorrect Melt Temperature
. Incorrect Mold Temperature
. Incorrect Casting Alloy
. Incomplete Burnout

**Mold Reaction** - Chemical reactions between the metal and the surface of the investment mold can cause at least two kinds of casting defects. The first would be porosity, and the second is a persistent kind of fire scale. These reactions can come from at least two distinct problems. If the mold is over-heated (above about 1400°F), the calcium sulphate base in non-ferrous investment tends to break and release sulfur compounds. These compounds can react with the metal and form a persistent deep kind of fire scale. This would be most common on sterling castings around the sprue connection where the sprue is short and direct. If the torch flame puts the crucible opening, it may heat the surface of the mold considerably above the safe temperature for the investment. The metal reacts with the reaction products and forms sulfur compounds which may penetrate deep into the surface of the metal. If the wrong combination of investment and modeling material is used, constituents in the alloy (alloys which have too high a melting point) may attack the surface of the mold and react. This second condition can produce varying degrees
of surface porosity or texture.

Gas Absorption - Molten metal is able to dissolve a small percentage of the gasses (oxygen, nitrogen, etc.) during the melting process. As the temperature of the metal drops, the solubility of the gas decreases; and there is a possibility that the trapped gasses will be rejected as bubbles or porosity. Although the reaction is different, you might think of it as the same kind of situation that you have when you open a bottle of carbonated beverage. The decreased pressure decreases the ability of the liquid to hold gasses in solution, and they simply reform as gas bubbles throughout the liquid. Gas absorption can also create further problems if the gasses are reactive.

Oxidation - Oxidation is simply the chemical reaction between oxygen and the various metal constituents in the alloy. As we have discussed elsewhere, the rate of this reaction varies widely with different materials. It should also be noted that other gasses may react to varying degrees with different alloys present. The longer the melt is held at temperature and the more gasses it's exposed to, the more likely you are to have this kind of reaction. Traditional fluxing simply re-dissolves the reaction product and takes them out of the melt. What this really does is prevent contamination of the
melt with the oxides. However, reducing fluxes go further in that they provide an atmosphere where the reaction can actually be reversed and the oxides broken back down into the constituent metals and various slag materials.

Contamination - We've seen two indirect mechanisms for contamination in the melt. Obviously, contamination can come from many other sources. In investment casting, probably the most common source of contamination is from the use of scrap metal and old sprue buttons. There is a rule of thumb which suggests that you should always use at least 50% fresh alloy in each melt. Like all emperical rules, this one is made to be broken. With good fluxing and care, I've had excellent success using 100% scrap (in the form of sprue buttons) and casting high Karat gold. On the other hand, 14K white gold is extremely difficult to cast successfully from scrap material. This would suggest that the alloying constituents are probably modified during the casting process in white gold. This could come through oxidation or contamination. In the event, experience is the best teacher in this area. However, any time I have a critical job where I've invested a great deal of time and effort in the model, I would tend to use new casting metal in order to minimize the possibility of contamination and subsequent flaws.
Over the years a number of low melting alloys have been used in the jewelry trade. Depending on the point in history these have commonly been alloys with major amounts of lead, tin, zinc or aluminum. Many were used in conjunction with.guilding or plating to enhance the appearance or value of the work. In the craft area pewter has been the most widely used of the low melting alloys. There has been a marked shift in the composition of pewter alloys in recent years. Historically pewter would have typically been 60% lead and 40% tin with small amounts of other metals. The health problem associated with the lead in such a composition has forced the development of new alloys. Today a pewter would typically be 95% tin, 3% copper and 1% antimony. This composition would melt at about 680°F. Even though tin is relatively expensive this material would still only be about 1/10 the price of sterling silver.
GOLD ALLOYS

It's important to be certain that your materials are of the highest quality. In addition to the problems caused by impure materials, other impurities may enter the metal during the melting process. Gases may be dissolved in the metal. The metal may oxidize and be contaminated by the oxidation products. Particles from the flux or crucible may be trapped. These difficulties are minimized in a number of ways.

First, it's important not to heat the metal any hotter or longer than necessary. If torch melting is used a slightly reducing atmosphere is helpful although this condition may be difficult to maintain with the type of equipment found in most small jewelry shops. In commercial application, various kinds of gas shielding may be used, either independently or in connection with induction melting.

If you're going to do any extensive amount of alloy preparation I would highly recommend that you use small induction melting furnace, such as the Kerr Electromelt. Since no flame or gases are used to melt the metal, there is a minimum interaction between the metal and the atmosphere. This situation is further improved by the use of a carbon crucible. With the lid in place the carbon crucible oxidizes until it consumes all the oxygen inside the chamber. At this point, the gas in the chamber is a combination of nitrogen and carbon dioxide,
which is much less harmful than oxygen. The induction furnace is a superior approach to alloy preparation. These units have come into particularly wide use since smaller hand held products came on the market. This situation was encouraged by the rapid run up in gold prices and the increased interest in gold refining by small shops.

Once you have the alloy prepared and melted, the next step is to put it into some form for use. There are really two clear options. First is to use some kind of ingot mold to prepare slugs for rolling or bars for the preparation of wire. The traditional method was to pour the metal in cast iron ingot molds. In recent years graphite molds have become available and these provide excellent ingots. You can also investment cast ingots or sheet and wire blanks for occasional use. The advantage of investment casting is the fact that the cast form can be much closer to the final shape. For example, I might cast 10 gauge round wire. This can be quickly drawn to any final shape. If you investment cast your blanks its important to be very careful to remove all traces of investment. Any silica residue may be very harmful to rollers or wire dies. You may also prepare a casting grain. In large commercial shops, casting grain is prepared by use of the perforated crucible. At my own shop, I simply pour a fine stream of gold or silver alloy out of the Electromelt into a large container of water. If you're going to use this procedure, certain pre-
cautions are in order. First, the crucible should be a two feet or more above the water. This will allow the alloy to break up into a fairly fine stream and cool somewhat before it hits. The container should be quite large since the water has to absorb a good deal of heat. Some years ago, I made a large pewter melt, which I was going to prepare into grain. When I poured this into too small a container, it simply brought the water to a boil and everything burst out all over the place. The third caution, is to use a metal container. In some cases the metal is so hot that it forms a thin layer of steam on surface and heat transfer is inhibited. You may actually end up with particles of molten metal in the bottom of your container under the water. If the container is plastic, they tend to go right on through.
Over the years I've discovered that it's generally less expensive to purchase various kinds of precious metal scrap and use this for casting purposes than it is to buy commercially prepared grain. There are, however, some problems with this technique. First of all the scrap must be scrupulously cleaned in order to provide a good quality of material. Second, since you're melting the scrap to prepare grain you essentially have already cast it once if you use your conventional, asselting type melting. This means that there is a certain amount of dissolved gasses and the opportunity for various other impurities in the metal. For this reason I would usually simply cut up any scrap such as tableware and use the cut up pieces directly i-n the melt for each batch of jewelry. However from time to time I would come upon various kind of scrap that really weren't practical to use this way and I would end up melting these and preparing my own grain. Although this worked adequately with the asselting melting I find that the Kerr electro-melt does a much better job since the metal is prepared in a reducing atmosphere without all the atenic gases and contamination of conventional melting.

Before going on I should point out one very important caution in this technique. Commercial sterling silver is alloyed with copper and possibly one or two other constituents in very small quantities which are safe to melt and work with. However, there are a number of industrial applications where silver has been combined with metal such as berilium, candium or chromium. Under the right conditions melting these kinds of alloyes can produce fumes which are toxic
and fatal. For this reason I would recommend that you never use any material which is not hallmarked. That is, material which you know positively to be sterling silver and not one of the other industrial alloys. Every few years in the hobby press one learns of a hobbieist who has died from cadmium poisoning in some area or another of the arts and crafts. As recent as 1978 it's my understanding that a jewelry worker was killed melting cadmium alloyed silver scrap. In addition to the obvious need for care in selecting the scrap it's always a good idea to perform all of the melting soldering and other high temperature jewelry operations in a well ventilated area. Although they may not be fatal or have long term medical affects, the human system is not enhanced by the ingestion of any of the metal fumes or vapors associated with doing jewelry work. If you're going to do a large cast or melt, do it outside or at least in a very well ventilated workshop.

The actual use of the electro-melt for preparing grain is very straightforward. You need only one other tool besides the basic electric furnace. That's some kind of a fairly large water container. I simply use an old metal (not plastic) waste basket with about a foot of water in it. Follow the directions carefully and heat the clean sterling silver scrap in the electro-melt. When the metal is melted, hold the crucible several feet above the level of the water and pour a very thin, slow stream of metal out of the crucible. As it falls through the air it will separate into drops which will be cooled when they hit the water. Be very careful not to miss the water since standing in globules of molt and silver is not too wise either. Simply continue to pour until the crucible is empty and you'll find a wide selection of
random grains of silver in the bottom of the water. As a matter of fact you might want to begin by carefully sorting them and looking for shapes or forms which can be used directly in jewelry. I've seen a number of very elegant flowers and other pieces made from the little cup shaped forms which occasionally occur when the metal strikes the water. Although the grains should be very clean when they're prepared by this process, if there is any sign of tarnishing or discoloration, the whole batch can be pickled, washed and dried to be absolutely sure that they're clean.

From time to time I accumulate a good deal of filings from my work. In a classic jewelers bench there is a piece of canvas which can be pulled out to collect the various filings. In my own case I sometimes work with a cloth in my lap or collect the filings in a newspaper. Although this isn't too critical in solo work, a large amount of material relatively can be collected if you work in gold and at the current prices these are well worth saving. The problem with using the very fine scrap is that it will be contaminated with all kinds of things from being around the shop. The basic contaminants are probably various abrasives from sandpaper or other finishing operations and/or bits of metal from broken off saw teeth, steel wool, or other metal sources of contamination from working the metal. When you accumulate enough of this very fine scrap to be interesting, it must be cleaned before it is used further. I usually begin by passing a small permanent magnet several times over the powder to draw out any of the iron filings. The first time you do this you'll be stunned to find out how much iron contamination is present in the metal. After this I usually wash the metal filings in a small, flat bowl and pan
them rather like a gold panner to remove any light contaminants and things such as abrasives. When the filings rinse clean, I usually decan off all the water and add a little borax powder to make a kind of paste out of the whole mess. At this point I divide the material up into lumps a little bit bigger than a pea and twist each one into a couple layers of white tissue paper. Then I just set everything aside to dry. When the tissue has dried (you can skip this if you're in a hurry) I put the blocks one at a time on a small charcoal block and use the asetaline torch to melt them. The tissue paper quickly burns off and leaves nothing but a carbon residue which is reducing in nature and actually helps keep everything clean. The flux obviously coats all the particles which eventually into one neat little melted bead which you can drop in a bucket of water. I work these kind of grains back into my castings a little at a time and have experienced no difficulty at all with contamination or other problems that I can identify from using this kind of scrap metal.
METAL FLUIDITY

The problem of metal fluidity has a fundamental impact on the nature and ease of the casting operation. This fluidity is expressed in terms of viscosity in simplest terms materials which are very thin in fluid and have low viscosities while substances that are thicker or flow less easily are said to have high viscosities. For example, the viscosity of milk would be much lower than that of molasses. The ease with which liquids flow through small channels is related to the viscosity. Thus, a molten metal with a low viscosity will flow easily through small, sprue holds and into the finest details of a mold. A metal with a higher viscosity might tend to flow less well through the sprue openings and might not even succeed in filling all of the details of the mold.

The second obvious factor with regard to the ability of the metal to fill the mold is the temperature of the mold itself. If the mold were at room temperature and the metal were only slightly above its melting point, the metal will tend to very quickly solidify while flowing into the mold. This solidification may block off parts of the sprue system or mold before filling is complete. Obviously, if the mold were at the temperature of the molten metal, there would be no heat loss and the metal melt would remain at the same temperature until the mold was completely filled. Generally, the nature of the mold materials is such that the molds cannot be operated at or above the melt temperature. The obvious exception would be the use of pewter which melts in the range of 450 to 600°F farenheit and an investment mold which can be maintained at 1,000 to 1,100°. However, generally the situation is a compromise where the mold is held well above room temperature and is still considerably below the melt temperature. Generally, for casting
materials with melt temperatures in the range of 1400 - 1900°C Farenheit
a mold temperature are recommended to range from about 700 - 1100°C Farenheit.
The lower mold temperatures being related to the casting of large massive sections
such as mens rings and the higher mold temperatures reserved for casting of fine
detailed parts.
ALLOYING

LOW COST GOLD AND SILVER

PART 3

By: Richard D. Austin

In the previous articles of this series we have discussed the economics of alloy preparation as well as the issues of contamination and melting procedures. In this final installment we will focus on:

- Alloy Standards
- Alloy Calculations and Adjustments

Alloy Standards - Compared to many other countries, Americans have historically displayed a casual attitude about the stamping of quality marks on precious metal items. The British have had an elaborate system to mark silver for hundreds of years. A brief historical perspective of how the present U.S. standards evolved may clarify the situation.

The first major legislation in the United States was passed in 1906. This was the National Gold and Silver Stamping Act. This act required that all items which were marked with a karat mark, assay to within 1/2 karat of the mark if it contained no solder, and that it be within 1 karat of its designated quality if it contained solder. The tolerance was either 21 or 42 parts per thousand. This meant that you could
buy a marked gold item which contained 4% less actual gold content than indicated by the mark. Another weakness of the law was the fact that manufacturers were not required to identify their work. This meant that the unscrupulous could easily slip their material into production without much fear of being apprehended.

In 1938 the U.S. bureau of standards established a voluntary 10 karat minimum fine for karat gold jewelry products. Anything that was less than 10 Karat gold couldn't be called gold. Many countries hold to the concept that gold isn't gold until it's 50% (12 karat rather than 10 karat). In 1978 there was an effort to drop this rule. It was decided to let the 10 karat gold rule stand.

The next major change was an amendment to the Stamping Act (in 1960) to require manufacturers to apply an identifying mark in addition to the gold content mark. This was consumer legislation intended to identify the manufacturer and therefore make enforcement of the rules more rigorous.

The final and perhaps most important change was the 1976 amendment to the Stamping Act, which required narrowing the 1/2 and 1 karat tolerances to 3 parts per thousand and 7 parts per thousand respectively. The change was effective October of 1981. Karat gold meeting this new standard is known as Plumb gold.
This sequence of events really sets the stage for the problem
jewelry collectors and gold buyers face in the market.
Domestically produced antique jewelry made before 1906 may or
may not carry any kind of a mark. In my own experience
I've often run into pieces of jewelry which seem to be 9 or
10 karat, but carry no mark. These are pretty difficult to
use as scrap. If their jewelry value is low, I usually send
them off to the refiner. To be on the safe side I generally
assume that marked antique pieces are 1 full karat below
their marked gold content. This puts me on the side of safety
and the couple times that I've had my work assayed, it seemed
to work out well.

Occasionally you will encounter pieces of jewelry which look
like gold but are marked with a "sterling" stamp. This will
usually turn out to be Vermeil. Vermeil is a gold cladding or
heavy plating over silver. Generally, it is expected that the
whole finished piece must meet the sterling silver standards
including the gold. From a scrap viewpoint the gold itself
would probably be relatively inoffensive since it would
disappear into the much larger mass of silver when the article
is melted. However, many Vermeil pieces prepared by electro-
plating also have a layer of nickel plate over the silver before
the gold is applied. There is some question about quite how
this nickel plated coating behaves when the material is intro-
duced directly into the casting process.
One or two additional comments are in order. The first relates to the matter of stamping. We will go into considerable detail about how to upgrade precious metal scrap to meet the current Plumb Gold standards. However, if you are going to make a piece for your own use and not stamp it with a mark of it's fineness, it doesn't really matter what the alloy is. The only time you need to concern yourself is when it is stamped or represented in writing as carrying a particular value of gold or silver. Many individual craftsmen do not put a mark of fineness on their work. This is probably most common in American Indian silver jewelry which very often is made of sterling or coin silver but carries no such marking or designation. Also, pieces of mixed materials are often not identified. It should be emphasized that if you are going to mark a piece for its fineness, you must also provide your own identification. Obviously, the government isn't going to come knocking on your door because you made a piece of jewelry for one of your friends and stamped it without adding your own mark. However, as a legal requirement and as good practice you should mark your work. Individual stamps can be purchased at very nominal costs from a number of advertisers in Gems and Minerals. I would strongly recommend that every goldsmith working in precious metals have his own mark made. One final issue is worth noting. Just because you are able to obtain a gold coin or piece of antique jewelry below the apparent market value of its precious metal content, does not necessarily signify that it's wise to begin by melting it down. In several cases,
I've melted pieces which I subsequently learned were worth far more than their gold content. A little caution is in order. If you have any doubt, take your piece to an antique dealer or a knowledgeable individual before it goes in the melting pot.

**Alloy Calculations and Adjustments** - In addition to the jewelry which is available as a source of gold, there are many forms of bullion and coins which can also be a source for your raw material. The use of these coins or bullion requires some understanding of how they are made and how much gold they contain.

A good place to begin is to differentiate between bullion coins and numismatic coins. Numismatic coins have a price or value established by their beauty or rarity and physical condition. In many cases, the actual value of the gold content of the coin is a small part of its selling price. Most American gold coins in reasonable condition would be far more valuable for the numismatic quality than for their simple gold content.

Bullion coins are coins which are valued primarily for their gold content. The Krugerrand is a classic example of a bullion coin. It contains one troy ounce of gold and transfers at a small premium over its gold value. Premiums for Krugerrands would typically be in the range of 3 to 10 percent. Bullion coins are popular because they are an easy and convenient form for handling gold. Since their weight and assay are well recognized, there is no need to have them analyzed or evaluated.
in most transactions. In essence, the bullion coin is simply a convenient way to package gold.

The difficulty in using either numismatic coins or bullion coins in the jewelry making process is the fact that they are not made of pure gold. A Krugerrand contains one ounce of gold. If you weigh a Krugerrand you will find that it weighs slightly more than one ounce. This additional weight is derived from copper added to make the coin harder and more durable. The Krugerrand contains one troy ounce of gold but weighs about 1.0909 troy ounces. This works out to be precisely 22 karats.

It is important to understand that there is no world-wide standard for the fineness of gold coins. For example, gold coins struck in the Bahamas might have a fineness of as low as 500 or 12 karats. In cases where contemporary or bullion coins have a nominal currency value, this may have relatively little to do with the gold content of the coin. Very often gold coins will have a nominal value appreciably below their gold value. This is indicative of the fact that the government would redeem them for this value (in local currency) but has relatively little interest in doing so. Many of the countries that mint gold coins do so to appeal to collectors and buyers of gold coins and have no serious interest in having the gold coins circulate as day-to-day currency.

Some gold bullion and coins are minted of pure gold and may
carry a fineness mark as high as 999. Unfortunately, many of
the metals used to harden gold coins (such as antimony) are
not particularly suitable as casting constituents. If you
are going to work with bullion or coins stick to something
of known content with suitable alloying constituents.

Fortunately the situation with silver is somewhat less complex.
Most sterling silver is a simple alloy of 925 parts silver and
75 parts copper. Many silver coins are 900 parts fine. It is
important to remember that industrial silver scrap may contain
significant amounts of cadmium. This material should be avoided
in all cases.

The preparation of a 14KYG casting alloy from a Krugerrand and
from mixed scrap will serve as good examples of how to calculate
your alloys. The simplest yellow gold alloys are usually com-
binations of copper, silver and gold. Equal parts of silver
and copper added to the appropriate amount of gold will yield
an attractive and workable alloy.

Let's begin with a Krugerrand which contains one troy ounce
of gold.

\[
\frac{14}{24} = \frac{1}{X} \quad \text{or} \quad \frac{24}{X} = \frac{14}{14}
\]

\(X\) is the total weight of 14K alloy to be prepared from one
ounce of gold.

\[
\frac{24}{14} = 1.7143 = X
\]

Therefore our Krugerrand will produce 1.7143 ounces of 14KYG.
The next step is to account for the copper which is already present. First of all, I've stated previously that an equal weight mixture of copper and silver make a good combination with gold. If we divide 0.7143 by 2 we find that we should have about 0.3572 ounces of copper and an equal amount of silver. However, the total weight of the Krugerrand was 1.0909 ounces. This means that there is already 0.0909 ounces of copper present. If we subtract this from the 0.3572 we find that we need 0.2663 additional ounces of copper. If we add 0.2663 ounces of copper and 0.3572 ounces of silver to the Krugerrand we would yield a very usable 14KYG casting alloy. Perhaps the only difficulty with this alloy would be the absence of any materials to adjust the grain size. In larger massive castings you might find that grain growth would be rather large. However, with careful casting you find that this would be an excellent craft material. What would happen to the process if you wanted to prepare your alloy from a Krugerrand, copper and sterling silver? We still need to end up with:

\[
\begin{align*}
\text{1.0000 oz. Gold} \\
\text{0.3572 oz. Copper} \\
\text{0.3572 oz. Silver} \\
\text{1.7143}
\end{align*}
\]

We are starting with 1 oz. of gold and 0.0909 of copper. 

\[
\frac{925}{1000} = \frac{0.3572}{Y} \quad \text{where } Y \text{ is the amount of sterling needed}
\]

\[
Y = \frac{1000 \times 0.3572}{925} = 0.3862
\]

Therefore we must add 0.3862 ounces of sterling to get 0.3572
ounces of silver. This also means that we have added 0.3862 - 0.3572 = 0.0290 ounces of copper. Therefore, 0.0909 ounces of copper come from the Krugerrand and 0.029 from the sterling. 

\[ 0.0909 + 0.0290 = 0.1199 \]

You must add an additional 0.3572 - 0.1199 = 0.2373 ounces of copper. The total melt weight is:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Krugerrand</td>
<td>1.0909</td>
</tr>
<tr>
<td>Sterling</td>
<td>0.3862</td>
</tr>
<tr>
<td>Copper</td>
<td>0.2373</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.7144</strong></td>
</tr>
</tbody>
</table>

The alternate approach is to prepare your alloys from upgraded karat gold scrap. In order to be on the safe side always begin with the assumption that old gold jewelry is one full karat below the marke content. If you have a quantity of 10KYG scrap (really 9 or 9½K) you can upgrade it by blending with 14K, 18K or 24K gold. The following tables illustrate how much high karat scrap to add to bring the alloy content up. Note that you can work in any unit of measurement as long as it is used consistently. If you weigh the scrap in ounces, grams or dwt, simply use the same units for both constituents.

To upgrade one ounce, gram or dwt of 9K scrap to 10K:

\[
\begin{align*}
\text{Add ounce, gram or dwt} \\
24K &= 0.08 \\
17K &= 0.15 \\
13K &= 0.34
\end{align*}
\]

To upgrade one ounce, gram or dwt of 13K scrap to 14K:

\[
\begin{align*}
\text{Add ounce, gram or dwt} \\
24K &= 0.10 \\
17K &= 0.34
\end{align*}
\]
To upgrade one ounce, gram or dwt of 17K scrap to 18K:

Add ounce, gram or dwt

24K = 0.07

An example will illustrate how to use these tables. Let's assume that you have a gram scale in your shop and you have somehow acquired 36.26 grams of old 14KYG scrap. All the findings and solder have been removed and the scrap is clean and ready to use. Let's also assume that you have a little nominal 18K scrap around. The table indicates that you need to add 0.34 grams of the high karat scrap to each gram of low karat. Therefore you need:

\[ 36.26 \times 0.34 = 12.33 \text{ grams } 18K(17K) \]

To check this out:

\[ \begin{align*}
36.26 \text{ grams} \times 13/24 &= 19.64 \text{ grams fine gold} \\
12.33 \text{ grams} \times 17/24 &= 8.73 \text{ grams fine gold} \\
48.55 \text{ grams} &= 28.37 \text{ grams fine gold}
\end{align*} \]

This means that the mixture will produce 48.55 grams of alloy containing at least 28.37 grams of fine gold.

\[ \frac{28.37}{48.55} = 0.5843 \quad \frac{14}{24} = 0.5833 \]

Therefore we have created an alloy which is above the 14K standard. If you use these tables your work should be consistently above the stated karat mark. You may be giving away a little gold but this should be more than offset by your purchase savings.

Let's summarize. In most cases you should be able to use sterling silver scrap directly in the casting or fabrication process. Fine gold or gold bullion may be alloyed to the
proper jewelry standards. Old gold jewelry may be upgraded to Plumb standards by proper blending or the addition of pure gold. I would recommend that you do not try to upgrade white gold scrap.

Please use care and good safety practices at all times. Work in a well ventilated area. Wear safety glasses and proper clothing. Most important of all, avoid cadmium alloys.

Good Luck and Good Savings!
GOLD STANDARDS

Generally speaking, the United States has had a rather casual attitude toward the marking of karat gold items. American manufacturers have been allowed considerably more leeway in the assay content of hallmarked items than almost any other modern country in the world. In America, a piece stamped 14k (14/24 pure) could be as much as one half karat (21 parts per thousand) less than 14 karat. At the same time, articles assembled by soldering could be even lower in total, overall assay. A 14 karat piece could be one full karat mark (42 parts per thousand) under or, it could actually assay at a total of 13 karat. In 1976, the Federal Trade Commission tightened the standards through an amendment to the National Gold and Silver Stamping Act.

The Stamping Act amendment requires that the assay of solid gold pieces come within three parts per thousand of the karat mark stamped and seven parts per thousand for soldered fabrications.

Although it's hard to criticize this move, it does cause some difficulty for the manufacturing jewelers and retailers. First of all, there is the obvious problem of the huge inventory of articles made to the old standard. The period of time from the passage of the Act until October, 1981, was provided to give a period of assessors five years to clean out inventories of material made to the old standards. In spite of this, I'm certain that most
manufacturing jewelers will find themselves with a certain inventory of non-"plumb" items in the Fall of 1981. After that time, these in theory should not be offered for sale. At the same time, another common practice will become more difficult. Many of the smaller jewelers, in my experience, have used a certain amount of purchased scrap gold to work into their ordinary casting production. Quite often, scrap gold can be purchased favorably (typically somewhat below the market price) compared to new casting grain which would normally sell somewhat above the market price. This spread in pricing can often be a distinct advantage. However, the karat gold scrap which will be offered for sale will not meet the new plumb standards. The primary purpose of this article is to demonstrate how scrap items of appropriate karats can be blended to provide casting material which will meet the new plumb gold standards and yet, provide a more economical solution to the gold supply problem for the small manufacturer. At the same time, I will make some other general comments on ways in which process scrap can be worked into ordinary production on an ongoing basis.

One of the more difficult kinds of scrap to deal with has always been the filings from various kinds of finishing operations. Even a shop with a few benches will generate a surprising amount of this kind of material. In my own shop, I always keep this type of scrap very carefully segregated. Since all of our work is either sterling silver or 14 karat gold, this is relatively easy. It should be noted that we work in both 14 karat yellow and white gold but no attempt is
made to salvage or reprocess the scrap from white gold operations in our own castings. All white gold scrap is returned directly to the refiner. The filings portion of the yellow gold scrap should be briefly cleaned before its blended back into other materials. Typically, I would accumulate this until I had at least a penney weight or two to make it worth the trouble. The first step is to use a small, permanent magnet to remove all iron and steel filings from the scrap. Simply put the material on a clean sheet of paper and work the magnet back and forth literally touching it for a few passes and you'll find that you should pick up a surprising amount of iron. The next step is to briefly wash the material in a small pyrex dish to remove any organic materials or other non-metallic and non-magnetic elements. I find that if you simply swirl it, rather like panning gold, you'll remove a little more material which will be a combination of wood dust from the bench, perhaps, a little investment and some polishing compound. The residue from this second treatment is dried and mixed with a little Borax. Take ordinary white tissue paper and a small quantity of the Borax and gold powder mixture and form a paper twist. This should be about the size of a pea or a little larger. Simply put the twists on a charcoal block and melt them with a torch. You'll find that the paper burns away cleanly but it does survive long enough to hold the gold and fluxment mixture together. The use of a large amount of flux should remove any other inorganic impurities; so after melting simply use the small gold shears a very thorough tickling and the
should be fairly clean. Obviously, there is some opportunity for contamination so I generally make it a practice to work these pellets into the casting over a period of time. They are essentially the same size as ordinary casting grain, so I might drop one pellet in each batch of castings until they’re gone.

For purposes of making our alloying calculations, you can make various assumptions about the quality of material which you have available as scrap. If you are a large shop and wish to prepare a large lot of grain, it's perfectly practical to go ahead and have the material assayed. However, in a smaller shop, it's probably least expensive to simply err on a side of being conservative and assume that all of the marked gold scrap will be one full karat mark below what is marked on the parts. In all likelihood, this means that you'll be working with nine, thirteen and seventeen karat gold scrap. The question then, becomes what mixture of these karats are required to bring a lot of casting grain up to the full 10, 14 or 18 karat mark.
istorically the government regulations required that parts made and stamped ith various karat markings could have an overall average metal content smewhat lower than the content indicated by the karat stamp. For example, in the case of 14 karat gold, there was a recognition that pieces assembled ith solder could legitimately have an average karat content somewhat below 4 karat because of the reduced amount of gold in the solder. To provide a little latitude for the jewelry manufacturer, the government would raditionally require that pieces so marked (14 karat) would be a minimum of 3½ karat on the basis of total analysis. Current government regulations equire that pieces marked 14 karat will actually and honestly be 14 karat or etter in total composition. In essence this allows or requires that overall average karat content move up about one half a point. At the most thisould represent roughly a 2% change in the standard. However on an ounce of old this amounts to about $8 per ounce increased gold value in the alloy. ther than the fact that this requires old inventories be used up and a light increase in product cost, this change has relatively little impact on e major jewelry manufacturer. However in smaller shops this may generate omething of a problem. For example, many small, limited production shops se a good deal of scrap gold to avoid the cost of purchasing newly refined ad alloy gold for custom work. Generally speaking, purchases made on the crap market can be made at something in the order of 60-30% of the daily arket value and this can represent a very substantial saving for the small inufacturer.

he real question now becomes to ensure that the materials cast meet the new tandards. Actually this is no particular problem since it's very easy to lloy a combination of 14 and 18 karat gold to ensure that the material will
e well over the 14 karat level required for the plumb marking system. Even if some excess gold is included in the formulation, the cost savings of this way should more than offset the little extra gold content included. However, this leaves the question of how to appropriately ensure that the materials are of the proper alloy content.

A solution to this problem has been to use the Kerr Electro-Melt to prepare my own casting grain. I can do this in batches which tends to give me somewhat greater uniformity of color and allows me to make at least a series of articles which are basically the same formulation.
METALLURGY

SPRUE CLEANING

The sprues buttons removed from a casting have considerable value for their precious metal content. Although they could be sold to a refiner as scrap, their economic value is much higher if they can be used in the next casting melt. However, the sprues are contaminated to varying degrees with flux and investment. A conventional pickle bath removes the flux. Since the investment contains a significant amount of silica some jewelry texts recommend cleaning the metal with hydrofluoric acid. Hydrofluoric acid is an excellent solvent for the silica present on the metal but I am strongly opposed to the use of HF because of its very hazardous properties.

A far safer and completely satisfactory method for cleaning is recommended. The sprue materials should be thoroughly picked and then cut apart to separate the sprue button from the wire network. Next, use a brass brush to clean all the surfaces.

In some cases you will be confronted with valuable scrap which may still be contaminated. In this case the metal is placed in a depression in a charcoal block and melted with a liberal covering of flux. (Boarax - Boric Acid.) After cooling, the metal is picked and scrubbed again. The metal should be clean enough to use for future castings. Since
the alloying elements in both gold and silver alloys are less noble than the gold or silver they will tend to form oxides faster than the precious metal. These oxides tend to dissolve into the flux leaving behind an alloy with a higher precious metal content. In order to maintain fairly constant composition in the finished work, it is a good practice to combine some new metal with the sprue pieces for casting.
METALLURGY

KIRKSITE

The application of Kirksite to the modeling process could be accomplished in different ways.

- Matched Metal Stamping Dies
- Vacuum Forming Dies
- Compression Molding Dies
- Injection Molding Dies
- Forging Stakes
- Blanking Dies

Each of these offer specific advantages and problems for the model maker. One of the most intriguing applications would be the preparation of compression molding dies. This would probably combine the best of both worlds. It would provide relatively thin lightweight models and yet it would not require the precision of stamping dies. The basic concept would be to compression form 0.010" rigid vinyl sheet which had been preheated. This could be accomplished at relatively low pressures and a match between the front and back dies would not have to be too close.
THERMAL CONDUCTIVITY

The capacity of a metal to store and transmit heat relates to the weight of metal involved, some coefficient or measure of thermal capacity and the physical configuration of the metal. Some materials have an ability to store a great deal of heat and transmit it efficiently from one place to another. Metals generally have a great capacity to store and transmit heat.

Wax modelling tools make use of these characteristics. A stainless steel spatula is heated in an alcohol lamp. Even after the lamp is removed, the spatula stores a certain amount of thermal energy and can transmit this to other materials. On the one hand, the ability of the material to store heat is related to its mass and thermal coefficient. Generally speaking, the transfer of thermal energy is related to the surface area of an object. A greater surface area tends to throw off heat at a faster rate. This means that the rate at which heat is lost from an object will relate to both the surface area and the volume (weight of material involved).

Our way to understand this relationship is to consider two metal objects each weighing one pound. If one is a sphere and the other is a 2 foot by 2 foot sheet of metal they have vastly different surface areas. If both are heated to the same elevated temperature and allowed to cool the sheet will cool much more rapidly. All other factors being equal the rate of energy transfer to the surroundings (in this case
the air) will be proportional to the surface area.

These phenomenon create an interesting difficulty in the design of spatualas for wax modelling. Very large tools store relatively large amounts of thermal energy, and cool off slowly. Although, they are able to maintain their temperature and usefulness for a long period of time they are too large to do detailed work. The size and mass of the tip mean that too much energy can be transferred, or the tool is simply too large to work delicate forms. On the other hand, if the tools are made very small and delicate, they lose heat quickly because of high surface-to-volume relationship. Therefore they must constantly be reheated. In searching for a solution for this problem, a new approach was developed.

Some materials have far greater ability than others to store heat. Copper and silver can store more thermal energy in a given mass than most other metals, and certainly far more than the materials such as stone or wood. This means that using these materials for tools will allow for greater thermal storage. Designing the tool to provide mass where it is needed for storage, and detail required for finish, will provide an effective and appropriate method or format for tool development.
CASTING

LOW MELTING ALLOYS

In a number of applications, the goldsmith or restorer may wish to cast objects of low melting alloys. This may be necessary for reasons of size, economy, or to match an existing piece of work. Most of the techniques described here were developed to cast parts such as spouts and handles in the restoration of silver-plated hollowware and other decorative antiques. I have also used this technique to cast pewter jewelry and even replacement parts for shop equipment.

For purposes of discussion, we will define the low melting alloys as materials which need to be cast into molds whose temperatures are below 400°F. This arbitrary definition is based on practical material considerations. The majority of jewelry casting investments contain various amounts of cristobolite. This is added to the formulation to provide a cushion and to adjust the thermo expansion properties of the molds. In conventional precious metal casting (at flask temperatures in the range of 800°F to 1100°F), cristobolite performs admirably. Unfortunately, it undergoes a major dimensional change of about 400°F. This means that if a mold is cooled below 400°F after burnout, there is a high probability that it will crack.
This means that if you want to investment cast pewter, you have a problem. A flask temperature of 500°F is far too high. Lower the temperature and you crack the mold. At the very least, the odds are that you'll have a badly webbed casting, no matter how carefully you work. This means that you need to find an investment with no cristobolite.

In our discussions of investment formulation, we have discussed the fact that the reactive base for an investment can be prepared for calcium, sulphate or phosphate. The phosphate base materials generally do not contain cristobolite, and although they are more often used for high temperature casting, they are able to withstand cooling to room temperature.
Low Melting Alloys - In commercial production, small castings are often made in vulcanized or silicone rubber molds. Larger objects may be cast in sand, plaster or permanent metal molds. Low melting alloys may also be cast with conventional investment casting equipment. The only basic difference in the process is the fact that flask temperatures at or near room temperature are used. This means that cristobalite based investments are to be avoided. The Kerr G-400 series investment is specifically formulated for this application. Pewter jewelry and small aluminum structural parts may be cast successfully using this material.