

An investment procedure for lost wax casting

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Preferences:

Clean, fresh investment, water and investment at room temperature, de-ionized or distilled water or water that has been sitting overnight. Follow the proportions suggested by the investment manufacturer. Usually 40cc of water to 100 grams of investment is good. Use a dust filter mask and gloves. Time yourself.

Remember: *'Well begun is half done'*

1. If investing by eye rather than using measurements then fill flask between 2/3 and 3/4 full of water, and pour it into the mixing bowl.
2. Sift the investment gently but fairly rapidly onto the water's surface and mix well with a spatula, smoothing out any lumps. Note the time. The investment procedure should be finished about nine to nine and a half minutes after beginning to mix.
3. As soon as the investment is smooth swirl the bowl in your hands so that the investment continually moves and any bubbles are removed. Don't whip in more bubbles. If desired use a vibrator on the investment to encourage bubbles to leave.
4. At about the five minute mark vacuum the investment for 1-2 minutes or until the investment boils for a moment or two. Too much boiling may damage the investment.
5. While the investment in the bowl is vacuuming pour debubbler over the wax in the flask and then pour it back into the bottle again, draining the flask well. While it is not supposed to be necessary to use it with vacuum investing I have found debubbler is of some help in aiding trapped bubbles to slide off the model.
6. Remove the investment from the vacuum bell and swirl it, then pour it into the tilted flask and rotate the flask while pouring to encourage bubbles to leave. Swirl the flask gently. This is when you realize why one puts tape around the top of the flask.
7. Assuming there are no air bubbles present in the wax vacuum the flask well. When finished this should put one at about the nine minute mark from starting. Remove the flask from the vacuum bell and if the investment is not yet reasonably hard gently swirl it until it thickens. This will discourage water tracking. When the investment seems thick and sluggish let it be. Glossing off should occur at about thirteen and a half minutes after beginning to invest. If it does not occur by fifteen minutes after starting then either the investment proportions were too watery or the investment has absorbed water from the air, is no longer fresh and therefore the ratio of water to investment was wrong. This can lead to water tracking and investment breakdown.
8. After the investment is hardened slightly (about 30 minutes from starting) remove the rubber sprue base with a slight twisting motion and clean off any excess investment from the outside of the flask. A small flask may be burned out immediately, a medium sized one should rest for a little while and a large one may dry overnight without damage. If one wishes to cast later one can store the flask in a sealed plastic bag until required for casting (I would suggest under a week).

Getting Optimum Performance From Your Casting Investment Powder

By Ralph Carter

Introduction

In each step of manufacturing jewelry, there are many factors that can adversely affect quality. Because of this, process control is very important. Investing is one of those steps in which process control is vital. Most investment manufacturers help the investor control the process variables by providing a consistent product, user instructions and technical support.

However, improper handling of the investment powder often destroys their efforts. Improper storage, poor water quality, wrong mixing ratios, insufficient mixing methods, uncontrolled temperatures and others can each reduce casting quality and thus cause loss of production and money. This paper will present some data that will show what some factors do to the various investment properties [1, 2] and discuss why these are important. The specific factors that will be focused on are: water quality, the temperature of the water and of the powder and also the water-to-powder mixing ratio. This paper will show how dependent are the properties, and thus the performance of gypsum-based investment, on these factors. To help in understanding the data, some background information on gypsum investments and the test methods employed needs to be covered.

Background

Gypsum-based jewelry investments contain three classes of materials, refractory material, bonding material and controlling chemicals. Refractory materials can withstand high temperatures without decomposing. Silica serves this function. Bonding materials are what hold the refractory materials in place to form a mold. This is the purpose of gypsum. Controlling chemicals are used to control how quickly the bonding materials set up and to accentuate various investment properties.

The bonding material, gypsum, is actually formed by the chemical reaction between water and plaster [3]. Water molecules chemically bond with plaster molecules to form gypsum. As with most chemical reactions, the rate in which it proceeds is highly dependent on temperature, interfering compounds, the condition of the reactants and the amounts of the reactants [4]. Investment manufacturers make great efforts to assure that this reaction proceeds at the designed rate. They achieve this by holding the raw material suppliers to strict standards of purity, quality and consistency. They also achieve this by using the controlling chemicals. However, compounds that affect the rate of reaction are often found naturally in water [5]. These interfering compounds can negate the effort manufacturers put towards making a consistent product.

Testing Procedures

Pour Time

Pour time is similar to working time, but there is a subtle difference. The working time is the amount of time from when all the powder is added to the water until the investor feels that the mixture is too viscous to continue to work or manipulate [6]. It is easy to understand how this will depend on the user's preference and the application. On the other hand, the pour time can be described in a less subjective manner. The pour time is the amount of time it takes the investment to become so thick it will not pour. It is a measurement of reaction time. For repeatability, the investment is mixed with a specific intensity and specific time and the pouring is done precisely every 15sec [7].

Set Time

The set time is the amount of time it takes the investment to become so hard that the Vicat needle will not penetrate more than 1mm. The Vicat needle is 1mm in diameter and has 300gm weight behind it [7]. At this point, the investment is about 22% of its full strength [6]. It will take 1-2hrs longer before it is hard enough to disturb by further processing, such as transferring to a burnout oven.

Slump

To measure the fluidity of an investment, a slump test is used. To measure the slump of an investment, it is mixed in the same way as for pour time and set time. Some material is poured into a cylinder, 5cm tall and 3.5cm diameter, standing on a glass plate. The top is struck off level. At exactly the 2min mark, the cylinder is lifted off the glass [7]. The investment material will drop out and spread out equally in all directions. The thinner investments will result in a larger disk (spread diameter) than the thicker ones.

Strength

The green compressive strength refers to the amount of pressure needed to destructively compress the investment 2hrs after it had set. Fired compressive strength refers to the amount of pressure needed to

destructively compress the investment after it has been through burnout and then cooled slowly to room temperature. The firing process weakens gypsum investments tremendously. Some investments are weakened more than others, depending on controlling chemicals, particle sizes, raw material percentages and plaster grades.

In order to obtain accurate and repeatable compressive strength results, it is critical to closely adhere to a consistent set of procedures [7]. The results can be affected by length of mixing time, mixing intensity, whether a vacuum step is included, air bubbles, unparallel ends and disturbing the molds too soon.

Castings

Castings were made at several water-to-powder ratios. The investment was mixed until the 3min had elapsed and then it was vacuumed for 20sec. The 10cm diameter by 12.7cm high flasks were filled to the top of the pattern and vacuumed for 1min. The flasks were then filled the rest of the way and set aside for hardening. The recommended burnout schedule was used [8]. The flasks were at 510°C when cast. A brass alloy of 60% copper and 40% zinc was centrifugally cast at 1091°C. The same pattern was used for each water-to-powder ratio.

Results & Discussion

Water quality

In order to see how much the investment properties are dependent on water quality, samples of water from various sources were obtained. The point of examining all of the water sources is not to predict what any particular water source might be like. Each water source is different and will change with time. The point is to simply use several different water sources from anywhere.

	Type	pH	Conductivity
1	City, Maumee USA	9.61	0.18
2	City, LA USA	7.93	0.64
3	Pool	7.66	1.50
4	Lake Surface	8.31	0.25
5	River Surface	8.43	0.58
6	Field Runoff	7.52	1.55
7	Farm Well	8.19	0.40
8	City, Hicksville USA	7.80	0.69
9	City, Birmingham UK	7.70	0.10
10	City, East London UK	7.99	0.66
11	City, Dartford UK	7.62	0.55

In Table 1, it can be seen that the acidity (as measured by pH) of the waters varies considerably as does as the conductivity. Conductivity is simply the inverse of electrical resistance. Pure water does not conduct electricity. Its resistance approaches infinity. The inverse of infinity is zero, so the conductivity of really pure water is zero. But when compounds dissolve in water, their ions give water the ability to conduct electricity [9]. Here the unit of conductivity is millimhos.

The main observation from this table is that each water source is different in terms of pH and conductivity. Using a single investment powder, each water source was used to make an investment mixture and test its pour time, set time and slump. The results obtained were then compared to a standard investment mixture made with de-ionized water from R&R's research facility.

De-ionizing is simply a method of water purification. It does what its name suggests, that is, it removes ions from the water. The investment properties obtained with the standard mixture were subtracted from the investment properties obtained with each water source. This was done because the difference from the standard is what is of interest. That is how the data is shown in the following graphs.

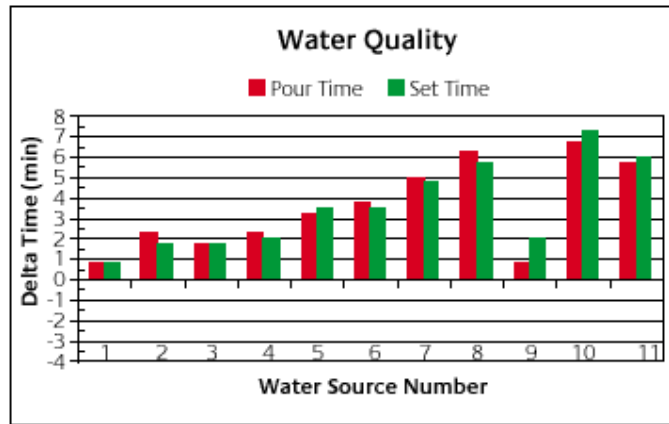


Figure 1 - Effect of water quality on pour time and set time

Figure 1 show what happened to the pour time and set time of each investment. On the y-axis is the difference between the standard and the result caused by a particular water source. On the x-axis is the water source reference number. The standard is represented by zero or the x-axis. Every water source caused the pour time and set time of the investment mixture to be longer than the standard. If a source was shorter than the standard, the bar would dip into the negative region. Some varied from the standard more than others.

What this means to the investor is that the working time and setting time are longer. In one instance we had a customer once who had a setting time greater than 24hrs. They never had problems like this before, but their water quality changed on them without their knowing. This brings up the point that water sources can change with time. So a water source may not cause trouble now but it may tomorrow or next week. The point of this is that if the water is changing, then the pour time and set time are changing and the investor is left guessing as to when it is appropriate to load the flasks into the oven.

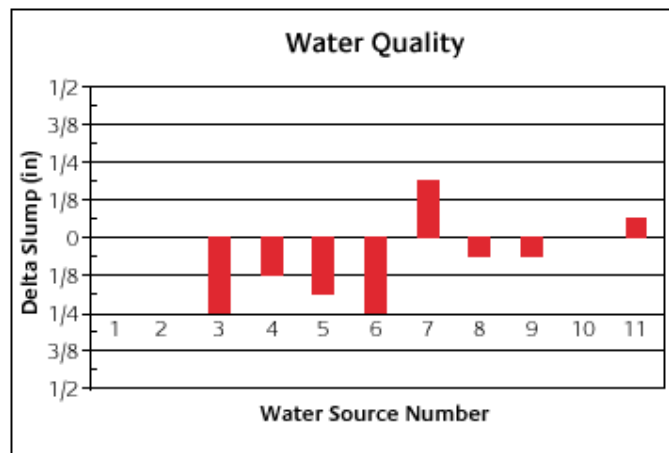


Figure 2 - Effect of water quality on fluidity (slump test)

The measurement of fluidity is the slump test. Figure 2 shows the degree of slump versus water source. Here again on the y-axis is plotted the difference from the standard. The standard is the x-axis. Notice that some water sources did not affect the slump at all. Source number seven made the slump larger than the standard. Most of the others made the slump smaller. Each water source affected the slump in its own way. Now do not get concerned about which water source most represents your water. The point here is that each water source does something different. As a result, this may cause casting defects, such as trapped air, watermarks or rough surfaces.

The water quality can change the designed pour time, set time and fluidity of the investment. This relationship is a source of variability in mold making. Because of this variability, the amount of working time is no longer known. The time when the molds are ready to be loaded into the oven is no longer known. Defects may occur due to the effect on the fluidity.

So what can be done to help this situation? The investment manufacturers suggest that de-ionized water be used, when mixing their product [8]. In order to test whether their suggestion works, each water sample was de-ionized, another investment mixture made with it and the tests run again.

Figure 3 is a graph of the pH of the water samples before de-ionizing (in red) and then after (in green). The pH in each case came down.

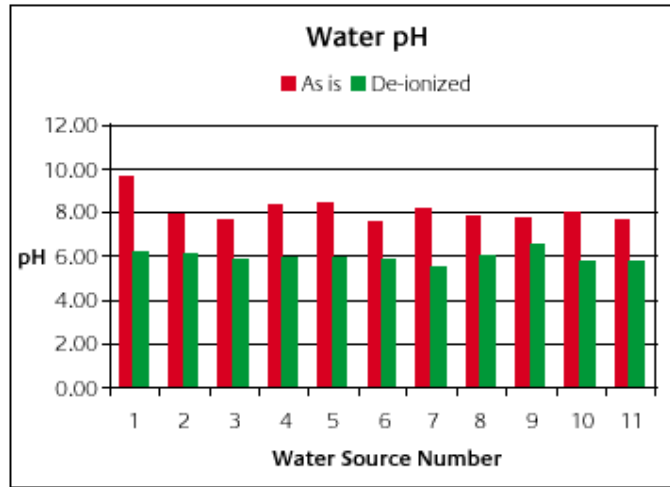


Figure 3 - Effect of de-ionizing on pH of water

Before the water samples were de-ionized, each sample could conduct electricity quite well. De-ionizing reduced the conductivity to zero, as shown in Table 2. The de-ionizing process removed ions. This is all nice but what does it do to the investment properties?

Water Source	As is (millimhos)	De-ionized
1	0.18	0.00
2	0.64	0.00
3	1.50	0.00
4	0.25	0.00
5	0.58	0.00
6	1.55	0.00
7	0.40	0.00
8	0.69	0.00
9	0.10	0.00
10	0.66	0.00
11	0.55	0.00

Figure 4 is a graph of the properties of the same investment as measured with the same water sources. Only now each water sample was de-ionized. Remember the y-axis is the difference from the standard. That means that the standard is at the zero line. The same standard was used as before. The range on the y-axis was kept the same as before to give perspective. Each water source gave essentially the same pour time and set time.

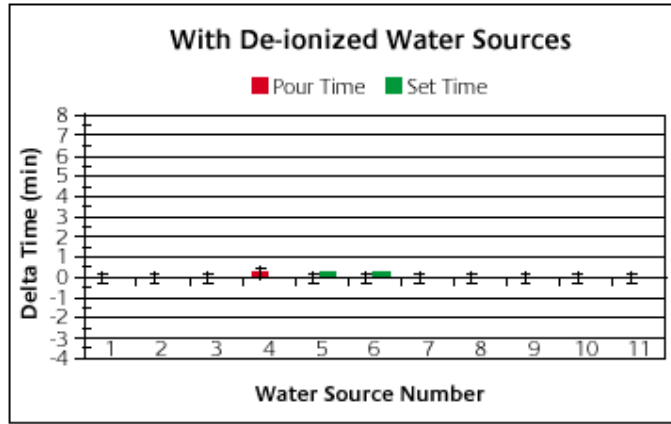


Figure 4 - Effect of water quality after de-ionizing on pour time and set time

Close inspection will show a very small deviation from the standard for mixtures made from waters numbered 4, 5 and 6. Included are error bars to represent the accuracy of the test. These error bars relate an idea of how small the variation really is. The small variation of number 4, 5 and 6 are absorbed by the variation inherent in the test. Therefore, the variation of 4, 5 and 6 are really quite negligible.

Remember that before, each water source caused the pour time and set time to deviate from the designed. By simply de-ionizing, all variation associated with each water source was removed. This is true with every water source tried. This suggests that, regardless of the beginning water condition, by de-ionizing, the investment properties will have the designed values.

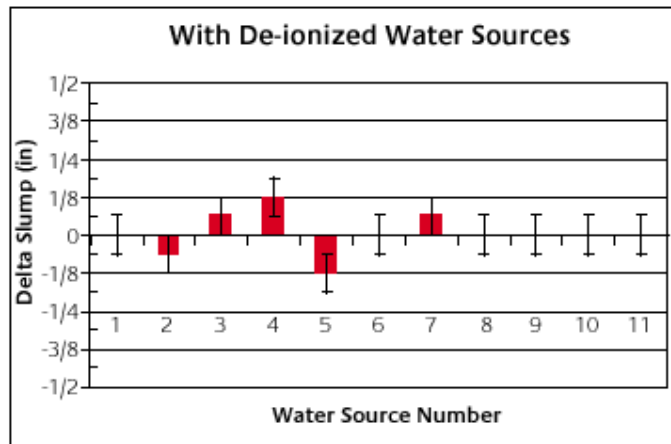


Figure 5 - Effect of water quality after de-ionizing on fluidity

Figure 5 shows the slump as a function of de-ionized water sources. The slump can be measured to $\pm 0.16\text{cm}$. The error bars reflect that. When considering the accuracy of the test, what little variation that remains is really negligible.

Reviewing the observations, de-ionizing reduced the pH and conductivity. The conductivity measurement is a good indication of whether the water is good enough. The lower the better. The variability in pour time, set time and slump was reduced. This means that the investing process would be more consistent and reproducible. That means more consistent castings. That means fewer worries, less reworked material, less scrap and less cost. The customer, mentioned earlier, who had a greater than 24hr set time, was recommended to de-ionize his water and it was observed that the set time went back to normal.

Temperature

The next factor explored was temperature. How does the temperature of both the water and investment powder affect investment properties? In order to determine this, the investment properties were measured several times, varying only the starting temperature, which is the temperature of both the

water and powder prior to mixing together. De-ionized water and the standardized test procedures were used each time.

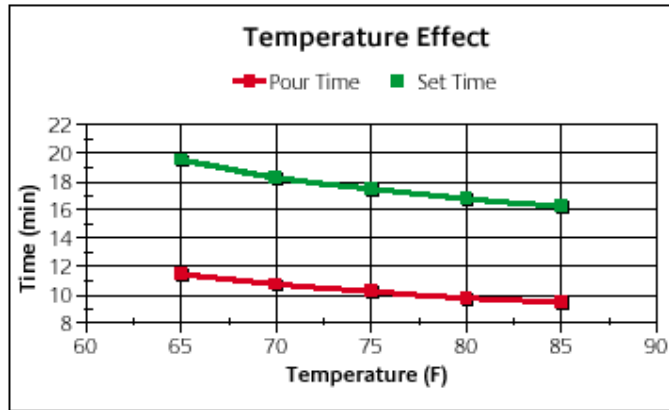


Figure 6 Effect of temperature on pour time and set time

Figure 6 shows the results. On the x-axis is the starting temperature. The y-axis has actual time and not a difference as in the previous graphs. The red line represents the pour time as a function of temperature and the green line is the set time.

In the temperature range shown on the graph, the pour time changes by two minutes. The set time changes by a little over three minutes. What this means is that if the temperature is not controlled, then there would be an uncontrolled swing in the pour time and set time.

This dependence on temperature may allow some investors to change the amount of time used to invest. An extra minute may be needed in certain applications or possibly the investor would like to slightly speed up the setting. The investor can do this by adjusting the temperature.

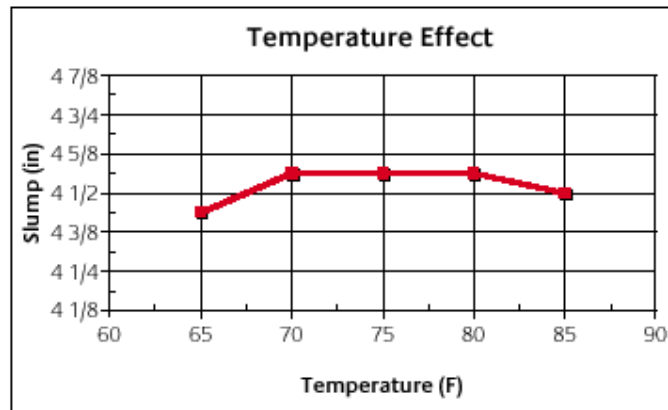


Figure 7 Effect of temperature on fluidity (slump test)

Figure 7 shows the fluidity versus temperature. The slump results were fairly constant even though the starting temperature was changed. The slight differences are negligible, when considering the precision of the test. This is reassuring to know. If the temperature is changed to over the setting time a little, then there need be no concern about causing problems associated with a change in fluidity.

In review, the pour time and set time are reduced as the temperature is increased. The fluidity is not very dependent on temperature. If the temperature is controlled, then the pour time and set time are controlled to some degree. If the temperature is not controlled, then the investment's pour time and set time will vary.

Water-to-powder ratio

The last factor explored is the water-to-powder ratio. How does the amount of water used to mix

investment affect the investment properties and ultimately the castings? Before answering this, it is important to know exactly what water-to-powder ratio is.

The best way to explain this might be to give an example. Commonly used in the jewelry industry is a water-to-powder ratio of 40ml of water for every 100gm investment powder. It is simply a ratio of how much of ingredient A to mix with ingredient B. It gets confused because it can be written in several ways, like 40:100, 40/100, 40, 0.40 and 28.57%water. Each of these is trying to convey the same water-to-powder ratio.

Back to how the water-to-powder ratio affects investment properties. To answer this, several investment properties were measured at several water-to-powder ratios. Castings were also made at several water-to-powder ratios in an attempt to observe detrimental effects. A premium investment powder was used for the tests. This is an important detail, as will be shown shortly. All measurements were made at 22.2°C - 23.3°C and with de-ionized water. All variables were held constant, except the water-to-powder ratio, which was varied from 34 to 46 (i.e. 34:100 to 46:100). The recommended water-to-powder ratio for this product is in the range 39-42, so some of the tests were outside the recommended water-to-powder ratio range [8]. The testing procedures used were from R&R's time honored ISO 9002 quality procedures [7].

Following are a series of graphs that are very similar. Each graph will show at the top what property it relates to. Each graph will have the water-to-powder ratio at the bottom, along the x-axis. The range of the x-axis is the same on each graph, which also has a box showing where the recommended water-to-powder ratio range is. Along the y-axis is the measured property and its units.

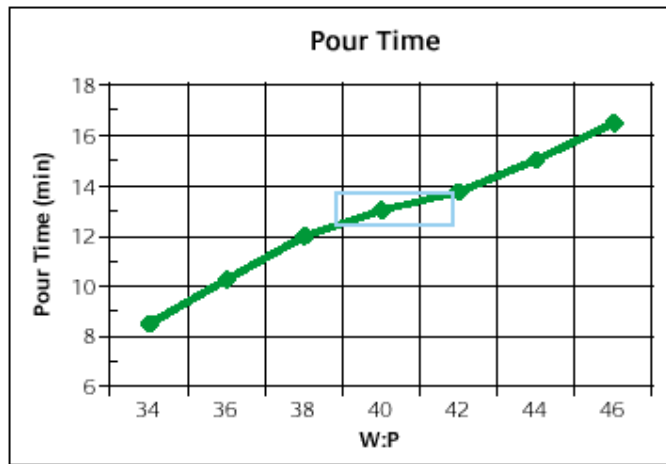


Figure 8 Effect of water: powder ratio on pour time

In Figure 8, it can be observed that the pour time is directly proportional to the water-to-powder ratio. There is actually quite a lot of change realized in the pour time. In the recommended range, 39-42, the pour time changes by 1.25min. This provides a moderate amount of flexibility for the investor who needs just a little extra time to complete all the process steps. In applications where this extra 1.25min is not enough, then possibly other process parameters should be looked into, rather than venturing out of the recommended water-to-powder ratio range. These other process parameters include mixing time, vacuum time and the number of flasks invested at any one time.

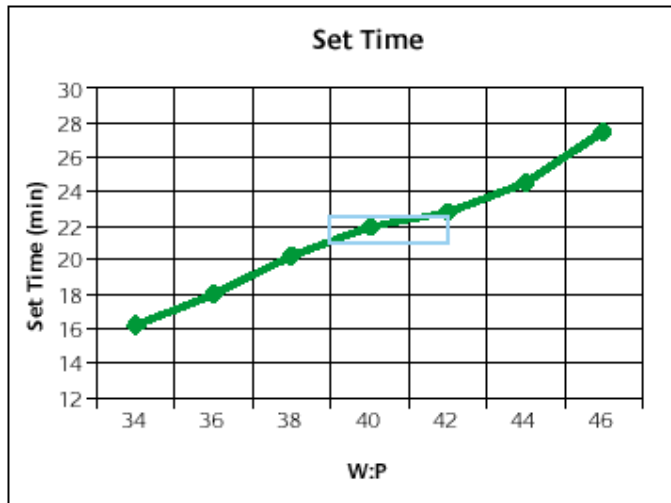


Figure 9 Effect of water: power ratio on set time

Figure 9 shows the set time as a function of water-to-powder ratio. In the recommended water-to-powder ratio range, the set time changes by about 1.5min. It is desirable to have a rapid setting after the flasks are filled. Otherwise, the chances of watermarks are increased [10]. For most investments, this is a serious problem; however, some will not cause watermarks regardless of set time.

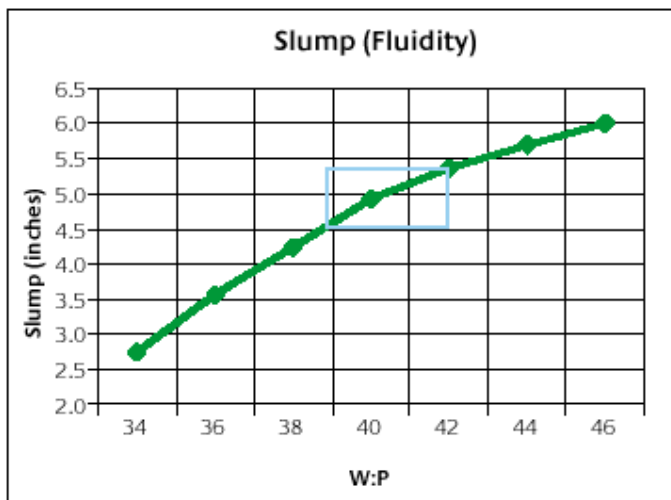


Figure 10 Effect of water: power ratio on fluidity

Figure 10 shows the fluidity as a function of water-to-powder ratio. As expected, the investment gets thinner with increased water-to-powder ratios. What is more interesting is the magnitude of the change in the recommended water-to-powder ratio range. It could be said that the slump is more dependent on water-to-powder ratio than pour time and set time. The pour time about doubled from the lowest water-to-powder ratio to the highest water-to-powder ratio. The set time did not quite double. Here the slump diameter doubled, making the area of the disk increase by close to five times.

The fluidity might be the one property most people want to change to their liking. It is thought that a more fluid mixture is needed to get better detail reproduction and better fill [10, 11]. Figure 10 definitely shows that by increasing the water-to-powder ratio you can achieve a more fluid mix. Within the recommended water-to-powder ratio range, plenty of fluidity change can be experienced to meet most needs. From a change in water-to-powder ratio from 39 to 42 the area increases by 1.37 times. By going outside the recommended range, changes in the other properties to a significant degree will create more headaches.

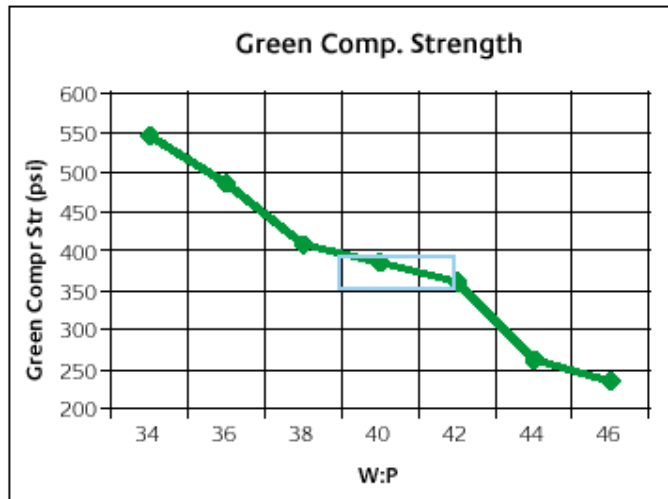


Figure 11 Effect of water: power ratio on green strength

Figure 11 shows the green compressive strength as a function of the water-to-powder ratio. This relationship is inversely proportional. There is a slight flattening of the curve in the middle. This indicates a less dramatic change in the green compressive strength near the recommended range and larger changes outside the recommended range. What this means is that there is some ability to change the green compressive strength, while within the recommended water-to-powder ratio range. Outside this water-to-powder range, the change in green compressive strength is more severe, the slope is greater, and may cause defects.

The weakening due to a high water-to-powder ratio may contribute to cracks or a rough surface finish [10,11]. I have actually seen in one application how a sandy surface occurred on close to 80% of the castings and when the water-to-powder ratio was reduced by only 1ml/100gm the defect went away. When a process is on the edge of the recommended range, it may only take a slight change in the water-to-powder ratio to cause problems. This idea is shown on the graph. It is like rolling or falling off a cliff.

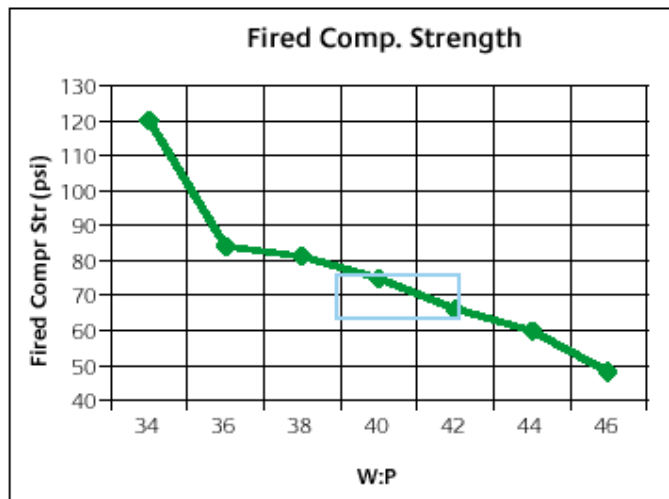


Figure 12 Effect of water: power ratio on fired strength

Figure 12 shows the fired compressive strength as a function of water-to-powder ratio. Because this is measured after firing and cooling to room temperature, it is more of an indication of the strength after casting. Therefore, it may impart some information on the ease of removing the casting from the mold. This is, of course, not the only factor affecting removal. There are formulation factors as well.

The dramatic increase at the lowest water-to-powder ratio could cause difficult removal of the casting. As with other properties, there is realized some flexibility within the recommended water-to-powder ratio range. The investment is designed for this range. By going outside the range, problems may arise.

The following are a few observations obtained while investing and casting at the various water-to-powder ratios tested. At higher water-to-powder ratios it was noticed that the investment would splash out of the mixer at normal speeds. This created a mess and called into question whether a good mix was achieved. After mixing, during the vacuum steps, the investment rose much higher than usual. This could potentially cause more housekeeping problems and loss of investment, unless a very tall collar is used. The chemicals added to control this were probably diluted too much by the excess water to be effective. However, the castings did not have watermarks or fins. All around they looked good.

At the lower water-to-powder ratios, the investment was really difficult to pour. The metal filled all the way, there were no air bubbles trapped, the mold may have broken away less than at high water-to-powder ratios, but it was still very good and all around the castings looked fine.

Why were there no defects? Conventional wisdom suggests that problems should have arisen. At high water-to-powder ratios there should have been cracking that gives way to fins, rough (sandy) surfaces and watermarks [10,11]. At the lower water-to-powder ratios there should have been non-fills, trapped air bubbles, loss of detail reproduction and difficult break away [10, 11]. These things did not happen. Why?

There are two possible reasons. One is the fact that a premium investment powder was used. Possibly this investment is fairly robust and can withstand some abuse. The second reason is the fact that a very simple and small pattern was used that probably did not challenge the mold enough, Figure 13.

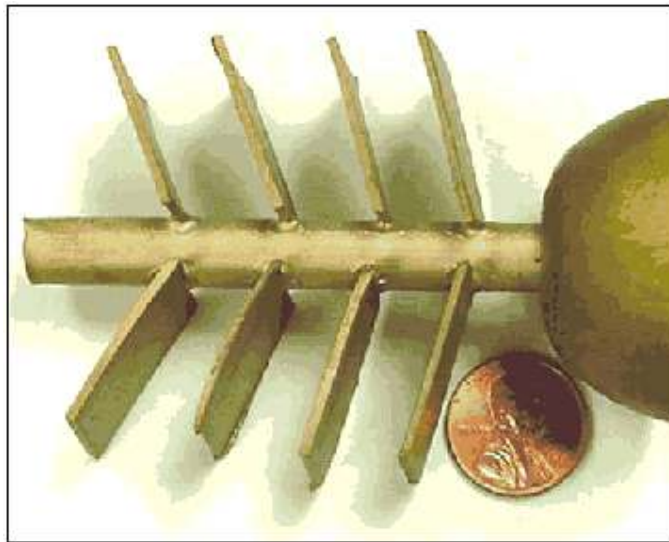


Figure 13 - Simple, small pattern used to test defect formation in casting

To check the plausibility of the argument about using the premium investment, the investing and casting was repeated with a non-premium investment. The same simple pattern was used. The following are the observations.

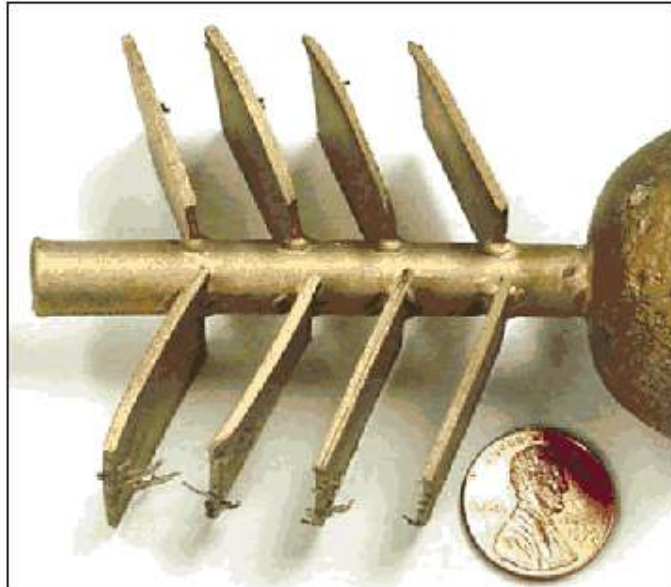


Figure 14 - Defects on casting from a non-premium investment mold

There were severe watermarks at the higher water-to-powder ratios, Figure 14. Air bubbles were present at every water-to-powder ratio and to about the same degree. Changing the investing process reduced some of these problems slightly. However, the point is that problems arose, as the industry experts and investment manufacturers say they would.

It appears as though the question as to why the defects did not occur is answered. It did have something to do with using a premium investment. Perhaps if the pattern was larger and more difficult, even the premium investment would get poor results. Even though some good results were obtained at water-to-powder ratios outside the recommended range, do not be fooled. These results simply show that it is sometimes possible to abuse some investments without getting defects. The results are far from saying that no defects occur while using water-to-powder ratios outside the recommended range every time, in any environment or with any investment.

The data presented shows that there are several investment properties that are affected by water-to-powder ratio. As the water-to-powder ratio goes up, so does the pour time, set time and fluidity. The strength, however, goes down.

Within the recommended water-to-powder ratio range, the investment manufacturer has built in some flexibility to change these properties to the investor's liking. But, by going outside the recommended water-to-powder ratio range, casting defects can arise, especially with non-premium investments. It is, therefore, very important to monitor the water-to-powder ratio. Make sure that the recommended range is being used and measure the water and powder carefully.



Figure 15 - Investment cast teazle

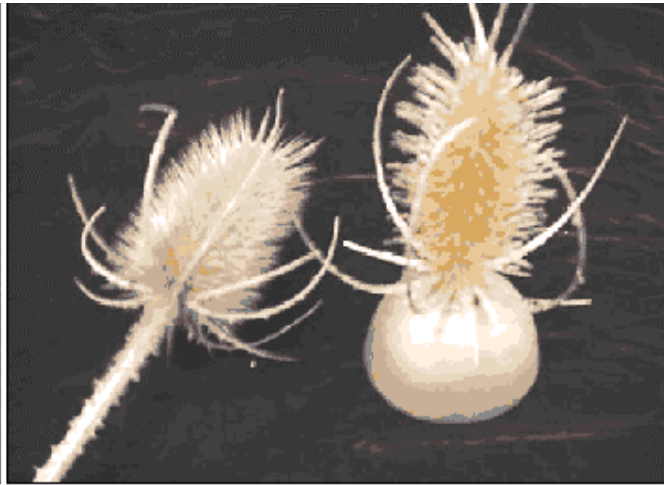


Figure 16 - Investment cast teazle with actual teazle

Summary

Water quality is an important factor that affects the investment properties. So, the recommendation is to de-ionize the water before using. Changes in temperature can change the setting rate. So, the recommendation is to control the temperature to reduce variability. The water-to-powder ratio affects many investment properties. So, again, it is sensible to use a ratio within the recommended water-to-powder ratio range. Finally, note that the investment manufacturer has considerable knowledge and facilities. So use the technical support offered by the investment manufacturer. Using these principles to your advantage, you can make very intricate castings like the one in Figures 15 & 16 made by Mike Kelley, the Jewelry Technical Specialist of Ransom & Randolph.

Casting Safety: a glimpse

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This is a very brief introduction to safety issues when casting in a small shop. It cannot hope to address the whole gamut of problems but can serve to introduce some important principles.

In general

Here's something to aim for: a well laid-out, orderly workshop, well-lit by multiple non glare light sources, well-maintained equipment, electrically and fire safe, with low dust and few procedures involving solvents, with excellent local ventilation at the appropriate work stations (such as investing or melting areas), the use of work clothing, which is cleaned frequently, lots of personal safety equipment (earmuffs, shoe covers to protect against molten metal splashes, safety glasses etc.), different jobs and heights to work at over the work day, ergonomically considered working actions and a conscious attitude and consciousness of safety. Choose procedures that don't involve exposure to risks. Set things up so that you can't hurt yourself. Make safety a habit and then it won't seem like work. If you don't use a certain chemical or hazardous procedure in your shop, then you are extremely unlikely to get hurt by it. Substitute less hazardous processes and materials for more dangerous ones. If you have an accident or a near miss it needs to be recorded in your accident book and discussed so as to avoid doing the same thing again.

To escape unnecessary work, look for examples of people who have solved the same kinds of safety problems you have to solve, and see if you can adapt some of their ideas and approaches for your own small shop. Look for models around you.

There are some general points to mention before we list specific hazards of casting.

There are dusts you can see in the air. It is, however, the smaller, completely invisible particles that are the most dangerous. These, especially fibrous or jagged ones like asbestos, cotton and silica, are stored between the air sacs of the lungs. That is, you breathe them in and they will never escape again. Once there, they cause scarring, thickening of tissues, eventually stressing the heart because it is more work to breathe. Cristobalite (a rather vicious form of silica) exposure is considered a real silicosis hazard. It is a major component of casting investment.

Fumes are small particles of a material, often from metals that have been melted. These may be very tiny and can be breathed deeply into the lungs. Metal fume fever can be a real problem with molten metals. Metal fume fever can be caused by zinc, copper, magnesium, aluminum, copper, antimony, cadmium, iron and silver.

If you think you need a respirator to do something, red flags should be waving in front of your eyes and alarm bells ringing in your mind. If you have to use a respirator, there is something seriously wrong with your ventilation system and working processes. And when you take it off, whatever it was you were afraid of will still be there, an invisible dust (such as cristobalite investment) on all surfaces, so that merely walking past later will stir it up into the air so you can breathe it in. If you are using one, make sure it is correct for your face and for the dusts, chemicals and fumes you are protecting yourself from. Talk to your safety supply company representative, or better still several of them. It is easy to use the wrong respirator or to have an imperfect seal when you use it.

Eye protection in the workshop usually consists of using safety glasses and/or a face shield. Polycarbonate glasses are good. Aside from protection from sharp objects, flying chunks, dust, chemicals, fumes, liquids and hot metal splashes, we have to deal with glowing materials (infrared light), the blue flame of a high-temperature torch (ultraviolet light) and "sodium glare or flare."

Most glasses and polycarbonates will stop the ultraviolet. So will most contact lenses. The infrared is stopped by a "shade": numbers 2 and up have been suggested. It is important that one understands that a "tinted" lens does not offer infrared protection-only a shaded lens offers protection. McCann notes that "most recent recommendations are to wear the darkest shade number consistent with being able to see your work (ANSI Z87.1-1989" (McCann, Artist Beware page 216). Side shields that stop UV and infrared are also a good idea. The sodium flare, which is more of a problem for glass workers, is stopped by didymium glasses.

Dilution ventilation is used in many shops, where you open a window next to you, and another one elsewhere, so that air passes you on its way out. Dilution ventilation is not generally an effective approach. What we really want most of the time is local ventilation, which means a sucking device, slot or tube very close to the working area that is generating the dust, mist or fumes so they are sucked away as they are produced: removed entirely from the workshop and vented safely (i.e. not near a makeup air intake).

Jewelers cast metals frequently, in making ingots for sheet and wire, sand casting, vacuum and centrifugal investment casting and so on. The investment burnout process normally occurs in kilns, and, depending upon the wax, or even plastic, used, the fumes can be from mildly toxic to extremely toxic, and in many cases are fairly polluting. Usually jewelers cast gold and silver alloys, sometimes other metals like platinum, brass, more rarely tin and zinc (white metals being spin cast) in the small workshop. Alloys may contain other metals which produce hazardous fumes such as lead, cadmium, beryllium, arsenic and antimony. Nickel, too is considered a suspect metal now. Manganese and chromium are also to be avoided. Casting involves heat and its dangers of burns, damaging infrared and ultraviolet light (radiation).

The preparations for casting involve wax working, solvent exposure, tool use, mold making (boy those scalpels are sharp), injection, and other jobs which are not dealt with here, nor are the issues of de-vesting and finishing castings. In this article investing, burnout and casting metals are discussed.

Casting hazards in general can be divided into certain types.

Chemical: by inhalation, ingestion and skin contact. Don't eat, drink, smoke, bite your nails or apply makeup in the workshop as a matter of principle. Smoking, besides being bad for you in all the ways you ought to know about by now, seems to react synergistically with many chemicals and dusts jewelers have been exposed to, in some cases multiplying the risk of damage really dramatically. The materials, waxes, metals, investments we work with are all chemicals and can affect the body. The fumes that waxes produce during burnout are dangerous. Toxic metals like cadmium may be in older metal that is remelted. Heat causes chemical reactions to accelerate and sometimes starts them. Heat is definitely part of the casting process.

Physical: Burns, cuts, crushings, electrocution, other accidents, breathing in silica (silicosis), metal fumes, radiation (ultraviolet and infrared light can damage the eyes). Noise is not much of a hazard for casters, though torch sound and other shop noises can cause damage.

Ergonomic: working heights, breaks in work, and repetitive movements have to be considered. Make sure that you do not have to be awkward at any point during the casting procedure or process, and if you're doing it as a production system, then examine the ergonomic issues quite carefully.

Fire: When working with gases, torch systems, hot metals, electric and gas kilns there is an increased chance of having a fire or an explosion. Gas handling and fire issues are of course, present with any torch use, and care and maintenance has to be had in regard to heating and melting with torches. Keep all flammable materials and liquids away from any source of heat or spark, make sure that you have fire extinguishers on hand, and that you have a fire plan.

The main dangers are breathing in cristobalite (silicosis hazard), dermatitis from repeated skin contact with investment, debubblers, fluxes etc., breathing in metal fumes, hurting your eyes by not using the right kind of eye protection against chunks and light, burns and accidents with the electrical, gas and mechanical equipment used for casting.

The next section lists the hazards along with the procedure. As you read it you should understand that in the main, I consider the casting process to be very safe, that this is a discussion of the possibilities - and by no means will I have covered them all. That part of things is up to you as you consider safety in your own particular circumstances. Safety is your own responsibility.

Investing

Chemical: Specific chemicals include alkalis in investment, so that skin contact can foster dermatitis. There are detergents and de-fatting agents in debubblers as well.

Physical: Electrocutation from electric short circuits, inhalation of cristobalite with the serious risk of silicosis (cristobalite is much more dangerous than ordinary silica), accidents due to tripping hazard or clutter in the workshop, investment splashed in the eyes. The main investments that jewelers use are up to sixty percent cristobalite.

Ergonomic: only a problem in real production situations, though working height and stance should be considered in any job.

Fire: electrical wiring problems. Always make sure the fusing is correct for the demands on it, and that you check and maintain wiring on any electrical device (such as a vibrator or vacuum investing machine).

Exposure routes: eyes, inhalation (of cristobalite), skin

Safety precautions to use: Use local ventilation to suck the investment in the air away from where you are mixing and measuring it. Wear a mask when investing- though a mask is no substitute for local ventilation. Try to control dust. Mop floors and sponge surfaces with water to keep the dust down. Use latex or vinyl gloves to protect skin when touching the investment.

Substitution options to reduce risk: McCann suggests replacing cristobalite with 30-mesh sand (Health Hazards 51); Richard Beckman's article in Art Hazards News (v. 16.3) gives details on this procedure, and notes that "the particles in the 30 mesh sand...are too large to be airborne, and thus have a much lower chance of being inhaled" Beckman suggests one part investment plaster to one part sand, measured by weight, and claims that "the use of 30 mesh sand will in no way bring down the quality of surface reproduction as the plaster will flow around the grain size and give you the exact detail that was in your original wax.". Rossol recommends using "non silica materials such as zircon when possible" (Rossol, 279). Outsourcing is an option.

Burnout

Chemical: Specific chemicals include wax and plastic fumes from burnout. Fumes from a gas heat source. If using polyurethane or Styrofoam, instead of wax, for the positive mold, burnout can produce hydrogen cyanide and other toxic gases (McCann, Health Hazards 51-52). Styrofoam also produces carbon monoxide when burned (Rossol 277). Using foams in this way is not recommended. "When ... waxes burn they release many toxic and irritating compounds including acrolein and formaldehyde. Acrolein is an exceedingly potent lung irritant, formaldehyde is a sensitizer and suspect carcinogen". Burning organic chemicals like rosin, petroleum jelly, mineral oil and so on, added to wax, "will release carbon monoxide, and other toxic decomposition products" (Rossol 277).

Physical: Electrocution from short circuits (happened to me once in Germany reaching into a kiln), accident due to tripping hazard or clutter in the workshop. Burns while checking progress of burnout. Irritation from wax fumes and by-product. The rare possibility of investment popping and shooting into you when inspecting it.

Ergonomic: not much of an issue except for working heights, confined space issues and access to equipment.

Fire: electrical wiring or gas kiln types of fire hazards. If you open the kiln before the wax residue is gone a flare up can happen and billowing flames erupt - just close the door to put the fire out. See casting "Fire" section for more.

Safety precautions to use: You should have eye protection when near the flasks and wear protective gloves and clothing when handling them. Use gripping tongs that do not slip to move the flasks about during the burnout and to check them.

Substitution options to reduce risk: Autoclaving can take care of some of the problems by removing the wax in a liquid form, and thus not converting the waxes into toxic fumes. Instead of using Styrofoam, consider wax as a safer alternative. Consider using waxes such as beeswax, which produce less toxic fumes than some of the plasticized waxes. One can always outsource.

Casting

Chemical: Specific chemicals include: borax, boric acid, possibly other casting fluxes like ammonium chloride or sodium chloride. Some people add a teensy smidgin of zinc to a melt a moment before casting to de-gas it. Some alloys may contain hazardous metals like cadmium, beryllium, arsenic, antimony and others. The torch flame is present as well during casting, with its chemical by-products. Metal fume fever causes flu-like symptoms: fever, chills, aches, usually 2-6 hours after exposure (Rossol 133) and lasts for 24 to 36 hours (McCann, Artist Beware! 425). Unless the metals are toxic, such as cadmium, those exposed seem to recover with no long-term effects. Be particularly wary of using non-precious scrap metal for casting, as it may contain metals that will produce toxic fumes when melted. Scrap and reclaimed mystery metals may also be coated with lead- or cadmium-based paints, which produce poisonous gases when heated. One is exposed to mineral oils and lubricants when working with machines.

Physical: Electrical hazards. If one is using an induction melting crucible, and electric kilns, then electrocution is a risk, as is fire. Accidents due to tripping hazard or clutter. Injuries in the form of mechanical parts cracking or smashing into a hand that is in the incorrect position or place. Burns while removing and preparing flasks for casting. Accidents with the casting machine through not having balanced it correctly or maintained and checked it properly before using it. Such an accident could result in a broken arm or red-hot metal globs spattering across the room. There is an explosion hazard if gas torches are used to heat during casting. Particles of investment dust, particularly present during centrifugal casting, can be breathed in and cause lung disease.

Ergonomic: Primarily this has to do with working heights, body positions, setting things up so you do not have to twist and turn your body when you are transferring things or checking on them. In a production situation, you would have to examine the workspace and the job very particularly to ensure that ergonomic issues are addressed.

Fire: You're dealing with heat here, so this means either electrical equipment or gas kilns or torches as a heat source for melting. If electrical, then all issues of electrical safety have to be addressed, current draw, fusing, wire conditions, maintenance, and the possibility of electrocution. If gas, then all gas handling issues have to be addressed: maintenance checking for leaks, proper storage, proper usage of equipment, flashback arrestors, and so on and so forth.

Exposure Routes: Inhalation of wax fumes, and metal fumes, of dusts of various kinds, fumes from fluxes, and gas. Skin contact with fluxes and other materials used should be avoided. Accidents and burns are possible. Radiation-infra-red and ultra-violet, possibly sodium flare as well-can affect the eyes, and a suitable shade should be worn.

Safety precautions to use: Use local ventilation. You are dealing with hot objects, so the kiln and casting spot must be in a segregated, fireproof area, and all flammable materials and liquids must be separated from the kiln and hot materials and open flame. Fireproof walls should surround the kiln area.

A burn kit and ice should be on hand in case you get burnt. Ensure that you have a fire plan available. The casting area should be damp-wiped frequently to remove cristobalite dust.

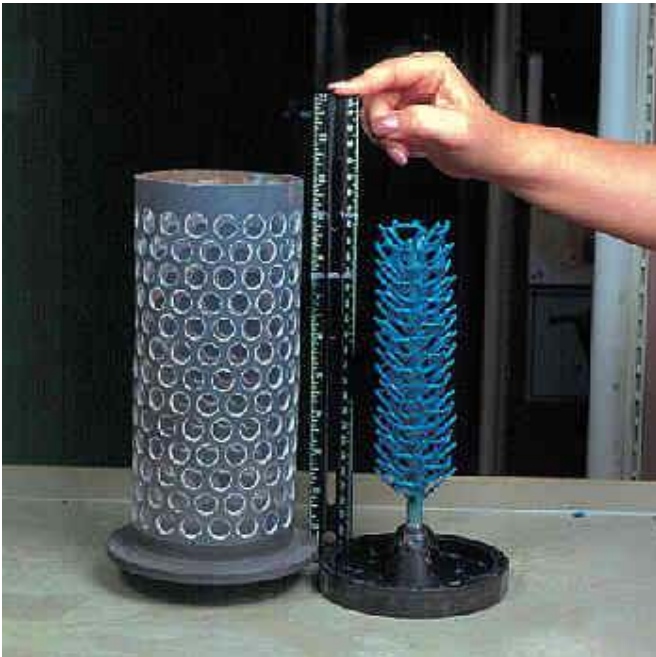
Good maintenance, good housekeeping, of all equipment including the torch systems. Good ventilation, eye protection, both from particles and from radiation (infra-red, ultra-violet, sodium flare), are particularly important when using an oxy-acetylene or oxy-propane torch system, which emits significant amounts of ultra-violet light. Heat-protective gloves, leather apron, steel-toed boots, metal splash covers over the face area, so that spilled metal cannot enter in. Have a shield around the casting machine to keep metal splashes segregated. The old washtub around the centrifuge is a reasonable shield. Have a full knowledge of all materials used: the fluxes, metals and the chemicals involved, as well as their effects. Make sure that copper, for instance, does not contain any beryllium.

Substitution options to reduce risk: Outsource. Switch to other types of manufacturing procedures, such as metal stamping, construction, milling, computer-aided design manufacture and so on. Attempts at substitute materials are possible: for instance, one can apparently make up a non-cristobalite, or lower-cristobalite investment for some casting purposes. One can try and use waxes that do not contain multiple chemicals. If using Styrofoam for burnout, or other plastics, one may consider wax as a substitute for them. Sand casting may substitute for investment casting. Autoclaving may substitute for at least part of the burnout procedure and is to be recommended as reducing the amount of wax fumes produced.

It is hoped that this glimpse at casting in terms of safety has been of interest.

Five Steps for Successful Investing

By Gregg Todd and Greg Gilman



1. Measure the Height of the Tree before Investing

A good practice for preventing investment blowout is to measure the height of the trees before investing. The maximum tree height should be between 0.5 inch and (for larger trees with more metal) 0.75 inch shorter than the fill level of the flask. It's also important to leave a 0.125 inch gap between the top of the investment and the top of the flask if you are using benchtop vacuum casting with a solid flask. With perforated flasks cast in a vacuum chamber or with centrifugal casting, the flasks can be filled completely and the tree height lengthened accordingly.



2. Dip the Tree in a Debubblizer

Unless you are mixing the investment and filling the flasks in a vacuum, dipping the tree in a debubblizer is recommended. This reduces the surface tension on the patterns, which helps to prevent air bubbles from clinging to the surface and forming nodules on the casting.



3. Properly Position the Tree in the Flask

How the tree is positioned in the flask for casting is very important in ensuring investment strength. There should be ample space—generally a minimum of 0.25 inch (6 mm)—between the outermost part of the pattern and the side wall of the flask.

The positioning will also help to calculate the amount of time you have before the flask has cooled and your castings are in danger. Most gypsum-based investments have a heat transference rate of about 400°F (204 C) per minute/mm. If the investment surrounding the tree is 6 mm thick, you will have about 1.5 minutes before the temperature at the outermost portions of the pattern drops 100°F (38 C). If you have a 200°F (93 C) window for casting, you will have about 3 minutes to complete the casting before the temperature drops below that limit. If you have 12 mm of investment between the pattern and side walls, you will have about 6 minutes to complete the casting.



4. Carefully Measure and Monitor the Investment

When it comes to investing, following manufacturers' recommendations for mixing and measuring is critical. Powder should be measured by weight and fluid should be measured by volume.

Safety is a consideration when mixing investment. You should wear a good particle mask that seals tightly to your face. Wearing a paper dust mask is only marginally better than wearing no protection at all; it provides a false sense of security.

After carefully measuring and achieving the correct water-to-powder ratio, the investment must be mixed thoroughly to form a creamy slurry (photo 4). Carefully follow the manufacturers' directions for mixing times and temperatures. Keep in mind that the water and powder temperatures will affect mixing time. The hotter the materials, the shorter the mixing time.

Note: Investment has a shelf life. Over time-between six months and one year-the investment can absorb humidity from its surroundings and become ruined. It's important to store investment according to the manufacturer's

instructions. One tip: Never store investment directly on a concrete floor, since concrete holds moisture.

Aside from problems with humidity, the silica begins to settle out of the investment powder after a while. If not re-mixed periodically, the investment formula can change enough to cause major problems in casting. The most common problems associated with this are fragile investment and poor surface texture on castings.



5. Vacuum the Investment

The mixed investment must be vacuumed to remove trapped and suspended air. When vacuuming is complete, carefully pour the investment into the flask and fill it to the top of the tree. Place a rubber sleeve over the top of the flask and vacuum the flask (photo 5). The investment will rise and boil during vacuuming as the trapped air expands and rises. After vacuuming, add a little more investment to top off the flask to the proper level, as described earlier, and set it aside to gloss off (solidify).

Before loading the flasks into the oven, care should also be taken when removing the rubber. Improper handling can cause small amounts of investment to chip off the surface

How to Make a Wax for lost wax casting

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To safeguard yourselves please follow these instructions carefully. A wax injector can be dangerous if not constructed and used correctly. These instructions are given freely and must only be used by those who are

competent to undertake this work in a safe and proper manner. No responsibility will be accepted by the designer for accidents caused during manufacture or use of this injector.



You will require a 5 to 6 inch by 3 inch wide brass or copper tube, silver solder a cover on both ends a thicker one or double up for the base to retain the heat. Ideally the tube and top plate should be 1/8th inch thick with the base plate being 1/2 inch thick approximately.

Drill a 3/4 inch hole in the top and silver solder a one inch brass internally threaded connector over the hole and in this connector fit a brass blanking cap with a rubber seal supplied by a plumbing store. This will serve as a supply point for the wax pellets and also a place where air pressure can be applied.

Drill the blanking cap to take a metal tyre valve and fit the valve into the end cap. **DO NOT BE TEMPTED TO PRESSURISE THE VESSEL AT THIS STAGE.** Next drill two holes either side of the central filler cap to take, on one side, a pressure gauge with its connector and on the other side a pressure relief valve with its connector. All connector can be obtained from a plumber's supply or DIY store.

Although I made my own pressure relief valve, I would recommend buying a professionally one for peace of mind. You will need a valve, which relieves pressure at 30 psi. Silver solder the pressure gauge connector and the connector for the relief valve into the top of the tank do not connect the relief valve or the pressure gauge just yet.

Next, drill a hole in the side of the tank at the front, one inch from the bottom to take a connector for the injector nozzle. This needs to be silver soldered in place. If you can purchase a commercially produced injector valve do so, but if you cannot I have included a sketch of the type I made for my own injector. A lathe will be required to do this work. As an update, it was found that an "O" ring works better than a tap washer to seal the injector delivery valve and by placing the spring outside, it allows room to fit a metal sealing cone between injector valve and tank body giving better sealing.

To heat the wax I've used a domestic hotplate with a thermostatic control. The thermostatic control is important to prevent overheating of the wax. Placing the injector tank in the centre of the hotplate helps prevent the wax solidifying in the injector nozzle.

Some way of measuring the wax temperature is required and I chose a digital clock/thermometer for this purpose. The type I bought had a wire with a sensor at the end, which allowed for the measurement of outdoor temperatures. These can be bought from a car accessory shop and I paid five pounds for mine. The range will need to measure as far as 80 degrees C. To use the temperature sensor you must first attach it with large nylon cable ties placed around the injector body so that the sensor is near the nozzle and in direct contact with the outside surface of the injector tank.

To secure the injector tank during use, I obtained a plumbers flange which fitted around the tank and then screwed it via a threaded bar securely to a wall. You will find these are standard plumbers fittings including the threaded bar. You should now be ready to fit and seal all components such as end cap with tyre valve, air pressure gauge, relief valve and injector valve.

To test the tank for leaks I used a tyre foot pump and pumped in air to a pressure of 5 psi. Then using a soapy water solution, I tested all joints for leaks and resealed as required using PTFE tape. When

satisfied release the pressure and reapply air pressure to the injector tank taking it to 30psi (the relief valve setting)

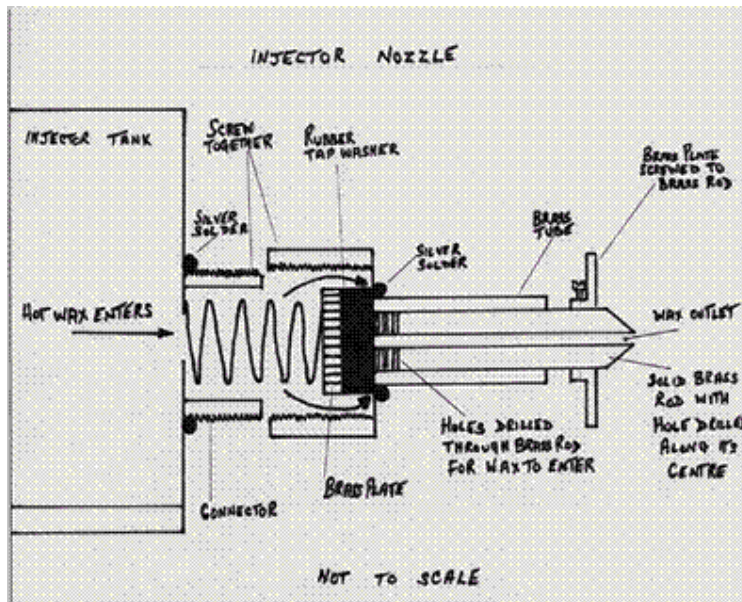
I would recommend taking the tank to a tyre-fitting centre and asking them to do this for you in their safety cage. Once this has been completed and you are sure the relief valve has operated correctly you are ready to melt some wax and use the injector.

Firstly unscrew the end filler cap with tyre valve and fill 3/4 full with wax beads leave the top off and turn on the hotplate until the wax starts to melt, which takes around 15 minutes. When fully melted reduce to about half the temperature just to keep the wax molten. It will be obvious that by leaving the filler cap off you will be able to see the point at which the wax has melted. You will need to experiment with these setting to get the melt and simmer temperature correct. DO NOT OVERHEAT THE WAX. I have found that simmer temperature was about half the melt temperature.

Now you can screw the filler cap on tightly and re-seal. Using the tyre foot pump inflate the injector tank to about 10 (ten PSI) and maintain a wax temperature of around 65 degrees C. (sixty five degrees C) at this point you should be ready for injecting. It may be necessary to vary temperature and pressure under different conditions and best results will be found with practice.

If available a compressor can be used to pressurise the injector but only when there is a pressure delivery regulator and water trap fitted. Using a foot pump will produce about three or four waxes before having to pump again, which is usually about two strokes.

Please follow these instruction carefully THEY ARE FOR YOUR OWN SAFETY.



Injector Nozzle Sketch



Injector Nozzle Dismantled



Plumbers Connector Used To Make Injector Valve



An Alternative External Spring Arrangement for the Injector Valve

Improved Anti-fire Scale Casting Procedure

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This paper describes a process that eliminated fire scale during a vacuum casting cycle. Castings should not have a fire scale problem if the casting are cooled following this procedure.



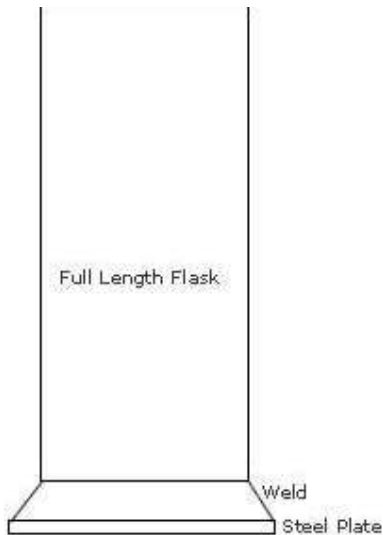
This casting was cooled using this process. This is what it looks like after quenching and brushing with a brass brush. It was not pickled.

The following two parts should be fabricated:



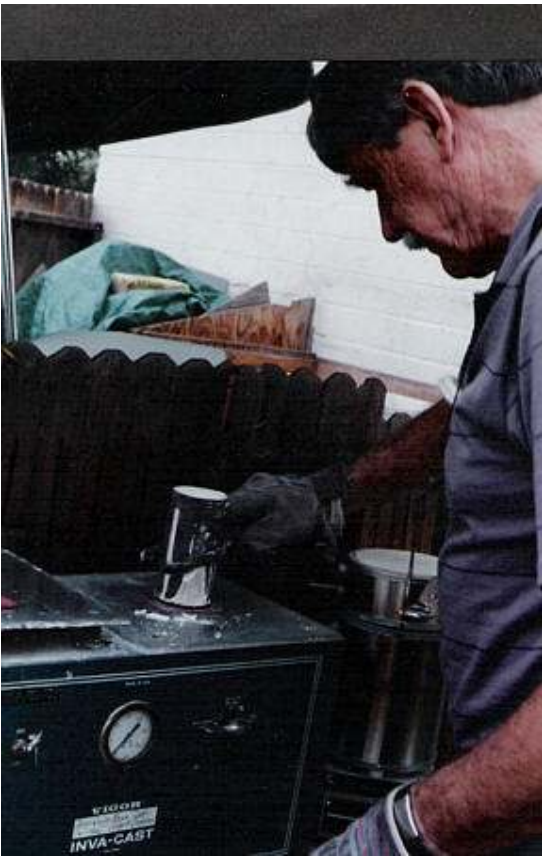
1. Cut a 1" high band off several different diameter flasks. Weld each size to a steel plate. This assembly will become the bottom part of the cover assembly.

2. Weld various diameter flasks to steel plates.





3. Before pouring the metal put about a teaspoon of wax shavings into the base assembly.



4. The mold flask is placed on the vacuum pump pad.



5. Metal is poured.



6. The hot flask is placed in the base assembly on the wax



7. Wax is placed on the sprue button.

8. Place the cover assembly on the mold flask.



9. The mold flask will cool slower than if it is cooled in free air. Allow the mold flask to cool a minute to several minutes longer than you would if you were not using this anti fire scale procedure. The length of increased time depends on the size of the casting. The bigger the casting the more time should be added to the cooling cycle.



10. Quench and complete the investment removal.
(QUENCH)





11. The cooling water will cause the scrap wax to form a bond with the investment when it hits the water. The flask should be quenched for a few seconds then removed from the water. A sharp tool should be used to break open the investment on both ends. The quenching cycle should then be continued.



12. This is an example of a casting that was cooled in free air and one that was cooled using the anti fire scale casting procedure.



13. This casting was quenched using the anti fire scale casting procedure. The casting was brushed with a brass brush to remove the surface investment

Detail Oriented - Testing new HD Patterns in the shop

Palry

By Linus Drogs, September 2006

I've been working in the jewelry industry for more than 20 years, and in that time I've seen many improvements in manufacturing. New materials, such as Precious Metal Clay, and new technologies, such as CAD/CAM, have changed the way we make jewelry, allowing us to do it faster, easier, and with better quality.

I was fortunate to stumble onto a new material that I would add to this category at the JCK Las Vegas show in June. I was told that this material would make injecting difficult pattern molds more successful. It's not a new wax. In fact, it's more like olive oil.

Invented by Victor Joyner, a Chicagobased manufacturing jeweler, patented High Definition (HD) Patterns are made of a light-curing polymer material that can be injected into a silicone mold with very low pressure at room temperature. After hearing about the exceptional detail achieved by these patterns, and the subsequent clean burnout, I decided to put the material to the test in my shop.

Injection properties

My staff and I tried several techniques of hand injecting and found that a simple micro-oiling bottle worked best. Because the material stays liquid throughout the injecting process, it doesn't chill or shrink like wax, resulting in a complete fill.

In addition to hand injecting, we tried automating the process by using a Yasui Vacuum Injector. Although productivity was five times faster with the Yasui, the machine needed to be heavily modified to do simple injecting; all of die brass parts in the injector needed to be replaced with stainless steel parts (or nickel-plated) to prevent a reaction between the pattern material and the metal.

When working with this material, your mold choice is limited to clear silicone because the pattern requires contact with light to change from a liquid to a solid. We tried several molds currently on the market, including Shin-Etsu and Zero-D products. All of the molds performed well, which would suggest that most clear silicones available will be suitable for use with HD Patterns. However, it's important to note that this material does not perform well with urethane molds.

Once we had injected enough HD material into the mold cavity, we found that a small amount of air usually got trapped in the pattern at the corners or in the undersides. We were able to remove the air by using two different techniques. First, we tried a hand-spinning device that uses centrifugal force to push the air out through the parting lines in the mold. This method seemed to also force more material into the vents, creating some flashing in the injection.

The other method we tried was to simply add pressure to the entire mold. By placing the filled mold into an empty cold wax pot and applying 20 psi for five minutes, the trapped air was forced through the vents and created less flashing.

It's important to note that, unlike on wax, the flashing that occurs on HD Patterns is minimal and does not leave parting seams.

Once we were satisfied with the fill of the molds and no trapped air was visible, we moved on to the next step in the process: curing the pattern material with light. Cure time depends on the light source; for example, it takes several seconds to cure in ultraviolet light and 10* minutes to cure in natural sunlight. After curing, the material's consistency resembles that of plastic rather than wax. The material handles well—it is very durable and has lots of memory—and its properties indicate that it should have a good shelf life, providing casters with the flexibility to hatch-inject for future casting needs without having brittle patterns that can break during investing.

One slight inconvenience we encountered is that wax doesn't bond well with the HD material for sizing or for attaching pieces to a tree assembly. We found that sticky wax worked best for bolt applications. After injecting several molds, I was impressed with the fill and detail achieved in the patterns. I was able to inject patterns such as a heavy 12 mm bar stock cross that wax can't fill in a rubber mold successfully due to the excessive sink when the wax cools. Because HD Patterns have zero percent shrinkage from model casting, we were able to cast this complicated cross successfully to scale.

In addition, I achieved a greater degree of detail in molds made from RP models -- a level of detail that is difficult to achieve with most waxes. This is clearly an important advantage, considering the growing popularity of CAD/CAM. Also, as intricate relief engraving of dates and verses continues to become more prevalent in wedding bands, crisp reproduction of these details in models will be critical to achieving a high quality product.

Casting properties

No matter how good a pattern is, the material it's made of needs to be castable. We started our casting experiments on HD Patterns using basic gypsum-bonded investments to cast sterling silver using a top-end burnout temperature of 1,350°F/732°C, and we achieved good results. A small amount of finning was visible on some of the sharp edges, but the surfaces of the castings were comparable to castings of wax models. It seemed to us that a higher top-end temperature would provide better results and less finning.

We decided to increase the burnout temperature to 1,450°F/788°C and switch to an investment designed for higher temperature white gold alloys, which contains proprietary ingredients that make the plaster mold stronger. When we inspected the flasks before pouring the metal, there were no residuals and burnout was complete. We cast a 400-square sterling grid and a 0.5 mm sterling plate and achieved good fill on both. During these trials, the casting results improved; we had slightly smoother surfaces and less finning than with the gypsum-bonded investment.

We also tested the material with our proprietary shell casting system, using a burnout temperature of 1,350°F/732°C, and got successful results—very smooth finishes and no finning.

That said, the main limitation of this material is its ability to successfully cast pieces with high mass and low surface area, or low mass and high surface area. Our tests on cube- and sphere-shaped pieces with masses between 12 and 14 dwt resulted in rougher and voided 14k gold castings.

A replacement for wax?

Considering its current casting limitations and its relatively high price compared to wax (see Supplier's Note) this material will not replace wax. However, as an alternative for specific projects, HD Patterns have some excellent applications. For example, manufacturers looking to produce highly detailed patterns with basic rubber molds in limited production will find the material's high quality detail and durability appealing. Also, manufacturers who mold RP models in wax may find the replication quality unmatched.

Second Opinion

Jason Borgstahl of Casting House in Chicago was one of the first casters to experiment with HD Patterns. He shares many of Drogs's opinions about the advantages of the technology. Below, Borgstahl describes three areas where these patterns excel, with examples from his own shop.

Improved Resolution. Even at injection pressures of 10 lbs. or more, it is common for small but crucial detail to be incomplete or softened in wax, usually due to air lock or insufficient pressure. Raised wording on the pattern, for instance, may appear less crisp to downright rounded off. Injection pressure may be increased to offset this, but distortion of piece thickness, inconsistent casting weights, and flashing are likely to occur. The only other options are to cut vent lines across the offending mold section, or to experiment with different types of wax, wax additives, and wax-pot temperature. Time-consuming and often fruitless solutions like these can make jewelry manufacturers and their employees go gray early. In contrast, HD Patterns provide resolution so precise a 10x jeweler's loupe is needed to fully appreciate its impact. The overall crispness of detail, however, is clear in the pattern, casting, and finished product as viewed by the naked eye.

Flatter Spans. Flat areas in a model that is to be reproduced in wax are prone to cupping or sinking when injected. The thicker the area, the more concave it is likely to become. This undesirable effect is due to the fact that wax is injected hot and pulls back during cooling. Not only is the integrity of the piece compromised, but time-consuming and wasteful filing is often necessary after casting to re-create the desired look. Since HD Patterns are made without heat, flat areas remain flat, preserving the integrity of the original and ensuring consistent casting weights.

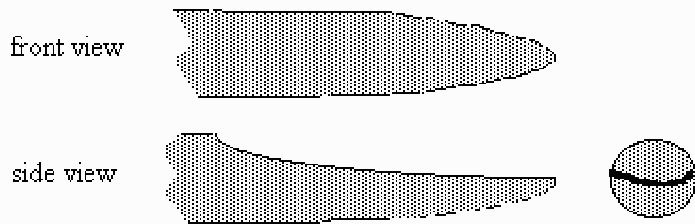
Shrinkage. One big advantage of not using pressure in this process is that there is no shrinkage in the negative areas. This means that finger sizes, areas to be set, and other open spaces remain precisely the same size. Try making one style in five to seven different finger sizes in wax and plastics and the benefit will be clear to you. I've found that the HD Patterns are the same size as the original, and stones picked using the master fit perfectly into the castings from the burned out patterns. No more guessing.

Wax Tools

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- ▶ Dental probes and knives make good wax tools. Your local dentist or dental hygienist or school for the same can supply you with used tools for free. If they don't sterilize them for you the procedure is to soak them in laundry bleach (Javex?) for twenty minutes and follow by baking in your oven at a very low temperature (200o) for about half an hour or so. This is supposed to kill all the nasties one might encounter.
- ▶ A good general purpose wax tool I use at times is made of bronze, which holds it's heat for a while yet does not conduct well enough to burn one's hand. The tool is made from brazing rod (thick stuff) and is about 10 inches long. One end is a long narrow tapered point and the other a small flat blade.
- ▶ Serious wax working and especially production spruing for casting needs an electric wax tool which is made easily by installing a light dimmer switch in the line for a pencil type soldering iron. For safety and looks install the assembly in an 'experimenters box' from Radio Shack. Get someone who knows simple wiring to help you do this if you are unsure of how to proceed. Shape the point of the tool to a long narrow taper. Some soldering tools have replacement tips that can be made into different shapes. Not all soldering tools can be used for this. Like any home-made electrical tool you must have a licensed electrician look at it before you use it in a home or business. Insurance people don't like them unless they are approved-not to mention the chance of injuring or killing yourself. Plan in all such things for the worst case such as spilling your coffee across the table and onto the tool and you. Wood burning tools cannot generally be reshaped-the end is a thin copper coating on a ceramic tip and is ruined by any abrasion.
- ▶ Because filing wax is soft it can be carved with almost anything even if the tool is not hardened steel. Many tools can be made from nails, forged out coat hanger wire and old files. For burrs any coarse tools will work, such as rotary rasps intended for wood and various milling and machining bits; even those which are no longer of use to machinists. Dremel? has several coarse burs that are very good.

- ▶ If one takes a tapered broken burr or tapered rod and grinds or files half of it away it becomes a drilling tool for wax or plastic that does not gum up.



- ▶ I also use various other tools for working wax such as gears out of broken alarm clocks as burrs. Often they have an spindle attached to them already to fit into the flex shaft. Even nails can be filed into toothed burrs for wax.

- ▶ A professional wax carver in Calgary named Gary McMillan uses a Bernz-o-matic? type propane torch for all his work because of its quick temperature control options; heating up a leaf-bladed hot wax tool for spooning wax on and building it up and a needle held in a pin vise for almost everything else. The pin vise enables him to adjust the length from the pin vise jaws easily and so alter the rate of temperature loss in the needle by using the jaws as a heat sink. This provides rapid control over a number of different temperatures of the wax when on a tool or being mixed in a spoon. The rapidity of use makes this the best option for speed and production applications of working wax. The torch is set into a wooden frame so that it is tilted to about 10 degrees up and with the tip pointing upwards.

- ▶ McMillan uses a large white Magic Rub? eraser as a sawing platform for cutting wax. This prevents it being broken from the pressure of sawing.

- ▶ Another McMillan innovation is to use ordinary nails as wax gravers. They have all the same end shapes as regular engraving tools but are rapidly made and stay sharp forever because one is only working wax. No handles are used, instead one pushes gently with the crook of the index finger. This makes a lot more sense than using metal gravers and handles on wax which is what most goldsmiths automatically do. It may also be quicker than using scrapers to shape the wax.

- ▶ For carving a flat bottomed hole into a filing wax to fit a cabochon stone (one cuts the hole first and then files wax down towards it to make a bezel) I have found that grinding a standard drill bit off flat at the tip gives one a burr that sinks to the depth required if tipped and then when held at a right angle to the wax being worked does not sink further but only carves outwards so that one can create perfect flat bottomed holes to fit cabochon stones and also make channels for channel setting.

Wax Injector

- ▶ I have seen several wax injectors made from a electric pressure cooker, fitted with gauges and the Jelrus? replacement injection nipple. A fridge compressor can serve as a compressor to run a wax injector with a gasoline filter in the line to filter the air going in to it. Jeff Demand has constructed a small wax injector intended for file-a wax type waxes which operates at higher pressures (30-40 psi) and enables him to inject his molds with wax which can then be filed and further worked.

- ▶ There is an orange injection wax available for regular injectors which is soft and flexible, has good memory during removal from the rubber mold but hardens after three days into a material that can be filed without gumming and clogging the files. Rio Grande is the source I've heard quoted.

Rubber Mold Vulcanizer

- ▶ This is basically a commercial heavy aluminum rubber mold frame, two steel plates and two C-clamps. The frame can be laboriously sawn out of thick aluminum sheet, be cast, be a cut-off a thick rectangular pipe or purchased. The model and rubber are laid in as usual, and then the steel plates are clamped as tightly as possible to the frame with the C-clamps and the whole assembly is placed in the oven at 350-400o F for an hour. Preheat the oven. Check instructions. It is a good idea to tighten the clamp periodically if you have used excess rubber. Jeff Demand uses a small toaster oven for his vulcanizing heat source with clamps similar to those pictured below for the frame. These days too one can use other molding compounds, for short runs the alginate systems and for permanent ones compounds such as the Silastic? ones.

