GETTING LOST: A LOST WAX PRIMER

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Centrifugal casting is a straight forward process, but there are a few places in which amateur--and professional--casters can go astray.

by

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Casting is the process of pouring or throwing molten metal into a hollow mold; as it cools, the metal solidifies and takes on the shape of the mold. A variety of materials can be used to make molds, for example, sand, clay, charcoal, cuttlefish bone, or high-temperature casting plaster called investment. Molds can be made by carving a hollow into the molding material; pressing the original model (such as a pendant) into a soft material, such as cuttlefish bone or charcoal; or creating the mold with an expendable model, such as a wax carving of a ring.

All these methods have been and still are used to make jewelry. The versatility and affordability of the lost wax casting process, however, has made it a favorite with professional and amateur jewelry makers. Wax models can be made in limitless shapes, sizes and textures; the casting process, when done correctly, faithfully reproduces even the most minute details put into the wax. The process lends itself to the production of one unique piece, or to the duplication of thousands of the same one. In addition, the equipment is relatively inexpensive: You can purchase a new casting set-up for around $1000; used equipment will be about half.

Casting is a broad subject and cannot be covered in the space of one article. If you are just beginning casting, it is recommended that you take a class from a local community college, art school, or rock and mineral club. We have also recommended a few books that can provide more information, guidance and reminders.

Centrifugal casting, when done correctly, results in a complete, highly detailed and solid piece of jewelry. However, there are any number of things that can go wrong. The most common problems result in castings that do not fill completely, blurred details, streams of bubbles on the jewelry surface, brittleness, or porosity, areas of holes or sponge-like structure. The causes of these problems usually lay in the spruing or the investing, however, the temperature of the metal at casting, the type of metal used, and the degree of burnout achieved can also contribute to imperfect castings.

THE PROOF IS IN THE SPRUING

Lost wax casting begins with a model carved or modelled from a variety of specially developed waxes. (The preparation of wax models will be covered in another article.) Then comes what experienced casters recognize as the most critical step in the casting process: spruing.

"Spruing is where it happens," says artist/jeweler Tim McCreight. "I emphasize to my students that you can carve a beautiful model, and the mold can be perfect, but if the sprues are in the wrong place, you could end up with nothing."

Spruing is vitally important because sprues are the passages which carry the molten metal to the far reaches of the hollow mold. If they are not placed right, the metal won't flow correctly and may leave places in the mold empty. You may end up with missing prongs, partial shanks, aborted filigree, and half-filled details.

When spruing, keep in mind that during casting the molten metal is being hurled with considerable force and at considerable speed in one direction: away from the crucible. It's like a river that has just exploded from behind a dam during a flood season. It is unrealistic to ask this power, yet rapidly cooling flood to flow back against that movement and fill corners of a piece that are lower than the sprue. "To the best of your ability," says Maine artist/jeweler, author and teacher, Tim McCreight, "make sure that all parts of the model are downstream, that the metal does not have to double back on itself."

The force of this metal river can tear sharp corner off the inside face of the mold as well; if your pieces contains sharp turns, such as the 90º angles in a cross, you must sprue not only into the upright of the cross but into the ends of the crosspieces as well.

To avoid having the metal tear pieces off the inner walls of the mold, says Portland, Oregon, artist/jeweler Deborah Spencer, "you want as little turbulence as possible. If I have square corners, I sprue into the corners so the metal will flow nice and smoothly and not bounce back off the wall of the mold."

The metal must also move from the thickest areas of the piece to the thinnest. Thin areas cool and solidify first. Once that happens, no more metal can reach the thick areas on the other side.

"Most casting books should be burned because of poorly illustrated examples of spruing," says Torry Hoover, of the Richmond, Virginia refinery Hoover & Strong, as they illustrate casting rings with a single sprue in what is often the thinnest part of a ring--the shank. Metal going into the mold would solidify first in the shank, blocking the entrance to the mold, and preventing any more metal from coming in. Spruing should always be done so that metal flows from the heaviest parts of the piece to the thinnest.

Not only do the manuals show a sprue in the thinnest part of a ring, they only show one sprue. You can get away with one sprue, says Spencer, if, like her jewelry designs, your pieces have little fine detail. "My rings average 7 pennyweights...I've found that one large sprue works better for me." However, with most jewelry, you'll need more than one sprue; if there are many changes in thickness, or the piece incorporates large open areas, you'll need many more.

"I use lots of auxiliary sprues because I do thin castings," says Evanston, Illinois, jewelry designer Eve J. Alfillé, who often casts thin sheets of texture to be incorporated into other pieces. Alfillé also uses spruing effectively to help eliminate porosity, probably the biggest bugaboo in casting. Porosity not only affects the appearance of the casting by leaving pits on the surface, it weakens the mounting. One cause of porosity is uneven solidification rates: As the metal in one area cools, it draws metal away from slower cooling areas. To eliminate this, Alfillé runs tiny sprues between all the pieces in the flask, "so the pieces make up a whole system." This balances the flow of metal among the pieces and has eliminated Alfillé's casting porosity.

In spruing, says Alfillé, "the best tool is your head. You have to be the metal. You have to put yourself in the molten state in the mold. Where are you going to settle in? Visualize where the metal will go and how far before it starts cooling and stops running."

HIGH-YIELD INVESTING

Once the model is sprued, it is positioned in a sprue base, a rubber snap-on lid, which fits the stainless steel flask. This forms an open-topped container into which the liquid investment is poured.

Investment is a high-temperature molding plaster made with silica to withstand the heat of burnout and casting. It comes in powder form that makes a slurry when mixed with water. The slurry is poured into the flask, over the wax pattern and spue, until the flask is full. Once the investment hardens, and you remove the sprue base, all you'll see are the ends of the sprues.

Mixing investment is pretty straightforward, but you have to pay attention. The investment sets up in 10 minutes, so there's no time to look for misplaced equipment or take phone calls. Be organized and concentrate. Most investment manufacturers provide complete instructions on how to use their products, with exact investment-weight-to-water ratios. Alfillé uses the procedure she learned at GIA: a strict 10-minute mixing procedure, that allows enough time for adding room temperature water, pouring it into the flasks, and vacuuming it twice.

While many jewelers and commercial casters successfully adhere to strict investing procedures, weighing their investment carefully according to manufacturer's guidelines, McCreight takes a different approach: He figures out his investment consistency by hand. Literally.

"The alternative [to following the manufacturer's instructions] is to learn how thick the investment is supposed to be. The best way to do that is to go to the refrigerator and take a handful of yogurt and memorize what that feels like." That is the thickness you want, says McCreight. "A lot of people mix their investment until it is too milky. When the investment is in the bowl, you should be able to pull your finger across the surface and feel resistance, like it's ploughing through something besides milk, or even a milkshake. The easier way is to push your finger into the mix about to the middle knuckle, then pull it straight out. If you can see any flesh-tone through the coating, it's not thick enough. It should be thick enough that only a drop or two drips off the end of your finger, but not much."

The reason McCreight takes investment preparation into his own hands, he explains, is due to investment's readiness to absorb moisture from the air. Commercial casters and jewelers keep investment sealed tightly and use it up quickly, before it can absorb much moisture. But investment in a home studio or classroom may be kept around for a while. If it is not kept perfectly dry, it may begin gathering moisture; moisture-laden investment, when weighed, contains less investment per volume of measure. "The same quantity of investment may gain as much as 20 percent in weight," says McCreight. Because there is actually less investment powder in the slurry, the mixture made with damp investment will be thin. "If the mixture is too thin, it doesn't harden sufficiently," says McCreight. "If the mold is spongy, [the molten metal] will rip off details or break through the back of the mold."

Break through can also happen if you position the model too high in the flask. If the hollow mold is too close to the surface of the investment at the end opposite the crucible, the investment might crack or break when hit with the high-velocity metal. "Lay a straight-edge across the top of the flask, and make sure you have 3/8” to 1/2” from the top of the model to the top of the flask," says McCreight.

Air is introduced into the investment slurry during the process of mixing. If it remains trapped in the plaster, it can create holes and weakness. If the bubbles are trapped against the surface of the model, they add bumps to the finished piece that have to be removed. Many casters use the vacuum bell on a vacuum casting machine to eliminate the air from the investment. (Vacuum casting machines eliminate the need for a centrifugal casting arm, and many casters prefer them.)

The investment is vacuumed once in the bowl after mixing, and once again after it has been poured into the flasks. Many vacuum tables also vibrate to encourage the release of air from the investment.

If you vacuum your flasks, before you prepare the investment slurry, wrap masking tape around the top edge of the flask so that it extends out from the edge. This in effect lengthens the flask. When you pour the investment into the flask, fill the investment only to the top of the flask, *not* to the top of the tape. The tape is only there to prevent the liquid investment from overflowing as the air bubbles out during vacuuming.

The tape is helpful if you are casting multiple flasks with multiple types of metal. You can use a felt pen to write the weight and type of metal going into the flask. When the investment is dry, transfer that information onto the surface of the hardened plaster and remove the tape. When the flask comes out of the kiln, you'll know which pile of metal goes into which flask.

Careful recordkeeping is important when you're casting more than one flask, more than one kind of model and more than one kind of metal. Alfillé keeps track of each flask on a chart, recording the date, the flask number, the kinds of pieces she's casting in that flask, the weight of the wax, the type of metal she's using, the weight of the metal in the piece, the weight of the metal in the sprue, how much old gold versus how much new gold is going into the crucible, the height and width of the flask, and the weight of the investment and the water. When she puts the flask into the centrifugal caster, she adds flask temperature to her chart. If she ever has a problem, Alfillé can go back and track down the source of it.

GOING FOR...WHICH GOLD?

You might think choosing a casting metal, at least, will be straightforward. But not all golds are alike, even if they are stamped with the same karat. Every refiner uses a slightly different recipe when making up batches of karat gold, adding slightly varying amounts of copper, silver, zinc, nickel, silicon, or boron. Different amounts of alloy in gold create different colors. More copper makes a yellow gold redder; nickel or palladium make it white; silver makes it green. Other chemicals reduce oxidation. (Sterling, being only a mix of fine silver and copper, is much simpler.) Combining different metals, or using metal you're not sure of can create unexpected problems.

1) If you combine colors of different gold, or sometimes even the same color gold from different manufacturers, you can get some strange colors due to the differences in alloy amounts.

2) Some refiners add deoxidizers, such as silicon or boron, to their golds to reduce oxidation and clean up time. "But deoxidizers can leave the metal a little brittle, as far as working goes," says Rich Wuennenberg, president of Hauser & Miller, in St. Louis, Missouri. "If you are not casting into the final form--for example, if you are casting your own sheet or wire, or if you're casting a piece with prongs that you'll have to work further--it could be a problem." These metals are meant primarily for commercial casters.

3) You can reuse gold when you cast, such as the metal in your sprues. However, because this metal has been through the kiln once, it has lost some of its fluidity. If you cast only used metal, your castings can develop porosity. Always add new metal to the mix. Wuennenberg recommends you not use more than 50 percent previously cast metal; if there is a lot of detail in the pieces you are casting, you should reduce this percentage.

"We have one customer whose work has a lot of fine detail in it. She's completely given up using any old metal at all," he says.

4) Be very, very careful about using old jewelry--yours or a customer's. Old jewelry contains a variety of different alloys in the heads and body of the pieces and they almost always contain some solder from sizing or attaching heads. Even if a piece of jewelry is marked 14k, the marking might not be correct. Before the mid-1970s, gold that was only 13.5k could legally be marked 14k; today, karat gold must be "plumb"--exactly the karat it is marked.

While Alfillé, often mixes her own colors from the metal of several refiners, with few side effects, she notes that some metals cast differently. Although she wants to use 18k white palladium, it frequently comes out as incomplete castings; she uses 14k palladium and rhodium plates it for whiteness. "Some metals are reluctant," she adds. "Pink or peach golds are very sluggish."

Some metals allow you more leeway when casting due to the difference between the melt and flow temperatures, explains Hoover. That difference becomes smaller as the karat of the metal increases. "In order to cast, you have to get the metal fluid. If there is little difference between the melt/flow temperatures, the metal doesn't stay fluid as long. It quickly turns back into a solid." For example, Hoover says, 10k yellow gold melts at 1500ºF, and flows at 1630ºF, a difference of 130º. However, 18k melts at 1580ºF and flows at 1615ºF--a mere 35º difference. "When the melt and flow temperatures are close together, you have a harder time getting the metal melted, into the flask, and cast," says Hoover. "The higher the karat, the trickier it is to cast."

Spruing, he says, is the way to get around problems with narrow melt/flow windows. "With 14k gold," says Hoover, "you may be able to get away with [single shank sprue] spruing. But when you go to 18k, it's more trouble." Enough sprues in the right place, however, will get the metal exactly where it needs to go before it begins to solidify. The answer, Hoover emphasizes, is *not* to heat the metal more. "If you do that, you'll get overheating problems such as porosity and brittleness."

TURNING UP THE HEAT

Burnout is pretty straightforward: Put the flasks in a cold kiln, bring slowly up to temperature, keep them there for a while, then ramp the temperature down to casting temperature. Spencer uses a five-hour burnout cycle taken in three steps: up to 750º for an hour, up to 1000º and 1350º for two hours each. She turns the kiln off, lets it sit for half an hour, and casts at 900º.

No matter what temperature you cast at, it is important to burn out cleanly, says McCreight. "Wax melts about 450º, and most of the wax comes out at that point. What's left is a gummy residue lining the inside of the mold in the flask." This residue, if left in place, he says, "robs you of some of the nuances of the details of the mold, and it seals the investment."

When the hot metal pushes into the mold during casting, it pushes against the air trapped in the mold. If the burnout has been clean, the air is forced out through the porous investment. If the investment is "sealed" with wax residue, the air cannot escape. If it cannot escape, the metal cannot fill the mold, and you end up with an incomplete casting.

"That's why you burn out up to 1250º," says McCreight. "That's when the residue vaporizes." So what happens if your pyrometer isn't working, or perhaps the instructions with your investment were wrong? "You can tell if you've reached this critical [temperature] stage," says McCreight, "by picking up the flask and looking around the sprue hole. There should be no stain, or a very faint gray stain, around the mouth of the flask. If you pick it up between 450º and 1250º, you'll find a sooty stain around the sprue hole. That means you're not ready yet."

HIGH-RISK INVESTMENT

The last step in the casting process is the release of the freshly cast model from the investment mold. Breaking the model free might seem like a chore, but it really isn't. Jewelers use the same technique old hardrock miners used when they heated mountain faces with fires, then hosed them down with cold water: thermal shock. When the flasks are removed from the casting machine, they are plunged into a bucket (***not*** a plastic bucket, ***please***!) of cold water. The thermal shock shatters the investment, the model is released, then cleaned up.

But beware! Though this process is used widely and carelessly in the jewelry industry, reminds Tim McCreight, it is very dangerous. Investment is not just any old plaster. It contains minute particles of silica so that it will stand up to the heat of burnout. "Silica dust is the cause of silicosis which creates lung damage," says McCreight. Because investment is so fine and soft, it can get into the lungs during the investment process simply when you pour it into a mixing bowl. (Wear a mask when investing; some casting kits come with respirators.) But the real danger is in the quenching process. "It's very dramatic," says McCreight, "but also very bad for your lungs." When the burst of steam created by the hot flask hitting the cold water, drives the silica particles deep into the lungs. At the very least, you should extend your arm, turn your head and exhale while quenching. Better to put a fan behind you to blow the steam away from your face."

When the model is free of the flask, Alfillé cleans the remaining investment off the piece while it is wet. The wet investment doesn't become airborne and so can't get into your lungs. Alfillé uses an old ultrasonic, putting the casting in a separate container of water and vinegar, and setting that container into the sonic tub. The sonic waves pass through the container and the vinegar helps remove the investment. "After about ten minutes," she says, "the castings come out almost clean."

The bottom line on casting? Experiment, talk to others, document every step, get to know your system, learn the materials and the process until they're intuitive. Take nothing for granted. It supposedly took Thomas Edison more than 1000 attempts to find the right filament for the light bulb. Take heart. Learning to cast won't take nearly as long.

In addition, see Tim McCreight's *Practical Casting: A Studio Reference*; Oppi Untracht's *Jewelry Concepts and Technology*; Murray Bovin's *Centrifugal or Lost Wax Jewelry Casting*.

CASTING 101 – AN OVERVIEW

The centrifugal jewelry casting process usually begins with a wax model. (Two definitions: A model is a solid, three-dimensional form, such as a wax carving, a brass ring, or pine cone, used to make a mold. Molds are hollow forms of the original model, created in rubber, plaster, charcoal, or other material, into which a fluid material--such as wax or molten metal--is cast.) The model can be a one-of-a-kind wax, carved and modelled by hand, or it can be one of thousands plucked from a rubber or silicon mold. Small organic items, such as tiny pine cones can take the place of wax models. So can plastic toys or other small items: One commercial caster once cast an IUD--an interuterine device used for birth control--for a customer.

The model, wax or otherwise, is attached to sprues, wax wires that leave channels in the plaster mold by which the melting wax will drain out and the molten metal will enter. The model and sprue complex is then encased in a high-temperature plaster called investment. When this hardens, it is placed in a burnout oven or kiln. The wax melts and drains out of the plaster, leaving a hollow mold gated by the tunnels left by the sprues.

The hot flask is placed in the cradle of a broken-arm centrifugal caster, butted up to a crucible in which the metal to be cast--silver, gold, or other craft metal--is melted. When the metal is molten, the arm is released, the heavy spring in the caster hurls the arm around (much like you'd swing a bucket of water over your head), and centrifugal force pushes the metal into the mold.

The hot flask is then plunged into water (see sidebar) and thermal shock shatters the investment. The metal model and sprue complex is removed, the sprues are cut from the model and the model is cleaned up.