

Investment Casting

How the Process Works

In investment casting, a shape is formed (usually out of wax) and placed inside a metal cylinder called a flask. Wet plaster is poured into the cylinder around the wax shape. After the plaster has hardened, the cylinder containing the wax pattern and plaster is placed in a kiln and is heated until the wax has fully vaporized. After the wax has fully burnt-out, the flask is removed from the oven, and molten metal is poured into the cavity left by the wax. When the metal has cooled, plaster is chipped away, and the metal casting is revealed.

When is Casting the Appropriate Process?

Casting is very useful for creating sculptural objects or engineering shapes with complex geometry (such as transmission housings) in metal. Cast parts have a unique look to them, quite different from machined parts. Some shapes which would be difficult to machine are more easily cast. There is also less material waste for most shapes, since unlike machining, casting is not a subtractive process. However, the precision achievable through casting is not as good as machining.

When Should You Choose Investment Casting and When Should You Choose Sand Casting?

One big advantage of investment casting is that it can allow for undercuts in the pattern, while sand casting does not. In sand casting, the pattern needs to be pulled out of the sand after it is packed, whereas in investment casting the pattern is vaporized with heat. Hollow castings and thinner sections can also be made more readily with investment casting, and a better surface finish is generally achieved. On the other hand, investment casting is a much more timely and expensive process, and can have a lower success rate than sand casting does since there are more steps in the process and more opportunities for things to go wrong.

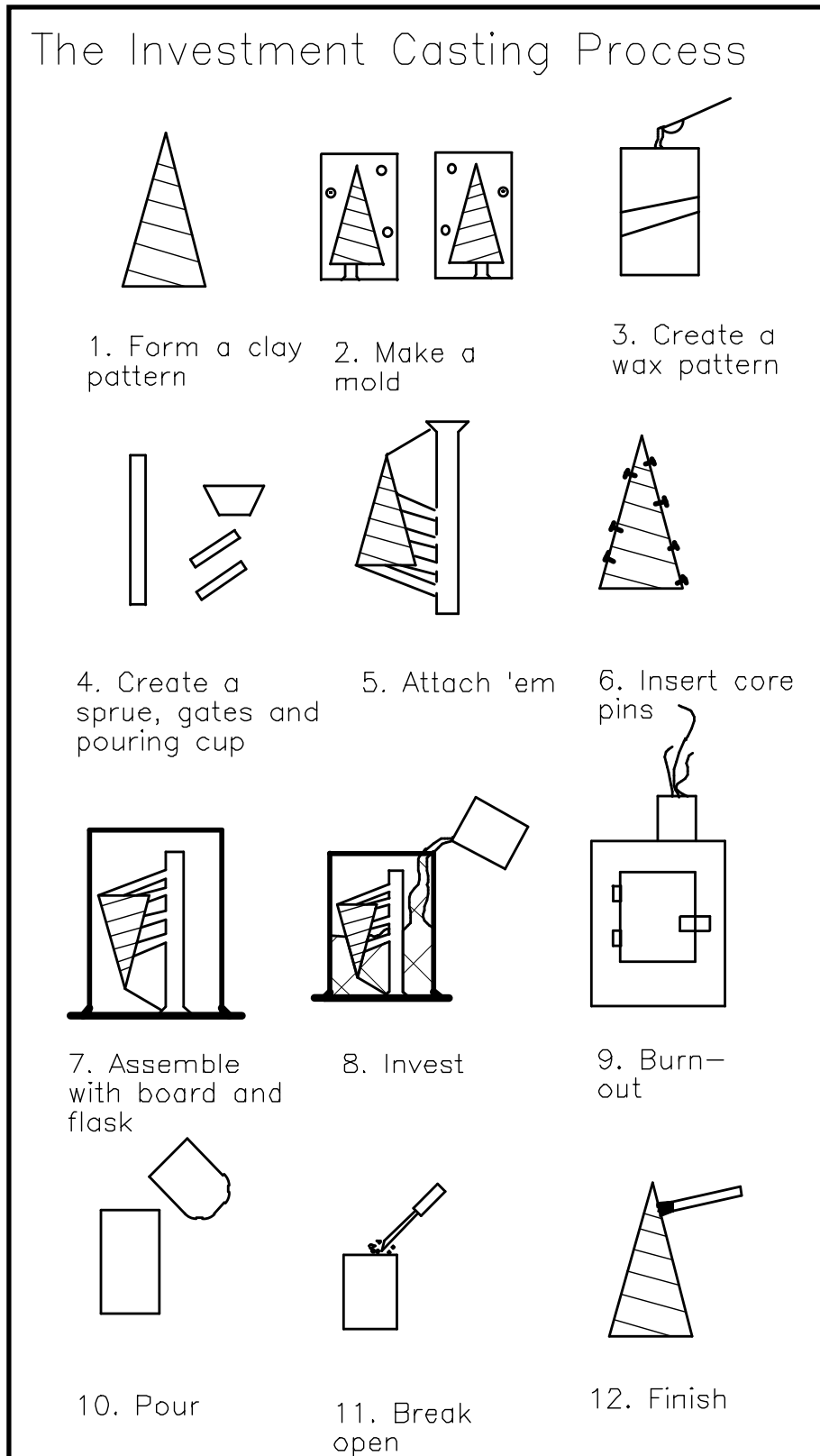
What You Should Know Before You Begin an Investment Casting Project

Small differences in the investment casting process lead to greatly different (i.e. sometimes poor) results. Experience is great to have, but if you don't have it, here are a few things you can do to improve your chances of success.

1. Follow instructions carefully and seek out the advice of the local investment casting experts. Investment casting is an involved process. Get help from a TA who has experience casting.
2. Pick a reasonable size casting. Bigger projects are harder and take longer. Ring or jewelry-sized castings are on the easy end of the investment casting scale (although even smaller items become more difficult). Castings that are the size of a banana are harder, and those the size of a loaf of bread are at the upper limit of the PRL's capabilities.
3. Start early. The process takes a long time, and castings don't always come out. Which means if you cast your carefully crafted goat head in week 9 of the quarter and something goes wrong, you probably won't get a second try.

The Step by Step Process

There are a few different variations in creating investment castings using the Stanford's facilities. Here is the most common procedure.



1. Form a master pattern. This is the actual object you want to eventually be out of metal. The pattern can be made out of anything that holds its shape at least reasonably well. Sculpy or modeling clay are both good choices because they hold their shape well, and are easy to form. You should probably bake Sculpy after forming it into the desired shape.

2. Make a mold. A mold is the negative shape of your pattern. The mold is created from a mixture consisting of casting plaster, sand, and water. The dry mixture of 1 part 30-minute casting plaster and 2 parts 30-grit sand is known as 30-30 mix. When it is mixed with water, it forms a viscous slurry. After about 30 minutes (sometimes less), the mixture “sets up” or becomes solid. You will need the following things for this step: Cardboard, duct tape, 30-minute casting plaster, 30-grit sand, 2 5 gallon bucket, and a bucket with quart graduations for measuring.

A. Place some brown paper on the floor in the area where you are going to work. (from the roll in the machine shop, near the bandsaw.) Working with plaster is exceedingly messy and hard to clean up; lay out a lot of paper (at least a 12' x 12' area, probably in the foundry or outside) and you will thank yourself come cleanup time.

B. Prepare the pattern. Draw the parting line or lines on the pattern with a pencil, or a score lightly with a blade. Parting lines should be drawn so that there will be no undercuts. That is, if you immerse the pattern into the plaster up to the parting line, you will be able to remove it when the plaster has hardened. This is important: if you have undercuts in your clay pattern you will not be able to remove your wax pattern later on without destroying it. You should also coat the pattern with Vaseline which will make it easier to remove from the plaster.

C. Make a 5-sided (open topped) cardboard box that is about 2 inches wider, longer, and thicker than your pattern. Tape the sides together with duct tape. You will be pouring the liquid 30-30 mixture into this box.

D. Make up some 30-30 dry mix: Three things are very important in this step. The first is crucial to your health: wear a dust mask to protect your lungs. Dry plaster consists of very fine particles which become airborne, and are quite bad for you. Dust masks are available from a TA. The second and third things are crucial to the success of your project: When you mix the sand and plaster together, do not assume that 8 qts of sand and 4 qts of plaster make 12 qts of mix. The plaster particles are much finer than the sand and will fill in the gap between the sand particles, creating a smaller volume than the sum of the two individual volumes. Also, make sure that the buckets you use are spotlessly clean and completely dry. If there is a little bit of water in the dry mix bucket, it will form hardened bits of plaster which will catalyze the reaction when you mix water with 30-30 mix causing it to set up too quickly. Mix 2 parts 30-mesh sand and 1 part 30-minute casting plaster in a spotlessly clean and completely dry bucket. 8 qts

of sand and 4 qts of plaster is about the most you can easily mix in a 5 gallon bucket.

E. Compute the amount of water and 30-30 mix required. To do this, measure the volume in cubic inches of the cylinder you are using, and convert to quarts. 1 quart = 58 cubic inches. Multiply the number of quarts by 0.65 to get the volume of water you'll need. The ratio of 30-30 mix to water is 2.4:1 by volume; compute the amount of dry 30-30 mix required. If the volume of water required is less than 2.5 gallons, you will be able to mix the plaster in one bucket with the help of just one other person. If it is larger, you will need 2 people and 2 5-gallon buckets per 2.5 gallons of water. If this is the case, you will need to have each set of two people mix the plaster and water simultaneously so that it is ready to pour at exactly the same time.

F. Measure out the water into a 5 gallon bucket. Again, make sure that the bucket is spotlessly clean. Any little bit of plaster left over from the last time someone investment will make the plaster set up before you have a chance to pour it around your pattern. Also, the ratio of water to plaster is important, so take considerable care in measuring the amount of water

G. Measure out the 30-30 mixture into a clean and dry 5 gallon bucket. Remember you must measure out the mixture now - do not assume that the 8 qts of sand and 4 qts of plaster you mixed before have made 12 quarts of mix! Many investments have been ruined by this error.

H. Prepare to pour the mold. Place your cardboard box and the two 5 gallon buckets (one with water, the other with 30-30 mix) on the floor, and make sure your clay pattern is nearby. You will need to recruit one other person to help you at this point.

I. Make sure that your hands and the hands of your helper are clean and dry, then sift the 30-30 mix into the water with your hands. You should do this quickly so that the plaster does not start to set up too early. Try to do the sifting in about 3 or 4 minutes. Try sifting the mix from just above the water, so as to not agitate it. Also, try to sift evenly over the water so that the dry mix gets well distributed and does not end up in one gigantic mountain in the center of the bucket.

J. Wait for 2 or 3 minutes so that the water has a chance to soak up the plaster.

K. Mix with your hands gently to combine the 30-30 mix and the water. Work out any lumps of plaster.

L. Pour the plaster into the box until it is half full. You should do this as soon as the plaster is mixed, since you only have a limited time until it sets up. Place the clay pattern into the plaster up to the parting line. Hold it there until the plaster has set up (probably less than 10 minutes; if it hasn't set up in 20 minutes you

probably used too much water and it will never set up, in which case you should pull your pattern out and go back to step 1.)

M. After the plaster has set up, carve 3 hemispheres about the diameter of a pea into the plaster with a wax working tool or knife. This will insure that the 2 halves of the mold line up. Leave the pattern in place and cover the first half of the mold with Vaseline.

N. If you have only one parting line, then mix the plaster as before and pour it into the other half of the box. If you have more than one parting line, see the variations section..

O. When the plaster has set up take the mold apart and remove the pattern. You may need to pry the plaster apart with a flat head screwdriver by working it around the outside of the parting line.

P. Carve a channel into one plaster section of the pattern so that it is possible to pour wax into the void.

3. Create a hollow wax pattern. For solid patterns see the variations section.

A. Heat up enough brown wax to fill your mold in the wax crock pot. It is extremely important to make sure that the temperature of the wax does not exceed 200 F. The flash point of wax (point at which it sets itself on fire) is only slightly above this temperature, and wax fires are very difficult to extinguish. Use a meat thermometer to regulate the temperature - do not trust the dial on the wax pot. You should pour the wax between 170 and 180 F.

B. Prepare the mold. Coat the inside of the mold with Vaseline. Hold the pattern parts together with rubber bands wrapped around the outside .

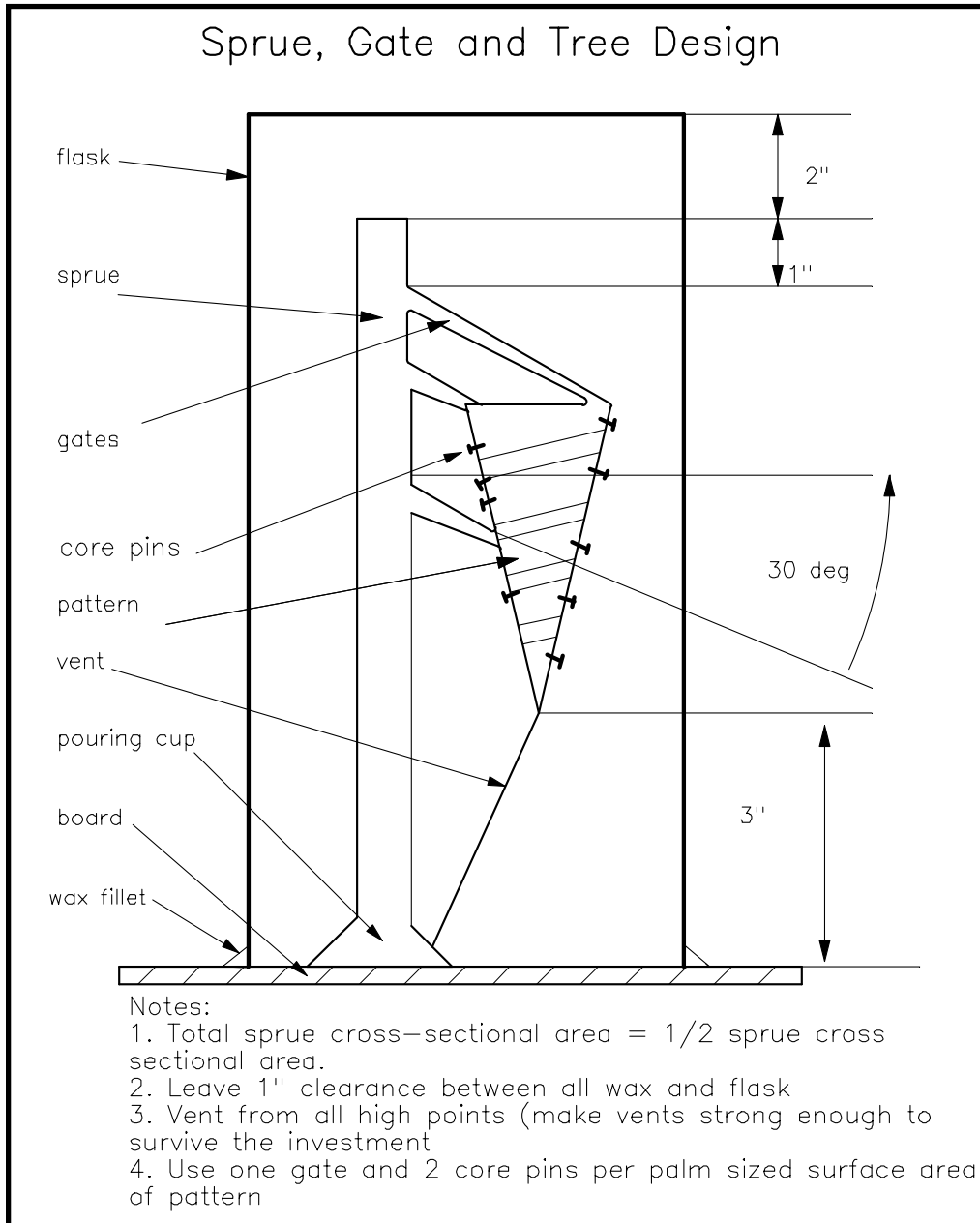
C. Pour the wax into the mold. Plug the pouring cup with Sculpy, and swirl the wax around for a few minutes. Take the Sculpy plug out and inspect the thickness of the hardened wax. You want it to be about a quarter inch thick. If it is too thin, the metal may freeze off before it reaches that part of the pattern. It can be somewhat thicker (although it will be heavier.) If it is not thick enough, replace the plug and swirl some more. When you reach the right thickness pour the unhardened wax back into the crockpot. Open the mold and take out the pattern. If you had undercuts, you won't be able to remove your pattern. Cut apart your wax pattern to see how good a job you did at achieving the desired even thickness of ¼ inch. Once you feel you have mastered the technology of creating waxes of even thicknesses, pour the real wax mold (and don't cut it apart) .

D. Smooth the wax. Dental tools (found in the jewelry cabinet) work well for removing flashing, and taking off and adding features. You can heat the dental tools up with a candle lantern, found in the flammables cabinet. Some people like

to use a soldering iron (you can get a cheap one for about 8 bucks) for working wax. For fine surface smoothing, wrap some turpentine soaked pantyhose around your finger and rub the wax. The metal will accurately reflect the smoothness of the wax, so make it as smooth as you want the metal to be. You can always finish the metal after, but it is easier to smooth wax than metal. The wax should, at the minimum, be smooth enough so that bits of plaster don't jut out into the void created by the vaporized wax. Such features will break off when the molten metal rushes in causing the inclusion of plaster in the casting. (You don't want that.)

4. Create sprues, gates and a pouring cup. See the design guide figure below. Good sprue and gate design is critical. For gravity-poured castings (at the PRL, most anything larger than about the size of a lime) you should use bottom gating. In this method, a sprue goes down from the pouring cup, gates come back up to the pattern. Vents run from the highest point of the casting back to the cup. (See diagram).

Form the pouring cup, sprue, gates and vents. Several sprue and cup molds have been made over the years and are good for many uses. Coat them with Vaseline, run them under cold water, then pour in molten wax and wait until it hardens, then pull the hardened wax out. You can also make your own sprue and cup molds by the same method you made the pattern mold. Pre-made sprues and gates are available (at Gems Galore in Mountain View) which look like red licorice. They are pretty cheap, and work very well, but do not come in particularly large diameters.



5. Attach the gates to the sprue, the sprue to the pouring cup, the gates to the pattern and the vents between the pattern and pouring cup. This step is tricky; “welding” the wax pieces together requires some practice. Weak welds are very common among beginning casters. Set aside some time to practice in order to get your technique down.. You do not want your pattern to fall apart before it is invested in plaster.

Heat the flat (spatula-like) end of a wax-working tool with a candle lantern, slide it in between the two pieces of wax to be welded. Slide out the tool, and then hold the wax pieces together for a minute. You need to hold the two parts together very steadily in order to avoid weakening the weld. With practice you can get a strong weld this way. If you think the weld may be weak, you can improve the strength of the weld by

augmenting it with thin (~1/16") slivers of wax which are warmed by holding in the palm of your hand, then placed so that they overlap the weld line. You can then use a heated wax tool to blend these slivers in. As an alternative to a heated wax tool, you can use an electric soldering iron to heat the wax.

6. Insert core pins if your pattern is hollow. Core pins are used to keep the core (or hollow center) of your pattern in place after the wax melts out. Failure to use core pins, or improper use of them, results in core shift (which means the plaster core moves), and can ruin the casting. You should use silicon bronze boating nails which have hatch marks in them. The hatch marks help keep the pins in the plaster. They are available at West Marine in Mountain View.

7. Assemble your wax with the flask and board.

A . Select an appropriately sized steel flask. You will need an inch of clearance around your pattern and between the tip of the sprue and the top of the flask.

B. Attach the tree (the sprue, gate pattern assembly) to a piece of masonite or plywood by the pouring cup. You will need to melt the pouring cup onto the board so it sticks. A board with a rough surface (such as masonite) works best.

C. Debubble the casting. Brush on some debubbler solution. This is basically a soapy water mix that keeps air bubbles from sticking to your casting. Air bubbles on the surface of your casting turn into metal warts when the casting is formed. They can be removed after, so air bubbles are not completely disastrous, but it is better not to have them.

D. Place the cylinder around the tree, and insure that you have good clearance. Create a wax fillet on the outside of the flask between the flask and board. A nice way to do this is with a disposable 2" paint brush. Dip the brush in molten wax and brush around the base of the flask to create a fillet. This fillet will seal in the plaster so that it doesn't seep out. If you don't have a brush, you can cut slivers of wax and melt them around the base, then hit the fillet with a propane torch to improve the seal.

8. Invest. This is when you mix 30-30 mix (or plaster Satin Cast, which is much finer but also much more expensive) with water and pour it around your wax pattern. You can use the same mixture and method as you did when you created the mold.

A. Follow steps 2A, and 2D through 2J to create the liquid 30-30 mix, or follow the instructions on the Satin Cast package..

B. Pour the mixture into the flask. One person should pour while the other person both continues to mix the investment (otherwise, it settles out and the investment in the bottom is much thicker than the investment on the top), and guides it into the flask. Try to guide the investment so that it does not pour directly onto the

pattern, sprues, or gates. A heavy flood of investment can knock your pattern over if you are not careful.

C. Tap the side of your flask with a piece of scrap metal in order to remove air bubbles from the investment. Do this for about 5 minutes, or until air bubbles no longer rise to the surface. Alternatively, you can put your flask inside the vacuum machine in the Plastics Room to get the air bubbles to rise to the surface.

D. Let the investment sit for 24 hours.

9. Burn-out. After the investment has sat for 24 hours, it is ready for the kiln. You will need to pour the metal immediately after removing from the kiln.

A. Remove the wood base from the flask.

B. Load the investments into the kiln. Be gentle with them. You should arrange each investment on top of firebricks so that the pouring cup is on the bottom but is not directly on top of a firebrick. This allows the wax to drip out of your pattern. It is a good idea to put the largest investments near the front of the oven, since they will be the last to burn-out and it will be easiest to check and see if they are burnt-out. It is also hard to pull a large investment out of the back of the oven.

C. Decide on an appropriate burn out schedule. Burn-out schedules can be found in the appendix. Ask a knowledgeable TA or Dave Beach (also knowledgeable) if you need help picking a schedule.

D. Set up a temperature measurement system. The shop owns a fluke voltmeter with a temperature probe which is an excellent choice.

E. Turn on fume hoods. Turn the one on which is over the oven/kiln area, and also the one which is near the muller/royer area. Open all the windows except for the ones near the muller/royer area (otherwise this fume hood just sucks in air from outside.) The fumes created by melting wax are not good for you!

F. Ignite the Kiln. First, make sure that the kiln door is closed. Round up a couple of paper towels and a lighter (or propane torch). Observe that at the back of the oven there are two gas petcocks, located at about knee level, one on the right, and one on the left. These regulate the amount of gas which flows into the oven. In the middle at about waist height there is an air flume. As you are looking at the back of the oven, off to your right and behind you a bit is a gas valve located on a pipe which goes to the kiln. This is the main valve. You will want to do the following steps fairly rapidly, so make sure you understand all the steps before you start. (A TA should definitely be present for this part.)

Put on a long sleeve shirt and some fireproof gloves. Make sure that the two gas regulators are completely closed. Gas valves are closed when the handle is

perpendicular to the axial direction of the pipe. Open the flue to the 2.8 marking. Open the main valve all the way (so that the handle is in-line with the pipe). Roll up a paper towel into a wand shape. Light the end of it, and stick it into the hole below one of the petcocks. Open this petcock part way so that it makes a 45 degree angle with the pipe. At this point, the gas should ignite and you should see a flame burning if you look into the hole. If this doesn't happen, turn off the regulator immediately, and try to figure out what happened. It is very dangerous to have the oven fill up with gas, since when it is ignited, it can explode and blow the shop to Kingdom Come. If everything went well with lighting the first petcock, light the other one.

G. Watch the oven. You should do this in shifts since it is not only boring but also unsafe to have one person sit by the oven for too long. Oven sitting has two major responsibilities. Most importantly, you should make sure that the kiln stays lit (check to see that there is a fire coming out of both regulators). Otherwise, the kiln and room are filling up with explosive gas. You should also make sure that the oven is following the burnout schedule. You can moderate the temperature by adjusting the 2 regulators at the back of the oven. Remember, in line is completely open, perpendicular is completely closed. A few hours after the burn-out has begun, you will hear the sizzle of molten wax, and smell the associated noxious vapors. Position yourself away from the oven at this point, and only walk over there every 10 minutes or so to check on the temperature and flame. These vapors aren't exactly good for you.

H. After the investments have soaked at the maximum temperature for the full length of time suggested by the burn-out schedule, check to see that they have all burnt-out. A TA should do this. Suit up in the full silver space suit gear, including the hood. Turn off the main gas line and close the flue. Closing the flue is important because if you don't do it, cold air will rush in the open door, out the flue, and perhaps cause enough thermal shock to the investments that they crack. Open the oven door. Note that the inside of the oven is quite hot! If any flames are coming out of the pouring cups or vents, the investments are not burnt out, and you should close the door and relight the kiln (explained below). Tilt the investment up so that you (or someone else also wearing a silver suit) can look up into the pouring cup. The casting is burnt out fully if and only if the pouring cup is white with no black streaks. Black streaks indicate that a carbon residue still remains in the investment, and that more burn time is needed. Pouring metal into a not completely burnt-out casting is catastrophic-the metal can explode back out of the investment, which is dangerous. If the largest casting is completely burnt-out, then it is likely all the others are too. In this case, you can leave the oven off with the door closed, and let the investments cool a bit to the pouring temperature. If the castings are not entirely burnt-out, close the door, open the flue, and open the gas line. You will probably not have to relight the kiln - it is probably hot enough that the incoming gas will ignite itself. But check to make sure that you can see a flame through the hole underneath both regulators.

10. The Pour.

A. Prepare for the pour. Clear out the aisle that runs along the oven and kiln. Place some sandbox sand on the concrete floor, about 1 1/2 ft wide, a couple inches tall, and long enough to easily place all the investments with a bit of room in between. Heat up what you are certain is more than enough metal ahead of time in the furnace.

B. Pull the investments out of the oven. After again checking to make sure that the oven is off, suit up in the silver suits. Removing the castings from the oven is physically demanding. The best way that we currently have to do this is to set up a stool in front of the door and place a fire board on top of it. The top of the fire board should be very close to the height of the base of the inside of the oven. Investments can then be dragged onto the fireboard with a pair of tongs, then carried (by two suited people) to the sand area where they are flipped with the tongs so that the pouring cup points up. This works well from small to medium size castings. Very large castings present a problem.

C. Pour the metal. You can pour just like you would for sand castings. As usual, try to pour quickly so that the metal does not have a chance to cool

D. Allow the castings to cool. Wait at least 6 hours before breaking the castings open. This is more than enough time, but it is much better to wait too long than not long enough.

11. Break open your casting. Lay down brown paper in the usual fashion, and use a chisel to knock out the dried plaster. Be sure to dispose of the dried plaster in the dumpster, and not down the sump.

12. Finish your casting. Finishing is a time-consuming and difficult process, but it is also extremely crucial if you want your casting to look good. This section is admittedly sparse. Much could be written about finishing. Here are the basic steps

A. Remove the sprues and gates. This can be done on the bandsaw. You will probably need to do some fancy fixturing if your casting isn't rectilinear. You can probably construct a stable structure using wood clamps and scraps of wood. Get a TA to help you with the setup - this is tricky and dangerous.

B. Sand or grind off what is left of the gates. Depending on the geometry of the gates you can use a belt sander, die grinder, or dremel tool. Ask a TA if you need help.

C. Remove the core pins. Sometimes they can be pulled out, but usually they will need to be drilled out.

D. Fill in the core pin holes or any sinks that may have occurred. Make sure that you fill them in with the same material that you used for the casting. PRL has a variety of welding rods including aluminum and silicon bronze. Probably the best way to get this done is to be nice to someone who knows how to TIG weld and get her to fill in the holes.

E. Re grind the TIG welds.

F. Finish. The best way to finish your casting is to patina it. Patinas speed up the natural oxidation and corrosion processes. This gives the castings a beautiful and venerable look. There are hundred of recipes for patinas, and they create all sorts of different color finishes. An excellent reference on this topic is “Metal Techniques for Craftsmen” by Oppi Untracht. Dave Beach has a copy. The PRL has had the most success with the black (it’s really more of a dark brown) Liver of Sulphur patina, so this one is recommended.

Variations on the Step-by-Step Process

RTV Molds

RTV rubber can be used instead of plaster for making molds. RTV stands for “Room Temperature Vulcanizing”. RTV is mixed from 2 liquid parts and sets up after about 30 minutes. The main advantage of RTV is that it allows for small undercuts in the pattern since it is rubbery, unlike plaster. Furthermore, a larger number of waxes can be made from an RTV mold than plaster before it degrades. The main disadvantage is the expense - it costs about \$150/ gallon. (1997 prices).

To use RTV, make a 5-sided box with an inch or so clearance for your clay pattern. Foam core and hot melt glue work well. Mix the RTV as instructed on the package. Pour it in, then tap the sides of the box for about 10 minutes (this helps get bubbles out.) The RTV needs about a day to set up. After 24 hours, tear off the foam core box. Then carefully slit the RTV at the parting line of your pattern. You will probably cut into your pattern some, this is no big deal. Pull off the RTV halves (or sections) and take out the clay pattern. You are now ready to make waxes just like the impoverished who are making them with plaster molds.

Carving Wax Directly

You can carve wax directly, and skip the whole clay pattern plaster mold deal. Wax is much harder to work than clay, so this is only really advisable for doing things which are small (usually just rings). Another advantage that making a mold offers over direct wax carving is that you don’t have to start all over if your first casting doesn’t come out. You can also purchase machinable wax and either turn or mill it. This is a good way to get the precision of machining without the material waste. (Good if you are casting expensive metals like gold or silver.)

Lost Other Stuff

You can burn out a variety of other things in addition to wax. Acrylic, which can be easily lasercut burns out quite nicely. This is especially useful for doing two-dimensional stuff. You can also heat-form acrylic and other plastics and then burn them out.

Many found objects have been burnt out successfully. The lost fortune cookie casting is a PRL legend, and is thought to have brought good luck to the shop community for many quarters. I have also seen successful burnouts of strawberries and seed pods, while things like bone and wood are generally too dense to burn out in any sort of reasonable time frame. I once heard of a 72-hour burn out for a lost pine cone belt buckle casting. Shop lore has it that someone burnt out a chicken foot once, and that it smelled up the shop for days.

Solid Wax Patterns

There are a couple of reasons that wax patterns are usually hollow. One is to avoid heat sinks. Castings of uneven wall thicknesses tend to sink around the area of thickest cross-section. What happens is that as the metal starts to cool, it shrinks. The inside of the area with the thickest cross-section cools last. When it does cool, because it shrinks it pulls in metal from the outside of the casting. Another reason why castings are usually hollow is that such castings require less metal, and therefore less thermal energy. Less thermal energy leads to a better surface finish. Also, you may be surprised to learn that hollow patterns are also lighter.

Solid patterns are appropriate for things like rings, which are too small to make hollow, or other things which already consists of thin even cross sections. In making a solid pattern, you will not need to swirl around the wax and dump it out of the plaster mold. Rather, pour enough wax in to fill up the whole mold. Also, you may omit the core pin steps.

Multiple Parting Lines

This process is slightly more difficult, and you may want to ask yourself (and Dave Beach) if you are really up for it. If you are, create a cardboard wall along one of the other parting lines. Coat the wall with Vaseline, then mix and pour plaster as above in the space between the newly created wall and cardboard box. Repeat this until you have created all the plaster sections

Jewelry-Sized Castings

There is a casting plaster called Satin Cast which has been specially formulated for jewelry, and if you are making a casting of this size and delicacy you will want to use it. It is often available from PRL for \$1/pound (1997 prices). You should use the same investment method as you do with the 30-30 mix, except for a few changes. As usual, pay careful attention to dustmasks, cleanliness of your mixing vessels, and the plaster to water ratio: Follow the instructions on the outside of the box with regard to mix ratios. (38-40 grams of plaster per 100 ml of water) Use only satin cast and water, do not mix in any sand. Also, PRL owns a small vibration table upon which the casting may be placed to remove bubbles.

The shop owns a small electric oven for burning out small investments. It is easier and less wasteful to use it for small stuff. Do not trust the temperature readout on the oven; use a separate temperature measurement method. (Like the fluke voltmeter with thermocouple attachment).

Vacuum Casting

Jewelry-sized parts should be vacuum cast rather than poured, as gravity alone will not be strong enough to fill the mold completely. The PRL has a great J-2R Vacuum Casting Machine for this purpose. It uses the force of a vacuum to better fill the casting and achieves very reliable results when used correctly. It has its own melting chamber, which holds a metal-filled crucible, directly above the chamber that holds the investment flask. The machine heats the metal up to the specified temperature, and then the user releases a plug at the bottom of the crucible, allowing the molten metal to be sucked down into the pattern. You should obtain the help of a knowledgeable TA before you begin a vacuum casting project, as there are many special guidelines for using this machine that are not listed here. The vacuum casting machine also has its own "Owner's Handbook" which should be referred to throughout the procedure.

Spin Casting

Jewelry-sized stuff can also be spin cast, which uses centrifugal force to better fill the casting. A spin caster consists of a metal tub, with a wind up arm. A metal filled crucible and the investment flask are placed on one end of the arm. Weights are placed on the other end of the arm to counterbalance. The arm is spring-loaded and is wound up the proper amount (3 1/2 turns), then held in place with a metal rod which slides through a hole. The metal in the crucible is heated with a flame-cutter torch. When it is molten, the arm is released, and it spins around and flings metal into the flask. Get a knowledgeable TA to help.

Burn-Out Schedules

General Notes

Pick a burn-out schedule according to the size of your casting. 7 hours is almost always sufficient for ring-sized castings. 12 hours is good for stuff smaller about the size of a hot-dog, while 16 for something the size of the machinery's handbook (provided it is hollow), and 24 is good for stuff the size of a hollow loaf of bread. Remember, you should always check to make sure that your casting is completely burnt-out before you pour. You may find that you have underestimated the burn-out time, in which case you will simply need to let it keep on cookin', and check periodically to see if it is done. Too long of a burn is not nearly so disastrous, but it will diminish the surface quality of the casting. It is best to plan on a burn ending in the middle of the day sometime, so if you go overtime you are not pouring metal at four in the morning. Also, if the parts are going to be hand poured, whoever is in charge of the burn (a TA) should get a decent night's sleep so she can be well rested for the pour.

Burn out schedules consists of a ramp (casting brought up to temperature), a soak at some maximum, and a ramp down to the casting temperature. It is important not to bring the investment up to temperature too quickly so as to avoid thermal shock (and cracking) of the investment. Larger investments need to be brought up more slowly because of their greater thermal mass. The maximum temperature is chosen to be above the temperature at which all of the carbon residue left behind by molten wax will completely vaporize, but below the temperature at which the investment begins to break down. Unfortunately, this is a very small temperature range and the kiln temperature must be carefully monitored. The casting temperature is generally chosen to be below the maximum burnout temperature, since a lower temperature means lower energy, and better surface finish. The temperature should not be too low however, since a warm flask allows for better flow of metal in thin sections of the casting, and will avoid the risk of thermal shock (and cracking) to the investment.

You should always check the castings to insure they are completely burnt-out before pouring them. Remember, that if the casting is not completely burnt-out it can explode quite violently.

7-Hour Burn

Time from Start (hrs)	Temp (C)
0	room
1	200
2	325
3	450
4	575
5	700
6	700
7	500

12-Hour Burn

Time from Start (hrs)	Temp (C)	Petcock range
0	room	0.2
1	150	0.2
2	260	0.5
3	371	1.8
4	482	2.1
5	593	3
6	700	3.3
7	700	3.5
8	700	3
9	700	2.5
10	700	2.3
11	700	off
12	500	off

For anything longer than the 12 hour burn, use the same temperature ramp up, but keep the investments at the maximum temperature (700, also referred to as “soak”) for the required amount of time, then drop it back to 500 before the pour.

revision history

- rev 0 9/97 Chuck McCall original text
 - Economy (30-30) investment mix recipe is from Mike Robinson.
 - Many insights are from either Dave Beach or Heather Andrus.
 - thanks to Bryan Cooperrider for correcting my bad grammar and formatting this document so it made sense.
- rev 0.1 10/01 Katherine Kuchenbecker minor revisions, addition of vacuum casting