Casting Tech Tips

In the realm of 3D one of the most traditional and often used processes is **CASTING**. Casting is a substitution process whereby the a hollow created in a mold by the original form is filled by another material. So the process has three basic steps: creation of an original object or pattern, fabrication of a mold, and casting of the new material into the mold.

Generally speaking any material that can change from a liquid to a solid can be cast. This would include wax, paper, clay and a number of plastics and metals. While the process is straight forward it is not simple or quick and the cast object often requires a considerable amount of post casting attention.

THE ORIGINAL or PATTERN:

The original object or prototype is often referred to as a pattern. This original object can be made of any number of materials and in any shape or form. It is the elements of the original object and the final material to be cast that will determine which technique and what materials you ultimately choose to make the mold of. A lot of surface detail or any undercuts would normally dictate a flexible mold. Simple forms and surfaces could utilize rigid molds.

Elements of the original can be made too thin or too delicate to cast such that the final work may need to incorporate other materials or parts

need to incorporate other materials or parts fabricated in other ways. Depending upon the casting process you use the original may be destroyed during that process or you may have to make a copy of the original in another material requiring yet another molding step.

If your final object is going to be cast in metal (and you are willing to risk the original on a bad pour to save the extra molding step) make it out of wax.

THE MOLD:

Molds typically come in two types: rigid and flexible. Rigid simply means that the final mold, when dry, is stiff and unable to "release" objects with undercuts and therefore are best suited to geometric forms or objects being cast of flexible materials. Flexible molds are "rubbery" and can undercuts so are generally used for complex objects or objects with highly textured surfaces. Either type of mold can produce the same detail and either type can be used to create molds from nature (aside from small objects people have been know to "pull" molds from trees, rock outcroppings, ice, etc).

Molds can be reusable or "waste" molds (meaning that they are destroyed, or wasted, when removing the cast object). A waste mold enables you to cast complex forms with undercuts without the use of flexible materials; but it is wasted and can only be used for that one casting.

Some elect to cast a number of originals and use them to make a number of waste molds for the

Typical Materials for Originals or "Patterns":

While near anything can be used to create the original object tradition leans towards:

Wax:	Microcrystalline or Bees wax,
Fine grained woods:	Mahogany, Basswood, or clear Pine,
Oil based clay:	Plasticene

Typical Materials for Molds:

Plaster	Rigid but really cheap,
Latex	Flexible but really slow.
Silicone	Faster but really expensive,
Various "rubbers"	Fast and slow, cheap and expensive usually not the way you would desire.
Investment	Plaster like refractory material for metal casting.
Sand	Simple mold for metal casting.
Resin Bonded Sand	"Glued" together sand for metal casting.
Ceramic Shell	Thin dip coated refractory material for metal casting.

final process. This is typical in metal casting where the refractory mold can only be used once (with the rare exception of some high temperature rubber molds that can tolerate low temperature metals). In the case of casting simple objects a single pattern can often be used to make a number of waste molds.

THE CASTING:

Is really quite simple in concept: once the original object has been removed from the mold the new liquid material is simply poured in.

In the case of metal casting an original object of wax is often melted out of the mold in a process appropriately called the "burn out". This involves heating the mold over an extended period of time letting the wax run out of it and vaporizing any remaining in the mold. In most other cases that do not require a refractory mold the original is just pulled out in the same way the final object will be.

THE FINISHING:

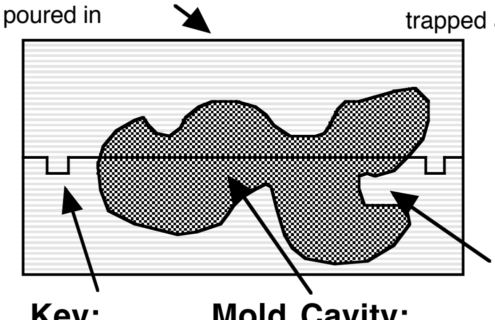
Now that you have finished the casting process are you relieved to know that you are almost done? Guess again! Now you have to finish the object.

Even the best mold and the most retentive attention to detail will not yield a finished casting, but this is often where the character of the object can be most effected. You will usually have to grind, sand, smooth, polish and clean the casting as a minimum to "finish" it off. You then can paint, patina, chase, dye, stain, or other wise change the surface through a number of differing processes that are not found on this tech tip sheet.

ANATOMY OF A MOLD:

This diagram is of a simple two piece mold showing some of the elements and options in construction of a simple mold.

This particular design could be executed in any number of mold materials for many different casting



Typical Materials for Casting:

Plaster	Cheap and quick but weak and cheap looking.
Cement	As in sidewalks.
Hydrocal	A cross between cement and plaster.
Plastic Resins	Oh so pretty but not too cheap and often quite toxic.
Foam	Useful for some things but hard to release from molds and toxic.
Rubbers	Like liquid rubber, Flexane, Urethanes, Plastisol, etc. Available in numerous "hardness" grades from gummy worm to stiff as a rock.
Clay	You know...CLAY! Clay "slip" is the liquid casting form.
Metals	About any that will melt. We typically cast Aluminum and Bronze at the college. Lead, Pewters, Tin and Zinc are typical "low-temp" metals but

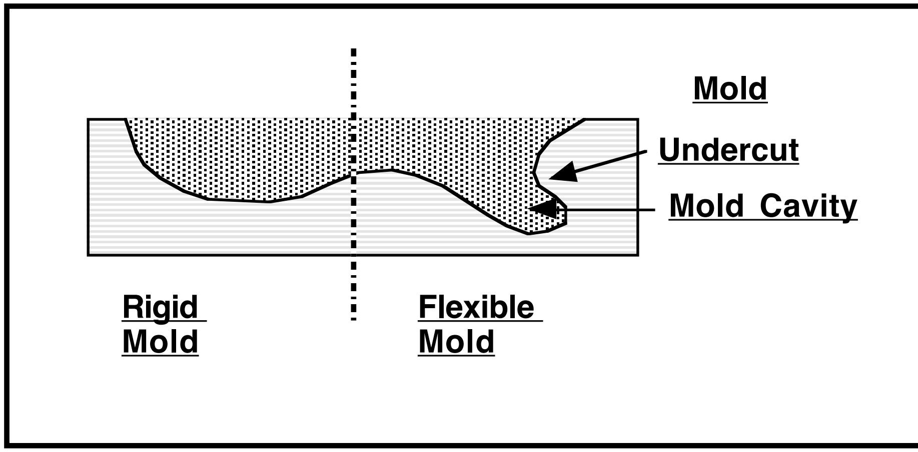
A FINAL MATERIAL NOTE:

You should review all materials, and especially these, in your materials hazards book. While these materials may seem rather innocuous when in your hands it is more likely that they are dangerous and, even if they are not, you should treat them as so until you know for sure. And don't think that once you are done casting the danger is past. While grinding or polishing these materials be careful to wear a particle (dust) mask as supplied by the shop and gloves.

The Simple Open Face Mold:

Open faced molds can be made of flexible or rigid mold materials. If undercuts are present in the original, and multiple castings are desired, then a flexible mold material would be required.

While most materials can be cast into an open faced mold they are not as effective as enclosed molds when casting metals as the surface tension of the metal creates a raised top or bump on

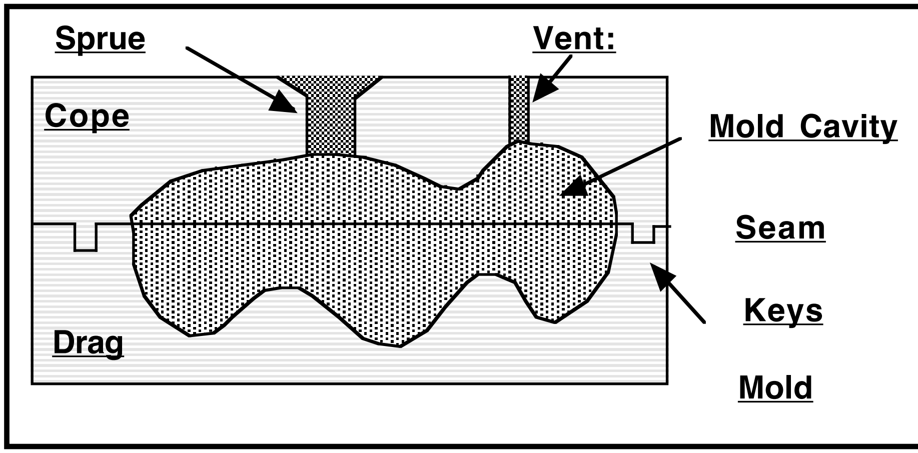


Multi Piece Molds:

While a simple two piece mold is diagramed here molds can be made up of any number of sections. Two pieced molds are the simplest for casting “in the round” and enable control of form and surface on all sides of the object.

High spots in the mold will require venting and any undercuts will require an additional sectioning of the mold to enable them to release.

If you can’t get the original out in one piece you can’t get the casts out in one piece without “wasting” the mold.

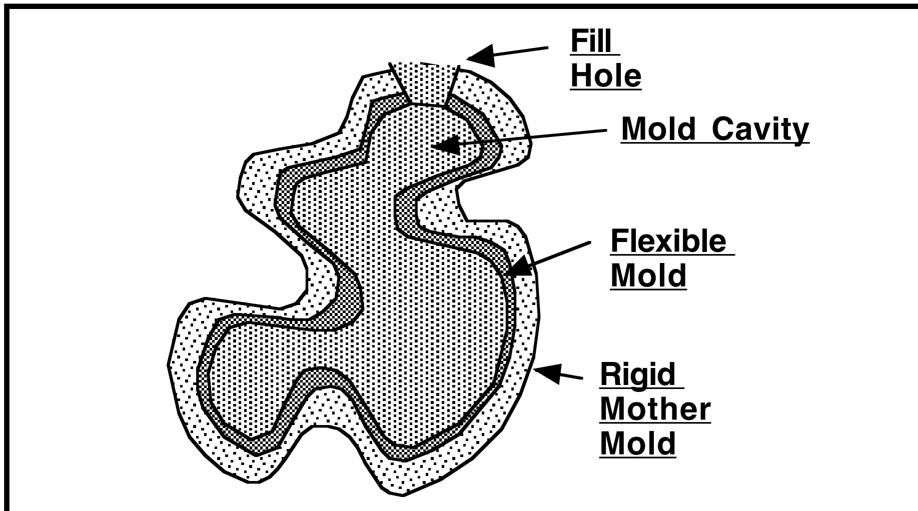


Flexible Thin Walled Molds with Rigid Mother Mold:

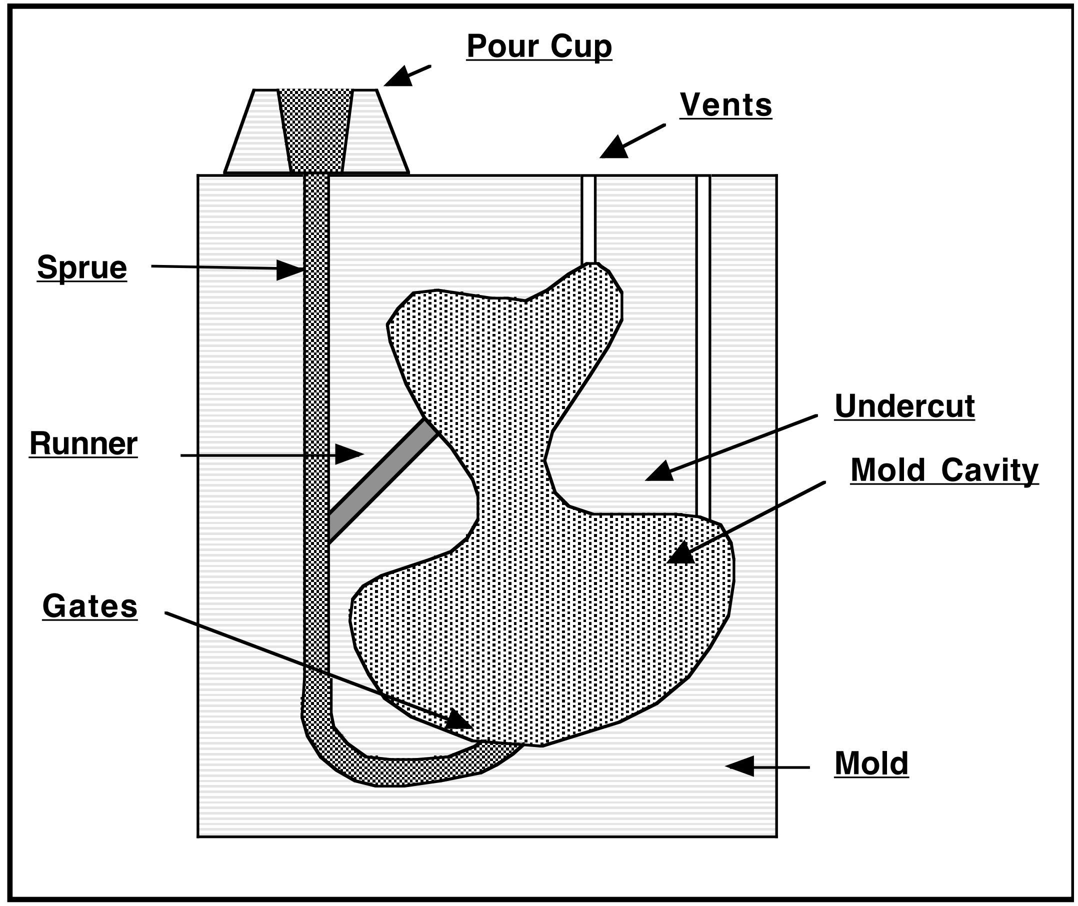
This type of mold enables the creation of thin flexible walled molds using less materials and less costly material that a large cast flexible mold.

The flexible “skin” of the mold must be backed up with a multi-sectioned “mother” mold to reinforce it and prevent distortion.

Typically both the mother mold and the flexible mold are seamed for easy removal from the original and subsequent casts.



Refractory Molds for metal casting:



Refractory molds are made from materials that will withstand the heat generated by the molten metals being poured into them. Typically these would be investment, sand, resin bonded sand, or ceramic. Normally these molds would be of the “waste” variety meaning that they are used once and then destroyed to remove the cast object.

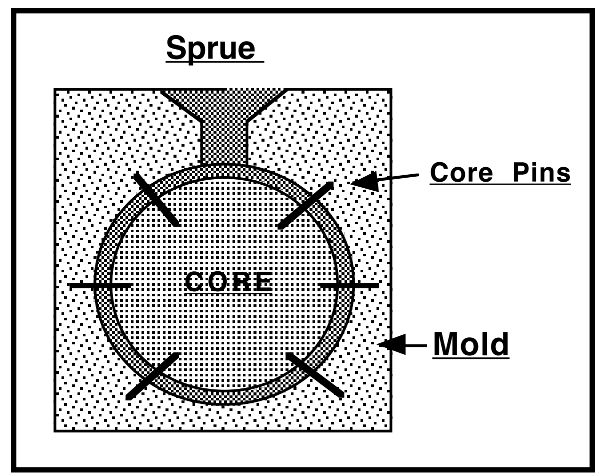
While metal molds can be open faced, cope and drag, or of the waste type the latter is the most typical in the foundry at MCAD.

The diagram illustrates a typical investment or resin bonded sand mold layout. Any high points or areas on the original that can trap gases must be vented to the outside top of the mold. The filling sprue is lead from the pour cup to the bottom of the mold cavity if possible with runners directed up and away from the main sprue to the object if required.

All sprues, runners, and vents should have radiused corners in square in form and should be of a size to enable quick and unobstructed passage of the molten metal to and from the mold cavity.

The original in a waste mold is made of wax which can be “burned out” of the mold. This process, know as “lost wax” creates a cavity within the refractory mold into which the metal can be poured. All of the sprues, runners, and vents are also of wax and burn out with the original.

It should be noted that this process destroys the original wax and, as the mold is destroyed during the casting process, if it doesn’t work you will have nothing to show for all of your time and energy. To improve these odds many choose to make a mold of their original to cast wax into such that they have multiple copies of the original to make the metal casting mold from.



Mold Cores: When creating an object of high volume you may often desire not to cast it solid. Especially in the case of metal where there are limits to the thickness that can be cast (about 2”). In this case you can displace some of the interior volume of the object with a “core”. Cores can be left in place or removed from the final object but the idea is to create a hollow volume with thinner walls.

A number of materials can be used for a core when casting most materials but when casting metal the core, like the mold, must be of a refractory material. It could be the same material used for the mold as: investment poured inside, resin bonded sand “rammed up” inside, or the core could be made of fire brick and the form built around it as a skin.

In any event it is necessary that the core be held in place during the casting process and this is most readily done by the use of “core pins”. Often welding rod inserted into the core before molding they then bond into the mold and hold the core “keyed” in place.

Ceramic Shell Molds for metal casting:

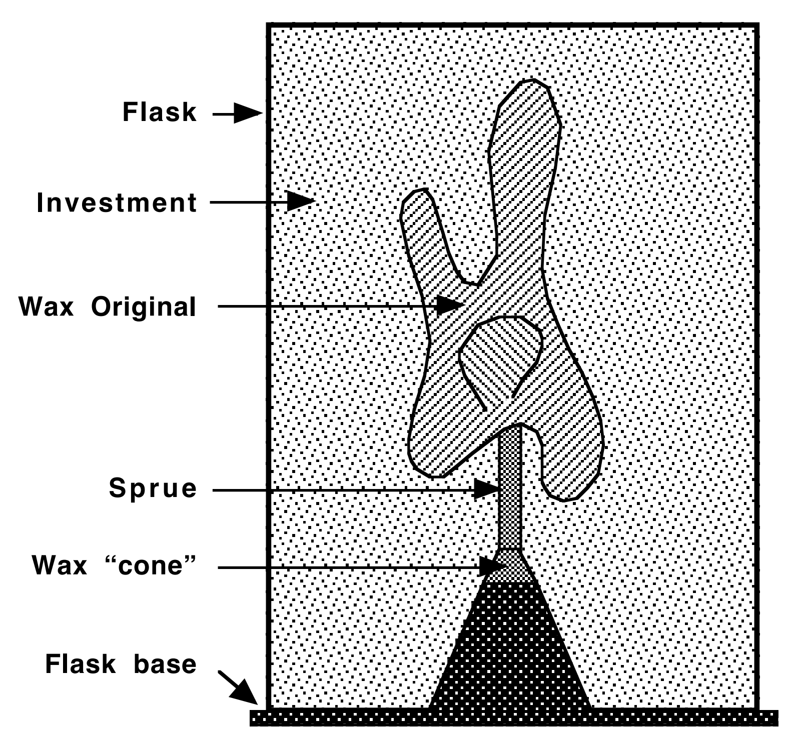
Ceramic shell is another type of refractory material used to make molds for metal casting.

A "waste mold" process Ceramic shell is easy, inexpensive, and reproduces excellent detail from an original wax.

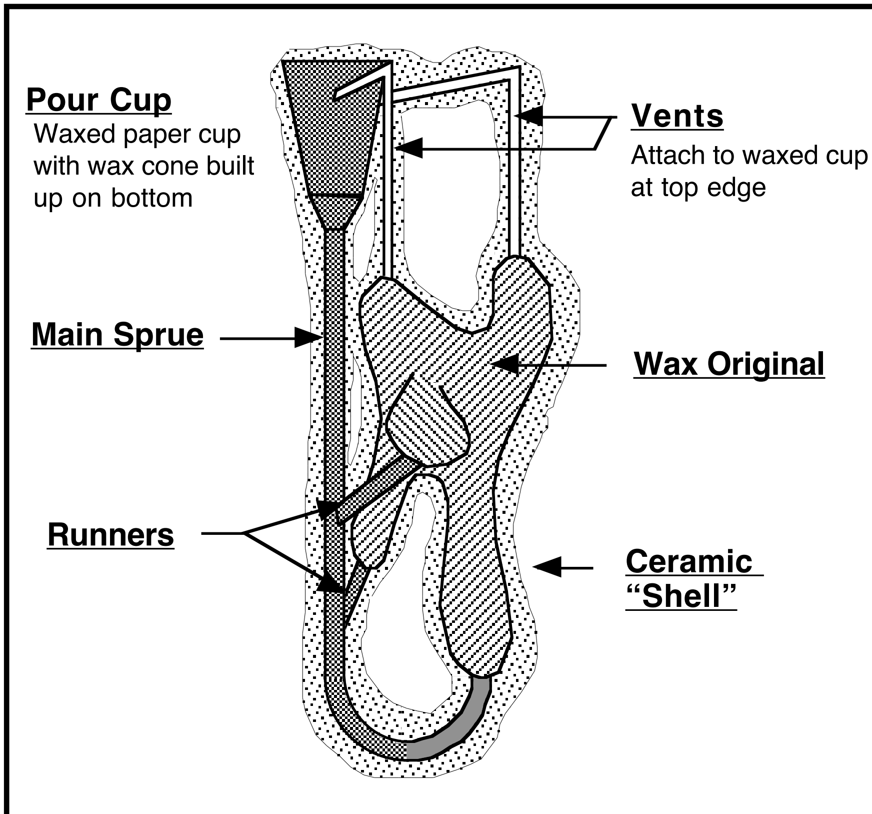
Basically the process is the wax original with sprues, vents, and pour cup attached, is "dipped" into a ceramic "slurry" and coated with refractory silica.

After the mold is built up in at least 13 steps (see attached "Shell Schedule") and is allowed to dry (8 hours) you will drill out and remove the top of the pour cup and the wax cup itself, burn it out in the flash kiln (2 hours), sinter it in the ceramic kiln (1 hour), and then place it into a sand bed when casting.

Like all waxes for molds the completed wax for a ceramic shell must be



Centrifugal Casting Flask
with Investment



Investment and Plaster Molds:

These two mold types are similar with the primary difference being the addition of a refractory material to the investment. Investment is commonly used in the jewelry and precision casting trades to create high quality high detail reproductions. The investment that we are using is a very fine jewelers casting grade that is very durable and withstands high temperatures when properly mixed and prepared. The plaster should be of a high quality molding type typically used in the ceramics field.

Both of these mold making materials should be carefully mixed according to the following guidelines for optimum performance in casting metals (investment) and clay slip (plaster). Other materials may also be cast into plaster but the mixing ratios are not as critical.

For Metal Investment Casting:

You will be pouring the investment into steel flasks which hold you wax originals already sprued, vented (if not centrifugally cast), and mounted flask base. The flask should be lined with ceramic paper prior to investing the wax.

The proper mixing ratio for water to Investment is 38 to 40 ml water per 100 grams of powdered investment. You can predetermine the amount of investment needed by filling the empty flask with water and pouring it back into the measuring flask. You can also use a similar "displacement" method for determining the amount of metal you will need for your cast.

The investment is then poured into the flask (all the way to the top for centrifugal casting) and then held on the pad of an inverted orbital sander to debubble the mixture. The molds are then burned out, as in any lost wax process, and cast while hot (near the temperature of the casting metal or glass). For our Rapid Prototyping purposes it might also be possible to burn out a complex original and cast other materials (resins, etc) into the mold with proper adjustment to the sprue and vent sizes. **Cast other materials into an investment mold only after the mold has cooled.**

After a brief cooling period the molds are quenched in water and the investment releases from the object.
Be careful with this part of the process as it creates "live" steam.

Plaster Molds for Slip Casting:

"Slip" is a thin mixture of clay and water that is cast into a plaster mold. The mold draws the moisture from the slip in contact with it first creating a wall that thickens as it dries. When the wall has reached the desired thickness the excess slip is poured back into its container, the thin walled copy is let dry to leather hard, then removed. Unless the object can be cast into an open face mold (has no undercuts) the mold will have to be of a cope and drag or multi part design. Other materials and solid objects my be cast from plaster molds but flexible rubber would normally give better results.

The plaster for a slip mold should be careful mixed to assure the proper consistency to permit the flow of water from the slip to the mold and the mold should be designed to leave at least 1" of plaster around the original. The mold will have to dry completely prior to use and be dried after a half dozen casts.

The mixing formula for a slip cast plaster mold is as follows:

The ratio is 11 lbs of plaster to 1 gallon of water (2.75 lbs/qt).

To find the amount needed use the follow formula:
In inches: length x width x height = volume in inches.
Vol ÷ 80 = amount of water in quarts; quarts x 2.75 = lbs of plaster.

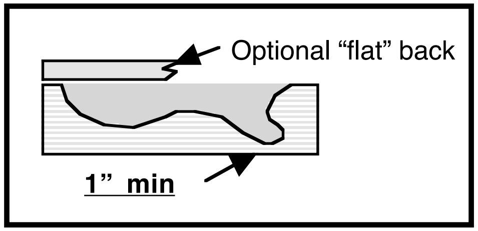
Sample solution for a 6" x 6" x 3" mold:
6 x 6 x 3 = 108 cu inches;
108 ÷ 80 = 1.35 quarts water;
1.35 x 2.75 = 3.71 lbs plaster.

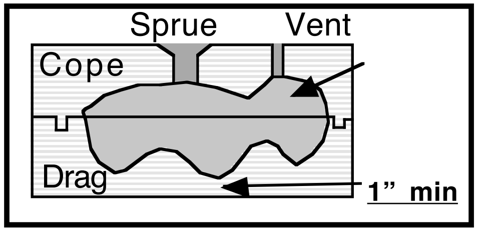
Resin Sand Molds:

Our typical sand molds are “bonded” with a resin/catalyst mixture. The sand is mixed in a cement mixer and then rammed (tamped) into the mold around a pattern or as a blank for “direct carving” of the mold.

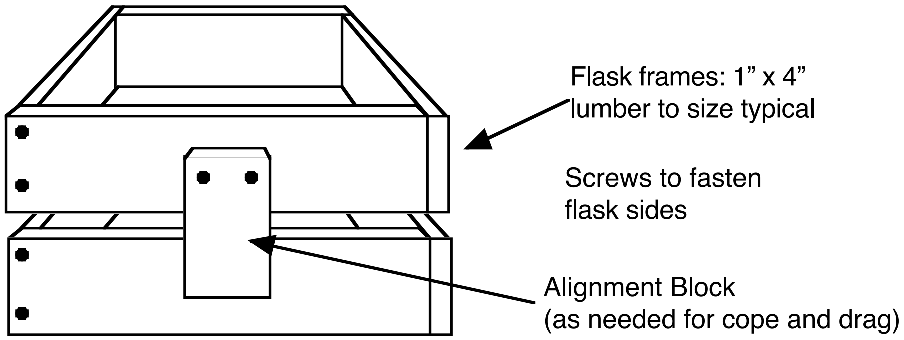
Molds can be open faced (with or without a top plate and best for relief work) or double sided “cope and drag” (best for objects in the “round”).

Vents, sprues, and pour cups can be carved into the mold after the sand has set.





TYPICAL SAND MOLD FLASKS:



Ceramic Shell Schedule:

date: ____________ name: ___________________________________ weight of wax: __________

Bronze Weight: ______________________ Aluminum Weight: ______________________

Dipping Schedule: (Leave a minimum of 40 minutes between coats)

Start with 2 coats of slurry only: Coat 1: _________(initial) Coat 2:_________(initial)

Then continue with coats of slurry and refractory:

A)	B)	C)	Close coats (slurry only)
1)_________(initial)	1)_________(initial)	1)_________(initial)	1)_________(initial)
2)_________(initial)	2)_________(initial)	2)_________(initial)	2)_________(initial)
3)_________(initial)	3)_________(initial)	3)_________(initial)	

Let Dry 8 hours Before Burn out

Ceramic Shell Schedule:

date: ____________ name: ___________________________________ weight of wax: __________

Bronze Weight: Aluminum
Weight: _____________________ _____________________

Dipping Schedule: (Leave a minimum of 40 minutes between coats)

Start with 2 coats of slurry only: Coat 1: _________(initial) Coat 2:_________(initial)

Then continue with coats of slurry and refractory:

A)	B)	C)	Close coats (slurry only)
1)_________(initial)	1)_________(initial)	1)_________(initial)	1)_________(initial)
2)_________(initial)	2)_________(initial)	2)_________(initial)	2)_________(initial)
3)_________(initial)	3)_________(initial)	3)_________(initial)	

Let Dry 8 hours Before Burn out