METAL CASTING MANUAL

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FOUNDRY PROCEDURES:

When melting metal it is a good practice to maintain a balance of 50% scrap and 50% virgin metal. The more you melt a metal the more alloy you lose, (roughly about 10% loss to oxidation). All alloys in bronze oxidize faster than copper. Never melt scrap only! By melting 50-50 you help maintain the balance in the alloy by replacing some of the loss in the scrap.

After weighing out the metal for a pour you should clear it of all possible oil, dirt and investment. These impurities may end up in your melt.

After initial charging at the beginning of your melt always pre-heat all metal before charging it into the crucible. Anytime you add cold metal to your melt you are adding gas and moisture.

Always make sure the crucible is clean. You should ream out the crucible after each pour is completed. You should clean crucibles out with powdered borax about every ten heats. The average life of a crucible is 50-75 pours if it has proper care.

Always check the bottom of the furnace before each melt to remove any inpurities such as ash, sand, broken down furnace refractory or broken down crucible refractory.

Always charge the crucible at the beginning of a melt with ingots and thick pieces first, then add the scrap. Bring the furnace up to maximum heat slowly.

Never let metal cool down in the crucible, it will shrink and pull the walls of the crucible in and upon heating it will expand and will eventually crack the crucible and definitely shorten the life span of the pot.

Always turn furnace off when the maximum pouring temperature is reached. Take a pyrometer reading always with the furnace off. Always pre-heat any tools that will come in contact with the hot metal, such as, skimmers, plungers, ingot molds. Skimmers, plungers and ingot molds should be painted with a refractory wash well in advance of the casting, at least one hour before you will need them to assure drying before contact with the hot metal.

Skim the crucible surface immediately after removing the crucible from the furnace.

Pour the metal into the mold as fast and as low to the cup as possible, slow high pours trap air and drag gases down into your mold, the metal is also chilled by a high pour, the closeness reduces the possibility of spilling and accidents.

Immediately after pouring, spread an exothermic retarder (Feedol #9) over the cup and risers to seal the molten cup off from the atmosphere so that it serves as an insulation for the molten cup and allows it to function longer as a reservoir of hot metal to feed shrinks.

Pour all excess metal out into an ingot mold and ream out the crucible.

FOUNDRY PROCEDURES (CONT.)

Always replace the crucible into the furnace and close the lid, also seal off the port hole in the lid of the furnace so that the furnace and crucible will cool off at the same rate thus contracting at the same rate reducing the thermol shock that would eventually cut short the life of your crucible and also the lining of your furnace.

Clean skimmer, plunger, and pyrometer regularly.

The furnace should be relined with a new refractory liner when conditions call for it, usually about once every two years (if you have good pouring habits) or as needed. Visual appearances will be your best measure of judgment.

FOUNDRY FACTS:

Gas is the biggest problem to casting.

Metal in a molten state absorbs gas and moisture out of the atmosphere.

The hotter the metal is the more gas and shrinkage will occur, never overheat or superheat the metal without a good reason.

Max expands up to 15% when heated (dangerous for ceramic shell molds).

Carbon is evacuated from a mold at 1300F., it is a general rule to take our kiln up to 1500F. just to be sure. Ceramic shell molds can be taken up to 1850F. but at about 1900F. the shell tends to crystallize and lose it strength.

If your molds are hot (500F.-1000F.) there is less chance of moisture being present and metal flowability will be increased.

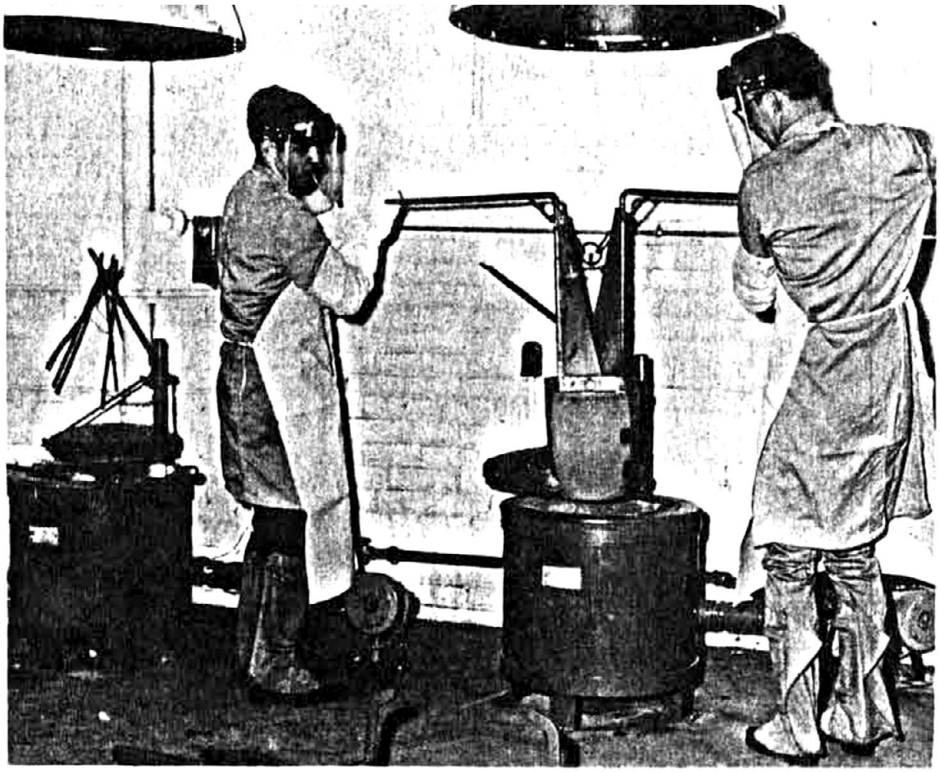
Wax pattern thickness should be as consistant as possible. Uniformity is important.

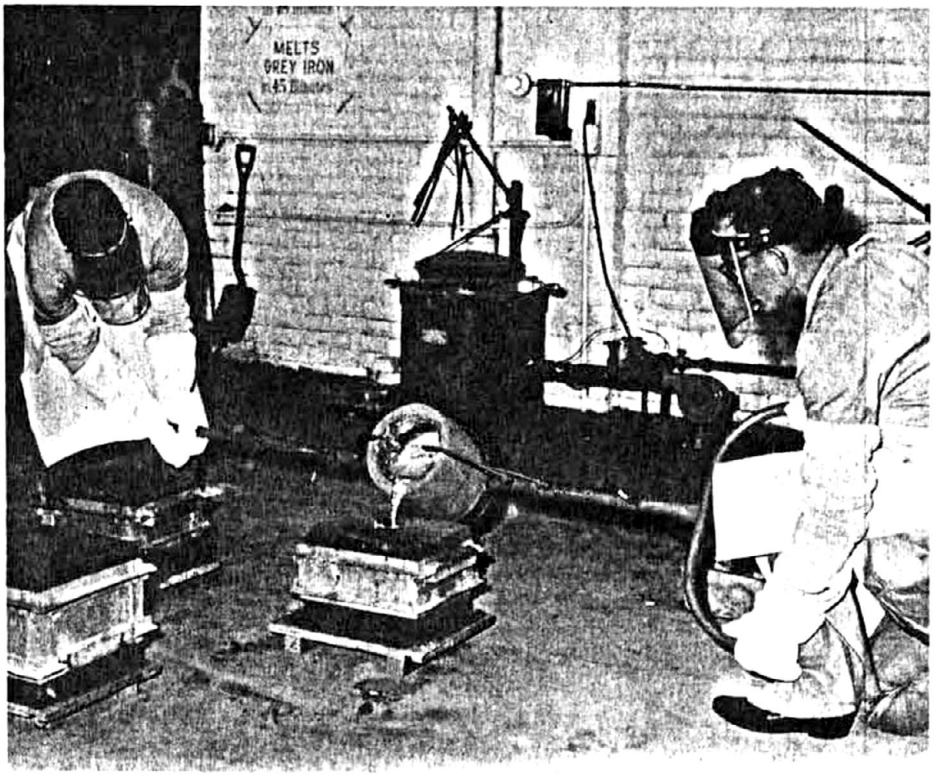
The thickest sections of your casting should be located nearest the cup.

Ceramic shell molds lose 300 F. the first minute after its removal from the kiln. Pour them as soon as possible.

Most casting errors can be avoided by proper sprueing.

If carbon is not sufficiently burned out of the mold it may leave a residue and cause inclusions and gas problems in your casting.




MELTS
GREY IRON

CRUCIBLES:

Crucibles are generally made of either clay/graphite or silicon carbide, longevity is about the same. The clay/graphite heats up a little faster, the silicon cardibde retains heat a little longer.

Crucibles are generally differentiated by a number corresponding to the number of pounds of aluminum it will hold.

A #30 crucible will hold 30 lbs. of aluminum and three times that for bronze, or, 90 lbs.

A #40 crucible will hold 40 lbs. of aluminum and 120 lbs of bronze.

A #100 crucible will hold 100 lbs. of aluminum and 300 lbs. of bronze.

A bottom pouring crucible pours from a channel at the bottom and eliminates slag, the metal at the bottom is hotter but protected by the top metal cutting down the possibility of gas problems.

TOOLS NEEDED FOR POURING:
One-man pouring shank
Two-man pouring shank
Skimmer
Plunger
Crucible tongs
Hand-gripping tongs
Pyrometer

FURNACE:
The stationary pit furnace operates on the principle of a combustable gas (natural, oil or propane) and forced air system. Much the same as an oxy-acetylene torch.

There are three types of furnace atmospheres:

1. That Neutral atmosphere: gas entering furnace is burned off right away in an even balance.
2. The Reduction atmosphere: There is more fuel (gas) forced in the furnace chamber than is being burned off, sometimes causes a smokey, black atmosphere, bad for melting aluminum and bronze. Slight reducing atmosphere used for smelting iron.
3. The Oxidation atmosphere: oxygen is burned off a little faster than it enters, creating a high amount of pressure at the top of the furnace, this is good because it prevents atmospheric gases from entering into your melt. It keeps out residue and impurities.

FURNACE (CONT.)

Oxidation causes desirable green flame above furnace port, works as a gas shield much the same as argon or helium does in Tungesten Inert Gas welding.

To prevent crucible from sticking to the bottom of the furnace or to the crucible block first place a piece of corrugated cardboard or heavy paper on the top of the crucible block prior to starting your melt or between each consecutive pour.

Furnace burner should come into the firing chamber at the top of the crucible block.

ALL NON-FERROUS ALLOYS SHOULD BE MELTED UNDER AN OXIDATION ATMOSPHERE.

WAX TO METAL CONVERSION:

1 lb. wax = 3 lbs aluminum

1 lb. wax = 10 lbs. bronze

[1 LB. OF WAX = 9 LBS. OF IRON.
1 OZ. FOAM = 12 LBS. OF IRON.]

PLASTALENE TO METAL CONVERSION:

1 lb. plastalene = 3 lbs. aluminum

1 lb. plastalene = 3 lbs. aluminum

1 lb. plastalene = 10 lbs. bronze 1 LB. PLASTALENE = 9 LBS. IRON.

RECIPE FOR PLASTALENE: (Schmidt Wax)

78 lb. batch:

44 lbs. fireclay
20 lbs. microcrystalline wax (can be previously burned out wax)
10 lbs. #10 wt. motor oil (5 1/3 qt.) 1 qt. oil = 2 lbs.
4 lbs. bearing grease

20 lb. batch:

12 lbs. fireclay
5 lbs. microcrystalline wax
2½ lbs. #10 motor oil
½ lb. bearing grease

FOUNDRY EQUIPMENT

The following list of equipment represents the minimum needed for an average Industrial Arts Section of Foundry, as a unit in General Metals. It was compiled with the thought in mind that aluminum and brass would be the metal used for castings.
A more complete description of each item will be found in the Product Description Section.

Minimum General Equipment For The Shop

Flasks	- Six to nine - Aluminum or light weight steel Three sizes, 10x12, 12x14, 12x18 *See Heading "Flasks" in Product Description Section*
Crucibles	- Three - Of correct size specified for furnace Clay graphite - standard or bottom pour
Foundry Sand	- Two or three barrels Albany No.1, 2 or Petro Bond - Petroleum base *See Heading "Molding Sand" in Product Description Section*
Parting Dust	- Twenty five Pounds (Cloth bags for same)
Aluminum Flux	- Twenty seven Pound Package Foseco #450 - 3oz. Ring tablets
Brass Flux	- Twenty five Pound Pail Foseco Cuprex #1 tablet or powder
Foundry Riddles	- Three - 18 inch diameter Screen size 16 mesh, 8 mesh and 4 mesh per inch
Ingot Mold	- One - #6 - three pig size For emptying crucible
Pick Up Tongs	- One pair - 36" or 48" For feeding metal to furnace
Crucible Tongs	- One pair for each size crucible Safety locking type - Plain or Bent Handle
Pouring Shank	- One pair for each size crucible Hnnd or Single End - Safety locking type
Molders Leggings	- One or two pair Asbestos or fireproof duck
Asbestos Gloves	- Two pair - lined, 14 inch
Molders Aprons	- One or two - 48" - Asbestos or fireproof duck
Safety Goggles	- Or Face Shields
Selection	- Of Foundry Patterns
Mold Boards	- Variety of sizes to fit flasks (3/4 inch reinforced plywood) (can make)
Bench for Molding	
Molders Bellows	- One - 8 inch
Buffing Compound	- For Aluminum - One Pound
Casting Metal	- Pig Aluminum and Clean Cast Scrap Clean Cast Brass Scrap

Minimum Equipment For Each Molding Station

One Sprue Cutter 3/4" x 10"
One Bulb Sponge
One Square Point Shovel
One Bench Rammer - 3 1/2" x 14"
One Finishing Trowel - 1 1/2" x 5" round point
One Gate Cutter and Spoon - 1"
One Slick and Oval - 1"
One Lifter 1/4" x 12"

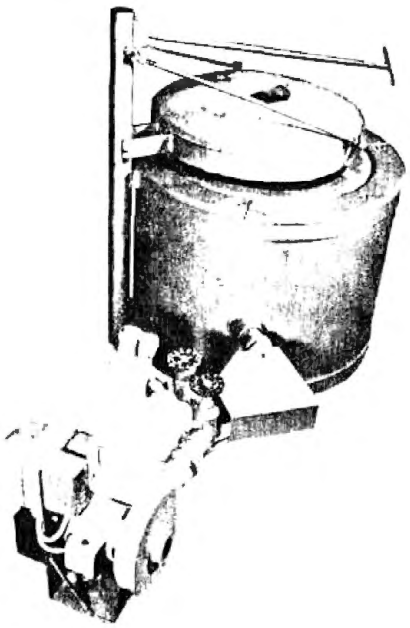
METAL MELTING FURNACES

Various types of melting equipment are used in foundries, including the Cupolo, Reverberatory Furnace, High Frequency Induction Furnace and the Stationary and Tilting Type Crucible Furnace.

The Cupolo is used in industry to produce high tonnage melts of grey and malleable iron. It consists of a tall cylindrical shapes, refractory lined furnace which is charged through its top, or charging bell, with pig, scrap, coke and limestone. Pig and scrap are the melt metal, the limestone serves as a fluxing agent during melting, and coke combined with forced air generates heat for melting. Blowers furnish high volumes of air which enter near the bottom of furnace, and heat generated by combustion of coke and air travels upward through the entire charge. The molten metal gathers in the bottom of the furnace and is tapped off at regular intervals. Charging and melting are continuous until it becomes necessary to dump accumulated slag and impurities from the bottom of the furnace. In large operations, the metal is tapped into an electric holding furnace where further elements or alloys may be added to the molten metal, and pouring temperature stabilized before pouring the molds.

Reverberatory Furnaces are high tonnage furnaces used in industrial non-ferrous metal foundries. Here again, charging and melting are continuous, wherein the scrap and pig are charged into a melting furnace chamber. Gas burners are directed against the roof of the melting chamber and the charge is melted by radiation from the hot roof and by the products of combustion passing over the charge metal. The molten metal gathers in the saucer shaped hearth, and flows into a holding chamber where it is either tapped off or used for continuous casting.

Electric Arc Furnaces and High Frequency Induction Furnaces are usually used in industry for melting high temperature metals. Both utilize heat generated by an electric arc passing through the charge, or by the high frequency induced current generated by an induction coil built into the furnace walls. Both methods are highly efficient and rapid, but the cost of such equipment for the School Shop is usually prohibitive.



Stationary Crucible Furnace

Crucible Furnace melting is the most widely used method, especially in the non-ferrous field, and shows a steady increase in popularity. The crucible size may vary from a No.10 crucible, capacity 50 lbs. of brass, to a No. 400, holding 1200 lbs. of brass. Two types of Crucible Furnaces are usually employed. They are the *Stationary Crucible Furnace* which uses a lift out or pull out type of crucible, ranging in crucible size from a No.10 thru No.150. Crucibles are lifted out by tongs, and set in a ring carrier called a shank. The crucible is carried by trolley or by hand, to molds, and poured. *A [illegible] Crucible Furnace is the most flexible and most [illegible] the average job foundry* which must cast many different alloys. They are the only type, which without any kind of modification, can be used for a variety of metals - copper, brass, bronze, iron and aluminum - since change of alloys means simply setting one crucible aside, and starting another.

The Tilting Type Crucible Furnace is not quite as flexible, because of its larger size and capacity. Its primary use is for pouring large castings, or making large production runs of the same alloy. It is impractical to switch crucibles in a Tilting Furnace to melt different metals. The Tilting Furnaces use crucibles with a long pouring lip which is fixed to the furnace wall. The furnace is built on a trunion base and when it is tilted, the metal flows from the lip into a ladle, a mold, or a carrying device. Changing crucibles requires complete shut down of the furnace, resetting the crucible with pouring lip, and resealing the furnace cover.

Several factors are considered when determining the superiority of one type of melting furnace over another. They include metal quality, flexibility, adaptability, investment cost, operating cost. Metal quality is listed first because it is most important. Crucible melting now, as in the past, is a standard by which other methods of melting are judged. The Flexibility and adaptability are outstanding in the Crucible type furnace, since no other type of melting equipment offers the wide variety of sizes and types. Regarding investment, Crucible Furnaces are of the simplest type and are among the lowest priced melting units. In foundries where castings vary greatly in size and quantity it is customary to have both Stationary Furnaces, with capacity up to No.100 Crucible, and Tilting Furnaces in No.200 to No.600 size Crucible. This range of sizes provides flexibility of different types of metal, and capacity requirements demanded of commercial foundries facilities. Operating costs include fuel, refractory maintenance, labor, and metal loss. Melting costs for Stationary Crucible Furnaces are the lowest obtainable. The life of high grade furnace crucible linings is expressed in terms of years, and cost of fuel per pound of metal melted is not excessive. Labor costs are comparable with other melting furnace types.

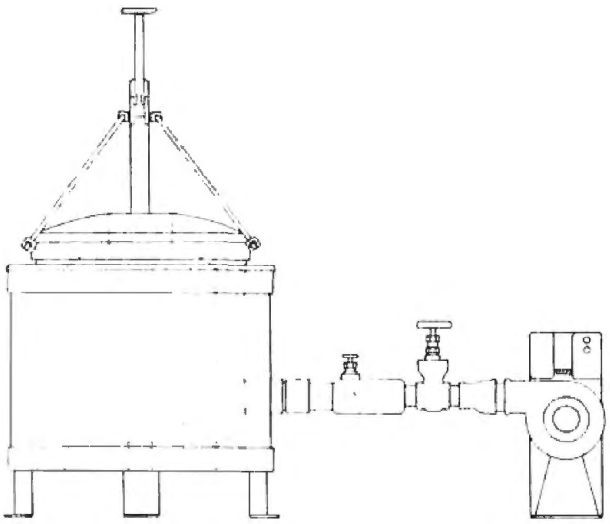
OPERATION AND MAINTENANCE OF CRUCIBLE TYPE FURNACES

The refractories most commonly used in Crucible Furnaces fall into the following categories: Linings, Insulating Materials, Base Blocks, and Cements.

Furnace linings are made of several types of refractories depending on the operating characteristics of the furnace. Industrial furnaces are lined with pre-burned, pre-formed sectional linings which *resist heat shock, abrasion, erosion, and have high thermal conductivity*. The two types most preferred are *Sillimanite* and *Silicon Carbide*. Silicon Carbide has high thermal conductivity, and must be backed with some good insulating material. Due to oxidation, Silicon Carbide linings grow vertically, and the furnace must be designed to compensate for this condition. Sillimanite Brick is made from Indian Kyanite, and burned at a high temperature to form highly stable mullite crystals. Mullite has an extremely low co-efficient of expansion, and a volume stability to produce a brick which has a very high resistance to thermal shock. It has a fusion point near 3260°F. and will stand up in service in excess of 3000°F. Other outstanding physical characteristics are its great resistance to abrasion, spalling, and the ability to carry heavy loads of high temperature without deformation. It can be heated and cooled rapidly, with no effect to the brick. Both Sillimanite and Silicon Carbide are expensive, but their service life offsets the initial cost of the furnace.

Crucible Furnaces, of all types and sizes, are designed with precise *combustion space and vent area*. Repair and maintenance of equipment is of prime importance and concern. *Slag accumulations, carbon deposits and other extraneous materials which build up on the lining wall should be removed regularly and the lining be resealed with a refractory cement*. The burner port should be smoothed up and freed of any obstacle in the way of refractory cement that may deflect the movement of the flame. The furnace cover is usually made of the same material as the lining and should be mainlained in the same manner. If the exhaust vent wears excessively, the cover should be replaced, otherwise the furnace performance will be impaired. *[illegible]* Following this procedure allows room for the cover to expand, minimizing cracking and lengthening life. Avoid overloading the cover with ingots placed around the exhaust port for preheating. Never drop ingots on furnace cover.

High temperature refractory linings should be backed up with a good grade of *Refractory Insulating* material. Insulating brick, block, and low conductivity castables are widely used. The insulation is normally cast between the refractory lining and the steel shell of the furnace. *Insulation [illegible] efficiency of the furnace, by cutting heat loss through the furnace walls, provides a support for the furnace [illegible] and provides greater furnace operation comfort.*



Cross Section

A Silicon Carbide *[illegible]* should always be used to support the crucible in the furnace. *[illegible]* Fire brick or fire brick material should be avoided, since fire brick has a low thermal conductivity and acts as an insulator, preventing heat from getting down to the bottom of the crucible. A block should be approximately the same diameter as the bottom of the crucible, and should be of height to correctly position the crucible within the furnace. *A Base Block is an essential [illegible] and should be replaced when it [illegible]*. A Section on Care of Crucibles gives further information.

The Industrial Gas Department of [illegible] Gas Utility Company [illegible] Gas Power. Their personnel can determine if the gas service installation is of *[illegible]* and also be capable [illegible] *the efficient operation*. Most localities are served with low pressure gas service. These lower pressures are generally expressed in terms of inches of water; as 1.73 inches of water equals 1 ounce. Nominal operating pressure for most brass and bronze metal melting furnaces is about 8 to 10 inches of water pressure.

It is highly important that a large enough gas service supply line be installed to the furnace, otherwise maximum melting efficiency will not be realized.

is the two valve manual control, in which the gas and air mixtures are manually adjusted. The advantage of the two valve system is the ease and convenience of *changing furnace atmosphere to suit a particular metal being melted.* See Section on Foundry Metallurgy.

Aluminum and copper alloys should be melted in a *neutral or slightly oxidizing atmosphere.* This condition results in faster melting, best fuel economy, and reduces gassed metals. Grey iron should be melted in a *slightly reducing, or rich atmosphere* to prevent oxidation and reduction of carbon in the analysis. The furnace atmosphere may be tested by holding a strip of zinc at the exhaust port. If black when withdrawn, the atmosphere will be strongly reducing; if yellowish, the atmosphere is oxidizing.

Fuel consumption in a well designed furnace should average 2000 to 3000 BTU per pound of yellow brass melted and poured at 2200°F. Laboratory tests on a Crucible Melting Furnace were run to determine the effect of melting time and economy of relatively high and low heat input furnaces. Tests show that by *increasing the heat input and raising the furnace temperature rapidly, less fuel was consumed and speed of melting more than doubled.* Faster melting also provides cleaner molten metal, since the metal charge is subject to the furnace atmosphere for a shorter length of time. The [redacted] High Speed Melter is an outstanding example of this type of furnace. Specifications can be found in the back section of the Manual.

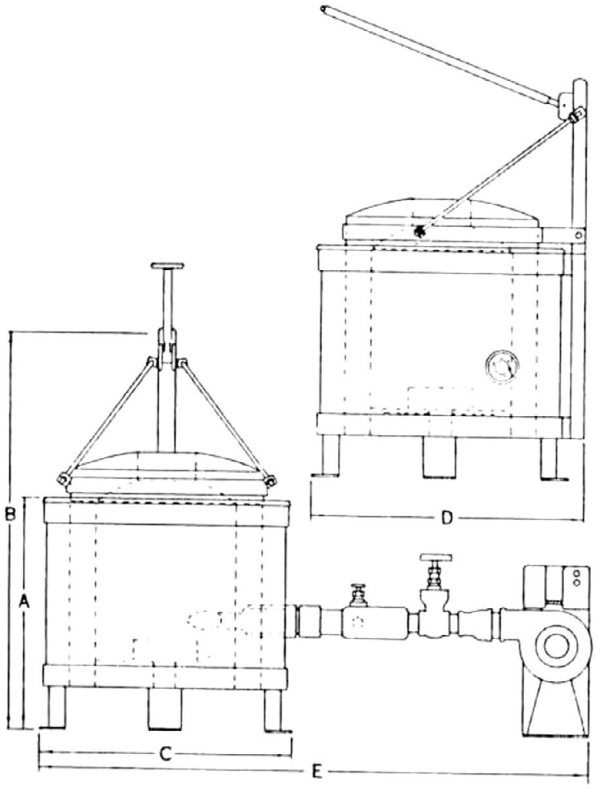
Temperature Indicating Instruments are a valuable asset to the School Shop Foundry, to aid in producing better castings, and to provide instruction in modern Foundry practice. The continued development of new casting alloys demands closer control for melting and pouring temperatures. *Automatic temperature control systems for Stationary Crucible Furnaces, or Cupolas, are seldom practical,* due to the rapid heating and melting cycles desired in these furnaces. When they are used, expensive modulating systems are used, which reduce the heat input gradually, as the melt approaches pouring temperature. Unless modulating controllers are used, the furnace operates at full burner capacity to control point before shut down, and the residual heat developed in the furnace walls by high BTU burners causes the furnace to overheat by 200 or 300 degrees. Most foundries use a *Portable Lance Pyrometer* and check molten temperature during the melt. As the metal temperature approaches the desired pouring temperature, the furnace is throttled manually. Residual heat from the furnace walls will raise the molten metal the remaining 50 or 60 degrees without overheating. The Portable Lance Type Pyrometer is less expensive than the automatic systems, and its use *provides training in furnace operation and control, as practiced in industry.*

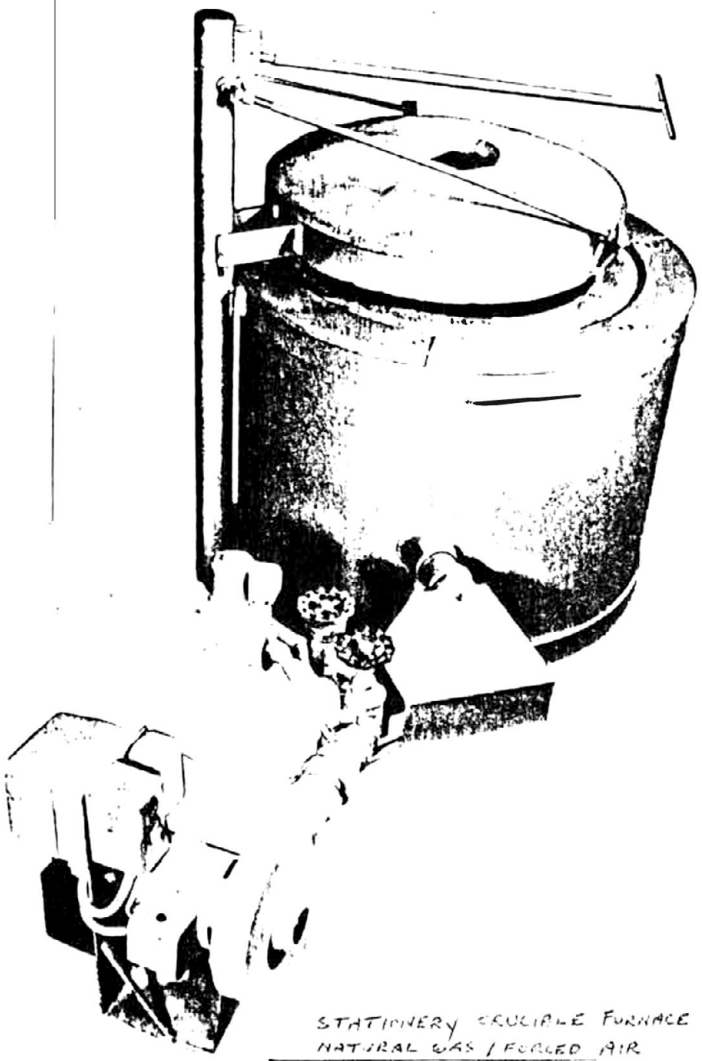
Portable Lance Pyrometer Used to Measure Molten Metal Temperature of Non-Ferrous Metals

Pot type melting and holding furnaces, *used for permanent mold casting,* present a different condition. These furnaces may hold 500 pounds of metal, *which is ladled from the pot into molds.* The furnace operates continuously, and the metal level in the pot is maintained by adding rejected castings or ingot. The melt is degassed and deoxidized constantly by a cover type flux. Once the initial charge is melted, a minimum amount of heat is required to maintain molten metal temperature. *Due to the lower heating rate* and the reduced tendency for overheating, a pot type melting furnace operates satisfactorily with standard automatic control systems.

Temperature measuring instruments, such as the *Pyrometer,* are actuated by a thermocouple. *The thermocouple consists of two dissimilar metals joined together by a positive bond,* such as the welded junction. If the weld junction is heated, an electromotive force is produced, roughly proportional to the temperature difference between their hot and cold junction ends. The thermocouple wires are usually separated by porcelain beads to prevent short circuit, and the thermocouple assembly is enclosed in a protection tube of heat resistant metal or ceramic. The electromotive force, or E.M.F., produced by heating, can be measured with a millivolt meter. The cold junction end is connected directly, or by lead wires of the same analysis as the thermocouple, to the meter. The scale of the millivolt meter is converted to read in degrees of Fahrenheit, instead of millivoltage. *As the thermocouple junction is heated, the E.M.F. increases proportionately, and is reflected by increased temperature reading on the meter scale.* Analysis of the thermocouple wire varies with the temperature range of the Pyrometer. Consequently, high heat resistant wires are used for higher temperatures. Different analysis wires develop different E.M.F., so the meter must be calibrated to match the thermocouple. Most common thermocouple analyses are Iron-Constantan between 600° and 1600°F.; Chromel-Alumel between 1200° and 2000°F. or 2300°F. intermittently; and Platinum-Rhodium between 2000° and 2800°F..

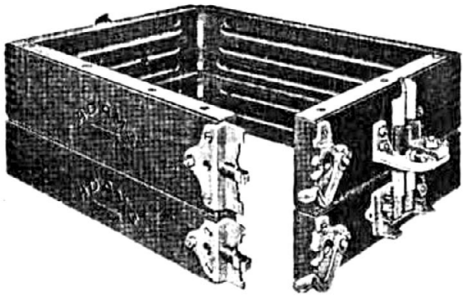
Automatic Temperature Control can be gained by designing the Pyrometer indicating needle to actuate auxiliary contacts which regulate the burner system. The controlling Pyrometer has the



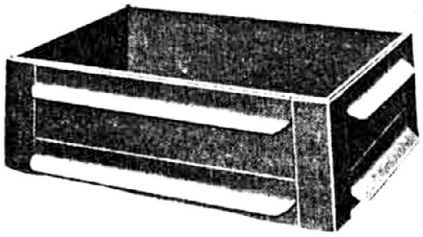


STATIONERY CRUCIBLE FURNACE
NATURAL GAS / FORCED AIR

Flasks are containers or boxes used to hold the molding sand when ramming a mold. They are made of wood, sheet steel, aluminum or magnesium, and consist of two sections - the bottom half, or *drag;* and the top half, or *cope*. The standard flask is rectangular or round, but they may be special shapes, depending on the casting. Flasks should be fitted with guide pins, so the mold cavities will align properly when the cope is fitted to the drag. Flasks are made in several styles but the most common are Solid and Snap types. The *Solid Flask* is used for both ramming and pouring the mold. This is the type generally used in School Shops. *Snap Flasks* are hinged at one corner so they can be unlocked, opened and lifted out of the mold for immediate re-use. The snap flask is more expensive, but one molder can re-use the same flask to produce any number of sand molds. When the snap flask is removed a *mold jacket* is placed over the mold to reinforce the sides of the mold, for pouring. Flasks for simple, flat back patterns, which do not require alignment of the mold cavities, can be made in the School Shops. Care should be taken to reinforce the corners to prevent spreading. Cherry, or similar lumber should be used. If flasks are to be purchased, *light weight aluminum* or magnesium should be selected, especially for the School Shop, *where weight is important*. A good selection would be two aluminum 10" x 12" with 4" cope and drag; two aluminum 12" x 14" with 4" cope and drag; one aluminum 12" x 18" with 4" cope and drag; one cherry snap flask 10" x 12" and one cherry snap flask 12" x 14". Two 12" x 12" and two 12" x 14" jackets can be made of 12 gauge steel, in the School Shop.



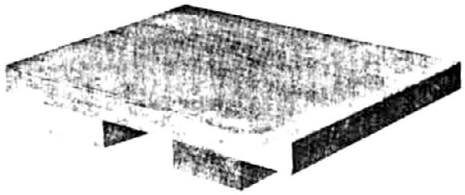
Cherry Snap Flask



Mold Jacket

Bottom Boards are used to support the flask and mold. They can be made in the School Shop to fit the various sizes of flasks. They must be sturdy enough to prevent sagging when the mold is rammed, and should be built with cleats. *Bench, or molding boards,* can be made of 3/4" plywood, preferably with 1/4" tempered, pressed wood working surface. The cleats should be 1" x 3" wood, securely fastened to the bottom. The bench boards are usually *2" larger in width and length* than the inside bottom flask dimension. *Bottom, or floor boards* support the finished mold during the transfer to the casting floor, and during casting. The bottom boards can be made of 1" lumber, spaced to provide ventilation for the mold, or of 3/4" plywood with 1/4" perforations on 3" centers, for ventilation. Cleats are 1-1/2" x 4" wide. Bottom boards are usually *3" larger than the inside flask dimension.*

Solid Flask



Bottom Board

Bench Hammer and Riddle

Foundry Riddles are used to screen the sand. The 4 mesh screen is used to aerate, and remove trash and lumps, from the molding sand after tempering. 8 and 16 mesh riddles are used to screen the fine sand, packed adjacent to the pattern, when ramming the mold. The wood hand riddle with galvanized mesh is inexpensive and adequate. They are made in several diameters, but the 18" is most satisfactory for the School Shop. A 4 mesh and an 8 mesh are the minimum requirements for the School Shop.

Bench Hammers are usually made of dried hickory, or hard maple. The butt end is turned and has a *flat face*. The other end is *wedge shaped*. Lengths vary from 15" to 14" and butt diameters vary from 3" to 3". Wedge end of rammer is used to pack the sand firmly around the outside edges of the flask. This area of a mold must be firm and strong enough to hold the pattern shape, and support the molten metal when it is poured into the mold cavity. The butt, or flat end, of the rammer is used to ram the center of the mold. If this area is rammed too hard it will prevent the gases escaping from the mold cavity. A molder must learn the correct ramming hardness through experience.

Molders Bellows are used to blow loose sand from the surface of the mold. High pressure air, unless used carefully, can destroy the mold cavity and convey detrimental condensation and compressor lubricant from the air tank to the surface of the mold cavity.

Sprue Pins are used to make the *vertical passageway* for the metal to pass through the cope to the runner or gate of the mold cavity. Tapered pins of wood may be turned out easily on a lathe, then smoothed and finished with shellac. A pin tapered from 1-1/4" to 5/8", and 7" long, is a good size for School Shops. The sprue pin is placed in position in the cope, and molding sand is rammed around it. It is then removed after the cope is rammed, and struck off.

Sprue Cutters serve the same purpose as sprue pins, except they are tapered hollow brass tubes used to cut the vertical shaft, after the cope is rammed. Standard sprue cutters are tapered 7/8" to 1/2", 1" to 5/8", 1-1/8" to 3/4", and 1-1/4" to 7/8". Lengths vary from 6" to 10".

Parting Dust, or Partien, is powdered silica, brick dust, bone flour or fine charcoal. It is sifted over the pattern and top surface of the drag to prevent sand in the cope from sticking to the pattern and drag. The powder is dispensed by placing it in a coarse weave bag, and dusting the area lightly. A more recent and satisfactory product is a fast drying *aerosol dispensed graphite and refractory material. Other similar formulations* can be purchased for spraying the mold cavity surfaces and cores for better casting finishes.

The *Molders Sand Shovel* is a light weight, sturdily constructed tool used for scooping,sluicing and tempering sand, and for filling the flask with molding sand. They have a square nose, flat dish blade 10" wide by 12" long. Production molders generally use the grip of the shovel to *ram the sand around the outside edge of the flask*, consequently the grip is sometimes designed like the wedge end of the bench rammer.

A *Bulb Sponge* is used to moisten molding sand around a loose pattern before lifting the pattern. It consists of a rubber bulb with a hair brush to control placement of moisture at the required area. *Great care must be exercised when using a bulb sponge* to prevent adding excess moisture at the mold cavity. Wet sand generates steam, causing blows and porous castings.

Molders Tools are the hand tools of the molding trade. There are an unlimited number of types, shapes and sizes, but they are all used for putting finishing touches and necessary repairs on the surface of green sand molds. They fall into four main categories - *trowels, slicks, spoons and lifters.* Trowel blade sizes are 1" to 2" wide by 4" to 7" long, with square, round or heart shaped points. The 1-1/4" x 5" round point is recommended for School Shop work. Trowels are used primarily for smoothing and slicking the surface of the drag prior to applying parting compound. Slicks and spoons of different shapes and sizes are used for repairing and slicking the surfaces of mold cavities, and for cutting gates and runners from the sprue to the mold cavity. Lifters are used primarily for removing or smoothing loose sand in the bottom of deep mold cavities. Strike off bars and vent rods can be made in the School Shop.

Gatecutter and Spoon

Trowels

Slick and Lifter

Patterns are made of wood, metal, plaster-of-paris or plastic materials, if they are to be permanent equipment. They are made of wax, plastic resins or polystyrene if the pattern is to be lost or destroyed by heating of the mold or by the hot cast metal. *Permanent type patterns* are the *loose flat back*, such as a paper weight or book end; *split patterns*, and *match plates* wherein the pattern is attached permanently to a plate of wood or metal. The flat back loose pattern can be made in the School Shop, or such items as ceramic or metal wall plaques, may be used to cast a master. When making or selecting an item for a pattern, *be sure the sides and cavities are designed with taper*, or "draft", so the pattern can be lifted from the mold cavity without damaging or drawing sand from the edges. To simplify lifting or drawing a loose pattern, simple *draw pins can be made in the School Shop.* For wood patterns, braze a No.10 flat head x 2-1/2" wood screw to the center of a steel slug 1/4" thick by 2" diameter. You are actually brazing a flat disc head to the wood screw. Prior to using the pattern, drill starting holes to depth of 1/2 the pattern thickness in the back, or flat side, of pattern. Work the screw threads in the starting holes so they enter and release freely. For metal patterns, follow the same procedure except use 1/4" x 20 NC stove bolts, and drill and tap the pattern. Split patterns will work more satisfactorily if permanently mounted on a board to make a *match plate.* Care must be taken to *align both halves of the pattern* so the mold cavities in the cope and drag match and align correctly. Plywood of 5/8" or 3/4" thickness with tempered, pressed wood surface will make suitable mounting boards.

CRUCIBLE TONGS AND SHANKS

After the crucible has been withdrawn from the furnace with tongs, it is placed in a Pouring Shank to facilitate pouring the molds. Like the tongs, the crucible shank should fit the size crucible being used. Crucible Shanks are manufactured in the "One Man" Hand Shank, and the "Two Man" Single End Shank. The Hand Shank is used for smaller size crucibles when the weight can be handled safely by a single man. *See Figure 6.* The Single End Shank is used with heavier crucibles where the weight requires two men, or the assistance of a hoist. When the size requires a hoist, it is necessary to use a Shank Bail to support the single end shank and crucible. *See Figure 5.*

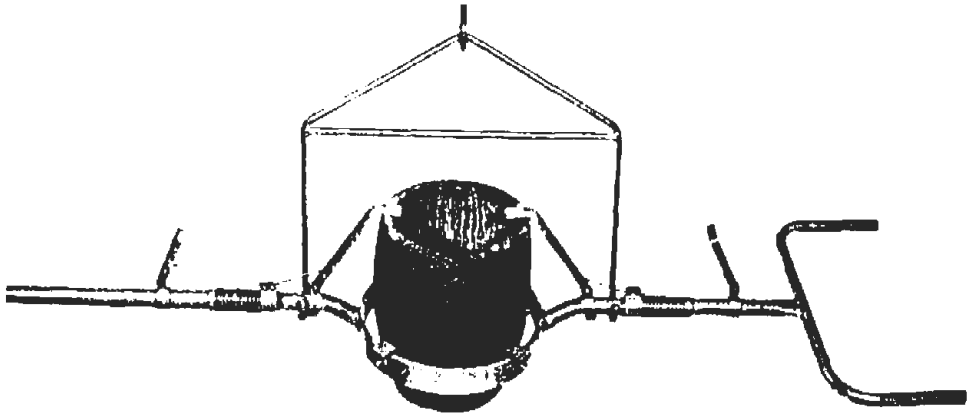


Figure 5

Safety Single End Shank with Adjustable Pads, Adjusts to Fit Two or More Sizes of Crucibles

There are several important features to consider when selecting pouring shanks. The crucible ring should be tapered, the upper and lower inside diameters held to close tolerance so the ring seats below the crucible bilge, or the largest diameter of the crucible.

Supporting pads should be located inside the ring, for three or four point suspension. Such a design provides an air space between the crucible and shank band, and prevents heat transfer from crucible to band, adding to life of both crucible and shank. Single End Shanks should be designed with offset handles for better balance and to facilitate pouring. *Figure 7.*

Crucible shanks are built with tubular handles to provide light weight and rigidity.

Figure 6
Safety Hand Crucible Shank
Fixed Pads Non-Adjusted

Figure 7
Safety Single End Shank
Fixed Pads Non-Adjusted

Stationary crucible furnaces require a "lift out" type of crucible as a vessel for holding casting metal during melting. Crucible tongs and shanks are tools necessary for handling the crucible during melting and pouring. Tongs are used to place the loaded crucible into the furnace chamber prior to melting, and to withdraw the crucible of molten metal at close of the melting period. When melt has been withdrawn, the crucible is placed into a Pouring Shank, or holder, to facilitate pouring of the metal into molds. Both tools should fit the specific size crucible being used. This prevents damage to the crucible.

There are certain hazards related to melting and pouring molten metal. These are minimized by using properly designed crucible handling tools. The following design features for such tools are recommended by leading crucible manufacturers.

One of the oldest, most satisfactory designs for Tongs, is the Claw type. Each gripper is die formed to fit the contour of the crucibles, so it nests securely with a minimum of squeeze, and pressure, and grips below the bilge of the crucible. An eyebolt is desirable when lifting the heavier crucibles from the furnace. *See Figure 1.*

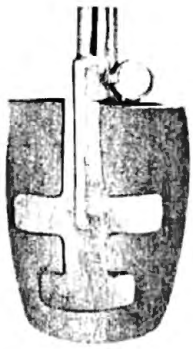


Figure 1
Illustrating Claw Gripper and Lifting Eyebolt

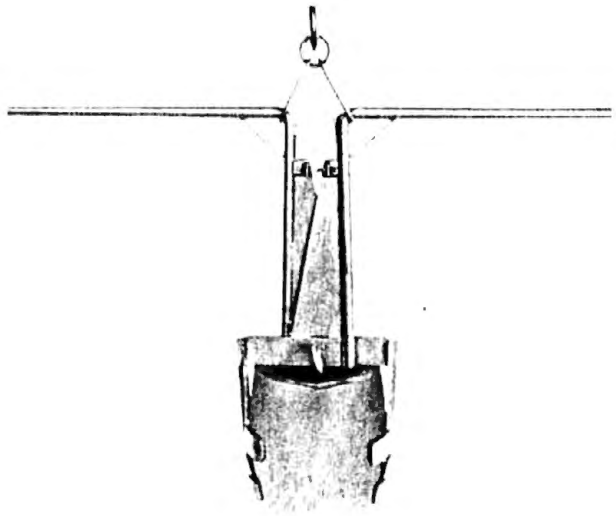


Figure 2
Bent Handle Tongs

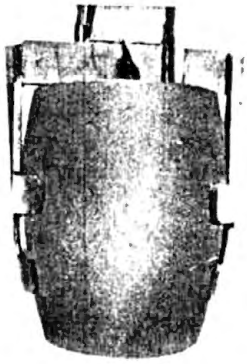


Figure 3
Illustrating Improper Top Clearance to Prevent Chipping

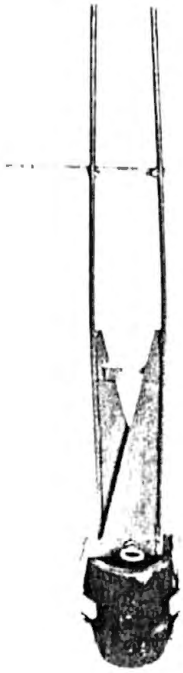


Figure 4

The problem of premature crucible failure is sometimes incorrectly attributed to furnace operation and rate of firing. If the instructor is experiencing short crucible life, the crucible tongs should be inspected for correct design features. Crucibles will normally burn out through oxidation and erosion of the outer diameter and flux attack and oxidation of the top inner diameter. This reduces the wall thickness of the crucible. Improper tong clearance is indicated by crumbling and breaking of the top lip. Vertical cracks, originating from the crucible lip, also indicate pinching and excess gripping pressure applied to the hot crucible.

The tongs must have proper top clearance to prevent pinching and chipping the top lip. Improper clearance at this point is one of the major causes for premature crucible failure. *See Figure 3.*

The tongs should close until they touch the side walls of the crucible and should have the adjustable stops to prevent additional squeeze or pressure. The stops are attached to the tong handles and meet when the gripping pads touch the crucible walls. It should be possible to spring the tong handles together without subjecting the crucible to additional pressure. The stops are adjustable to compensate for crucible wear, or for when starting a new crucible. The tong handles should be reinforced with a web to add rigidity and strength. *See Figure 3.*

Plain tongs should have an adjustable locking bar, to lock them securely closed after gripping the crucible. The lock prevents accidentally opening the tongs while raising the crucible from the furnace. *See Figure 4.*

Crucible tongs are manufactured in several designs. Most popular are the one man Plain Tongs with straight vertical handles for raising the smaller size crucibles, and the two man Bent Handle Tongs for heavier charges and

MIXING INSTRUCTIONS FOR PLASTALENE:
Melt wax in a large metal container (garbage can) over medium heat, when wax has completely melted pour in oil and grease and stir. Next, sift in the clay and stir with a paddle until all ingredients are mixed thoroughly. Turn off the heat and let cool. Prepare a tray or a pan several inches deep and as wide as possible to pour the mix into. A large cookie pan works fine. When mix has cooled but is still pourable start to pour out the mix into the pan. Let it stand until solidified then cut squares and remove them putting them into another container. At first it will be quite sticky but this can be avoided by increasing the amount of clay and wedging talcum powder into the mix when it is cold.

ALLOY COMPOSITIONS:

ALUMINUM

*Silicon aluminum: 10-13% Silicon, .10% Copper, .05% Manganese, .60% Iron, .10% Magnesium, .10% Zinc, .10% Lead, .05% Tin, .02% Titanium, the remainder is aluminum. It is a Binary alloy.

-Melting Point 1280 F.

-Pouring Temp. 1350 F. (ceramic shell)

1450 F. - 1550 F. (bonded sand)

De-gaser 190 tablets or some comparable degasing agent should be plunged into the melt to rid gases and impurities from the molten metal.

Aluminum is very sluggish in the melted state, it shrinks at a high rate and is soft and crystalline in strucutre internally. It absorbs a tremendous amount of gas in a molten state.

Advantages: It is light in weight, less ramming is needed for sand molds than for copper base alloys, it is relatively cheap.

Disadvantages: High rate of gas absorption, must be de-oxidized, hard to patina, hard to weld without a T.I.C. welder, cools very slowly.

Contains Silicon which is a natural flux and forms a vapor shield over the crucible when alloy is melted, the vapor shield prohibits atmospheric gases from pentrating into the melt and contaminating it. Self cleans to a minimal extent.

MELTING PROCEDURE:
Clean Furnace: Clean Crucible: Clean Metal Scrap: Melt under slight oxidizing atmosphere. When aluminum begins to become turbulent and starts to spin in the crucible, stop furnace and take a pyrometer reading. Generally it is very close to pouring temperature.

MELTING PROCEDURE: (CONT.)

Crucible should be taken out of the furnace 100 F. below the desired pouring temperature because it is characteristic of aluminum to gain in temperature after it has been removed. It may increase as much as 200 F. - 300 F.. If you plunge the degaser tablet while it is still gaining temperature, the metal will still be absorbing gas and defeating the purpose of your degasing procedure.

Always preheat your foundry tools such as; plunger, skimmer, and ingot molds.

You should always pre-heat ingots or scrap before adding them to your melt, this will avoid additions of gas and moisture as well as decreasing the possibility of molten metal spueing from the pot due to gas expansion and moisture.

Mold wash should be painted on ingot molds, skimmer, and plunger at least one hour prior to pouring.

When degasing try to create as little turbulance as possible, unneeded stirring causes more gas to enter the metal. Plunge a pre-measured tablet of degasser with the aid of the plunger to the bottom of the crucible and hold it there until all bubbling has stopped. Remove the plunger and immediately skim the surface of all impurities.

The skin which continually forms over the surface of the aluminum is desireable, it forms a gas shield to keep out atmospheric contamination and gas. When you pour have someone pealing the skin back with a skimmer throughout the pour.

When pouring remember to pour continously and low to the cup. Fill the cup to the top to increase pressure and to insure that it will function as a reservoir as the metal below shrinks.

Aluminum alloys once poured should be left undisturbed over a longer period of time than copper base alloys. The larger the volume of metal poured the longer the setting time.

Available book on aluminum alloy information: "Federated Aluminum Casting Alloys Handbook"

Write: A.S.A.R.C.O. (American Smelting and Refining Company)
P.O. Box 219
Alton, Illinois 62002

Free book on aluminum: Reynolds Metals Company
130 So. Beniston Ave.
St. Louis 5, Missouri

BRASS AND BRONZE CASTING ALLOYS:

The only difference between brass and bronze is the percentage of zinc in the alloy. The more zinc content the more chance the alloy is brass, the less content of zinc the more the chance is that it is bronze. Brass tends to be more gas ridded and needs careful melting procedures, good ventilation and a flux and deoxidant whereas with silicon bronze there is no need to flux or deoxidize the melt.

ALLOY SPECIFICATION:

1. Leaded tin bronze: Melting point 1800 F. - 1820 F.
   Solidification Range: 250 F. (very good)
   Pouring Temp. between 3/16" per ft. average
   Must be melted under oxidizing atmosphere

2. Red brass and semi-red brass (85-5-5-5): Previously very popular alloy used by sculptors, recently replaced by silicon bronze.

   85% Copper, 5% Zinc, 5% Tin, 5% Lead
   Melting point 1800 F. - 1840 F.
   Solidification Range 100 F. (very short)
   Pouring temp. 2100 F. - 2250 F. (2300 F. for cold molds)
   Absorbs a lot of gas and must be deoxidized with Phos-Shot pellets

3. High leaded tin bronze:
   Melting point: 1760 F. - 1770 F.
   Solidification Range: 280 F. (very good)
   Pouring temp.: 2000 F. - 2100 F.
   Shrinkage rate: 1/8" per ft.

   80% Copper, 10% Tin, 10% Lead
   --Not good for sculpture because of the high rate of gas absorption and the metal is very sluggish.

4. Yellow brass: (Naval Brass)
   Melting point: 1600 F. - 1680 F.
   Solidification Range: 40 F.
   Pouring temp.: 1900 F. - 1950 F. (you must use a flux with the melt)

   60% Copper, 30% Zinc, 5% Tin, 5% Lead
   --(Sand cast at 2100 F.)

*Metal tends to distort and loose shape under stress, it warps very easily. Metal has a very high shrinkage rate 5/32" per ft. (very high), pour as cold as possible. When white smoke appears this is the zinc oxidizing off the alloy, you should pour it immediately. In melting it a second time you should add some zinc to compensate for the loss.

*Good metal for pouring into traditional molds and sand by very poor for ceramic shells

*Very weldable but cannot withstand stress. Sprues should be larger so that metal will enter without agitation.

ALLOY SPECIFICATIONS: (CONT.)

5. Nickle Silver: (German Silver)
Melting point: 2000 F.
Solidification Range: 200 F.
Pouring Temp: 2200 F. - 2350 F.
Shrinkage Rate: 3/16" per ft.

58% Copper, 3% Tin, 5% Lead, 16% Zinc, 18% Nickle.

-Fine mechanical properites, resistant to corrosion and tarnishing, after polishing it looks like stainless steel. Absorbs carbon and hydrogen gases readily, melt under good oxidizing conditions. Tin added for hardness and strength, also polishing qualities. Lead added for increased machineability.

-Good for Ceramic Shell.

5. Manganese Bronze: (High strength Yellow brass)
Melting Point: 1690 F.
Solidification Range: 40 F. (very low)
Pouring Temp: 1900 F. - 2000 F.
Shrinkage Rate: 7/32" per ft. to 9/32"(very high)

66% Copper, 3% Iron, 3% Manganese, 5% Aluminum, the remainder is Zinc.

-Manganese increases stability, tremendous amount of strength. Zinc added for strength and hardness. Aluminum and iron added for strength. Metal will withstand high thermol shock.

-Oxidizing atmosphere needed for melting. Use large sprueing system to eliminate turbulance of metal entry.

7. Aluminum Bronze:
Melting Point: 1880 F. - 1900 F.
Solidification Range: 60 F. (low)
Pouring Temp.: 2100 F.
Shrinkage Rate: 7/32" to 9/32" per ft. (very high)

89% Copper, 1% Iron, 10% Aluminum.

-High amount of gas absorption, large sprueing system needed. You must use a commercial de-oxident.
-Very hard to machine surface, cut, weld and patina. About the best you can get would be gray or black.

Silicon Bronze:
Melting Point: 1830 F. - 1870 F.
Solidification Range: 260 F. (excellent)
Pouring Temp.: 2050 F. - 2150 F.
Shrinkage Rate: 3/16" per ft.

91.32% Copper, .02% Tin, .02% Lead, 4.16% Zinc, .06% Iron, .06% Nickle, .16% Aluminum, 4.20% Silicon.

-Considered to be the best sculpture casting bronze available. Foundry, welding and pouring characteristics are excellent. Has excellent flowability and needs no additional fluxing procedures or de-oxidants.

REPAIR OF CASTINGS:

Aluminum: Aluminum can be repaired by welding, it is possible but very difficult to weld aluminum with oxy-acetylene. Special commercial fluxed reds must be used and a slight reducing atmosphere. Aluminum soldering can be done but again commercial fluxed rods must be used with a slight reducing flame. For best results use Tungsten Inert Gas (T.I.G.) with matching alloy rods and either helium gas or argon. The welder should be set for A.C. current and on inert gas arc and "Continuous."T.I.G. welding aluminum is very easy, fast, clean, and will reduce warpage. Tungsten should be ground to a round point.

Commercial Non-Metallic Products: Devcon Aluminum Putty, aluminum powder mixed with epoxy. The main problem is color matching. Sets generally in 24 hours.

Bronze: Bronze can be easily welded with either oxy-acetylene using matching rods and a commercial all-purpose brazing flux and a slight oxidizing flame. Bronze can be welded very easily and cleanly with Tungsten Inert Gas, the welder should be set for D.C. Straight Polarity and the tungsten should be ground to a very sharp point, the machine should be set for "inert gas arc" and "Continuous" should be off.

Commercial Non-Metallic Products: Devcon Bronze Putty, bronze powder mixed with epoxy. Again color is hard to match. Putty sets in 24 hours.

CASTING DEFECTS:

Terminology:

1. Gas Flow: Rough, jagged holes.

2. Cold shut: Round-edged holes

3. Hot Tear: Usually a small thin crack, generally found where thinner sections occur next to thicker sections. Where cooling of thin areas is faster than thick areas, auxiliary sprues will compensate for the thin areas.

4. Misrun: Also called non-filled areas, result is an incomplete casting. Caused by:
   1. Too low a pouring temperature.
   2. Mold temperature too low.
   3. Metal fluidity too long.
   4. Holding time between mold pre-heat and metal pour is to long, causing mold to cool.

5. Mold-Buckle: On long flat surface (reliefs) it is sometimes difficult to maintain proper dimensional stability becaouse the mold has flexed from heat and pressure of the poured metal. This causes an increase in the size of the casting. The cause is a weak mold.

CASTING DEFECTS: (CONT.)

Mold-Buckle: For Ceramic Shells CHECK:
1. Slurry for any possible gelation
2. Viscosity, insufficient powder (Pl-W)
3. Apply additional dip coats

6. Scabs: Jagged lines of demarcation usually seen on flat surfaces. Caused by pre-dip or second coat slurry finding its way into a crack on the surface of the first coat.

7. Metal Flash: Sometimes called "fins" or "plus-metal", occur as a thin positive piece of metal caused by a crack in the surface mold.

8. Slag: Rough cavities, saucer-shaped and smooth, caused by dirty metal, incorrect sprueing is generally the cause.

9. Mold Erosion: Characterized by rounded corners on castings where there should have been sharp corners, caused by oxcessively high slurry viscosity. Could also be caused by inadequate draining techniques of the shells in the process of applying slurry.

10. Metal Breakthrough: Bubbles of excess metal apprear on the casting, usually on concave surfaces, inside sharp corners, holes and recessed areas.
1. Due to insufficient wetting of the wax pattern by the slurry.
2. Use proper amount of Ultra-wet 601
3. Clean wax pattern thoroughly with alcohol, let dry adequately.
4. Use a light jet of air from a hose or bellows to break bubbles accurring on the surface during the dipping.

11. Gas defects: Not too common with Ceramic shell molds because of the mold permeability. If it occurs usually it is because carbon has not been completely removed in the de-waxing or burnout causing non-fill or porosity and possible gas absorption.

-Extend burn-out time and check burn-out atmosphere and temperature. Atmosphere must be oxidizing.

12. Shrinkage and Draws: Rough cavities entering casting on heavy sections or at joint of sections.
-Cause: Incorrect sprueing.

13. Blowholes: Rough shaped holes occurring on the outside of the casting of the area of thicker sections. May be found just below surface after machining. In severe cases, sections of the casting may be hollow.

CASTING DEFECTS: (CONT.)

Blowholes: Cause, Too low a pouring temperature.
(cont.)

14. Inclusions: Non-metallic inslusions can be stemming from many things and and are caused by:
    1. Poor mold handling, stucco particles may drop into the mold prior to casting.
    2. Mold cracks, erosion from the sharp edges drop into the mold and are dispersed throughout the casting when the metal enters the mold.
    3. Furnace or crucible refractories breaking away and finding its way into the melt.
    4. Dirty metal
    5. Poor de-oxidizing procedures.

15. General Rough Surface: General surface roughness can generally be traced to the first drip slurry viscosity when doing Ceramic shell. Higher viscosities produce castings with smoother surfaces. Intricate patterns cannot be drained properly so a lower viscosity is favorable for a very complex piece and the proper drain-in procedures should be executed.

    -Facing slurry must be accurate to insure proper wetting of the wax pattern and precision surface. If the second coat and additional coats are not accruate the hot metal upon entering the mold may break down previous coats and cause plus metal and fins and also possible inclusions.

    -When investing the wax with the first two coats of Ceramic shell DO NOT LAY THE PIECE DOWN IN THE STUCCO. HOLD ON TO IT!

FORMULAS FOR PICKLING AND CLEANING CASTINGS:

Cleaning Solutions for Bronzes:

1. Nitric acid	1 Gal.	2. Hydrochloric		
Sulphuric acid	2 Gals.	acid	30%	
Water	5 Gals.	Water	70%	

-Extended time in the solution is not advised, visually check periodically.

-Aside from Traditional patination with acids some other possibilities are:

1. Electro-plating with copper, Nickle-chrome, Nickle silver
2. Painting
3. Oils
4. Waxes

TRADITIONAL INVESTMENT CASTING PROCESS (LOST-WAX):

Investment Recipes:

1. 2 parts moulding plaster
   1 part silica flour
   1 part medium or coarse grog

   (Parts by weight).

-I have used the above formula for the past seven years with very satisfying results.

2. 1 part moulding plaster
   1 part silica flour
   1 part medium or coarse grog
   1 part fireclay

-This formula also has proved to be fairly successful.

3. 1 part moulding plaster
   1 part medium or coarse grog
   1 part silica flour
   1 part luto

-Luto is crushed up previously cast traditional investment.

4. 1 part moulding plaster
   1 part silica flour
   1 part luto
   1 part mica (Perlite)

-MOLD TO WAX FACING SLURRY SHOULD BE MADE UP OF 50% MOULDING PLASTER AND 50% SILICA FLOUR--TO BE APPLIED TO THE WAX TO REPRODUCE SURFACE DETAIL AND BUILT UP TO AT LEAST 1/2". THE PLASTER AND SILICA FLOUR SHOULD BE DRY MIXED IN EQUAL PARTS THEN WATER IS ADDED TO MAKE A SMOOTH CREAM CONSISTANCY SLURRY WHICH IS SPLASH COATED ONTO YOUR WAX PATTERN.

-All dry materials can be pre-mixed and stored indefinitely as long as it is kept dry! For best results store in sealable plastic garbage can liner bags inside a dry garbage container, A standard cement mixer works fine for mixing dry materials.

MAKING THE MOLD: mix your facing with water (ALWAYS ADD ~~WATER TO DRY MIX~~ DRY MIX WATER NEVER ~~DRY~~ WET TO ~~WET~~ DRY) and splash coat your wax piece and sprue system with 1/4" of facing mix making sure also to coat entire surface of wax, sprues and outside of pouring cup. Mix a second batch and apply an additional 1/4" over the first coat (remember to keep the mold material moist at all times). If your piece is hollow prior to the facing coat insert your core pins, the pins can be pieces of bronze rod or welding rod or better yet nails that have a head on one end. These pins should be strategically placed around your pattern and inserted through your wax wall so that half the nail protrudes on either side of the wax wall. These core pins will support the inner core of investment once the wax is evacuated. If your wax piece is solid core pins are not needed.

After the facing coat is complete you then mix up your coarse back-up investment (plaster, silica flour, grog), the consistancy should be like that of oatmeal DON'T OVERDO THE WATER!

This mixture should be poured into the core and upon filling it

MAKING THE MOLD (CONT.)

allow it to harden but keep ; it moist. When facing and core are set hard but moist, mix another batch of the coarse investment and hand pack it around the entire pattern and sprues and cup, this should be done in overlapping layers. Build up at least 1 to 1 1/2", let set until hard but keep moist.

Next invert pattern so that the cup is down and place it on a sheet of cardboard (the cardboard should exceed the size of the entire diameter of the pattern by at least one foot, the distance however will increase with the size of the sculpture). Prepare a cage to fit areound the diameter of the invested pattern (chicken wire is generally used) if possible try to make it a cylinder shape to make it easier to handle, the mesh should be laced with wire to hold the cylinder together. Next wrap the wire with an outer cylinder of tarred roofing paper and secure it by wire or tying. THE MESH CYLINDER SHOULD EXCEED YOUR PATTERN IN EVERY DIRECTION BY AT LEAST 2 to 3" (depending on how large your piece is and the volume of metal it will be receiving). THE HEICHTH OF THE CYLINDER SHOULD EXCEED YOUR PATTERN BY AT LEAST 4". The outer mesh retainer can be shaped to conform to any irregular shaped mold to conserve weight, material, and kiln space. The mesh does not have to retain a cylinder shape of you have an irregular shaped mold.

Your inverted mold can be held by someone or you can secure it to the cardboard with wax or even investment material. Now place your mesh/paper cage around your pattern and seal the retainer to the cardboard, again plaster can be used for rigid support.

Mix a sufficient amount of coarse investment (ideally mix enough to fill the entire cylinder with one pour) and pour it down the side of the cylinder so you do not disturb your pattern, fill retainer to the top and let it set hard and undisturbed. DO NOT POUR ONE MIX AND LET IT SET AND THEN POUR THE REMAINDER, IT SHOULD BE ONE HOMOGENOUS UNIT! DO NOT SEGMENT THE MOLD!

The mold should set for at least one day before setting it in the kiln, the mold should be kept moist when it is placed in the kiln, if it has dried to the touch use water in an atomizer to dampen it-AGAIN MODERATION IS THE BEST POLICY! Before loading in the kiln and after the mold has hardened to its maximum remove the outer retainer of tar paper and into the top scratch into its surface your initials, number of pounds of metal to be poured into the mold and the abbreviation of the type of metal to be poured (Al.-aluminum, BR.-bronze). Now invert your mold and remove the cardboard and duplicate the same information as you did on the bottom (initials, metal weight, metal type).

For extremely large molds a drain spout can be designed into the pattern at the bottom of the pattern to allow wax to drain out from there eliminateing the need to invert the heavy fragile mold after burn-out. The void left for the drain spout after wax burn-out is plugged prior to lowering the mold into the pouring pit with a plug of refractory brick and fireclay tamped into the hole.

You can now place the mold into the kiln cup down on a platform of bricks to elevate the molds for even heating and wax drainage (be sure the bricks do not block the passage of wax out of the mold).

MAKING THE MOLD: (CONT.)

When all the molds are loaded (molds can be carefully stacked with smaller, lighter molds on top of larger molds and molds may touch each other side by side to conserve kiln space), the kiln can be sealed and soaked at 100 F. for 24 hours. The larger the molds the longer the burn-out should be (molds in excess of 50 lbs. need 24 to 36 hours, soak time). The burn-out generally requires 4 days time, one day soak time, one day very minimal temperature increase, one day up to peak temperature and one day down to pouring temperature. Heating should be even and consistant both up and down--Avoid irratic heat changes.

The kiln on the second day should increase in temperature +50 F. every 5 hours until it reaches 300 F. On the third day the kiln temperature should be increased hourly at +50 F. increments up to 1000 F. The temperature should remain at 1000 F. for at least 12 hours (longer for larger molds). On the pouring day (4th) the kiln temperature should be decreased -50 F. hourly until 500 F. is reached where the temperature should be allowed to level off and remain until the metal is ready to pour.

When the metal is ready the molds should be very carefully removed from the kiln and either inverted or plugged if necessary and placed gently in the sand pit and buried as high as possible to support the mold and insulate the heat. TRADITIONAL MOIDS ARE NOT IMMUNED TO THERMOL SHOCK, once the mold is burned-out for casting the mold must be poured immediately. If the mold is left to set it will cool, absorb moisture, limit metal flowability, and disintegrate. LET MOLDS SET AT LEAST ONE HOUR AFTER POURING (BRONZE) AND OVERNIGHT FOR ALUMINUM, LARGER MOLDS SHOULD SET FOR A LONG TIME BEFORE REMOVING THEM OR DE-VESTING.

For easy de-vesting of bronze castings, after one hour of solidification in the mold lower the entire mold into a container of cold water (a 55 gal. drum or garbage can work fine), the investment will literally explode off the casting. A water hose can be used also but it leaves more of a mess and adds additional clean-up time.

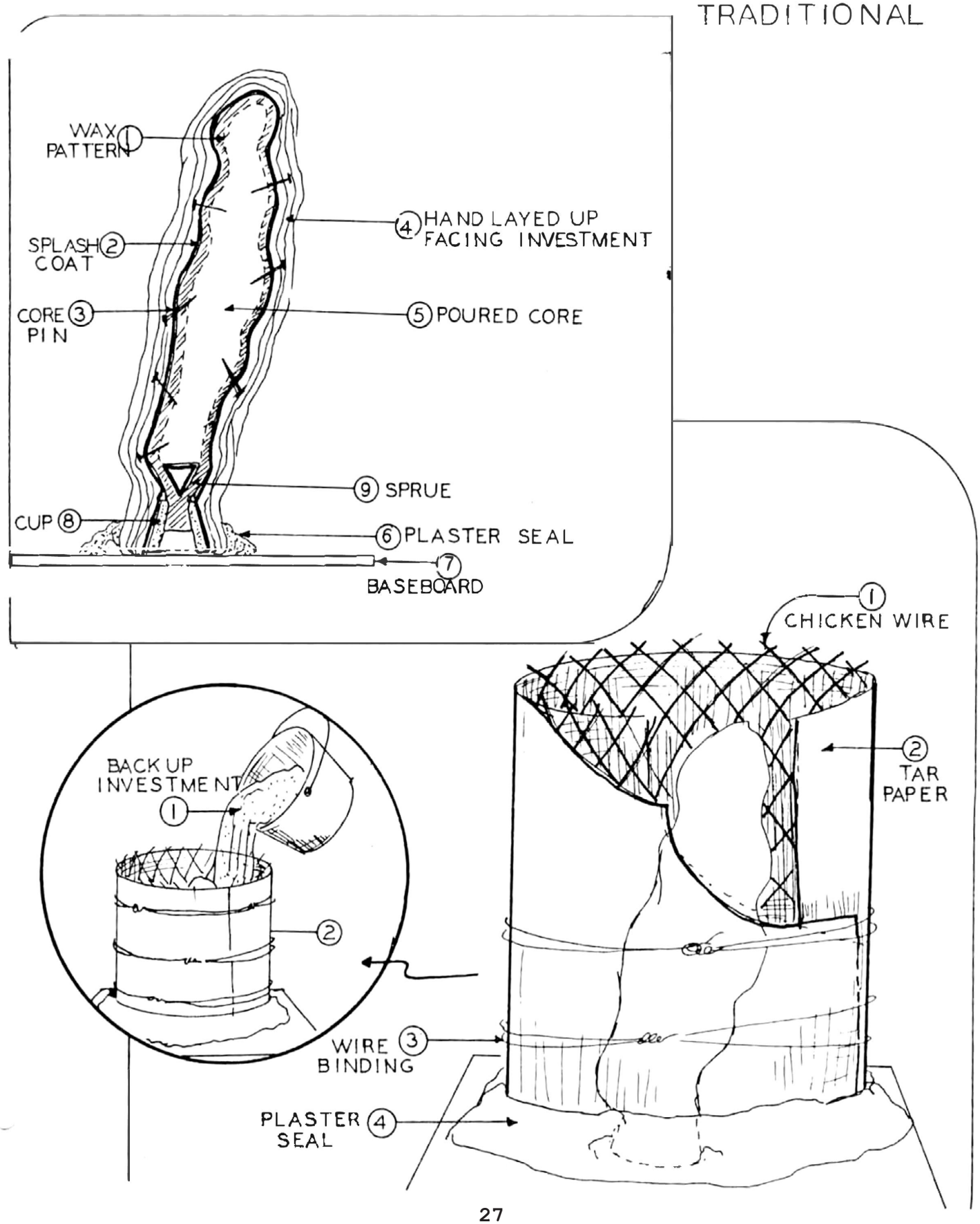
Following is a typical burn-out schedule:

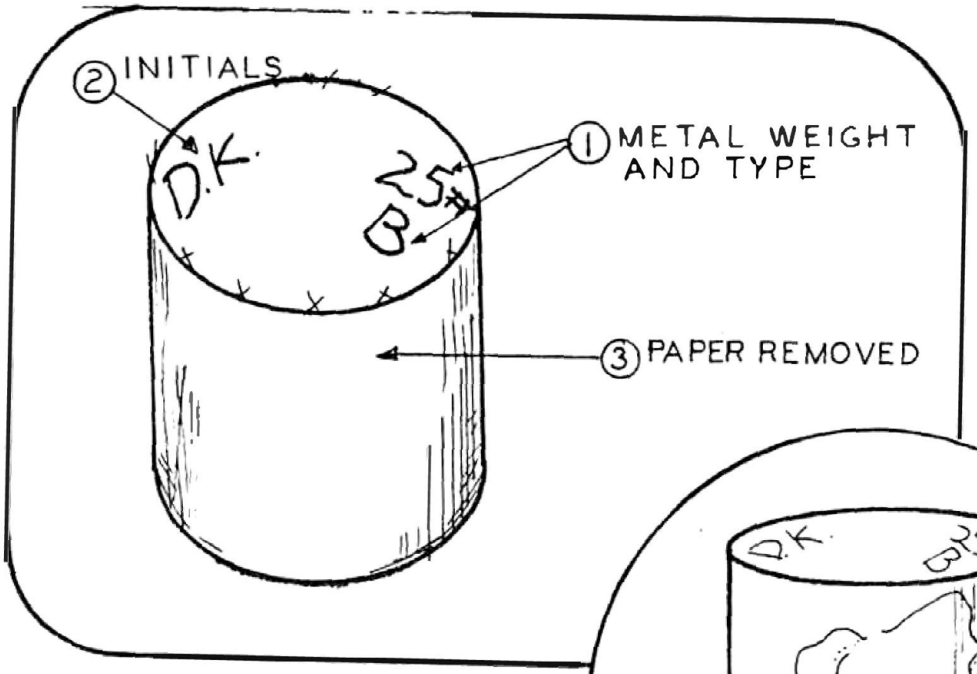
(see next page)

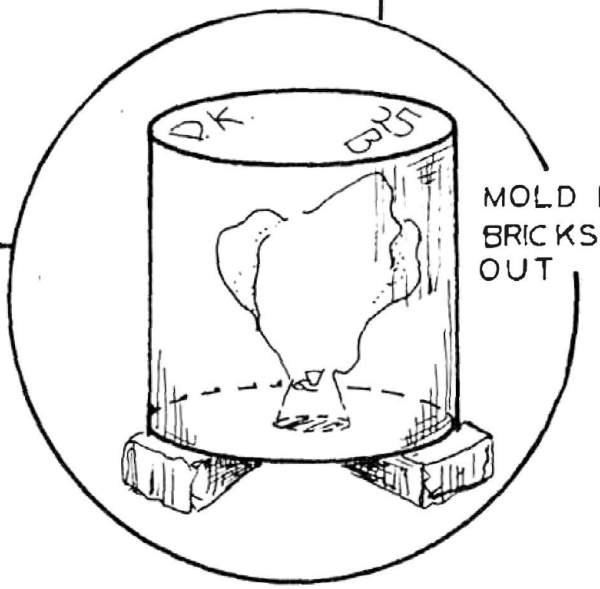
BURN-OUT SCHEDULE FOR TRADITIONAL MOLDS:

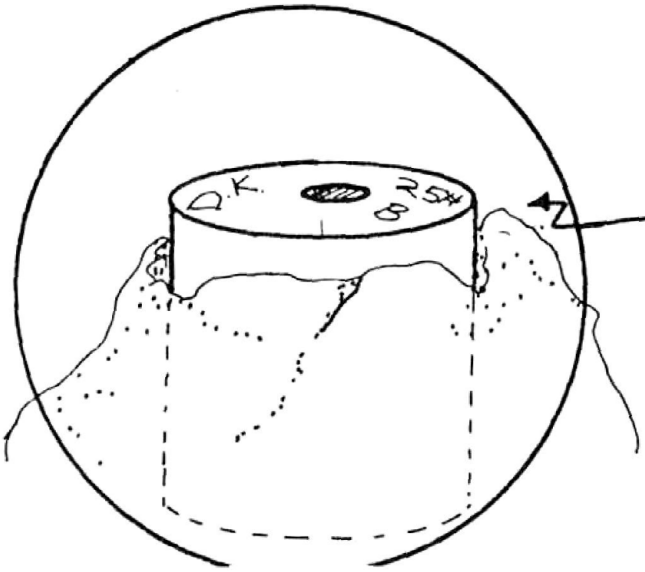
SUNDAY DAY 1 (SOAK)			MONDAY DAY 2 (+50 F.)			TUESDAY DAY 3 (+50 F.)			WEDNESDAY DAY 4 (-50 F.)		
HOUR:	TEMP.	INITIAL.	HOUR:	TEMP.	INIT.	HOUR:	TEMP.	INIT.	HOUR:	TEMP.	INIT.
2:00	100 F.		8:30 am.	150 F.		9:30am.	350 F.		10:30am.	950 F.	
						10:30	400 F.		11:30	900 F.	
						11:30	450 F.		12:30pm	850 F.	
						12:30 pm	500 F.		1:30	800 F.	
						1:30	550 F.		2:30	750 F.	
						2:30	600 F.		3:30	700 F.	
			1:30	200 F.		3:30	650 F.		4:30	650 F.	
						4:30	700 F.		5:30	600 F.	
						5:30	750 F.		6:30	550 F.	
						6:30	800 F.		7:30	500 F.	
						7:30	850 F.		STOP! HOLD KILN AT 500 F. UNTIL POURING		
			3:30 pm	250 F.		8:30	900 F.				
						9:30	950 F.				
						10:30	1000F.				
						STOP UNTIL WED. 10:30 am.					
			10:30 pm.	300 F.							
			STOP UNTIL TUES. 9:30 am.								

TRADITIONAL




2 INITIALS
D.K.
25#
B
1 METAL WEIGHT AND TYPE
3 PAPER REMOVED


D.K.
B25
MOLD RAISED ON BRICKS FOR BURN-OUT


D.K.
25#
B
1 READY TO POUR

LOOSE SAND VAPORIZATION CASTING USING STYROFOAM:

This technique is one of the fastest methods of casting metal sculpture but it is strictly confined to only aluminum casting. This technique must be done with dry, sifted sand, or with very minimally moistened sand.

Make a styrofoam sculpture and attach a pouring cup (styrofoam cup) to the very top of it and, if desired you can bring a styrofoam runner up from the very bottom of the piece to the surface. Build a box or use a metal cylinder, or just dig a deep hole in the foundry sand pit deep enough to accomodate your styrofoam piece, there should be 3" - 4" clearance surrounding your pattern.

Place your pattern in the hole, have someone else hold the top of it while you sift dry sand up and around your pattern (if moist sand is used, moisten MODERATELY and hand pack the sand around your styrofoam pattern). Continue this until the pattern is completely covered up to the cup and riser. Pour aluminum in as soon as possible, once pour has started DO NOT STOP until cup and runner is filled with metal. As soon as the cup and runner is filled STOP POURING IMMEDIATELY otherwise over filling will distort your pattern do to the metal pressure and without the sand being bonded nothing will restrict expansion of the metal beyond your pattern shape!

PETROBOND CASTING (COPE AND DRAG) USING STYROFOAM OR PATTERN:
Aluminum Casting from styrofoam for direct vaporization burn-out.

Make your pattern out of styrofoam and then place your pattern on a flat board or tray using either a commercial casting flask or a wooden 4-sided box whose sidewall heighth exceeds the thickness of your pattern by at least 2". Place the flask with the female locking device around your pattern leaving ample space around the pattern for sprue and gating systems. This bottom flask is called the "drag". At this point using a fine sieve (riddle) sift a light layer of Petro-Bond sand over the entire area inside your flask and over your pattern. When your pattern has been completely covered with about 1 1/2 to 2" of sand, gently hand-press the sand around and directly in contact with your pattern. When the flask has been filled to the top and tightly rammed, level off the surface with a straight edged piece of metal called a "strike-off bar".

Next, place another board on the top of your bottom flask, holding top and bottom board firmly flip the entire mold-flask completely over and remove the top board (previously was the bottom board).

At this point dust the entire surface of the drag with a light coat of either parting sand or talcum powder lightly brush away excess (sand should not be disturbed). Now take a 1" diameter piece of wooden dowel well coated with talcum powder and insert it firmly but gently about 1/4" deep into the Petro-Bond sand about 2" to 3" away from your pattern. The heigth of the dowel should exceed the heigth of the total two-piece flask by 1 1/2". This piece of dowelling will later be removed and the void forms your pouring column by which your metal will enter the mold.

Now attach the top flask called the "cope" to the drag matching the male locking device of the cope to the female receptacle of the drag. Lightly sift about 3" of Petro-Bond sand onto the powsered surface and gently hand ram. Entirely fill the flask with sand and firmly tamp sand around dowel but very careful not to move or disturb it. Level off the surface with the strike-off bar as before

PETRO-BOND SAND CASTING (CONT.):

Using a metal spatula called a "slick" cut a 45 degree angle bevel about 1" deep around the dowel rod, this forms your pouring cup, when this is completed using a bellows gently blow away all excess sand and firmly hand tamp the bevel. Now very carefully and with a steady hand rotate and pull out at the same time the dowel. Now carefully and in one consistant motion lift and raise the cope off the drag. Gently set the cope on its edge and blow away any excess sand out of the pouring column.

Now dig about a 1/2" deep depression out of the well formed by the impression of the dowel and remove excess sand and hand tamp ;it firmly, this forms your pouring well. Next using a gate-cutter cut two or three (number will be determined by the size of your pattern) gates (channels) as deep as the thickness of your pattern and connect them from your pattern to your pouring well, blow out all excess sand and tamp firmly with your fingers.

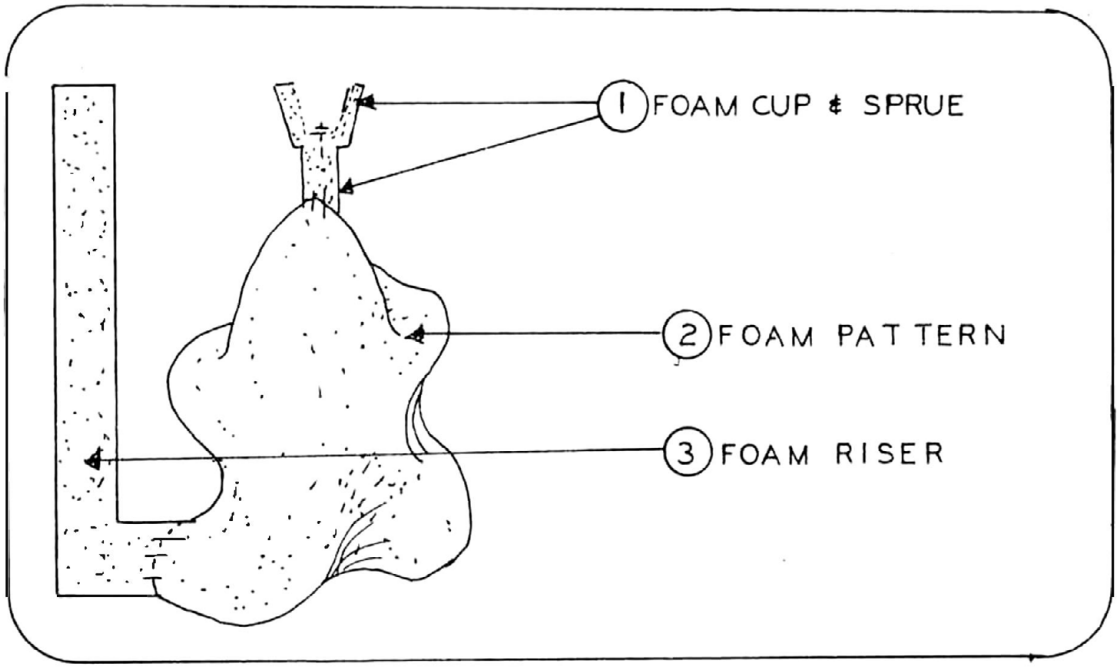
Now your final procedure is to slowly and carefully (without jerking) replace the cope onto the drag making sure the cope is matched to the drag perfectly. Cover the cope with a board or paper to prevent dust or sand from falling down your pouring column. Flask weights or clamps may be used to secure cope to drag but avoid weight directly on sand.

Because of weight and amount of pressure plus solidification range aluminum works the best for this method, bronze is too dense and heavy causing dimensional instability and mold erosion.

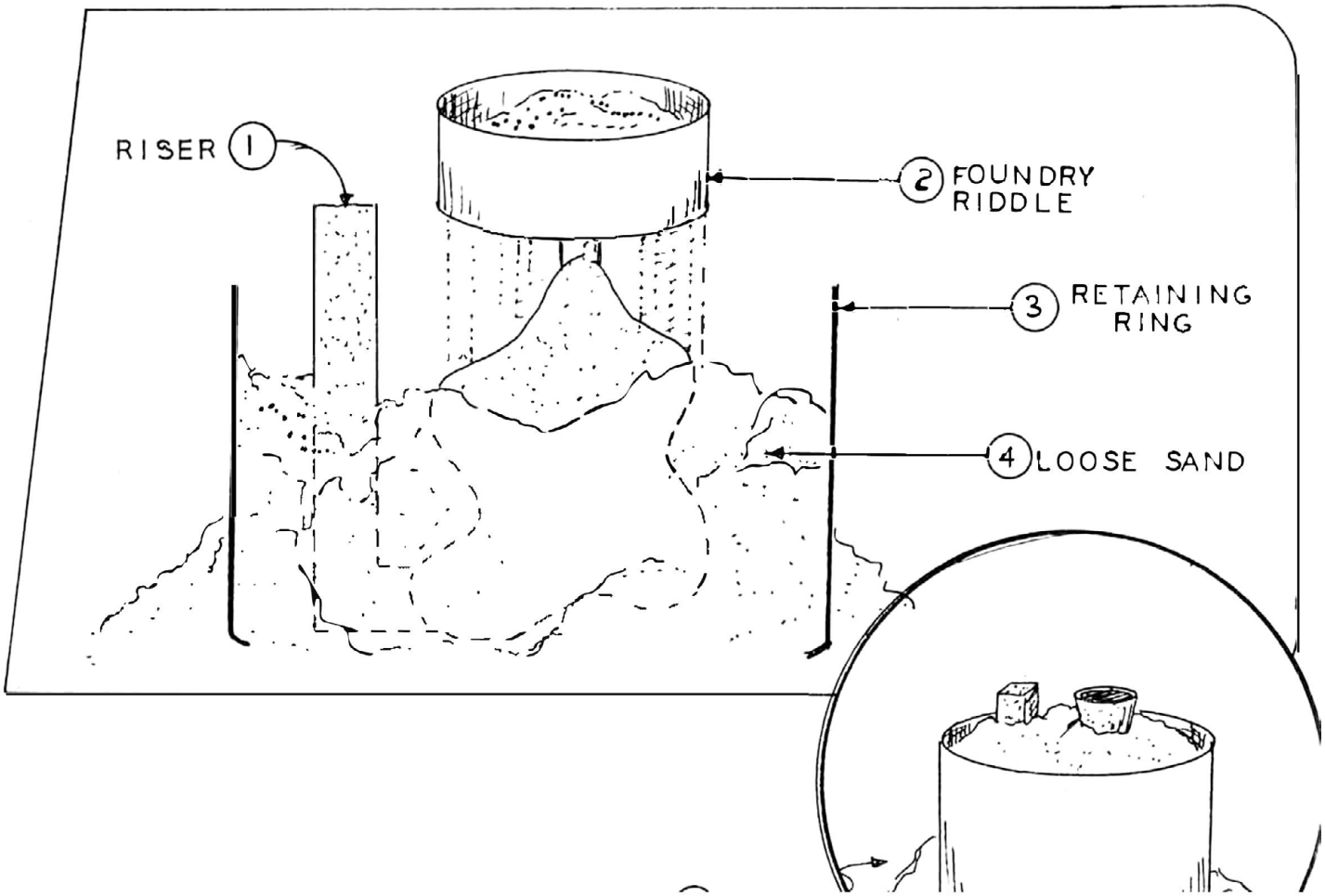
The aluminum will cool and solidify fairly quick, within 30 minutes you may shake out the mold, remove the pattern and as soon as your sand cools you can ram another mold. The Petro-Bond needs very little maintanance except for occasionally breaking up the lumps or adding a little water to keep it moist. DON'T OVER DO THE WATER! Your sand should be moist enough to pick up a hand-full and squeeze it and it should retain the shape of your hand and break cleanly.

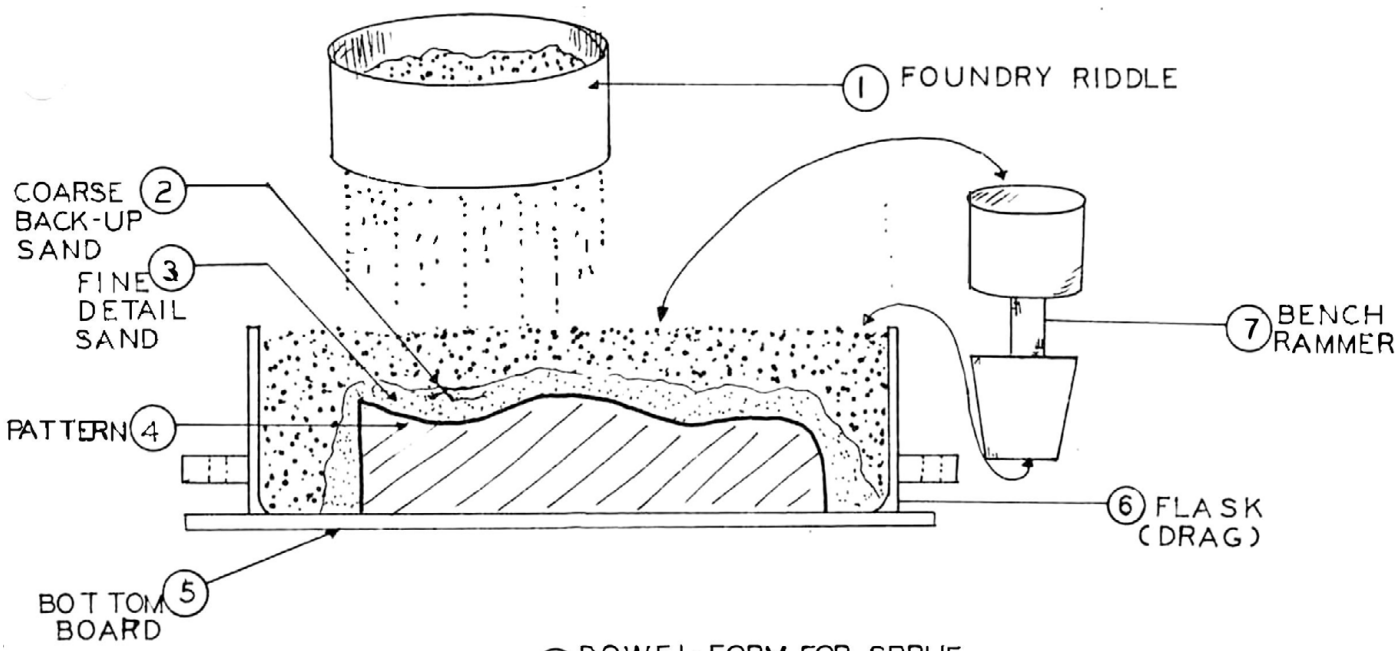
Petro-Bond is very fast and inexpensive method of casting and the material is recycleable indefinitely.

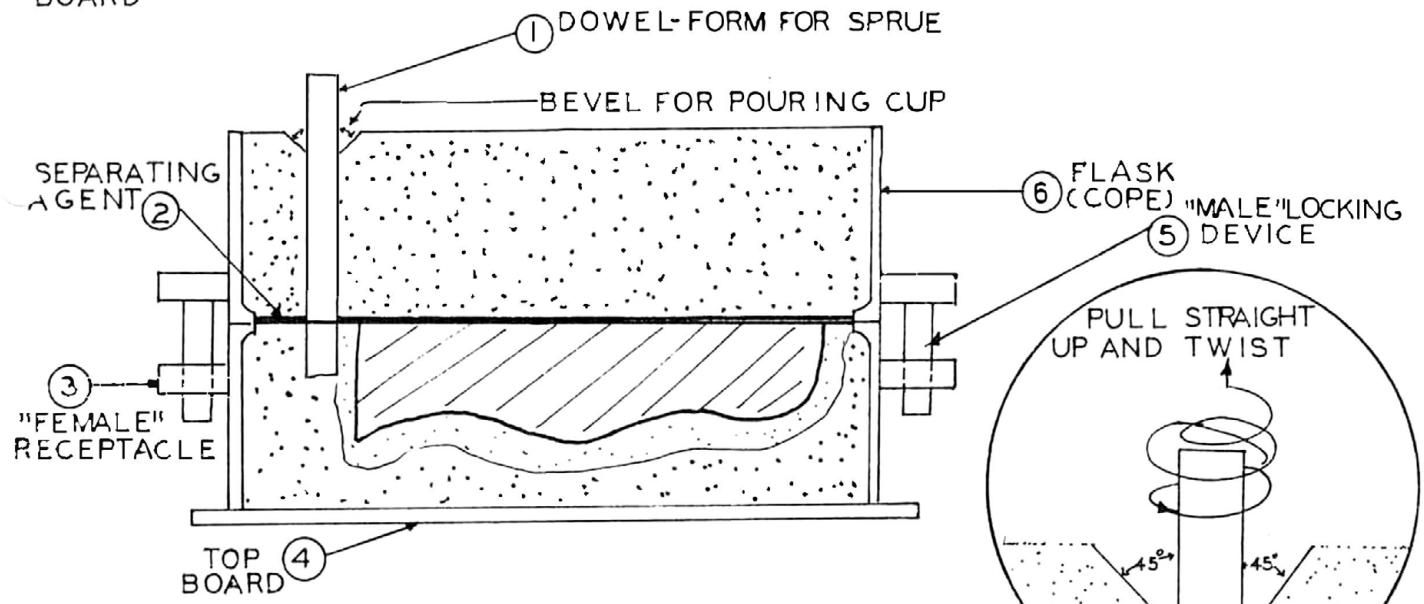
Wooden patterns can be used but they must not have any undercuts on them and edges need a slight draft on them. The pattern must be well powdered and VERY carefully removed prior to cutting your gates.


1 FOAM CUP & SPRUE
2 FOAM PATTERN
3 FOAM RISER

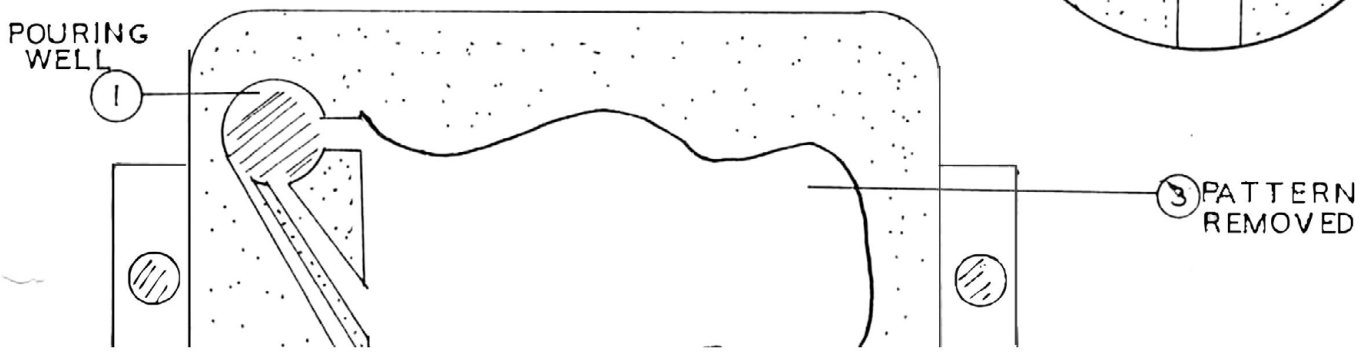
LOOSE SAND


RISER 1
2 FOUNDRY RIDDLE
3 RETAINING RING
4 LOOSE SAND





TOP VIEW OF DRAG (COPE REMOVED)



CHEMICALLY BONDED-SAND CASTING:

Can be done as a one-piece styrofoam vaporization technique following the previously described method using styrofoam, a box and sand. The only difference now being that the sand will be chemically bonded and will turn rigid very easy to handle and transport.

The molds can also be made in multiple pieces similar to a plaster piece mold.

The pattern can be made of such materials as styrofoam, urethane foam, wood, plastalene, vaccum-formed styrene, metal, wax, plaster, and bonded-sand. IF RIGID PATTERN IS USED THE PATTERN MUST BE FREE OF UNDERCUTS. Otherwise a complicated piece mold must be made.

TWO-PIECE-MOLD: (Using styrofoam)

Place styrofoam pattern on a flat level surface on some paper or plastic sheet, then construct a 4-sided wooden box exceeding the perimiter of your pattern by at least 3". The heighth of the box should exceed the thickness of the pattern by at least 2" to 2 1/2". There should be additional space on the sides where you intend to place your pouring system and end risering system. At least 4" in length.

Patterns other than styrofoam should be coated with either talcum powder or painted with graphite. The pattern should be placed inside the box and mulled sand hand-packed first around the pattern and then over it. Once the pattern is covered fill the box with sand and ram firmly with a wooden ramming tool, level off the surface with a strike-off bar and allow to set until concrete hard (usually overnight).

When the first half is hard remove the wooden box and carefully turn the mold over. Once the mold is turned over use a carburundum stone tool or file to cut register keys at least in two places on the mold, blow out all excess sand then dust the entire surface with talcum powder (mold separating agent). Place one row of firebrick along the floor-line of the mold then replace the wooden box to create the container for the top half. Mull your sand and ram the sand over the bottomhalf, fill the mold all the way up to the top and level it off with the strike-off bar, then let it turn hard.
When the top of the mold is hard then remove the box and if possible stand the mold on its edge and with a block of wood and a hammer carefully tap along the seam line all around until the seam opens then gently separate the two sections.

Once apart you will see an impression of the pattern on the top section which is a key factor in establishing and strategically placing your pouring system, blind risers, risers, and vents. Using a masons drill (at least 3/4" to 1") locate and drill pouring column, risers, vents and blind risers. The top should now be replaced on top of the bottom section and the pouring wells should be drilled using the top holes as a template. When this has been done once again remove the top section. Now you may carefully remove the pattern.

CHEMICALLY BONDED-SAND CASTING (CONT.)

Once the pattern is removed connect the gates leading from the pattern to the pour well and from pattern to vents. Blow off any excess loose sand and spray a refractory mold wash into the cavity and onto the top section over the metal will come in contact with the molds. Let mold wash dry completely.

At this point using core glue, lay a heavy layer of glue along the outside edge of the mold (it sometimes helps to blow or brush off any remaining talcum powder from the edge surface, the glue will adhere better.) Glue the top to the bottom section and place weights on the surface distributed evenly. Also glue on the pre-made pre-drilled pre-mold-washed pouring and vent stacks made up from extra remaining sand after mulling.

The glue requires 24 hours, to completely set, steel strap banding or wiring can also be used.

The mold is capable of receiving bronze, aluminum and cast iron with good results.

-Wax can be used as a pattern, however, it must be coated with graphite and talcum powder and either torn out of the mold or after glueing the mold can be put into a kiln and heated up to 400 F. slowly where as the wax permeates into the surrounding mold material. You are never sure of the total evacuation and good surface reproduction cannot be guaranteed. If possible avoid this technique.

-Bonded-sand molds ARE NOT IMMUNED TO THERMOL SHOCK and must not be taken above 400 F. otherwise bindings of sand and chemicals deteriroate. Wax residue inside the mold can cause turbulance and boiling results sometimes violent erruptions occur leaving poor surfaces and added safety hazards.

-Bonded-sand molds must be kept as dry as possible, because the molds are poured cold. Pouring temperatures for aluminum, bronze and iron may have to be 100 F. to 200 F. higher to compensate.

BLIND RISERS: Blind risers are risers that come off the surface of the pattern but only come halfway to the surface of the mold, they are not visible at the surface. They function as reservoirs of metal to feed internal shrinkage. On a styrofoam piece you should have a pouring cup at either end and a series of blind risers under the surface.

MIXING AND MULLING INSTRUCTIONS FOR BONDED-SAND PROCESS:

TYPES: 1. Air-Set 2. Self-Cure 3. Machine-Set

4. Heat-Set 5. CO2 Bonded-Sand

MIXING AND MULLING INSTRUCTIONS FOR BONDED-SAND (CONT.)

All of the before mentioned types require the use of a two part recipe consisting of resin additive and catalyst binder. In the case of the Heat-Set type the mold must be cured in a kiln to set the binders. In the case of the CO_2 Carbon Dioxide gas supplies the catalyst for setting all the others use a chemical action catalyst.

ADDITIVE AND CATALYST RATIO:

(Instructions pertain to the muller capacity at the University of Wisconsin-Milwaukee)

FOR MIXING 50 lbs. OF SAND THE RATIO IS:

FOR 100 LBS. 1½ LBS. RESIN
8 OZ. CATALYST

RESIN: 3/4 lb.
CATALYST: 4 oz/
-The above ration is according to Delta Oil Products chemicals:

-Delta Machine set 309-6X-0, 309-6X-B and Delta Machine set 217-6X,
(Resin) (Resin) (Catalyst)

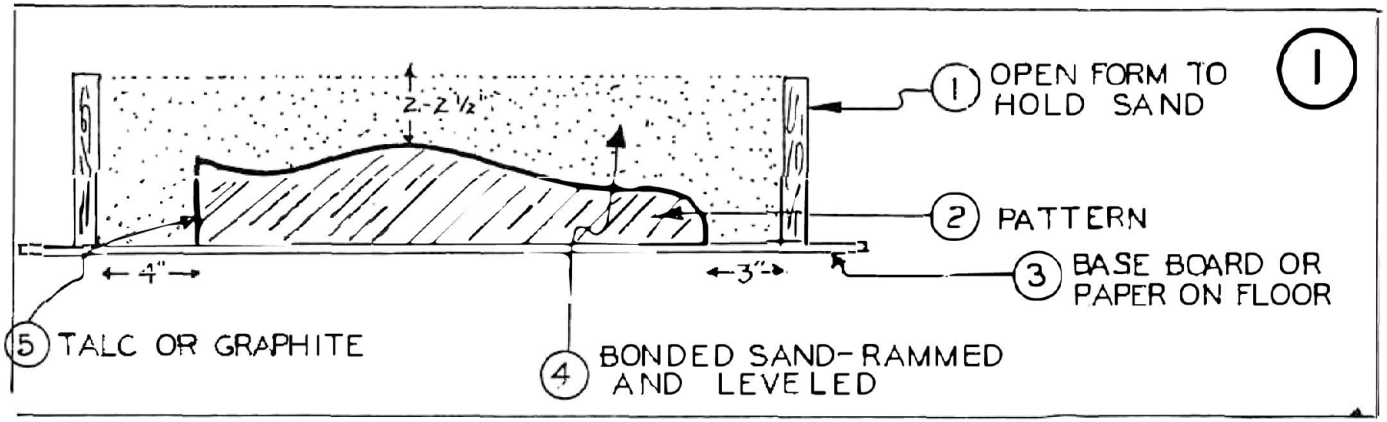
MULLING INSTRUCTIONS:

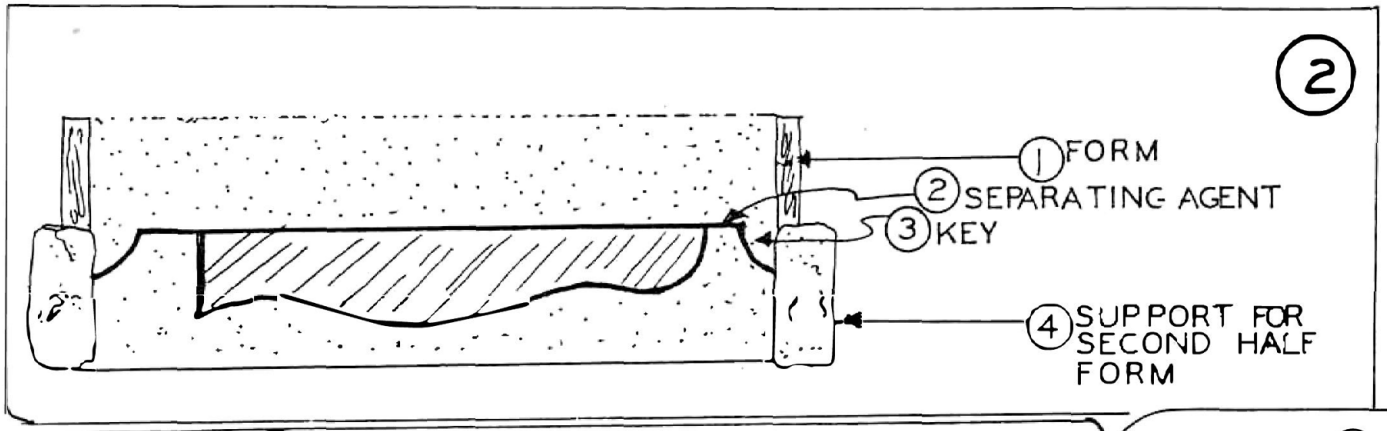
1. Weigh out 50 lbs. of sand, 3/4 lb. resin and 4 oz. catalyst.
2. Pour the sand into the muller bed.
3. Turn on the muller and add all of the resin, mull for one minute.
4. Add the catalyst and mull for an additional minute.
5. Stop muller and empty into bucket, scrape as much sand off the sides of the muller as possible.
6. Repeat the above procedure for as many times as it takes to finish the mold.
7. Clean muller completely after final mix.
   It is a wise practice on large molds to weigh out additional sand, chemicals during each mulling cycle to save time.

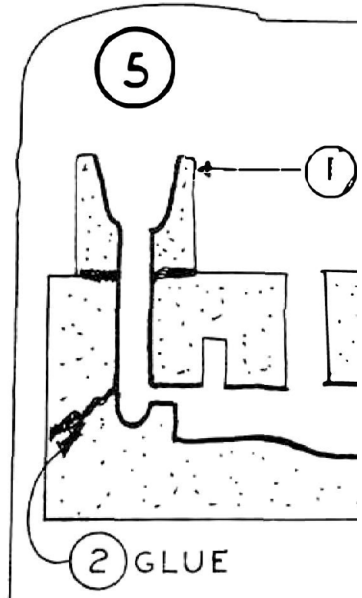
ADVANTAGES AND DISADVANTAGES TO BONDED-SAND CASTING:

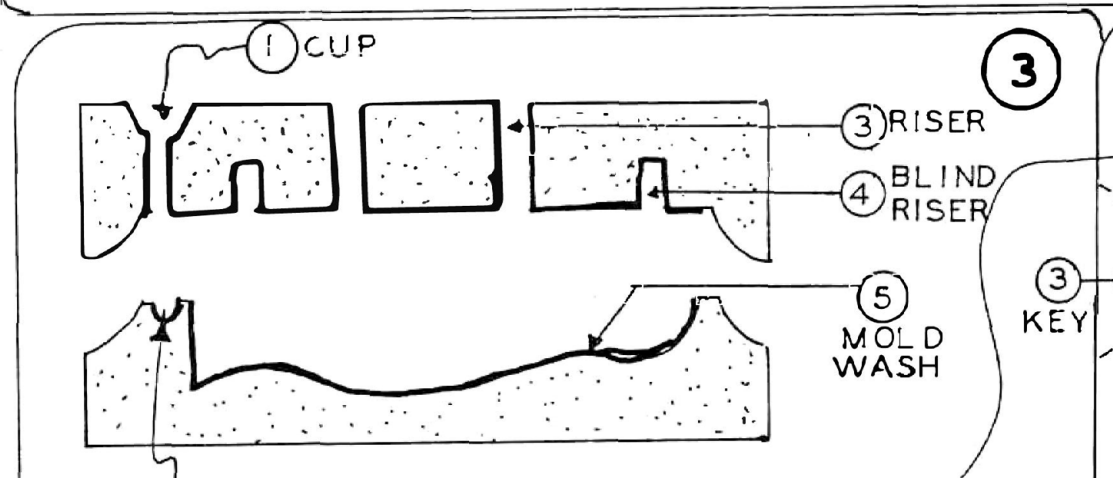
ADVANTAGES:
1. Relatively inexpensive
2. Can cast large pieces in one section
3. It is relatively fast.
4. Relatively flexible in terms of possibilities and effects obtainable.
5. Molds will receive nearly any metal, except brass (Too much gas).

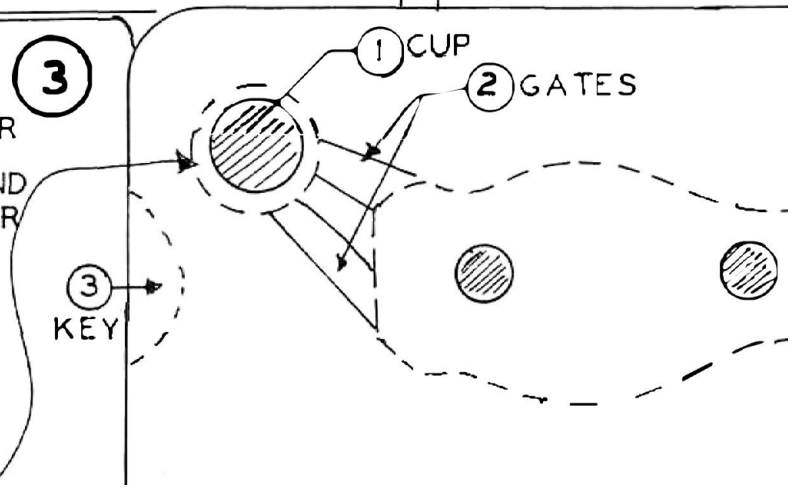
BONDED SA


1
2-2 1/2"
4"
3"
1 OPEN FORM TO HOLD SAND
2 PATTERN
3 BASE BOARD OR PAPER ON FLOOR
4 BONDED SAND-RAMMED AND LEVELED
5 TALC OR GRAPHITE


2
1 FORM
2 SEPARATING AGENT
3 KEY
4 SUPPORT FOR SECOND HALF FORM


5
1
2 GLUE


3
1 CUP
3 RISER
4 BLIND RISER
5 MOLD WASH


1 CUP
2 GATES
3 KEY

CHEMICALLY BONDED-SAND (CONT.):

DISADVANTAGES:
1. It is a cold mold process.
2. Molds can become extremely heavy. (One cubic ft. sand 100 lbs.)
3. Gas problems, resin additives contain a lot of organic materials; cause hydrocarbons.

CERAMIC SHELL CASTING:
Ceramic shell is an industrial casting process developed in 1920 and used exclusively in the industrial foundires until sculptors began tapping into the possibilities of casting their sculpture using this method; this didn't happen until 1950. Ceramic shell is a very precision method of casting and affords very excellent detail production.

Ceramic shell is a two part process involving a liquid slurry and a dry stucco. All of the ingredients are based on a fused silica sand formula either in the dry state or suspended in solution. Preparation of the wax pattern is about the same as in the Traditional casting method; once the wax model is made the wax sprues are attached and a styrofoam cup is attached to act as the pouring cup and main feeder to the sculpture. After the cup and sprues are attached you then paint the surface of the wax and sprues (NOT THE STYROFOAM CUP) with a solution of 50% alcohol and 50% Chlorothene. Let air dry, then paint once again with one coat of straight alcohol and let air dry. This procedure cleans surface of all oil or dust from handling. Allow the wax to completely dry before applying the first coat of slurry.

When the wax is dry, weigh the wax to determine the expected metal weight; a pound scale works fine. The weight should now be recorded with the weight of the wax, the weight of the metal needed and a diagram of the piece in the pouring position, labeling wax, sprues and cup. Casting sheets are kept as a complete record of the entire wax weight, metal weight, type of metal to be poured, type of mold to be poured, diagram of the sculpture, and the cost of mold material and metal per pound. All of this material and information is later used to compute the casting cost for materials.

You are now ready to start the ceramic shell mold.

SLURRY PREPARATION:
A plastic or stainless steel bucket must be used, mild steel cannot be used because the oxidation of the surface would contaminate the slurry.

Step 1. Pour in a quantity of the Nalcoag #1030 liquid.
Step 2. Slowly sift in the Pi-W powder and gradually stir with either a stainless steel spoon or a wooden spoon (it can also be done by hand, you may want to use a rubber glove). Pi-W should be added until you reach a heavy cream consistancy of smooth texture. To be accurate use a #5 Zahn Cup and you want a 30-40-second slurry.
Step 3. While agitating the slurry put in about 1 Tbls. of Ultra-wet 60L wetting agent, make sure you are agigating the slurry when it is added.

SLURRY PROCEDURES (CONT.):

Mix the ingredients thoroughly and all particles must be suspended in your slurry. Every time you mix a new batch or a previously made batch, make sure all ingredients from the bottom of the bucket are mixed into your slurry. if you do not have all the ingredients off the bottom mixed in, you do not have the proper mixture of materials resulting in a very weak shell. Follow this procedure EVERY TIME you come in to mix the slurry. The Nalcoag #1030 will evaporate quickly so ALWAYS COVER THE CONTAINER WITH SOME SORT OF COVER, EITHER A PRE-MADE COVER OR A SHEET OF PLASTIC OR A PLASTIC BAG. Whenever you finish coating your mold, unless someone is immediately following, you cover the slurry up tight. THIS IS VERY IMPORTANT!

To check the proper viscosity of your slurry, take a piece of clean wax and dip it into the slurry, let it drain. It should leave a smooth consistant coating over the wax. If the slurry beads up or separates, you need to add a little more Ultra-wet 60L. Add moderately because too much Ultra-wet 60L causes excessive foam, consequently it will give you a foamy surface on your wax and a weak shell.

Now that the slurry is mixed and ready, you can now begin investing your pattern. You may spray the slurry onto your pattern, dip it into the slurry or pour the slurry over it. Be sure to cover the entire surface of your wax inside and out (if it is a core piece) and cover all sprues and the outside of the styrofoam cup. Allow the slurry to very adequately drain out of all recesses and evenly off the surface leaving a very consistant smooth coating over your pattern. Improper draining will give you all kinds of problems later, so do it carefully. During the ivesting procedure, hold the pattern firmly but with as few fingers as possible because wherever you hold the slurry will be sparse (don't worry about bare spots after the first coat, hold the piece differently on the second coat, and the bare spots will be covered).

After proper draining move over to the stucco (and) area and lightly dust the entire slurried surface, sprues and cup with the Nalcast S-1 stucco. DO NOT SET THE WAX PIECE IN THE SAND ON THE FIRST TWO OR THREE COATS. The first two coats are done with the S-1 stucco to insure good surface detail as the S-1 is very fine. Set the piece on a table to air dry at room temperature. Avoid a humid or hot area on these initial coats. DO NOT FAN DRY FIRST TWO COATS. If it is at all possible you should try to get at least three coats on the pattern the first day, however, each previous coat HAS TO BE COMPLETELY DRY TO A WHITE SUGAR-LIKE APPEARANCE. IF THERE ARE GREY SPOTS, IT IS STILL WET! Core pieces will require longer drying time and may take several days to completely dry, especially on the first and second coats, starting with the third coat, you can focus on a fan right into the core and that will speed the process.

Starting with your third coat and previous to mixing your slurry pre-soak the shell mold by pouring a wash of straight Nalcoag #1030 over the pattern and set aside to soak in while you mix your slurry, i ollow this pricedure prior to every coat from the third to the eigth. From the third coat to the seventh you follow this procedure. Pre-soak with Nalcoag #1030, LET SOAK WHILE MIXING SLURRY, SLURRY THE SHELL, DRAIN, DUST WITH NALCAST S-2 (coarse stucco). ON THE EIGTH COAT, you pre-wet, soak, slurry and let dry. (YOU DO NOT ADD STUCCO TO THE LAST COAT, Large castings often require more than eitht coats (it all depends on the volume of metal to be poured into the mold). Whatever number of coats you determine the mold should be, the procedure is the same except that on your final coat, whatever number that my be will only be slurry.

CERAMIC SHELL MOLDS:

An eight coat shell generally measures about 1/4" when it is completed. BEGINNING WITH THE THIRD COAT THROUCH THE EIGHT A FAN MAY BE USED TO SPEED UP THE DRYING PROCESS BUT NEVER USE ANY HEAT SOURCE!

When the ceramic shell has been completed the next step is to very carefully grind off about 1/4" off the bottom of the cup exposing the styrofoam edge of the cup. This if cone for several reasons, it allows you to measure the thickness of your shell mold and it allows you a channel to burn out the styrofoam cup with the aid of an oxy-acetylene torch to open a free channel for the interior wax to be evacuated late by a larger immersion burner.

When the cup area is free of overflow shell and styrofoam place the shell cup down on a gate mounted above a bucket of cold water and slowly heat the outside surface of the min sprue area leading from the cup to the pattern, try to heat the piece evenly on all sides and melt out about 3/4 of the sprue leading to the pattern. When this is completed put the shell cup down on a larger grate over a tub of cold water and starting at the cup and using a gas/air immersion burner gradually and slowly work the burner up and down the surface of the entire shell (it may be necessary to rotate the position of the mold from time to time).

Melted wax will slowly drain out of the cup, continue this burn-out procedure until wax ceases to drip from the mold and only after you have advanced the burner all the way up to the top of the mold it is a good idea to work your way back down the mold from the top to the cup again. Ceramic shell molds have to be flash burned out in a fast method otherwise the slower methods allow the wax to expand and too much pressure is exerted on the 1/4" shell and it will crack, this is generally a problem with large or complex molds, however, the cracks are easily patched and generally the surface shows only a very minimal fin.

Once the wax has stopped let the mold cool and then weigh it on a pound scale to determine the weight of the investment, record the weight on your casting sheet for later fee assessment. After weighing, place the mold into the kiln for the final carbon burn-out (because of the rapid burn-out with the immersion burner and the nature of the wax, a black carbon is generally left inside and outside of the shell), this carbon must be eliminated.

The kiln can be set immediately for 1500 F. and the shells brought up to that temperature as soon as possible, the shells are totally immuned to thermol shock but must not be heated beyond 1850 F. The shells need only remain at 1500 F. for 15 minutes unless some sort of combustable material such as wood or plastics have been incorporated into the mold. Prior to pouring (about one hour before pouring) adjust the kiln down to 1000 F. (only necessary because we remove the shells with asbestos gloves). The hotter the molds the better, flowability is increased with hotter molds. Allows your metal to be poured a little cooler eliminating some of the gas and shrinkage problems.

CERAMIC SHELL MOLDS (CONT.)

When metal is ready to be poured turn off the kiln and remove the shells as fast as possible as they tend to cool fast once removed from the kiln. Bury the shells in sand up to the cup to support shell and to insulate the heat inside.

Pour the molds steadily, consistantly and position the crucible low to the lip of the shell mold, remember, you only have a 1.4" mold, undue turbulance may break the shell.

After the molds have set for about 45 minutes to an hour generally you will note the shells will begin to crack and breakdown of their own accord, this is due to internal contraction of the metal and the failure of the mold to expand or contract. Aluminum pieces should be allowed to set much longer than bronze pieces because of its crystalline structure. Also larger, heavier pieces should be allowed to set much longer than smaller pieces.

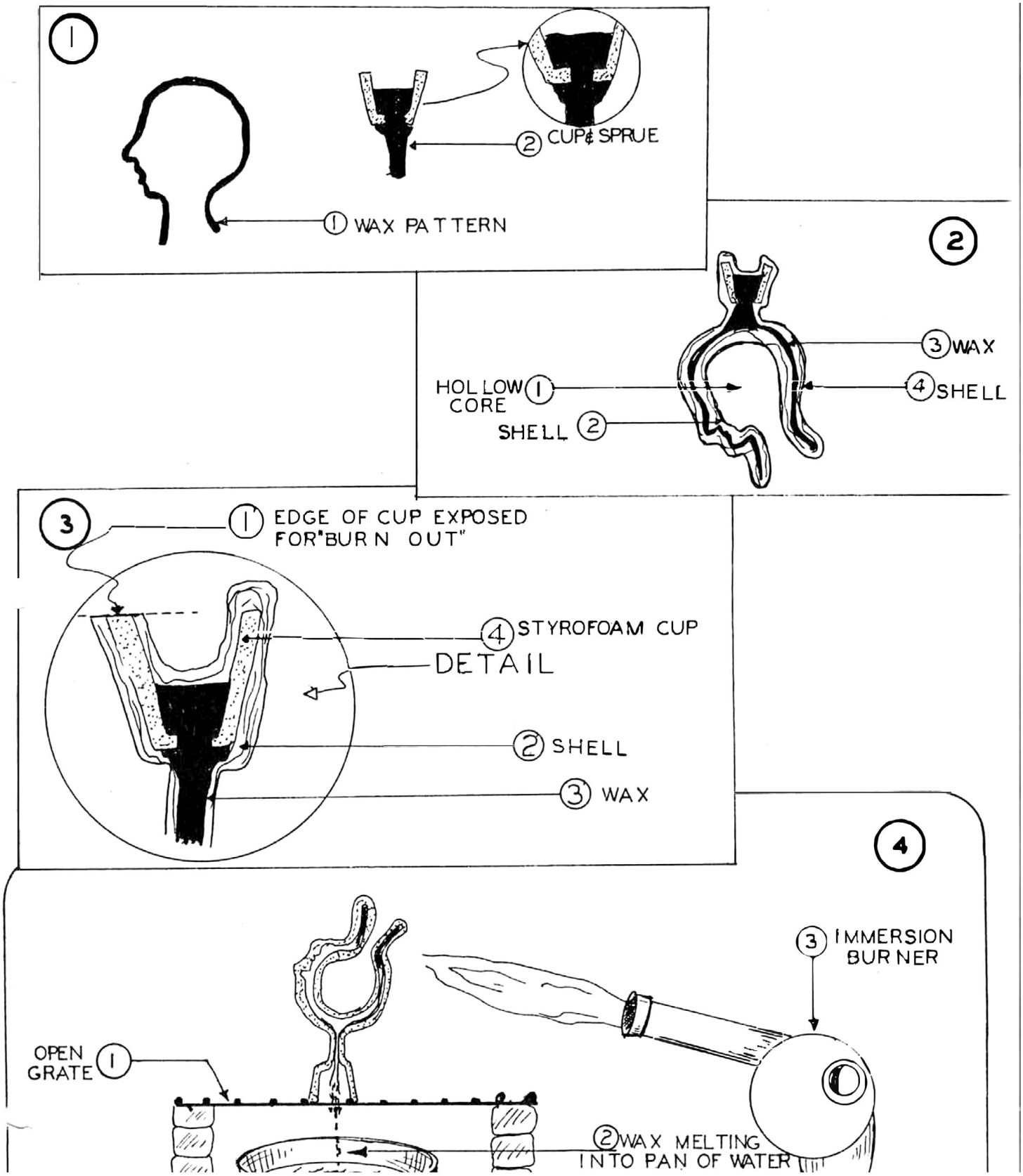
The longer you let a piece cool down the easier it is to remove the shell because the metal will shrink away from the surface of the inner shell leaving a hollow air space between the metal and the shell, plus it will crack by itself by contraction. Having this air space makes it easy later to just rap it with a hammer and it will fall right off. A good practice is to leave it overnight making the next days devesting very simple.

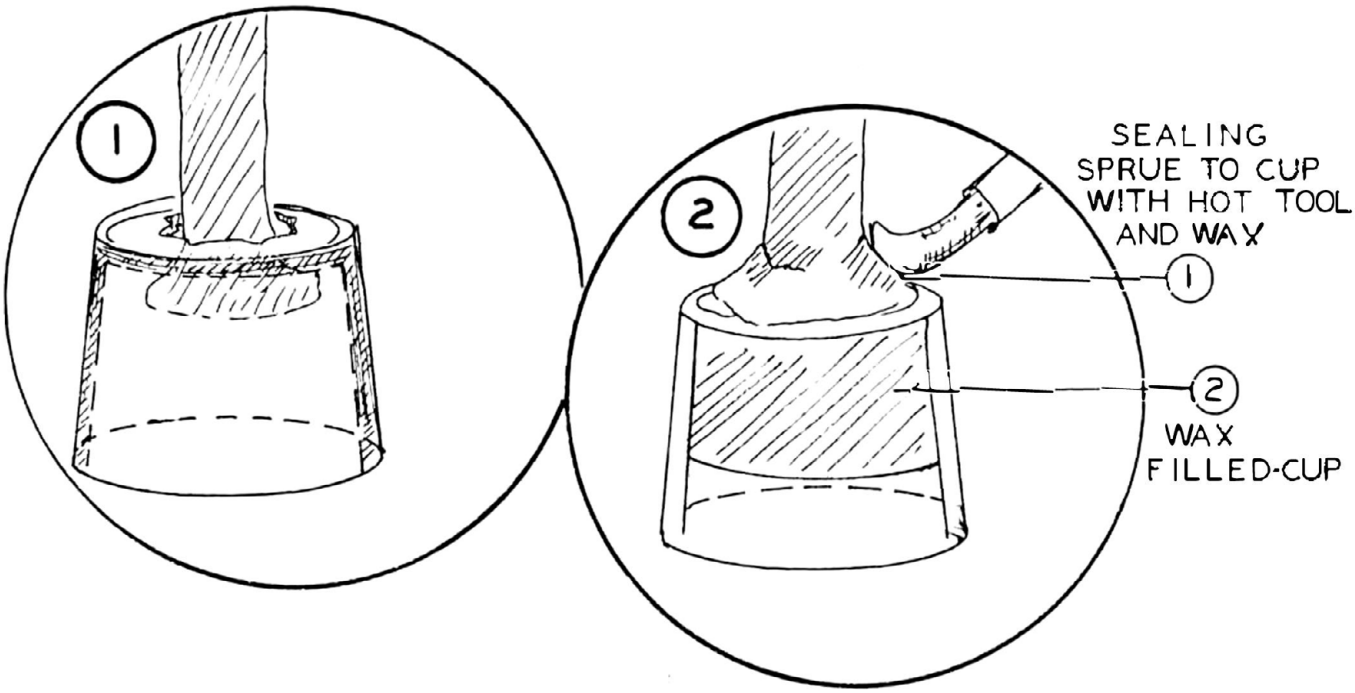
CERAMIC SHELL:

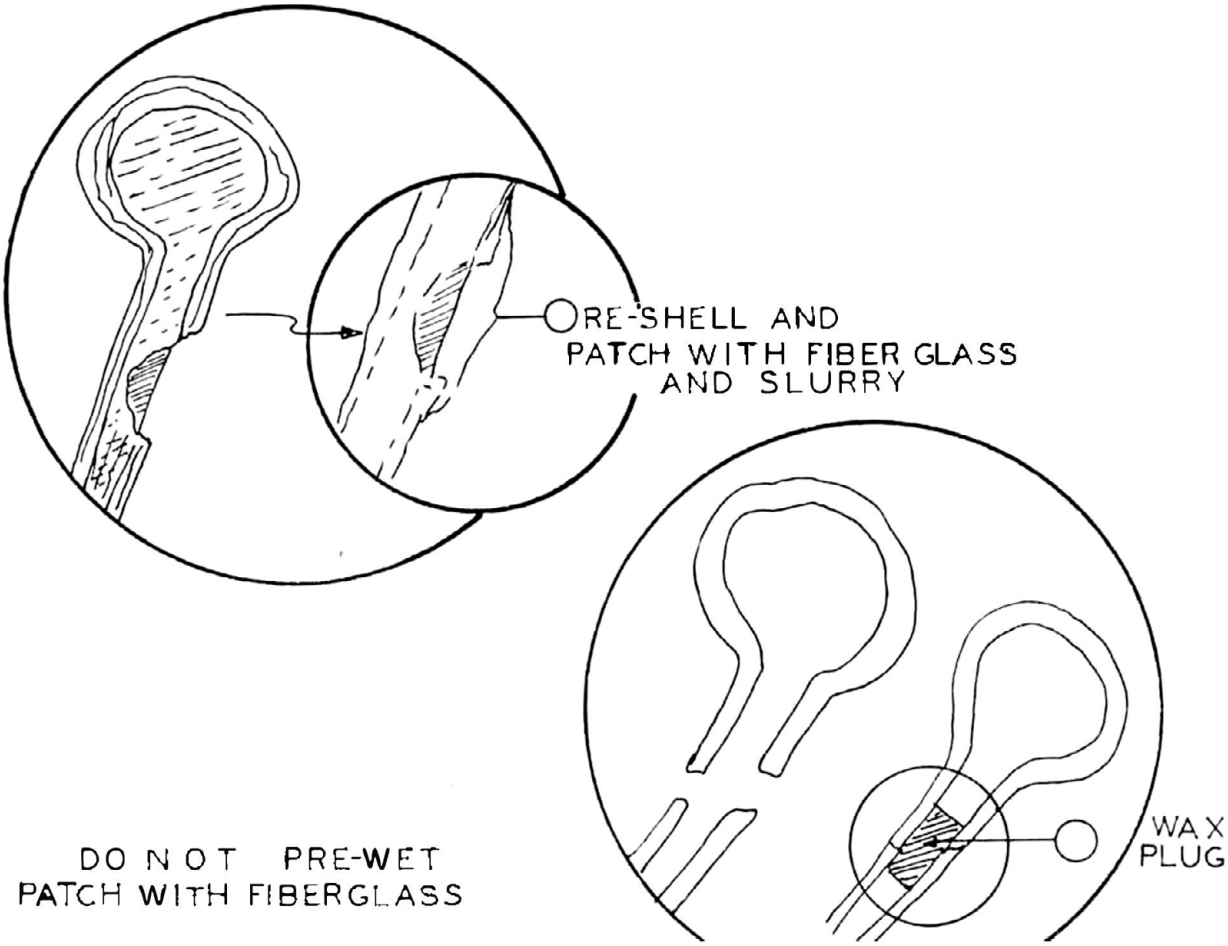
ADVANTAGES:

1. Sprueing system simpler, all ceramic shell pieces can be poured with a direct pour.
2. Better surface reproduction
3. Mold very light, easily handled, especially hot.
4. Totally immuned to thermol shock.
5. Shell porosity good for gas evacuation, no need for excess venting. Gas venting is done right through the walls of the shell.
6. Easy evacuation of carbon.
7. Molds can be poured extremely hot. Can be as high as 1850 F.
8. Shells do not expand of contract or change physically with heat exposure.
9. Carbon can be evacuated at 1300 F., generally take kiln to 1500 F. to be sure.
10. When the molds are poured hot it eliminates chilling the metal and increases flowability.
11. Non-wax materials can be used to an extent incorporated in your piece if they are combustable and don't have a high rate of expansion such as Nylon, Paper, Soft woods (balsa, thin dowelling, toothpicks), Cloth, String,Thread, Styrene and low expanding plastics)!!

-FOR ALL NON-WAX MATERIALS INCREASE YOUR IMMERSION BURN-OUT PROCEDURE AND EXTEND YOUR CARBON BURN-OUT TIME, IT ALSO HELPS TO VACCUMM OUT OR BLOW OUT THE MOLDS PRIOR TO BURNING THEM FOR POURING!


1
2 CUP & SPRUE
1 WAX PATTERN
2
3 WAX
HOLLOW CORE 1
4 SHELL
SHELL 2
3
1 EDGE OF CUP EXPOSED FOR "BURN OUT"
4 STYROFOAM CUP
DETAIL
2 SHELL
3 WAX
4
3 IMMERSION BURNER
OPEN GRATE 1
2 WAX MELTING INTO PAN OF WATER





DO NOT PRE-WET
PATCH WITH FIBERGLASS

CERAMIC SHELL CASTING (CONT.)

DISADVANTAGES: 1. Wax expansion is very critical to the shell molds. When the mold is complete, the wax should be evacuated as soon as possible. Increased room temperature in the early stages of the shells (first or second coats) could expand the wax enough to crack the thin surface of the mold. NEVER UNDER ANY CIRCUMSTANCES OR CONDITIONS LEAVE A CERAMIC SHELL MOLD WITH LESS THAN FIVE COATS IN THE FOUNDRY ROOM DURING KIIN BURN-OUTS OR POURING DAYS.

ONCE THE SHELL MOLD IS VOID OF WAX IT CAN BE STORED INDEFINITELY AND POURED AT A LATER DATE, JUST PUT A SMALL PLASTIC BAC OVER THE OPEN CUP WITH A RUBBER BAND.

2. Size of the wax piece can be an inhibiting factor due to flexing of long wax sections or bending in investing process, this causes cracking of the shell especially on the early coars. Also the handling of the wax sections during the investing process is often difficult. The bending problem can be somewhat eliminated by adding parafin to your wax to make it more rigid.

3. Cracks often occur in the immersion burn-out of large pieces due to the fact that your burner is moving up the piece slowly from the bottom to the top, however, seeing as heat rises, the deflected heat from the bottom will reach the top of your mold before your burner does causing early wax expansion and cracking. The cracks are nothing serious but will need patching before pouring can take place.

REPAIR OF CERAMIC SHELL MOLDS:

If by some accident a cup or sprue or even a part of the piece should break off at any stage in the investing period it can be salvaged and successfully repaired. If it is a simple crack from burn-out or just during the investing process and the piece doesn't completely break off, clean off the immediate area removing the broken shell and wash the area with alcohol and allow to dry. When the alcohol is dry, seal the broken wax part with a hot knife or hot wax tool sealing and welding the wax joint back together fusing both sections securely. Clean again with alcohol and let dry, then start re-investing as though it never happened, using slurry and S-1 for two coats then pre-soak with Nalcoag on the third coat, slurry, and S-2 until the section has caught up with the coat you were doing when the break occurred. If the section is exceptionally delicate or a joint bearing alot of pressure after three coats of slurry and sand on the fourth coat take a small quantity of slurry out of your batch and out a patch of fiberglass cloth big enough to wrap the area and dip into the amall quantity of slurry and let it soak a few seconds while you pre-soak and slurry the weak area on the mold, squeeze the cloth out an' wrap ; it gently around the weak spot, next dust S-2 over it and model it to the contour of the piece by hand. Let dry longer because the cloth will hold the moisture much longer than the normal drying time of your shell. On your fifth coat and through your seventh invest over the patch normally as you would the rest of the shell.

REPAIRING CERAMIC SHELL MOLDS (CONT.)

If a cup or wax section completely breaks off, first clean off the broken area with alcohol and let it dry. Next imbed a wooden toothpick or matchstick into one half of the broken section then insert the sections back together. Paint the seam with alcohol and let dry then resume the slurry, sand procedure with the S-1 for two coats, pre-soak with Nalcoag #1030 on the third coat, slurry and S-2, Fiberglass cloth patches can now be used as was before mentioned, complete the shell with the pre-soak and slurry on the last coat.

IMPORTANT!

If you break off a piece, sprue or cup AFTER the wax is burn-out take a secton of wax and fashion a plug (Roman joint) to join both segments back together. Squeeq the sections back together until they again match and join each other (actually the wax being soft acts as an adhesive). Once joined DO NOT PRE-WET AT ANY TIME ONCE THE WAX HAS BEEN BURNED-OUT WITH NALCOAG #1030 BUT SIMPLY APPLY A HEAVY SLURRY MIXTURE (MAKE IT A SMALL BATCH AT A TIME AND SOMEWHAT THICKER THAN THE NORMAL SLURRY) AND STUCCO HEAVILY WITH THE S-2,REPEAT THIS AT LEAST THREE TIMES (MORE FOR LARGE PIECES).

PRE-WETTING WITH NALOAG #1030 AFTER THE WAX IS EVACUATED WILL TEND TO SOFTEN THE INTERIOR SURFACE OF YOUR SHELL AND THE DETAIL MAY BE DESTROYED!

CONCLUSION!
~~CONSLUSION~~:

Certainly I have just barely scratched the surface of all of the many, many wayx sculpture can be made and processes that can be used and techniques employed and innumberable brands of materials that can be found. Hopefully for the beginning casting student this will offer a basic grasp of some of the more simpler techniques of casting a metal sculpture. There always are and hopefully always will be artists, technicians, experts that will argue "that can't be done" or "that could be done better or faster" and it is with knowledge fully in mind that I offer this meager text compared to the vast resource of knowledge available if you are willing to look further which I hope this beginning will inspire artists first experiencing casting to seek out.

Charles A. Kraus

KILN OPERATING PROCEDURES FOR TRADITIONAL AND CERAMIC SHELL MOLDS:

KILN CONTROL SEQUENCE: (Instructions only for kiln at the University of Wisconsin-Milwaukee)

Step 1. Turn "on-off" switch to the on position (Black 110 Volt button).

Step 2. Set desired starting or maximum temperature figure with small grey knob below numerical dial window. YOU MUST HOLD THE SMALL GREY KNOW IN WHILE AT THE SAME TIME YOU TURN IT TO ADJUST DESIRED TEMP.

Step 3. Press two top (Black) buttons in marked "Blower" and "Exhaust".

Step 4. Wait for the small Red light marked "Purge" to come on.

Step 5. Wait until the second small Red light comes or (far left button), then turn on the button marked "Ignition" (lower left black button).

Step 6. Wait for the third small Red light to go on marked "Pilot".

Step 7. Now step to the rear of the kiln and you will see a silver lever with a black knob on it and a sign saying "Shut-off", raise this lever up as high as it will go then put it in the "DOWN" position and leave it there. This is the gas release lever.

-The kiln controls are totally electronic and once set need not be tampered with unless in the case of traditional molds where as the temperature will be raised or lowered periodically.

-THERE IS A BUZZER WARNING SYSTEM CONNECTED TO THE KILN AND SHOULD THE SEQUENCE NOT BE FOLLOWED PROPERLY OR IF THERE IS A MALFUNCTION THE BUZZER WILL SOUND. IF THIS SHOULD HAPPEN, TURN OFF ALL CONTROLS IN THE FOLLOWING ORDER:

FIRST: IGNITION SWITCH.

SECOND: "ON-OFF SWITCH"

-At this point you must repeat the entire sequence from the very begining

-IF THE BUZZER CONTINUES TO GO OFF AFTER REPEATING THE SEQUENCE, TURN OFF THE KILN ACCORDING TO THE ABOVE PROPER SEQUENCE AND GET HELP FROM A SCULPTURE FACULTY MEMBER.

For traditional molds follow the posted kiln schedule exactly and all temperature adjustments are made in +50 F. or -50 F. movements and that is adjusted at the small grey knob below the numerical temperature scale seen through the small glass window at the top of the control panel.

For Ceramic shell the initial setting of the temperature will be for the maximum desired temperature (1500 F.) and needs no further adjustment until pouring time when it is lowered to 1000 F.

For Ceramic shell molds the molds only need to remain at maximum temperature for 15 minutes unless combustable materials have been used, then the time should be extended depending upon the extent of the interior material.

It is adviseable to lower the kiln to 1000 F. about one hour prior to pouring.

PATINATION RECIPES:

-Patina, surface oxidation of the base metal caused by natural or artifically applied acids to form a coloration on the surface of your casting, Oxidation takes place with the interaction of water, acid, heat and air. Acids and heat speed up the patination process. Very difficult to achieve on Aluminum alloys but very good results with copper base alloys such as copper, brass, and bronze.

ALUMINUM: Color range very limited (Gray to black)

~~-Lamblack~~ LAMPBLACK
-Stove Polish
-Enamels
-Anodizing
-Plating

CHEMICAL treatment

Gray: Rub the metal with a soft cloth moistened with a diluted solution of muriatic acid. A few drops of linseed oil is then applied after which you rub with steel wool. Result is a dull gray finish.

Black: Make a bath consisting of:

CAUSTIC ~~Caustic~~ Soda	4 oz.
Calcium Chloride	1 oz.
water	1 qt.

Water should be heated in an earthenware container. The caustic soda should be dissolved in heated water and the solution should be stirred after which the calcium chloride is added. The temperature of the solution bath should be kept at 200 F. Immerse the aluminum piece for 15 minutes, remove, rinse with clean water and immerse for a few seconds in a second solution of:

Hydrochloric Acid	1 qt.
White Arsenic	4 oz.
Iron Sulphate	4 oz.
Water	1 qt.

AFTER REMOVING THE PIECE THOROUGHLY RINSE WITH CLEAN HOT WATER

PATINATION RECIPES FOR COPPER ALLOYS (CONT.)

7. Black

Copper Carbonate	2 parts
Ammonium Carbonate	4 parts
Sodium Carbonate	1 parts
Water	32 parts

Heat the solution to a boil, the bronze should be immersed. The solution should be stirred occasionally.

8. Green

Cupric Nitrate	1 tsp.
Water	1/2 qt.

Heat the bronze and apply the solution.

10. Antique White

Bismuth Nitrate	2 tsp.
Water	1/2 pt.

Heat the bronze and apply the solution.

11. Verde

Copper Nitrate	1 part
Ammonium Chloride	1 part
Calcium Chloride	1 part
Water	32 parts

Parts by weight. Immerse the bronze into the solution until dull green appears.

12. Blue

Potassium Sulphide	15 grams
Ammonium Chloride	100 Grams
Water	1 qt.

Brush on surface.

13. Blue-Green

Copper Sulphate	5 oz.,	Cupric Acetate	5 oz.,	Copper Carbonate	5 oz.
	Water	128 parts			

Dip the bronze into the solution. Parts by weight.

14. Black-Green

Potassium Sulphide	15 grams
Ammonium Chloride	100 grams
Water	5 oz.

Brush on surface cold.

PATINATION RECIPES FOR COPPER ALLOYS (CONT.)

15. Black

Copper Nitrate	50 grams
Water	100 cc.

Followed by:

Potassium Sulphide	50 grams
Hydrochloric Acid	25 cc.
Water	500 cc.

Brush on surface hot or cold.

16. Black-Green

Copper Nitrate	30 grams
Ammonia	15 cc.
Water	00 cc.

Brush on surface.

17. Light Brown

Ferric Chloride	500 grams
Water	500 cc.

Brush on surface.

18. Brown to Black

Sodium Thiosulphage	5 grams
Ferric Nitrate	40 grams
Water	640 cc.

Brush on the surface.

19. Antique Green

White Vinegar	1 qt
Ammonium Chloride	15 grams
Table Salt	15 grams
Ammonia	1/2 oz.

Brush on the surface cold.

20. Light Blue-Green

Copper Nitrate	15 grams
Sodium Chloride	95 grams
Water	16 oz.

Brush on the surface.

PATINATION RECIPES FOR COPPER ALLOYS (CONT.)

21. Green

Cupric Nitrate	1 tsp.
Water	1 qt.

Brush on the surface.

22. Apple Green

Sodium Chloride	5 parts
Ammonium Hydroxide (Aqua Ammonium)	4 parts
Ammonium Chloride	5 parts
Water	32 parts
Glacial Acid	4 parts

Brush on the surface. Parts by weight.

23. Russet (Green)

Copper Nitrate	1 part
Ammonium Chloride	1 part
Calcium Chloride	1 part
Water	32 parts

Parts by weight. Brush on surface cold.

24. Umber Brown

Ferric Chloride	70 grams
Water	1 qt.

Brush on the surface.

25. Black

Potassium Sulphide	½ crystal
Water	1 qt.

Heat bronze with a torch and brush on the surface while piece is hot. Dissolve crystal in container of hot water. Boil water with crystal in it and immerse the piece in the solution.

26. Turquoise

Ammonia	½ qt.
Sno-Bowl Toilet Cleaner	½ qt.

SOURCES FOR CASTING SUPPLIES:
(Companies and brand names may vary by area)

CERAMIC SHELL MATERIALS:

Nalco Chemical Company
Metal Industries Division
9165 South Harbor Avenue
Chicago, Illinois 60617
[redacted]: 312-731-3020
TEL:

Materials Needed	
Nalcoag #1030	(5 Gals. or 55 Gal. Drums)
Nalcast Pi-W	(50 lb. bags)
Nalcast S-1	(50 lb. Bags)
Nalcast S-2	(50 lb. bags)
Ultra-wet 60L	(Qts. or gals.)

CHEMICAL BONDED-SAND SUPPLIES:

Delta Oil Products
6263 No. Teutonia Ave.
Milwaukee, Wisconsin
Tel: 414-462-1200

Materials Needed:
Resin: Delta Machine Set 309-6X-0
Catalyst: Delta Machine Set 217-6X
(Delta Machine Set 309-6X-B Resin can also be used with the Delta 217-6X0
Liquid Pyrokoat Mold Wash (Qts., Gals.)
Core Adhesive (Qts., Gals.)

FLUXES, DE-OXIDANTS, HOT TOPPINGS AND BINDERS:

Foseco, Inc.
P.O. Box 8728
Cleveland, Ohio
Tel: 216-234-3551

(Minimum Order of $25.00)
DE-OXIDANT: DE-GASSER 190 (Tablet form)
2 oz. & 4 oz. tablets.
EXOTHERMIC HOT TOPPINGS: Feedol #9
100 lb. kegs

WELDING SUPPLIES:

Bentley Welding Supply
200 S. Hawley Rd.
Milwaukee, Wisconsin
Tel: 414-476-1222

or

Linnehan Welding Supply Corp.
6533 N. Teutonia Ave.
Milwaukee, Wisconsin
Tel: 414-352-4600

Materials Needed:
Silicon Bronze Welding Rods (varying Diameters)
Silicon Aluminum Welding Rods (varying Diameters)
General All-Purpose Brazing Flux

SOURCES FOR SUPPLIES (CONT.)

Aluminum Alloys:

Lawran Foundry
4700 W. Electric Ave.
Milwaukee, Wisconsin
Tel: 414-645-4070

Material Needed:

Silicon Aluminum Ingots Alloy #43

COPPER BASE ALLOYS:

Bronze:

R. Lavin & Sons
3426 S. Kedzie Ave.
Chicago, Illinois
Tel: 312-[redacted]-1800
847

Material Needed:

Alloy Se #12-A Silicon Bronze

CRUCIBLES:

Carpenter Brothers, Inc.
606 W. Wisconsin Ave.
Milwaukee, Wisconsin
Tel: 414-276-0140

or

Milchap Products Inc.
8656 W. National Ave.
Milwaukee, Wisconsin
Tel: 414-321-3111

Materials Needed:

Clay-Graphite Crucibles (Various)
no.: 10, 20, 30, 40, 50, 60, 80, 100, 180

Silicon-Carbide Crucibles (Various)
no.: 10, 16, 20, 30, 40, 50, 60, 80, 100, 180.

FURNACE REFRACTORIES:

Crichton Corp.
4080 N. Port Washington Rd.
Tel: 414-964-6222

Material Needed:
Brikcast 3100 (100 lb. bags)
(used for relining or repairing inside of pit furnace).

TRADITIONAL CASTING SUPPLIES:

Tews Lime and Cement Co.
2826 W. Silver Spring Dr.
Milwaukee, Wisconsin
Tel: 414-466-4300
or
Firebrick Engineers Co.
2400 S. 43rd St.
Milwaukee, Wisconsin
Tel: 414-383-6000

Materials Needed:
2.5 Expanded Steel Mesh (By the bundle)
Black Tar Roofing Paper (By the roll)
No. 1 Art Moulding Plaster (By the ton)

Fine Mesh (200 Mesh) Silica Flour (by the bag or ton)
Medium and coarse grog (By the bag or ton)

SAND FOR CHEMICALLY-BONDED SAND PROCESS:

Firebrick Engineers Co.
2400 S. 43rd St.
Milwaukee, Wisconsin
Tel: 414-383-6000

Materials Needed:

Natural Grain Flint Silica Sand (By the ton or bag)

FURNACES:

MC Englevan Heat Treating and Mfg. Co.
700-708 Griggs St.
Danville, Illinois

(Write for Free Catalog)

TONGS, SHANKS, & SAFETY EQUIPMENT:

Voell Machinery Co.
21925 Doral Rd.
Milwaukee, Wisconsin
Tel: 414-786-6640

(Write or Call for a Free Very Inclusive Catalog)

PYROMETER:

Pyro-Matic Industries Inc.
12555 Lisbon Rd.
Milwaukee, Wisconsin
Tel: 414-781-2222

Pyro-Lance Type Pyrometer
(0 F. - 2500 F.)

SOURCES FOR SUPPLIES:

WAXES:

Petrolite Corp./Bareco Division
40% Oakbrook Profession Bldg.
Oakbrook, Illinois 60521
Tel: 312-242-1963

Main Office: 6910 East 14th St.
P.O. Drawer K.
Tulsa Okla. 74115

Material Needed:

Victory Brown, microcrystalline casting wax.

(Melting Point 165 F.)

Best for sculpture casting, good for direct modelling and is suitable for fabrication. Vaseline can be added when the wax is in a melted state to add plasticity to wax once solidification has re-occurred. Parafin can be added in small amounts also to add stiffness if desire, especially good if the wax is to be used for fabrication or pouring into a plaster mold.

2 lbs. Parafin to 10 lbs. of wax

1 lb. Parafin to 5 lbs. of wax.
