A Gypsum Cement for Every Industrial Need

Metal Casting Methods

Casting methods available to industry include plaster mold casting. Special plaster formulations are available for casting various nonferrous metals and alloys. These plasters will:

1. Produce fine, intricate surface detail
2. Permit use of many parts in as-cast condition
3. Produce castings that require little or no machining
4. Offer better dimensional accuracy for cast-to-size parts
5. Allow casting of thin sections not possible with other methods
6. Lower total cost of finished parts in some cases

Metal casting plasters can be classified according to use or permeability. In this bulletin, classification by permeability will be followed.

In using the following impermeable plasters (2½ AFS units and below) for closed-mold applications, it is common practice to use some form of air pressure or vacuum to fill the mold cavity with metal. This external force helps overcome the low permeability of the mold material. In some cases it is possible to pour metal into a closed plaster mold without aid of an external force.

Metal Casting Plasters

USG® *Metal Casting Plaster*, a formulated product containing plaster and refractory materials to give greater strength and dimensional accuracy after water has been removed during "burnout". Designed especially for production of aluminum matchplates, cope-and-drag sets, core boxes and loose patterns. Readily mixed, poured and carved, but has ample strength for handling.

Foundry Practices

Many foundries need a method for making high-precision castings. For a successful change from sand casting to plaster casting, it is necessary for both supervisors and molders to change their work habits and methods. This section will deal with many of these differences in production methods.

Patterns—Many materials work satisfactorily for patterns including any of the following: Flexible materials such as Cold Molding Compound (Perma-Flex Mold Co., 1919 E. Livingston St., Columbus, Ohio 43209), rigid patterns such as lacquered HYDROCAL® Gypsum Cement, polished metal, properly prepared wood and EPOXICAL® Tooling Plastics. Care should be taken to choose the proper pattern material, since the surface finish of the casting can be only a as good as the surface finish on the pattern.

Parting Compounds—Suitable parting agents are described in Bulletin IG-515. A parting agent should be insoluble in water, and fluid enough to form a thin film. Common forms are stearine, soft soap, waxes in a suitable solvent, light oils and emulsified oils.

Among the many parting agents, stearine appears to be the most widely used. It is prepared by melting down ¼ lb. stearine, and after removal from heat, adding 1 pint kerosene. Material is brushed thoroughly over pattern surface. If brush marks show, thin by adding kerosene or by warming slightly. Patterns should be coated lightly. A heavy coat will penetrate the plaster, resulting in a poor metal surface, or will reduce sharpness of detail on the pattern.

Consistency (plaster-to water ratio)—Use-consistency of these plaster formulations will vary. Generally, use of more water results in lower green and dry strength, higher permeability and lower expansion. Recommended use-consistency proportions: 100 parts by weight USG Metal Casting—140-160 parts water.

Mixing—Basically, 10 parts of a metal casting plaster to 14 parts water would be a starting point. For optimum results carefully weigh all ingredients and use water at 110°F. Use either hand or power equipment. Usually a round-bottom vessel similar to that used by bakers for mixing dough works well for plaster. Always add plaster to the water. Strew a weighed amount of plaster into a weighed or measured amount of water. Allow to soak 1 to 3 min. to become thoroughly wetted before mixing. Mechanical mixing is recommended for uniform densities. Mix plaster from 3 to 5 min. or until plaster starts to cream. A 2- or 3-in., 3-blade standard-pitch propeller rotating at 1,750 rpm is recommended. Direction of rotation should force slurry downward. Bucket dimensions should be such that depth of slurry is 1½ to 2 times diameter of bucket. Mixing of large batches or delays in pouring should be avoided.

Pouring—Pour plaster into core boxes or molds immediately after mixing since the setting time is usually about 20 to 25 min. Be sure the mold surface is clean and has a smooth surface properly treated with parting agent.

Mechanical vibration, brushing slurry on pattern face and careful pouring help to eliminate pinholes in the surface of the mold. Screed back surface flat and level to minimize problems when metal is forced into mold. Failure to have surfaces true and flat may cause movement of plaster molds causing oversize castings.

Pattern Release—Remove the plaster part from the core box or pattern with extreme care to avoid marking or breakage. One method is to insert a thin wire through the partially set plaster then, when the plaster has set, blow gently through the hole with compressed air. Another is to start wedges at the parting line and separate the plaster from the pattern with compressed air. Remove flexible patterns by forcing compressed air between pattern and mold. To release mechanically, form bridge with draw spikes and a horizontal piece. Rap upward with short blows.

Forming Gates and Risers—Because of the insulative quality of plaster molds, gates, sprues and runners may be made much smaller than for sand molds. Wherever possible, gates, runners, etc. should be part of the pattern system and molded in place.

If not molded in place, cut gates and runners in mold before plaster is dry; then clean and prepare mold for casting. Place molds in dryer 2 hr. min., 8 hr. max. after removing from patterns. Allowing molds to air dry for more than 8 hr. can lead to abnormal shrinkage. Proof the casting before production begins to confirm correct locations of gates, runners and risers.

Drying Mold—One of the most important operations in successful plaster-mold casting is drying the mold. Complete dehydration is necessary to avoid generating gas that can cause defects in the casting when poured. Many drying methods can be used successfully, depending on the nature of the work, but all require a source of heat and air circulation.

Most plaster foundries use a gas- or oil-fired furnace with a recirculating air and exhaust system. Electronic controls are used extensively to minimize difficulties resulting from improperly dried molds. Oven temperatures are often controlled thermostatically during drying cycle, which may range for 16 to 36 hr. depending on the work load. The drying cycle is controlled by thermocouples placed at strategic locations in the oven.

Temperatures ranging from 350 to 1,500°F can be used to dry plaster molds—often referred to as mold "burnout." In general, a higher burnout temperature results in greater burnout shrinkage. During drying, all free water and a substantial part of the combined water must be removed. Drying rate depends on (1) oven temperature, (2) air velocity and humidity, (3) mold thickness, and (4) oven load.

Set up molds for pouring immediately after removal from dryer since the plaster will pick up moisture if exposed to air for long periods.

Casting Metal—Melting and pouring metal in plaster molding is much the same as in sand casting. Plaster molding has proved effective not only in production of electronic parts but in other areas where good surfaces, thin sections and close tolerances are required. Good results also are attained in brass, bronze and aluminum.

Metal-pouring temperatures are critical and require close control. A lower pouring temperature can be used with plaster molds due to the insulative property of the plaster. This insulative factor also requires additional cooling time before shake-out is attempted. Alloys are melted in the same manner as for sand, and dry nitrogen or chlorine used for degassing purposes.

Pressure Casting in Plaster

Most pressure casting is done in shops that produce aluminum matchplates, pattern castings, cope-and-drag plates, core boxes and driers. There are nine major steps in the manufacture of cast aluminum patterns and matchplates:

1. Planning the job
2. Making the match
3. Pouring of individual cope-and-drag plaster molds
4. Trimming and scoring individual molds
5. Combining individual molds into multipatterned matchplate
6. Mold baking
7. Pouring aluminum
8. Removing casting
9. Rough finishing matchplates and castings

How Process Affects End Result

Success in the mold casting process depends on the care of special techniques used at each stage of processing. Materials and techniques are outlined.

Original Pattern—Thorough knowledge of the casting process, plus the best manner for preparing pattern halves are required. Design and shape of each individual pattern, core requirements, if any, and similar matters must be determined to produce the part of desired specifications. Brass is generally chosen as the die material since it is easily worked and modified, yet has the necessary hardness, corrosion resistance, and dimensional stability to hold the 0.002 in. tolerance. Life of a brass pattern is practically unlimited since the soft plaster molding slurry subjects it to neither abrasion, pressure nor thermal shock. Some patterns in daily use for seven years show no signs of wear. The mold material actually tends to polish the pattern. Alterations to the original pattern are easily made should changes be required. Wood or plastic patterns also may be used, although life expectancy and precision will not be as good.

Split-Pattern Technique—The unit strip system is primarily a cost influence, permitting more competitive pricing of the final product along with flexible use of patterns. However, it does have certain qualifications. Since all individual parts in the same flask are poured with the same alloy at the same temperature, they must be compatible with each other. In commercial small-lot production, it has been necessary to limit the number of alloys used to four—two copper-base and two aluminum-base—to insure full use of all space in each flask. Where a run permits handling of patterns on a full-flask basis, a wider selection of casting alloys is economically feasible.

Preparing the Mold—Essentially, mixing the plaster, pouring, setting and extraction techniques determine the detail accuracy of the plaster mold, hence accuracy of the process. The plaster is mixed for a predetermined length of time and at a predetermined temperature, then carefully poured into the flask over the pattern. To obtain maximum production, the time cycle for each stage must be carefully controlled. Mixing time should be controlled so that even the largest flask can be poured while the slurry is fluid enough to insure removal of air bubbles from the pattern face and to pick up every fine pattern detail.

The length of the entire molding cycle is just long enough to deposit the slurry and permit is to set sufficiently for extraction without breaking. Exact time is regulated by experience but must be consistent to hold maximum detail and provide uniform consistency in the molds. It is unnecessary to use draft angles on the outside surfaces of the casting. Normally, draft can be held to 1° or less on inside surfaces. Perpendicular outer edges will be true; inner corners need vary from a right angle only by a slight amount. Many foundries use flexible rubber patterns when possible.

Cores—Proportions of plaster to water for loose cores depend on size of pieces involved. All factors are established so that both cores and molds come out of the drying oven uniform in porosity, strength and degree of hardness.

Casting—Control over the casting operations begins with the original mixing of the alloys. Composition of alloy ingots to meet rigid specifications is most important. Contamination is then best prevented through continuous good housekeeping in every part of the plant, and includes careful re-use of scrap and accurate makeup of a heat.

Pouring temperature depends on the specific alloy in use and the type of pattern used in any particular set of molds, and must be regulated carefully. For this purpose, a recording pyrometer checks the temperature of the metal in the crucible before and during pouring.

Porous gypsum molds make good insulators, allowing casting metal to fill mold cavity completely before it starts to freeze to permit escape of entrained gas. Resulting casting is sound, free of internal stress and without skin hardness. Its surface is comparable to die casting in smoothness and superior in smoothness to certain aluminum casting alloys. A finish of 125 microinches is typical. Close control of the pattern dimensions, together with regulated pressure on the molds during pouring and cooling, sharply cuts down finishing with a minimum of cleaning and finishing. Shrinkage is a negligible, requiring no precautions for smaller pieces. For large castings, see section on insulated risers.

Plaster-mold castings may be successfully produced in any size from fractions of an inch in the short dimension to several feet in the long dimension. Tolerances obtainable in either aluminum or copperbase alloys are comparable to ordinary machining limits on dimensions of ¼ to 3 in. Dimensions in this region, when cast from one side of the parting line, are supplied to tolerances of 0.005 in., with tolerances for larger dimensions increasing at the rate of approx. 0.002 in. per in. Precision regulation of the molding and drying operations also insures good stability in across-parting-line dimensions extending across the line cannot be held as closely as those which are all made from one side of the mold. For certain commercial purposes mismatch along the parting line, not exceeding 0.015 in., is permitted without causing rejection. Generally, mismatch is held to less than one-third this figure.

Casting Metals

Manganese-Bronze Alloy is superior for high strength applications. This alloy tends to work-harden slightly in use. After a period on initial usage, and where there is no visible wear on the casting, dimensions of the part do not change; and the physical properties remain essentially constant for millions of operating cycles of impact or rubbing. Performance is not duplicated by other methods of casting since uniform, sound grain structure of the material results from its production with plaster mold casting techniques. While this alloy makes a tough casting, it handles easily, drills and taps readily, and can be milled with ordinary high-speed tools.

Aluminum-Bronze Alloy No. 2 Special is a zinc-free alloy developed for high-strength applications. When plaster cast, it is strong and tough and can attain, on heat treatment, physical properties in excess of 125,000 psi with no appreciable reduction in elongation. In heavy sections, fine detail will not be as good as with other alloys, but it presents an attractive appearance and meets all ordinary requirements for precision castings.

Yellow Brass—This is one of the oldest casting alloys. It is typified by ease of machining, bright surface on a machined face and complete uniformity from the skin to the core.

Aluminum Alloys—Present a special problem when handled by plaster mold methods. Sections ¼-in. or less meet standard sand-cast values in both Numbers 355 and 356 in the T6 condition. Heavier sections show some evidence of a slightly enlarged grain structure due to the insulating characteristics of the mold which slows the cooling rate. Physical values for the heavier sections are somewhat lower than standard sand cast values. Superior handling and pouring techniques are employed to obtain the highest physical properties. Successful results also are obtained with high-strength aluminum alloys which require no heat treatment. Alloys such as Tenzaloy will, after a natural aging period, exhibit physical characteristics completely satisfactory for many stressed castings.

The upper temperature limit of the plaster molds is about 2,200°F. Ferrous metals, and some nonferrous alloys having a very high pouring temperature such as some nickel bronzes and alloys with a very high lead, tin, or copper content, will not cast to best advantages in plaster.

Comparison with Other Casting Methods

Recognizing that local factors often affect selection of a casting process, some general characteristics should be considered for the various processes, including sand casting, investment casting, shell molding, die casting, and permanent-mold casting.

Sand Casting—Both piece-price and die cost are generally higher for plaster mold castings than for sand castings. Thus, plaster mold castings are more suitable where higher precision and retention of detail are required. The smoother surface finish obtained with plaster-mold casting make it more economical in those cases where considerable machining of sand castings would be required.

Investment Casting—While a greater range of alloys, including the ferrous types can be used, the two processes are not always directly comparable, each being able to produce some parts the other cannot. However, where a part can be produced with either process, plaster molding will be found more economical in the piece-price, and approximately equal in die costs. Order of precision is roughly the same for both casting methods.

Shell Molding—Direct comparison with molding is more difficult. For small quantities, the piece and die prices for plaster molding are usually less. However, if greater tolerances and rougher surface finish inherent in shell molding are acceptable, then it may be more economical when the quantities are large enough to absorb the higher pattern costs and resolve the gating problems. Since shell moldings accent ferrous alloys, the plaster process is not competitive in this regard.

Die Casting—Die casting copper-base alloys is practical where the material has a relatively low pouring temperature. This applies to certain brasses, zinc alloys and aluminum. The use of die casting for alloys having the higher pouring temperature characteristic of high-tensile materials is limited because of the resulting shortened die life. With aluminum, the choice is based on shape of the part and required quantity. Plaster molds permit use of more, complicated shapes and intricate core structures, as well as thinner sections. A plaster mold die may cost only one-third the price of a single-impression die-casting die. Piece prices of plaster mold castings are higher. For quantities from a hundred to a few thousand the plaster mold process will be more economical.

Permanent Molds—These also experience relatively short die life with copper base alloys. However, the method is highly advantageous for large pieces which do not lend themselves will to mechanized plaster molding. Permanent mold castings are generally less critical in their dimensional and surface finish requirements. As a result, there are relatively few pieces which can be handled successfully by both processes. In addition to die cost and the piece prices, tool life, rejects, and satisfactory performance of the end product are important factors in selecting a casting process. Plaster casting is generally superior in these factors.

Insulated Risers

The problem of completely filling a mold cavity is an old one. Producing castings in metal molds, as is done in the permanent molding process, exaggerates this problem. The rapid rate of heat transfer between the molten metal in the riser and the mass of the molds tends to quickly freeze the supply of metal present in the riser. The loss of this reservoir of metal increases the problem of overcoming shrinkage porosity and provide a substantial improvement in metal soundness.

Sleeves are made from a gypsum-base material and aid in producing a sound casting by maintaining a positive metal feed for a considerably longer period than do standard risers.

Additional time must be allowed for riser solidification. Although all cores can be pulled without delay, any attempt to remove the casting from the mold quickly will allow the still-fluid riser to collapse onto the piece being cast. It has been determined that solidification of the riser is a direct function of the insulating riser I.D. a delay of ½ min. was necessary when using a ½ in. I.D. sleeve and ¾ min. when using a ¾ in. I.D. sleeve.

Insulating riser sleeves are fragile and only 6 casting were produced per sleeve. If the insert block had been a permanent part of the mold, the number of castings produced per sleeve could easily have been increased to 12 or 15. Although sleeves will heat-check, they can easily be cut down below point of checking and reused. Cycling sleeves also will aid in increasing number of pieces obtained per sleeve.

Some difficulty is involved in adapting insulating riser sleeves for use in permanent mold castings because of the nature of permolding. Some of these difficulties are:

1. Permanent-mold operations are designed to produce castings at moderately high rate of speed. Insulating sleeves are fragile and require careful handling, thus will slow down operation.
2. Riser sleeves are expensive and increase the cost of each casting.
3. Mold would have to be specifically designed so that insulating riser sleeve would be easily accessible.

When conventional methods of risering casting fail to produce sound castings, use of an insulated riser should be considered. Insulated risers can definitely be used to advantage in molds which are designed to make use of blind risers.

Parameter Effect on Physical Properties of Plaster Molds

This section generalizes the effect of certain parameters on physical properties of metal casting plasters. Effect of mixing time can be seen in Fig. 1. The fact that setting time decreases as mixing time is increased is familiar to those accustomed to mixing and pouring plaster.

Permeability decreases at a rapid rate as mixing time is increased. When time of set has been reduced to 50% of its maximum value, permeability is reduced to 30% of its maximum value. This is probably due to the fact that faster setting produces a much greater number of smaller, closely interlocking crystals that offer more resistance to the passage of gases than a mass of larger interlocking crystals resulting from a slower setting action. This decrease in permeability could account for some of the "blows" that occur in practice, resulting in defective castings.

Setting expansion increases to a maximum between 3 and 4 min. of mixing and then falls off rapidly. Formerly, it was thought that setting expansion was a reliable guide to burnout shrink and that the two were directly proportional to each other. This conclusion was probably based on previous comparisons where batches were mixed for only 3 min.; under this condition the relationship holds. It is now shown that for mixing times longer than 4 min., or after the setting time has been decreased to about 70% of its maximum value, the setting expansion varies inversely with the burnout shrink.

Burnout compressive strength varies with the mixing time in the same manner as setting expansion. Its maximum occurs about 1 min. later than the maximum for setting expansion. Green compressive strength variation parallels that of burnout strength but is considered to be of lesser importance, and in interest of legibility was omitted from the graph.

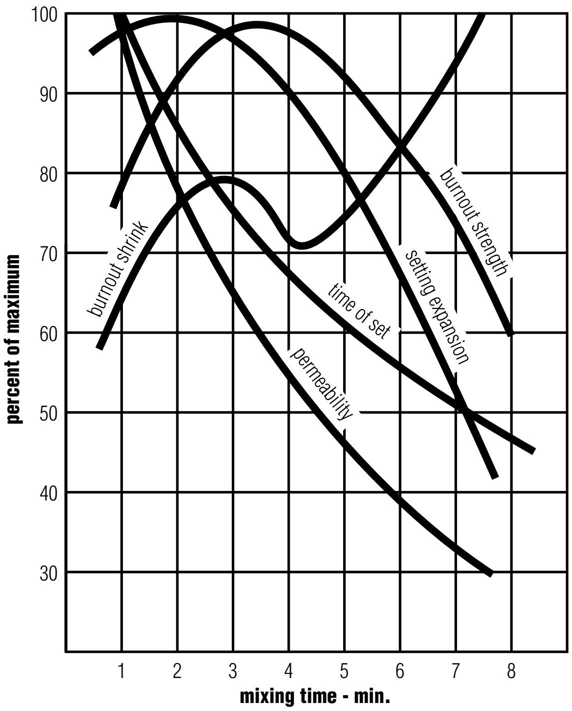

Fig. 1—Mixing time effect on time of set, permeability, setting expansion, burnout strength and burnout shrink.

Mixing Time and Burnout Shrink Relationship

The relationship between mixing time and burnout shrink is rather peculiar. As mixing time increases so does burnout shrink, reaching its first maximum after about 3 min. Following this, it decreases up to between 4 and 5 min. of mixing and then increases at a rather rapid rate, reaching a new maximum after about 8 min. of mixing far in excess of the first maximum. The inverted nature of this curve was assumed, at first, to be due to experimental error, but subsequent tests proved it to be correct.

The extremely rapid increase in burnout shrink after 5 min. of mixing and the fact that values as high as 0.346% were obtained is, undoubtedly, the cause of mismatches in matchplate molds. When a large batch pf plaster is mixed in the shop and used for pouring a number of molds, the material used in pouring the last mold often has begun to thicken appreciably. This indicates that setting action of the plaster is underway. This material is then equivalent to material that has been mixed for 8 min. or more. It will exhibit excessive shrinkage, causing the individual molds to shift in the flask in such a manner that they will not line up, or match, their respective halves in the other flask.

Effect of temperature is shown by Fig. 2. It is interesting to note that as the slurry temperature increases setting expansion decreases rapidly. This effect, again, has been generally recognized by those skilled in the art of plaster casting.

Time of set decreases rather slowly as the slurry temperature increases from about 50 to 110°F, then it lengthens rather rapidly as the slurry temperature increases further. At the boiling point of water the time of set is practically infinite, because at that temperature hemi-hydrate is the stable phase in contact with water.

Permeability shows a gradual increase as the plaster slurry temperature increases. Burnout shrink remains practically constant throughout the temperature range employed. Changes in plaster slurry temperature have little effect of green, or burnout compressive strengths.

Plaster Slurry Temperature Effect

The effect of plaster slurry temperature suggests a possible means of improving shop technique. Using a plaster slurry temperature of approximately 100 to 110°F should result in these benefits:

1. Time of set will decrease, reducing setting of plaster in the mold thereby producing a more uniform mold density from top to bottom.
2. Burnout shrink will remain substantially constant, even though the time of set decreases.
3. Permeability will be increased.
4. Decrease in setting expansion will result in easier release of set plaster from the patterns.

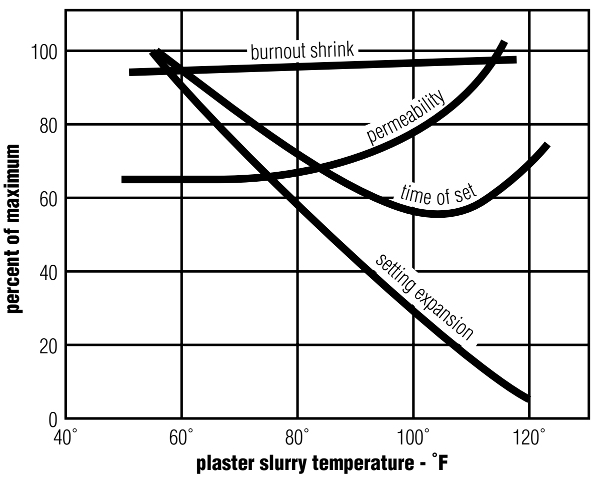

Fig. 2—Plaster slurry temperature effect on setting expansion, time of set, permeability and burnout shrink.

Effect of Burnout Temperature

The graph shown in Fig. 3 is not applicable to most matchplate operations, since the burnout temperature employed is fairly well stabilized at 400°F. However, some metal casting operations employ temperatures as high as 1,500°F for burnout, and in such instances the graph is pertinent.

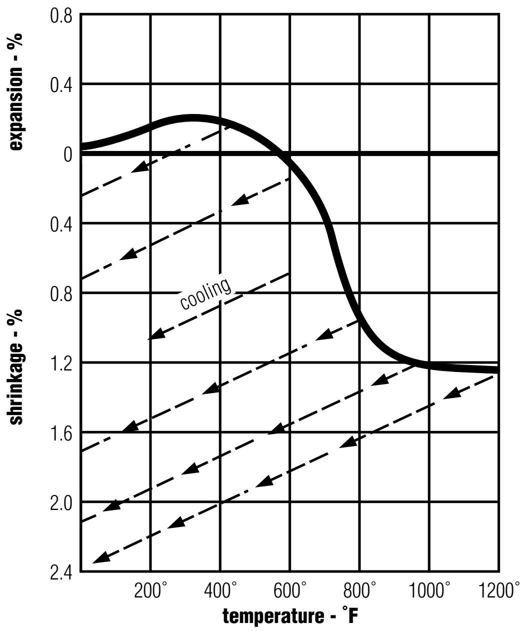

Fig. 3—Burnout temperature effect on burnout shrink.

The preceding graph illustrates dimensional changes that occur in a plaster mold on heating and cooling. The solid line represents the heating cycle and the dashed lines represent the heating cycles. As burnout temperature increases, plaster mold expands, reaching a maximum of about 400°F.

Heating beyond this point causes a contraction that reaches a maximum of about 1.25% at a temperature of 1,000°F. Should heating be stopped at any point along the solid curve, the dashed lines show dimensional changes on cooling to room temperature. For instance, if the mold is cooled after reaching a temperature of 400°F, resultant shrinkage at room temperature is about 0.25%. Heating to 600°F and cooling will result in a shrinkage of nearly 0.8%; similarly at 1,000°F, shrinkage will be about 1.7% after cooling. Thus it may be seen that localized overheating in some areas of burnout ovens employed in the shops could well account for excessive shrink in certain molds.

Observing the rules outlined in this report will aid in achieving these favorable results from casting of metal in plaster molds.:

1. Weigh accurately both water and plaster.
2. Adjust the temperature of the water to get a plaster slurry temperature of about 100 to 110°F.
3. Use a water plaster ratio of between 140 and 160 lb. water per 100 lb. plaster.
4. Mix no longer than 5 min.
5. Mix no more material than can be poured in 1 min. after mixing.
6. Use a burnout temperature of not over 450°F.
7. Air circulation in burnout ovens should be as high and uniform as possible.
8. Vent continuously about 20 to 25% of the circulating air load in burnout ovens.
9. After burnout, keep exposure of molds to shop atmosphere to a minimum before pouring metal.
10. Avoid putting molds through two burnout cycles, since this will increase burnout shrinkage.

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HEALTH AND SAFETY INFORMATION

WARNING: When mixed with water, this material hardens and then slowly becomes hot. DO NOT attempt to make a cast enclosing any part of the body using this material. Failure to follow these instructions can cause severe burns that may require surgical removal of affected tissue. Avoid dust. Dust may cause irritation to the eyes, skin, nose, throat, or upper respiratory system. Wear eye and respiratory protection to avoid irritation. Product safety information: (800) 507-8899.