BULLETIN NO. TAC-138



# PLASTER MOLD CASTING

Plaster mold precision castings should be considered when (1) the process can reduce machining time and costs; (2) close tolerances are mandatory; (3) exceptionally clean or smooth finishes are desired; (4) structural characteristics of available plaster mold casting alloys are suitable; (5) the production quantity involved is economical; (6) the size of the casting does not exceed the flask size of the foundry; (7) complicated shapes or thin sections (to 1/16 in.) are required; (8) and there are design and assembly advantages derived from reliability and uniformity of all cast parts.

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(April, 1961)

PLASTER MOLD CASTING provides a means for securing any desired quantity of accurate reproductions of a pattern by preparation of a series of identical, expendable plaster negative molds of the original pattern. From these plaster molds, in turn, positives may be cast in a wide variety of non-ferrous metals.

## THE PROCESS

Our process begins with the preparation of very precise brass patterns, similar to certain sand casting patterns except that tolerances can be held to less than 0.002 in.

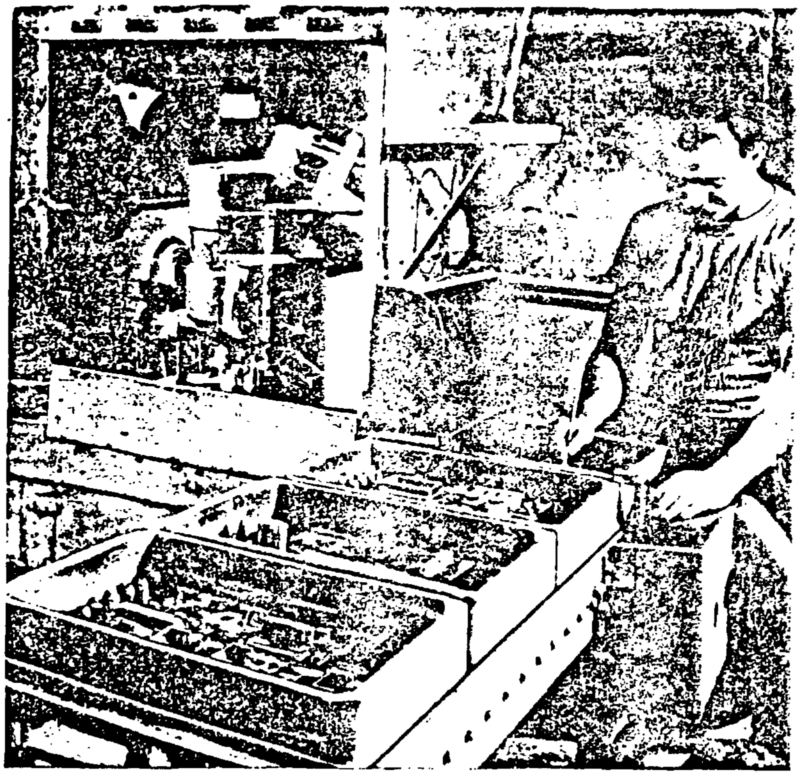
The pattern is prepared in split style, each half mounted on a special type of mold board precisely subdivided by interchangeable sections—unit strips. A flask size of 11½ in. x 17½ in. is divided into 20, 1¾ in. x 5⅝ in. strips mounted in rows of ten each. A single die pattern may be so small that one strip will accommodate several patterns of the same piece. In other cases, a pattern may require several strips for mounting, or may even use all 20 strips and occupy the entire pattern area of the container.

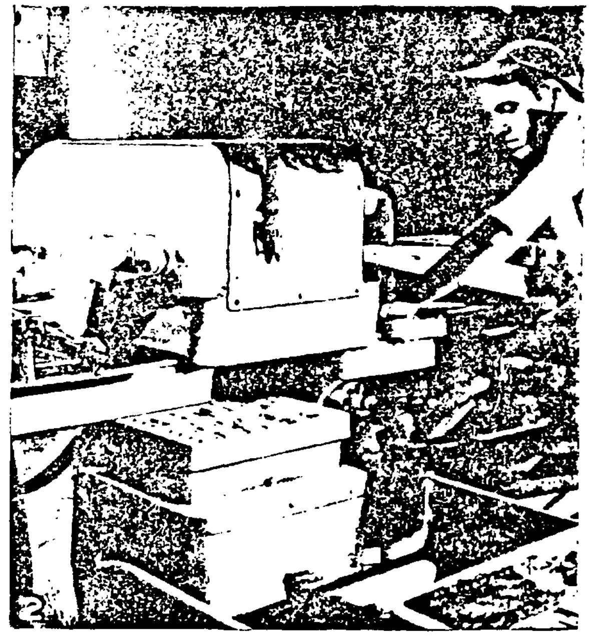
The strip mounted patterns are placed in the flask rim so that all the space is occupied. A runner for the metal and gates to bring the metal to each part is also contained on the strips. When the required number of plaster molds have been made from any particular pattern, the strip or strips on which the pattern is mounted may be removed from the flask, and another pattern of the same strip size substituted. The entire replacement operation takes only a few minutes. A short run for a particular casting may thus be made without materially interfering with the longer run of other castings in the same flask, thus providing for economical small lot production.

Plaster molds of the patterns are made by automatic machines which, after application of a parting agent, Fig. 1, deposit a slurry of plaster and water on the face of the patterns in a flask. Another machine properly agitates the flask. Then, with minimum movement and vibration, the flask rotates about a circular setting table while the final setting action takes place.

An automatic pneumatic machine rapidly removes the wet firm plaster mold from the flask without vibration, as shown in Fig. 2, thus maintaining its accuracy, reproducing all the details of the pattern even including scribe lines left by the pattern maker. Lettering, small gear teeth, indents and details normally lost with rougher casting methods are clearly impressed in the mold for later reproduction in the casting.

While making the plaster mold, a similar process with more hand control goes on to mold any loose cores which are required for a particular casting. The small individual cores are fed into a continuous drying oven together with the wet mold, as shown in Fig. 3. The water in the slurry is uniformly removed and, in addition, the mold is calcined by the regulated heat to a sufficient depth so





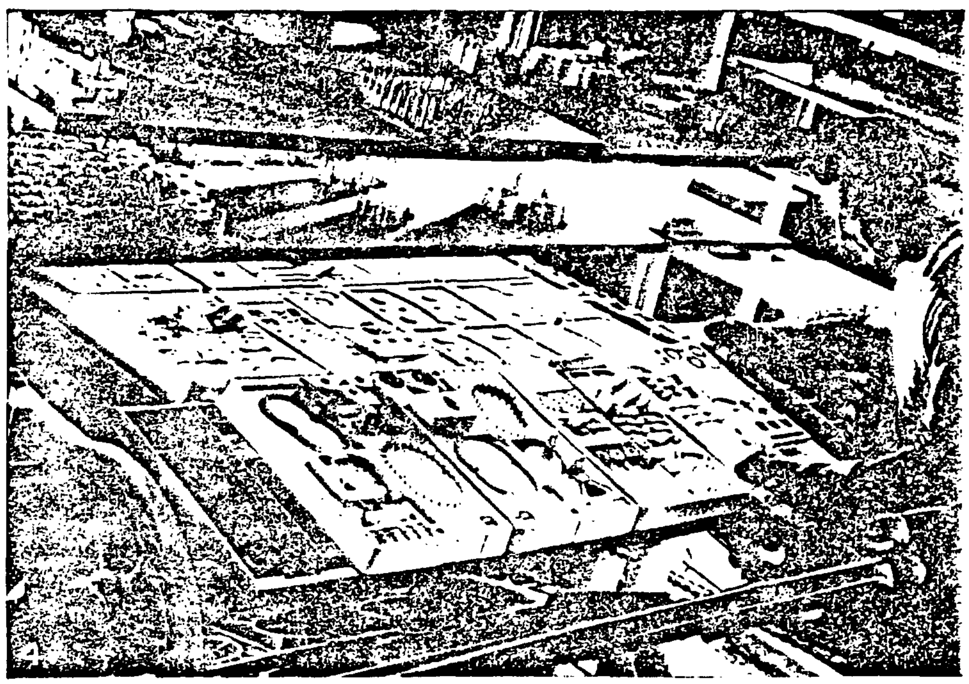


FIG. 1—Flasks with die patterns in position are sprayed with parting agent and automatically poured with plaster and water slurry.

FIG. 2—Non-vibrating pneumatic device smoothly extracts set mold from flask.

FIG. 3—Continuous type drying oven removes all moisture from mold and calcines surface to eliminate gas formation during pouring.

FIG. 4—Ten-mold truck at pouring stand showing asbestos lined sprues.

that when the molten metal comes into contact with it, there will be no evolution of gas.

**Casting and Finishing** come next. Following calcination, the loose cores are inserted in their proper positions in the molds, as shown in Fig. 4. The molds are then assembled, top with mating bottom, in standard cope and drag fashion. Since the method of pouring and extracting the molds eliminates outside supports, hard plaster dowels are used between the cope and drag, rather than flask pins. Asbestos pouring sprues are inserted in the mold, as shown in Fig. 5, and groups of ten molds are trucked over to the pouring area for placement in a pouring jig which holds each individual mold assembly together under uniform pressure. This insures uniformity of vertical dimensions and prevents accidents during the pour. The non-ferrous alloy melt is removed from the furnace in a crucible and carried to the pouring station. (In general, the molds in the jig are all taken from the same patterns and all take the same casting alloy.) The crucible proceeds to the pouring stations without agitation for fluxing, skimming and final temperature check. The same device that conveys the crucible to the pouring stations also carries the crucible to each individual mold for pouring, as in Fig. 6. After the pour, there is an extended cooling period while the molds remain under the pressure plates of the pouring jig. If the castings in process require the use of vacuum or air pressure, these means are also employed during the pouring period.

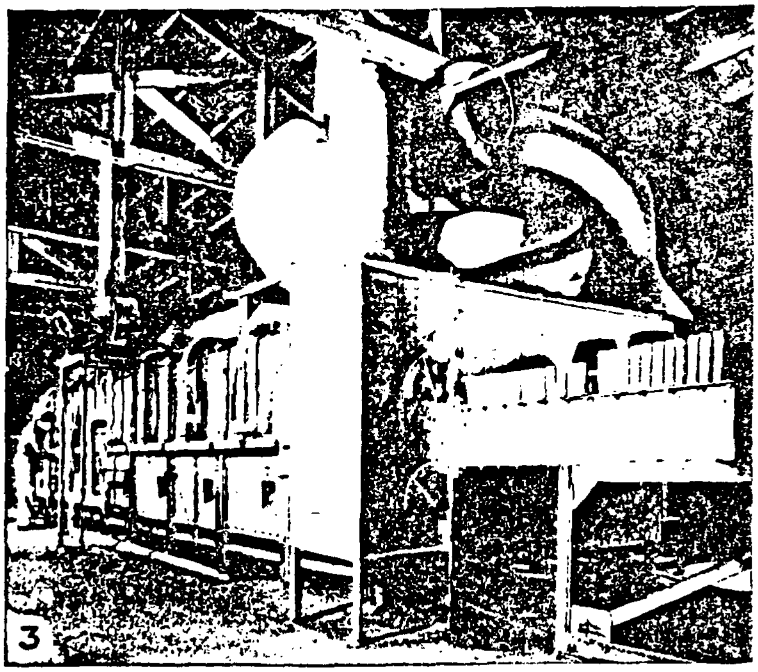
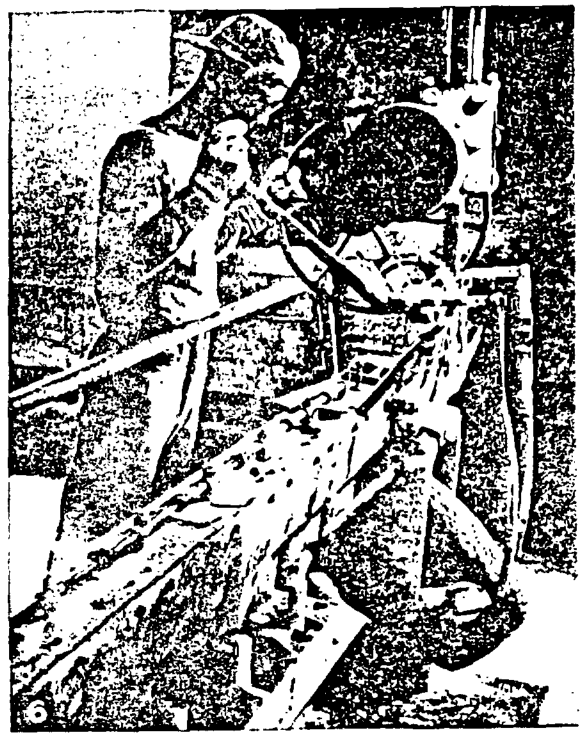
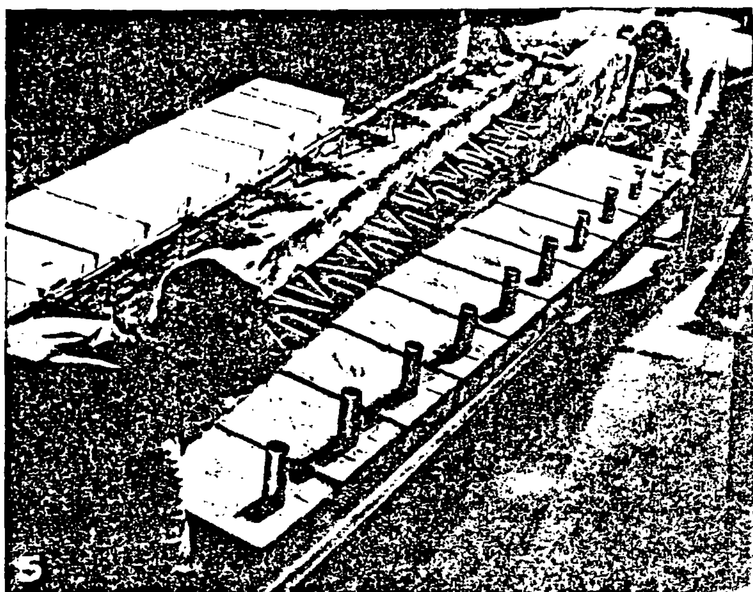


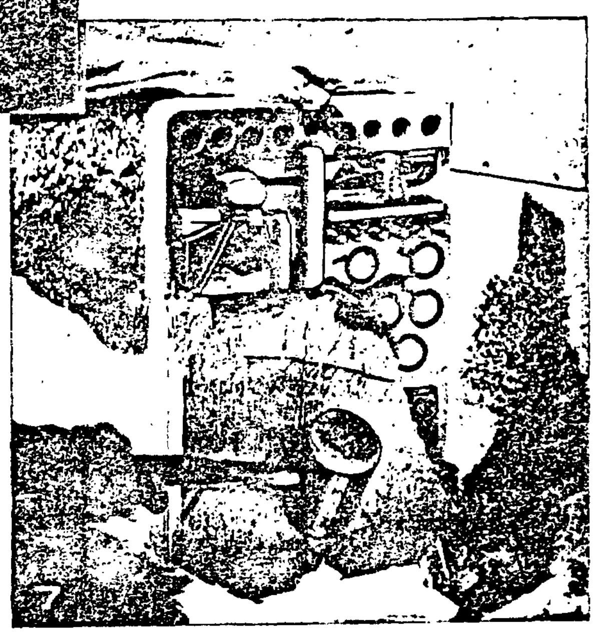
FIG. 5—Loose cores are inserted in fully dried, hard surfaced molds.

FIG. 6—Recording pyrometer determines proper moment for pouring; one-man pouring monorail permits accurate control.

FIG. 7—Castings are removed by breaking up mold after cooling.







The cooled molds are wheeled from the pouring stand, and the castings are removed by breaking up the friable plaster, as shown in Fig. 7. The molds have served their purpose and are now waste. A pressure spray removes all remaining plaster particles.

Because of the sharp definition and accurate dimensions of the castings, practically no additional finishing is required other than the separation of the individual cast parts in a complete gate. Using abrasive cut-off wheels, operators separate each cast element and also remove gates, runners, shrink bobs, fins, and other extraneous elements accompanying the casting process. Sand blasting gives final finish, after which the castings are already for packing and shipping.

## Characteristics of Plaster Mold Castings

1. Blow holes and porosity are eliminated; thus, castings will not arrive at the finishing process with a defect which scraps all prior work.

2. Elimination of hard spots increases tool life.

3. Castings from the same die are completely uniform and will fit jigs without additional adjustment.

4. Where machining is necessary because final tolerances are closer than can be cast, material to be machined will be a minimum. In general, the dimensional tolerance and smooth clean finish of the castings meet ordinary machining tolerances and thus reduce or eliminate further machining or finishing.

5. Complex designs are produced by using loose cores. Complicated assemblies including stops, internal teeth, and blind gear teeth can be cast in one piece. Thin sections down to 1/16 in. thick can be cast for substantial weight savings.

## HOW STEPS IN PROCESS AFFECT END RESULT

Factors which determine selection of the plaster mold casting process depend, in final analysis, upon the care, attention, or special techniques used at each stage of processing.

**Original Pattern.** The pattern maker must be an artisan as well as an exacting worker. Thorough knowledge of the casting process, plus a creative insight into best manner for preparing two pattern halves which, between them, will produce the desired cast part, are required. The design and shape of each individual pattern, the core requirements, if any, and similar matters must be determined to produce the part to 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. Also, the life of a brass pattern is practically unlimited since the soft plaster molding slurry subjects it to neither abrasion, pressure or thermal shock. Seldom is it necessary to replace any brass patterns; some 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 he required in the specifications of the completed casting. Where desired, wood or plastic patterns may also 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 this respect. 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, the plaster mixture, pouring, setting and extracting techniques determine the detail accuracy of the plaster mold, and hence the accuracy of the process. Casting gypsum is used for the slurry, the only special requirement being automatic control of the mixing and pouring. The surry must be mixed with water, measured and poured in fast sequence since the material sets rapidly. The time for each stage, as well as the water temperature, is carefully controlled. Agitation time is regulated according to the flask size used and is the major control required to insure removal of all air bubbles from the pattern face, porosity, and thorough investment of the pattern such that the plaster penetrates every fine detail. The length of the entire molding cycle is just long enough to deposit the slurry and permit it to set sufficiently for extraction without breakage. The exact time is regulated by experience but must be consistent to hold maximum detail and provide uniform consistence in the molds. It is unnecessary to incorporate draft angles on the outside surface of the castings, while draft normally can be held to 1 deg or less on inside surfaces. Perpendicular outer edges will be true; inner corners need vary from a right angle by only a slight amount.

The mix proportions of gypsum to water for the loose cores depend on the 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.

**Drying.** The heating characteristics of the oven are regulated to provide additional permeability in the mold. This additional protection is required so that any gas which may be trapped in the mold or which may have been generated during some part of the pouring operation will have freer access to the air. Surface calcination of the mold provides further protection from gas bubbles and a smooth finish on the plaster which will hold all the detail of the pattern.

**Casting.** Control over the casting operation 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.

The 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.

The porous gypsum mold makes a good insulator, allowing the casting metal to fill the mold cavity completely before it starts to freeze, thus permitting the escape of any entrained gas. The 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 with 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 finning and results in a minimum of cleaning and finishing. Shrinkage is negligible, requiring no precautions for smaller pieces. For larger castings, shrink bobs feed the casting.

In general, plaster mold castings may successfully be 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 copper-base alloys are comparable to ordinary machining limits on dimensions of ¼ in. 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 approximately 0.002 in. per in. Precision regulation of the molding and drying operations also insures good stability in across-parting-line dimensions. However, vertical 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 of this figure.

## CASTING MATERIALS

Characteristics of casting alloys which meet most requirements are shown in Table I. In addition to the alloys shown, other aluminum manganese bronzes, aluminum bronzes, a wide range of brasses, silicon bronzes and a few special nickel bronzes are poured regularly and successfully.

**Manganese bronze** alloy is superior for high strength applications. As cast, this alloy tends to work harden slightly in use. After a period of initial usage, and where there is no visible wear on the casting, dimensions of the part do not change; and the physicals remain essentially constant for millions of operating cycles of impact or rubbing. Performance figures shown are not duplicated by other methods of casting since the 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 especially developed for high strength applications. When plaster cast, it is strong and tough and can attain, on heat treatment, ultimate 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** is one of the oldest casting alloys. It is typified by ease of machining, bright surface on a machined face and complete uniformity from skin to core.

**Aluminum Alloys** present a special problem when handled by plaster mold methods. Sections ¼″ 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 are also obtained with the 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 2200 F. Ferrous metals, and some non-ferrous 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.

### Table I—Alloy Specifications

| Alloy ➡ | Yellow Brass | No. 1 Special Aluminum Bronze | No. 2 Special Aluminum Bronze [1] | High Tensile Manganese Bronze | High Strength Aluminum [2] | Aluminum Alloy [3] |
|---|---|---|---|---|---|---|
| **Nominal Physicals As Cast (approx.)** | | | | | | |
| Ultimate Tensile | 50,000 | 70,000 | 85,000 | 100,000 | 26,300 | |
| Yield Point | 25,000 | 40,000 | 52,000 | 60,000 | 19,500 | |
| Elongation Per Cent in 2 in. | 12 | 7.0 | 4–6 | 7.0 | 6.0 | |
| Brinell | 100 | 160 | 180 | 190 | ........ | |
| Patterns Required | Open Flask | Full Flask | Full Flask | Open Flask | Open Flask | See Note Below |
| **Nominal Composition (approx.)** | | | | | | |
| Copper | 58.00 | 82.50 | 78.0 | 65.00 | 0.8 | |
| Zinc | 40.25 | | | 23.00 | 8.0 | |
| Tin | 1.00 | | | | | |
| Lead | .75 | | | | | |
| Aluminum | | 11.25 | 10.5 | 5.00 | Balance | |
| Iron | | 5.00 | 4.0 | 2.50 | | |
| Manganese | | 1.25 | 1.25 | 5.00 | | |
| Nickel | | | 4.0 | | | |
| Silicon | | | | | | |
| Magnesium | | | | | 0.4 | |

[1] Heat treating No. 2 Special Aluminum Bronze gives the following Physicals: Ultimate Tensile 125,000; Yield Point 75,000; Elongation 5 to 6 Per Cent in 2 in.; Brinell 260.
[2] Results obtained from test bars aged two weeks at room temperature.
[3] Alloys #356 & 355 in ¼″ sections or less in the T6 condition meet guaranteed values for sand castings. Values for heavier sections are somewhat less.

## Table II—A Few Plaster Mold Casting Applications

| Type of Service | Application |
|---|---|
| Aircraft and Marine | Instruments and controls, hydraulic system parts, flanges, fittings, flap hinges, wing nuts, pistons and cylinder heads, impellers and propellers. |
| Automotive | Chassis, body and engine fittings, gears, ornaments, bearing retainers. |
| Appliance | Small appliance casings, washing machine parts, vacuum cleaner parts, cooking utensils, appliance hardware and decorations. |
| Electrical | Brush holders, wire connectors, cable clamps couplings, transmission line connectors and pole line hardware, sparkless tools. |
| Electronic | Microwave and radar components, tuning gears, operating mechanisms and frames. |
| Industrial and Hardware | Wrenches, pliers, clutches, sprockets, hinges, valves, fittings, impellers, control levers, springs, miscellaneous plumbing supplies. |
| Railroad | Locks, handles, lighting fixtures, gears, ornamental, plumbing and miscellaneous hardware. |
| Miscellaneous | Surgical instruments, toys, plaques and insignias. |

## 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** techniques are still limited to production of relatively small parts; although a greater range of alloys, including the ferrous types, is available. The two processes are therefore 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. The order of precision is roughly the same for both casting methods.

**Shell Molding.** Direct comparison with shell molding is more difficult. For small quantities, the piece and die prices for plaster molding are usually less. However, if the 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 allow for the gating problems to be ironed out. 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 the shape of the part and the 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. However, the piece prices of plaster mold castings are higher. Experience indicates that in 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 well 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.

## INDUSTRIAL ACCEPTANCE

Increased use by industry of the plaster mold process may be attributed partially, at least, to the steady rise in machining costs and the growing dearth of skilled machinists. Since plaster mold castings hold ordinary machining tolerances, their use can effect considerable labor savings —both in machining and assembly. Increased mechanization of the plaster casting process, with resulting closer control over every step, has provided less costly casting of greater reliability so that more companies have found it advantageous.

As the potentialities of the process are better understood, further use of plaster mold castings will undoubtedly result. In many instances a conservative design policy tends to ignore the possibility of using non-ferrous alloys. Of course, there are cases where only steel will serve the purpose; and as other casting processes make ferrous alloys available in precision castings, there will be some encroachment on the plaster mold field.

## PRESENT APPLICATIONS

A partial list of applications for plaster mold castings is given in Table II. Parts that have been successfully cast are numerous; therefore, the selection was made from among heavy alloy parts, used where durability and high strength are needed—rather than from aluminum and other light alloy plaster mold castings with which designers and industrial users are perhaps more familiar. (See *Product Engineering*, September, 1954, "Plaster Casting the Light Metals", by George R. Gardner.)

The York Corporation's original design of an ice cutter for their automatic ice maker contemplated the machining of three separate stainless steel parts, to be joined by an additional welding operation. Instead, it was found possible to cast the entire part in one piece, comprising six spiral blades on a center shaft, Fig. 8. Manganese bronze was selected, to provide necessary endurance and strength, as well as the corrosion resistance and retention of smooth surface finish required in food equipment.

An aircraft generator brush holder developed for the General Electric Company, with their collaboration, was another interesting design. The company's older model, Fig. 9(A), machined from steel, added objectionable weight and cost, but seemed necessary for strength. The part was completely redesigned so that it could be produced as a one piece casting, Fig. 9(B). Manganese bronze was used to provide adequate rigidity, despite an 0.076 in. minimal wall dimension in the new brush holder. The cost of the casting was substantially lower than the machined parts it replaced.

Specifications for the skirt door operating mechanism on cars for the Pennsylvania Railroad, manufactured by the Budd Company, have been based on the necessity for them to absorb continuous punishment. When plaster-mold cast in manganese bronze, Fig. 10, each separate part provided a tensile strength of 100,000 psi and a Brinell hardness of 190 without any additional heat treatment. Also, by using an assembly of plaster-mold cast parts, no machining was required, the installation being reduced to the drilling of two holes.

**EDITOR'S NOTE—Reference is made to a previous article, "Plaster Castings The Light Metals" by G. R. Gardner, on p 164 of *Product Engineering* for Sept. 1954. This article gives additional design considerations, including data on dimensional tolerances, a discussion of some additional casting alloys with test data on mechanical properties, methods of finishing, and mention of several other applications for the plaster mold process.**

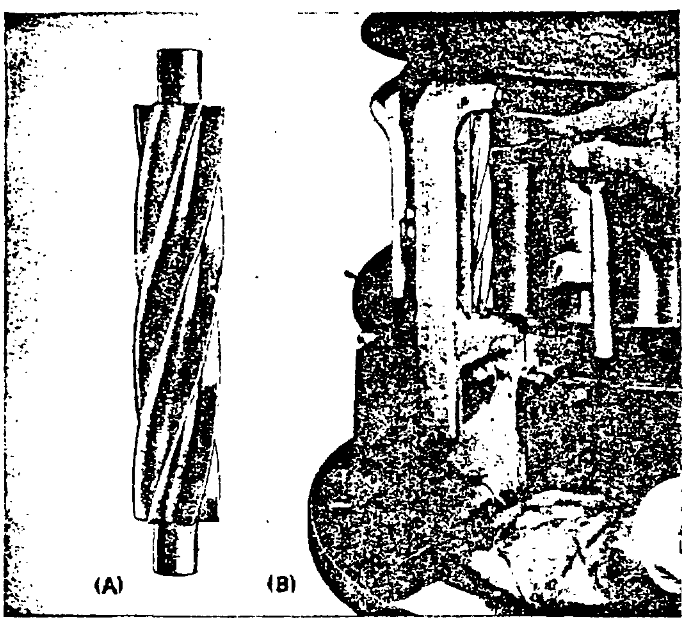
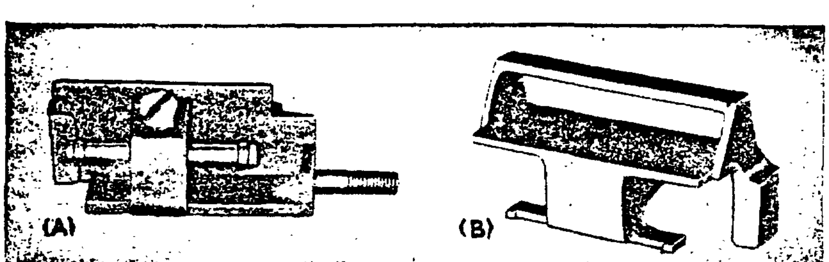



FIG. 8—(A) Six spiral blades on center shaft of ice cutter were cast in one piece, replacing contemplated design using three machined and welded stainless steel parts. (B) Ice harvesting system in automatic ice maker showing ice cutter casting in position. Spiral cutter shaves ice into curved flakes, avoiding ice splinters.

FIG. 9—(A) Original design of brush holder for use on aircraft generators, using several machined steel parts. (B) Newly designed one-piece manganese-bronze cast brush holder provides adequate rigidity.



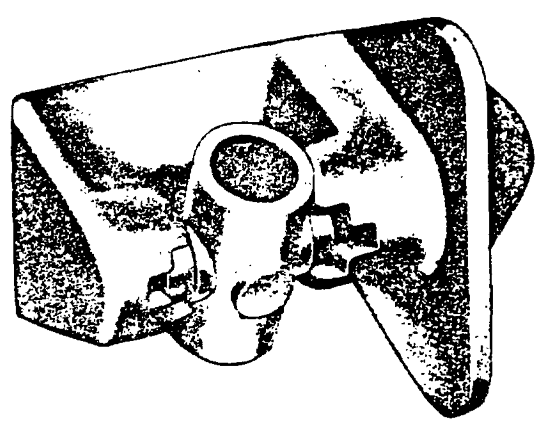



FIG. 10—All parts in this skirt-door operating mechanism for Pennsylvania Railroad cars, were cast by the plaster mold process in manganese bronze. No machining was required for assembly of parts; only two holes were drilled to complete installation.

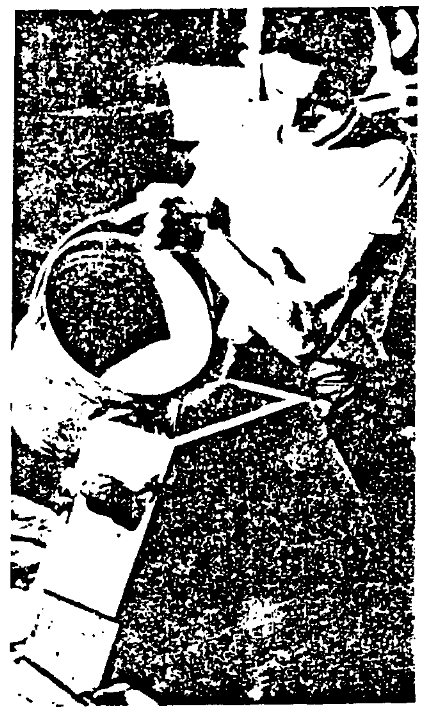
## *New Plaster Makes*

# PERMEABLE MOLDS

CASTING plaster-for nonferrous metals is said to yield quickly produced molds that combine the smoothness of plaster and permeability of sand. Manufactured by United States Gypsum Company, Chicago, it is called HYDROPERM.*

Following advantages are cited: 1. Molds can be poured by gravity; 2. Heads and gates can be planned according to good foundry practice; 3. Steam formed during the pouring operation escapes readily through the permeable mold; 4. Because calcination of the mold is not necessary, molds are more nearly true to size; 5. Mold shrinkage is minimized because high-temperature burnout is not required.

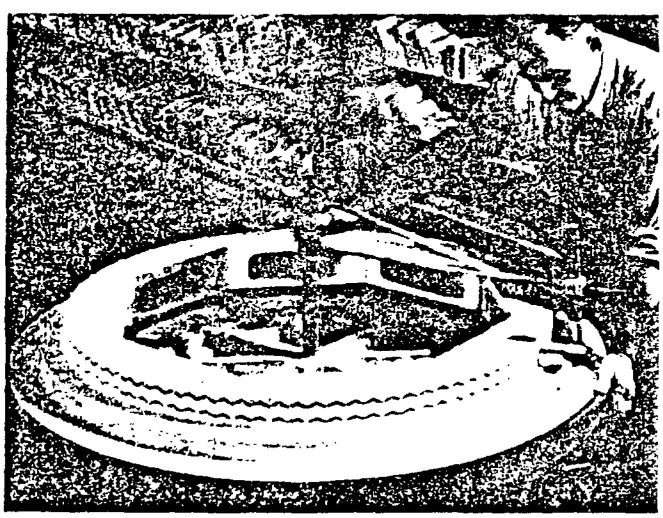
The permeability range can be varied and controlled to meet requirements. A mixer must be used to beat air into the mix to produce cells, and the higher the power input per unit of mix, the finer the permeable structure and the smoother the mold surface. Consistency can be varied from 70-100 parts water to 100 parts plaster. Enough air can be incorporated to increase the volume from 50 to 100 per cent during the mixing operation.

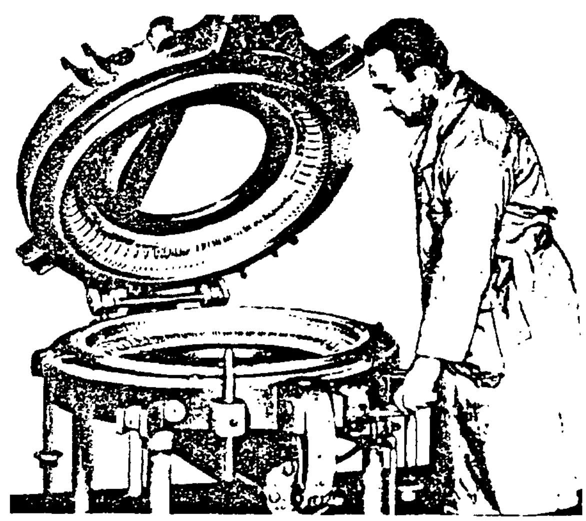


*At left below*—Plaster core segments fit precisely to form over-all circular core and meet exact tolerances

*At right below*—Final product is an intricate tire-recapping mold, cost from the new, permeable plaster mold

*Above*—Plaster slurry is poured into the assembled corebox housing. Calcination of the mold is not required





*Reg. U.S. Pat. Off.