

Aug. 26, 1958

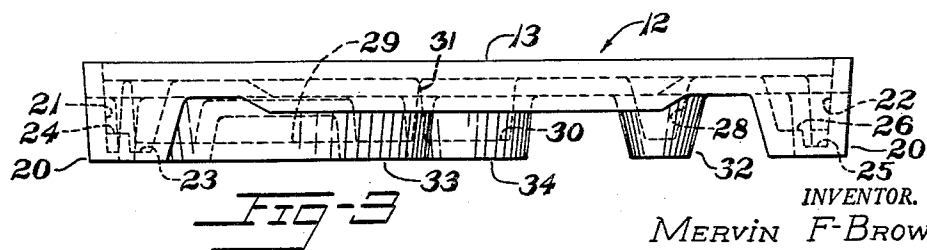
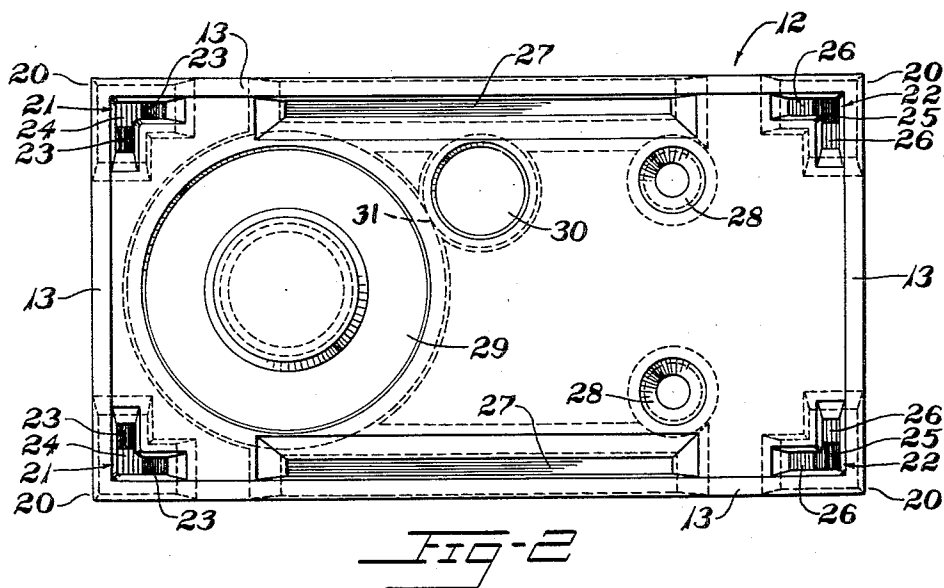
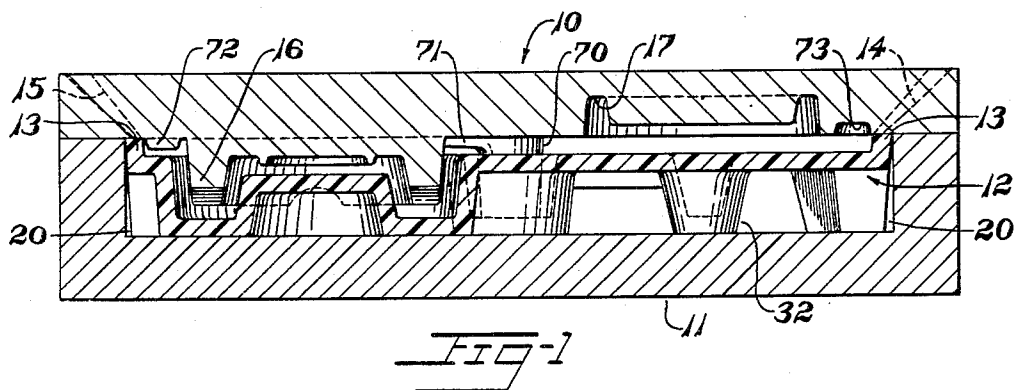
M. F. BROWNE

2,848,773

METHOD OF PRECISION CASTING

Filed May 14, 1953

4 Sheets-Sheet 1



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Aug. 26, 1958

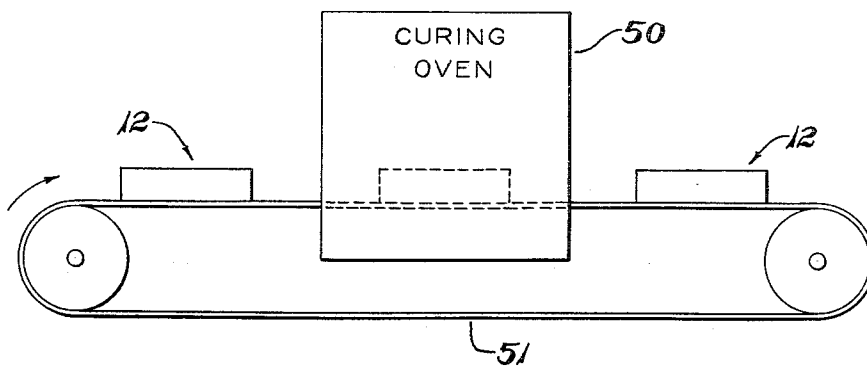
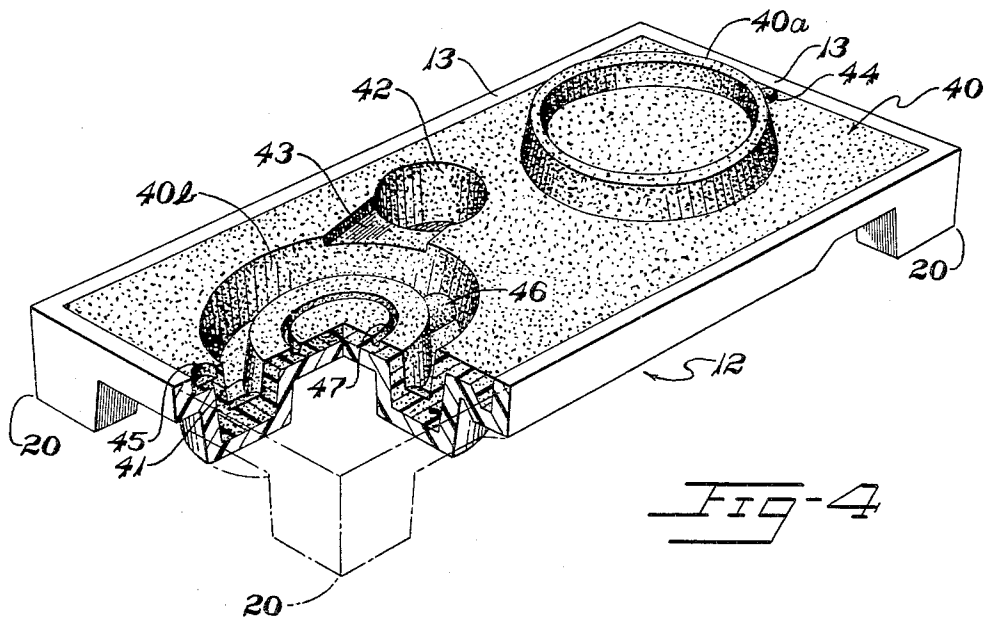
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METHOD OF PRECISION CASTING

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4 Sheets-Sheet 2



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METHOD OF PRECISION CASTING

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4 Sheets-Sheet 3

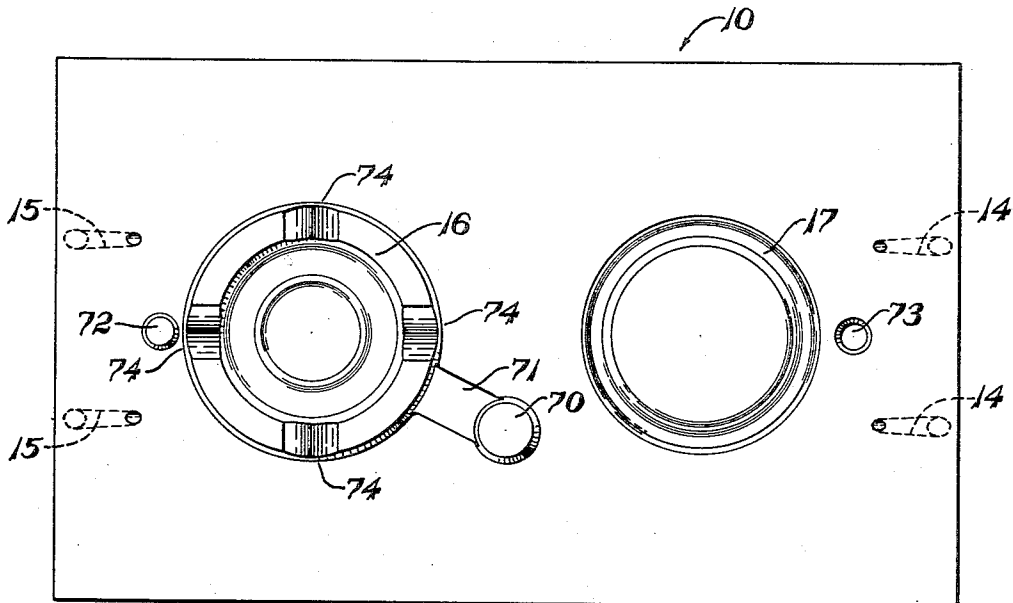
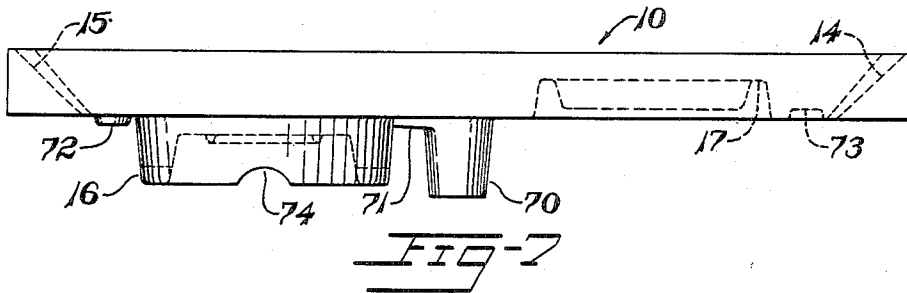
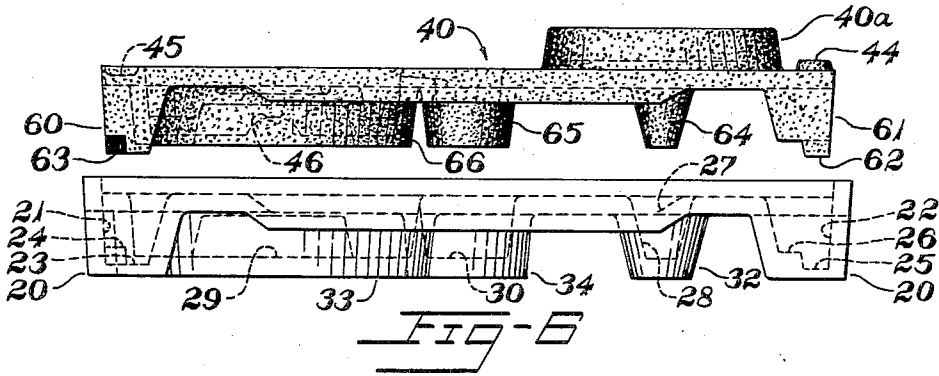


FIG-8

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METHOD OF PRECISION CASTING

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4 Sheets-Sheet 4

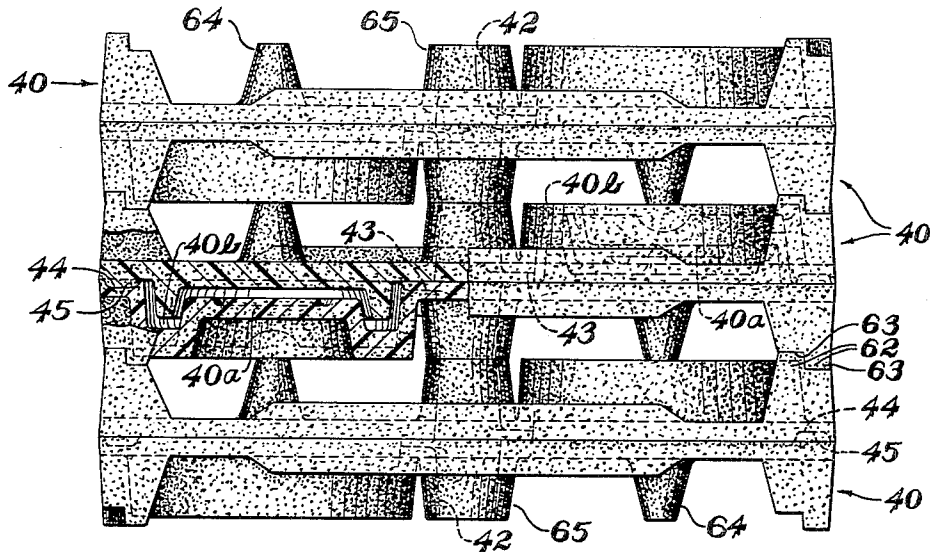


Fig-9

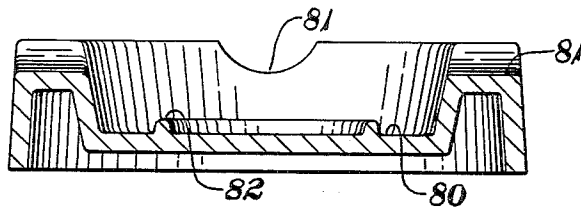


Fig-10

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METHOD OF PRECISION CASTING

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6 Claims. (Cl. 22—193)

The present invention relates to precision casting methods and more particularly to a method for precision casting metals utilizing rigid, self-supporting, resin-bound sand molds of high permeability and high finish.

In general foundry practice metals are cast in molds made of moist or "green" sand. In ordinary sand molding the sand is merely mixed with a clay and dampened so as to be readily packed, rammed or blown into shape over a pattern. Since the wet sand has very low strength, a large quantity of the sand is packed or rammed about the pattern in a heavy frame or flask usually made of metal. This method produces metal castings having a rough finish and of only approximate dimensions since the wet sand mixture is easily eroded or displaced by the molten metal. Considerable machining and finishing of the castings is necessary to produce metal parts of good finish and accurate dimensions. Rather coarse sand is required in this method in order to permit escape of gases from the heavy mass of sand surrounding the molten metal.

Another process known as the "C" process or Croning process utilizes thin resin bonded molds or "shells" made from a fine powdery mixture of a dry, very fine sand and a dry, fine powdery resin binder composed of a mixture of spray-dried phenol-formaldehyde resin and hexamethylene tetramine. In this process the shell mold can be made of much finer sand than ordinary green sand molding because vapors can escape because of the thinness of the shell and the porous nature of the shot or gravel backing. In this shell molding method the fine, dry sand-resin mixture is dumped onto a heated metal pattern and allowed to stand until a thin crust forms by melting of the resin binder. The excess dry sand-resin mixture is then poured off and the thin crust rendered hard and dimensionally stable by continued heating in contact with the hot pattern to cure the resin to the thermoset condition. The thin shell or mold is then stripped from the pattern, assembled, clamped together and supported by metal shot, gravel, or other supporting means. Finally, molten metal is then poured into the shell mold and allowed to solidify. The resultant casting possesses a very smooth finish due to the use of very fine sand and firm binding of surface grains. When the shell is properly and carefully made, and adequately supported, the castings are accurate as to dimension and very little machining or finishing is necessary.

The described "C" process of shell molding has not enjoyed as wide an application as would appear justified by casting quality because of several fundamental and inherent disadvantages. Firstly, since the manner of forming the shell is dependent on a sintering or melting of a dry resin which will later cure to the thermoset condition, the method is virtually limited to the use of the phenolic resin and the hexa curing agent. Other thermosetting resins such as urea-formaldehyde resin cure too rapidly, alkyd resins cure too slowly and both do not melt or flow sufficiently to ensure good sand binding action. Such resins have not formed satisfactory shells

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in contact with a heated pattern. Secondly, the light metals, particularly magnesium, can not be cast satisfactorily in phenolic-bonded shell molds due to the poor collapsibility characteristics of the phenolic resins. Thirdly, the dry sand-resin mixture raises a dusting problem that is only partially overcome by special handling equipment. Fourthly, the dry sand-resin mixture is sensitive to moisture, producing weaker shells after standing for any length of time in contact with a humid atmosphere. In commercial use this means fresh daily preparation of the sand-resin mixture for best results. Fifthly, in order to obtain adequate bonding of the sand grains a very high resin-to-sand ratio is required.

A sixth disadvantage is that production capacity is strictly limited by the "dwell" time necessary for sintering and cure of the resin while in contact with the metal pattern. Production with each pattern consequently is strictly limited by the resin curing characteristics so that multiple patterns and their accompanying heavy dump boxes, sand handling equipment, etc. are required for high output. A seventh disadvantage resides in the requirement of the process for massive and expensive equipment of special design which is not, nor is it susceptible of, general use in ordinary foundry practice. The dumping boxes, special sand handling equipment and shot-cleaning and handling equipment are illustrative of the more expensive units required. Moreover, since the patterns must be of metal and fitted with special heating devices, they tend to be very heavy and expensive, their cost constituting a substantial proportion of the total installation cost. Retooling for design changes is likewise a considerable element of cost.

An eighth disadvantage of the process is the properties or rather the physical shape of the shell mold itself. The dump-box technique makes it extremely difficult to accurately control the thickness of the shell or its outer configuration. The thickness of the shell depends on a great many variables including "dwell" time, the weight of sand overburden on the pattern, and on the maintenance of an even temperature over the entire surface of the pattern. In any case, the outer surface of the mold is very rough and uneven. Warping troubles are encountered when the hot shells are removed from the pattern and especially when it is attempted to support the shell by its outer surfaces. The method is limited in the size of castings that may be produced because (1) the weight of the metal pattern becomes excessive (patterns up to 300 lbs. or more are not uncommon) and because (2) thin shells in larger sizes are very difficult to handle, assemble and support. Other disadvantages exist, and although of lesser importance than those enumerated, in the aggregate they make for a costly and difficult operation.

It is the principal object of this invention, therefore, to provide a process of precision casting of metals that is susceptible of general application and utilizes standard foundry techniques and equipment.

A further object is to provide such a method which is applicable to all metals and which makes possible the utilization of wet sand mixtures and inexpensive water-soluble or water-dispersible resinous binders.

Another object is to provide such a method which is capable of higher production rates at a lower cost and without the disadvantages of known sand molding methods. Still further objects will become apparent in the description which follows.

I have found that economical casting of metals with great precision and hard, rigid, self-supporting and highly permeable sand molds are economically produced by a method wherein molding sand or other finely-divided refractory molding material is mixed with an aqueous solution of a water-dispersible or water-soluble but heat-

hardenable binder to form a wet sand molding mixture which is then molded into a sand molding, or component part thereof, while in contact with a reusable or removable box-drier, the box-drier and its adhering wet or "green" sand mold removed from the pattern, pattern box or other enclosure and subjected to baking to heat-harden the binder and drive off a major share of the moisture, and finally the heat-hardened and self-supporting mold, or its components, separated from the drier and assembled. The box drier is of a unique type in that it does not function in the shaping of any metal-contacting surface of the mold, but rather shapes the exterior surface or surfaces thereof only so as to incorporate therein supporting and reinforcing means whereby there is produced a strong, rigid and self-supporting sand mold which does not require racks, frames, shot-support, or clips or fasteners for assembly. A preferred embodiment utilizes integrally-molded interlocking legs or other means on the mold exterior and integrally molded runners, sprues, etc. in the mold to permit vertical or horizontal assembly or stacking of a plurality of sand molds for simultaneous pouring.

The method of this invention has many advantages, the most important being the production of castings accurate to 0.003 inch or less and with an exceptionally smooth surface requiring little machining or finishing. The water and binder may be incorporated in the sand in conventional muller-type mixers now standard in the foundry industry. The method also makes the most efficient use of binder by coating each sand grain with a thin coating. The wet sand mix may be molded by any conventional foundry technique such as ramming, bumping, or blowing, although the latter is greatly preferred because of its speed, simplicity and flexibility.

The use of a box-drier in the manufacture of sand molds makes possible the production of rigid, self-supporting sand molds because the drier is easily designed to convert an otherwise odd-shaped mold into a free-standing or self-supporting mold or component part thereof. The drier permits absolute control over wall thickness of the mold and eliminates warpage problems during cure and cooling. Most importantly, the drier completely eliminates dwell time in the pattern or pattern box and thus makes for maximum utilization of expensive patterns and accompanying molding equipment. The drier also permits the use of the high efficiency and high speed of electronic heating during baking. For this latter purpose the drier must be made of a suitable dielectric material such as wood, plaster, plastic, and the like. An especially suitable material of construction for the drier is a mineral fiber filled or glass fiber filled alkyl molding compound.

In the practice of the method of this invention a moist mixture of fine sand (about A. F. S. No. 100) and an aqueous dispersion or solution of a water-dispersible or -soluble binder, preferably a resinous binder, is compacted and given its proper shape while in place on a novel-type of box-drier. This compacting and shaping may be performed by tamping the sand into a box or flask containing the box-drier or it may be done by blowing with a sand blowing machine of the type used in making cores. The latter procedure is much preferred because of the ease, speed and economy of operation.

The box-drier which makes the method of this invention practical is of a novel type. In the core-making art box-driers or trays are utilized to support odd-shaped cores which are not free-standing or self-supporting. The surface of such driers are hollowed-out so as to fit an outside surface of the core and support it during baking. Thus such a drier actually contacts surfaces of the core eventually to be exposed to molten metal. The driers utilized in this invention are quite different in that they never function in the shaping or supporting of metal-contacting sand surfaces, rather they shape and mold the outer surfaces only of the sand mold. The drier molds

the exterior surfaces of the sand mold into smooth planar surfaces, into supporting bosses and legs and, if desired, into precision-fit interlocking means whereby the finished, cured sand mold can be assembled and will support itself without backing or support of any kind. By suitably designing the box-drier the finished sand molds can be made to nest one within or against each other and to interlock so as to form a self-supporting multiple-mold assembly. It is not necessary to design a special box-drier for each article to be molded. A suitable range of sizes of box-driers of standard design can be provided for the production of molds for a wide variety of articles or castings. Thus the exterior configuration of the sand mold can be standardized irrespective of the configuration of the interior metal-contacting surfaces. When such a box-drier is utilized in a blowing machine, in many cases only the design of the blower head need be changed.

The drier, with its adhering mass of moist sand, is removed from the mold box or flask, or from the blower-head assembly, and placed in a curing oven to effect drying and/or curing of the binder. In this way the expensive mold box or blower head is not tied up in "dwell time" but may be utilized to a maximum extent in the forming or blowing operation. Wet sand molds can be produced at a rate of 100 to 350 or more an hour, for example, with a suitable core blowing machine. This is a rate of production far beyond any of the so-called "shell" molding processes. Breakage or damage to the wet sand molds is at a minimum.

The curing or baking of the sand molds may be performed in any way and with any equipment conventionally used to bake cores. Gas or oil fired ovens may be used although the preferred oven employs high frequency or electronic radiation as a source of heat. The wet sand mix is ideal for this type of heating for the resin binder is fully cured in a matter of seconds. Continuous tunnel-like ovens can be used for maximum production rates.

Once the resin binder is cured or the non-resinous binders dehydrated or dried out the sand mold is strong and not susceptible to damage in handling. The sand mold may then be removed from the box-drier without fear of damage.

The sand mold or component thereof made as just described is easily assembled for pouring. For ordinary operations it is not necessary to glue, bind or otherwise fasten the various parts of the mold together. The precision-fitted outer surfaces of the mold permit vertical or horizontal stacking to form a multiple-mold assembly capable of pouring off in one step.

By this method single or multiple-cavity molds can be assembled into multiple-mold assemblies. The gates, sprues and runners can be incorporated in the sand mold itself to further simplify the assembly and pouring steps. The method thus makes possible precision casting of metals at costs approaching those of ordinary foundry methods. The method employs conventional foundry equipment and techniques well understood by those skilled in the art, thus further reducing installation and operating costs. The method uses the inexpensive and readily-available water-soluble or water-dispersible resins binders such as urea, phenolic, melamine, and others. Since the method permits the use of urea resin binders it solves the problem of precision-casting of magnesium and aluminum and their alloys, and, moreover, makes possible the inclusion in the sand mix of the water-soluble inhibitors needed for the casting of these highly-reactive light metals. Other advantages of the method will become apparent in the more specific description to follow.

The invention will now be more fully described with reference to the drawings which demonstrate the application of the method to the production of a simple ash-tray. Of the drawings:

Fig. 1 is a vertical section through a blowing machine

assembly including the blower head, a box-drier and supporting plate.

Fig. 2 is a plan view of the box-drier or tray shown in Fig. 1.

Fig. 3 is a front view of the box-drier of Fig. 2.

Fig. 4 is a perspective view, partially in section, of the box-drier of Figs. 1 to 3 with freshly blown sand in position thereon.

Fig. 5 is a schematic view of a continuous mold curing machine with box-driers and their adhering blown sand mold parts in position thereon.

Fig. 6 is an exploded view of the box-drier with a cured sand mold component of Fig. 4 partially lifted away.

Fig. 7 is an elevational view in detail of the blower head shown in Fig. 1.

Fig. 8 is a plan view in detail of the blower head shown in Fig. 1.

Fig. 9 is a front elevation, partially in section, showing an assembly of molds made by the blower-head assembly of Fig. 1.

Fig. 10 is an elevation in section of an individual ash-tray made in the mold assembly of Fig. 9.

Fig. 1 illustrates a blower-head assembly comprising a blower-head 10, a base-plate 11 and a box-drier or tray 12. The blower-head 10 is movable in a vertical direction and fits tightly down on the drier 12 forming a seal around the upstanding drier edge 13. The moist sand-resin mixture is blown into the cavity thus defined through one or more small tapered holes 14, 14 (only one of which is shown in dotted lines in Fig. 1). The air escapes from the cavity through a number of similar exhaust holes 15, 15 (likewise only one of which is shown in dotted lines in Fig. 1). Screening the exhaust holes materially reduces sand loss. The placement of the holes in the blower-head 10 of Fig. 1 is merely illustrative, since this is a matter of skill for the tool and die designer and usually requires slight modifications for each blower-head design.

In Fig. 1 the blower head 10 contains both a projecting male molding or shaping member 16 and recessive female molding or shaping member 17 in side-by-side arrangement. Thus the blower head 10 is designed to form one-half of a two-cavity sand mold, the complete mold being formed by assembling two such sections in mirror-image end-for-end fashion. In this arrangement the blower head 10 functions as a pattern that forms all interior surfaces of the mold which eventually contact molten metal while the box-drier 12 forms only the exterior mold surfaces. For the latter reason the design of the box-drier 12 does not have to be changed with each blower-head, a satisfactory standard drier design of suitable size being capable of use in the blowing of molds for variegated-shaped articles. Thus the cost of the drier 12 for each molding production item is but a small fraction of the total cost. It is obvious also that the blower head 10 can contain a plurality of each of the shaping members 16, 17 so as to form a plural-cavity mold. The blower head 10 will be described in greater detail in connection with Figs. 7 and 8.

The box-drier 12 is shown in greater detail in Figs. 2, 3 and 4. The upper sand-contacting surfaces of the box-drier 12 appear in detail in Fig. 2. For example, the four corners 20, 20 are hollowed out to form right-angular depressions 21, 22 of a novel stepwise design, the left hand corners 21, 21 of the drier 12 having shallower central projections or legs 23, 23 and deeper side steps 24, 24 while the right-hand corners 22, 22 have a mating stepwise leg design in which the central portion 25 is deep and the side steps 26, 26 are shallower. As a result of this leg design, which will be referred to in terms of the sand mold itself in connection with Figs. 6 and 9, it is possible to fit vertically-stacked molds together and lock them against rotation in the horizontal plane.

Also showing in the view of Fig. 2 are two rectangular

edge reinforcing sections 27, 27 whose purpose is to reinforce the long edge of the sand mold against warpage or breakage after cure or baking of the mold. Also provided are two circular leg-forming depressions 28, 28 which form supporting bosses on the mold exterior. A circular depression 29 is provided for forming a massive supporting boss on the exterior of the sand mold roughly corresponding to the bowl section of the ash-tray. The hole 30 is provided to define a sprue hole in the final mold. Between the hole 30 and the circular depression 29 there may be provided a connecting passageway or gate-defining slot 31 to receive a corresponding projection on the blower head 10. Through this latter arrangement, as will be more fully described in connection with Figs. 6, 7 and 9, there is provided a runner-gate assembly for pouring off a vertical stack of two-cavity molds.

In the front elevational view of Fig. 3 the details of the underside of the box-drier 12 are more readily seen. The four rectangular exterior corner legs 20, 20 are provided along with the two small conical supporting bosses 32, 32 (corresponding to 28, 28) a massive circular supporting boss 33 corresponding to 29, and connected therewith another circular supporting boss 34 corresponding to 30. In this manner adequate supporting surfaces are provided for the drier without excessive weight and wastage of material. The underside of the box-drier 12 could be solid if the weight and material cost were no consideration.

In Fig. 4 there is shown the box-drier 12 with a freshly blown sand mold 40 in place thereover. The top surface of the sand contains a circular raised male sand mold member 40a, a recessed circular female sand mold member 40b, and a sprue hole 42 and its connecting gate or channel 43. Also shown on the right-hand side is a small projecting peg or positioning box 44 which is adapted to fit into a corresponding hole in a superimposed mold member such as is shown in the left-hand side at 45. When two mold members are matched, the pegs 44, 44 and holes 45, 45 cooperate to align and position the mold sections and prevent slippage of one mold-half relative to the other. Minor details visible in Fig. 4 are a plurality of circular humps 46, 46 (only one being shown) for forming the cigaret-rests in the outer lip of the ash-tray and a circular decorative ring 47 in the face of the sprue hole 42.

Referring now to Fig. 5, the freshly blown green sand mold of Fig. 4 is cured by placing it in a curing oven 50 which causes heat-setting of the binder and drying of the cured mold. In an electronic heat oven the moisture is driven off before the sand temperature rises to cure temperature. Fig. 5 is a schematic representation of equipment conventionally used for curing or baking cores. The box-drier 12 filled with sand is placed on the conveyor belt 51 which carries it through the curing oven where electronic or other source of heat causes the cure. The box-drier 12 and its adhering cured sand mold is removed from the end of the conveyor and sand mold knocked out as shown in Fig. 6.

The bottom side of the sand mold is shown in Fig. 6 with greater clarity. For example, the corner depressions 21, 22 of the drier form the corresponding legs 60, 61, respectively of the mold. The interlocking features of legs 60, 61 are shown more clearly, the projection 62 on leg 61 being adapted to fit into the rectangular socket 63 on a left-hand leg 60 of another mold section. The small conical leg 64 and the circular legs 65, 66 are formed by the corresponding parts 28, 29 and 30 in the box-drier 12.

The blower head 10 is shown with greater clarity in Figs. 7 and 8. A circular projection 70 cooperates with the corresponding depression 30 in the box-drier 12 to form a hole for a sprue. Between the projection 70 and the male member 16 is a gate-forming projection or ridge 71 which is suitably tapered to withstand flow of

molten metal. A small circular knob 72 is provided to shape the positioning hole 45 while a small circular recess 73 is provided to shape the positioning pin 44. The edge of the male mold member 16 is scalloped out as at 74, 74 to provide a plurality of cigaret rests in its outer edge. It is clear that the blower-head 10 is a relatively inexpensive item to build as compared to heated patterns such as are used in the "shell" process or, for that matter, as compared to a conventional multi-part pattern and its accompanying box or flask for forming the molds in the conventional manner of molding.

In Fig. 9 there is illustrated a vertical stack of molds, each composed of two half-molds as made in the blower-head assembly of Fig. 1. Pairs of the cured mold sections 40, 40 brought together in upside-down, end-for-end fashion and then hooked together by positioning the pins 44, 44 in the holes 45, 45 to form individual assembled molds. Then the assembled molds are stacked one on top of another by fitting the projection 62 of one mold into the rectangular socket 63 of another. In this way a rigid mold assembly such as appears in Fig. 9 is built up. A heavy weight can be placed atop the stack to keep the individual mold sections 40, 40 from separating when liquid metal is poured into the hole 42 contained in the leg 65. The similar hole 42 at the bottom of the stack is blocked by resting the entire stack on dry molding sand or by a plug of molding clay (not shown). A funnel of molding clay (also not shown) can be affixed to the top of 65 to facilitate pouring direct from the ladle. After the metal has been allowed to cool the burned out sand can easily be shaken off. The individual ash trays are then cut off the solidified runner. They are found to be of such a high finish as not to require polishing or buffing. The finished ash-tray appears in Fig. 10. Lettering (not shown) disposed in the circular recess 80 is faithfully and clearly reproduced. No faults occur about the cigaret rests 81, 81 or about the raised ring 82. Dimensions and fine detail are reproduced to a tolerance of 0.01 to 0.001 inch or better.

The invention will now be more fully illustrated with reference to several specific examples illustrating various sand mixes and their manner of handling in the method of the invention. These examples are intended to be illustrative only and not as limiting the invention.

The ash-tray of the drawings is cast by the method described above. A blower-head such as is shown in Figs. 1, 6, 7 and 8 is cast in iron or steel alloy and then polished to final dimensions. If desired, it may be chromium plated to give it a smooth, glass-like surface. A suitable, inexpensive mold for molding the tray-drier or box-drier of Figs. 1 to 4 can be inexpensively cast in aluminum. Box-driers are molded of a glass-filled alkyd molding compound as "Plaskon Type 440-A" or "Plaskon Type 444."

As one example, a sand mix is prepared using the following formulation:

Material:	Lbs./wt.
Silica sand—#100 A. F. S. fineness	100.0
Binder resin ¹	4.0
Water	3.0
Kerosene	0.5
Oleic acid	0.01

¹ A water-soluble, one stage, spray-dried phenolic resin in powder form and containing a curing catalyst.

The dry sand is mulled with the dry resin until a uniform mixture is obtained. The water is then added to the resulting mixture and mulling continued until a uniform, damp mixture is obtained. The oleic acid is mixed with the kerosene and this mixture is added to the damp sand with continued mulling for several minutes. This mixture is utilized in a core blowing machine having an agitated hopper. The box-drier-blowerhead assembly utilized is shown in Fig. 6. A uniformly compacted green sand mold component adhering to the box-drier is ob-

tained. A suitable sand blowing machine can blow from 100 to 350 or more of these half-mold sections per hour.

The box-drier and its adhering green sand mold is placed in a radio-frequency or electronic core baking oven for cure. In a matter of several minutes or less the sand mold has dried out and cured to a hard thermoset condition. When a plurality of these are assembled as shown in Fig. 9, a multiple-cavity, plural-mold assembly is obtained. Cast iron, malleable iron, brass, steel, aluminum and bronze are cast in such molds. The resultant ash-tray castings have a high finish and are of accurate dimensions. They require no polishing before use.

A sand mix adapted for blowing and to produce a better finish, to prevent metal penetration and to permit the casting of higher melting steel alloys is as follows:

Material:	Lbs./wt.
Silica sand—90 A. F. S.	100.00
Silica flour—200 mesh	1.0
Iron oxide—200 mesh	0.5
Fire clay—200 mesh	0.5
Dextrine powder—200 mesh	1.0
Binder resin ¹	4.0
Kerosene	0.2
Water	4.0
Isopropanol	0.25
Kerosene	0.4
Oleic acid	0.01

¹ Same as above.

As another example of this invention, magnesium and its alloys may be cast in sand molds made as above using a sand mix as follows:

Material:	Lbs./wt.
Silica sand—#120 A. F. S.	100.0
Resin binder ¹	4.0
Powdered sulfur	0.5
Boric acid	0.25
Potassium fluoborate	0.25
Dextrine powder	0.5
Kerosene	0.1

¹ Powdered water-soluble urea-formaldehyde resin.

The above materials are mixed in a muller, then 3.0 lbs. of water, 0.5 lb. of diethylene glycol, 0.40 lb. additional kerosene and 0.02 lb. of oleic acid are added and mixing continued for several minutes. The resultant damp sand mix is easily blown to form strong, firm green sand molds using the box-drier of the drawings. When baked in a dielectric oven, the sand molds are hard and strong. They are easily removed from the box-drier without damage. If preferred, the interior surfaces of the mold parts can be sprayed lightly with water or a water solution of boric acid or an active fluorine-containing salt, a mixed solution of such materials, or a mixture of boric acid and a suspension of sulfur before being placed in the oven for cure. An assembly mold prepared in such a manner produces a sound, smooth casting of accurate dimensions.

In the molding process of the invention the water-dispersible binders are utilized in amounts which vary quite widely depending on the binder agent employed. For example, the water-soluble binder resins are utilized in amounts ranging from 2 to 8% by weight based on the weight of sand. A preferred range is from 3 to 7% and most preferred from 3 to 5.5%. These amounts of resin produced strong molds easily susceptible of handling in the cured state. Other conventional binders such as water glues, clays, magnesium oxychloride, iron oxide, magnesium oxide, natural gums, and others are utilized in amounts, for example for clay, up to 10 to 20% or more. By the use of cementitious binders more or less permanent molds can be prepared by the process. The resinous binders, however, are most desirable for general application. Other conventional additives may be added in minor amounts to the resin-containing mix including core oils, other resins, starches, dextrines, cereal products,

humectants such as glycols and glycerol, silica flour, fire clay, wood flour, iron and other metal oxides, release agents such as kerosene, fatty acids and other oily materials, and others.

It is preferred to utilize sand binder resins which are truly water-soluble such as the urea-formaldehyde resins, melamine-formaldehyde resins, phenol-formaldehyde resins, acrylic resins, polyvinyl alcohol, water-soluble polyesters, styrene-maleic anhydride resins and their salts, carboxymethyl cellulose and its salts, vinyl alkyl ether polymers, and many others. The water-soluble thermosetting resins of the urea- and phenol-aldehyde types are more preferred because of their ready availability and ability to produce strong molds unaffected by moisture. Urea resins are most preferred because of their wide applicability and speed of cure.

The amount of moisture in the sand mix is important, as is well understood in the art. In general the moisture content may vary from 1 to 6% by weight on the resin, although a more preferred range is from 2 to 5%. Dextrine or cereal products permit the use of greater amounts of moisture since they have a drying effect on the sand mix. Humectants such as ethylene glycol and glycerol act to hold the moisture content on exposure to air and prevent variations in moisture content.

From the above, it is apparent that the present method utilizes a relatively higher resin/sand ratio than is conventional. Conventional core binder use of these resins is from 0.5 to 2% based on the amount of the sand. Thus the use of the method involves the molding of sand mixes containing relatively larger proportions of resin and moisture. The blowing of such sand mixes in blowing machines of the core-making type is also a novel and preferred embodiment of the process of the invention.

In general any refractory material of a suitable size and particle size distribution may be utilized in the casting method of this invention. Silica, various fire clays and mixtures thereof alone or with sand may be utilized, desirably in the casting of higher melting metals and alloys. Ordinary molding sands, which are free of substantial amounts of clay and other refractory binder substances should preferably be of the round or sub-angular grain type. Such sand is available in a wide range of particle sizes over the entire A. F. S. range containing particles ranging from about 30 to 210 mesh or finer, U. S. Series. In general the coarser sands favor higher baked strength, higher permeability, greater hardness, and greater ease of blowing. The finer sands favor higher green strength and better collapsibility. However, since the invention is concerned with precision casting and the production of castings with a superior finish, the finer sands in the range of 60 to 150 A. F. S. or finer will usually be required. Coarser sands can be utilized if the green molds are surface treated with slurries of very fine refractory materials to produce a sooth finish. Sands of 80 to 120 A. F. S. will usually be satisfactory for most uses.

While the invention has been described with particular reference to certain preferred embodiments thereof, it is possible to make variations and modifications therein without departing from the spirit and scope of the invention as defined in the appended claims.

I claim:

1. The process of precision casting of metals which comprises shaping a wet sand molding mixture comprising fine molding sand, water and a water-soluble urea-formaldehyde resin in an enclosure containing a pattern means adapted to shape at least two of the inner, complementary, metal-contacting sand surfaces only and a removable drier support adapted to shape the outer supporting surfaces only of a sand mold component, removing said drier support and its adhering green sand mold component from said enclosure, heat-hardening said green sand mold component in contact with said drier support, assembling a plurality of said heat-hardened mold components to form a complete, self-supporting sand mold, and casting

metal in said completed sand mold while it is supported by the shaped outer surfaces thereof.

2. The method of making self-supporting, resin-bonded molds for the precision casting of metals which comprises packing a wet molding mixture comprising a finely-divided refractory material and an aqueous dispersion of a water-dispersible, heat-hardenable binder into the molding cavity defined between a re-usable drier support adapted to shape the outer surfaces only of a mold and a forming member adapted to shape at least two of the inner, complementary, metal-contacting surfaces of said mold, heat-hardening the resulting green mold while in contact with said drier support, and separating the resulting heat-hardened mold from said drier support.

3. The method of making self-supporting, resin-bonded sand molds for the precision casting of metals which comprises blowing a wet sand mixture comprising molding sand and an aqueous solution of a water-soluble resinous binder into a molding cavity defined between a blower head adapted to shape at least about two of the inner, complementary, metal-contacting surfaces only of a sand mold and a reusable drier support adapted to shape the outer surfaces only of said mold, heat-hardening the resulting green sand mold while supported in contact with said drier support, and separating the resultant heat-hardened, self-supporting, resin-bonded sand mold from said drier support.

4. The method of making self-supporting, resin-bonded, multiple-cavity sand molds for the precision casting of metals which comprises blowing a wet sand molding mixture comprising molding sand and an aqueous solution of a water-soluble, thermosetting resinous binder into a plurality of complementary portions of molding cavities defined between a blower head adapted to shape at least two of the inner, complementary, metal-contacting sand surfaces only of a sand mold component and a drier support adapted to shape the outer sand surfaces only of said mold component, said drier support also being adapted to form in the outer surfaces of said mold component planar supporting surfaces and reinforcing elements, heat-hardening the resultant green mold component while in contact with said drier support, separating the resultant heat-hardened, resin-bonded sand mold component from said drier support, and assembling a pair of the so-formed sand mold components, each of which has said plurality of complementary mold cavity portions, in face to face relationship with one component turned 180° with respect to the other so that the complementary metal-contacting surfaces of adjacently assembled components are in cooperative face to face relationship to form a complete, multiple-cavity, self-supporting sand mold.

5. The method of making self-supporting, resin-bonded, multiple-cavity, multiple-mold sand mold assembly for the precision casting of metals which comprises forming green sand mold component parts by blowing a wet molding mixture comprising fine molding sand and a water-soluble thermosetting resinous binder selected from the group consisting of the intermediate, water-soluble condensation products of urea and formaldehyde and of phenol and formaldehyde into a plurality of complementary portions of molding cavities defined between a blower head adapted to shape at least two of the interior, complementary, metal-contacting surfaces only of a sand mold and a drier support adapted to shape the exterior surfaces only of said sand mold, said drier support also being adapted to form in exterior mold surfaces integrally-molded planar supporting surfaces, reinforcing means, and positioning and interlocking means, heat-hardening said sand mold component parts while in contact with said drier support, separating the resulting heat-hardened sand mold components from said drier support, assembling a plurality of said mold components, each of which has said plurality of complementary mold cavity portions, in face to face relationship with one component turned 180° with re-

spect to the other so that the complementary metal-contacting surfaces of adjacently assembled components are in cooperative face to face relationship to form a multiple-cavity sand mold, and interlocking a plurality of said sand molds to form a multiple-cavity, multiple-mold sand mold assembly.

6. The method of making self-supporting, resin-bonded molds for the precision casting of metals which comprises packing a wet molding mixture comprising a finely-divided refractory material and an aqueous dispersion of a water dispersible, heat-hardenable binder into the molding cavity defined between a re-usable drier support adapted to shape the outer surfaces only of a mold and a forming member adapted to shape at least two of the inner, complementary metal-contacting surfaces of said mold, removing said forming member, heat-hardening the resulting green mold while in contact with said drier support, and separating the resulting heat-hardened mold from said drier support.

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