United States Patent [19]

Lirones

[11] **3,903,950**

[45] **Sept. 9, 1975**

[54] **SANDWICH STRUCTURE MOLD**

[75] Inventor: **Nicholas G. Lirones**, North Muskegon, Mich.

[73] Assignee: **Howmet Corporation**, Greenwich, Conn.

[22] Filed: **Dec. 26, 1973**

[21] Appl. No.: **427,732**

[52] **U.S. Cl.** **164/26;** 106/38.35; 164/361

[51] **Int. Cl.**[2] **B22C 1/08;** B22C 1/10

[58] **Field of Search** 164/23, 24, 25, 26, 34, 164/35, 36, 131, 361, 349; 106/38.3, 38.35, 38.9

[56] **References Cited**

UNITED STATES PATENTS

2,912,729	11/1959	Webb	106/38.9 X
3,011,986	12/1961	Operhall et al.	106/38.35 X
3,239,897	3/1966	Lirones	164/26
3,256,574	6/1966	Lirones	164/24

Primary Examiner—Francis S. Husar
Assistant Examiner—Carl Rowold
Attorney, Agent, or Firm—McDougall, Hersh & Scott

[57] **ABSTRACT**

A mold and fabrication method is disclosed for use in molding precision cast parts. In cross-section the mold has inner and outer layers, the essential ingredients of which include a ceramic refractory material and an inorganic binder. Intermediate layers are disposed between the inner and outer layers and employ an organic fugitive binder. When the mold is heated prior to receiving molten metal, the fugitive binder is volatilized, leaving the intermediate layer unbound. After the parts have been cast the mold is easily collapsed for removal of the casting without damage.

16 Claims, 2 Drawing Figures

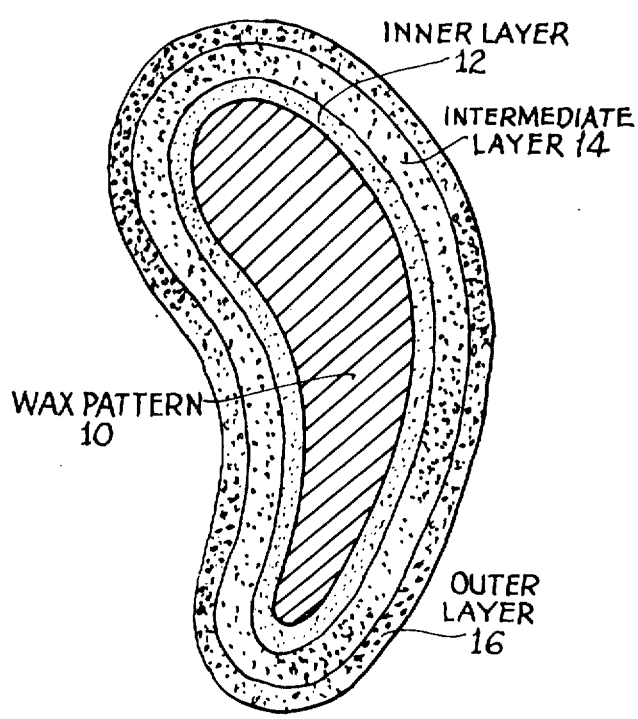


FIG. 1

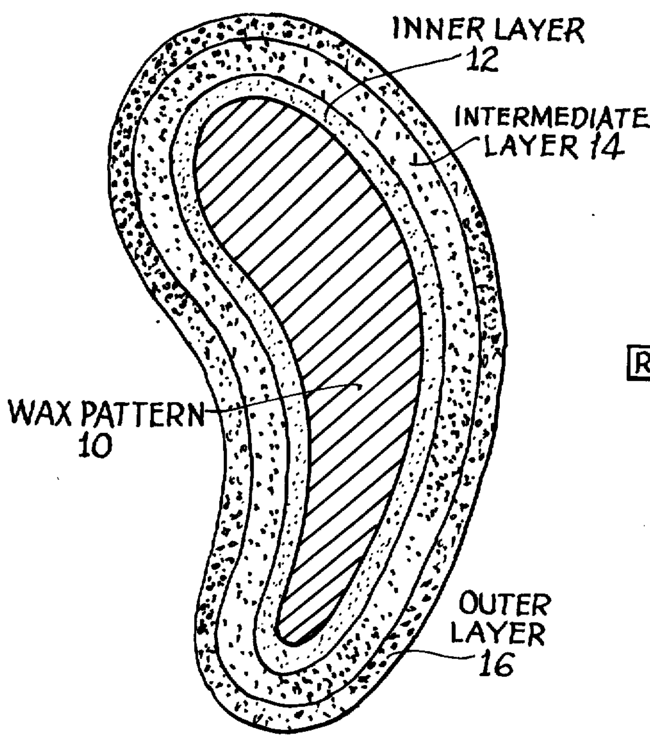
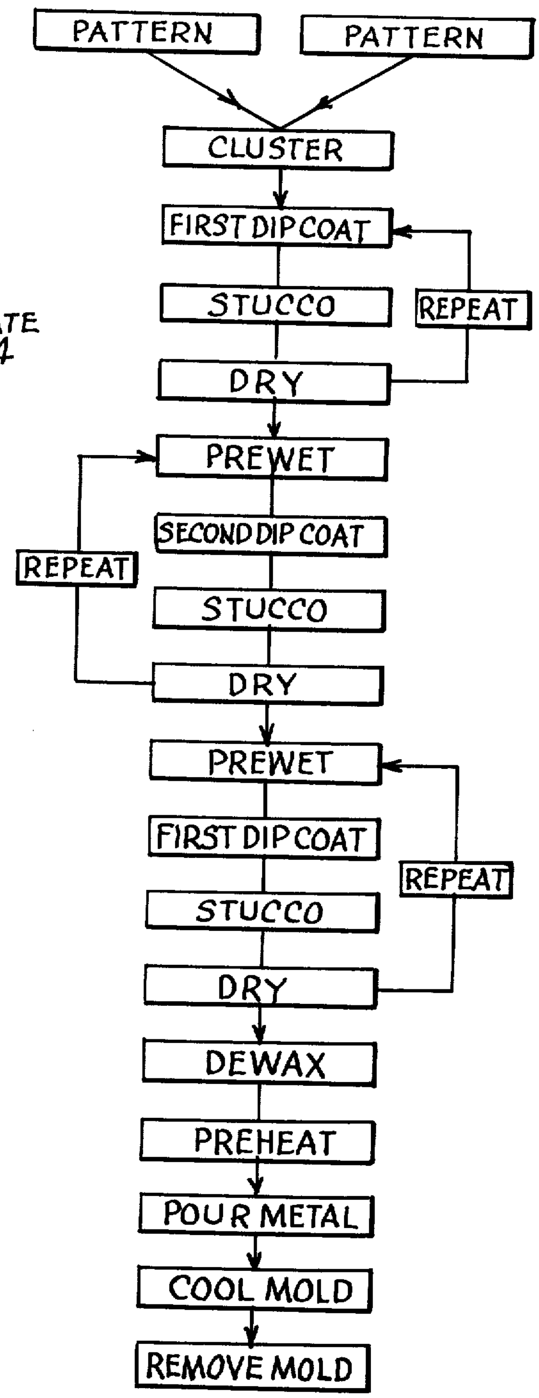

INNER LAYER
12
INTERMEDIATE
LAYER 14
WAX PATTERN
10
OUTER
LAYER
16

FIG. 2


PATTERN
PATTERN
CLUSTER
FIRST DIP COAT
STUCCO
DRY
REPEAT
PREWET
SECOND DIP COAT
STUCCO
DRY
REPEAT
PREWET
FIRST DIP COAT
STUCCO
DRY
REPEAT
DEWAX
PREHEAT
POUR METAL
COOL MOLD
REMOVE MOLD

SANDWICH STRUCTURE MOLD

BACKGROUND OF INVENTION

This invention relates to the art of precision casting and to materials employed in the practice thereof. More particularly, the invention relates to a casting process and to compositions and methods used in the preparation of molds.

A basic process employed in casting precision parts is known as the lost wax process. This process is particularly adapted to producing precision castings for the production of turbine blades, vanes, as well as other complex parts. The conventional lost wax process consists of producing disposable patterns formed of wax, plastic or other suitable material having the desired shape. If necessary, these patterns are assembled into clusters to form a complete assembly. The patterns are then dipped into a ceramic slurry dipcoat containing a colloidal silica or other inorganic binder. While the pattern is wet from the dipcoat, it is stuccoed with granular refractory particles and then dried. This forms a coating on the patterns and by repeating the dipping, stuccoing and drying steps, a mold of a desired thickness can be formed about the pattern.

The pattern is then removed from the mold and the mold is heated to a temperature whereby the silica binder cures and strongly bonds the ceramic dipcoating and granular stucco into a monolithic mass. After inspection, the mold is preheated to a high temperature suitable for receiving molten metal.

After pouring the metal, the casting is allowed to cool to a solidified state. At this stage, the mold strength can be higher than the metal strength, often resulting in "hot tears" on the casting. After cooling, the mold is broken away from the casting by mechanical or pneumatic vibration, salt bathing, sand blasting or other techniques.

The above described techniques for separation of the casting from the mold have several disadvantages. The high amplitude mechanical vibration necessary to break the mold can cause cracking of the casting. Salt bathing techniques and sand blasting are excessively time consuming and also detrimental to the casting surface in that intergranular attack and surface erosion occurs.

It is accordingly an object of the present invention to produce and provide a method for producing new and improved molds for use in precision casting.

More specifically, it is an object of the present invention to produce a mold which is of sufficiently high strength and stability to enable casting materials to be poured directly therein for molding, and yet which can be easily broken away from the casting without damage thereto.

It is another object of the present invention to provide a mold in which the molded products can be easily and efficiently separated from the mold.

It is a further object of the present invention to provide a mold in which at least some of the materials used therein can be reclaimed and re-used.

It is still a further object of the present invention to provide a sandwich structured mold which eliminates casting "hot tears" and knock-out cracks.

Other objects of the present invention will become apparent from the concluding portion of the specification.

SUMMARY OF THE INVENTION

A mold for casting precision parts is formed by dipping a wax or plastic pattern into a dipcoat of a first composition including finely divided refractory materials and an inorganic binder, such as a silica binder. While the pattern is still wet, it is stuccoed with granular refractory particles, and then dried. This sequence is repeated as desired to build up an inner layer of a desired thickness. The pattern and inner layer are then dipped into a second dipcoat, the principal constituents of which are finely divided refractory material and an organic fugitive binder. After stuccoing, this coating is dried. This intermediate layer may be built up as desired by repeating the sequence.

Finally, an outer layer is formed over the intermediate layer and is composed somewhat of the same inorganic constituents as the inner layer, thereby forming a mold which is sandwich structured. When the mold is preheated prior to metal pouring (after the pattern has been removed), the organic fugitive binder of the intermediate layer is substantially eliminated by burning and/or volatilization. This leave the materials of the intermediate layer without binder sandwiched between the inner and outer layers.

After molding, the sandwich mold is easily removed from the casting by collapsing the outer layer onto the intermediate layer and removing the thin inner layer. This mold avoids hot tears as well as cracking in the casting due to the force heretofore required for mold removal.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic sectional view through a pattern having a mold formed thereon in accordance with the practice of this invention; and

FIG. 2 is a flow diagram of the process embodying the practice of this invention.

DETAILED DESCRIPTION

The concepts of this invention are embodied in two phases, a "mold phase" which includes the compositions employed in the manufacture of the mold and the method for the production thereof, and the "use phase" wherein the formed mold is employed in the process of molding compositions and materials.

The mold phase will be described with reference to compositions employed and the methods of manufacture in a representative process illustrating the practice of this phase of the invention.

In the following description, the term "pattern" will be used interchangeably with "cluster" to refer to a wax or plastic pattern **10** or a cluster formed of a multiplicity of such individual patterns.

The pattern **10** is formed of conventional materials disposable by heat or chemicals. If the mold is to be formed about more than one pattern, the plurality of patterns are connected by runners for communication with a pouring spout to form a completed cluster, as described in the issued U.S. patent to Lirones, U.S. Pat. No. 3,266,106. Where the cluster is to be repeatedly dipped into slurry, identified as a dipcoat, it is desirable to provide a hanger rod for carrying the cluster and for suspending the cluster for drying and the like.

First Dipcoating Composition

8000 cc. colloidal silica (30% grade) (specific gravity 1.198)
165 pounds zircon (99% through 325 mesh)
6150 cc. water
110 grams sodium fluoride

Application of First Dipcoat Composition

The pattern or cluster is first inspected to remove dirt, flakes and other objects which may have adhered to the surfaces of the pattern and which, if allowed to remain, would impair the preparation of a good mold and lead to an unacceptable casting. The cleaned cluster is immersed into the stirred dipcoat composition to cover all of the surfaces of the cluster. To promote the elimination of air pockets, it is desirable to rotate the cluster while immersing in the dipcoat composition. Alternately, the dipcoat composition can be applied by spraying the dipcoat composition onto the surfaces of the pattern.

When fully wet, the pattern or cluster is suspended to drain excess dipcoat composition. During drainage, the cluster can be inspected to detect air pockets which can be eliminated by addressing a stream of air onto the uncoated portions and thereafter allowing the slurry of the dipcoat composition to flow onto the uncovered area. While the cluster is being drained, it should be held in different spatial planes designed to achieve uniform coating on all surfaces. In general, drainage should be completed within a few minutes but, in any event, in less time than would allow the dipcoat composition to dry whereby the surface would not retain stucco, as will be described.

First Stucco Coat

Stucco combination—Alundum (100% through 50 mesh with less than 3% through 100 mesh—better than 90% between 60 and 80 mesh).

Application of Stucco Coat

After the uniformity of coating has been achieved in the first dipcoat and dripping from the patterns has become minimized, the stucco is sprinkled onto the wet cluster substantially uniformly to cover the wet surfaces with a layer of the stucco while, at the same time, minimizing flow of the dipcoat whereby non-uniformities might otherwise develop. In practice, the stucco particles will be rained down from above through a screening member constantly being fed by a vibratory feeder to remove foreign matter from the Alundum particles, while the particles are sprinkled over an area to give more uniform and complete coverage. The stucco will adhere to the wet coating of the slurry and will become partially embedded in the slurry to become integrated with the coating formed on the cluster of wax patterns.

By repeating the above steps, after intermediate drying, the first dipcoat composition and stucco are built up onto the pattern to form an inner layer **12** of a desired thickness. For the purposes of casting molten metal products of normal weight, it is desirable to provide for more than one dipcoat-stuccoing cycle. After sufficient drying, the pattern is then emersed into a second dipcoat to form an intermediate layer **14**.

Second Dipcoating Composition		
Example A.		
−325 Mesh Alumina Flour	3500	Gr
Polyvinyl Alcohol (7.26% aqueous Solution)	1033	Gr
Potato Starch (3% Water Solution)	938	Gr
Anionic Wetting Agent	42	cc
Example B.		
−325 Mesh Alumina Flour	3500	Gr
Polyvinyl Alcohol (7.26% Aqueous Solution)	2000	Gr
Anionic Wetting Agent	42	cc
Example C.		
−400 Mesh Zircon Flour	4040	Gr
Polyvinyl Alcohol (7.26% Aqueous Solution)	1033	Gr
Potato Starch (3% Water Solution)	938	Gr
Anionic Wetting Agent	42	cc
Anti-foam Colloid	21	cc
Example D.		
−400 Mesh Zircon Flour	4040	Gr
Polyvinyl Alcohol (7.26% Aqueous Solution)	1975	Gr.
Anionic Wetting Agent	42	cc
Anti-foam Colloid	21	cc
Example E.		
−325 Mesh Alumina Flour	122.7	Lbs
(Aquadag) Colloidal Graphite (22% Solids)	10.7	Lbs
Water (Distilled)	26.3	Lbs
Anionic Wetting Agent	418.0	cc
Gum Tragacanth Solution	456.0	cc
Example F.		
−325 Zircon Flour	33.0	Lbs
(Aquadag) Colloidal Graphite (22% Solids in Water)	8.8	Lbs
Water (Distilled)	11.0	Lbs
Anionic Wetting Agent	200.0	cc
Gum Tragacanth Solution	300.0	cc
Example G.		
−325 Mesh Zircon Flour	160.0	Lbs
Latex	280.0	cc
Water	14000	cc
Gum Tragacanth Solution	300.0	cc
Anionic Wetting Agent	400.0	cc
Octyl Alcohol	49.0	cc

In examples E, F, and G the gum tragacanth solution has the following compositions:

Gum Tragacanth Powder	445 Gr
Sodium Benzoate	5 Gr
Water	20,000 Gr

As the anionic wetting agent, use can be made of sodium heptadecyl sulphate, such as Tergitol Anionic No. 7 of Union Carbide Corporation.

Representative of the antifoam colloids which may be used in the above formulations is Antifoam Colloid No. 581B produced by Colloids, Inc., Newark, N.J.

Application of Second Dipcoat Composition

The second dipcoat composition is applied to the coated pattern in a manner similar to that of the first dipcoat composition. A significant difference between the dipcoat compositions is in the selection of the binder. The first dipcoat composition employs a colloidal silica binder. The second dipcoat composition preferably utilizes an organic fugitive binder as, for example, polyvinyl alcohol. By organic fugitive binder it is intended to describe an organic compound which is capable of being volatilized and/or burned out by heating or otherwise. By employing an organic fugituve binder it is possible to form a second intermediate layer about the pattern, and at a subsequent time drive off the binder to leave the intermediate layer closely packed but unbound.

In the preferred practice of this invention, it is desired, although not essential, to precede the emersion of the coated pattern into the first and second dipcoat compositions with a pre-wetting step in which the pre-wetting composition employs substantially the same formulation as the dipcoat composition, with the exception that a lower viscosity is employed. The pre-wetting composition includes additional amounts of water sufficient to reduce the total solids to about 25 to 75 percent of the total solids in the dipcoat composition. Thus, the coated pattern, having the inner layer **12** dried thereon, is submerged into a pre-wetting composition more completely to penetrate and wet out the coated surface prior to being immersed in the second dipcoat composition. Immersion into the second dipcoat composition follows immediately after the pre-wet immersion.

After the immersion in the second dipcoat composition, the pattern is again allowed to drain and is stuccoed and dried. The steps of pre-wetting, dipcoating, stuccoing and drying are repeated one or more times, as necessary, to build up the intermediate layer **14** to a desired thickness. The stucco employed for the intermediate layer may be the same as that employed for the inner layer.

For special applications and particularly where large molds are utilized, it is desirable to add a very small percentage, on the order of 0.125 percent by weight, of colloidal silica binder to the second dipcoat composition which also contains the organic fugitive binder as previously discussed. The presence of the colloidal silica binder prevents the intermediate layer from becoming completely powdery after the fugitive binder is driven off as will be described. The small amount of silica binder added to the second dipcoat does not increase the strength or increase the task of removal but permits patching and repair of the mold should such operations be necessary. The following example illustrates the use of a small amount of silica binder in the second dipcoat:

Example H.	
Zircon Flour	154 Lbs
Antifoam Colloid	500 cc
Anionic Wetting Agent	720 cc
Colloidal Silica (30% Sol.)	242 cc
Polyvinyl Alcohol (7.26% Sol.)	30.0 Lbs
Water	18.7 Lbs

Third Dipcoat Composition and Application

The composition of the third dipcoat, which forms the outer layer **16** of the mold can, but need not be, the same as the composition of the first dipcoat. It is applied and stuccoed in a manner similar to that of the first dipcoat. However, usually a coarser stucco is applied. When the outer layer **16** has been built up to a desired thickness the mold is subjected to a final drying cycle.

As an example of the number of dipcoats required to form each of the three layers of the sandwich structure for an average weight casting, two dipcoatings have been employed to form the inner layer **12,** three dipcoatings have been employed to form the intermediate layer **14,** followed by two dipcoats in the first dipcoat composition to form the outer layer **16.** For heavier castings or for large molds, the thickness of the layers may be increased as necessary.

After final drying, the completed mold is heated to remove the pattern contained therein, and leave a mold cavity in which the material to be cast is poured. Pattern removal, hereinafter referred to as dewaxing, can be achieved in a number of ways, as disclosed in U.S. Pat. No. 3,266,106. Usually dewaxing the mold is accomplished by firing it to a high temperature. During such heating, the colloidal silica binder in the inner and outer layers **12** and **16** strongly bonds the ceramic dipcoat and granular stucco into a monolithic mass. Simultaneously, the organic fugitive binder in the intermediate layer **14** is volatilized and/or burned out leaving the materials making up the intermediate layer unbonded and sandwiched between the inner and outer bonded layers.

Alternatively, the sandwich structure mold of the present invention can be dewaxed at a lower temperature on the order of 200° to 400° F. This dewaxing method is possible due to the high green strength achieved in the present sandwich structure mold.

If the sandwich mold is dewaxed at a low temperature, then it will be preheated to a high temperature prior to use, as indicated in FIG. **2,** for burning out the mold, i.e., removing any small traces of remaining wax, for burning out or volatilizing the organic binder used for the intermediate layer and for curing the silica binder. Preheating is usually carried out at temperatures in the range of 1,000° to 2,850° F.

The sandwich structure mold, after being preheated, is ready for pouring the molten metal in the mold cavity. During the preheating and pouring of the metal, the sandwich structure mold does not gain sufficient additional strength to cause excessive hardening of the mold. Another advantage of a sandwich structure mold is that, during the cooling process, the relatively thin inner layer **12** is able to collapse, thereby eliminating the possibility of casting hot tears.

After the casting has cooled completely, the mold is removed. Its construction permits the use of low amplitude mechanical vibration to crack the thin outer layer **16,** which breaks off easily. The intermediate layer, being unbound, falls away from the mold and, if desired, may be reclaimed for re-use. The portions of the inner layer are similarly easily broken away.

The castings resulting from this process are relatively free of mold materials, hot tears, and knock-out cracks. Also, sand blasting for final cleaning is minimized.

While I have shown and described an embodiment of this invention in some detail, it will be understood that this description and illustration are offered merely by way of example, and that the invention is to be limited in scope only by the appended claims.

I claim:

1. A method of producing a recyclable sandwich structure mold about a disposable pattern which is removed to define a mold cavity comprising the steps of:

a. providing a homogenous first layer by wetting the surface of the pattern with a first dipcoat composition, the essential solids of which consist of finely divided refractory material, including a high strength inorganic binder which is chemically inert to metal to be molded in said cavity;

b. covering the surface of the pattern, while wet with the first dipcoat, with a granular refractory stucco;

c. repeating, at least once, steps (a) and (b) with intervening drying to form a first layer of said mold;

d. wetting said first layer with a second dipcoat composition, the essential ingredients including finely divided refractory material and an organic fugitive binder;

e. covering the surface of the first layer while wet with the second dipcoat with a granular refractory stucco;

f. repeating, at least once, steps (d) and (e) with intervening drying to form an intermediate layer of said mold; and

g. forming an outer layer over said intermediate layer in the manner recited in steps (a), (b) and (c), to thereby produce a three layer sandwich structure mold.

2. The method of claim **1** further including the step of volatilizing the organic fugitive binder to leave the intermediate layer unbound and sandwiched between said inner and outer layers.

3. The method of claim **1** wherein the organic fugitive binder is polyvinyl alcohol.

4. The method of claim **1** wherein the organic fugitive binder is one of the group comprising vegetable gums, starches and polymeric latices.

5. The method of claim **1**, further including the steps of

a. removing said pattern; and

b. heating said mold to a temperature sufficient to volatilize said organic fugitive binder to leave said intermediate layer unbound.

6. The method of claim **1** further including the steps of heating said mold to remove said disposable pattern, to volatilize said organic fugitive binder in said intermediate layer, and to fuse said inorganic binder in said inner and outer layers.

7. The method according to claim **5** wherein the step of removing the pattern is accomplished at a temperature within the range of 200° to 400° F., and the step of volatilizing the organic fugitive binder is accomplished at a temperature within the range of 1,000°F. to 2,850° F.

8. A sandwich structure recyclable mold for precision casting having a wall structure in cross-section comprising:

a. a homogenous relatively thin inner layer consisting essentially of finely divided refractory material, including a high strength inorganic binder which is chemically inert to metals to be molded and granular refractory stucco;

b. an intermediate layer consisting essentially of finely divided refractory material, refractory stucco and an organic fugitive binder;

c. an outer layer identical in composition to said inner layer.

9. The mold of claim **8** wherein prior to use the mold is subjected to heating sufficient to volatilize said organic fugitive binder, to thereby leave the intermediate layer refractory material and stucco unbound and sandwiched between the bound inner and outer layers.

10. The mold of claim **8** wherein the inner and outer layer refractory materials and stucco essentially comprise ceramic flour and binder and ceramic stucco.

11. The mold of claim **8** wherein the intermediate layer refractory materials essentially comprise alumina or zircon flour.

12. The mold of claim **8** wherein the organic fugitive binder is selected from the group comprising vegetable gums, starches, polymeric latices and polyvinyl alcohol.

13. A method of precision casting materials, such as metal alloys, comprising the steps of:

a. producing a sandwich structure mold about a disposable pattern, said mold having homogenous inner and outer layers consisting essentially of finely divided refractory material, including a high strength inorganic binder chemically inert to said alloys and granular refractory stucco, and an intermediate layer consisting essentially of finely divided refractory material, refractory stucco, and an organic fugitive binder;

b. removing said disposable pattern from said mold to provide a mold cavity;

c. firing said mold to a temperature sufficient to volatilize said organic fugitive binder to thereby leave said intermediate layer unbound and sandwiched between the bound inner and outer layers;

d. pouring a molten metal alloy into said mold cavity;

e. cooling the mold; and

f. removing the mold from the cast metal alloy.

14. The method of claim **13** wherein the disposable pattern is formed of wax and steps (b) and (c) are accomplished simultaneously by the heating of said mold to a temperature within the range of 1,000° to 2,850° F.

15. The method of claim **13** wherein step (f) includes the sub-steps of:

a. breaking the outer layer with low amplitude mechanical vibration;

b. permitting the unbound intermediate layer to fall away from the mold and collecting for re-use;

c. removing the inner layer.

16. A sandwich structure mold according to claim **9** wherein said intermediate layer also includes approximately 0.125 percent by weight of an inorganic binder for preventing said intermediate layer from becoming completely unbound when said organic fugitive binder is volatilized.

* * * * *