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REFRACTORY MOLD, METHOD OF MAKING SAME AND COMPOSITION THEREFOR

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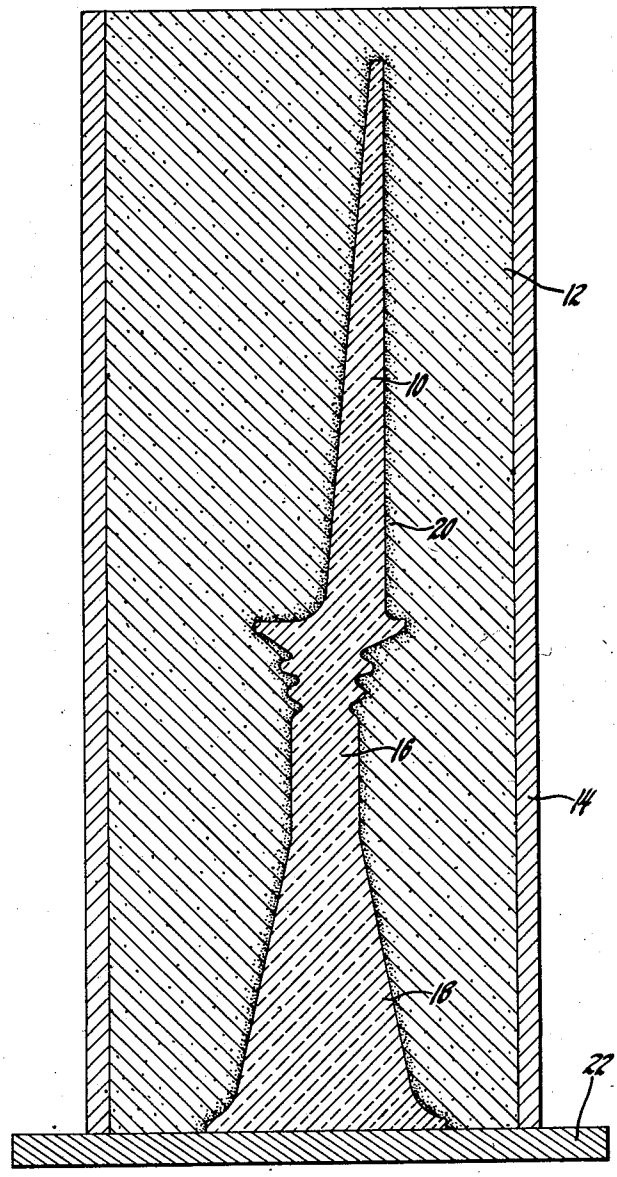

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REFRACTORY MOLD, METHOD OF MAKING SAME AND COMPOSITION THEREFOR

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This invention relates to refractory molds for casting metal and particularly to an improved investment material for forming such refractory molds. The present application is a continuation-in-part of patent application Serial No. 324,706, which was filed on December 8, 1952, now abandoned.

In precision casting metallic articles by means of refractory molds it is frequently necessary that the casting surfaces of the molds possess high strength and exceptional smoothness. Thus, in investment molding it is usually desirable to form the principal refractory portion of the mold of a hard material to which a coating on the invested pattern will tightly adhere, thereby providing the mold with a smooth casting surface upon removal of the destructible pattern. The mold must have sufficient strength and rigidity so as to withstand the pressure of the molten casting metal. It is important, moreover, to use an investment material which not only has the necessary porosity, strength and rigidity, but which also possesses surface and setting characteristics permitting it to bond tightly to the coating on the pattern after investment.

Accordingly, a principal object of the present invention is to provide an improved investment composition for forming refractory molds to be used in precision casting operations. A further object of this invention is to provide a refractory mold and a process for forming the same wherein the investment material tightly adheres to the coating on the destructible pattern upon investment. Moreover, upon setting, this investment material is sufficiently strong and rigid to aid in preventing warping, cracking or rippling of the coating layer under the localized pressure caused by the molten casting metal.

The above objects are obtained in accordance with the present invention by the provision of an investment material consisting of a mixture of an ethyl silicate binder and a dry mix or grog comprising a pulverized fire clay, a fine refractory filler material, and an accelerator for the binder. Borax glass is preferably included in the mixture to increase its high-temperature strength.

Other objects and advantages of this invention will more fully appear from the following detailed description of the invention in conjunction with the accompanying drawing, which contains a somewhat schematic sectional view of a destructible pattern invested in a refractory mold formed in accordance with the invention.

Referring more particularly to the drawing, a pattern 10 of a turbine bucket to be cast is shown invested in a refractory mold 12 within a metallic container or flask 14 positioned on a base plate 22. The pattern 10 is preferably formed of a low fusing substance, such as wax or a thermoplastic material, or any other vaporizable, fusible, combustible or otherwise destructible material. However, plastic patterns are preferably employed in order to provide optimum results with the refractory mold embodying the present invention. Among the plastic patterns which have been found to be satisfactory are those formed

of polystyrene, although other thermoplastic pattern materials, such as resinous polymerized derivatives of acrylic acid and resinous polymerized derivatives of methacrylic acid, may be used.

The pattern may be initially cast under pressure in a conventional manner. A gating portion 16 having a pouring basin part 18 at its outer end is attached to the pattern, the portions 16 and 18 usually being formed of a destructible material similar to that of the pattern. After the pattern is formed, it is preferably cleaned with an alcohol solution and air dried prior to application of the coating solution. Before the pattern is invested within the mold, it is coated with an appropriate coating material which is to form the casting surface 20 of the refractory mold. This coating material may be comprised of an aqueous dispersion of conventional finely comminuted refractory materials, a binder, and defoaming and wetting agents, an air-setting silicate cement being preferably used as the binder. Gelatine and acids may also be included in the coating mixture. This type of coating is disclosed in our co-pending patent application Serial No. 320,736, filed November 15, 1952, now Patent No. 2,752,257.

Coating of the pattern is preferably accomplished by dipping the pattern in the coating solution. Although in some instances the coating may also be applied by spraying or painting it on the pattern or in any other suitable manner, dipping is preferred because it assures more uniform coating of all the pattern surfaces and is the simplest method of application.

The dip coat slurry is preferably kept in constant motion by stirring means except during the actual dipping operation. However, the mixing action should not be such as to unnecessarily introduce air into the slurry. The destructible pattern used for forming turbine buckets or other precision cast parts is immersed in the dip coat slurry, preferably to within ½ to ¾ inches of the end of the gating portion of the pattern. Care should be exercised in immersing the pattern in the slurry to prevent air entrapment on the pattern. Normally the dip coat solution is retained at room temperature during the dipping operation because excessive heat can result in distortion of the plastic pattern. The excess coating material is permitted to drain off prior to subsequent treatment and investment.

After the pattern has been completely coated with the dip coat slurry, it may be "sanded" or "stuccoed" to provide a rough surface on the coating thus insuring greater adhesion between the principal refractory portion 12 of the mold and the dip coat 20 on the pattern. This "sanding" may be accomplished by merely screening or otherwise applying silica or other suitable refractory materials in known manner to the outer coated surface of the destrucible pattern. When all the molding surfaces of the pattern have been effectively covered with sand, the pattern should be air dried.

Following the formation of the pattern, the investment material 12 is formed about the pattern and sprue, the latter being permitted to extend through the wall of the resultant refractory mold so as to permit the escape of the destructible pattern material and to form an ingate for the fluid casting metal. This main refractory mold may be formed about the pattern in any suitable manner, but the following procedure provides excellent results. The base plate 22 is preferably first sprayed or otherwise coated with molten wax so as to form a thin film of wax over its upper surface. Before the wax is completely solidified the pattern to be invested is positioned on the plate 22 with the gate and pouring basin portions 16 and 18 thereof extending downwardly and seated firmly in the wax film. The sleeve or flask 14 is then placed around the pattern and pressed lightly into the wax layer. In

order to completely seal the flask 14 to the plate 22, it is preferable to again spray molten wax over the outer surfaces of these parts at their junction. The resultant assembly should be allowed to set for several minutes to permit the wax to thoroughly solidify.

After the refractory mixture, which will be hereinafter described in detail, has been mixed with a proper amount of the liquid binder, it is poured into the sleeve or flask 14, which is preferably vibrated during this pouring operation, and the mold is then allowed to set.

When the mold body has solidified or set to a sufficient extent, the base plate 22 is removed from beneath the mold and heat is applied to melt the pattern. It is necessary to apply sufficient heat to raise the mold temperature above the fusing point of the material, thus permitting the molten pattern to escape through the gate and sprue opening in the mold formed by the pattern portions 16 and 18. In this manner the dip coat which had covered the pattern tightly adheres to the remainder of the mold and provides the casting cavity with a smooth coating. It is also possible to vaporize the pattern, if a vaporizable material is used, by heating the mold rapidly to a high temperature.

After removal of the pattern from the mold in the foregoing manner, the mold is "burned out" to remove substantially all the volatile matter. The mold is then preferably preheated to the desired temperature, and the molten casting metal is poured or otherwise introduced into the mold cavity formed by the pattern. In the majority of instances it is necessary to pour the casting metal while the mold is still hot. After the molten metal has been poured and the casting has solidified, the refractory mold body 12 and the adhering coating 20 may be broken to permit the removal of the casing. As a result of using the improved refractory mold formed in accordance with the present invention, the finished casting possesses excellent surface smoothness and detail and requires few finishing operations.

The investment material used to form the body or principal refractory portion 12 of the mold embodying the invention consists of a dry mix or grog to which an ethyl silicate binder is added. This dry mix comprises major proportions of a pulverized fire clay, such as dead burned fire clay or fire brick and a finely comminuted refractory material and a minor proportion of an accelerator or gelation agent for the binder. Magnesium oxide is the setting accelerator preferably employed, but magnesium carbonate, calcium carbonate, sodium carbonate, and other alkaline oxides or carbonates may be used. In order to improve the high-temperature bond of the resultant mold, borax glass is preferably also included in the mix. The binder for the grog consists of an aqueous solution of condensed ethyl silicate, alcohol and an acid. Denatured ethanol of approximately 190 proof spirit is the alcohol preferably employed, while concentrated hydrochloric acid is the acid which we have found most desirable to add to the binder solution.

Accordingly, an investment dry mix or grog which provides excellent results is one comprising, by weight, approximately 65% to 90% of the finely ground fire clay or brick, 9% to 34% silica flour or other finely comminuted refractory material, and 0.15% to 1.5% of an accelerator or gelation agent, such as magnesium oxide, for the binder. In order to provide optimum results, the fineness of this mix should be between 90 and 100 A. F. A. The accelerator content which is preferred for most applications is between 0.2% and 1%, the greater the amount of accelerator added, the lesser the "gel" time. When borax glass is included in the grog to provide the resultant mold with improved high-temperature bond, it should be present in an amount not in excess of 2% by weight. Moreover, quantities of borax glass as small as 0.1% have proved to be beneficial in improving the high-temperature strength of the mix. At present we prefer to use a grog containing about 0.3% to 1% borax glass.

The ethyl silicate type of binder used in accordance with the invention comprises, by weight, approximately 35% to 60% condensed ethyl silicate, 35% to 60% alcohol, 0.1% to 0.4% concentrated hydrochloric acid and 5% to 13% water. Depending on the particular application, the ratio, on a weight basis, of the dry mix or grog to the ethyl silicate binder may vary from about 2.5 to 4.5. When the above investment dry mix and the binder are mixed in the proper ratios, the resultant investment material generally comprises, by weight, approximately 43% to 74% pulverized fire clay or brick, 6% to 25% silica flour, 0.1% to 1.2% magnesium oxide, 6% to 17% condensed ethyl silicate, 6% to 17% alcohol, 0.02% to 0.1% hydrochloric acid and 0.9% to 3.7% water. A sufficient amount of additional water may be added during mixing of the grog and binder to raise the water content to as high as 7%. If borax glass is included in the mixture, in accordance with the preferred embodiment of the invention, it preferably constitutes between 0.1% and 1.6% of the final investment material. For optimum results the fire clay content should be between 55% and 70% of the weight of the entire mixture, this amount being equivalent to approximately 70% to 87% of the dry mix or grog.

The finely ground fire clay functions as the refractory base of the investment mixture and must be selected so that it has desirable expansion characteristics. This material should also be of uniform quality and composition and reasonably free of foreign matter. "Calmo" is an example of a pulverized dead burned fire clay. Various mixtures of relatively coarse and fine Calmo fire clays may be used, these clays varying in A. F. A. finenesses from approximately 20 to 120.

Silica flour is aded to increase the "fines" in the refractory base and to eliminate voids in the backing of the mold. Other refractory powders, such as zirconium silicate or zirconium oxide flour, may be used for particular applications, however. Generally it is desirable to use a silica flour which is fine enough to permit at least 99% of it to pass through a 140 mesh screen. The magnesium oxide is used in powdered form and may consist of either heavy or light magnesium oxide, or mixtures of these oxides. It is preferable that this material be of sufficient fineness so that at least 90% of it will pass through a 200 mesh screen. Likewise, the borax glass, which functions as a secondary high-temperature bonding agent in the investment mix, should be added in powder form, preferably of approximately 90 to 110 mesh.

The condensed ethyl silicate in the investment binder, of course, is a source of silica for the reaction in which ethyl silicate and water react to form silica gel and alcohol. Upon drying, silica is the ultimate binder for the investment. Alcohol is included to produce mutual solubility of ethyl silicate and water since these latter constituents are immiscible in the absence of the alcohol. The hydrochloric acid is necessary for pH control and to regulate the speed of the aforementioned reaction and the subsequent mold gelation.

It is preferable to use a condensed ethyl silicate having not less than 25% available silica as SiO_2. An example of such an ethyl silicate is one consisting of approximately 85% tetraethyl orthosilicate and 15% polysilicates. Satisfactory commercially available products of this composition frequently have 0.1% maximum acidity as hydrochloric acid, a flash point (open cup) of approximately 90° F., and a specific gravity between 0.920 and 0.950 at 20° C. Hence a typical example of the ethyl silicate solution preferably used is a condensed ethyl silicate which contains, by volume, approximately 50% ethyl silicate, 0.1% hydrochloric acid, and the balance alcohol and water. It will be appreciated, however, that any hydrolyzed or condensed ethyl silicate solution may be satisfactorily used so long as the ethyl silicate content is sufficient to provide the proper bonding properties.

With respect to the permissible upper limit of the con-

centration of the ethyl silicate solution, it is desirable that condensing conditions exist. Accordingly, to assure these conditions, we have found it feasible to use a solution which contains only enough water to provide a sufficient amount of hydrolysis to obtain the above satisfactory bonding and strengthening effects, or to otherwise use ethyl silicate under hydrolyzing conditions. Thus, we have obtained best results by the use of a mixture containing hydrolyzed or condensed ethyl silicate solution with the ethyl silicate content between 25% and 75% by volume.

In preparing the binder solution, the water and acid are first mixed together, and the alcohol and condensed ethyl silicate are subsequently added. The solution is then stirred and permitted to "set" for several hours prior to use. A preferred method of mixing the grog and liquid binder consists of adding approximately two-thirds of the binder and the additional water, preferably about 2% of the weight of the binder, to a rotating batch mixer. The dry mix is then slowly added to the liquid and the slurry mixed for approximately ten minutes.

The above-described high-strength refractory mold for investment molding is particularly adapted for use in coating articles having curved surfaces, such as turbine buckets, because it tightly adheres to the coating on the destructible patterns and prevents distortion of this coating. Furthermore, the resultant mold does not react with nickel-base alloys, a material used in cast turbine buckets, and hence has no adverse effect on the surface qualities of such buckets.

While the present invention has been described by means of certain specific examples, it is to be understood that the scope of the invention is not to be limited thereby except as defined in the following claims.

We claim:

1. A mold composition consisting essentially of a mixture of an ethyl silicate solution and a grog comprising, by weight, approximately 65% to 90% of a pulverized fire clay, 9% to 34% of a finely comminuted refractory material, a small but effective amount of borax glass not in excess of 2%, and 0.15% to 1.5% of a setting accelerator for the ethyl silicate solution.

2. A mold composition consisting essentially of a mixture of a dry grog comprising, by weight, approximately 65% to 90% of a pulverized fire clay, 9% to 34% of a finely comminuted refractory material, 0.15% to 1.5% of a setting accelerator for ethyl silicate and 0.1% to 2% powdered borax glass, and an ethyl silicate binder solution comprising, by weight, about 35% to 60% condensed ethyl silicate, 35% to 60% alcohol, 0.1% to 0.4% of an acid, and 5% to 13% water.

3. An investment composition for a refractory mold consisting of a mixture of an ethyl silicate solution and a grog comprising, by weight, approximately 65% to 90% of a finely pulverized fire clay, 9% to 34% silica flour, 0.2% to 1% of a setting accelerator for ethyl silicate and a small but effective amount of borax glass not in excess of 2%, the ratio, by weight, of the grog to the ethyl silicate solution being between 2.5 to 1 and 4.5 to 1.

4. An investment composition for a refractory mold consisting essentially, by weight, of approximately 70% to 87% of a finely ground burned fire clay, 9% to 34% silica flour, 0.2% to 1% magnesium oxide and 0.1% to 2% borax glass, and an ethyl silicate binder solution comprising, by weight, about 35% to 60% condensed ethyl silicate, 35% to 60% alcohol, 0.1% to 0.4% concentrated hydrochloric acid and 5% to 13% water.

5. An investment composition for a refractory mold consisting essentially, by weight, of approximately 55% to 70% of a finely pulverized dead burned fire clay, 6% to 25% silica flour, 0.1% to 1.2% magnesium oxide, 0.1% to 1.6% powdered borax glass, 6% to 17% denatured ethyl alcohol, 0.02% to 0.1% concentrated hydrochloric acid, 0.9% to 3.7% water, and 6% to 17% condensed ethyl silicate solution, the ethyl silicate content in said solution being between 25% and 75% by volume.

6. A refractory mold having a body portion resulting from setting of a mixture of an ethyl silicate solution and a grog consisting essentially, by weight, of approximately 65% to 90% of a finely pulverized fire clay, 9% to 34% silica flour, 0.2% to 1% of a setting accelerator for ethyl silicate and a small but effective amount of borax glass not in excess of 2%, the ratio, by weight, of the grog and ethyl silicate solution being between 2.5 and 4.5.

7. A refractory mold comprising an investment body portion formed of the residue of a mixture consisting, by weight, essentially of approximately 43% to 74% of a pulverized fire clay, 6% to 25% of a finely comminuted refractory material, 0.1% to 1.6% powdered borax glass, 6% to 17% condensed ethyl silicate, 6% to 17% alcohol, 0.02% to 0.1% of an acid, 0.9% to 7% water, and 0.1% to 1.2% of a setting accelerator for the condensed ethyl silicate.

8. A method of forming a refractory mold which comprises coating a destructible pattern with a refractory coating mixture, investing said coated pattern in a refractory molding mix consisting essentially of a grog comprising, by weight, approximately 65% to 90% of a finely ground fire clay, 9% to 34% silica flour, a small but effective amount of borax glass not in excess of 2% and 0.15% to 1.5% of a setting accelerator for ethyl silicate, and a binder for said grog comprising a solution of approximately 35% to 60% condensed ethyl silicate, 35% to 60% alcohol, 0.1% to 0.4% of an acid and 5% to 13% water, and thereafter eliminating the pattern from said mold, whereby said coating adheres to the refractory mold.

9. The process of forming a refractory mold having a smooth casting surface, said process comprising applying a refractory coating to a fusible pattern, drying said coating, thereafter investing said coated pattern in an investment material comprising, by weight, approximately 43% to 74% of a finely pulverized dead burned fire brick, 6% to 25% silica flour, 0.1% to 1.2% magnesium oxide, a small but effective amount of borax glass not in excess of 1.6%, 6% to 17% condensed ethyl silicate, 6% to 17% ethyl alcohol, 0.02% to 0.1% concentrated hydrochloric acid and 0.9% to 7% water, setting the investment material, melting and removing the pattern from the formed mold, whereby the coating tightly adheres to the walls of the casting cavity of the investment material, and thereafter treating said mold at a temperature sufficient to remove substantially all of the volatile matter therefrom.

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