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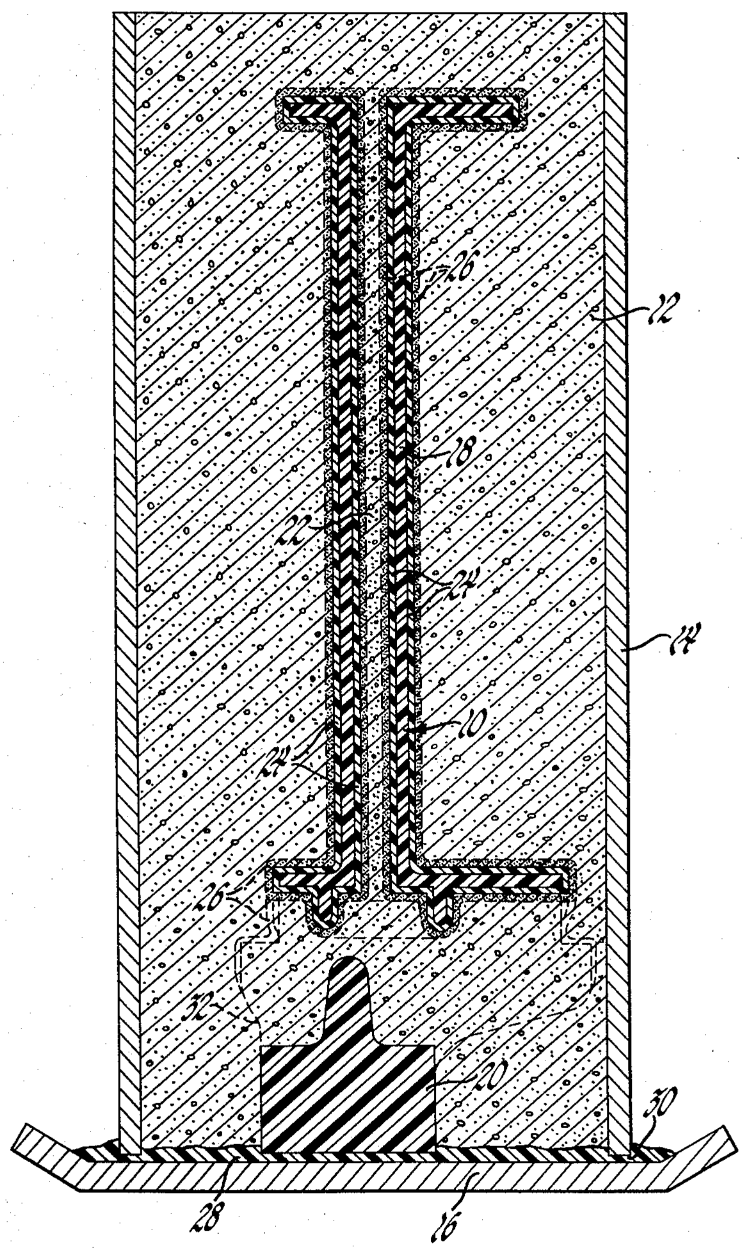

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METHOD OF FORMING AN INVESTMENT MOLD

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This invention relates to investment molding. More particularly it pertains to a method of forming a refractory investment mold by means of a wax pattern having a surface film which protects the pattern from attack by constituents in the molding material.

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 surface smoothness. Thus, in investment molding it is usually desirable that the invested pattern be coated with a refractory-containing material which will tightly adhere to the principal refractory portion of the mold and provide the mold with a smooth casting surface upon removal of the fusible pattern. The resultant mold must have sufficient strength and rigidity to withstand the pressure of the molten casting metal and the stresses set up in the mold during the burnout or firing operation. This is especially important when the investment mold is to be used for producing hollow castings such as turbine blades having cored cavities or passages of small cross-section. Of course, the mold also should possess satisfactory porosity, and the surface and setting characteristics of the principal investment material should enable it to bond tightly to the refractory-containing coating on the pattern.

However, either or both the pattern coating and the principal investment mix employed in the refractory molds of this type usually contain constituents which attack wax patterns. Alcohol, which is ordinarily present in both of these mold components, tends to dissolve surface portions of wax patterns. As a result of this solvent action, proper dimensional control of the pattern cannot always be obtained. Also the refractory-containing coating on the pattern does not always wet and bond to the pattern uniformly. Moreover, the binder of the principal investment mix frequently carries refractory fines in the mix into the dip coat. These fines reach surfaces of the wax pattern and are deposited on the walls of the mold which define the casting cavity, thus producing rough molding surfaces.

Accordingly, a principal object of the present invention is to provide a wax investment molding pattern having a thin surface film of a solution which eliminates the aforementioned problems. A further object of the invention is to provide a process for forming a refractory investment mold by means of a wax pattern coated with a protective film which protects the pattern against solvent action by the investment material and which also aids in more uniformly bonding the refractory-containing dip coat to the pattern.

These and other objects are attained in accordance with this invention with a wax investment molding pattern which is protected by a thin surface film of a coating solution containing a lower alkyl cellulose, preferably methyl cellulose, and a wetting agent. Usually, it is desirable to likewise include silicic acid and a defoaming agent, as well as a suitable additive to adjust the pH of

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the solution. A protective film of this type not only provides the aforementioned advantages, but it also covers up small defects in the surfaces of the wax pattern. It is very effective in controlling penetration of the investment slurry binder and prevents fines in the slurry from being deposited on the otherwise smooth casting-defining surfaces of the mold.

Other objects and advantages of the present invention will more fully appear from the following detailed description in conjunction with the accompanying drawing. This drawing contains a somewhat schematic sectional view of a refractory mold having an invested wax pattern provided with a protective surface film in accordance with the invention.

Referring more particularly to the drawing, a wax pattern **10** of a hollow 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 **16**. The particular pattern shown in the drawing consists of two sections: an elongated, slender turbine blade-forming portion **18** and a lower portion **20** which forms the sprue or pouring basin for the blade casting. The former is provided with a "cored" area or passage **22** of small cross-section which extends through its entire length.

The wax pattern sections may be formed in a conventional manner by injection molding. They are then preferably cleaned with an alcohol solution, air dried, and joined together with molten wax or by other suitable means. The blade-forming portion **18** of the pattern is next coated with a protective film **24** of a solution embodying the invention and subsequently provided with a refractory-containing dip coat layer **26** which is to form the casting surface of the refractory mold. Thereafter the coated pattern is invested within the mold in the manner hereinafter described.

The thickness of the protective film **24** generally does not exceed a few ten-thousandths of an inch, and normally the film need be only about 0.0001 inch thick. However, for purposes of illustration the thickness of both this film and the layer **26** are greatly exaggerated in the drawing.

Coating of the wax pattern with the thin protective film **24** is preferably accomplished by dipping the pattern in the methyl cellulose-containing solution. A dip period of approximately 10 seconds has proved to be highly satisfactory. However, depending on the size and configuration of the pattern and the age of the wax, somewhat longer or shorter dips may be employed. Care should be exercised, of course, to insure complete coating of all areas of the pattern which are normally subjected to distortion due to the solvent action of the investment materials. The wax pattern is then drained and the film allowed to dry. Although in some instances the protective coating may also be applied by spraying or painting it on the wax 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 wax pattern with its protective surface film is subsequently provided with the outer refractory-containing layer **26** by a dipping procedure or other appropriate means. The coating material which forms the layer **26** preferably comprises an aqueous dispersion of conventional finely comminuted refractory materials, a high-temperature binder such as an air-setting silicate cement, and defoaming and wetting agents. Gelatine, octyl alcohol and hydrochloric acid can be advantageously included in this coating mixture. A refractory-containing coating of this type is disclosed in United States Letters Patent No. 2,752,257, which issued on June 26, 1956, in the names of James P. Bradley and Robert R. Dohrmann. An example of such a dip coat composition which provides satisfactory results is one consisting essentially, by weight, of about 15% to 30% refractory cement, 35% to 70% silica flour, 15% to 35% water, 0.1% to 0.3% wetting agent, 0.1% to 1% octyl alcohol, 0% to 2% glycerine, 0.1% to 0.4% gelatine and 0.05% to 0.3% concentrated hydrochloric acid.

The slurry which forms the outer dip coat **26** is preferably kept in constant motion by stirring means except during the action dipping operation. However, the mixing action should not be such as to unnecessarily introduce air into the slurry. The wax pattern used for forming turbine buckets or other precision cast parts is immersed in the dip coat slurry, preferably to within an inch or so of the outer end of the pouring basin portion **20** of the pattern. Care should be exercised in immersing the pattern in the slurry to prevent air entrapment on pattern surfaces. This is particularly important when coating a hollow pattern of the type shown in the drawing because it is essential to coat all the surfaces which define the passage **22** in the pattern. The surplus coating material is permitted to drain off before further treating the pattern. Normally both the protective film-forming solution and the refractory-containing dip coat slurry are maintained at or near room temperature during the dipping operations because excessive heat can result in distortion of the wax pattern.

After the wax pattern has been coated in the foregoing manner, it may be "sanded" or "stuccoed" to provide the layer **26** with a rough outer surface, thus insuring greater adhesion between the principal refractory portion **12** of the mold and the layer **26**. The "sanding" can be accomplished by merely screening or otherwise applying silica or other suitable refractory materials in known manner to the outer coated surface of the destructible pattern. When all the molding surfaces of the pattern have been effectively covered with sand, the pattern should be air dried.

The investment material, which forms the principal refractory part **12** of the mold, is thereafter poured around both the blade-defining portion **18** and the sprue portion **20** of the coated wax pattern. Although this investment material may be distributed about the pattern in any suitable manner, the following procedure provides excellent results. The base plate **16** is preferably first sprayed or otherwise coated with molten wax so as to form a thin layer **28** of wax on the upper surface of the plate. Before the wax has completely solidified, the pattern to be invested is positioned on the wax-coated plate **16** with the pouring basin portion **20** thereof extending downwardly and seated firmly in the wax film. The sleeve or flask **14** is next placed around the pattern and pressed lightly into the wax layer. In order to completely seal the flask to the plate **16**, it is preferable to again spray or pour molten wax over the outer surfaces of these parts at their junction **30**. The wax layer should be allowed to thoroughly solidify before proceeding further.

The refractory mixture is then poured into the flask, which is preferably vibrated during this pouring operation, and the mold is allowed to set. The pattern sections **18** and **20** are spatially separated at **32** to permit the lower end of the passage **22** to freely communicate with the investment material **12**. With this construction, vibration of the flask causes the investment mix to completely fill the passage **22** and form an elongated, narrow core therein. This core extends the entire length of the blade portion of the turbine bucket to be cast.

It will be noted that the sprue portion **20** of the wax pattern projects through the lower wall of the refractory mold so as to permit the escape of the wax from the pattern and to form an ingate for the molten casting metal.

When the mold body **12** has solidified or set to a sufficient extent, the base plate **16** is removed and the mold is heated to melt the wax pattern. The molten wax escapes through the sprue opening in the mold formed by the pattern portion **20**. In this manner the refractory-containing dip coat **26**, which had covered the surfaces of the pattern, tightly adheres to the mold and provides the casting cavity with a smooth coating.

After removal of the pattern from the mold in the foregoing manner, the mold is fired or "burned out," usually at a temperature of about 1800° F. to 2000° F., 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 in order to obtain satisfactory results. After the molten metal has been poured and the casting has solidified, the refractory mold body **12** and the adhering coating **26** may be broken to permit the removal of the casting. As a result of using the protective film **24** on the wax pattern, the casting possesses excellent surface smoothness and detail and requires little finishing.

The mold body **12** may be formed of a silica investment having an ethyl silicate binder or may be formed of other suitable investment materials. Examples of investment molding mixes which are highly satisfactory for various applications are described and claimed in co-pending United States patent applications Serial Nos. 637,586, now U.S. Patent 2,818,619, 637,768, now U.S. Patent 2,861,308, 649,962, filed April 5, 1957, and 651,273, now U.S. Patent 2,851,752 all owned by the assignee of the present invention. An example of an investment dry mix or grog which may be used is one containing major proportions of pulverized fire clay and finely comminuted refractory material and minor proportions of magnesium oxide and borax glass. The binder for this grog may include an aqueous solution of ethyl silicate to which small amounts of alcohol and acid have been added. A typical investment composition comprises by weight, approximately 43% to 74% finely divided burned fire clay, 6% to 25% silica flour, 6% to 17% condensed ethyl silicate, 6% to 17% ethyl alcohol, 0.02% to 0.1% hydrochloric acid, 0.9% to 7% water, and 0.1% setting accelerator for the ethyl silicate.

In accordance with the present invention, the protective film **24** is formed from an aqueous solution of a film-forming alkyl cellulose such as methyl cellulose. Although methyl cellulose is preferred, other short-chained alkyl celluloses, such as ethyl cellulose, butyl cellulose and propyl cellulose, may be employed. In general, the methyl cellulose content of the solution should range between approximately 0.5% and 4% by weight. However, a solution containing 1% to 3% methyl cellulose is preferred.

The film **24** may be formed in the following manner. Approximately 400 grams of methyl cellulose is added to hot water, and the mixture is allowed to stand for a period of time sufficient to thoroughly wet the methyl cellulose. Normally this will require about five minutes, although occasionally a wetting period as short as two minutes is sufficient. Longer periods may be employed if desired. Thereafter approximately three gallons of cool or cold water is added to the aforementioned mixture, and the resultant material is thoroughly mixed to place the methyl cellulose in solution. Normally it is desirable to use water which is at a temperature between 32° F. and about 80° F. The above procedure is advantageous because cold water will not satisfactorily wet methyl cellulose and hot water will not dissolve it. Hence, the hot water is used for its wetting action, while the cold water is employed to place the methyl cellulose in solution.

A suitable wetting agent is then added to the solution in order to satisfactorily wet the wax pattern when the protective film is applied. Approximately 160 cc. of wetting agent has proved to be satisfactory for use in the above-described solution. Although a wetting agent content of about 0.8% by weight appears to provide optimum results, this constituent may be present in the solution in amounts ranging from 0.08% to 8% by weight. Any conventional wetting agent may be advantageously employed, but a detergent such as an alkyl ether of polyethylene glycol is particularly advantageous because it forms a brittle foam which "breaks" easily. An example of such an ether is "Tergital wetting agent TMN." Approximately 0.5% to 2% by weight of this stable, non-ionic penetrant provides excellent results. A wetting agent is especially necessary if a silicone mold release agent was used in injection molding the wax pattern and a thin coating of this material has remained on the pattern. If the wetting agent is omitted the water-base solution will not satisfactorily wet the silicone film or the wax.

It also has proved advantageous to add to the methyl cellulose solution about 16 cc. of a concentrated aqueous solution of formaldehyde. This substance prevents souring of the methyl cellulose by inhibiting bacterial action, thereby permitting the solution to be stored for long periods of time. The aqueous solution of formaldehyde should be used in a quantity sufficient to destroy bacteria. This amount may range from approximately 2 cc. to 50 cc. in a batch of the above-described size. Such a formaldehyde content is roughly equivalent to 0.01% to 2% of the weight of the protective coating solution.

Silicic acid, preferably containing about 15% to 40% by weight of silica, may be beneficially included in the methyl cellulose solution to increase the insolubility of the dry film **24** on the wax pattern. Approximately one gallon of silicic acid solution is satisfactory for addition to the aforementioned batch, although the silicic acid content of the methyl cellulose solution may vary from approximately 5% to 50% by weight. For most applications a solution containing 15% to 30% appears to produce optimum results. The silicic acid prevents alcohol in the principal investment mix and in the dip coat from dissolving the protective film on the wax pattern. It also serves to roughen the protective film **24** and provides a better bond between this film and the refractory-containing dip coat layer **26**.

In order to properly regulate the pH of the above methyl cellulose solution and maintain it in the non-jell range between about 8.5 and 10.5, approximately 60 cc. to 160 cc. of ammonium hydroxide is added to it. Although other completely volatilizable alkalis may be used, ammonium hydroxide is preferred because many metal hydroxides, such as NaOH, attack the methyl cellulose. Such hydroxides also may be detrimental to the refractory-containing dip coat layer **26** because it tends to form a deposit on the dip coat surface when the protective film **24** is burned off during firing of the mold. A deposit of this type somewhat lowers the fusion point of the layer **26**. Moreover, metal hydroxides are often disadvantageous to the investment process since they frequently precipitate an undesirable slag. NH_4OH successfully prevents jelling of the silicic acid if used in amounts equal to about 0.025% to 0.07% of the total weight of the protective coating solution. It also should be noted that a volatilizable acid may be used instead of an alkali as a pH control agent since lowering the pH of the methyl cellulose solution to about 3 or below also places it in a non-jell range.

Thus it will be seen that the film-forming alkyl cellulose solution may comprise, by weight, approximately 0.5% to 4% methyl cellulose, 0.08% to 8% wetting agent, 0.01% to 2% formaldehyde, 0.025% to 0.07% ammonium hydroxide, and the balance substantially all water. As indicated above, if silicic acid is included in the solution, it may be beneficially added in an amount equal to about 5% to 50% by weight. We have obtained excellent results with a methyl cellulose solution consisting essentially, by weight, of about 1% to 3% methyl cellulose, 0.5% to 2% wetting agent, 0.01% to 0.2% formaldehyde, 0.025% to 0.07% ammonium hydroxide, 15% to 30% silicic acid and 65% to 84% water.

The above-described coating for wax patterns to be invested in refractory casting molds adheres tightly even to sharply concave surfaces and therefore is particularly adapted to patterns having such surfaces, such as hollow turbine blade patterns. Moreover, the use of this coating does not cause the resultant investment mold to react with nickel base alloys and cobalt base alloys, materials commonly employed for cast turbine blades, and hence has no adverse effects on the surface qualities of such blades.

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.

I claim:

1. A protective coating solution for application to surfaces of a wax pattern to be invested in a refractory mold, said solution comprising, by weight, approximately 0.5% to 4% of a film-forming short-chain water soluble alkyl cellulose, 0.08% to 8% wetting agent, 0.01% to 0.2% formaldehyde, 0.025% to 0.07% ammonium hydroxide, and the balance substantially all water.

2. A room temperature-setting dip coat for application to mold-defining surfaces of a wax pattern to be invested in a refractory mold, said dip coat consisting essentially, by weight, of 1% to 3% methyl cellulose, 0.5% to 2% wetting agent, 0.01% to 0.2% formaldehyde, 0.025% to 0.07% ammonium hydroxide, 5% to 50% silicic acid, and 65% to 84% water.

3. A pattern for use in a refractory investment mold, said pattern being formed of wax having surfaces provided with a thin, dry film resulting from coating said surfaces with a solution comprising, by weight, approximately 0.5% to 4% of a film-forming short-chained water soluble alkyl cellulose, 0.08% to 8% wetting agent, 0.01% to 0.2% formaldehyde, 0.025% to 0.07% ammonium hydroxide, 5% to 50% silicic acid and the balance substantially all water.

4. A pattern for investment in a precision casting refractory mold, said pattern being formed of wax having mold-defining surfaces provided with a thin, dry film resulting from immersing said pattern in a room-temperature setting solution consisting essentially, by weight, of about 1% to 3% methyl cellulose, 0.5% to 2% wetting agent, 0.01% to 0.2% formaldehyde, 0.025% to 0.07% ammonium hydroxide, 15% to 30% silicic acid and the balance substantially all water.

5. An investment mold and pattern assembly comprising a solidified investment composition containing refractory material and an ethyl silicate type binder, and a wax pattern invested in said composition, said wax pattern having mold-defining surfaces provided with a thin film produced by coating said surfaces with an aqueous solution containing about 5% to 50%, by weight of silicic acid, about 0.5% to 4%, by weight, of methyl cellulose, a small amount of a wetting agent sufficient to cause said solution to satisfactorily wet said surfaces and a volatilizable pH control agent in a small amount sufficient to place said solution in a non-jell range.

6. A method of forming a refractory mold which comprises applying an aqueous solution containing a film-forming short-chained water soluble alkyl cellulose to surfaces of a wax pattern to form a thin film thereon, drying said film, thereafter applying a refractory-containing mixture to the outer surface of said dried film on said pattern, investing said coated pattern in a refractory molding mix, and setting said mix.

7. A method of forming a refractory mold which comprises applying an aqueous solution of methyl cellulose to surfaces of a wax pattern to form a thin film thereon, drying said film, thereafter applying a refractory-containing slurry to the outer surface of said dried film on said

pattern to form a thin coating of said mixture on said surfaces, drying said coating, thereafter investing the resultant coated pattern in a refractory molding mix, and setting said mix.

8. A method of forming a refractory mold which comprises applying a coating solution to mold-defining surfaces of a wax pattern to form a thin film thereon, said solution comprising, by weight, approximately 0.5% to 4% methyl cellulose, 0.08% to 8% wetting agent, and the balance predominantly water, drying said film, investing said pattern thus treated in a refractory molding mix, setting said mix, and finally heating the resultant mold to a temperature and for a period of time sufficient to melt and remove the wax pattern from said mold.

9. A method of forming a refractory mold which comprises applying a solution to surfaces of a wax pattern to form a thin film thereon, said solution comprising, by weight, approximately 0.5% to 4% methyl cellulose, 0.08% to 8% wetting agent, 0.01% to 0.2% formaldehyde, 0.025% to 0.07% ammonium hydroxide and the balance predominantly water, drying said film, thereafter applying a refractory-containing slurry to the outer surface of said dried film on said pattern to form a thin coating of said slurry on said surfaces, drying said coating, investing the resultant coated pattern in a refractory molding mix, setting said mix, and subsequently heating the mold thus produced to melt and remove said wax pattern from said mold.

10. A method of forming a refractory mold which comprises applying a coating solution to surfaces of a wax pattern to form a thin protective film thereon, said solution comprising, by weight, approximately 0.5% to 4% methyl cellulose, 0.08% to 8% wetting agent, 0.01% to 0.2% formaldehyde, 5% to 50% silicic acid, a volatilizable pH control agent in a small amount sufficient to place said solution in a non-jell range, and the balance substantially all water, drying said film, thereafter applying a thin coating of a refractory-containing slurry to the outer surface of the dried film on said pattern, drying said slurry, investing the pattern thus coated in a refractory molding mix, setting said mix, and subsequently heating the resultant mold to melt and remove the wax pattern from said mold.

11. A method of forming a refractory investment mold which comprises immersing a clean wax pattern in a solution to form a thin protective film on mold-defining surfaces thereof, said solution consisting essentially of about 1% to 3% methyl cellulose, 0.5% to 2% wetting agent, 0.01% to 0.2% formaldehyde, 0.025% to 0.07% ammonium hydroxide, 15% to 30% silicic acid and 65% to 84% water, drying said film on said pattern, thereafter immersing said wax pattern with said film thereon in a refractory-containing aqueous slurry to form a thin layer of said slurry on surfaces of said film, drying said layer, investing the pattern thus coated in an investment composition comprising major proportions of pulverized burned fire clay, a finely comminuted refractory material, ethyl silicate and alcohol, and minor proportions of an acid and water, setting said investment composition, heating the resultant mold to melt and removing the wax pattern from said mold whereby said layer tightly adheres to the walls defining the casting cavity of said mold, and thereafter firing said mold at a temperature sufficient to remove substantially all of the volatile matter therefrom.

12. An investment mold and pattern assembly comprising a solidified investment composition containing refractory material and an ethyl silicate-type binder, and a wax pattern invested in said composition, said wax pattern having mold-defining surfaces provided with a thin, dry film resulting from coating said surfaces with an aqueous solution of a film-forming, short-chain, water soluble alkyl cellulose.

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