

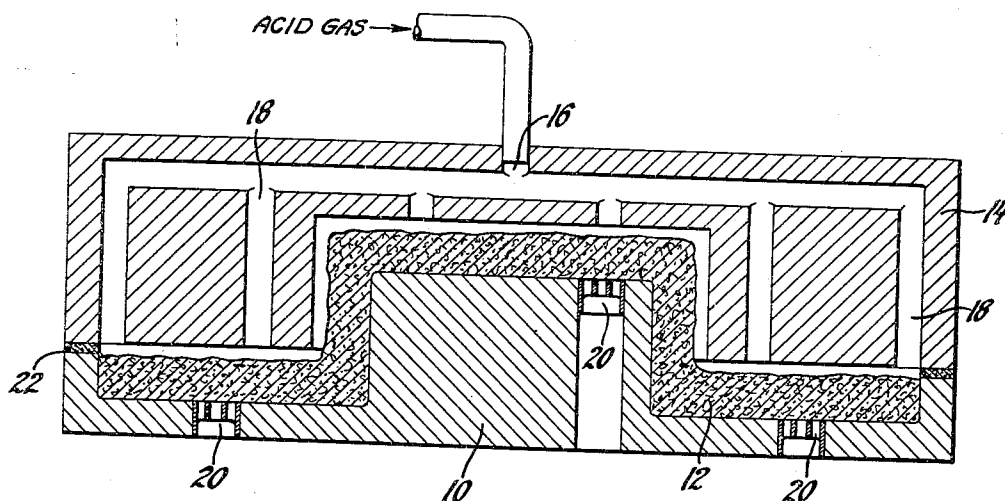
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SHELL TYPE MOLDS AND CORES

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SHELL TYPE MOLDS AND CORES

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This invention relates to thin-walled foundry molds and cores for metal casting operations and particularly to molds and cores of this type which may be formed without the application of external heat.

This application is a continuation-in-part of my co-pending application S.N. 637,802, filed February 1, 1957, now abandoned, and assigned to the assignee of the present application.

During the past few years the shell molding process has come into rather extensive use in the United States and in various other countries. This process involves the formation and use of thin-walled dispensable molds and cores composed of sand and resinous binders. Although the shell molding process can be successfully employed to produce precision castings in a wide variety of metals, it is necessary to use heated metal patterns. A thermosetting resin must be used as the binder since it is essential that the heat from the pattern melt and set the binder. Thereafter additional heat normally must be applied to the mold in order to cure the binder and make the mold usable for metal casting operations.

Shell molding patterns are relatively expensive since they must be formed of steel or other heat-resistant metal to satisfactorily withstand elevated temperatures. Pattern temperatures between 250° F. and 550° F. are typical, but temperatures as high as 700° F. or even higher may be employed under particular conditions. Ovens which are usually used to subsequently cure the molds are heated to temperatures between 300° F. and 1500° F. In some instances the sand-resin mixture may be cured by applying heat to the mold by means of heating coils within the pattern. In any event, the patterns are subjected to high temperatures, whether internally or externally heated, and hence are exposed to the possibility of thermal distortion or warping. Of course, it is also relatively costly to provide the required apparatus for initially heating the metal patterns and thereafter curing the molds on the pattern.

It is also obvious that the necessity for melting the binder and subsequently baking the mold to set the binder involves a rather extended period of time. In order to reduce the length of the mold-forming cycle, it is desirable to devise a process for forming thin-walled dispensable molds in which the pattern dwell time and subsequent curing time are substantially reduced.

Accordingly, a principal object of the present invention is to provide a thin-walled dispensable mold which may be formed without the application of external heat. A further object of the invention is to provide an inexpensive and rapid method of forming smooth-surfaced, thin-walled foundry molds and cores in which it is unnecessary to employ a heated metal pattern and which eliminates subsequent baking of the mold to cure the binder.

These and other objects are attained in accordance with my invention by a process in which a layer of sand-binder molding mix is treated with an acid gas which converts the binder into a hard, strong compound which securely bonds the sand grains together. The acid gas functions as a catalyst, causing the binder to polymerize and harden into an infusible and insoluble condition. This binder thus bonds the sand grains together into a relatively strong, rigid, shell-like layer which has a smooth surface satisfactory for use in precision casting opera-

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tions. After treating the sand-resin mixture with the acid gas, the formed shell mold or core is preferably treated with a neutralizing gas such as ammonia.

It is not necessary to apply heat to the pattern in order to melt the binder or to subsequently bake the mold in order to cure it. Consequently, there is no need to use an expensive pattern of heat-resistant metal. In addition, the process described herein is an efficient and low-cost method of producing precision molds and cores since the manipulative steps can be easily performed by unskilled labor with the facilities commonly available in the average foundry. Thus it will be seen that the cost of producing these thin-walled, dispensable molds is substantially less than the cost of forming conventional shell molds, while the advantages of the shell molding process are retained.

Other objects and advantages of this invention will more fully appear from the following detailed description of preferred embodiments thereof, reference being made to the accompanying drawing showing a somewhat schematic, vertical sectional view of a mold half produced by the present process and an apparatus for forming this mold half.

The binder for the mold may be any organic material which can be mixed with sand to provide it with the necessary green strength and which will cure under acid conditions or any reactive organic material which, when added to sand in the presence of a green strength additive, will cure under acid conditions. In order for the binder to be properly catalyzed by the acid gas, it should be in liquid condition. Satisfactory results can be obtained in some instances with normally solid binder constituents if they are made liquid or partially liquid by addition of a liquidizer. Binder constituents which may be mixed with sand and subsequently caused to polymerize by the gaseous acid include furfuryl alcohol, furfuryl alcohol resin and other furfurylated materials which will set in the presence of the acid gas. Various other resins and resinous materials, such as novolak, resole, urea formaldehyde, melamine formaldehyde and phenol formaldehyde resins, as well as other organic materials which will polymerize or set under acid conditions, also may be employed.

The gaseous catalyst which is used to treat the molding mixture must be acidic or capable of forming an acid in the chemical environment of the molding mixture. An example of suitable acid compounds which are normally gaseous or which may be made gaseous to practice the present invention include hydrogen chloride, boron trifluoride, aluminum chloride, aluminum bromide, chlorine, hydrogen bromide, ammonium chloride, hydrogen iodide and sulfur dioxide, hydrogen chloride and chlorine gas being preferred because of their general applicability. It will be noted that such terms as "acid gas" and "gaseous acidic catalyst" are used herein to include the Lewis type acid gases which in a broad sense are materials capable of accepting a pair of electrons and in a more restricted sense include materials which are proton donors. As is well known, Lewis type acids include proton donors and it is believed that the protons are responsible for the catalytic action of the above gases. Hydrogen chloride gas and chlorine gas, for example, are proton donors in the presence of moisture or certain liquid binder constituents such as furfuryl alcohol. Since hydrogen chloride is a catalyst which causes monomeric furfuryl alcohol to polymerize, it is also possible to use partially polymerized furfuryl alcohol and to further polymerize it with the acid gas. As a result there is obtained a high molecular weight polymer which is infusible and insoluble.

It does not appear that the presence of the halogen in the aforementioned Lewis acids contributes to the

polymerization or setting process. However, the above-listed halogenated compounds are readily available commercially and are easy to gasify. Apart from the aforementioned Lewis-type acids, phthalic anhydride, phthalic acid, maleic acid and maleic anhydride also may be considered to be Lewis acids and can be employed as satisfactory catalysts. Of course, the selection of the particular acid gas to be used in polymerizing or partially polymerizing the liquid binder component in the molding mixture is determined primarily by the nature of the binder. For example, hydrogen chloride gas and chlorine gas have been found to be excellent polymerization agents for furfuryl alcohol. Since the particular chemical mechanism causing the acid gases to catalyze the organic binders involved in the present invention is not well understood, the above theoretical explanation is not intended as limitation of the process involved in the invention.

At the present time I prefer to employ a mixture of silica sand, such as Juniata sand or lake sand, and furfuryl alcohol as the molding material. Other suitable comminuted refractory substances can be employed, of course, and silica flour or similar fine facing materials likewise may be included in the molding mix to provide the molds with exceptionally smooth working surfaces. The use of a mix containing a fine refractory powder is especially desirable in casting steel or other high melting metals.

Furfuryl alcohol is a preferred binder because it is inexpensive and produces excellent results. As is well known, the relatively high cost of the organic binder is one of the major reasons why the shell molding process is not used more extensively. Inasmuch as shell molding mixes normally contain up to about 10% by weight of phenolic binder, the cost of the binder is a substantial item of expense in that process. Only a very small amount of binder, depending on the fineness and purity of the sand, is normally required in the molding mixes used in practicing the present invention. Hence, a mix containing approximately 1% to 5% by weight of furfuryl alcohol has proved to be highly satisfactory, although a 2% to 4% furfuryl alcohol content appears to provide optimum results. Analogous quantities of other binder constituents may be used since in no instance is it necessary to employ large quantities of the binder. Of the various acid gases listed above, hydrogen chloride and chlorine provide excellent results when furfuryl alcohol is used.

Referring more particularly to the drawing, the sand and polymerizable liquid binder are first mulled together in order to thoroughly distribute the binder throughout the sand particles. This generally uniform mixture is then applied to a contoured pattern 10 preferably made of an epoxy resin filled aluminum powder or other suitable material to form a thin layer 12 of predetermined thickness which covers the mold-forming surface of the pattern. This may be accomplished by blowing the mixture on the pattern or by a dumping, ramming or sprinkling procedure or the like. A blowing operation is normally preferred because the shell layer 12 may be rapidly and conveniently formed of proper thickness in this manner. The above-described type of molding mix usually has sufficient green strength to enable it to be satisfactorily used on patterns of typical contour.

Thereafter the pattern 10 with the adhering thin layer of the sand and binder mixture is positioned under a gassing head or manifold 14, and the acid gas is introduced through an inlet opening 16 in the gassing head. The gas may be distributed by suitable ducts 18 or the manifold may be in the form of a simple container which envelops the upper surfaces of the mold layer 12.

As shown in the drawing, a plurality of vents 20 are provided in the pattern and extend from the lower surface of the shell layer 12 through the pattern. In this manner excess acid gas and displaced air are conveyed through the mold to the atmosphere. Although the gassing head

can be designed so that the venting ducts are located within the head, the above-described arrangement is generally preferable since maximum penetration of the gas throughout the sand-resin layer results when the gas passes through the layer to the greatest possible extent. Of course, in some instances it may be disadvantageous to locate the vents in certain areas of the pattern because these vents may prevent the formation of a satisfactory smooth surface at that particular location. Suitable seals 22 are shown as located between the pattern and the gassing head to prevent loss of the acid gas during the curing operation.

Of course, it is also possible to introduce the gas from the pattern side of the mold or through both the gassing head and pattern. Since the molds normally have very thin walls, however, it is generally unnecessary to employ such an arrangement.

Due to the porosity of the molding mixture, the gas readily permeates the layer 12 and catalyzes the liquid binder constituent in the mix. The polymerized binder therefore sets and bonds the individual sand particles into an integral shell of desired thickness and rigidity.

The above-described gassing or curing operation, which transforms the mold layer into a fairly rigid, relatively hard shell, is accomplished in only a few seconds. When furfuryl alcohol, for example, is used as the mold binder and in most other instances, a gassing period of only 5 to 10 seconds is sufficient. However, depending on the size and shape of the mold to be formed, the molding mix may be exposed to the acid gas for as short a time as two or three seconds and as long as 15 or 20 seconds. Longer gassing periods are permissible, of course, but appear to provide no additional advantages. Thus it will be seen that only a very small amount of the gaseous acid catalyst is required.

It does not appear that the pressure of the gas has an appreciable effect either on the hardness of the mold produced or on the processing time involved. Accordingly, in order to preclude any possibility of disturbing the mold, a relatively low pressure is preferred. Thus the gas may be introduced into the mold at a pressure only slightly above atmospheric, pressures of approximately 10 to 20 pounds per square inch being satisfactory.

In some instances where a relatively dense, thin-walled mold shell of high strength is desired, it may be advantageous to apply pressure to the mold before and/or during the gassing operation. This can be accomplished by means of a contoured press head which may also function as the manifold for distributing the acid gas. Pressure thus can be exerted on the surfaces of the mold to compress it slightly before it is completely cured.

As hereinbefore explained, since it is not necessary to apply external heat to form the mold, expensive heat-resistant metal patterns need not be employed. These patterns therefore may be made of wood, plaster, rubber, plastic or other relatively inexpensive and easily workable or machinable materials. Of course, the patterns could be formed of metal or various combinations of the above materials.

Upon completion of the gassing or curing step, the formed shell is at a temperature somewhat above room temperature, indicating that the reaction involved is exothermic in nature. The exact reaction is not thoroughly understood, and it is unnecessary to specifically identify this reaction in order to practice this invention. As explained above, however, it is believed that the acid gas at least partially polymerizes the liquid binder constituent, such as furfuryl alcohol, and causes it to become a hard resinous material. In instances where furfuryl alcohol resins or similar resins are initially employed, it is believed the acid gas further polymerizes these resins and causes them to become substantially cured. Hence partially polymerized furfuryl alcohols, which are composed principally of dimers, trimers and tetramers, may be satisfactorily employed.

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Upon completion of the gassing or curing step, the acidic material remaining in the cured shell or core is neutralized by subjecting it to a neutralizing gas such as ammonia. This may be accomplished by forcing the ammonia gas under pressure through the inlet opening 16 of the gassing head in a manner similar to the application of the acidic material. To more efficiently neutralize the acidic material the ammonia introduction step may be preceded by introducing a blast of air through the inlet 16 whereby a substantial portion of the acidic material is blown out through the vents 20. In most instances the acidic material may be neutralized by subjecting the gassed mold or core to an ammonia blast of a period of only 1 to 2 seconds.

It has been found that the step of neutralizing the acidic material is extremely beneficial to the process regardless of the type of binder or curing gas used. In some instances the neutralization step is essential to provide a mold or core of adequate strength.

The beneficial effects of the neutralization step are illustrated by the following examples:

A shell mix was prepared of 100 parts of lake sand and 3 parts of furfuryl alcohol monomer. A core forming box basically similar to the apparatus shown in the drawing was used to prepare a number of test samples. The samples were gassed with hydrogen chloride for a period of 4 seconds.

A first group of samples were stripped from the core box and merely permitted to stand in a normal foundry environment for three days. A second group was stripped from the core box and heated to about 180° F. for about 10 minutes and then permitted to stand in a normal foundry environment for a period of three days. A third group was neutralized with ammonia gas immediately after the gassing step in the manner above described, stripped from the core box and then permitted to stand in a normal foundry environment for three days. A fourth group was gassed, neutralized, heated to about 180° F. for about 10 minutes and then stripped from the pattern and permitted to stand in a normal foundry environment for three days. It was found that the first group gradually lost tensile strength on standing. The second group showed a marked improvement in the tensile strength after the heating step, and this improved tensile strength was maintained on standing. The third group showed a gradual increase of tensile strength markedly above the tensile strength of the second group on standing, and the fourth group showed a rapid increase in tensile strength to a point substantially equal to the third group which did not diminish on standing. It is apparent from these tests that it is essential to neutralize a core or shell mold using a furfuryl alcohol binder unless the cores are suitably heated after the gassing step. This series of tests was repeated with chlorine as the catalyzing gas with substantially the same results.

A shell mold mix was prepared using a binder consisting of 70 parts of a mixture including substantially 60% formaldehyde, 25% urea, 15% water, 0.3% methanol and no free formic acid; 30 parts of urea powder; and 20 parts of furfuryl alcohol monomer. A sand-resin mix consisting of 100 parts of lake sand and 3 parts of the above binder was mixed and a number of test samples were prepared as in the case of the first example. A first group of samples were stripped from the core box after gassing and merely allowed to stand in a normal foundry environment for three days. A second group was stripped from the core box and thereafter heated to about 180° F. for about 10 minutes and then allowed to stand in a normal foundry environment for three days. A third group was neutralized with ammonia gas as above described and then permitted to rest in a normal foundry environment for three days. A fourth group was gassed, neutralized and finally heated to about 180° F. for about 10 minutes. It was found that on standing the first

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group gradually lost tensile strength. The second group lost in tensile strength very rapidly as a consequence of the heating step. The third group showed a marked improvement in tensile strength over a three day period.

The fourth group showed a rapid increase in tensile strength after the heating step to a point substantially equal to the third group which did not diminish on standing over a three day period. It is apparent from these tests that unless the shells or cores are subjected to a neutralization step, satisfactory cores may not be made utilizing the above binder. This series of tests was repeated with chlorine as the catalyzing gas with substantially the same results.

After curing and neutralization of the mold layer the pattern and adhering mold are separated from the gassing head. This may be accomplished, of course, by either lowering the pattern or by raising the gassing head. The cured mold is then stripped from the pattern and is ready for use. Mold sections or cores thus formed can be assembled in association with other mold parts in conventional fashion to receive molten casting metal. These thin-walled molds have sufficient strength and stiffness to make them suitable for many casting operations.

It is frequently advantageous to treat the molding surface of the pattern with a mold release agent or lubricant before applying the molding mix to it. In order for such a lubricant to effectively aid in releasing the cured mold from the cold pattern, it must possess satisfactory lubricating properties at room temperature and should not depend on being heated. Accordingly, oleic acid, paraffin oil, dibutyl phthalate, lard oil, stearates, and waxes may be employed. Epolene "N," a polyethylene wax manufactured by Eastman Chemical Products, Inc., is an example of a synthetic wax which has satisfactory lubricating properties in the unheated state.

Under some circumstances it also may be desirable to incorporate an internal lubricant in the molding mix to aid in releasing the cured mold from the pattern. The internal lubricant may be either liquid or solid. However, it likewise must have inherent lubricating properties which are independent of the application of heat. The aforementioned external mold release agents also are examples of materials which can be satisfactorily employed as internal lubricants. The amount of mold release agent to be used will vary with the type of pattern, of course, as well as with the type of sand employed and quantity of binder in the molding mixture. Normally an internal lubricant content of approximately 0.05% to 1% by weight is appropriate since it tends to reduce the strength of the resultant mold if it is present in an excessive amount.

Since a liquid binder is employed, the molding mix has satisfactory green strength for almost all applications. Generally this mix packs properly in the blowhead and can be blown without difficulty. Hence it is normally unnecessary to use any special green strength additive. In the event it is found desirable to employ such an additive for blowing a particular type of shell, however, dibutyl phthalate can be used satisfactorily. Usable green strength additives also include other dialkyl phthalates having one to five carbon atoms in each alkyl group, such as dimethyl phthalate, diethyl phthalate and diamyl phthalate, linseed oil, and a mixture of linseed oil fraction and non-curing phenolic resin. These materials likewise aid in mixing the binder with the refractory constituent or constituents in the molding mix. Ordinarily about 0.5% to 2% by weight of dibutyl phthalate or similar green strength additive is appropriate.

Upon pouring molten metal into a thin-walled mold which is formed in the above-described manner, the hot metal, on coming into contact with the mold, burns the resinous binder to essentially carbon. The gases which are generated readily escape through the highly perme-

able sand-resin shell. As a result of the binder breakdown, the shake-out is easily accomplished.

The above-described fast-setting shell-type molding mix permits a substantial increase in the number of molds produced per unit time. These molds, which show no evidence of segregation even on high rises, faithfully reproduce pattern details, maintain good dimensional tolerance, and possess excellent surface qualities. As a result of this superior definition of the shells, there is little "burn-in" on the vertical surfaces of the castings produced. The surfaces of the castings are also substantially free of gas folds. Hence these castings are of very high quality and the scrap rate may be maintained at a low level.

The term "mold," as used herein, is applied in its generic sense to mean a casting form which includes both molds and cores, this invention not being limited to the former. Similarly, the word "pattern" is used herein as including both mold patterns and core boxes.

While I have disclosed certain preferred procedures and specific compositions which may be used to carry out the method of the present invention, it will be understood that such procedures may be varied and that functionally equivalent materials may be used, as will be apparent to those skilled in this particular art, without departing from the spirit of the invention and the scope of the following claims.

I claim:

1. A method of forming a foundry mold for metal casting operations, said method comprising applying to a pattern of molding mix comprising a major proportion of comminuted refractory material and a minor proportion of an organic binder which is hardenable in the presence of an acidic catalyst, exposing said molding mix while on said pattern to a gaseous acidic catalyst to harden said organic binder, thereafter exposing said hardened organic binder to ammonia gas to neutralize the residual acidic catalyst and finally removing the mold thus formed from said pattern.

2. A rapid and inexpensive method of producing a sand-resin foundry mold for metal casting operations which comprises forming a molding mixture consisting essentially of a small amount of an acid catalyzed polymerizable organic binder and the balance substantially all sand, applying said mixture to a pattern to form a layer thereon, thereafter positioning a manifold over said layer and said pattern, forcing an acid gas into said manifold

and causing said gas to penetrate said layer for a period of two to twenty seconds thereby causing said binder to harden and bond said sand into a solid unitary mass, forcing ammonia gas into said layer for at least one second to neutralize residual acid gas within said layer and finally stripping the shell so formed from the pattern.

3. A rapid and inexpensive method of producing a sand-resin mold which comprises forming a mold mixture consisting essentially of about 1% to 5% by weight of a liquid acid-catalyzed polymerizable organic binder and the balance substantially all sand, placing said mixture into contact with an unheated pattern to form a layer of said mixture thereon, forcing a gaseous acidic catalyst into said layer for a period of time sufficient to cause said binder to polymerize and harden, thereafter forcing ammonia gas into said layer for a period of time sufficient to neutralize the residual acidic catalyst therein and finally stripping said layer from the pattern.

4. A process for rapidly producing an inexpensive mold for use in metal casting operations, said process comprising forming a uniform mixture consisting essentially of about 2% to 4% by weight of furfuryl alcohol and the balance substantially all sand, applying the molding mixture thus formed onto the molding surface of an unheated pattern to form a layer thereon, subsequently forcing hydrogen chloride gas into said layer for two to twenty seconds to cause said furfuryl alcohol to polymerize and bond the particles of said sand together into a relatively hard integral mass, forcing ammonia gas into said layer for at least one second to neutralize residual acid within said layer, and thereafter removing said shell from said pattern.

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CERTIFICATION OF CORRECTION

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November 14, 1961

Herbert O. Blaies, Jr.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, line 28, for "said", second occurrence, read -- sand --.

Signed and sealed this 24th day of April 1962.

(SEAL)

Attest:

ESTON G. JOHNSON
Attesting Officer

DAVID L. LADD
Commissioner of Patents