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INDUCTION HEATING METHOD FOR MAKING MOLDS

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This invention relates to articles formed of particulate refractory materials bound together by a binder into a selected configuration, particularly mold and core type articles for molding. This invention relates more specifically to a method of and a composition for forming cores and molds and other configurated articles of refractory materials bound together by using heat.

The art of forming molds and cores for metal casting and molding processes necessitates interbinding of refractory particles, e.g., sand, into a self-sustained mold or core with a specific innersurface configuration. Prior to the late 1940's, this was done primarily with sand molds, using an oil type binder. This older method is presently supplemented largely by shell molding techniques, using a resin binder.

The binders of very simple sand cores, or shell molds or cores, is cured by baking articles with heat in a large controlled oven. However, when the mold or core configuration is complex, especially when it has portions of differing thickness, uniform curing becomes a major problem and cannot be obtained with an oven. In fact, for most complex core work today, complicated and extremely expensive core making boxes are first carefully made, each with an intricate system of manifolds and a plurality of gas burners, to try to obtain proper heat distribution through the core box to the core material for uniform baking. Since these cores assume a variety of configurations, and must be made to exact tolerances, each metal box is an intricate work of metal forming and finishing, carefully done by highly paid craftsmen from expensive materials that will conduct heat and yet resist breakdown under heat. This all causes a very great expense, as is well-known.

Frequently, the burner arrangement for core boxes must be re-vamped on repeated trial and error methods after initial formation of the core box, to obtain the exact amount of heat necessary for each thin, thick and intermediate section of varying configuration. Very often, initial burner arrangements have to be changed by moving individual burners, adding certain burners, plugging burner mounting holes, and so forth.

Differences in the bulk of various sections of the core itself create problems of heat transmission through the section. Ideally, for completely uniform curing, the heat in the center of the section should be the same as that at the outer surface where the heat is applied. This is never really the situation of course, due to the fact that the heat is transmitted indirecly through the core box itself, and then through the core from its exterior to its interior.

Even when these factors have been taken into consideration and the core box is specially engineered and re-vamped to suit a particular core, subsequent erosion, warpage, and corrosion of the box occurs constantly along the carefully formed surfaces and on the precise drawing and guiding mechanisms, due to the high temperatures to which they are exposed. This, of course, seriously affects the quality of the products.

Further, vent systems and blow systems operate at a low efficiency under these high heat conditions, sometimes even making it necessary to install complicated local coolant arrangements at various points in the heating core box.

Also, with the use of these core boxes, installation of the equipment requires expensive custom designing of

the core blowing machine itself for each different installation.

During the use of hot core box equipment, the excessive heat loss occurring into the foundry, coupled with the resulting smoke and fumes, create a definite working condition problem. Further, loss of heat due to shift changes, mechanical failure, etc. requires considerable down time to reheat the core box equipment whenever this occurs.

Briefly, therefore, these hot core box techniques, while reasonable serving the purpose to form intricately shaped cores, present tremendous expenses and problems in their manufacturing and use, and still provide a core that could be substantially improved since it is not really uniformly cured throughout.

The shell molding process has another substantial disadvantage—the requirement of heavy backing material, such as sand or shot, to support the shell elements in their face-to-face contact. Shell molds are made with uniform thickness to enable quite uniform curing of the shells in an oven. In this respect, the problems encountered with curing the different thickness sections of a core are not normally found to a considerable extent in shell molds, because of their uniform thickness. However, the uniform thickness of the shell does require this resulting support disadvantage causing bulky, large assemblies for each pair of shells. The shot or sand material must be removed after each molding and subsequently replaced against the next set of shells. This is time consuming, space consuming and hence, adds a substantial cost to the system.

With these factors in mind, it is an object of this invention to provide a novel core and mold composition, and a novel method of curing mold and/or core materials to actually enable the complete elimination of expensive, elaborate hot core boxes and all of the associated equipment. The vast expense involved with the intricate forming of the accurate metal surfaces, providing the complex manifolds, and installing the large number of specially placed burners, as well as the resulting corrosion, warpage and handling problems, are all made completely unnecessary. The resultant savings in time, labor, and costs and the resulting advancement in efficiency of operations, space, personnel time is tremendous. The capacity for forming and uniformly curing exceedingly delicate and/or complex cores, molds, and the like is increased manifold.

Another object of this invention is to provide a novel method of curing cores, molds and other like articles, whereby materials such as non-heat conductive materials including plastic or wood can even be used for the mold forming patterns, rather than specially machined heat conductive metal. Inexpensive plastic or wood patterns can be quickly formed, even on a mass production basis, to enable dependable core and/or mold making with complete and exact accuracy.

It is another object of this invention to provide a core and mold composition, and a method of curing cores and molds that uniquely applies the exact amount of heat necessary for each section of each portion of the article, whether it is thick or thin, whether it is curved, flat or of other configurations. Moreover, it applies heat in direct proportion to the mass of that portion, so that all parts are heated completely uniformly, even the center of thick portions. The result is a completely uniform curing of the article binder. No portions are over cured or under cured.

Another object of this invention is to provide a novel composition and method for forming articles such as cores or molds, where heat is not applied externally, but rather is created immediately at all exact internal zones of application, and in exact proportion to the mass in-

volved, with each unit mass being able to receive the same heat, whether it is deep in a thick article portion or adjacent the surface. This achieves completely optimum curing in the core and/or mold. Moreover, complete curing is achieved in an extremely short time interval of about one to five seconds, i.e., about one-tenth to one-twentieth of that previously required.

Another object of this invention is to provide a novel composition and method whereby shell molds can be formed with a structure configurated so that a series of mold sections will stack together face-to-face and back-to-back, without any reinforcing backing material. The invention enables them to be made of varying thicknesses so that they will still have a specially configurated, accurately formed face surface for cooperation with a like face surface to form the mold cavity, and with a flat back surface for abutment with the like flat back surface of an adjacent mold section, yet with capacity for completely uniform curing throughout.

It is a further object of this invention to provide a method of curing a binder material in a form of refractory particles, to form an article of selected configuration whether the article is of the foundry type such as molds and cores, or some other item such as ceramic articles of clay base materials for use as the final article, or for use as a ceramic mold, or otherwise.

These and several other objects of this invention will become apparent upon studying the following detailed description.

This invention is especially useful for making cores and molds for foundry use. Indeed, this is the main area for which the invention was conceived and tested. Particularly, it has unique application to resin binder type cores and molds, often termed in the trade as part of the "shell molding process," because of the shape of the typical shell mold sections which were originally formed by this method. The invention is also applicable in its broader aspects to other molding techniques such as ceramic molding, and sand molding using an oil binder. It is furthermore applicable to other types of articles and foundry type molds and cores, e.g., ceramic articles, or other articles formed of bonded refractory particles from a loose particulate condition to a final integrated state. Since, however, its main use is intended for molds and cores, it will be chiefly described with respect thereto.

When forming molds and cores, a refractory particulate material, i.e., one resistant to break down under heat, is interbonded from an initial particulate condition to a final, desired configuration, in a self-sustaining, integral article. The typical refractory materials used include acid types such as silica and fire clay, basic types such as magnesite and dolomite and neutral types such as chromite and graphite.

When making resin bonded type cores and molds, a heat curable resin is employed. A great many of such resins are known today. The most popular are formaldehyde resins including phenolic, melamine, urea, cresol, and thiourea formaldehyde resins. Typical of these are the phenol formaldehyde resins taught for example in United States Patents Nos. 2,706,163, 2,718,681, 2,706,188, 2,683,296 and 3,140,518. As is well-known to those in the art, the basic components of these comprise the suitable resin such as phenol formaldehyde, often a few additives such as cryolite and also often kerosene or core oil as dampeners and cereal as a supplemental core binder. Several other ingredients may be added further, as is known in the trade, to obtain particular characteristics. These form no special part of my invention.

A typical thermosetting resin used in the trade is known as "10–4576 Acme Resin Bond Sand" sold by the Acme Resin Company of Chicago, Illinois. Often the material is slightly varied in composition if it is used as a phenolic core binder, or is used as a shell binder, since cores are of differing thicknesses whereas conventional shell molds are of substantially uniform thickness. Another typical shell resin is General Electric's S–1073 and a typical core binder is General Electric's 12353. A typical curing agent used with the resin is hexamethylene tetramine.

Of course, the basic shell molding techniques were taught in the field information agency technical bulletin of the United States Department of Commerce Fiat Final Report No. 1168 of May 1947. The amount of binder often varies, usually within ½–12% by weight of the refractory.

Typical of the sand and drying oil mixtures used is a silica sand mixed with a linseed oil, as is well-known to those in the foundry field. The amount of linseed oil will vary depending upon the thickness of the mold and core, the use to which it is to be put, the type of metal to be cast, the type of sand, the type of characteristics desired in the core, and other factors as is well-known. Various additional additives can be mixed with the molding sand to achieve desired characteristics. Since all of these factors are well-known in the foundry field, and since detailed examples of all of these materials would require extensive disclosure in a needless manner, further descriptive material is not given.

The inventive concept involves one particular aspect of the composition formed from the refractory materials and a heat curable binder. Other materials may or may not be employed, it does not matter. In this respect, the term "heat curable" includes, in its broadest aspects, the typical setting of a core caused by "drying" of a linseed oil type binder, as well as the chemical "curing" of a synthetic resin binder. It is also intended, in its very broadest aspects, to encompass the direct fusion of ceramic type materials together due to interbinding of the particulate materials.

The invention was discovered in efforts for a solution to the core box difficulties, and in efforts to really obtain uniform curing. The inventor conceived of a new method employing a special additive to the refractory material to achieve just that. Experimentation proved the inventive concept to be completely sound.

The novel composition is achieved by mixing thoroughly throughout the refractory material which is to be bonded into an integral article, normally by the presence of a binding agent, a magnetically responsive material, i.e., a paramagnetic material in a finely divided state. Typical of magnetically responsive materials are the transition metals of iron, nickel, cobalt, manganese, alloys thereof, certain compounds thereof, and mixtures thereof. An iron powder for example is an excellent example. This powder need not be of any particular particle size, but the larger the particles, the more heat generated thereby.

In experiments, it was found that even iron and steel dust removed from a conventional machine shop grinder, for example, a Blanchard surface grinder, worked completely effectively. The novel composition is formed by mixing, preferably uniformly, throughout the particulate refractory material, a small percentage of the magnetically responsive material. The paramagnetic powder must be in a sufficient amount to achieve a relatively rapid heat generation throughout the mixture when it is exposed to a high frequency magnetic field. It was found that the percentage of magnetically responsive substance is not real critical. It may be present anywhere from about one percent up to twelve or more percent, depending upon the reaction time and amount of heat desired. A typical core sample formed of a silica sand mixed with six percent phenol formaldehyde bonding resin, and six percent iron powder, mixed uniformly throughout, cures in the magnetic field in approximately three seconds. Increasing the iron powder to about twelve percent lessens the time of curing below about two seconds. Percentages smaller than six percent lengthen the amount of time required for curing. There must be a sufficient amount to generate more heat than is dissipated by the material, to increase the temperature to an amount necessary to cure the particular binder employed. Most binders can

be cured with a small percentage of magnetically responsive powder mixed throughout the sand, by consuming more time.

When exposing a six to twelve percent magnetically responsive mixture in a magnetic field, the reaction occurs so rapidly that if the mixture is inserted after the field is actuated, and at the rate of a few inches per second, the reaction can be visually observed by the color change, as curing occurs. It is extremely rapid compared to conventional methods, i.e. about one-tenth to one-twentieth of that normally required.

Preferably, it is best to apply the magnetic field simultaneously to the entire article to be cured, by first placing the mixture in the area and then activating the magnetic field for a limited time interval. This achieves constant time application for all portions. The particular high frequency of the magnetic field can be varied widely from about 800 cycles from the generator type machine up into radio frequencies of about 450 kilocycles, depending upon the application. A typical magnetic field machine is a Reeves Induction Machine which normally operates from about 50 to 450 kilocycles. As is well-known, these induction machines are not limited to particular helical coil structures, but rather the primary induction element can be formed, for example, of a copper tube formed into the necessary configuration to induce a high frequency, secondary magnetic field in the sand. A flat pancake type structure can be formed or even other configurations, to cooperate with the particular core, mold or other article to be cured. Of course, efficiency is lower if the typical helical coil is departed from, but the modified configurations are still effective.

By utilizing this method, the coil can be brought to the work rather than requiring the work to be brought to a heating source. Therefore, the activating magnetic field can be exerted in a variety of systems while allowing maximizing of system layout efficiency. This makes the curing process a conveniently adaptable step in a manufacturing system, rather than a complex separate operation requiring vast amounts of specialized equipment and time loss.

It was found with testing that the retainer for the particulate substance for curing need not even be a heat conductive metal at all, as of course was previously necessary. In fact, even when a sheet paper pattern retaining the particulate refractory material with magnetically responsive powder mixed throughout, was inserted in a high frequency magnetic field for a few seconds to cure the material, no harmful action occurred on the paper except for very slight increase of its temperature. The pattern and substance could be held by a person's hand directly in the field while curing occurred, without discomfort. In fact, this was the way in which the very slight temperature rise was detected. Therefore, the initial pattern for the cores, molds and other articles need not be formed by expensive procedures, out of heat conductive metals which are difficult to pattern, but rather can be formed out of any support material such as plastic, wood, laminates of various types, etc. Consequently, cores, molds, etc. can be baked and cured in a variety of ways, using a selected retainer of cardboard, paperboard, plastic, wood, etc. The pattern can be rapidly carved out of wood, for example, on small production set ups. It can be massed produced from plastic materials by molding or pressure forming techniques. Consequently, this invention opens up a whole new area of forming procedures because it eliminates the present necessity of expensive core boxes, and enables the substitution of inexpensively and rapidly produceable patterns.

The amount of heat generated in the article is directly proportional to the mass of that section. Every unit mass of the core receives the same amount of internal heat generated at that particular local, to cause all parts to be locally heated the same amount, with no heating conducted from the surface inwardly. Further, when the paramagnetic material is uniformly distributed, the heat generated is in direct proportion to the mass so that thick sections having internal portions do not become underbaked and under-cured while surface portions become over-baked and over-cured, as frequently occurs with conventional techniques.

Because of these factors, shell molds can be made of varying thickness, and will still achieve completely uniform curing. Therefore, the back surface of a shell mold can be made flat, for example, while the front face is configurated accurately with the specific molding cavity pattern desired. Then, by stacking or placing the half shell molds into face-to-face and back-to-back relationship, an entire series can be placed together. Then, merely by supporting the ends of the series as by clamps, to keep them together, the backing material of sand or shot customarily used is no longer necessary for each pair of shell mold sections.

The magnetically responsive material can be readily incorporated into a sand mixture by adding it during mulling, when the uncured phenolic resin binder is added. Since both are added as powders, they readily mix throughout the mass in uniform quantities, as has been determined by experimentation.

In fact, it was determined that the iron powder and phenolic resin powder tend to mix so well with each other to coat each other, that the small iron particles cause local heating directly on the phenolic resin particles to optimize curing action instantaneously over the entire mixture. In other words, the only substance that needs heating, the binder, is heated since the paramagnetic powder clings to it. Therefore, it is not really necessary to heat the surrounding refractory particles very high at all, but just enough to be cohesive with the binder resin as it liquifies. It is no longer necessary to conduct heat through the particulate refractory material—a difficult task at best. The heat is created and concentrated exactly where it is needed. The result is a uniform coating of the sand particles with the resin and powder to produce the optimum integral article. The resulting mold, core, or other article exhibits no disadvantages from the added materials, but can be of better quality.

It will be realized that, if desired, the heat generated in each portion of an article can be controllably varied rather than the entire article being completely uniformly heated as is usually desired with core and mold making. This variation is achieved simply by mixing a greater amount of magnetically responsive material in certain portions where more heat is to be generated. The heat generated in the magnetic field is greater in these portions, in proportion to the amount of paramagnetic substance present. If it is desired to obtain a glazed surface on a ceramic article, for example, by greater heating of the surface portions than the interior portions, but still is desired to heat all interior portions uniformly, the surface is provided with a greater amount of magnetically responsive powder. The greater heat production at the surface causes increased temperatures and glazing during the same curing time as the rest of the article requires for uniform curing.

A few illustrative specific examples of the method in composition are as follows:

Example 1

A silica core sand containing 6% by weight phenol formaldehyde binder is mixed uniformly with 6% by weight iron powder. The mixture is placed in a formed paper pattern and inserted by hand into a high frequency 450-kilocycle magnetic field of a Reeves Induction Machine. The field is activated for approximately 3 seconds. The article is thereby cured, and is removed. It is slightly warm to the touch during curing. Very little vapor occurs. The article exhibits excellent strength, and when broken, shows completely uniform curing throughout.

Example 2

A silica sand containing 3% by weight linseed oil is mixed with 5% by weight iron powder, packed into a wood pattern, and placed in a high frequency magnetic field of 200 kilocycles for 5 seconds to cure the binder.

Example 3

A fire clay particulate refractory material is mixed with 10% by weight melamine formaldehyde and 10% by weight iron powder, placed in a plastic pattern, and exposed to a high frequency magnetic field at 100 kilocycles for 2 seconds.

Countless other examples could be recited, but would only unduly lengthen this specification. The variations will be apparent to those in the art upon studying the descriptive material presented. The invention is intended, therefore, to be limited only by the appended claims and the reasonable equivalents thereto.

I claim:

1. A method of forming an integral article from a refractory particulate material, comprising the steps of: mixing uniformly throughout the particulate refractory material a small percentage of binder and a small percentage of magnetically responsive material; forming the resultant mixture into a desired configuration; and subjecting the mixture to a high frequency magnetic field to heat and cure the binder.

2. A method of making cores and molds, comprising the steps of: providing a mixture of particulate refractory material having therein a heat responsive binding agent capable of binding said particulate material into an integral article when heated; dispersing through said material a small amount of a finely divided paramagnetic powder; forming the resulting mixture into a desired configuration; and applying to the resultant mixture for several seconds a high frequency magnetic field, creating heat uniformly throughout said material in said binding agent in proportion to the mass of the mixture, to uniformly cure said binding agent.

3. A method of forming a shell type mold assembly, comprising the steps of: providing a refractory particulate material having throughout a small percentage of heat curable resin binder and a small percentage of magnetically responsive material; forming the resultant mixture into a mold section having a flat back face and a configurated front face; subjecting said mold section to a high frequency magnetic field for a few seconds, thereby creating uniform internal heat and curing the binder; and placing a plurality of the cured mold sections into mutually supporting face-to-face and back-to-back relationship to form a plurality of mold cavities.

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