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METHOD FOR FORMING A METAL CASTING MOLD

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This invention relates to improvements in alkali metal silicate-containing mold-forming compositions adapted to be cured or hardened by impregnation with carbon dioxide or other gaseous curing agent.

This is a continuation-in-part of Ser. No. 568,442—Ilenda et al., filed February 29, 1956, now U.S. Patent No. 2,905,563.

In recent years there has been considerable interest in the preparation of molds and cores from sand-silicate mixtures which are cured or hardened in the desired casting-defining shapes by injections of carbon dioxide or other gaseous materials. Generally, the curing of molds embodying binders of this type involves a chemical reaction between carbon dioxide or other gaseous material and the alkali metal silicate dispersed throughout the sand or other refractory material to form a uniformly-dispersed silicon dioxide gel binder.

The advantages of such molds are many. Not only are aging and post-curing treatments eliminated, thus permitting rapid fabrication of molds without requiring the use of expensive equipment, but also close tolerance castings are obtainable and the process is relatively simple and can be carried out readily on a large scale.

However, despite the many advantages of such molds, it frequently has been found that certain difficulties are encountered with prior silicate-containing mold-forming compositions of this type, especially in the casting of high temperature melting metals, such as cast iron and steels melting at temperatures of 2500° F. or higher.

At high casting temperatures, prior silicate-containing mold-forming compositions generally have been characterized by excessive evolution of steam and/or other gases during casting. While mold porosity certainly is essential, often when sufficient porosity is provided to permit escape of the large volume of gases generated using prior mold-forming compositions in high temperature casting of cast iron and steels, such molds have not achieved the widespread application they might otherwise enjoy.

Accordingly, it is the principal object of the present invention to avoid the difficulties heretofore encountered and to provide a new and improved method of forming metal casting molds.

A further object of the invention is to provide new and improved methods for forming metal casting molds adapted to be cured by exposure to carbon dioxide or other gaseous materials.

A still further object of the invention is to provide new and improved methods of metal casting.

These and other objects and advantages of the invention will appear more fully from the following description thereof.

As used throughout the specification and claims, the term "mold" is intended in a generic sense to mean casting forms which include both molds and cores, this invention in no manner being limited to the former. Moreover, "mold" is intended to include various patterns for use in the casting art, as well as shell molds

including shell mold-forming elements in addition to the completed shell mold structure prepared by assembling two or more complementary thin-walled shell mold elements.

This invention is an improvement over the invention described and claimed in co-pending application Ser. No. 549,850, filed November 29, 1955, and Ser. No. 540,633, filed October 14, 1955. While the inventions there described provide greatly improved results over the prior art, it has now been found that in many instances even more advantageous results are obtained with the practice of the present invention, especially with respect to casting of high melting metals.

Accordingly, molds formed in accordance with the present invention are especially advantageously employed in the casting of metals melting at a high temperature, e.g., cast iron and/or various steels.

The present invention comprises a method for forming metal casting molds which comprises placing in contact with a casting-defining surface a composition comprising an intimate mixture of a major amount of a finely-divided refractory and a minor amount of a binder composition obtained by combining a liquid alkali metal silicate and a solid alkali metal silicate. Another embodiment of the invention contemplates such a process wherein the binder composition is that obtained by combining a liquid alkali metal silicate, a finely-divided solid, soluble, alkali metal silicate and an organic compound.

The foregoing compositions are particularly advantageous when employed as binders for sand or other finely-divided refractory materials employed in preparation of metal casting molds cured by exposure to carbon dioxide or other gaseous material. Hence, it will be appreciated that the practice of this invention preferably contemplates composition of matter comprising a major proportion of at least one finely-divided refractory material, preferably sand, and a minor proportion of a binder comprising the material obtained by combining a liquid alkali metal silicate and a finely-divided solid, soluble alkali metal silicate.

Another embodiment of the invention comprises a mixture of a major proportion of a finely-divided refractory material, preferably sand, and a minor proportion of a binder comprising the material obtained by combining a liquid alkali metal silicate, a finely-divided solid, soluble alkali metal silicate and an organic compound.

More specifically, the present invention contemplates the use in the preparation of gas-curable molds of a binder, a liquid alkali metal silicate, i.e., an aqueous solution of a silicate normally liquid at room temperature, having a silica to alkali metal oxide molar ratio greater than about 1.0:1.0, preferably within the range from about 1.5 to 3.3, i.e., an alkali metal oxide:silica ratio of from about 1.0:1.5 to 1.0:3.3, such as an $Na_2O:SiO_2$ ratio of 1.0:1.5 to 1.0:3.3. The liquid alkali metal silicate to be used in the practice of this invention generally may be any commercially available alkali metal silicate which is normally liquid at room temperature. Such silicates typically have a solids content of about 30% to 50% solids, preferably about 34% to 46%.

To the liquid silicate is added a solid, soluble, alkali metal silicate, i.e., a silicate normally solid at room temperature. The solid silicate generally may vary in alkali metal oxide to silica molar ratio from about 2.0:1.0 to 1.0:3.3, such as an $Na_2O:SiO_2$ ratio of about 2.0:1.0 to 1.0:3.3, soluble, solid sodium silicates having an $Na_2O:SiO_2$ molar ratio of about 1.0:1.0 being preferred, such as sodium metasilicate. As indicated above, silicates having silica:alkali metal oxide molar ratios greater

than about 1.0:1.0 are generally given in terms of weight ratios, while silica to alkali metal oxide ratios of silicates having a silica:alkali metal oxide molar ratio of 1.0:1.0 or less are generally given as molar ratios. In a preferred embodiment, soluble, solid sodium silicates are employed, notably anhydrous sodium metasilicate. The particle size of the soluble, solid alkali metal silicate generally can vary somewhat, the upper limit on particle size being dictated by the desired rate of solution. However, in most instances superior results are obtained using particles less than 60 U.S. mesh size, a preferred particle size range being from −60 to +200 U.S. mesh size.

While the proportions of components included in compositions of this invention may, of course, be varied somewhat, it generally is preferred to employ a major proportion of a finely-divided refractory material and a minor proportion of a silicate binder. In this connection, it generally is preferable to employ mixtures of finely-divided refractory materials and silicate binders of this invention wherein the refractory material comprises from about 90 to 97% by weight of the mold-forming composition as employed, a preferred range being from about 90 to 95% by weight, and the silicate binder constituting the balance. Considering the silicate-containing binder compositions per se, it has been found that superior results are achieved when the liquid alkali metal silicate comprises about 80 to 99% by weight of the total silicate-containing binder, the soluble, solid alkali metal silicate comprising about 1 to 20%, the maximum upper limit being dictated by its solubility.

In many instances, in order to improve the collapsibility of fired mold compositions and to improve bench life of mold-forming compositions, it is desirable to include in the mold-forming composition an organic compound which is burned out during the casting operation and thus to promote collapsibility of the fired mold. In the practice of this invention, organic compounds, preferably polyhydroxy organic compounds may be incorporated in minor amounts in the silicate-containing mold-forming composition. The expression "polyhydroxy organic compound" as used in the specification and claims is intended to include a variety of organic compounds containing more than one hydroxy grouping. While the especially preferred compounds are polyhydroxy in nature, it is intended to include various sugars such as glucose, fructose, sucrose, and various other mono- and disaccharides as well as certain tri- and tetrasaccharides, which compounds, of course, need not be in a highly purified state, excellent results having been obtained using relatively impure sugar, such, e.g., as tanner's sugar, blackstrap molasses, bagasse, as well as other low cost sugar products. In addition, another type of organic polyhydroxy compound suitable for use in the practice of this invention is a polyhydroxy alcohol such as glycerol, sorbitol, and other hydroxy alcohols. Presently preferred organic compounds are sorbitol, glycerine and sugars, notably sucrose.

In those applications where an organic compound is employed, it has been found that excellent results are obtained using a mixture containing about 60 to 95% by weight liquid alkali metal silicate, 1 to 20% by weight soluble, solid, alkali metal silicate and about 1 to 25% by weight organic compound, preferably a polyhydroxy organic compound. In ferrous metallurgy involving casting at temperatures of 2500° to 3000° F., it is preferred to employ a composition comprising about 90% by weight of a liquid sodium silicate having a silica to alkali metal oxide weight ratio within the range from about 2.0 to 3.3, preferably about 2.84, about 5% by weight anhydrous sodium metasilicate having a particle size within the range from 60 to 200 mesh, and about 5% by weight of sorbitol, glycerine, or a mixture thereof.

In the casting of non-ferrous materials at temperatures generally within the range from 1400° to 2000° F., a

presently preferred silicate binder composition comprises about 85% by weight of a liquid sodium silicate having a silica to alkali metal oxide weight ratio within the range from about 2.0 to 3.22, a 3.22 ratio material being preferred at the present, about 5% by weight anhydrous sodium metasilicate having a particle size within the range from −60 to +200 mesh and about 10% by weight of organic compounds, notably sucrose in the form of crude or refined cane or beet sugar.

When no organic compound is employed, silicate composition embodying the present invention generally comprise about 80 to 99% liquid alkali metal silicate and 1 to 20% soluble solid alkali metal silicate. Illustrative of a typical preferred formulation of this type for use in ferrous metallurgy, i.e., when casting metals melting at temperatures within the range from about 2500° to 3000° F. or higher is a composition comprising about 10% by weight of at least one soluble solid alkali metal silicate, notably anhydrous sodium metasilicate having a particle size between about −60 and +200 mesh, and about 90% by weight of at least one liquid sodium silicate having a silica to alkali metal oxide ratio within the range from about 2.0 to 3.3.

When lower casting temperatures are to be employed, e.g., in non-ferrous metallurgy such as the casting of bronze and aluminum at temperatures within the range from about 1400° to 2000° F., a preferred binder composition consists essentially of 5% by weight of at least one soluble solid alkali metal silicate, notably anhydrous sodium metasilicate having a particle size within the range from 60 to 200 mesh and about 95% of at least one liquid sodium silicate having a silica to alkali metal oxide ratio within the range from about 2.0 to 3.33.

The expression "alkali metal" as used throughout the specification and claims is intended to refer to the various alkali metals, i.e., sodium, potassium, rubidium, cesium and lithium, sodium generally being preferred.

While carbon dioxide or gases containing carbon dioxide comprise a presently preferred form of curing agent for refractory material-silicate binder mold-forming compositions of this invention, it is to be understood that other gaseous materials or mixtures of gases also may be employed. For example, sulphur dioxide, nitrous oxide, hydrogen chloride, and the like, also may be used. Moreover, in many instances, various combustion or stack gases containing proportions of carbon dioxide and the like also may be utilized advantageously. The length exposure to the curing gas required to effect the desired cure depends, of course, on a number of variables including mold mass porosity, gas employed, and the like. However, the time required typically is of the order of a few seconds, e.g., 5 to 10 to several minutes, e.g., 10 minutes.

While sand constitutes a preferred refractory material because of its widespread foundry usage, low cost and availability, other refractory materials may also be used advantageously such, e.g., as silica flour, and various other inorganic refractory materials.

The high solids content provided by the practice of this invention insures the presence of sufficient silica to provide an excellent inorganic binder, i.e., silica in the form of a gel uniformly dispersed throughout the mold, in order to provide and maintain the necessary mold strength during metal solidification in casting whereby mold erosion is minimized and excellent cast metal tolerances are achieved.

In order that those skilled in the art may more completely understand the present invention and the preferred methods by which the same may be carried into effect, the following specific examples are offered:

Example I

To illustrate the practice of the present invention, a silicate binder composition consisting of 90% by weight liquid sodium silicate ($1Na_2O:2.84SiO_2$) containing

43.1% solids, and 10% by weight finely-divided anhydrous sodium metasilicate (−60 to +200 mesh) is prepared by adding the solid silicate to the liquid silicate. Using the thus-prepared binder (solids content 48.8%) a sand-silicate mixture is prepared by admixing 95% by weight of 80 grain fineness sand, and 5% by weight silicate binder. This mixture is formed into 2 inch square cubes which are then impregnated with carbon dioxide for 10 seconds. The thus-treated cubes have an unfired or green strength of 277 p.s.i.

Example II

The procedure according to Example I is repeated using 90% by weight liquid sodium silicate ($1Na_2O:2.4SiO_2$) containing 46.6% solids, and 10% by weight powered anhydrous sodium metasilicate. The resultant silicate mixture has an $Na_2O:SiO_2$ ratio of 1:2.0 and a solids content of 51.94. Compressive strength of a two inch square cube of the thus-formed 95% sand-5% silicate composition after exposure to carbon dioxide for 10 seconds is 172 p.s.i. A similarly-proportioned sand-silicate mixture employing a silicate binder consisting of 100% liquid sodium silicate ($1Na_2O:2.0SiO_2$) containing 43.5% solids has a compressive strength of but 55 p.s.i.

Example III

Using the procedure of Example I, a 95% sand-5% silicate composition is prepared, the silicate comprising a mixture of 93% by weight liquid sodium silicate ($1Na_2O:3.22SiO_2$) containing 38.35% solids, and 7% by weight powdered anhydrous sodium metasilicate. The resulting silicate mixture ($1Na_2O:2.59SiO_2$) has a solids content of 42.65%. The compressive strength of a two inch square cube of such material after impregnation with carbon dioxide for 10 seconds is 177 p.s.i.

Example IV

The process of Example I is repeated using as a binder a composition obtained by mixing 95% by weight liquid sodium silicate ($1Na_2O:3.22SiO_2$) and 5% by weight powdered anhydrous sodium metasilicate, the resulting silicate mixture ($1Na_2O:2.75SiO_2$) having a solids content of 41.45%. The compressive strength of a two inch square cube formed of such a sand-silicate mixture after impregnation with carbon dioxide for 10 seconds is 167 p.s.i. A comparative test using as the silicate a liquid sodium silicate ($1Na_2O:3.3SiO_2$) having a solids content of 37.3% indicates a compressive strength of only 67 p.s.i.

Example V

Using the procedure of Example I, a sand-silicate composition is prepared containing 5% of a silicate binder which consists of 88.35% by weight liquid sodium silicate ($1Na_2O:3.22SiO_2$) containing 38.55% solids, 4.65% anhydrous sodium metasilicate, and 7.00% glycerine, the resultant silicate mixture having the ratio $1Na_2O:2.75SiO_2$. The compressive strength of such a sand-silicate mixture after impregnation with CO_2 for 10 seconds is 168 p.s.i.

Example VI

Using the procedure of Example I, a sand-silicate composition is prepared containing 5% of a silicate binder which consists of a mixture of 90% by weight liquid sodium silicate ($1Na_2O:2.4SiO_2$) containing 46.6% solids, 5% by weight anhydrous sodium metasilicate, and 5% by weight sucrose, the resultant silicate mixture having the ratio $Na_2O:2.03SiO_2$. The compressive strength of such a sand-silicate mixture after impregnation with CO_2 for 10 seconds is 372 p.s.i.

Example VII

The procedure of Example I is repeated using a 5% silicate binder comprising a mixture of 82% by weight liquid sodium silicate ($1Na_2O:3.22SiO_2$) containing 38.55 solids, 7% by weight anhydrous sodium metasilicate, 10% by weight sucrose, and 1% by weight paraffin oil, the resulting silicate mixture having the ratio

$$1Na_2O:2.52SiO_2$$

The compressive strength of such a sand-silicate mixture after impregnation with CO_2 for 10 seconds is 162 p.s.i.

Example VIII

The procedure of Example I is repeated using as the silicate binder 5% of a mixture consisting of 90% by weight liquid sodium silicate ($1Na_2O:2.84SiO_2$) containing 43.1% solids, 5% by weight anhydrous sodium metasilicate, and 5% by weight sucrose, the resultant silicate mixture having the ratio $1Na_2O:2.45SiO_2$. The compressive strength of such a sand-silicate composition after impregnation with CO_2 for 10 seconds is 333 p.s.i. A similar comparative test using 5% of a mixture of 95% liquid sodium silicate ($1Na_2O:2.4SiO_2$) and 5% sorbitol indicates a compressive strength of but 107 p.s.i.

Example IX

One ton of a sand-silicate binder composition embodying the invention is prepared by mixing 80 mesh sand with 5% by weight of silicate binder consisting of 90% liquid sodium silicate ($1Na_2O:2.84SiO_2$) and 10% by weight anhydrous sodium metasilicate.

The thus-prepared sand-silicate mixture is pressed against the face of a pattern with an air hammer to a thickness of 4 to 5 inches and backed with green sand. The thus-prepared material is impregnated with carbon dioxide for seven minutes. After the pattern is withdrawn, the casting-defining surface is brushed with a conventional alcohol-graphite wash. The mold is then assembled and cast. Following solidification, an excellent casting is obtained with substantially no penetration or veining noted.

The following silicate compositions illustrate use of solid silicates other than sodium metasilicate in compositions embodying the invention.

Example X

83% liquid sodium silicate ($1Na_2O:2.84SiO_2$)
17% powdered sodium disilicate ($1Na_2O:2SiO_2$) (17% H_2O)
Resultant mixture—$1Na_2O:2.56SiO_2$—total solids 49.0%

Example XI

95% liquid sodium silicate ($1Na_2O:2.4SiO_2$)
5% solid sodium silicate ($1Na_2O:3.22SiO_2$)
Resultant mixture—$1Na_2O:2.46SiO_2$—total solids 48.5%

Example XII

80% liquid sodium silicate ($1.0Na_2O:3.22SiO_2$)
5% anhydrous sodium metasilicate
12% sugar (sucrose)
3% sorbitol

Example XIII

To illustrate the surprising improvement in mold collapsibility provided by the practice of the invention a series of experiments are carried out wherein 5% by weight of sodium silicates having identical total solids content and $Na_2O:SiO_2$ ratios are employed as binders for 95% by weight refractory materials in the formation of 2" diameter x 2" high test cylinders which are cured with CO_2 and crushed and the breaking strength, which is indicative of the collapsibility, recorded. The test cylinders are prepared using a conventional cylinder mold after two minutes of mixing time. The resultant cylinders are impregnated with carbon dioxide for 10 seconds at 20 p.s.i.g. and in a Tinius-Olsen compression testing machine and pressure applied at the rate of 0.05 inch per minute. The silicate compositions employed

as binders and the results obtained are indexed comparatively in the following table:

Sample No.	Sodium Silicate		Total Solids (percent)	Silicate Treatment and/or Mixture	Compression Strength (p.s.i.)
	Percent by Wt.	SiO_2:Na_2O Ratio			
1	5	2.58	43.55	7% anhydrous sodium metasilicate. 93% Grade 42 [1]	280
2	5	2.58	43.55	97% Furnace Grade Sodium Silicate. 3% Water	165
3	5	2.58	43.55	100 Parts Grade 42 [1] 3 Parts Anhydrous NaOH evap. 7.5 Parts H_2O.	181

[1] Grade 42 sodium silicate is an aqueous silicate produced by Diamond Alkali Company having an SiO_2:Na_2O ratio of 3.22:1.0, and a total solids content of 38.8%.

It will be observed that in the above tests the silicate compositions all had an identical total solids content and Na_2O:SiO_2 ratios. However, it will be observed that the compression strengths differ radically in a manner which certainly would not be expected solely from a consideration of the solids content of the silicates. Thus, silicate composition No. 1, prepared by adding solid anhydrous metasilicate to a liquid silicate to increase the total solids content, produces an extremely high initial mold compression strength which facilitates mold handling without damage to the mold prior to use. On the other hand, silicate composition No. 2, having an identical total solids content and Na_2O:SiO_2 ratio, but prepared by water dilution of a silicate initially having a solids content greater than 43.55%, and silicate composition No. 3 produced by adjusting the Na_2O:SiO_2 ratio by the addition of NaOH and adjusting the total solids content by evaporation of water, both yielded initial mold strengths singularly lower than those obtained with composition No. 1.

Example XIV

A further series of tests are conducted using the previously described test cylinder forming procedure but comparing two different silicate materials. The compositions used and the results of these tests are set forth in the following table:

Sample No.	Percent by Wt.	Sodium Silicate Total Solids (percent)	Silicate Composition	Compression Strength (p.s.i.)
A	5	34.3	50 Parts Furnace Grade Silicate-Na_2O:SiO_2=2.6. 20 Parts Sugar	227
B	5	34.3	75% Grade 42 Silicate [1] 5% Anhydrous Metasilicate. 19% Cane Sugar 1% Water	286
C	5	34.3	Commercial Silicate Binder "X".	205

[1] 42.5 Bé.° 3.22SiO_2:1.00Na_2O.

From the above data it will be observed that two sodium silicate-containing materials having identical solids content and containing identical additives, notably, 20% sugar, and having identical SiO_2:Na_2O ratios, yield compression strength values which are radically different, a much higher strength being produced using a silicate in which the total solids content has been adjusted by adding a solid sodium silicate thereto. It will further be observed that both of the just referred to values are greater than a commercially available silicate binder "X" having the same total solids content.

Example XV

A further series of tests are run using the foregoing procedure wherein Ottawa sand containing 3½% by weight of a silicate binder is employed. In these tests, a commercially available silicate binder "Y" having an SiO_2:Na_2O ratio of 2.0:1.0 and containing 39.1±0.3% by weight total solids, is compared with a silicate composition of this invention containing the same total solids content and SiO_2:Na_2O ratio, the latter material being prepared by adding a solid sodium silicate to a commercially available silicate to adjust the total solids content to 39.1±0.3%. The results of the tests, including surface hardness values, are as follows:

Sample No.	Total Solids, percent	Silicate	Surface Hardness [1]			Compression Strength p.s.i.
			Initial	15 min.	30 min.	
1	39.1±0.3	Commercial Mtl. "Y".	38	38	41	159
2	39.1±0.3	79% Grade 42 Silicate [2]. 6% Anhyd. Metasilicate. 15% Sugar	65	67	67	458

[1] Surface Hardness determined by Gordon-Campbell Core Hardness Tester, Model 3635, Patent No. 2,720,754.
[2] 42.5Bé.° 3.22SiO_2:1.0Na_2O.

From the above data it will be observed that the practice of the present invention produces a more than threefold increase in unfired mold strength over a commercial binder of identical solids content. Moreover, there is obtained a singular increase in mold surface hardness by the practice of the invention.

It is to be understood that although the invention has been described with specific reference to particular embodiments thereof, it is not to be so limited, since changes and alterations therein may be made which are within the full intended scope of this invention as defined by the appended claims.

What is claimed is:

1. The method of forming a casting mold which comprises placing in contact with a casting-defining surface a composition comprising an intimate mixture of a major proportion of about 90 to 97% by weight of a finely-divided refractory material and a minor proportion of about 3 to 10% by weight of a liquid binder composition comprising in combination about 80 to 99% by weight of an aqueous alkali metal silicate having a solids content of about 30 to 50% and about 1 to 20% by weight of a finely-divided water soluble, solid alkali metal silicate having an alkali metal oxide:silica ratio within the range of 2.0:1.0 to 1.0:3.3, inclusive, and subjecting the mix-

ture to contact with a gaseous material capable of rigidifying the mold-forming mixture.

2. The method according to claim 1 wherein the alkali metal is sodium.

3. The method according to claim 2 wherein the gaseous material is carbon dioxide.

4. The method according to claim 2 wherein the gaseous material is a carbon dioxide-containing gas.

5. The method according to claim 1 wherein the liquid alkali metal silicate is a sodium silicate and the solid alkali metal silicate is sodium metasilicate of a particle size within the range from about —60 to +200 mesh.

6. The method according to claim 1 wherein the refractory material is sand.

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