

*Additive Table I*

April 28, 1959

W. H. MOORE ET AL

2,883,723

PROCESS FOR IMPROVED SILICATE BONDED FOUNDRY MOLDS AND CORES

Filed Nov. 20, 1956

2 Sheets-Sheet 1

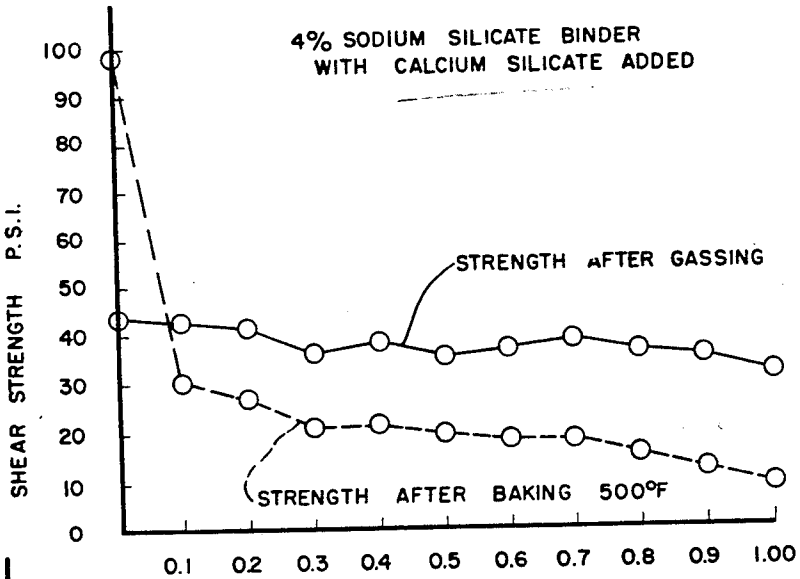


Fig. 1

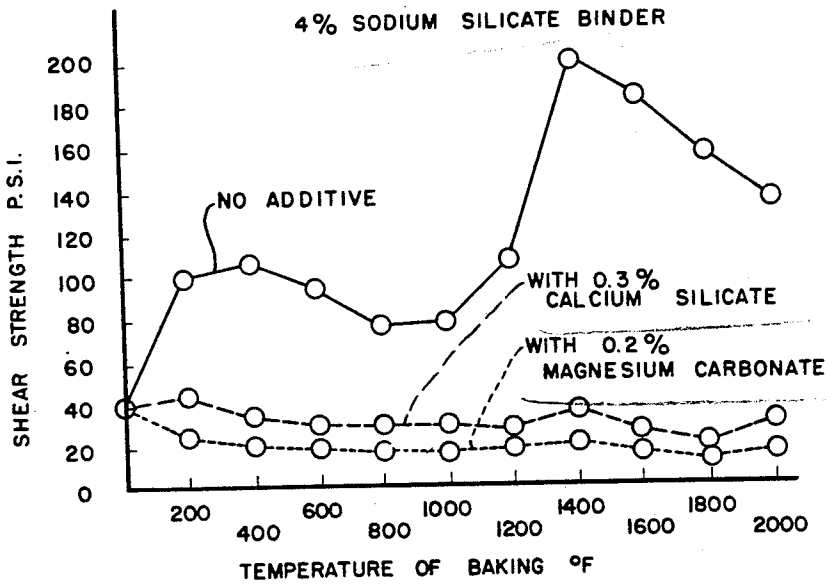


Fig. 2

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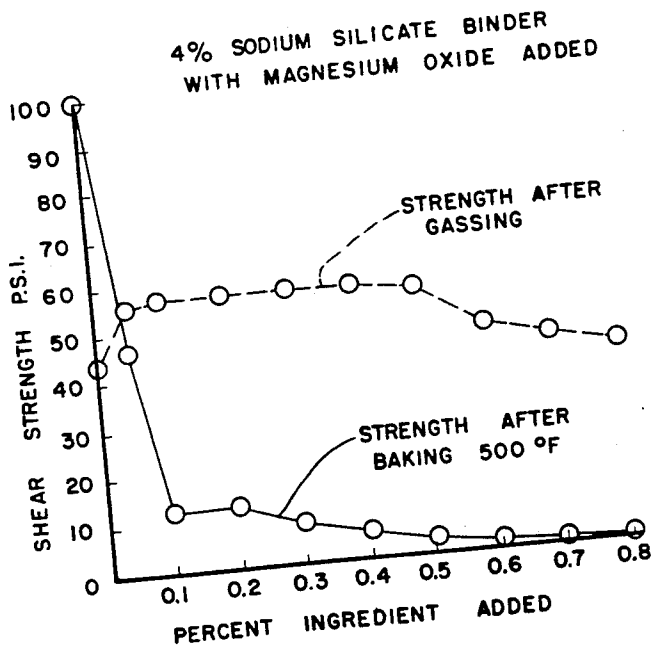


Fig. 3

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*Na + K Silicate Binders + CO<sub>2</sub> ⇒ Silica Gel  
Molds hardened by CO<sub>2</sub>*

# United States Patent Office

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## PROCESS FOR IMPROVED SILICATE BONDED FOUNDRY MOLDS AND CORES

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6 Claims. (Cl. 22—193)

This invention relates generally to foundry molds and cores and more particularly, to molds and cores bonded with silicate binders such as sodium and potassium silicates.

An object of this invention, is to improve the collapsibility of shakeout qualities of cores and molds made from foundry sands containing silicate binders and hardened wholly or partially by carbon dioxide gas.

Another object is to provide a means of eliminating the need for baking or heating of silicate bonded molds and cores after hardening with carbon dioxide, in order to obtain maximum strength qualities.

Another object is to reduce the possibility of casting strains resulting from casting metals in molds and cores bonded with silicate bonded cores.

Other objects of this invention will become apparent to those skilled in the art on reading the specification in which:

Figure No. 1 is a graph having shear strength in p.s.i. as a vertical ordinate and percentage of ingredients added as the horizontal ordinate and in which the strength after gassing with carbon dioxide is compared with the strength after gassing and then baking at 500° F. In Figure No. 1 the binder used was 4 percent sodium silicate and the additive was calcium silicate.

Figure No. 2 is a graph having shear strength as the vertical ordinate and the temperature of baking in degrees Fahrenheit as the horizontal ordinate and in which a comparison is made between the strength of a 4 percent sodium silicate bonded sand heated to various temperatures and another similar sand to which has been added .3 percent calcium silicate heated to the same temperatures and a third sand to which has been added .2 percent magnesium carbonate and heated to the same temperatures.

Figure No. 3 is a graph having shear strength in p.s.i. as a vertical ordinate and percentage of ingredient added as the horizontal ordinate and in which the strength after gassing with carbon dioxide is compared with the strength after gassing and then baking at 500° F. In Figure No. 3 the binder used was 4 percent sodium silicate and the additive used was magnesium oxide.

The foundry art of using silicate binders has developed very extensively during the past few years. Sodium silicate, in particular, has found widespread use as a binder for molds and cores and its use for this purpose has enlarged rapidly, due to the process of partially hardening the sodium silicate by chemical means such as the use of carbon dioxide gas.

Certain silicates can act as binders for foundry sands, because of their ability to precipitate a skeleton of silica around the sand grains. This silica is usually in the form of a silica gel. Carbon dioxide in particular, when brought into contact with sodium silicate mixed with sand grains, will immediately cause the precipitation of silica gel, which will bond the grains together. This process has become known as the carbon dioxide process for molds and cores.

The carbon dioxide process has offered many advantages to the foundry industry and has provided relatively inex-

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pensive molds and cores which are used either with or without further hardening, by baking at a temperature in excess of that required to dehydrate sodium silicate.

In the use of this carbon dioxide process, a serious drawback has been encountered, due to the inability of a silicate bonded core to collapse or disintegrate after the metal poured in contact with it has solidified. This has limited the application of the process and has led to such difficulties as cracked or strained castings. The inability to collapse has also very seriously increased the problem of removing the core or mold from the casting during the cleaning operation.

The inability of a silicate bonded core or mold to collapse is due, firstly, to the very refractory nature of the bond, because it is non-carbonaceous and does not disintegrate under normal heating conditions, and secondly, that heating up to a certain point causes an actual increase in bonding power. This is because hardening by precipitation of silica gel is usually incomplete and subsequent heating during casting causes dehydration of the remaining binder and a very sharp increase in the amount of silica available for bonding.

The problem of shakeout has always been a serious one and has led to the use of a variety of materials, usually carbonaceous in nature, which are added to a silicate bonded sand mixture, in order to subsequently augment the rate of collapse under heat. Examples of materials used for this purpose are pitch, sugar, sawdust, oil and coal dust. These materials are only partially effective and when used in too great a quantity, actually lower the original hardness of the mold and core, to the extent that it becomes useless for the purpose intended. These additives also detrimentally affect the workability of the silicate bonded sand mix.

We have discovered that relatively small quantities of special ingredients may be added to foundry sands bonded with silicate and hardened by precipitation of silica gel. These ingredients considerably reduce the bond produced on heating during the casting operation, without in any way reducing the workability of the foundry sand, or the ability of this sand to initially harden into a useable mold or core. The use of these special ingredients has modified the properties of silicate bonded foundry molds and cores, particularly with regard to shakeout propensity in such degree, as to considerably extend their use in the manufacture of all types of castings.

The use of these ingredients also has enabled maximum bond strength to be obtained from sands containing sodium silicate as a binder, without the use of heat. This production of maximum bond strength in the cold condition, prevents subsequent increases in strength or rigidity of the mold or core during the casting operation, thereby reducing the danger of cracked and strained castings.

We have found that the compounds of the alkaline earths and earths occurring in groups II and III of the periodic table, are particularly effective as additive ingredients in the process of our invention.

To illustrate the workings of these additive materials in improving shakeout properties, it is necessary to consider what happens to a foundry core or mold when it becomes heated.

In the case of a sand core which is contacted by molten metal, only a small portion of the core which is actually contacted by the molten metal is heated up to a temperature equal to that of the molten metal. The interior of the core, which is at a distance from the molten metal, is only heated slightly, or in some cases, not at all. As is to be expected, the exact extent to which a core is heated, depends on its relative mass, compared to that of the molten metal. Thus, a massive core contacted by a small quantity of metal, may not become heated at all in its interior, whereas a small core, surrounded by

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a large mass of metal, may become heated throughout to a very high temperature.

As cores contain binders which normally decompose on heating, it is difficult to gauge the extent of decomposition that occurs, because of the number of variables involved. Usually the extent of decomposition of the binder is referred to by the all-embracing term "collapsability" or "shakeout ability."

For a binder to have good shakeout properties, it should weaken at any temperature to which it is subjected above its normal baking temperature. Thus, regardless of the amount of heat the cores receive, it will always be weaker after heating. If it is subjected to a lot of heat, it will become very weak and will shakeout very readily, whereas, if it is only slightly heated, it will shakeout with a little more difficulty.

In the case of silicate bonded cores, particularly those bonded with sodium silicate and hardened with carbon dioxide gas in the cold condition, any subsequent heating, as in baking, usually causes a severe increase in strength. This means that such a core when slightly heated, becomes stronger and is, therefore, extremely difficult to shakeout. By decreasing the amount of silicate used and then baking the core in an oven to develop maximum strength, it is possible to slightly improve shakeout behavior, because during casting, further heating will not result in an increase in the core strength. This, however, detracts from the major advantage of such cores, because silicate bonded cores are normally hardened by chemical means, eliminating the necessity for subsequent oven baking.

In the process of our invention we add special ingredients to the sand mixture which allows the attainment of normal strength by chemically hardening, but prevents any substantial increase in strength by temperature effect. Our preferred additives actually decrease the strength of the sand molds or cores when they are subjected to even a very small amount of heat such as when they are heated to 200° F. This prevents the major cause of the shakeout difficulty common to silicate bonded molds and cores.

The action of our special ingredients may be observed very readily by utilizing laboratory test cores which have been bonded with sodium silicate and hardened with carbon dioxide.

A series of sand mixes were made. To each mix was added 4 per cent by weight of sodium silicate having a specific gravity of 52° Baumé. Varying quantities of calcium silicate powder were also added to the mixes.

Cores were rammed from each mixture and were gassed with carbon dioxide. Some of these cores were tested for shear strength in the gassed condition and others were baked at 500° F. prior to testing.

The results of these tests are illustrated graphically in Figure No. 1. It may be seen from Figure No. 1 that the strength after gassing and baking at 500° F. is approximately 100 p.s.i.

When as little as .1 percent of calcium silicate is added, this strength drops to a value of 30 p.s.i. after both gassing and baking. Further additions of calcium silicate drop the gassed and baked strength to a still lower value. In all cases where the sand mixture contains .1 percent or more of calcium silicate, the strength after baking is considerably lower than the strength before baking.

In a second example, a similar series of cores were prepared by gassing test samples made from a sand mix containing 4 percent sodium silicate and .3 percent calcium silicate. These cores were then baked at temperatures ranging from 200° F. to 2000° F. and on cooling were tested for shear strength. Another series of test samples were made from the same sand mix containing a .2 percent addition of magnesium carbonate, instead of a .3 percent addition of calcium silicate.

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In Figure 2 the upper graph represents the shear strength of the sample made with sodium silicate and not containing any of the additive of this invention. It will be seen that the strength after heating increases in all temperature ranges to a value considerably higher than the initial strength obtained on gassing, which was 40 p.s.i.

On the otherhand, the middle curve shows the strength obtained in the sand which contained a .3 percent calcium silicate addition and which was heated to the same temperatures. In this case the shear strength at all temperatures is considerably lower than that obtained where no additive was present.

In the lower curve, it may also be seen that the strength obtained with a .2 percent addition of magnesium carbonate is always considerably lower than that obtained when no additive was used.

In a third example, a series of cores were prepared using mixtures containing 4 percent sodium silicate and varying percentages of magnesium oxide (calcined magnesia).

Some cores were tested directly after gassing, whereas, others were gassed and then baked at 500° F. before treat. In Figure 3 the upper curve shows the strength after gassing, whereas the lower curve shows the strength after gassing and then baking.

It should be observed, that the addition of magnesium oxide in amounts up to .5 percent results in an increase in gassed strength and a severe drop in baked strength. Additions of magnesium oxide in excess of .5 percent result in very little change in gassed strength, but cause a remarkable drop in the strength after heating. This illustrates the improved collapsability caused by a magnesium oxide addition.

In a fourth example, a series of test cores were made using 4 percent sodium silicate as a binder, and adding to the sand mixture a number of different materials as additives. Each test core was gassed with carbon dioxide for hardening and was then baked at 500° F. Shear strength tests were conducted on the gassed cores and on the baked cores. The results obtained are tabulated hereinafter in Table No. 1.

Some of the cores were tested for shear strength and some others were baked at 500° F. and then tested for shear strength.

In Table No. 1 it should be noted that an addition of .2 percent by weight of additive was used. More or less additive would have been more or less effective. The table is shown only to illustrate the general effect involved and it by no means includes all the materials that are useful in the process of our invention.

The ratio of gassed to baked strength may be taken as an indication of shakeout ability. Thus, with no additive this ratio is 1:2.7. Any ratio less than this represents an improved shakeout ability, but for superior shakeout ability the ratio should be less than 1:1.5 or preferably less than 1:1. In some cases, where the ratio increases over that of 1:2, it may be considered that the additive is actually detrimental to shakeout ability.

Certain additives are effective in promoting a low baked strength and, therefore, a good shakeout ability, but they also promote a low gassed or initial strength and are, therefore, not useful. According to Table No. 1, lithium carbonate, calcium chloride and talc are examples of materials that promote poor gassed strengths.

In the process of our invention we prefer to use the oxygen compounds of the elements listed in groups II and III of the periodic table, more specifically, the oxygen compounds of the alkaline earths and the earths in these groups. We find to a lesser extent, that some of the oxygen compounds of the elements of group IV of the periodic table tend to help shakeout properties, but they are inferior to our preferred ingredients.

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**TABLE NO 1**

*Effect of 2% additions of various additives on cores bonded with 4% sodium silicate*

Additive	Gassed Shear Strength	Baked Shear Strength	Ratio, Gassed: Baked
No Additive.....	44.0	120.0	1:2.7
Lithium Carbonate.....	24.7	67.8	1:2.7
Silicon Dioxide.....	51.9	130.0	1:2.5
Iron Oxide.....	50.0	125.0	1:2.5
Manganese Oxide.....	50.9	125.0	1:2.5
Chromic Oxide.....	47.0	116.0	1:2.4
Cuprous Oxide.....	48.2	115.0	1:2.4
Calcium Fluoride.....	51.5	113.0	1:2.2
Calcium Chloride.....	11.0	18.8	1:1.7
Lead Oxide.....	48.8	78.3	1:1.6
Barium Sulfate.....	45.2	69.5	1:1.5
Barium Carbonate.....	46.9	66.7	1:1.4
Barium Oxide.....	50.2	67.3	1:1.4
Calcium Oxide.....	37.2	48.7	1:1.3
Zinc Oxide.....	54.8	67.0	1:1.2
Calcium Carbonate.....	53.5	63.0	1:1.2
Talc.....	29.9	33.8	1:1.1
Calcium Sulfate.....	42.5	41.8	1:1
Aluminum Oxide.....	55.9	49.0	1:0.9
Boric Oxide.....	47.5	35.0	1:0.7
Calcium Silicate.....	44.0	32.0	1:0.7
Magnesium Carbonate.....	43.2	13.5	1:0.3
Magnesium Oxide.....	58.6	13.4	1:0.2

Oxygen compounds are those which contain oxygen in their molecular structure. Examples of these are oxides, silicates, nitrates, carbonates and sulfates.

The elements which comprise groups II and III of the periodic table are as follows:

<i>Group II</i>	<i>Group III</i>
Beryllium	Boron
Magnesium	<del>Aluminum</del>
Calcium	Scandium
Zinc	Gallium
Strontium	Yttrium
Cadmium	Indium
Barium	Lanthanide rare earths
Mercury	Thallium
Radium	Actinium

Compounds within this classification that react with water at normal temperatures and have a positive heat of solution must complete their reaction with water before addition to sodium silicate, or they may not be effective. An example is calcium oxide, which has a heat of solution of plus 18.33 kilogram calories.

When a test core was made by adding .2 percent by weight of calcium oxide to a sodium silicate bonded sand and then gassing with CO<sub>2</sub> followed by baking at 500° F., we obtained a gassed strength to baked strength ratio of approximately 1 to 2.9.

When we allowed the calcium oxide to react with water and cool before adding it to the sodium silicated bonded sand, we obtained a gassed to baked strength ratio of 1:1.3 under the same test conditions.

By allowing any heat of solution to dissipate in this manner, we are able to usefully employ all the oxygen compounds of all the elements in groups II and III of the periodic table in the process of our invention.

The reason for the efficacy of the ingredients of our invention is not readily apparent. We believe that the oxygen containing compounds of the elements of group II and III of the periodic table act in the direction of causing a more complete precipitation of silica gel during the gassing operation when carbon dioxide is passed through a sand bonded with sodium silicate. This may be due to a mechanism of ion exchange. On subsequent heating of a sand which contains our additive and which has been gassed with carbon dioxide, the silica gel which has precipitated during the gassing operation becomes dehydrated and brittle in nature. This causes a loss in strength and the improved properties of the sand of our invention. When the silicate bonded sand does not contain our additive, precipitation of silica gel on the

passage of carbon dioxide gas is usually incomplete, with the result that unreacted sodium silicate may harden during heating by a process of evaporation. Such hardening adds to, or completely negates any weakening due to dehydration of silica gel. The net result is that such a sand actually increases in strength during heating after gassing.

We have successfully used the process of our invention on a commercial scale and, in general, we prefer to use the oxides and carbonates of magnesium, calcium and aluminum, because these offer commercial advantages over some of the other workable additive ingredients of our invention.

In a typical example, on a working scale, a core was made for a casting using 3 percent of sodium silicate, as a binder, without any other additives. This core was hardened with carbon dioxide prior to placing it in the mold. After the casting had been poured and allowed to cool, the core was removed by poking with rods. This operation took five hours.

A second casting was made using a core to which had been added 5 percent of sodium silicate and .2 percent of magnesium oxide, and where the core had been gassed with carbon dioxide before placing it in the mold. When the core was removed from the second casting, the operation was accomplished in only 25 minutes.

This illustrates the improved shakeout properties we are able to obtain in the process of our invention.

In another example of the working of our invention on a practical scale, molten metal for a large casting weighing 3200 pounds was poured into a mold made from a sand containing 3 percent of powdered sodium silicate and 2 percent of water. This mold was hardened with carbon dioxide gas prior to the casting operation. When the casting was removed from the mold after it had cooled to approximately room temperature, it was found that it was cracked and had to be rejected.

A second casting was made in a mold which was made from a sand containing 3 percent of powdered sodium silicate and 2 percent of water and to which had also been added .5 percent of powdered calcium silicate. This mold was hardened by passing carbon dioxide prior to casting. When this casting was removed from the mold, it was found to be completely free from cracks.

In still another example a casting was made using a core containing 2 percent of potassium silicate as a binder. The core was hardened with carbon dioxide prior to the casting operation. This casting was badly strained during solidification. A second casting was made using a core containing .3 percent powdered calcium carbonate along with the potassium silicate binder. The core was hardened with carbon dioxide prior to the casting operation. This second casting was completely free of strains.

We have found that our additives may be added directly to the sand mix when it is being prepared. This method has the advantage that the amount and type of additive may be adjusted to suit the end use of the particular sand mix being used.

We have also found that we may incorporate and mix our additives with the silicate binder, whether it be a liquid silicate or whether it is in the powder form. This method has the advantage of modifying the behavior of the binder so that it will always give good shakeout properties without requiring a special addition as the time of preparing the sand mix. In the present invention, the phrase "foundry shape" is utilized and includes molds and cores.

Although the invention has been described in its preferred form with a certain degree of partiality, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes may be made by those skilled in the art, without departing from the spirit and the scope of the invention as hereinafter claimed.

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## What is claimed is:

1. The process of making a casting in foundry molds consisting of selecting a sand mixture containing a binder selected from the group consisting of sodium and potassium silicate and to which has been added from 0.1 to 1.0 percent magnesium oxide, preparing said mold from said mixture, hardening said mold by the application of externally produced carbon dioxide gas, and casting molten metal into said mold, said magnesium oxide acting to improve the collapsibility of said mold.

2. The process of making a casting in foundry molds consisting of selecting a sand mixture containing a binder selected from the group consisting of sodium and potassium silicate and to which has been added from 0.1 to 1.0 percent magnesium carbonate, preparing said mold from said mixture, hardening said mold by the application of externally produced carbon dioxide gas, and casting molten metal into said mold, said magnesium carbonate acting to improve the collapsibility of said mold.

3. The process of making a casting in foundry molds consisting of selecting a sand mixture containing a binder selected from the group consisting of sodium and potassium silicate and to which has been added from 0.1 to 1.0 percent calcium silicate, preparing said mold from said mixture, hardening said mold by the application of externally produced carbon dioxide gas, and casting molten metal into said mold, said calcium silicate acting to improve the collapsibility of said mold.

4. The process of making a casting in foundry molds consisting of selecting a sand mixture containing a binder selected from the group consisting of sodium and potassium silicate and to which has been added from 0.1 to 1.0 percent boric oxide, preparing said mold from said mixture, hardening said mold by the application of externally produced carbon dioxide gas, and casting molten metal into said mold, said boric oxide acting to improve the collapsibility of said mold.

5. The process of making a casting in foundry molds consisting of selecting a sand mixture containing a binder selected from the group consisting of sodium and potas-

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sium silicate and to which has been added from 0.1 to 1.0 percent aluminum oxide, preparing said mold from said mixture, hardening said mold by the application of externally produced carbon dioxide gas, and casting molten metal into said mold, said aluminum oxide acting to improve the collapsibility of said mold.

6. The process of making a casting in foundry molds consisting of selecting a sand mixture containing a binder selected from the group consisting of sodium and potassium silicate and to which has been added from 0.1 to 1.0 percent of an additive selected from the group consisting of magnesium oxide, magnesium carbonate, calcium silicate, boric oxide and aluminum oxide, preparing said mold from said mixture, hardening said mold by the application of externally produced carbon dioxide gas, and casting molten metal into said mold, said additive producing a strength value in said mold which is lower after casting said molten metal than after hardening but before casting.

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