106/84

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Boston et al.

[11] 3,920,460

[45] Nov. 18, 1975

[54] **PROCESS FOR PRODUCING A BONDED PARTICULATE MATERIAL**

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[21] Appl. No.: **430,148**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 361,009, May 16, 1973, abandoned, which is a continuation-in-part of Ser. No. 191,910, Oct. 22, 1971, abandoned.

[52] **U.S. Cl.** **106/38.3;** 106/38.35; 106/74; 106/84

[51] **Int. Cl.** **B28b 7/34**

[58] **Field of Search** 106/38.35, 38.3, 74, 84

[56] **References Cited**

UNITED STATES PATENTS

3,255,024 6/1966 Alexander et al. 106/38.35

3,642,503 2/1972 Beaney 106/38.35

Primary Examiner—Lorenzo B. Hayes

Attorney, Agent, or Firm—Carothers and Carothers

[57] **ABSTRACT**

A process for binding particulate material such as sand in foundry operation wherein the binder consists of an aqueous alkali metal silicate. The particulate material and binder are mixed together with a catalytic agent consisting in combination of (a) diacetin and (b) triacetin and (c) ethylene glycol diacetate. This three-part catalytic agent, when applied under certain controlled conditions, has been found to lower initial indentation hardness of the bonded particulate material to be shaped and molded while providing for a longer "plastic" stage without increasing the desired set time which can be accurately predetermined.

5 Claims, 5 Drawing Figures

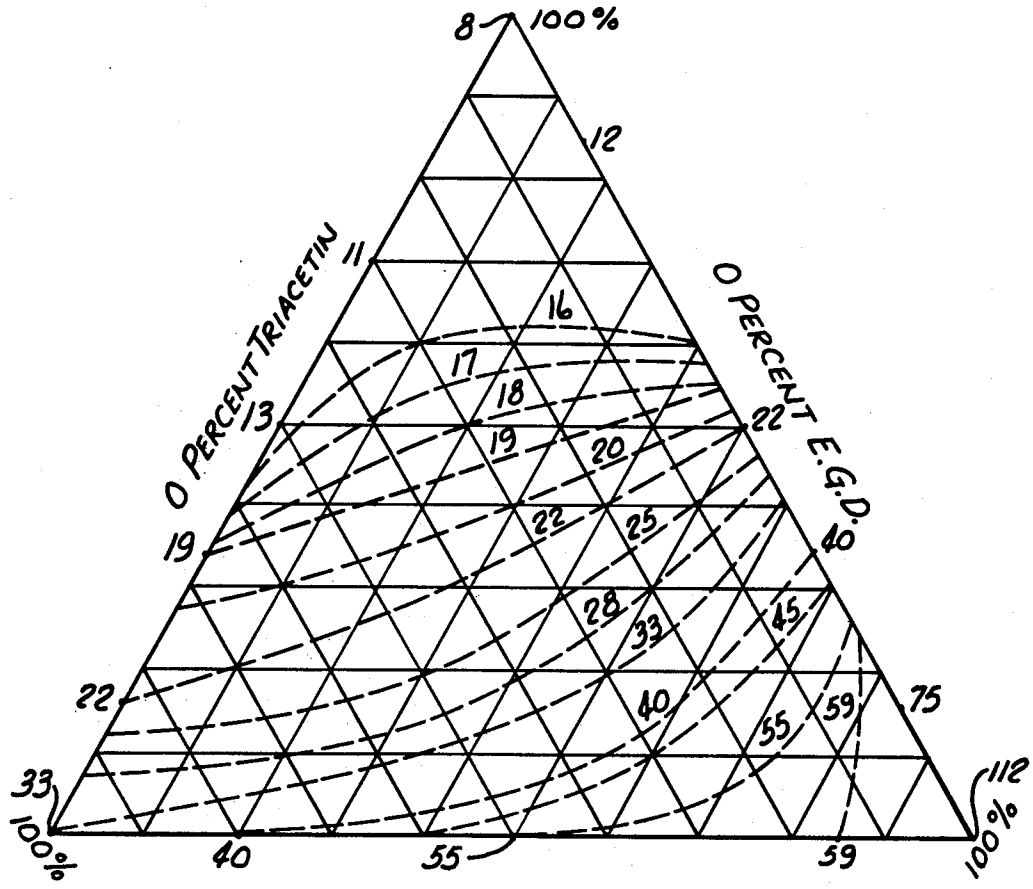


Fig. 1

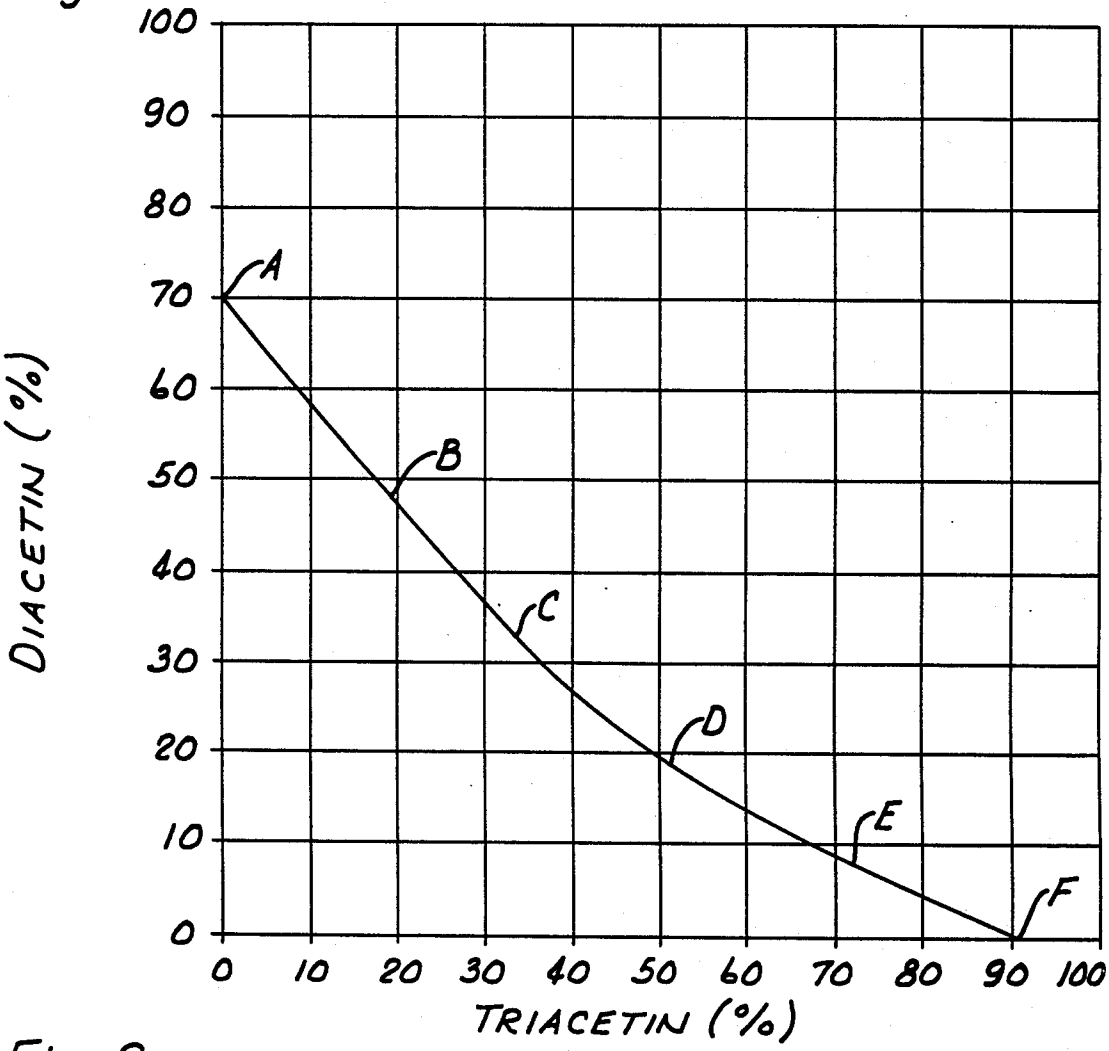


Fig. 2

POINT / SAND TEMP.	A	B	C	D	E	F
40°F	45	55	70	90	100	115
50°F	30	40	55	75	85	100
60°F	25	35	50	70	80	95
70°F	20	30	45	60	75	90
80°F	10	20	30	50	60	80
90°F	3	8	20	30	35	60

Fig. 3

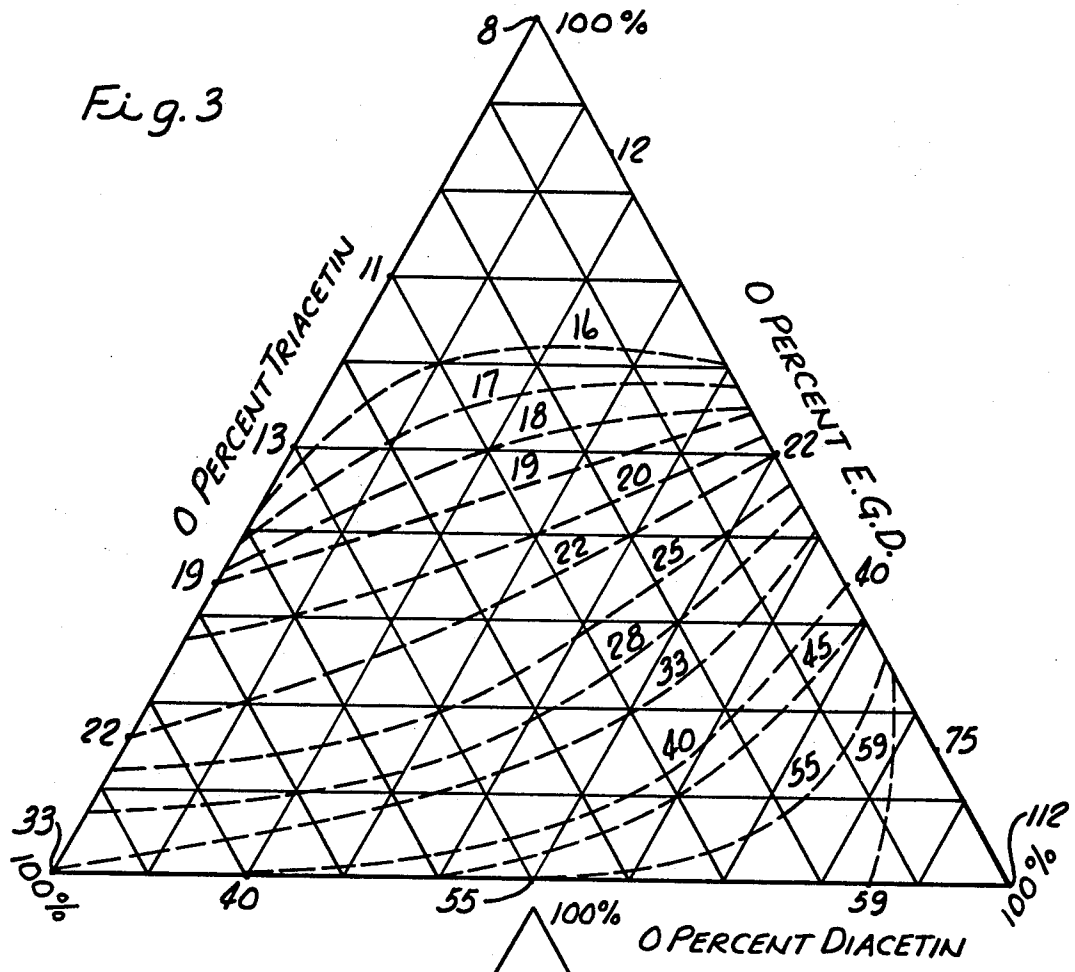

8
100%
12
11
16
17
18
19
20
22
25
28
33
40
45
55
59
75
112
13
19
22
33
40
55
59
100%
100%
100%
0 PERCENT TRIACETIN
0 PERCENT E.G.D.
0 PERCENT DIACETIN

Fig. 4

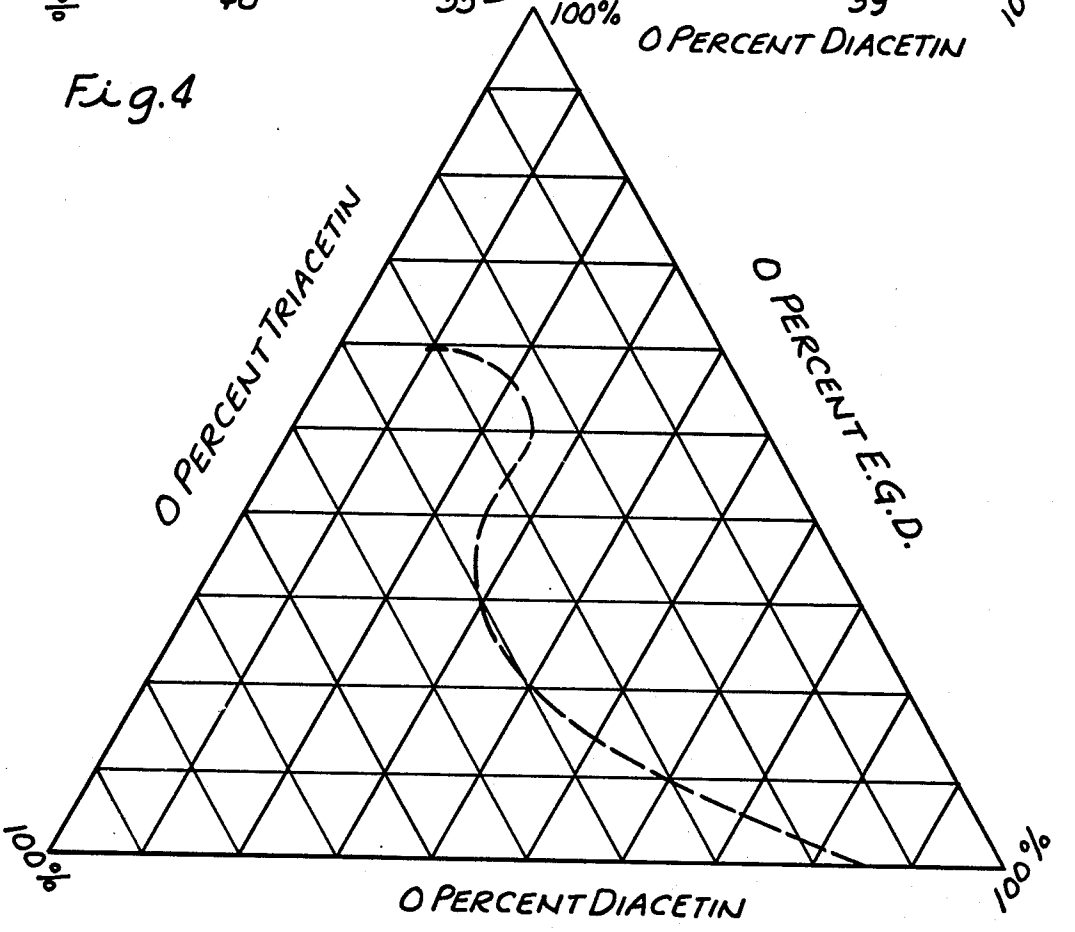
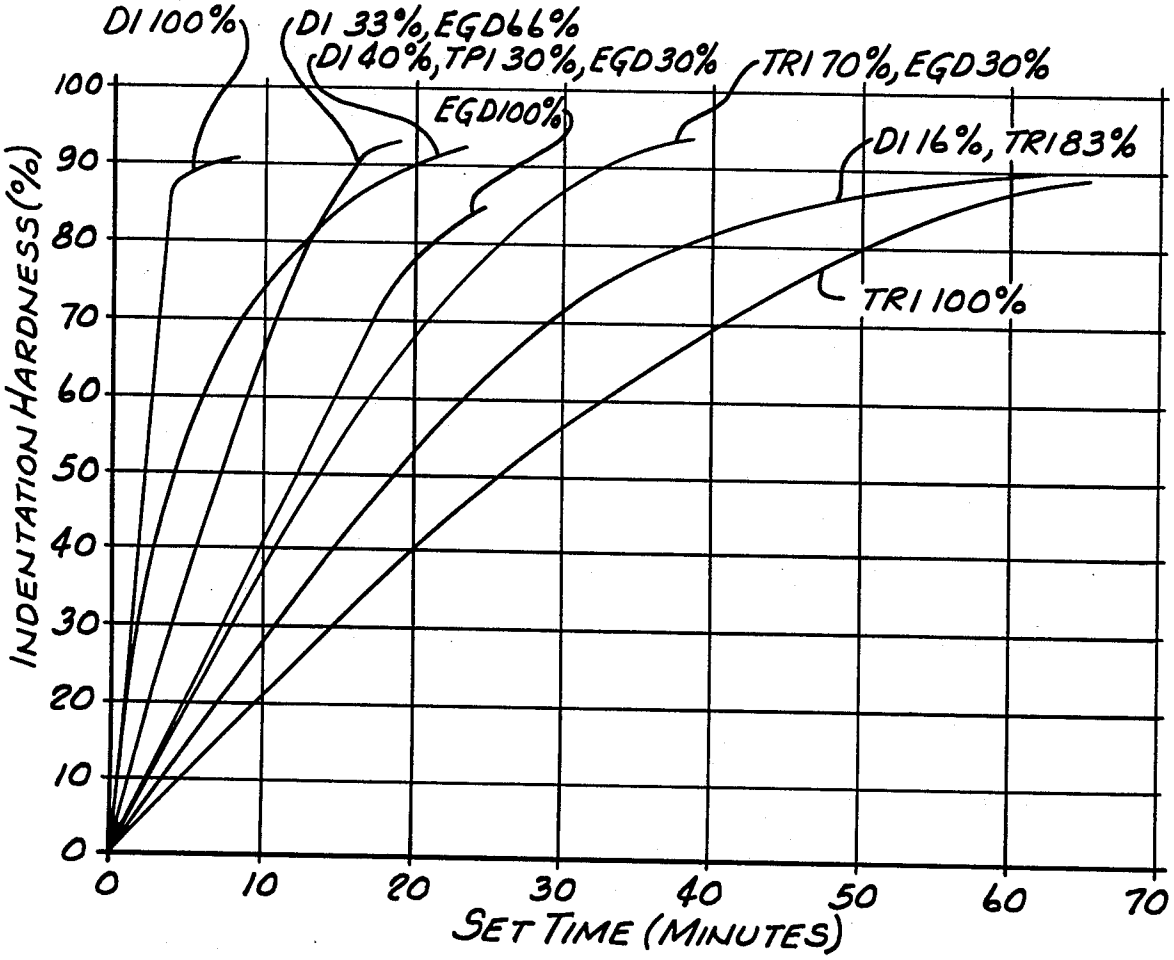

100%
100%
100%
0 PERCENT TRIACETIN
0 PERCENT E.G.D.
0 PERCENT DIACETIN

Fig.5


DI 100%
DI 33%, EGD 66%
DI 40%, TPI 30%, EGD 30%
EGD 100%
TRI 70%, EGD 30%
DI 16%, TRI 83%
TRI 100%
INDENTATION HARDNESS (%)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
SET TIME (MINUTES)

PROCESS FOR PRODUCING A BONDED PARTICULATE MATERIAL

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of our patent application Ser. No. 361,009 filed May 16, 1973 entitled Process for Producing a Bonded Particulate Material, which is a continuation-in-part of Ser. No. 191,910 filed Oct. 22, 1971, entitled Self-Setting Silicate Binder, both now abandoned.

BACKGROUND OF INVENTION

This invention relates generally to the employment of binders used in foundry operations for binding together particulate material such as sand in forming a mold and more particularly to the employment of an aqueous solution of an alkali metal silicate, sometimes referred to as no-bake binders or air setting binders, together with a three-part catalytic agent.

The employment of alkali metal silicate as a bonding agent for particulate material is well known as exemplified by U.S. Pat. No. 2,492,790. Also, the employment of weak esters with such silicates as a hardening agent in not new. U.S. Pat. No. 2,492,790 makes reference to diacetin or a mixture of diacetin and monoacetin. U.S. Pat. No. 3,149,985 makes reference to a silicate solution mixed with either diacetin or triacetin and formamide as a hardening agent. By far, the most pertinent prior art patent is U.S. Pat. No. 3,642,503, wherein there is set forth in strict detail the combination of an alkali metal silicate with a hardening agent consisting especially of a mixture of monoacetin or diacetin in combination with either triacetin or ethylene glycol diacetate.

Thus, the art is clear as to the employment of so-called no-bake binders wherein a polyalcohol ester is provided to act as a hardening agent for an alkali metal silicate such as sodium silicate. However, the application of these different weak or polyalcohol esters in combination with existing environmental conditions, such as ambient temperature and humidity conditions and particulate material temperatures, has made it very difficult, if not next to impossible, to use these hardening agents in a predictable set time manner with the silicate solution in foundry operations. As explained in U.S. Pat. No. 3,642,503, diacetin is quite unstable by itself and has a very short "shelf-life." The use of this weak ester as a hardening agent when ambient temperature conditions are like those in the middle of the summer season would not be possible on a practical basis. The particulate material would be bound together in lumps before a mold could even be formed and shaped. On the other hand, the use of triacetin alone would not be possible, particularly when ambient temperature conditions are like those in the middle of the winter season, as the particulate material as molded would not harden for such a long period of time that foundry production would be materially hampered.

U.S. Pat. No. 3,642,503 teaches the employment of a mixture, for example, of either diacetin and triacetin or diacetin and ethylene glycol diacetate (hereinafter referred to as EGD). In order to provide these mixtures in large quantities to foundry operations, it has been necessary to provide a series of mixtures in separate containers so that, in general, foundrymen can select the best mixture for their foundry operation, depending upon ambient temperature conditions for the particular

day. Each different mixture will be provided with different proportions of diacetin to triacetin, for example, so that on a relatively hot day, one would want to provide a hardening agent mix that in ratio by weight has more triacetin than diacetin. In this way, foundrymen can be sure that sufficient time is provided for proper mold preparation as well as removal of the pattern without damage to the shaped mold.

The problem arises, however, that ambient temperature conditions can quickly change, and moreover, no one is sure of the temperature of the particulate material, which together have a material effect on the overall set time of the bonded particulate material. More importantly, the foundryman does not know precisely what the full length of the set time may be because of these varying conditions.

As experienced foundrymen, we have found it extremely difficult to employ mixtures of diacetin and triacetin or diacetin and EGD, particularly as supplied in the market on a commercial basis because of changing atmospheric conditions, particularly the temperature of the particulate material and the outside environmental temperature.

Experimentation of these two types of mixtures by us has revealed clearly that the more of either triacetin or EGD by weight added to diacetin, a proportionately longer set time is obtained from the point of original mixing of the particulate material, alkali metal silicate and the hardening agent mix. By the same token, the more diacetin by weight added to either triacetin or EGD, a proportionately shorter set time is obtained. Thus, diacetin being used as a fast set material and triacetin, and more particularly EGD, being used as a slower set material, one can, by trial and error, provide for a desired mixture of these two-part catalysts depending on existing foundry environmental conditions. The proportionate uses of these materials in the two catalytic mixtures is purely additive.

The foregoing discussion further brings out the problem foundrymen have in employing these mixtures. It is very difficult from a practical application point of view to determine the desired proportions of the catalytic agents in the mixes to precisely match prevailing foundry environmental conditions, particularly where there is wide fluctuation in ambient temperature like that in the springtime, for example. The resultant effect in attempting to use various proportional mixes of these catalytic materials on a continuous trial and error basis to obtain a desired set time for particular molding operations is reduction of foundry production due to an inconsistent rate in producing acceptable molds and down time required in changing from one proportional mix of catalytic agents to another.

Through a series of studies, we have found a reliable method for controlling set time regardless of ambient environmental conditions with a three-part catalytic mix which has been found to be unexpectedly improved over that of the prior art, particularly U.S. Pat. No. 3,642,503, in precisely controlling the set time regardless of ambient environmental conditions.

SUMMARY OF THE INVENTION

The principle object of this invention is the provision of a three-part catalytic agent consisting in combination of diacetin, triacetin and ethylene glycol diacetate (EGD) to be employed as a hardening agent with an aqueous solution of an alkali metal silicate and particulate material wherein a less critical amount of catalytic

agent by weight need be employed to obtain a very precise control over the set time in combination with obtaining uniform hardness under varying conditions of sand temperature and ambient air temperatures.

Another object of this invention is the provision of a three-part catalytic agent consisting in combination of diacetin, triacetin and EGD to be employed as a hardening agent with a mixture of an alkali metal silicate and particulate material wherein the set time, that is the time it takes the bonded particulate material to achieve a hardness of at least 90% of its final value, can be precisely controlled even to the minute, while lowering initial indentation hardness thereby providing for a longer plasticity stage, that is, a large time span within a given set time wherein the particulate material as mixed with the silicate binder and catalytic agent will not immediately harden, but will provide sufficient plasticity to accomplish the given molding operation and pattern removal within the predeterminable set time.

We have found that by providing EGD in combination with diacetin and triacetin, particularly in ratios of 20% to 40% by weight, that EGD has a stabilizing effect on the overall catalytic mixture so as to create a longer plasticity stage during the predeterminable set time, without appreciably increasing or otherwise affecting the set time and without any loss in the final hardness strength of the molded particulate material.

In comparison with set time of the previously mentioned two-part catalytic agents, the optimum set times for the three-part catalytic agent of this invention is 16 to 59 minutes. On the other hand, usable set times for mixtures of diacetin and EGD provide only for a range of 19 to 22 minutes. Mixtures of triacetin and EGD provide only for usable set times between 40 and 50 minutes. Mixtures of diacetin and triacetin provide a very broad range of 8 to 112 minutes, but, as previously indicated, the change in set times is too rapid as to continuously produce on a practical basis uniform mold conditions as well as provide a sufficiently long plasticity stage to permit withdrawal of the pattern at predetermined and desired time. With the addition of EGD to this latter mixture, we have found that optimum conditions can be obtained that will produce uniform and continuously reproducible set times being very slightly affected, if at all, by working or environmental conditions. EGD in the three-part catalytic agent has a stabilizing and control effect and is not purely additive.

The three-part catalytic agent of diacetin, triacetin and EGD contributes to producing different desired physical properties over the catalytic agents and specific combinations of the prior art. Of all three components, diacetin produces the fastest set time, but causes a weakening effect in final mold hardness and has a weakening effect in high concentrations in the three-part mixture. Triacetin has the longest set time of all three components and retains its bonding capability at high concentrations in the three-part mixture. The addition of EGD acts as a stabilizer, as it, in effect, increases the set time for diacetin and decreases the set time for triacetin. This stabilizing effect allows for a larger degree of freedom in working conditions resulting in a uniform and reproducible set time of 16 to 59 minutes with uniform quality of molds to prevent friable molds, sags and other mold defects.

Another important object of this invention is the provision for heating the particulate material or foundry sand to a predetermined temperature level so as to be better able to precisely determine the set time of the particular mix involved. By providing for the heating of the foundry sand per se, the ambient temperature effects during the mixing and molding operations are actually negligible. Furthermore, since the bonding agent itself has to be heated to a higher temperature, such as 80°F, or at least 72°F, to possess sufficient viscosity to be easily mixed with and worked into the foundry sand, the heating of the foundry sand per se eliminates the potential problem of reducing the viscosity of the bonding agent and catalytic solution mixture during its mixing with the foundry sand. Furthermore, the heated sand will not, in the end, affect the desired predetermined set times as compared to the situation where the foundry sand is not heated. In the latter case, the lower the sand temperature, the longer the resultant set time, since the sand, being the bulk of the mix, will reduce the temperature level of the silicate solution and catalytic agent mix. Thus, it can be seen that a multitude of problems occur in attempting to produce a standard set time and uniform mold conditions. By selecting, for example, the temperature of the foundry sand with the three-part catalytic agent being maintained at a sufficient viscosity state for mixing purposes, we have found that the set time can be precisely determined down to the minute by selectively varying the percentage by weight of triacetin to diacetin dependent upon the foundry sand temperature while selecting the percentage by weight of EGD in the catalytic agent to control the rate of hardening of the molded and bonded foundry sand, which affects the quality of the mold produced.

Another object of this invention is the process of producing bonded particulate materials in foundry operation wherein mold set time to the 90% level of indentation hardness for a particular molding operation can be controlled to the shortest set time possible, while at the same time providing a longer plasticity stage to permit efficient and proper molding of the particulate material and subsequent pattern removal from the mold.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages appear in the following description and claims.

The accompanying drawings show, for the purpose of exemplification without limiting the scope of invention or the claims thereto, certain practical embodiments illustrating the principles of this invention wherein:

FIG. 1 is a graphic illustration of the proportional relationship of diacetin to triacetin with the balance being EGD.

FIG. 2 is a time table showing set times in minutes by depicting points A through F on the graph of FIG. 1 versus various particulate material temperatures shown as "Sand temp." to illustrate what proportions by percentage weight of diacetin and triacetin is selected to obtain a desired set time depending on the sand temperature.

FIG. 3 is a triangular coordinate graph showing the proportional relationship of the three-part catalytic agent comprising this invention and the resultant set times.

FIG. 4 is a triangular coordinate graph showing the maximum deflection curve for optimum uniform set time results based on information from the graph of FIG. 3.

FIG. 5 is a graphic illustration of indentation hardness versus set time for various combinations of diace-

tin, triacetin and EGD employed in two-part catalytic agents including the three-part catalytic agent of this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference is now made to FIGS. **1** and **2**, wherein there is shown data in the form of proportional relationships by weight of diacetin, triacetin and the balance EGD. As previously indicated, the prior art shows the employment of these weak esters or latent acids as catalytic or hardening agents as mixed with the aqueous silicate solution. In all cases, the art teaches either the employment of either one of these esters or any two of them in combination. However, the art does not address itself to the real problem confronted by foundrymen which we have previously outlined. With these esters available to effect the length of the set time of the bonded particulate materials, how is one going to know and control set time without continual trial and error?

Variations in sand temperature and atmospheric temperature and humidity causes wide variations in reaction time and, thus, set time and compensation for these variations has been on a trial and error basis, obviously affecting foundry mold quality and production. The prior art silicate binder systems are especially sensitive to variations in temperature.

The basic problem encountered when using latent acid catalytic systems for silicate binders in forming foundry molds and cores as taught in the prior art has been the inability to predictably control set time of the mold or core due to variations in working conditions, in particular the ambient temperature. These bonding materials must be heated to a temperature of 70°F to be employed on a practical basis. At temperatures lower than this, the consistency of these materials is more like that of molasses.

We have discovered that the three-part catalytic agent consisting in combination of a mixture of diacetin, triacetin and EGD employed with the silicate binder provides for precise and predictable control of set time under varying working conditions upon proper variation of the proportions of the separate ingredients.

Broadly speaking, diacetin may be present in a percentage proportion in the three-part catalytic agent from 10% to 70% by weight, triacetin from 10% to 92% by weight and EGD from 20% to 40%. At a given constant ambient temperature, an increase in the percentage of triacetin will result in a lengthening of the set time of the binder.

The silicate binder most ordinarily used is sodium silicate (Gravity at 60°F, 47.0 Be ± 0.25, Viscosity at 77°F, 690 ± 65 cps. Ratio 2.88 ± 0.05). The molecular ratio SiO_2:Na_2O is the same ranges as set forth in U.S. Pat. Nos. 3,149,985 and 3,642,503. It is standard practice that this ratio of SiO_2:Na_2O is in the range of 1.4:1 to 3.3:1. As to the particulate material, foundry sand such as Portage-AFS No. 52 is employed. It should be realized that the silicate solution and sand are standard as taught in the prior art and therefore do not in substance form an important feature in the present invention.

The percentage weight of catalytic agent to silicate binder may generally be in the range of 5% weight to 15% weight of the binder weight but tests and actual employment of the process of this invention has shown that best results are achieved in the range of 8% to 12% by weight of the three-part catalytic agent added to the binder weight. In other words, best results are obtained by adding the three-part catalytic agent, with the individual elements selected according to desired set time as illustrated in FIG. **3**, to the mixture at a percent weight value equivalent to 8% to 12% of the binder weight added to the mixture.

The diacetin to triacetin percentage relationship shown in FIG. **1** is in the form of the curve **10**. In this relationship the balance is EGD. The set times for the points A through F on this graph, by way of example, are indicated in FIG. **2** at various ambient temperature levels. If, for example, there is an ambient and sand temperature of 70°F, a 45 minute set time is obtained by using a mixture of the three-part catalytic agent at point C along curve **10** consisting of 32% by weight of diacetin, 33% by weight of triacetin, and 35% by weight of EGD being the balance. If an increase in set time is desired for the same sand temperature, the percentage of triacetin is increased while that of diacetin is decreased. Likewise, the percentage of triacetin is increased with an increase in sand temperature to maintain the same set time with the percentage of EGD remaining essentially the same. For example, if the sand temperature is increased to 80°F, the same set time by using proportions of ingredients near point D on line **10**, which are 20% by weight of diacetin, 48% by weight of triacetin and 32% by weight of EGD.

From the foregoing, it can be seen that the set time can be precisely determined by providing for the proper proportion of ingredients in the three-part catalytic agent based on the known temperature at which the particulate material is held. We provide for electric heaters in the conveying chutes for the foundry sand. These heaters are adjusted usually to heat the moving sand to a temperature of approximately 80°F. As the sand is by far the major component in the bonded particulate material, its temperature would have a major effect on the silicate binder and the three-part catalytic agent. As can be seen from the Table in FIG. **2**, sand temperature variations have a great effect on the ultimate set time.

The heated sand passes directly from the chute into an upwardly open elongated mixing trough having an auger screw for its full length which continually rotates to mix the sand with silicate binder and catalytic agent, which are also deposited into the trough at approximately the same temperatures as the sand. The auger screw also conveys the materials as mixed forwardly in the trough to the trough end where they are deposited into a waiting mold.

Thus, an important feature of the present invention is heating the particulate material to a predetermined temperature level or at least knowing the level of the sand temperature. With sand temperature maintained at a constant level, the optimum proportions of the three ingredients in the catalytic agent can be readily determined from the graphs shown in FIGS. **3** and **4**.

The data provided in FIGS. **3** and **4** was obtained by way of the following testing.

Bonded particulate materials were prepared according to the teachings of the present invention by employing a blender to provide 4% by weight an aqueous solution of grade 47 sodium silicate binder and 0.4% by weight of the three-part catalytic agent and the remainder foundry or Portage sand having an average grain fineness number of 52. The preferred range for the binder is 4.0% to 4.5% by weight. The binder was maintained at a temperature of 80°F. Employing less per-

centage by weight of the binder would not provide for good mold hardness, and more than this will affect the desired set time and, in any regard, does not provide for better mold hardness or bonding power, i.e., excessive amounts do not provide for improved mold quality.

Mold quality was determined in relationship to set time, mold hardness, shear strength and visual differences. Set time is determined by a Deitert 473 B-scale green hardness tester and values of set time were taken when a stable green hardness of 90 was attained. Mold hardness was determined through the employment of a Deitert 670 dry hardness tester and testing was done after a 24-hour curing period to determine final mold surface quality.

Shear strength was measured to determine internal quality of the mold through the employment of a Deitert 400 universal sand strength tester. Samples of mold cylinders were rammed six times with a number 315 sand rammer, the tests being performed after these molds had cured for 48 hours.

Three sizes of molds were actually employed, and the results averaged for different proportionate mixes of the three-part catalytic agent. These were 1 ¾ inch, 4 ½ inch, and 8 inch molds. Sand temperature was maintained constant and the average temperature for all testing was 79°F.

The tests conducted for the large part included all three ingredients, diacetin, triacetin and EGD. However, the employment of only two-part catalytic agents, that is, diacetin and triacetin or diacetin and EGD, or triacetin and EGD, is also taken into consideration. In this manner, a comparison can be made between the three-part versus the two-part catalytic agents and also gives some insight into the range of usable or practical set times as well as the uniformity of reproducing desired set times when employing the three-part catalytic agent of the present invention.

The results of these tests relative to set time are shown in FIG. 3. From an examination of FIG. 3, it can be seen that with temperature conditions held constant, the increase in set times increases fairly uniformly, particularly in the area where the catalytic agent includes EGD in the range of 20% to 40%. Also, it should be noted the large spacing between the "minute lines' from 16 minutes to 28 minutes, for example, in the central left portion of FIG. 3 as compared to the much smaller spacing of these minute lines in the cases where no EGD is present in the three-part catalytic agent. This smaller spacing is also present at the extreme left side of FIG. 3 wherein no triacetin is present in the three-part catalytic agent. A more definable control can be obtained where these minute lines are of wider spacing, because slight changes, for example, in the proportions of ingredients in these areas will not have a material effect on the resultant set time. By the same token, small temperature changes also will have no material effect in the outcome of the resultant set time. These two points as graphically illustrated in FIG. 3 are very important in the employment of the present invention.

Where there is no EGD present, as shown in right end portion of FIG. 3, small changes, even to 1%, in the proportion of diacetin and triacetin brings about a definite change of set time of at least 1 minute or so. This same fact is true also with regard to diacetin and EGD where no triacetin is present. These two just mentioned two-part catalytic agents are those proscribed in U.S. Pat. No. 3,642,503, with these results illustrating the lack of control over the ultimate set time where slight variations in proportions or temperature conditions are involved. It can be seen that the presence of EGD in combination with diacetin and triacetin is a significant factor in the predictability of set time, particularly when working under changing temperature conditions.

Higher concentrations of diacetin will produce faster set times. Higher concentrations of triacetin will produce slower set times. The addition of EGD acts as a stabilizer, for, in essence, the set time of diacetin is increased and the set time for triacetin is decreased, so that the curing rate becomes more uniform and more easily reproducible, particularly where concentrations of EGD are between 20% to 40% of the catalytic agent.

FIG. 4 represents the maximum deflection points for each of the set time curves of FIG. 3 in employing the three-part catalytic system of this invention. This curve crosses the optimum catalytic concentrations needed to obtain uniform and reproducible set times. It can be seen that the entire optimum concentration range for EGD is within 20% to 40%. For triacetin, this range is approximately from 10% to 85%, and for diacetin this range is approximately from 10% to 60%. This maximum deflection curve will shift horizontally where sand and ambient changes differ from that used during the present testing, which averaged 79°F. The curve of FIG. 4 is an example of what is used and followed in the foundry for determining the desired proportions of diacetin, triacetin and EGD to produce a precise and accurate set time. Precise set time can be obtained between 13 to 112 minutes. For comparison purposes small size molds usually require set times between 12 to 20 minutes. Larger molds may require set times 1 to 1½ hours.

Tests for shear strength showed in excess of 73 p.s.i. up to 200 p.s.i. in some cases. Shear strength for the area above the deflection curve of FIG. 4 varied widely from 14 p.s.i. to 54 p.s.i., which strengths are not adequate. Thus, high shear strengths were obtained in the area of the deflection curve.

Indentation hardness showed the highest results in the area of FIG. 4 where the deflection curve appears. On the average the area of FIG. 4 where the upper portion of the deflection curve appears had a hardness of 77. In the area of FIG. 4 where the lower portion of the deflection curve appears, the average hardness was 72. In the area of FIG. 4 above the entire curve, the average hardness was only 58. Thus, catalytic concentrations in the area of the deflection curve produce, on the average, the highest surface hardness results.

As to visual appearances, in the area for mixtures of the three catalytic ingredients above the deflection curve, difficulty was experienced in molding the particulate material because the binder would preset prior to being placed into the mold. Soft but coherent lumps of sand were forming in the material prior to the molding operation. In the area in FIG. 4 below the 20% diacetin line, mixtures of the particulate material showed a tendency to sag and crack when drawn from the pattern after at least a curing time of 10 minutes.

That area of the deflection curve of FIG. 4 above the 20% diacetin line was found to produce uniform high quality molds without any presetting or sagging experienced in connection with the previously-mentioned areas.

These test results indicate quite clearly that good uniform quality molds can be produced for catalytic concentrations along the deflection curve of FIG. 4.

Reference now is made to FIG. 5, wherein there is illustrated, through a series of curves, the longer plasticity stage achieved for relatively short preset times when employing the three-part catalytic agent herein disclosed, particularly when EGD is present in concentrations in the agent between 20% to 40% by weight. Each curve represents the set time when using one of any of the three ingredients, diacetin, triacetin and EGD, or in any combination of two. To obtain information for these curves, indentation hardness tests were made immediately upon mixing and molding the bonded particulate materials. Indentation hardness values close to 90% begin to taper off quite rapidly, as the bonded material has almost reached complete and final hardness. In identifying the curves, the abbreviations DI, TRI, and EGD, respectively stand for diacetin, triacetin and ethylene glycol diacetate. The percentage figure following each abbreviation is its concentration by weight in the total catalytic agent mix. As can be seen from the data in FIG. 5, the DI 100% curve has a very short set time, actually less than 8 minutes. On the other hand, the TRI 100% curve is at the other end of the spectrum, wherein hardness reaches approximately 90% of its value in about 60 minutes. The EGD 100% curve is fairly within the middle of this spectrum.

With high concentrations of EGD with either diacetin or triacetin will appear in respective areas between the EGD 100% curve and the DI 100% and the TRI 100% curve, particularly closer to the EGD 100% curve. Thus, the DI 33%, EGD 66% is between the DI 100% curve and EGD 100% curve, while the TRI 70%; EGD 30% curve appears between the XD 100% curve and the TRI 100% curve. In any case, these curves are fairly steep showing that their particular set times are reached directly in the sense that continual setting of the binder and, thus, resultant hardness is steadily reached at a rapid pace. However, where there is a high concentration of triacetin, such as the DI 16%, TRI 83% curve, there is a large curve section indicating a change or slow down in the rate of hardness and providing a sufficient amount of plasticity time within the total set time to permit uniform molding and pattern removal. However, set time in this particular case is longer than normally desired, with 90% hardness reached in a little more than 50 minutes.

The DI 40%, TRI 30%, EGD 30% is a typical concentration for the three-part catalytic agent of this invention. This curve in form is quite similar to that of the DI 16%, TRI 83% curve, just mentioned, but 90% hardness is reached within a much shorter set time, approximately 20 minutes. The rate of hardness gradually reduces or slows down beginning at 45% hardness. It can readily be seen that this change in the rate of hardness is a direct indicator that lowering of the indentation hardness by using the three-part catalytic agent brings about a longer plasticity stage within the desired predictable set time. This lengthened plasticity stage permits the production of acceptable foundry molds continuously and uniformly without defects within the proscribed set time.

We claim:

1. In a process for producing a bondable particulate material for foundry use comprising the steps of mixing with the particulate material a binder comprising an aqueous alkali metal silicate having an SiO_2 to alkali metal oxide ratio in the range of 1.4:1 to 3.3:1, the improvement comprising the steps of

initially heating the particulate material above 70° F, and

adding to the mixture as a predeterminable set time additive a selective amount of a catalytic agent consisting in combination by weight of the ingredients, 10% to 60% diacetin, 10% to 85% triacetin and 20% to 40% ethylene glycol diacetate, the selected amount of catalytic agent being within the range of 5% to 15% by weight to the binder weight,

the percentage selection of said ingredients dependent upon the desired period of setting time and the temperature level of the particulate material.

2. The process of claim 1 wherein the alkali metal silicate is sodium silicate and the particulate material is sand.

3. The process of claim 1 wherein the preferred amount of catalytic agent is 8% to 12% by weight to the binder weight.

4. The process of claim 1 characterized by maintaining the particulate material temperature level at approximately 80°F.

5. The process of claim 1 characterized by the step of selectively varying the percent weight of triacetin to diacetin dependent upon the maintained temperature level of the particulate material while selecting the percentage by weight of ethylene glycol diacetate in said agent to control the rate of hardening during forming of the mixture into a desired shape within the selected period of setting time.

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