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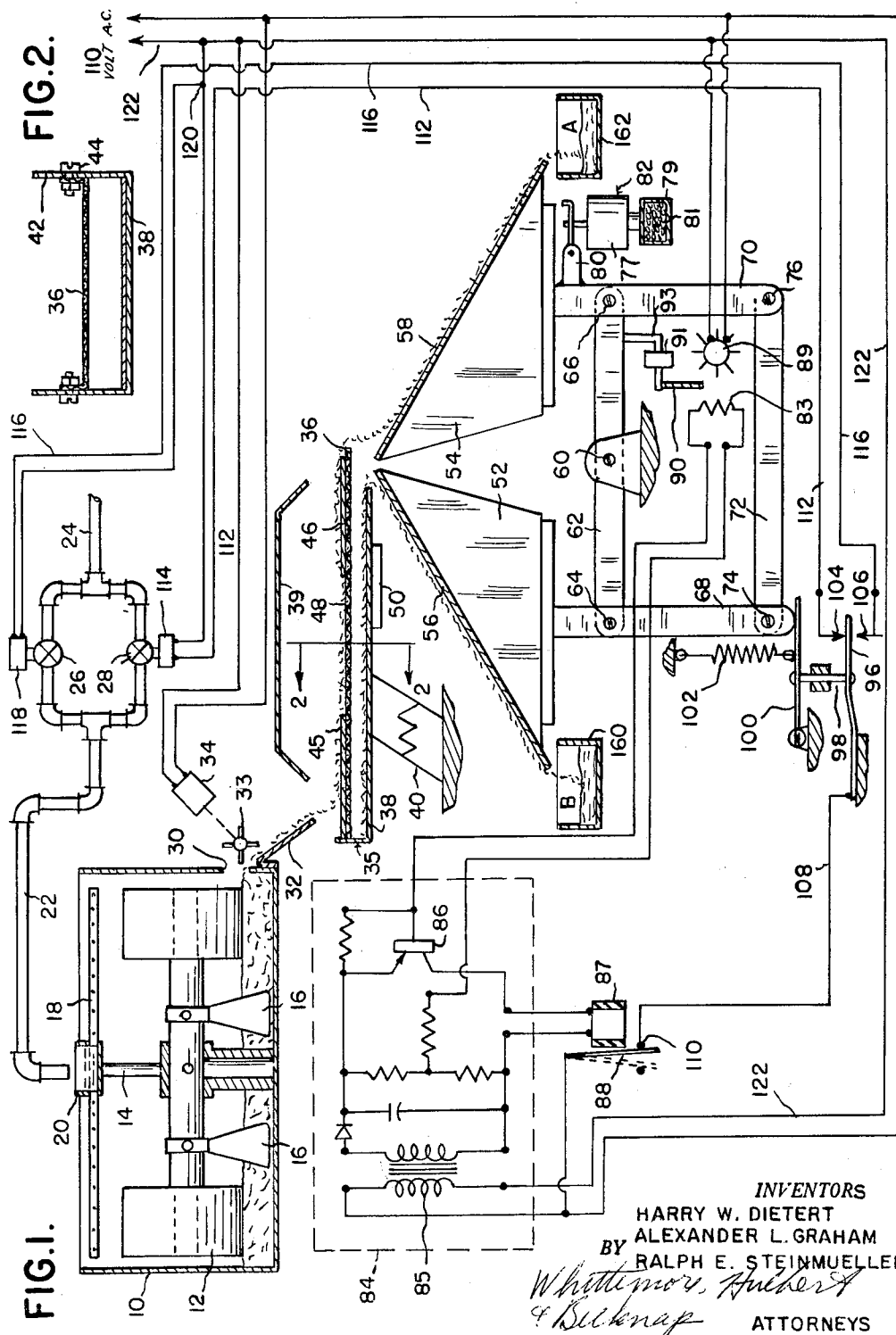
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MOLDABILITY MEASURING AND CONTROLLING APPARATUS AND METHOD

Filed Jan. 16, 1961

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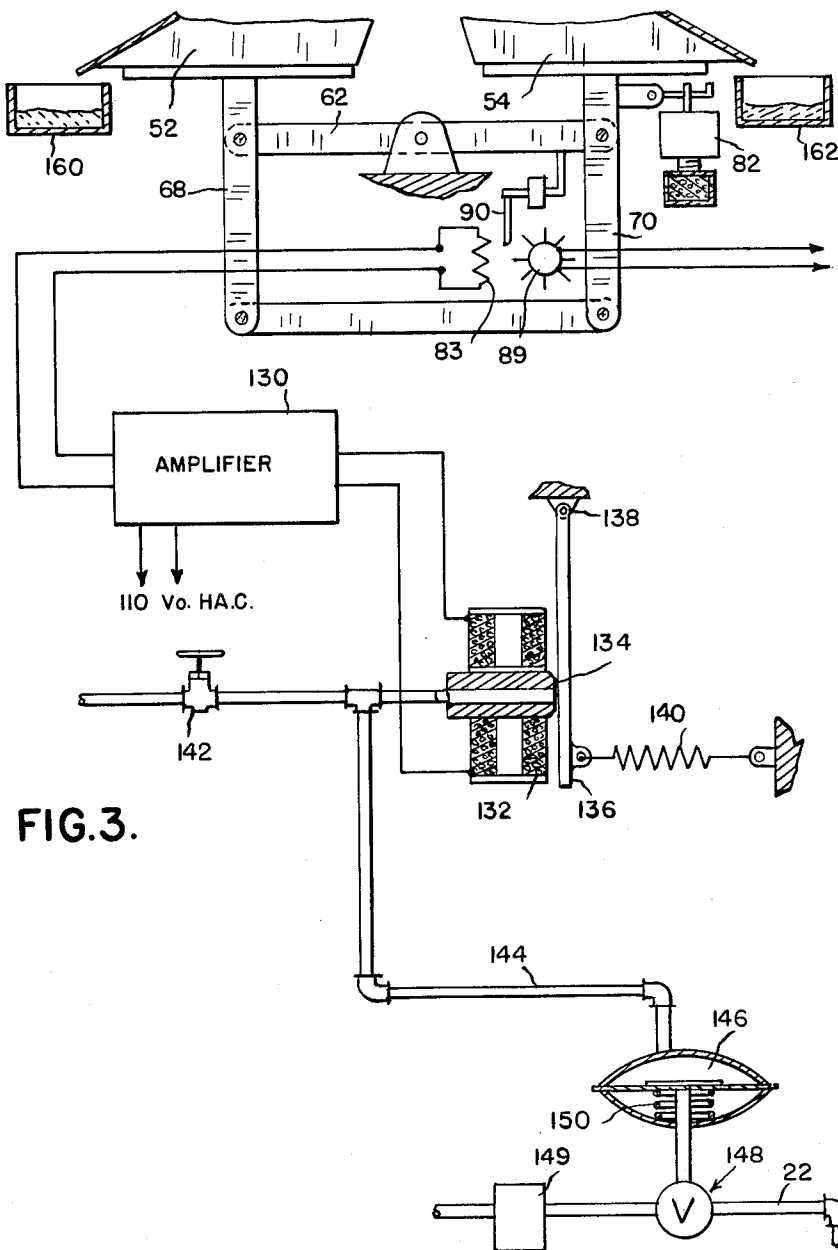


FIG. 3.

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MOLDABILITY MEASURING AND CONTROLLING APPARATUS AND METHOD

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The present invention relates to moldability measuring and controlling apparatus for use in conjunction with granular material, such for example, as foundry sand.

In preparing sand for use in making molds for casting metal, sand of a particular type is mixed with additives such as fines, active clay substances, carbonaceous material or cereal binders, and with water. This mixture is milled or mulled to insure uniformity of the mixture and to improve its physical properties.

In the past, the processing of the molding sand has been under the primary control of instruments responsive to moisture content of the sand. This prior method is subject to the objection that the molding sand does not remain at a constant composition. Some or many of the additives are burned out when a casting is poured so that it is necessary to replace additives to maintain the molding sand mixture at substantially constant proportions. The actual moisture content of the sand, which is required to bring it to desirable physical properties, will vary widely in accordance with the particular grade of sand and types and proportions of additives.

By the present invention, control of the compounding of the sand and additives and water is under the control of instrumentation which measures the critical physical properties of the molding sand composition as it enters into its usefulness in molding.

The physical property of the molding sand composition which is measured and which is used to control the conditioning of the sand is the moldability of the sand. The moldability of the sand determines its ability to flow under pressure. In general, moldability of the sand is recognized as being approximately the opposite of the sand toughness. The toughness of the sand is recognized as the property dependent upon its cohesiveness. In general terms, the greater the moldability of the sand, the less its toughness.

Variations in moldability or toughness resulting from changes or fluctuations in grain fineness, fines grain distribution, active clay substance, sand temperature, carbonaceous material, cereal binder content, and chemical purity, cause variable working or ramming sand, which in turn produces mold surfaces that possess a varying mold hardness, varying false voids, and a varying creep deformation or load carrying ability when the sand is tempered to a constant moisture content.

The present improved method of preparing molding sand has been developed to overcome the objectionable variations referred to above. The new method is based on the premise of preparing the molding sand to a constant degree of moldability which is measured continuously or intermittently during processing of the sand. The processing of the sand ordinarily includes milling the sand during the continuous or intermittent addition of water or other sand additives, and discontinuing the addition of the water or sand additives when the sand reaches a predetermined desired moldability. It has been found that when the optimum moldability is reached, the sand composition may have widely different percentage moisture contents in accordance with variations in the particular molding sand composition.

The moisture present in the sand is not a property of the sand, but instead is only an ingredient of the sand. In

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the present invention, measurements are taken of a critical physical property, namely, its moldability, instead of a mere ingredient thereof, and the final composition of the sand including its moisture content is thus varied as required to produce the desirable moldability.

It may also be mentioned that the present invention does not ordinarily intend to obtain a maximum moldability, but instead, a definite predetermined intermediate value of moldability, as related to toughness, in accordance with the particular use to which the molding sand is to be put.

With the foregoing in mind, it is an object of the present invention to provide apparatus for determining the moldability or workability of a granular material.

It is a further object of the present invention to provide means for measuring the moldability of a granular material such as a molding sand which includes means for separating a specimen of the sand in accordance with the size of cohesive masses of the sand, as for example, by passing the sand over a screen or riddle of predetermined mesh.

It is a further object of the present invention to provide apparatus for measuring moldability and/or toughness of molding sand by separating a specimen of milled sand in accordance with the size of cohesive masses thereof, collecting the separated portions of the sand specimen and determining sand moldability and/or sand toughness therefrom.

It is a further object of the present invention to provide apparatus for measuring sand moldability which comprises means for causing sand to travel over or across a screen so as to permit individual sand grain and cohesive masses of sand of less than critical size to pass through the screen while causing cohesive masses of larger than critical size to pass across the screen, and determining the relative proportions of material which passes through the screen as compared to the material which passes across the screen.

It is a further object of the present invention to provide sand conditioning apparatus including means for measuring the moldability of sand during the addition of ingredients thereto, together with continued milling, and discontinuing the addition of ingredients when the moldability of the sand reaches a desired value.

It is a further object of the present invention to provide sand conditioning apparatus as described in the preceding paragraph in which the added ingredient is water.

It is a further object of the present invention to provide sand conditioning apparatus as described above in which the additional ingredient is an additive other than water.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawings, illustrating preferred embodiments of the invention, wherein:

FIGURE 1 is a diagrammatic view illustrating the present invention.

FIGURE 2 is an enlarged sectional view on the line 2-2, FIGURE 1.

FIGURE 3 is a fragmentary diagrammatic showing of a portion of the system shown in FIGURE 1, modified to produce regulation of water addition.

Referring now to FIGURE 1, there is illustrated the sand moldability measuring apparatus employed in conjunction with control equipment to control the conditioning of sand for use in making molds for a foundry. The apparatus comprises a mixer or mill 10 in which a quantity of sand is placed and is subjected to the action of relatively heavy rollers 12 which are caused to revolve about a vertical spindle 14. Preferably, intermediate the rollers 12 are plows 16, some of which may act as scrapers to remove rolled sand from the bottom of the mill 10,

and others of which may remove sand from the side walls of the mill 10 and displace the sand inwardly.

Positioned above the sand in the mill 10 is a sprinkler pipe 18 leading outwardly from a catch basin 20 into which water is admitted through a pipe 22. The supply of water is from a main 24 and through either a large automatically controlled valve 26 or a small automatically controlled valve 28, or both.

During the continued mixing of the sand, specimens are discharged through a port 30, preferably located in a side wall of the mill 10. As indicated, the port 30 is preferably adjacent the lower portion of the mill 10 and in some cases, the port 30 may actually be located in the bottom wall of the mill 10. In fact, it is contemplated that in some cases, the port 30 may actually be in a position to be traversed by the rollers 12 so that a relatively compressed specimen of the molding sand will be discharged from the mill 10 during passage of a roller 12 thereover. The port or opening 30 may be of any desired shape, as either round or square, and preferably has a transverse dimension of between one and two inches. The opening 30 is preferably provided with a closure so as to prevent discharge of specimens before it is desired to determine the existing moldability of the sand.

Disposed beneath the opening 30 there is provided an inclined plate 32 along which the discharged sand specimens slide, and preferably a rotary bladed feed device 33 is provided actuated by a motor indicated diagrammatically at 34.

The apparatus for determining the moldability of the sand comprises a separator indicated generally at 35 including a screen or riddle 36 carried by a tray 38 and disposed beneath a hood 39. The tray 38 is connected to a vibratory feeder 40 of the type known in the trade as Syntron feeder.

As best illustrated in FIGURE 2, the tray 38, which may be formed of sheet metal, has upstanding side walls 42, and the screen, riddle or grate 36 has upturned side edges carried by the side flanges 42 of the tray 38 by screws or bolts indicated at 44. In practice, excellent results have been obtained when the tray has an approximate length of about 14 inches and a width of approximately three inches. In practice, a substantial portion of the screen or riddle 36 is covered, as for example, by tape. This arrangement is illustrated in FIGURE 1 where tape is shown at 45 and 46, leaving an exposed intermediate portion of the screen at 48. The Syntron feeder 40 is operated so that the sand traverses the screen rather quickly, as for example, with a transit time of from one to three seconds.

In order to prevent the sand from sticking in the opening in the screen 36, it is preferred to form the screen 36 of Teflon filaments, or metal filaments coated with Teflon, or a Teflon plate having openings punched or otherwise formed therein. Alternatively, sticking of the sand to the screen 36 may be eliminated by providing means for slightly heating the screen 36, such means being illustrated in FIGURE 1 as a strip heater 50.

The Syntron feeder 40, as is well understood, has a fast stroke in one direction and a slow recovery, and results in transferring material from left to right on the screen 36 and similarly, from left to right in the bottom of the tray 38 as material falls through the screen 36. It will be observed that the screen 36 extends beyond the end of the bottom of the tray 38 so that the material which passes over the screen 36 without falling through is separated from the material which falls through the screen 36 and is then discharged from the right hand end of the tray 38.

A pair of vertically movable slides 52 and 54 are provided having inclined surfaces 56 and 58 respectively, preferably formed of or covered with Teflon. The inclined surfaces 56 and 58 are at an angle greater than the angle of repose of the sand and excellent results are obtained when the angle of inclination is approximately

45 degrees from the horizontal. With this angle of inclination, the material discharged from the separator 35 and falling upon the surfaces 56 and 58 slides smoothly at a substantially uniform rate to the lower end of the inclined surfaces 56 and 58 where it is discharged. During the interval while the material is sliding along the inclined surfaces 56 and 58, its weight is, of course, supported by the slides 52 and 54 and balancing mechanism which is employed to sense when the correct proportion of separated components is present.

The balancing mechanism comprises a stationary pivot support 60 on which is mounted a beam 62 connected at opposite ends as indicated at 64 and 66 to posts 68 and 70 extending downwardly from the slides 52 and 54 respectively. Parallel linkage is provided by the additional link 72 pivoted at its ends as indicated at 74 and 76 to the lower ends of the posts 68 and 70.

Provision is made for adjusting the control apparatus and comprises a support 80 from which may be suspended one of a group of weight units 82, each of which has a predetermined effect and will cause the controller to terminate the addition of ingredients to the molding sand compound at different values of sand moldability. Each of the weight units 82 includes a toughness tab 77 which has a flask 79 threadedly connected to the tab 77. The flask 79 contains lead shot 81. In other words, the tabs 77 are loaded to a given weight so that a required amount of sand must pass through the screen 36 to cause the beam 62 to pivot counterclockwise. Normally, when there is no sand flowing out of opening 30 onto the screen 36, the weight 82 pulls the slide 54 downwardly cutting off the water or liquid flow. This provides a fail-safe feature in the system.

Thus, by merely putting on the proper tab on the hanger of the weight unit 82, one is able to quickly and automatically produce sand of a predetermined moldability suitable for each type of molding. Each tab 77 is numbered with a proper identification mark.

A control circuit regulated by movement of the slides 52 and 54 is provided for controlling the valves 26 and 28. This circuit includes a light sensitive resistor 83 connected to an amplifier indicated generally at 84. This amplifier includes a transformer 85, a transistor 86, and is connected to a relay 87 having a movable contact 88. Adjacent the light sensitive resistor 83 is a light source 89 and movable into and out of position intermediate the light source 89 and the light sensitive resistor 83 is an opaque flag 90 which is connected to the beam 62 in such a way as to move downwardly into light intercepting position upon downward movement of the slide 54. A weight adjustment 91 is provided on the arm 93 connecting the flag 90 to the beam 62.

A snap acting metal leaf spring 96 is provided which serves as an electrical contact and which is connected by a slidable pin 98 to a pivoted lever 100, the lever in turn being biased upwardly by an adjustable tension spring 102. The lever 100 has its free end in position to be engaged by the lower end of post 68 and it will be apparent that downward movement of the post 68, when sufficient force has been developed to overcome the opposing resistance, including that of the snap acting leaf spring 96, will snap the spring 96 downwardly from its point of engagement with the contact 104 into engagement with the contact 106. The leaf spring 96 is connected by a line 108 to a fixed contact 110 which may be engaged by the relay contact 88. The contact 104 is connected by a line 112 to a solenoid 114 of the small valve 28. The contact 106 is connected by a line 116 to a solenoid 118 of the large valve 26. Return lines from the solenoids 114 and 118 unite at 120 where they are connected to the line 122 leading to one side of the power source which is designated at 110 volts A.C.

The operation of the system as so far described will now be reviewed. When the system starts in operation and before any of the sand reaches either of the inclined

surfaces 56 or 58, the slide 54 will be in a downward position due to the bias weight 82. At this time, the flag 90 is in position to intercept light between the light source and the light sensitive resistor 83, and accordingly, the relay 87 is not energized. At this time, the mill 10 may start operation and sand which passes through the discharge opening 30 falls to the separator 35. Since this sand does not have the ultimate desired moldability, the greater proportion, if not all, of the sand falls through the screen 36 to the tray 38 and upon operation of the Syntron feeder 40, this sand is discharged onto the surface 56 of the slide 52. Since at this time substantially no sand reaches the surface 58 of the slide 54, a very small quantity of sand discharged to the slide 52 results in rocking of the beam 62 in a counterclockwise direction.

This results in downward movement of the post 68 which thus overcomes the force of the adjustable bias spring 102 and the force required to snap the snap acting leaf spring 96 from the illustrated position to the lower position into contact with the stationary contact 106. This prepares a circuit to the solenoid 118 of the large valve 26. At the same time, counterclockwise movement of the beam 62 withdraws the flag from its blocking position between the light source 89 and the light sensitive resistor 83 so that the output of amplifier 84 is sufficient to operate the relay 87, thus moving its contact 88 to the illustrated position. This completes a circuit to the solenoid 118 with the result that the large valve 26 opens and water flows to the catch basin 20 at a substantial rate. This water is sprinkled over the upper surface of the sand in the mill 10 and the sand is continually mixed by rotation of the rollers 12 and passage of the plows 16.

During this continued operation in which the moldability of the sand undergoes a continuous change, specimens of the sand pass through the opening 30 onto the separator 35. As the moldability of the sand approaches its required value, more and more of the sand traverses the screen 36 and hence, is discharged onto the surface 58 of the slide 54. A correspondingly lesser amount of the sand passes through the screen 36 and is deposited upon the surface 56 of the slide 52. Accordingly, as the moldability of the sand approaches its correct value, the beam 62 is caused to swing clockwise and eventually, the leaf spring 96 will snap to the upper illustrated position. This will break the circuit to the solenoid 118 of the large valve 26 and complete a circuit to the solenoid 114 of the small valve 28. This reduces the volume flow of water which continues at a slow rate until the sand attains its exact predetermined moldability. At this time, downward movement of the slide 54 will have interposed a sufficient part of the flag 90 between the light source 89 and the light sensitive resistor 83 to deactivate the relay 87, thus shifting its contact 88 away from the contact 110, thereby breaking the circuit to the valve solenoids and terminating a cycle.

Referring now to FIGURE 3, there is illustrated the use of the flag 90 to produce a variable output of an amplifier circuit so as to regulate the position of a water proportioning valve. In this figure, the light sensitive resistor 83 is illustrated as connected to an amplifier 130 which may be identical with the amplifier 84 previously described. The output of the amplifier 130 is connected to the winding 132 of an electro-pneumatic transducer which includes an air jet or nozzle 134 and a plate 136 pivoted as indicated at 138 and spring biased away from the nozzle 134 by a spring 140. Air is supplied to the nozzle 134 under a pressure regulated by a pressure regulator valve 142, and a branch line 144 leads to the pressure chamber 146 of a proportioning water valve 148. The valve includes spring means 150 normally effective to maintain the valve 148 closed. When the sand in the mixer is below the desired moldability the beam 62 will move counterclockwise exposing the light sensitive resistor 83 and the output of the amplifier 130 will actuate plate 136 toward the nozzle 134 increasing pressure

in the passage 144 and chamber 146 opening the valve. When the sand reaches the desired moldability the beam will move clockwise and the flag 90 will interrupt the light beam to the light sensitive resistor 83 reducing the amplifier output to the winding 132 of the electro-pneumatic transducer and thereby reducing the pressure in chamber 146 allowing the spring 150 to close the valve 148 terminating the water addition from a water supply line including a pressure regulator 149.

Where the flag 90 is used to produce a modulating effect of a water proportioning valve, the flag 90 will normally have its lower edge inclined or suitably shaped, inasmuch as the position of this edge determines the amount of light passing to the light sensitive resistor 83.

As previously discussed, the moldability and toughness of the sand are modified by a number of factors, of which moisture content is only one. Accordingly, the moldability controller may be connected to gate valves or hoppers or automatic material dispensers which, in place of adding water or liquid, add cereal binders or clay or Bentonite bond to cause or impart a predetermined moldability or toughness. Alternatively, the unit may be equipped with two or more light sensitive resistors or equivalent devices connected to open or close valves adding liquid in addition to other ingredients.

Reference has previously been made to the fact that the moldability of the sand is related to its toughness. It has been found convenient to assign a numerical value to sand moldability and sand toughness and this is determined by means forming a part of the present measuring apparatus.

Referring again to FIGURE 1, there is shown a first container 160 adapted to receive all of the sand which slides off the surface 56 of the slide 52. A similar container 162 is provided adapted to receive all of the sand which slides off the surface 58 of the slide 54. After a particular specimen of sand has been passed over the separator 35 and divided into two parts and these parts collected in the containers 160 and 162, a numerical determination of the sand moldability and toughness may be made. For this purpose the weight of the sand received in the container 160 is designated B, and the weight of the sand collected in the container 162 is designated A. With these values, in weights of identical units, the moldability of the sand is determined by the formula

$$\text{Moldability} = \frac{B}{A+B} \cdot 100$$

Similarly, the toughness of the sand is determined by the formula

$$\text{Toughness} = \frac{A}{A+B} \cdot 100$$

It will be understood that these numerical values are empirical in nature.

It will further be recognized that the best sand for a particular purpose will have optimum moldability characteristics and optimum toughness characteristics which may not in all cases be compatible. In such cases, it will be necessary to determine a particular moldability which will be suitable and which will result in a particular suitable toughness.

The advantage of preparing sand to a predetermined constant moldability characteristic is that the sand will always possess a constant workability or rammability. Thus, the quality of molds are maintained at a preselected value in respect to mold hardness, absence of false voids on mold surface, and the mold wall surface will possess a constant load carrying power, as measured by creep deformation.

In the illustrated embodiment of the invention, the conditioned sand is caused to move over a screen by a vibratory feeding device known as a Syntron. Instead of this, it will of course be apparent that the sand may be caused to pass over the screen by inclining the screen surface

so that the sand slides over the screen by gravity, or by passing the sand through a rotating inclined cylindrical screen, or the like.

In any case, when the sand is of low toughness and corresponding high moldability or flowability, tests with different sand specimens have been made using the present apparatus and the results of these tests are set forth below in tabular form:

Sand Toughness Controller Test Data

REGULAR SAND

Sand No.	Moisture, percent	Specimen Weight	Green Compression	Green Deformation	Mold Hardness, 1 Ram	Laboratory Toughness, percent
1-----	2.70	153.0	16.4	.0108	85	87.6

REGULAR SAND PLUS 0.5% CEREAL

2-----	3.3	154.0	11.2	.0102	80	89.6
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REGULAR SAND PLUS 5% SEACOAL

3-----	3.05	154.0	13.4	.0156	83	87.0
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REGULAR SAND PLUS 10% SILICA FLOUR

4-----	3.5	160.0	11.6	.0151	78	86.2
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It will be observed from this figure that a substantially constant value of toughness results. It will of course be understood particularly from the formulae set forth above that correspondingly constant values of sand moldability are obtained. Particular attention is directed to the fact that the moisture content of the different specimens varies widely from a value of 2.70% to a value of 3.5%, depending basically upon the additives which in this instance are cereal, seacoal, or silica flour.

While FIGURES 1 and 3 disclose the apparatus for measuring moldability of the sand as connected into an automatic control system, it will of course be apparent that the measuring apparatus may be employed independently of the control system merely as means for arriving at the true moldability and/or toughness of a particular specimen of conditioned sand.

It will of course be apparent that a number of variable factors are present in the method, all of which will influence the particular results. These variable factors can be controlled as desired in order to calibrate the system or to obtain a particular result as desired. For example, it has been found that the results are effected most directly by the particular screen. Screen of 20 mesh is employed for certain sand compositions, while for tough steel sand, a screen having 1/2 inch openings is required. Some mortars will require a screen having better than 1 inch openings.

Obviously, the results are variable in accordance with the area of screen or the dimension of the screen in the direction of sand travel. It is possible to take a coarser screen than is normally required and restrict the total area of the screen and thus increase the moldability of the screen produced by the moldability controller. It has been found using a screen having a width of 3 1/2 inches and a length of 6 1/2 inches in the direction of travel, reducing the length to 4 inches has only a slight effect. However, when the length is reduced below 3 inches, the control becomes positive so the screen area must be reduced to an effective area.

It is recognized that the present invention can be used for measurement and/or control of sand or other granular material or slurry and is readily adaptable for use in the ceramic industry or in the processing of welding rod flux material. It is further recognized that while a

screen having multiple openings is at present preferred, similar results may be obtained by a separator having a plurality of slotted openings or, in some cases, a single opening.

With the method described herein, it is possible to control separately, or in sequence, or in combination liquid additions, material or materials in solution or suspension or dry additions to reach a predetermined moldability.

It has been found desirable to continue milling for a short interval, as for example, two minutes, after termination of the addition of the water or other ingredient.

The drawings and the foregoing specification constitute a description of the improved moldability measuring and controlling apparatus in such full, clear, concise and exact terms as to enable any person skilled in the art to practice the invention, the scope of which is indicated by the appended claims.

What we claim as our invention is:

1. The method of conditioning granular material which comprises continuously mulling a quantity of granular material during addition thereto of an ingredient which affects its moldability, directly measuring the varying moldability of the granular material during continued mulling and addition of the said ingredient as determined by the formula $B/A+B \cdot 100$ where A is the weight of a sample of granular material passed onto an apertured support which completely passes over the apertured support and B is the weight of the sample of granular material which drops through the apertured support, and terminating the addition of the said ingredient when the moldability of the granular material reaches the required value.

2. Apparatus for conditioning granular material comprising a mill for mulling granular material, means for adding water to the mill, a valve controlling said means, means for removing samples of granular material from the mill, a separator comprising a perforated support, means for advancing said samples across the support and separating them into a part of substantially uniform composition which falls through the perforated support and another part of substantially the same uniform composition which traverses the support, a pivoted balance beam, supports on said beam at opposite sides of its pivot, and means for retaining the separated parts of the granular material on said supports for a brief period, and means actuated by the position of said beam controlling said valve.

3. Apparatus for conditioning granular material comprising a mill for mulling granular material, means for adding water to the mill, a valve controlling said means, means for removing samples of granular material from the mill, a separator comprising a perforated support, means for advancing said samples across the support and separating them into a part of substantially uniform composition which falls through the perforated support and another part of substantially the same uniform composition which traverses the support, a pivoted balance beam positioned beneath the portion of the separator toward which the sample is advanced, supports on said beam at opposite sides of its pivot, said supports having surfaces inclined at an angle greater than the angle of repose of the granular material on which the parts are received and supported for a brief interval, and means actuated by the position of said beam controlling said valve.

4. Apparatus for conditioning moist granular material comprising a mill for mulling the granular material, means for adding water to the mill, a valve controlling said means, means for substantially continuously withdrawing a sample of material from said mill, a separator having sized aperture structure therein, means for advancing the sample across said separator and dividing the sample into a first part of substantially uniform composition which falls through the aperture structure and a second part of the same substantially uniform composition which traverses said separators, means for accumulating a quantity

of the material falling through the aperture structure proportional to the percentage of material which falls through the aperture structure, means for accumulating a quantity of material traversing the aperture structure proportional to the percentage of material traversing said aperture structure, and means for comparing the accumulated quantities of material as an indication of the moldability thereof, and means responsive to the attainment of a predetermined moldability to shut off said valve.

5. Apparatus for conditioning moist granular material comprising a mill for mulling the granular material, means for adding water to the mill, a valve controlling said means, means for substantially continuously withdrawing a sample of material from said mill, a separator having sized aperture structure therein, means for advancing the sample across said separator and dividing the sample into a first part of substantially uniform composition which falls through the aperture structure and a second part of the same substantially uniform composition which traverses said separator, and means for determining the ratio of the fraction of material falling through said aperture structure to the fraction of material traversing said aperture structure as a measure of moldability thereof, and means responsive to the attainment of a predetermined moldability to shut off said valve.

6. Apparatus as set forth in claim 5 wherein said means for determining the ratio of the fraction of material falling through said aperture structure comprises a balance and the means to shut off said valve comprises a pressure responsive valve actuator, a conduit for supplying a medium under pressure thereto, an opening in said conduit, a pivotally mounted lever secured over said opening to form a valve in said conduit, a light sensitive source of electrical energy, a solenoid connected to the light sensitive source of electrical energy and positioned relative to said lever for pivoting the lever in accordance with the signal provided by the light sensitive source of electrical energy to vary the pressure in the conduit and a light shield secured to the balance operably associated with the light sensitive source of electrical energy to cut off the light thereto in response to the attainment of the predetermined moldability.

7. Apparatus for conditioning moist granular material comprising a mill for mulling the granular material, means for adding water to the mill, a pair of valves controlling said means, means for substantially continuously withdrawing a sample of material from said mill, a separator having sized aperture structure therein, means for advancing the sample across said separator and dividing the sample into a first part of substantially uniform composition which falls through the aperture structure and a second part of the same substantially uniform composition which traverses said separator and means for determining the ratio of the fraction of material falling through said aperture structure to the fraction of material traversing said aperture structure as a measure of the moldability thereof, means responsive to approach of the granular material to a predetermined moldability to shut off a first of said valves and open the other of said valves and means responsive to the attainment of a predetermined moldability of said granular material to shut off the other of said valves.

8. Apparatus as set forth in claim 7 wherein said means for determining the ratio of the fraction of material falling through said aperture structure comprises a balance and the means responsive to the approach of said granular material to a predetermined moldability to shut off the first of said valves and open the other of said valves comprises a snap acting switch for simultaneously breaking an electric circuit to said first valve and making an electrical circuit to said second valve responsive to the position of said balance and wherein the means for shutting off said other valve comprises a light sensitive source of electrical energy, a solenoid actuated switch responsive to said source of electrical energy and means carried by

said balance for interrupting light to the light sensitive source of electrical energy on a predetermined moldability being attained by the granular material.

9. Apparatus for conditioning granular material comprising a mill for mulling granular material, means for adding an additive which affects the moldability of the granular material to the mill, a valve controlling said means, a separator operably associated with the mill including an apertured support, means for advancing a sample of the granular material from the mill across the separator and separating it into a first part which falls through the apertured support and a second part which traverses the support, a pivoted balance beam, supports on opposite ends of said balance beam and means for retaining the separated parts of the granular material on said supports for a brief period, and means actuated by the position of said beam controlling said valve.

10. Apparatus for conditioning granular material comprising a mill for mulling the granular material, means for introducing an additive which affects the moldability of the granular material into the mill, a valve controlling said means, a separator operably associated with said mill having sized aperture structure therein, means for advancing a sample of granular material from said mill across said separator and dividing the sample into a first part which falls through the aperture structure and a second part which traverses said separator and means for determining the ratio of the fraction of material falling through said aperture structure to the fraction of material traversing said aperture structure as a measure of moldability thereof and means responsive to the attainment of a predetermined moldability to shut off said valve.

11. The method of conditioning granular material which comprises continually mulling a quantity of granular material during addition thereto of an ingredient which affects its moldability to form the granular material into cohesive masses, passing a sample of the cohesive masses of granular material onto an apertured structure, separating the granular material at the apertured member into a part passing through the apertured structure and a part not passing through the apertured structure in accordance with the moldability of the granular material, determining the relative division of the granular material as a measure of the moldability of the granular material during continued mulling of said granular material and addition of said ingredient thereto and terminating the addition of said ingredient to the granular material when a predetermined moldability thereof is measured.

12. The method of conditioning granular material as set forth in claim 11 wherein determining the relative division of the granular material comprises depositing the part of the granular material passing through said apertured structure on one side of a balance and depositing the granular material not passing through the apertured structure on the other side of the balance to produce movement of the balance in proportion to the moldability of the granular material.

13. Apparatus for conditioning granular material which comprises means for continually mulling a quantity of granular material during addition thereto of an ingredient which affects its moldability to form the granular material into cohesive masses, an apertured structure, means for passing a sample of the cohesive masses of granular material onto the apertured structure, means at the apertured structure for separating the granular material on the apertured structure into a part passing through the apertured structure and a part not passing through the apertured structure in accordance with the moldability of the granular material, means operably associated with the apertured structure for receiving at least one part of the granular material and for determining the relative division of the granular material as a measure of the moldability thereof during continued mulling

of said granular material and addition of said ingredient thereto, and means operably associated with and responsive to the receiving and determining means for terminating the addition of said ingredient to the granular material when a predetermined moldability thereof is measured.

14. The apparatus set forth in claim 13 wherein the means for receiving the parts of the granular material and determining the relative division of the granular material comprises a balance, means for depositing the part of the granular material passing through said apertured structure on one side of the balance and means for depositing the granular material not passing through the apertured structure on the other side of the balance to produce movement of the balance in proportion to the moldability of the granular material.

15. The method of determining the moldability of a sample of granular material comprising forming the granular material into cohesive masses, passing the cohesive masses of granular material onto an apertured structure, separating the granular material at the apertured structure into a part passing through the apertured structure and a part not passing through the apertured structure in accordance with the moldability of the granular material and determining the relative division of the granular material as a measure of the moldability thereof by depositing the part of the granular material passing through the apertured structure on one side of balance means and depositing the granular material not passing through the apertured structure on the other side of the balance means to produce movement of the balance means in proportion to the moldability of the granular material.

16. Apparatus for determining the moldability of a sample of granular material comprising means for forming the granular material into cohesive masses, means for passing the cohesive masses of granular material onto an apertured structure, means at the apertured structure for separating the granular material on the apertured structure into a part passing through the apertured structure and a part not passing through the apertured structure in accordance with the moldability of the granular

material, and means for determining the relative division of the granular material as a measure of the moldability thereof including balance means, means for depositing the part of the granular material passing through the apertured structure on one side of the balance means and means for depositing the granular material not passing through the apertured structure on the other side of the balance means to produce movement of the balance means in proportion to the moldability of the granular material.

17. The method of determining the moldability of a sample of granular material comprising forming the granular material into cohesive masses, passing the cohesive masses of granular material over an apertured structure, separating the granular material at the apertured structure into a part passing through the apertured structure and a part not passing through the apertured structure in accordance with the moldability of the granular material and determining the moldability of the granular material in accordance with the formula

$$\frac{B}{B+A}$$

wherein A is the weight of the part of the granular material not passing through the apertured structure and B is the weight of the part of the granular material which passes through the apertured structure in accordance with the division of the granular material passing over the apertured structure.

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