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Maurer

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[54] **APPARATUS AND METHOD FOR CONTROLLING MOISTURE CONTENT OF GRANULAR MATERIALS**

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[21] Appl. No.: **294,607**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 861,874, Sept. 29, 1969, abandoned.

[30] **Foreign Application Priority Data**

Oct. 7, 1968 Switzerland 14931/68

[52] **U.S. Cl.** **259/149,** 259/3, 259/14, 259/165, 259/168, 259/177

[51] **Int. Cl.** **B28c 7/04**

[58] **Field of Search** 259/149, 154, 161, 165, 259/164, 168, 3, 148, 175, 176, 177, 14

[56] **References Cited**

UNITED STATES PATENTS

2,954,215	9/1960	Warmkessel	459/154
3,129,928	4/1964	Huntington	259/154
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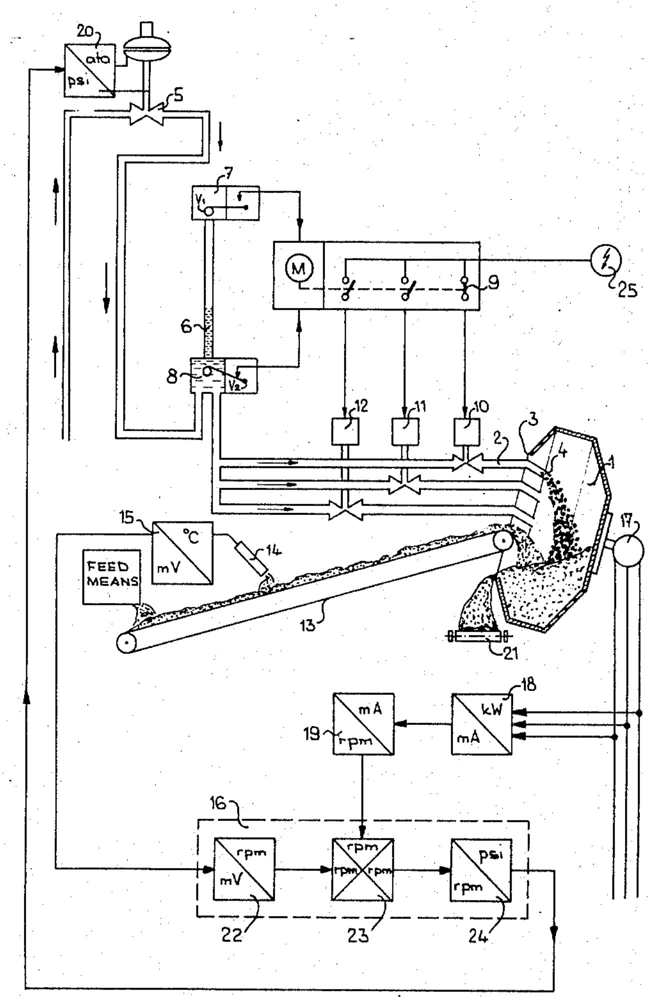
3,277,540	10/1966	Buhrer	68/16
3,291,304	12/1966	Fuchs	259/3

Primary Examiner—Robert W. Jenkins
Attorney, Agent, or Firm—Flynn and Frishauf

[57] **ABSTRACT**

Granular material is fed to a mixing drum, and a plurality of controllable nozzles are aligned with the interior of the mixing drum for selectively introducing water into the mixing drum. A control circuit is responsive to at least one of the power input and the driving torque of the drive means for the mixing drum, to control a main control valve which controls the total quantity of water per unit time delivered into the interior of the mixing drum. The control circuit may also be responsive to the temperature of the granular material fed to the mixing drum for further control of the main control valve. A pressure control device is provided between the main control valve and the nozzles to maintain the water pressure between predetermined boundary values so that water is delivered to said drum with an approximately constant droplet size.

16 Claims, 2 Drawing Figures



PATENTED MAR 12 1974 3,796,412

o = open c = closed

Switches	7	8	7	8	7	8
Values ↓	o	o	o	c	c	c
10	c		o		o	
11	c		c		o	
12	c		c		o	

FIG. 2

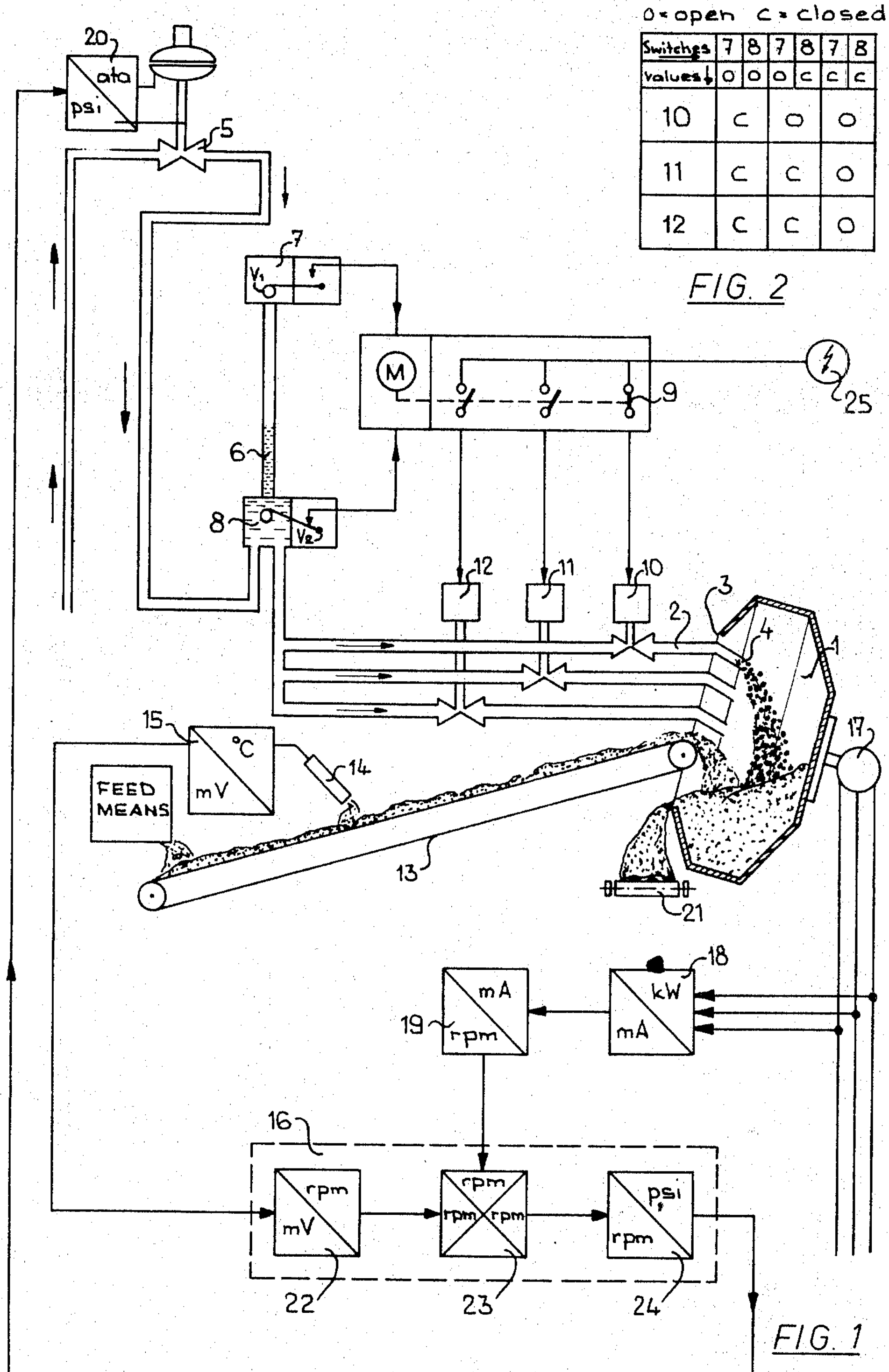


FIG. 1

APPARATUS AND METHOD FOR CONTROLLING MOISTURE CONTENT OF GRANULAR MATERIALS

This is a Continuation-In-Part of U.S. application Ser. No. 861,874, filed Sept. 29, 1969 now abandoned.

Techniques for the determination of the moisture content of molding sand are already well known to the art. Such known techniques generally rely upon the cohesion of the loose sand prior to compaction, such as, for instance, the sievability or the angle of repose of the sand layer. However, these techniques only determine several thousands of the entire sand volume and are unsuitable for inhomogenous sand, especially fill or floor sand.

Other known techniques or methods for measuring the moisture of molding sand rely upon, for instance, the electrical conductivity, the dielectric constant, the microwave absorption, the absorption of β-radiation, the braking of high velocity neutrons, or nuclear-resonance absorption. This group of techniques possess the drawback that the measured value is not only dependent upon the moisture content, rather, also is influenced to a considerable extent by the degree of compaction, or the chemically or electrically active constituents which, as a general rule, are present in addition to water. Moreover, in this connection, it should be understood that there is only ascertained the instantaneous moisture content at the measurement location, and it is not possible to ascertain by these techniques, the average moisture content of so-called floor or filling sand.

It is also known that for mixing sand in a drum different power requirements are necessary in accordance with the moisture content of the sand, because dry sand and wet sand have different mixing resistances. The greater the resistance the greater amount of power or driving torque is needed to rotate the mixing drum for a given quantity of sand. However, it was found that this method is not suited for practical use because there cannot be obtained a water infeed having a constant size of water droplets. That is, depending on the quantity of infed water there is either an atomization or a jet formation of the water. During atomization of the water, the sand adheres to the drum so that any effective admixing of the sand is discontinued. The same effect also exists when there is a formation of a jet of water, resulting in a very irregular moistening of the sand which then can only be worked into a uniform mixture with extreme difficulty.

The main object of the present invention is to provide an apparatus for controlling the moisture content of granular materials which allows a quick and regular moistening of the granular material.

SUMMARY OF THE INVENTION

According to the present invention, an apparatus for controlling the moisture content of granular material such as molding sand, comprises a mixing drum for processing the granular material, means arranged to feed granular material to the drum, a plurality of controllable nozzle means aligned with the interior of said mixing drum for introducing water into said mixing drum, drive means for driving said mixing drum, a main control valve for controlling the total quantity of water per unit time delivered into the interior of said mixing drum, which main control valve is controlled by a control circuit having electrical measurement means for the measurement of the power input or the driving torque of said drive means for said mixing drum, the feed of water to the mixing drum being controlled as a function of said power input or driving torque, and a pressure control device arranged between the main control valve and the nozzle means and operable for measuring the water pressure in front of the nozzle means and for maintaining it between predetermined boundary values, whereby upon the water pressure exceeding the predetermined maximum value a nozzle means is switched in and upon the water pressure dropping below the predetermined minimum value a nozzle means is switched out.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 schematically illustrates a preferred embodiment of appratus of the invention for controlling the moisture content of granular materials such as molding sands; and

FIG. 2 shows the states of the water flow valves as a function of the states of the level switches.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to FIG. 1 of the drawings, it will be recognized that the exemplary embodiment of inventive apparatus depicted therein is equipped with three nozzle means or nozzle groups **2**, **3** and **4**, directed towards the interior of a mixing drum **1** and serving for the introduction of water into the mixing drum **1**. A mixing drum suitable in this respect is described in detail in U.S. Pat. No. 3,277,540.

A riser conduit **6** is arranged between the nozzles or nozzle groups **2**, **3** and **4**, and a primary or main control valve **5** serving for the control or regulation of the total quantity of water delivered into the drum interior. Riser conduit **6** is equipped with an upper level switch **7** and a lower level switch **8**. These level switches **7** and **8** are operably connected through a suitable incremental or stepped control device **9** with the valve means **10**, **11** and **12** provided for the individual nozzle groups **2**, **3** and **4**, respectively, so that when the water level in the riser conduit **6** reaches the level switch means **7**, one nozzle group **2**, **3** and **4** is switched in and when the water level in the riser **6** reaches the level switch means **8** a nozzle group **4**, **3**, or **2** is switched out. This is particularly important inasmuch as the size of the water droplets sprayed into the interior of the mixing drum also remains practically constant even with variable total water quantity per unit time, because the water pressure in the riser conduit **6** varies only between two levels indicated by the switches **7** and **8** and remains relatively small. Riser conduit **6**, switches **7** and **8**, and control device **9** together with valves **10**, **11** and **12** form a pressure control device operative to keep the inlet pressure of the nozzle groups **2**, **3** or **4** approximately constant between the boundary levels defined by the switches **7** and **8**. For example, the riser conduit **6** contains a 3 to 4 meter water column. Within these limits the water is delivered to the mixing drum in the desired form of droplets even if the water quantity is variable. FIG. **2** shows the states of values **10**, **11** and **12** as a function of the states of switches **7** and **8**.

Water under constant pressure is delivered to the main control valve **5** and the quantity of water is controlled by a control circuit. The temperature of the granular material (such as sand) delivered by delivery conveyor **13** to the drum **1** is measured by a thermo-element **14** arranged at the feed path of the delivery conveyor **13**, which is aligned with the interior of the mixing drum **1**. The temperature signal developed by the thermo-element **14** is transformed by a transducer **15** to a proportional signal which is introduced into a regulator device **16** of the control circuit. The transducer **15** converts the signal from thermo-element **14** into an electrical signal suitable for use in the regulator device **16**. The addition of water into the mixing drum is also controlled in such a way that the power input or the driving torque of the mixing drum drive corresponds to a respective pre-set or predetermined reference value which is fed to the regulator device **16** as another control parameter. The output of regulator device **16** controls water delivery to the drum **1**, as will be described in more detail below.

The drive motor **17** for driving the mixing drum **1** is operably connected to a control device **19** through the intermediary of a transducer **18** which transforms the actual power input signal to motor **17**, which is indicative of the mechanical load on the motor **17**, into a control signal which is a function of the power input to the motor **17**. The output signal from control device **19** is likewise fed to the regulator device **16**. The resulting output signal of the regulator device **16** is used to adapt the water quantity per unit time delivered by the main control valve **5** through the action of a valve positioning means **20** as a function of the said power input to motor **17** and the temperature of the sand or other granular material. This control leads to a granular material such as molding sand discharged by the drum **1** having a desired moistness and temperature. Beneath the mixing drum **1** there is arranged a sand removal conveyor **21**, or any other suitable expedient, for the purpose of transporting away the moistened sand coming out of the mixing drum **1**. Of course it is to be understood that the continuous feed and the continuous discharge of the granular material to and from the drum **1** allows a continuous operation of the mixing drum **1** with a constant quantity of material in the drum **1**. As shown in the above-mentioned U.S. Pat. No. 3,277,540, the constant quantity of the mixing drum is defined by the height of a flange or retainer wall on the front opening of the mixing drum.

A feature of the present application is that the sand quantity delivered by conveyor **13** is not measured; it is fed between certain limits continuously, but its quantity can be varied. If a small quantity of sand is fed to the mixing drum, the period of dwell of the sand in the mixing drum is longer than for a large quantity. However, the moistening control of the sand always works in the same manner and leads to the same moisture content independent of the sand feeding. The fact that the sand delivery does not need to be measured is based on the specific characteristics of a type of mixer used in this case. In such a mixer the quantity of sand in the mixing drum is practically constant and independent of the sand supply. If the sand supply fed to the mixer is small, then the output of the mixer is also small, and if the supply of sand is large then the output is also large. But the sand quantity in the mixer drum is practically constant and therefore the power input of the mixer motor is measured always for the same quantity of sand. Thus, the discharging rate of material from the rotating drum depends on the rate of the sand fed to the mixing drum.

As mentioned above, the constant quantity of sand in the mixing drum is defined by the height of the retainer wall. As a result, the moistening of the sand by using the above-discussed specific type of mixer does not depend on the sand supply and this leads to a constant sand quality up to a maximum sand supply for which the mixing drum is dimensioned. The reason why the capacity of a mixing drum as mentioned is large is guaranteed by the pressure control device which avoids the disadvantages of an irregular formation of the water delivered by the nozzles **2, 3, 4.**

In summary, since the control of the moisture content of the sand can be effected without the measuring of the sand supply because of the fact that the sand quantity in the mixing drum is practically constant, the control device can be made in a rather simple manner and controls the moisture input as a function of the sand temperature and the input power of the mixing drum only.

Conveyor systems for the continuous infeed and removal of sand or other granular material from a mixing drum, such as those embodying conveyors corresponding to the delivery conveyor **13**, and the removal conveyor **21**, disclosed above, are also disclosed for instance in the above-mentioned U.S. Pat. No. 3,277,540.

In the simplest case, the means for feeding the conveyor **13** is the station of a foundry where moulding boxes are opened after casting and the castings are knocked out. The sand falls through the knockout grid onto the conveyor **13** and is transported to the mixing drum. However, it is also possible to direct the sand from the flasks and the castings into a silo and from there to the conveyor **13**. In order to avoid a large sand silo, the sand is, as quickly as possible, reconditioned and used again for moulding. Therefore, it is possible that the sand temperature can vary in a high degree, say, for example, from 20°–80° C. This typical example is only representative of uses for the present invention.

It should also be readily appreciated that the mixing drum **1**, in known manner, can be operated for batch-wise charging, whereby the moisturing and homogenization of the granular material occurs in one given direction of rotation and emptying of the mixing drum **1** in the opposite direction of rotation. The fact that the properties of the mixing granular material are measured, by considering the temperature of the infeed material at the mixing drum where the incoming material is continuously mixed provides over longer operational periods an improved average value in respect of moisture content.

In the batch-wise operation of the mixing drum, the drum is fed with a quantity of sand which is equal or higher than the constant quantity retained in the mixer. After starting of the mixing drum the control circuit operates in the same manner as disclosed for continuous operation and stops the water supply when the correct moistening of the sand is achieved. The mixing drum is then stopped and emptied and so on.

The control circuit for the water supply as a function of the power input and temperature of the sand or other granular material can be executed in a different manner. Several standard components are available, manufactured by well-known specialized firms such as

Honeywell, Foxboro, etc. In FIG. 1, the level switches 7 and 8, which may be in the form of simple float switches, are also commercially available from the British firm Mobray or the German firm Besta. The control device 9 is a standard type of stepping switch, including, for example, a synchronous motor with a cam shaft which, by virtue of its rotation switches on or off the valve means 10, 11 and 12, depending on the position of level switches 7 and 8. Valves such as valves 10, 11 and 12 are commercially available from the Swiss firm Chemap, for example. Transducer 15, is a commercially available transmitter which can be procured from Honeywell. Its function is to linearly transform the temperature measured by the thermo-element 14 into an electric voltage. Thermo-element 14 is preferably an iron-constantan thermocouple.

Transducer 18 may be a Honeywell transmitter which linearly transforms the measured current of the drive motor 17 into a direct current of a few milliamperes. Transducer 18 may also be composed of a transformer with a ratio 40-5 followed by a transducer of the type Monax, which is also a standard component manufactured by several firms. Transducer 19 also commercially available from Honeywell, is a transmitter which linearly transforms the current signal into a rotational speed of an electric motor which is superimposed into a mechanical differential 23 which receives a rotational speed of a transducer 22 which transforms the voltage signal of the thermo-element 14 into a rotational speed of an electric motor which is coupled over to the mechanical differential 23. The output rotational speed of the differential 23 is transformed in a transducer 24 into a proportional "pressure" signal of 3 to 50 p.s.i., which signal is transmitted to the positioning control means 20. Control means 20 may be, for example, a simple positioning relay which is pressure operated. With this arrangement, the pressure signal from control means 20 is transformed into a proportional stroke of the main control valve 5 by using, for instance, a servo pressure of two atmospheres absolute pressure.

The block diagram of the various control units of FIG. 1 show the transducing steps in the terms of their operational dimensional units, e.g. milliampere, milli-Volt, R.P.M., p.s.i., etc., of the input and the output signals fed to each block. The transducer 19 is a commercially available item from Honeywell. The components 22, 23 24 may be combined into a single apparatus 16 as is commercially available from Honeywell in the form of a temperature regulator. Also transducer 19 can be a regulator. The term regulator is used herein to mean that a preset reference value can be set in the apparatus which is compared with the actual input signal. The difference, i.e., the error signal, is then transmitted in suitable form to the positioning relay 20. For the illustrated embodiment, if regulators are used, reference signals would be fed to blocks 19 and 22.

In the case where two regulators are used, the error signal of the power regulator 19 is superimposed to the temperature error signal in the differential 23. The resulting error signal is then transformed into a proportional pressure signal which is used for the actuation of the main control valve 5.

If, for example, the thermo-element 14 is omitted, then its respective error signal is zero and the apparatus is controlled only by the power of the mixing drum measured by the current for the electric drive motor 17 of the mixing drum 1. The apparatus could be operated also by using the thermo-element 14 and by omitting the power regulator 19. These are not practical, but rather are theoretical cases.

Several systems according to the concepts of the installation of FIG. 1 have been fabricated and they operate in a very convincing manner. The smallest apparatus was designed for 80 tons per hour and the largest for 400 tons per hour. However, it is pointed out that these are not final boundary values and it is possible to build systems of more or less of these indicated values.

The explanation concerning the control circuit regulating the water delivery to the mixing drum 1 are facts well known to one ordinarily skilled in the art. The components used for the control circuitry can be varied in a different manner as to have a control circuit regulating the water delivery to the mixing drum as a function of the temperature of the sand and/or power respectively torque of the mixing drum.

I claim:

1. Apparatus for controlling the moisture content of granular material such as molding sand, comprising:

a mixing drum for processing granular material;

means for feeding granular material to the drum;

a plurality of controllable nozzle means aligned with the interior of said mixing drum for selectively introducing water into said mixing drum;

drive means for driving said mixing drum;

a main control valve means for controlling the total quantity of water per unit time delivered into the interior of said mixing drum;

a control circuit coupled to and controlling said main control valve means, said control circuit including electrical measurement means for measuring at least one of the power input and the driving torque of said drive means for said mixing drum, and means for controlling said main valve means to control the feed of water to the mixing drum as a function of at least one of said power input and driving torque; and

a pressure control device arranged between said main control valve means and said nozzle means and being operable for measuring the water pressure upstream of said nozzle means and for maintaining said water pressure between predetermined boundary values, such that upon the water pressure exceeding a predetermined maximum value a nozzle means is switched in, and upon the water pressure dropping below the predetermined minimum value a nozzle means is switched out.

2. Apparatus according to claim 1, wherein said control circuit includes a temperature measuring device for measuring the temperature of the granular material being fed to the mixing drum, and means for operating said main control valve means as a function of both said temperature and at least one of said power input and driving torque.

3. Apparatus according to claim 2, wherein said pressure control device includes a riser conduit arranged between said nozzle means and said main control valve means, and an upper level switch and a lower level switch operably coupled to said riser conduit to sense the water level in said riser conduit and switching means coupling said upper and lower level switches to individual nozzle means such that the water level in said riser conduit reaches said upper level switch at least one of said nozzle means is switched in and when

the water level reaches said lower level switch at least one of said nozzle means is switched out.

4. Apparatus according to claim **1**, wherein said pressure control device includes a riser conduit arranged between said nozzle means and said main control valve means, and an upper level switch and a lower level switch operably coupled to said riser conduit to sense the water level in said riser conduit and switching means coupling said upper and lower level switches to individual nozzle means such that when the water level in said riser conduit reaches said upper level switch at least one of said nozzle means is switched in and when the water level reaches said lower level switch at least one of said nozzle means is switched out.

5. Apparatus according to claim **4**, wherein said nozzle means each include a control valve operatively connected to said upper and lower level switches.

6. Apparatus according to claim **4**, wherein said switching means includes a motor, the rotation of which is controlled by said upper and lower level switches, and a plurality of control switches respectively coupled to said nozzle means and operably connected to said motor to selectively switch in or out said nozzle means as a function of the rotation of said motor.

7. Apparatus according to claim **1**, wherein said nozzle means each include a control valve.

8. Apparatus according to claim **1**, wherein said control circuit controls said control valve as a function of the power input.

9. Apparatus according to claim **1**, wherein said control circuit controls said control valve as a function of the driving torque.

10. Apparatus according to claim **1**, wherein said mixer maintains a substantially constant quantity of said granular material therein independent of the supply of granular material thereto.

11. Apparatus according to claim **1**, wherein said feed means feeds said granular material to said drum at a substantially constant rate.

12. Apparatus according to claim **1**, wherein said pressure control device maintains said water pressure such that said nozzles deliver said water to said drum with an approximately constant predetermined droplet size.

13. A method for controlling the moisture content of granular material such as moulding sand, comprising:

feeding granular material to a mixing drum;
driving said mixing drum;
measuring at least one of the power input and driving torque of the driving means for said mixing drum;
controlling the feed of water to a plurality of nozzles which are aligned with the interior of the mixing drum for introducing water into the mixing drum, as a function of at least one of said power input and driving torque; and
measuring the water pressure upstream of said nozzles and maintaining said water pressure between predetermined boundary values by switching in a nozzle when the water pressure exceeds a predetermined maximum value and switching out a nozzle when said water pressure drops below the predetermined minimum value.

14. The method according to claim **13** comprising controlling a main control valve means located upstream of said pressure control device as a function of at least one of said power input and driving torque.

15. The method according to claim **14** comprising measuring the temperature of the granular material being fed to the mixing drum, and controlling said main control valve means as a function of both said temperature and at least one of said power input and driving torque.

16. The method according to claim **13** wherein measuring the water pressure upstream of the nozzle means and maintaining same between predetermined boundary values comprising maintaining a water column upstream of said nozzles, sensing when said water column reaches upper and lower predetermined levels, and switching in or out at least one of said nozzle means when said upper and lower predetermined levels, respectively, are detected.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,796,412 Dated March 12, 1974

Inventor(s) Emil MAURER

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, line 58 (claim 3), change "2" to --1--;
Column 6, line 65 (claim 3), after "that" insert --when--;
Column 7, line 15 (claim 5 formerly claim 6), change "4" to --3--;

Column 7, line 18 (claim 6 formerly claim 10), change "4" to --3--.

Signed and sealed this 6th day of May 1975.

(SEAL)
Attest:

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Attesting Officer

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Commissioner of Patents
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