

[54] **POWDER DISPENSING APPARATUS
HAVING A PREDICTABLE, CONTROLLED
FLOW RATE**

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241/175**

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[58] Field of Search 222/142.1, 160, 161, 173, 199,
222/200, 196, 196.1, 565; 118/637; 96/1;
259/29, 72, DIG. 42; 241/153, 175

[56] **References Cited**

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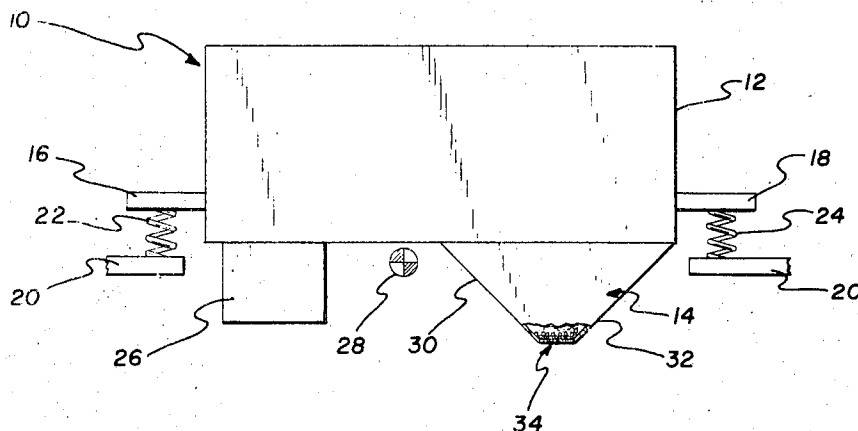
Primary Examiner—Stanley H. Tollberg

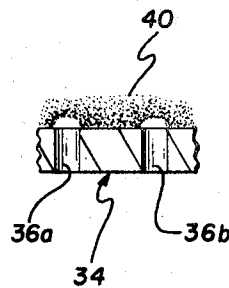
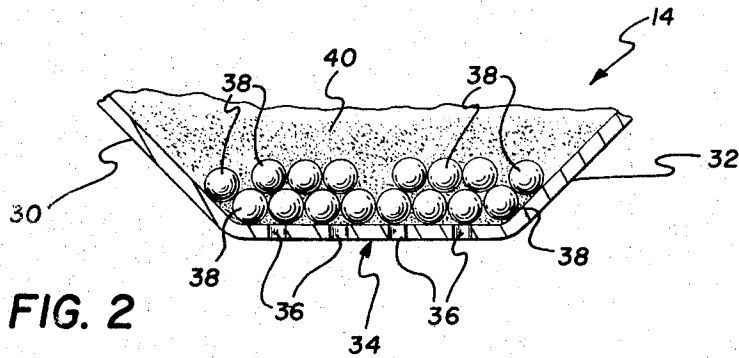
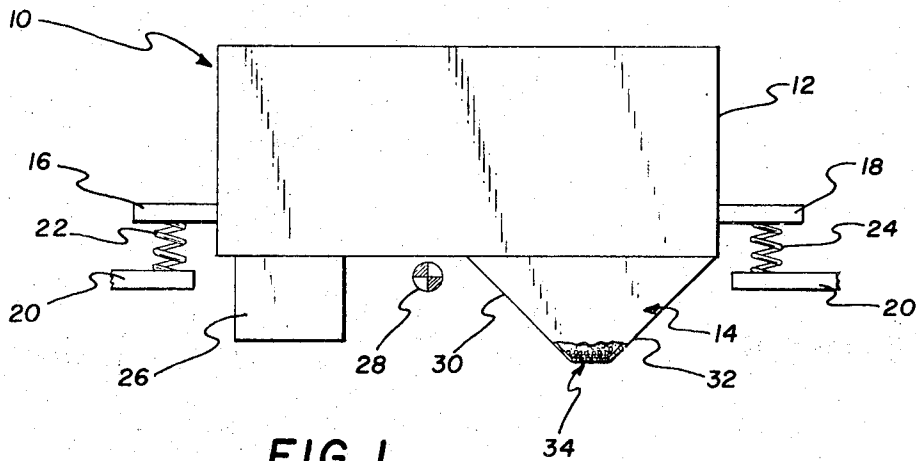
Assistant Examiner—Joseph J. Rolla

[57] **ABSTRACT**

Powder dispensing apparatus including a hopper having at least two sloping side walls which converge to an orificed bottom section. A plurality of loose balls disposed in the hopper are caused to circulate therein by vibrating the apparatus to produce elliptical motion in the hopper, which results in the balls climbing the furthest sloped wall from the center of gravity of the apparatus and then rolling off the far wall onto adjacent walls. From there, the balls fall back through the powder towards the orificed plate and break up any clumped or bridged powder masses. The balls then climb the far wall again and continue to circulate through the powder in the hopper for as long as the elliptical vibratory influence is applied, thereby effecting a predictable, controlled flow rate of powder from the hopper.

10 Claims, 3 Drawing Figures





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POWDER DISPENSING APPARATUS HAVING A PREDICTABLE, CONTROLLED FLOW RATE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to powder dispensing apparatus and, more particularly, to powder dispensing apparatus having a predictable, controlled flow rate.

2. Description of the Prior Art

In the past, considerable difficulty has been encountered in utilizing a hopper having converging side walls for dispensing powdered material through orifices located for such a purpose at the bottom of the hopper. Such materials are prone to form clumps about and over the dispensing orifices, a process known as "bridging", thereby limiting or prevent the flow of powdered material from the hopper. Such difficulties were understandably magnified where low flow rates of material are desired since the reduced diameter orifices necessary to achieve lowered flow rates dramatically increased the bridging effect. Furthermore, in electrographic systems where powdered toner must be replenished at a controlled, low rate in developer mix, the electroscopic powders which are thermoplastic in character, exhibit a pronounced tendency to bridge about and over the discharge orifices. Therefore in such electrographic systems, the requisite low flow rates and the nature of the powdered material combine to frustrate the ready achievement of a low, predictable rate of flow.

One known expedient employed to prevent bridging and to achieve predictable, controlled flow rates calls for vibrating or exciting the hopper to break up any clumps impeding flow. Such a solution is not always practical or satisfactory since certain materials, as pointed out above, are more prone to bridging than others. In addition, where low flow rates are required, the smaller diameter dispensing orifices necessary to achieve reduced flow rates, serve to increase the bridging effect and consequently the vibratory energy necessary to negate the resultant increased bridging. However, increasing the vibratory energy input produces a diminishing return, that is, a point is soon reached at which further vibratory energy yields no improvement in flow. In fact, it has been found that increased vibratory energy tends to cause the powdered material to pack into a solid mass.

Another known expedient employed to prevent bridging contemplates the use of a plurality of balls disposed within the hopper. Under ordinary vibratory influence, the balls are randomly thrown about in the hopper in order to break up any bridged clumps of powder which might form over and about the dispensing orifices. However, it has been found that, for several reasons, the use of such an arrangement is not totally effective when a controlled, low flow rate of powder is desired. Firstly, excessive vibratory energy must be applied to maintain controlled flow rates through the small dispensing orifices. While the quantity of vibratory energy employed can be reduced by increasing the dimension of the dispensing orifices to a point where the powder cannot develop sufficient internal strength to form a bridge, a requirement of low flow rates rules out this possible solution. Secondly, the vibratory mode contemplated in the prior art often resulted in dead spots in the hopper, that is places where none of the balls impinged to break up powder clumps,

or in hot spots, that is places where the balls continuously collided at or near the dispensing orifice, peening the edges of the orifices and restricting material flow.

As noted above, low flow rates are particularly desirable in electrographic systems. In such systems, it is highly desirable to achieve and control a predictable rate of toner flow in order to optimize the quality of the image to be formed. It has been determined that, in one such system, the primary requirement of the toner metering or dispensing mechanism is an ability to predictably deliver toner at a typical rate of less than 2 grams per second. Achieving the requisite controlled low mass flow rates of toner power has consistently proven difficult, especially a small range of variation over relatively long periods of time. Enlarging the size of the dispensing orifices is a limited, if not entirely impractical solution, where low flow rates are desired. The alternative expedient of vibrating the hopper, where it contains antibridging means such as metal balls, is also less than satisfactory either because of the lack of predictable controlled flow rate, dead spots in the hopper or damage to the hopper from the vibrating metal balls.

It is therefore an object of this invention to provide apparatus for dispensing powder at a predictable, controlled flow rate.

It is a further object of this invention to provide apparatus for dispensing powder at a low, predictable, controlled rate of flow over extended periods of time.

It is yet another object of this invention to provide apparatus for dispensing powder at a low, predictable, controlled rate of flow, which apparatus is economical to fabricate and use.

It is still another object of this invention to provide apparatus for dispensing powdered material at a low predictable controlled rate of flow wherein the powder to be dispensed can be mixed by the circulating action of metal balls disposed within the hopper included in said apparatus.

SUMMARY OF THE INVENTION

In accordance with the teachings of this invention, these and other objects and advantages are realized by dispensing apparatus including a hopper having an inlet port for admitting powder thereto and at least two sloping, converging side walls which terminate at the bottom of the hopper. An orifice section having a plurality of powder dispensing openings therein is disposed at the bottom of the hopper. A plurality of loose, generally spherically shaped balls are disposed in the hopper. Also included in the dispensing apparatus is means for vibrating the apparatus in a dual mode. First, a vertical acceleration force is created by vibrating the hopper in a rotary mode about the center of gravity of the apparatus. This acceleration force is manifested as a gradient which increases in magnitude across the hopper width. Second, the apparatus is simultaneously caused to vibrate in a linear horizontal mode. Both accelerations are sinusoidal and of the same frequency as the vibrating means. A plot of the vector sum of the acceleration forces would describe an elliptical pattern in a plane parallel to the acceleration. Upon energization of the vibrating means, the predetermined sloping of the side walls and the elliptical acceleration gradient cause, in combination, the plurality of balls to climb the furthest sloping side wall from the center of gravity of the apparatus and to then roll off the furthest wall to describe a circulating pattern through the hopper. The circulat-

ing balls effect a predictable, controlled flow rate of powder from the hopper by sweeping across the orifice plate to break up any clumps or bridges of powder which form about the dispensing orifices. The circulating balls also achieve a mixing action which is highly desirable if a mixture is to be dispensed from the hopper.

BRIEF DESCRIPTION OF THE DRAWINGS

In the detailed description of the preferred embodiment of the invention presented below, reference is made to the accompanying drawings in which:

FIG. 1 illustrates apparatus according to the present invention having a portion of the hopper shown partially broken away to depict a plurality of balls and powder disposed therein;

FIG. 2 is an enlarged view of that portion of the hopper shown broken away in FIG. 1; and

FIG. 3 is an illustration of the formation of powder bridging about the dispensing orifices of the hopper.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, wherein like reference numerals have been used in the several figures for like elements, there is shown in FIG. 1 powder dispensing apparatus 10 in accordance with the teaching of this invention. The powder dispensing apparatus 10 includes a housing 12 for storing powder 40 having a hopper 14 fixedly attached thereto. Powder 40 is introduced via an inlet port (not shown) into hopper 14 as required. Two lugs 16 and 18, extending respectively from the ends of housing 12, are connected to a mounting plate 20 via coil springs 22 and 24 respectively. It should be noted that although elements 22 and 24 are illustrated herein as coil springs, other resilient means, such as rubber mounts for example, can be employed. The most important characteristic of such resilient means is that they be capable of permitting motion along both their major and minor axis.

Coil spring 22 is a relatively stiff spring having a high spring constant. Coil spring 24, on the other hand is a relatively loose spring having a low spring constant. The use of mismatched coil springs 22 and 24 produces a maximum amount of vertical acceleration within hopper 14 with a minimum amount of energy input when the powder dispensing apparatus 10 is vibrated in accordance with the teaching of this invention. The use of the properly mismatched coil springs 22 and 24 insures that the instantaneous center of rotation under elliptical vibratory influence will lie outside of hopper 14, thereby avoiding dead spots within the hopper 14 where powder would clump and not be transported to the hopper bottom 34.

A vibrator or electromechanical excitor 26, of any suitable and known type, is connected to the housing 12 and is adapted to elliptically accelerate hopper 14, in particular, about some point, herein illustrated as the center of gravity 28, of the dispensing apparatus 10. Hopper 14, as is best shown in FIG. 2, has at least two sloping side walls 30 and 32 which converge towards and terminate at the hopper bottom 34. The hopper bottom 34 contains a plurality of dispensing orifices 36 formed therein of suitable size and number to insure a desired flow rate of powder upon excitation of vibrator 26. Alternatively, the hopper bottom 34 may be a separate and non-integral plate having a predetermined

number of suitably sized dispensing orifices formed therein. In the latter case, an orifice plate may be provided for each particular flow rate of powder which is desired. In such a case, the proper orifice plate need only be slid into place prior to introduction of powder 40 into hopper 14 to yield a particular flow rate.

In addition to powder 40, a plurality of generally spherically shaped balls 38 are disposed within the hopper 14. These balls are included to insure that bridging does not take place about and over the dispensing orifices 36, as is best shown in FIG. 3. In FIG. 3, two of the dispensing orifices 36a and 36b have been shown having powder bridges formed thereabove, which bridges block the flow of powder from the hopper 14. As will be discussed below, the balls 38 serve to break up such bridging, and any other clumps of powder which might form to insure that a predictable and controlled flow rate of powder can be maintained.

When the apparatus 10 shown in FIG. 1 is excited into a vibratory mode, the mismatched springs 22 and 24 which are free to move in any direction, cause the apparatus 10 to exhibit a forced response or steady-state harmonic oscillation at the frequency of the applied exciting force. This forced response or solid-state harmonic oscillation can be and is mathematically described as elliptical in nature. Consequently, the displacement of the hopper and the velocity and acceleration forces created therein are elliptical in nature. Since the apparatus 10 will tend to rotate about its center of gravity 28 unless otherwise constrained, the mismatched coil springs 22 and 24 act as though they were a loosely mounted hinge being vibrated to exhibit forced response.

By locating the hopper 14 as far as possible from the center of gravity 28, the vertical component of the elliptical acceleration force, created across the width of the hopper under vibratory influence, increases outwardly from the center of gravity. Under this vibratory influence, the balls 38 are induced to climb the far wall 32, then roll off onto the walls of hopper 14 and describe a circulating pattern through the powder 40 wherein the hopper bottom 34 is periodically swept clean by the balls 38 as they pass thereover. It has been found that the balls 38, when excited in this manner, tend to spread out and form a larger single layer which artificially causes the diameter of the dispensing orifices 36 to be effectively increased to approach the diameter or width of the hopper bottom 34. That is, it appears with respect to tendency of the toner 40 to bridge as though the powdered toner 40 is exiting hopper 14 from a single, large dispensing orifice, rather than from the many smaller dispensing orifices 36. The "live," artificial dispensing orifice has the same effect as though it were actually present, and is large enough so that there is no possibility that the powdered toner 40 can bridge or clump about it.

The circulating pattern of the balls 38 described above is, among other factors, a function of the number and size of the balls, the slope of the side walls 30 and 32 and the degree of elliptical vibratory excitation achieved. In view of the relatively large number of factors which control the movement of the balls 38, it is rather difficult to assign critical values to the many factors. However, it will be recognized that given a value of vibratory energy introduced into apparatus 10, the side walls 30 and 32 must be sloped a predetermined amount to allow the number and type of balls 38 em-

ployed to circulate, as described, through the particular powder to be dispensed.

It will also be realized, as pointed out previously, by those having skill in this art, that the bridging effect of the powder to be dispensed can be overcome by at least two known methods. In the first, the critical or smallest dimension of the dispensing orifice can be made so large that the powder cannot develop sufficient internal strength to form a bridge or arch thereover. In the second, sufficient vibratory energy can be introduced into the dispensing apparatus 10 to break up any bridges which may form. In practice heretofore, one method or factor was often traded off for the other within practical ranges. However, where, as in this case, the desired flow rates are in the order of less than two grams per second, too much energy has to be applied to maintain predictable flow rates through the very small orifices required for such reduced flow rates. By inducing the balls 38 of the present invention to describe a circulating pattern through the powder 40 in hopper 14, the effective dispensing orifice area is artificially increased to the largest possible size and permits a predictable, controlled rate of flow for dispensing powder without any danger of bridging or the creation of dead spots and hot spots within hopper 14. In addition, where a mixture of two or more powders is to be dispensed from the hopper 14, the circulating pattern of the balls 38 effects a continuous mixing action which prevents the constituent powders of the mixture from separating.

The invention has been described in detail with particular reference to a preferred embodiment thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

I claim:

1. Apparatus for dispensing powder at a predictable, controlled flow rate, said apparatus being adapted to receive powder and a plurality of loose balls and comprising:

- a. a powder and ball receiving hopper having a bottom wall and at least first and second opposed side wall portions connected to said bottom wall, said second side wall portion sloping outwardly and upwardly from said hopper bottom wall;
- b. said bottom wall including means defining a plurality of powder dispensing orifices; and
- c. means for moving said hopper in a manner which provides a plurality of loose balls disposed in said hopper
 - i. vertical acceleration forces on said balls which increase in magnitude from said first to said second wall portions across the width of said hopper, and
 - ii. horizontal acceleration forces on said balls across said hopper to and from said first to said second side wall portions,

said acceleration forces causing, in combination, said balls to describe a circulating pattern in said hopper during which said balls sweep across said dispensing orifices formed in said bottom wall and then move upwardly along said second wall portion and then away from said second wall portion so that under the influence of gravity, said balls return to proximity with said bottom wall to effect a predictable, controlled flow rate of powder from said dispensing orifices in said bottom wall.

2. The apparatus according to claim 1 wherein said means for moving includes resilient means for coupling said apparatus to at least one fixed point, said resilient means being resiliently deformable along and about both its major and minor axes.

3. The apparatus according to claim 2 wherein said resilient means comprises a pair of coil springs, connected at one end to said apparatus and at the other end to the fixed point.

4. The apparatus according to claim 3 wherein said coil springs have relatively different spring constants along their respective major axes.

5. The apparatus according to claim 4 wherein the coil spring having the lower spring constant is placed furthest from the center of gravity of said apparatus.

6. Apparatus for dispensing powder at a predictable, controlled flow rate, said apparatus being adapted to receive powder and a plurality of loose balls and comprising:

- a. a housing for storing powder to be dispensed;
- b. a powder and ball hopper fixedly mounted to said housing at a position furthest from the center of gravity of said apparatus, said hopper having a bottom and at least two opposing first and second side wall portions converging toward said hopper bottom;
- c. said hopper bottom including means defining a plurality of powder dispensing orifices;
- d. a plurality of loose balls disposed in said hopper
- e. mounting means for resiliently coupling said housing to at least one fixed point; and
- f. means for moving said hopper in a manner which provides
 - i. vertical acceleration forces on said balls which increase in magnitude from said first to said second side wall portions across the width of said hopper, and
 - ii. horizontal acceleration forces on said balls across said hopper to and from said first to said second side wall portions,

said acceleration forces causing, in combination, said balls to describe a circulating pattern in said hopper during which said balls sweep across said dispensing orifices formed in said bottom wall and then move upwardly along said second wall portion and then away from said second wall portion so that under the influence of gravity, said balls return to proximity with said bottom wall to effect a predictable, controlled flow rate of powder from said dispensing orifices in said bottom wall.

7. The apparatus according to claim 6 wherein said mounting means includes resilient means resiliently deformable in response to said moving means along and about both its major and minor axes.

8. The apparatus according to claim 7 wherein said resilient means comprises a pair of coil springs, connected to one end to said housing and at the other end to the fixed point.

9. The apparatus according to claim 8 wherein said coil springs have relatively different spring constants along their respective major axes.

10. The apparatus according to claim 9 wherein the coil spring having the lower spring constant is placed furthest from the center of gravity of said apparatus.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,791,558 Dated February 12, 1974

Inventor(s) Jerome M. Katusha

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

Column 5, Lines 48 and 49, delete "a plurality of loose balls disposed in said hopper".

Column 5, Line 50, after "on" add ---a plurality of---

Column 5, Line 50, delete "said".

Column 5, Line 50, after "balls" insert ---disposed in said hopper---

Column 5, Line 52, after "second" insert ---side---

Column 6, Line 17, change "apparauts" to --apparatus---

Column 6, Line 29, delete "a plurality of loose balls disposed in said hopper".

Column 6, Line 30, delete "e."

Column 6, Line 33, change "f." to ---e.---

Column 6, Line 34, after "on" insert ---a plurality of---

Column 6, Line 34, delete "said".

Column 6, Line 34, after "balls" insert ---disposed in said hopper---

Signed and sealed this 23rd day of July 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents