METHOD AND APPARATUS FOR DISTRIBUTING PARTICLES

When a particulate material is admitted to a storage vessel (10), it is passed through an electrode system (12, 14), the electrodes have a sieve-like construction to allow the material to pass therethrough. A voltage source and signal generator (16) applies a potential difference between electrodes (12 and 14) to create an electric field between the electrodes which stops the passage of the material between the electrodes. Consequently a mass of material is held back by the electrodes. The electric field is controlled by the voltage source and signal generator (16) to release the held back mass of material intermittently. This avoids the formation of a cone of material in the storage vessel and improves the distribution of the particles by preventing the segregation of particles caused by the coarser particles rolling down the sides of a cone of material.
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METHOD AND APPARATUS FOR DISTRIBUTING PARTICLES

The present invention relates to the storage of a particulate material in a container so as to reduce segregation of the material.

Many substances are in the form of particulate material, for example, being granular or in the form of a powder. Usually there is a distribution of particle sizes in the material. At present, storage devices, such as silos, receive such materials by conveyor or pneumatic piping which deliver the material to the top of the silo. The material then falls under gravity usually into the middle of the silo forming a conical pile. The angle between the sloping surface of the pile and the horizontal (the angle of repose) depends on the particular material forming the pile, but is typically between 25° and 35°. As filling continues, coarse particles run down the sides of the pile in avalanches and congregate towards the internal walls of the silo. This results in serious segregation between fine and coarse particles. Material is discharged from the silo usually from the centre of the base which results in much of the initially withdrawn material consisting of only fine particle sizes because it has been depleted of coarse particles which have accumulated towards the walls of the silo.

It is desirable that the distribution of particle sizes in the discharged product be consistent and correspond to that received into the silo. The problem of segregation has been recognized for many years. Some attempts have been made to reduce segregation using mechanical means such as baffles to subdivide the interior of the storage device to prevent the formation of large conical piles or cones positioned beneath the inlet point of the storage device to spread the inflow and avoid conical pile formation. These have been shown to reduce segregation but are not ideal and often involve heavy
installations.

Although discussed above in terms of particle size, the problem of segregation can also occur between particles of different surface characteristics e.g. smooth or angular, or between particles of different densities. Consequently, the different components in a mixture can become segregated, as well as size segregation occurring in an otherwise homogenous batch of product. The present invention is generally applicable to nearly all potential particle segregation situations.

It is an object of the present invention to alleviate, at least partially, the problem of segregation of particles.

According to one aspect of the present invention there is provided a method of spatially distributing particles of at least one particulate material, said method comprising the steps of:

- passing the particles between electrodes; and
- generating an electric field between the electrodes to disrupt the flow of material and cause the distribution of particles.

According to another aspect of the present invention there is provided an apparatus for spatially distributing particles of at least one particulate material, said apparatus comprising:

- a container;
- an inlet for admitting said particles into the container;
- at least two electrodes disposed within said container in the path of said particles admitted into said container via said inlet; and
- a controller for controlling an electric field produced by said electrodes to disrupt the flow of said particles and cause the distribution of particles.

According to a further aspect of the present invention there is provided an apparatus for spatially distributing
particles of at least one particulate material, said apparatus comprising:

at least two electrodes for being placed in the path of said particles; and

a controller for controlling an electric field produced by said electrodes for disrupting the flow of said particles such that a mass of particles held back by said electric field is intermittently released so that segregation of particles of different physical properties in the material released by said electric field and subsequently deposited is counteracted.

The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 illustrates schematically in cross-section a first apparatus embodying the present invention;

Figure 2 shows a second embodiment of an apparatus according to the invention; and

Figure 3 is a graph showing particle size discharge profiles achieved with and without the invention.

Figure 1 shows a container 10 having a domed configuration, often known simply as a dome. Figure 2 shows a cylindrical silo in cross-section. The same numbering system will be used for corresponding parts in Figures 1 and 2. The invention is generally applicable to storage containers having other shapes and dimensions, for example containers of square or rectangular cross-section. The container may be static or may be mounted on a vehicle such as a lorry or railway wagon.

The powder or granular material is admitted into the top of the container as indicated by the arrow A by means of a powder feeder 11, and falls onto the electrode system 12, 14. The electrode system illustrated comprises two spaced apart electrodes, 12, 14, which are facing each other and are substantially horizontal and flat. However, the electrodes may take other forms such as domed or corrugated. The Figure only illustrates the electrodes
viewed edge on in section. Preferably the size and shape of the electrodes conform to those of the internal dimensions of the container. Typically the electrodes would be circular with a diameter as much as 5m or more for a 2000 tonne silo storage facility. In a larger dome storage facility, having a capacity for around 20,000 tonnes, the area of a circular electrode would be in the region of 100 m².

The electrodes may also be oriented non-horizontally.

In one alternative embodiment of the invention, the electrodes have a conical shape with the sides forming a shallow angle of 5 to 10° to the horizontal.

The electrodes are perforate to allow particles to pass through them and may be in the form for example of a mesh or a plate with apertures in it. In one preferred form, each electrode comprises a mesh similar to a sieve. The electrodes may have substantially the same configuration as each other or may be different. Each electrode may be divided into portions electrically insulated from each other to which different voltages can be applied. Alternatively, a uniform voltage may be applied across the whole of each electrode.

The choices of thickness and material for construction of the electrodes will depend on both the mesh size and overall dimensions of the electrodes so as to give adequate strength and rigidity. Any suitable metal or other conductor may be used for the electrodes, with stainless steel being one preference. The electrodes may be constructed in sections and the electrodes may be spaced apart by means of insulators to maintain the desired separation over their area. These two features are especially applicable to the construction of large area electrodes.

It is known that an electrode system can be used to control the flow of particulate matter. This has been used to control the flow rate and to act as a valve. The flow
can be stopped when a sufficiently high electric field is established between the electrodes, even though the aperture size in the electrodes can be considerably larger than the largest particle size. The particles can exist in a locked or immobile state bridging the apertures in the electrodes and spanning between the electrodes. The present invention applies this effect to control the distribution of particle sizes by intermittently releasing a held back mass of particles in a "snowstorm" effect.

As the material flows through the electrodes 12, 14, a potential difference is applied between the electrodes 12, 14 by means of a voltage supply and signal generator 16 to generate a pulsed electric field. The potential difference may be of the order of 20 kV, but can go up to as much as 80 kV; the coarser the electrode mesh, the higher the voltage required to stop the flow. The separation of the electrodes is ideally the minimum that can be obtained without sparking occurring, preferably about 20 mm minimum, but an electrode separation of up to about 100 mm is still practical.

The electric field disrupts the flow of material and causes a build up of material 17 on top of both of the electrodes. The flow may be completely stopped or only partially restricted. After a period of time, the electric field is switched off and the accumulated material then descends into the container in a shower known as a "snowstorm". The process is then repeated, by pulsing the electric field at a frequency lower than 10 Hz, to produce intermittent snowstorms by which significantly less segregation of particle sizes in the container can be achieved. The frequency and mark-space ratio of the electric pulses can be varied to ensure that the feed rate of material to the storage device is equal to the discharge rate through the electrodes.

The snowstorm effect ameliorates segregation of particles caused when a steady stream of material enters
the silo from a single pour point and forms a cone. The snowstorm will create a flat top surface rather than a conical pile and hence prevent the rolling of coarse particles to the edges of the pile. Alternatively, an inverted pile can be produced when some rolling of coarse particles to the centre of the container is achieved resulting in better mixing of fine and coarse particles. Particle segregation may occur in the pile 17 on top of the electrodes, but on pulsing the field, the snowstorm effect commences at the periphery of the pile i.e. the coarser particles at the periphery will drop first and roll towards the centre of the container.

The container can be discharged via a discharge hole 18 in the base as indicated by the arrow B in Figure 1 or via valve 20 in Figure 2. Discharge may be gravity fed or may be assisted by a screw and the material may be transported away by conveyor.

The area of the electrode system would be roughly equal to the cross-sectional area of the container. The electrode system is ideally located as close to the top of the container as practical to maximise the benefits of the method. It is not located at the very top because allowance must be made for a cone of material to be formed on top of the mesh of the electrodes (the height of which will depend on the angle of repose of the material). In preferred usage the cone extends over the whole area of the electrodes. A rough value for the minimum clearance necessary is given by the equation $h = \tan \theta \times r$, where $h$ is the clearance distance of the electrodes beneath the top of the silo, $r$ is the radius of the silo and $\theta$ is the angle of repose. In practice, the distance $h$ can be more than this to leave room for a reservoir of product on top of the electrodes.

The overall capacity of the container is, of course, not significantly reduced by the electrodes because the material can be stored both beneath and on top of them.
In the case of a dome it is likely that the diameter of the electrode would be no more than one third of that of the dome at this maximum diameter. It would be positioned about one fifth of the height of the dome from the top.

The avoidance of segregation in the present invention depends on the nature of the material, for example its resistivity and dielectric constant. A medium resistivity material is ideal i.e. resistivity in the range $10^6$ to $10^{12}$ $\Omega$m. Metal or other conductive powders tend to short out the voltage difference applied across the electrode system. Materials with a resistivity higher than this range tend to be too insulating and can hold the charge for too long a period after the field is switched off. Preferably the size of the particles of the granular material will be no greater than 5 mm.

The invention has been demonstrated with disodium tetraborate pentahydrate, also known as Neobor (Trademark) having a maximum particle size of approximately 1.4 mm and using electrodes with a mesh size of 4 mm. Electrodes with a mesh size of up to 10 mm or more are envisaged. A test apparatus comprising a laboratory scale cross-section of a dome container was used in which the electrodes were each 300 mm by 90 mm in size and had a 20 mm gap between them. The current passed through the electrodes was very low in the present example, about 0.1 mA at a voltage of 20 kV, so the power consumption of the electrode system is small.

Figure 3 illustrates an example of the improved distribution achieved with the present invention, by plotting the percentage (by mass) of particles of greater than 850 $\mu$m in size (coarse particles), in samples of material taken during the course of discharging a test storage container. The dashed line is for the case where the storage container was filled by a standard method without using the invention. The samples early in the discharge have a very low percentage of coarse particles (less than 10%), while some of the later samples consist of
over 70% particles of over 850 μm, but there are very great fluctuations in the percentage even between closely separated samples. The thick solid line gives the discharge profile following filling the storage device using the electrostatic distributor of the invention with square pulses of 20 kV at a frequency of 0.5 Hz applied to the electrodes. The consistency of the samples is clearly much improved, with the percentage of coarse particles generally lying between 15 and 30%.

The average proportion of coarse particles in the batches in the tests with and without the invention are indicated by the upper and lower horizontal lines respectively, and are around 22-23%. However, the standard deviation without use of the invention was 12.73 compared with only 4.82 standard deviation when the storage device was filled using the electrostatic particle size distributor of the invention.

A reduction in segregation has also been demonstrated for an experimental core flow silo.
CLAIMS

1. A method of spatially distributing particles of at least one particulate material, said method comprising the steps of:
   passing the particles between electrodes; and
   generating an electric field between the electrodes to disrupt the flow of material and cause the distribution of particles.

2. A method according to claim 1, wherein said electrodes are perforate to allow passage of said particles therethrough.

3. A method according to claim 2, wherein the electrodes are in the form of a mesh.

4. A method according to claim 3, wherein the mesh size is substantially 4 mm.

5. A method according to any one of the preceding claims, wherein the electrodes are disposed substantially horizontally.

6. A method according to any one of the preceding claims, wherein the separation between the electrodes is at least 20 mm.

7. A method according to any one of the preceding claims, wherein the step of generating the electric field between the electrodes comprises applying a potential difference of 20 kV between the electrodes.

8. A method according to any one of the preceding claims, wherein the electric field is pulsed.

9. A method according to claim 8, wherein the electric field is pulsed at a frequency of 10 Hz or lower.

10. A method according to any one of the preceding claims, wherein the particles are passed between the electrodes under gravity.

11. A method according to any one of the preceding claims, wherein the step of generating an electric field
between the electrodes stops the passage of particles therethrough.

12. A method according to claim 11, wherein the electric field is controlled to stop the passage of particles, which accumulate, and is controlled to release the accumulated particles intermittently.

13. A method according to any one of the preceding claims, wherein the particles are passed between two electrodes.

14. A method according to any one of the preceding claims, wherein the electrodes are located above the base of a container and the particles are introduced into the container.

15. A method according to claim 14, wherein the area of each electrode is substantially equal to the cross-sectional area of the container at the location at which each respective electrode is positioned.

16. A method according to claim 14 or 15, wherein the electrodes are positioned between 1/3 and 1/5 of the height of the container from the top of the container.

17. A method according to claim 14, 15 or 16, wherein the container is a silo.

18. A method according to claim 14, 15, or 16, wherein the container is a dome.

19. A method according to any one of the preceding claims, whereby particles of different sizes are distributed.

20. A method substantially as described herein with reference to the accompanying drawings.

21. An apparatus for spatially distributing particles of at least one particulate material, said apparatus comprising:

   a container;

   an inlet for admitting said particles into the

   container;

   at least two electrodes disposed above the base of
said container in the path of said particles when being admitted into said container via said inlet; and a controller for controlling an electric field produced by said electrodes to disrupt the flow of said particles and cause the distribution of particles in said container.

22. An apparatus according to claim 21, wherein the area of each of said at least two electrodes is substantially equal to the cross-sectional area of the container at the position where the electrode is located.

23. An apparatus according to claim 21 or 22, wherein said at least two electrodes are positioned between 1/3 and 1/5 of the height of the container down from the top of the container.

24. An apparatus according to any one of claims 21 to 23, wherein said container is a silo.

25. An apparatus according to any one of claims 21 to 23, wherein said container is a dome.

26. An apparatus for spatially distributing particles of at least one particulate material, said apparatus comprising:

   at least two electrodes for being placed in the path of said particles; and
   a controller for controlling an electric field produced by said electrodes for disrupting the flow of said particles such that a mass of particles held back by said electric field is intermittently released so that segregation of particles of different physical properties in the material released by said electric field and subsequently deposited is counteracted.

27. An apparatus according to any one of claims 21 to 26, wherein said at least two electrodes are perforate to allow passage of said particles therethrough.

28. An apparatus according to claim 27, wherein said at least two electrodes each comprise a mesh.

29. An apparatus according to claim 28, wherein the
size of said mesh is substantially 4 mm.

30. An apparatus according to any one of claims 21 to 29, wherein said at least two electrodes are disposed substantially horizontally.

31. An apparatus according to any one of claims 21 to 30, wherein said controller applies a potential difference of at least 20 kV between said electrodes.

32. An apparatus according to any one of claims 21 to 31, wherein said controller pulses said electric field.

33. An apparatus according to claim 32, wherein said electric field is pulsed at a frequency of 10 Hz or lower.

34. An apparatus according to any one of claims 21 to 33, wherein the separation of two of said at least two electrodes is at least 20 mm.

35. An apparatus according to any one of the claims 21 to 34, wherein particles of different size are distributed.

36. An apparatus substantially as described herein with reference to the accompanying drawings.
### A. CLASSIFICATION OF SUBJECT MATTER

IPC 6  B65G69/04  B65G69/10  B65G69/16  B65G90/54

According to International Patent Classification (IPC) or to both national classification and IPC

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6  B65G  B65D  B03C  B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of database and where practical, search terms used)

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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| A        | US 4 561 818 A (CAPPS ERNEST R)  
31 December 1985  
see the whole document | 1,21,26 |
| A        | EP 0 260 995 A (UNIV SURREY)  
23 March 1988  
see the whole document | 1,21,26 |
| A        | US 4 248 539 A (GLOCKER EDWIN M)  
3 February 1981  
see the whole document | 1,21,26 |
| A        | DE 195 13 779 A (ZIMMERMANN & JANSEN GMBH)  
17 October 1996  
see the whole document | 1,21,26 |
| A        | US 3 824 010 A (PRESSMAN G)  
16 July 1974  
see the whole document | 1,21,26 |

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

- **A**: document defining the general state of the art which is not considered to be of particular relevance
- **E**: earlier document but published on or after the international filing date
- **L**: document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- **O**: document referring to an oral disclosure, use, exhibition or other means
- **P**: document published prior to the international filing date but later than the priority date claimed

### Date of the actual completion of the international search

18 September 1998

### Date of mailing of the international search report

28/09/1998

Name and mailing address of the ISA

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