Oct. 27, 1942. R. C. THOMPSON 2,300,324

METHOD OF AND MECHANISM FOR CLASSIFYING FINELY COMMINUTED MATERIAL

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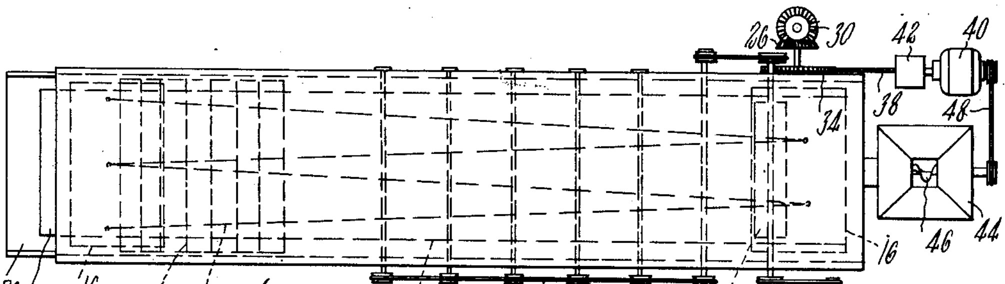


Fig. 1.

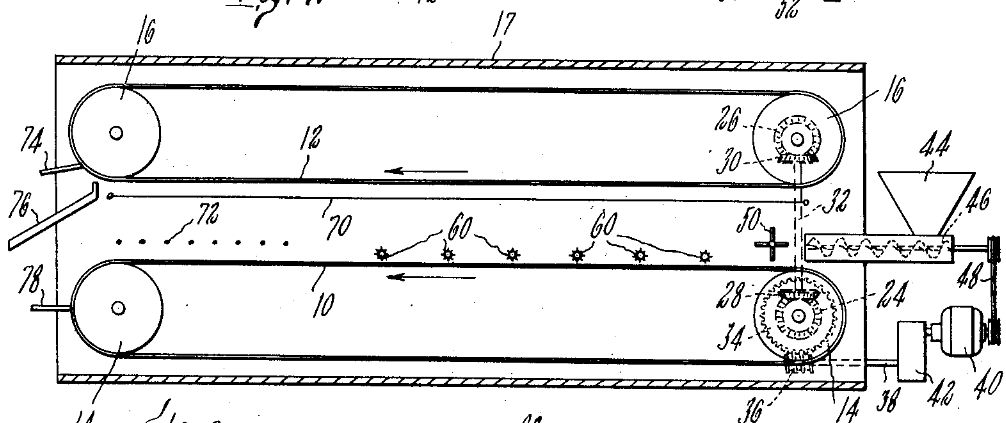


Fig. 2.

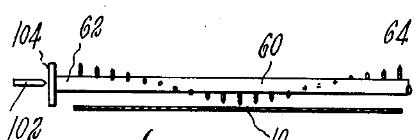


Fig. 3.

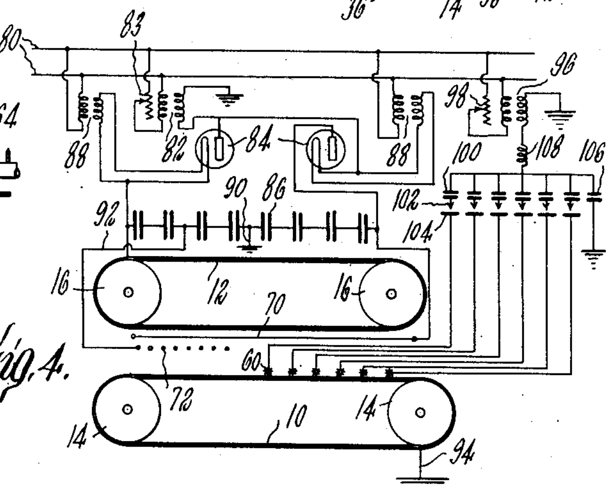
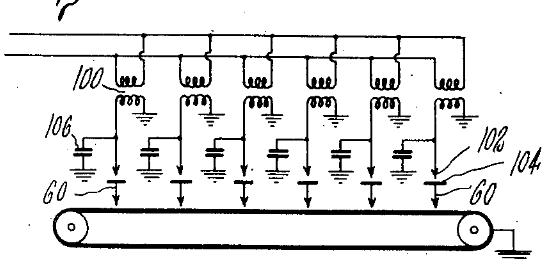


Fig. 4.

Fig. 5.



Inventor
Richard C. Thompson
by Nathaniel P. Wheaton
Atty.

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METHOD OF AND MECHANISM FOR CLASSIFYING FINELY COMMINUTED MATERIAL

Richard C. Thompson, Cohasset, Mass., assignor to Sturtevant Mill Company, Boston, Mass., a corporation of Massachusetts

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14 Claims. (Cl. 209—127)

This invention relates to a method of and apparatus for sorting out or classifying from finely comminuted or pulverized material particles of a size in the order of magnitude of one or two microns or less in diameter, these particles being separated from particles of larger size up to say 100 microns or so.

Heretofore it has been impossible to separate particles of such small size when in dry condition. Wet separation is objectionable since the product must be dried and usually has a tendency to cake on drying, this largely defeating the purposes of the fine separation. Another method which has previously been used to separate fine particles is a process of centrifuging in an air stream, but this process proves to be unsatisfactory when the particles to be classified are very fine, for instance, are of colloidal fineness, such as exhibited by kaolins. Such very fine particles do not respond to this method owing to the occluded film of air which surrounds every solid object. In objects of comparatively large sizes, this film of air is so thin as to have little or no effect on the characterictics of the object itself, but in objects of very small size the film, which is of constant thickness regardless of the size of the object, may be of greater thickness than the diameter of the object itself. In such cases, the mass of occluded film may be greater than that of the object so that two particles may have nearly the same effective specific gravity even though the actual densities of the solid material of the particles differ considerably. Similarly, when two particles are so small that the occluded film of air has a thickness as great or greater than the particles themselves, the respective sizes of the particles do not greatly affect the size of the spheres which include not only the particles but the air compartments about them.

It is an object of the present invention to provide a method of and apparatus for separating or classifying in a dry condition particles of sizes much smaller than can be classified by centrifugal means. According to the invention, electric sparks are discharged through a thin layer of finely pulverized material so as to blast the individual particles in the mass away from each other and at the same time to bring all of such particles to the same potential. These particles are then subjected to a field of electric potential such as causes the finer particles to move in one direction and the coarser particles to move in another direction. The finer particles are then collected by means to be described hereinafter, the coarser particles being collected by other means.

For a more complete understanding of the invention, reference may be had to the following description of certain embodiments thereof, and to the drawing of which

Figure 1 is a plan view of apparatus embodying the invention.

Figure 2 is a longitudinal sectional view of the same.

Figure 3 is an elevation of one of the spark-discharging members with a sectional showing of a conveyor thereunder.

Figure 4 is a diagrammatic view of the apparatus, indicating the wiring.

Figure 5 is a wiring diagram of a modification of a portion of the apparatus shown in Figure 4.

As shown in Figure 2, the apparatus may comprise a pair of suitable conveyors, which, as illustrated, may take the form of the endless belts **10** and **12**, each of which consists of a band of sheet metal or equivalent electro-conducting material supported by pairs of rolls **14** and **16**, respectively. A suitable housing **17** may enclose the conveyors, this housing being fully open at its ends, if desired, as shown. The lower conveyor **10** has an upper horizontal stretch which is parallel to and spaced from an opposite horizontal stretch of the upper conveyor **12**. These conveyors are driven at a relatively slow rate in such a manner that the opposed stretches move in the same direction. To this end, rolls **14** and **16** at one end of each conveyor may be supplied with gear wheels **24** and **26** meshing respectively with gear wheels **28** and **30**, the latter being mounted on a common shaft **32**. As shown, the lower roll **14** may also be provided with a worm gear **34** which meshes with a suitable worm **36** on a shaft **38**, this shaft being driven by a suitable motor **40** through any preferred type of reducing gears **42**. Finely pulverized material consisting of particles having diameters ranging from, say, 100 microns or so down to 1 micron or less is placed in a hopper **44**. Material from this hopper is forced by a feed screw **46** to discharge onto the supply end of the belt **10**, the feed screw being driven by the motor **40** through a suitable belt connection **48** or otherwise. The material deposited on the belt **10** is spread out into a thin layer, any suitable spreading means being employed for this purpose. As shown, a 4-bladed paddle wheel **50** is mounted so as to extend across the conveyor adjacent to the discharge end of the feed screw **46**. This paddle wheel is rotated by a suitable motor 52 in a direction opposed to the movement of the belt 10. This or equivalent spreading mechanism spreads the pulverized material in a thin layer on the surface of the belt 10. The motion of the belt 10 carries the layer of pulverized material under a succession of spark-discharging members 60, six such members being indicated in Figures 1 and 2. Each of these members may conveniently consist of a shaft 62 rotatably mounted above the belt 10 so as to extend across it from one side edge to the other. Suitable means for rotating the shafts 62 may be provided, such as pulleys and belt connections 63 indicated in Figure 1. Projecting radially from the shaft 62 are pointed elements 64 which are equal in length and are arranged in a helical series of a single turn extending along the portion of the shaft 62 which is directly above the belt 10, as indicated in Figure 3. By this arrangement, the elements 64 on each shaft 62 successively in turn become the nearest element to the belt 10, so that when sparking potential is impressed on the member 60 during rotation thereof, the sparks passing from the pointed elements 64 to the belt progress across the belt from one side edge to the other. The shafts 62 are preferably revolved at a relatively high speed compared with the rate of progress of the belt so that sparks are discharged from the elements 64 to substantially every point of the belt.

Between the opposed stretches of the two conveyors is supported an open screen 70 consisting preferably of fine piano wire which may be stretched tightly in a zigzag formation resembling the letter "M", as indicated in Figure 1. As shown in Figure 2, this screen is preferably nearer to the upper conveyor than it is to the lower conveyor. Between the screen 70 and the portion of the stretch 20 adjacent to the discharge end thereof is a suitable grid 72 consisting of spaced rods or wires. By means hereinafter described, the upper conveyor is maintained at a high positive electric potential, 8,000 volts being found satisfactory. The upper screen 70 is maintained at a high negative potential of 8,000 volts or so. The grid 72 is maintained at a positive potential of 5,000 volts or so. The lower conveyor is grounded.

The operation of the apparatus thus far described is as follows. Finely pulverized material is fed onto a metal sheet such as the supply end of the belt 10 and is spread into a thin layer by the spreader 50. This layer of material passes into the zone of operation of the successive spark-discharging members 60. The sparks which are discharged from the pointed elements 64 through the material to the belt 10 stir up the fine material into a cloud in the space between the two conveyors, thus deflocculating the mass, the particles in this cloud being separate from each other and of uniform electrical potential. The potential gradient between the screen 70 and the conveyor 10 induces charges on the opposite ends of each particle, the charges on the larger particles being sufficiently separated so that the particles are attracted to the conveyor 10. On the particles of one or two microns diameter or less the induced charges and the distance between them are so negligible that the particles migrate at random in the atmosphere between the two conveyors, most of them eventually coming into the field of the screen 70 where they are bombarded by negative ions and receive strong negative charges. They soon wander into the positive field from the belt conveyor 12 and are thus attracted to, and precipitated on, this conveyor. These precipitated particles travel with the conveyor 12 until they reach a suitable doctor blade 74 which scrapes them off so that they fall into a chute 76 leading to a suitable receptacle not shown. The larger particles which return to the conveyor 10 travel thereon until removed by a doctor blade 78. The positively charged grid 72 sets up a strong positive field near the discharge end of the apparatus which prevents migrating particles from traveling beyond it. Thus, practically no dust emerges from the discharge end of the apparatus, all of the particles being forced to one or the other of the conveyors.

Figure 4 shows a wiring diagram embodying the electrical part of the invention. A source of alternating current is conventionally indicated by the lines 80. The line voltage is stepped up to half the desired D. C. potential by a suitable transformer 82, one end of the secondary of this transformer being grounded. A voltage regulator 83 is preferably provided for the primary. The other end of the secondary is connected through a pair of rectifier tubes 84 to a bank of condensers 86. The filaments of the rectifier tubes are heated by any suitable means such as transformers 88. The positive pole of the bank of condensers is connected to the conveyor belt 12, the negative pole being connected to the screen 70. The bank of condensers is grounded at its center, as at 90. An off-center tap 92 on the positive side of the bank of condensers is carried to the grid 72. Suitable voltages are thus impressed on the upper conveyor 12, the screen 70 and the grid 72, the lower conveyor 10 being grounded, as at 94. Thus, for example, the upper conveyor may be supplied with a positive charge of 8,000 volts, the screen 70 with a negative charge of 8,000 volts, and the grid 72 with a positive charge of 5,000 volts. It is understood that, while these voltages have been found to be satisfactory in operation, the invention is not to be limited to these or other particular voltages.

A high-potential alternating current is supplied to the spark-discharging members 60, a potential of 10,000 volts being found to be satisfactory. For this purpose, a transformer 96 is connected across the supply lines 80 with a voltage regulator 98 in the primary circuit. The secondary of this transformer is grounded, the other end of the secondary being connected to one pole of each of a group of condensers 100. The other pole of each of these condensers is connected to the point 102 of a point-to-plate spark gap, the plate 104 of the spark gap being connected to one of the members 60 from which sparks are discharged to the belt 10. As indicated in Figure 3, each plate 104 may be mounted on the end of a shaft 62 to rotate therewith, the point 102 which cooperates therewith being stationary. An extra condenser 106 is connected to the secondary of the transformer 96 and is grounded directly without any spark gap. A choking coil 108 may be connected in the circuit between the secondary of the transformer 96 and the condensers in order to prevent feed back of high frequency current. When a discharge takes place from the points 64 to the conveyor belt a certain amount of rectification of the current results from this point-to-plate gap. This rectification is increased by the point-to-plate spark gap between 102 and 104. As is well known, when a condenser discharges, it tends to discharge beyond its total capacity, reversing its polarity with the result that the discharge from the condenser produces a high frequency oscillation, the typical discharge being a damped high-frequency wave. However, the impressed voltage on the condensers **100** is an alternating current, and a condenser of given capacity impressed with an alternating current of a given voltage will pass only a fixed amperage. Hence the condensers **100** serve two purposes. First, they serve to produce the high-frequency oscillations required for the deflocculation of pulverized material at the points **64**; and second, they serve to distribute the flow of current equally between the spark-discharging members **60** so that all six of these members will operate satisfactorily at the same time. The extra condenser **106** is not essential to the operation of the apparatus but serves to improve such operation by amplifying the high-frequency oscillations, thus appreciably increasing the output.

A modified form of wiring for the spark-discharging apparatus is shown in Figure 5. Instead of employing a single transformer to supply high potential for all of the spark-discharging members **60**, each of these members is supplied from a separate transformer **110**. One end of the secondary of each transformer is grounded, the other end being connected to a point-to-plate spark gap which in turn is connected to one of the spark-discharging members **60**. A grounded condenser **106** is also provided for each transformer secondary. Such apparatus functions satisfactorily although the current consumption is somewhat higher than in the apparatus indicated in Figure 4.

Some of the factors affecting the operation of the apparatus hereof will now be indicated. Thus, it is to be observed that the positively charged grid **72** deflects therefrom to either the upper or lower belt, as the case may be, any particles that may have received an adventitious positive charge in the course of their passage between the belts. Again, the positively charged particles are actively repelled by such grid **72** as they approach thereto; and such neutral and/or negatively charged particles as may land thereon quickly acquire the potential thereof and are immediately repelled thereby. To be sure, there usually is a thin layer or film of pulverulent material on such grid while the apparatus hereof is operating, but such layer or film is negligible insofar as concerns effect on the process hereof. It might also be noted such layer or film is constantly sloughing off from the grid **72** and renewing itself in the course of the process hereof.

Not only does the lower belt or conveyor **10** bear a "bound" charge (positive) induced thereon by the screen **70** but it also functions as a conductor for the high-frequency discharges from the points of the rotary members **60**, wherefore, there constantly ensues on such belt a highly erratic or variegated potential, which, however, constantly remains on a distinctly positive side. The rectifying effect arising from the point-to-plate discharge by the point-bearing members **60** relative to the belt **10** and the point **102** relative to the plate **104** is of considerable value in that the effect of such rectification is always to impress the particles with a negative charge rather than a positive one.

It is to be observed that the spark-discharging members **60** may be rotated in either direction. In any case, however, the speed of rotation of such members should be low enough so that no appreciable air-currents are generated thereby, for, should noteworthy air-currents be generated thereby, they are apt to carry or convey undesirably large particles to the upper belt **12**. As already stated, the potentials under which the apparatus hereof may be operated are subject to considerable variation. In general, it may be said that intensification or increase of potentials, especially when impressed on the screen **70**, increases both the size and quantity of material collected on the upper belt or conveyor **12**.

Apropos of the M-configuration of the screen **70**, it is to be observed that such configuration comports with complete coverage of the cross-sectional area of the upper belt **12** while at the same time making for the widest possible spaces for the travel of the migrant particles around the wires of such screen. Experimentation has shown that a number of short wires arranged transversely of the upper belt **12** can function fairly satisfactorily in lieu of the screen **70**, but that such expedient is attended by considerable increase in current consumption and by some decrease in recovery of the fine-particle size fraction as compared with the results attained when an M-configured screen was employed. It is possible also to use an X-configured screen and certain other wire-arrangements in lieu of the M-configured screen **70**, but, so far as applicant has to date determined, the M-configured screen **70** functions most satisfactorily for the purposes hereof.

While the drawing shows an endless belt **10** for conveying a layer of pulverulent material progressively through the apparatus hereof, other conveying means can be employed, including, for example, a vibrating plate of the type frequently used for feeding hot materials in the food-processing industry. Indeed, experiments have indicated that such last-described conveying means can be employed quite satisfactorily in lieu of such endless belt **10** as is specifically illustrated herein.

It is evident that various other modifications and changes may be made in the embodiments of the invention herein shown and described without departing from the spirit or scope of the invention as defined in the following claims.

I claim:

1. A method of classifying by size the particles of a particulate mass, which comprises deflocculating said mass while dry by discharging therethrough electric sparks capable of blasting it into a cloud of discrete particles, and subjecting the resulting discrete particles to a field of electric potential adapted to cause particles of relatively small size to move in one direction and particles of relatively large size to move in another direction.

2. A method of classifying by size the particles of a particulate mass, which comprises spreading said mass while dry as a thin layer on an electro-conducting sheet, discharging disruptive electric sparks through said layer to said sheet at substantially all points thereof and thereby disrupting it into a cloud of discrete particles, and maintaining an electric field adjacent to said sheet adapted to cause particles of relatively small size, which have been disturbed by said spark discharge, to move away from said sheet and to cause particles of relatively large size to return to said sheet.

3. A method of classifying by size the particles of a particulate mass, which comprises deflocculating said mass while dry by discharging therethrough disruptive oscillating electric sparks and

thereby disrupting it into a cloud of discrete particles, selectively acting upon the particles of relatively small size with a field of electric potential to separate them from the particles of relatively large size, negatively charging the separated particles of relatively small size, attracting said charged particles to a positively charged member, and collecting said particles from said member.

4. Apparatus for classifying by size the particles of a particulate mass while dry, which comprises an electro-conducting sheet adapted to support a layer of the mass to be classified, a plurality of pointed discharge elements above said sheet, means for progressively moving said layer relative to said elements so as to bring said elements successively into spark-discharging relation with said layer at different points, and means for impressing on said elements a high-frequency alternating current of suitable voltage for the discharge of sparks to said sheet.

5. Apparatus for classifying by size the particles of a particulate mass while dry, comprising a conveyor consisting of an electro-conducting band having a horizontal stretch, means for driving said conveyor, means for spreading finely comminuted material in a thin layer on said conveyor, spark-discharging means above said conveyor for deflocculating the comminuted material carried thereby, an upper conveyor above said spark-discharging means consisting of an electro-conducting band having a horizontal stretch spaced above and substantially parallel to the horizontal stretch of the first-mentioned conveyor, means for maintaining a positive potential on said second conveyor, an open screen between said conveyors, and means for maintaining a negative potential on said screen.

6. In an apparatus for classifying finely divided particles, means for deflocculating dry finely comminuted material comprising an endless metal band having a horizontal stretch, means for supporting and driving said band, means for supplying material in a layer near one end of said stretch, a series of spark-discharging members above said stretch, each said member including a shaft extending transversely above said stretch and a series of pointed elements projecting from each shaft and arranged in a single helical turn whereby said elements are successively in turn nearest to said stretch as the shaft is rotated, and means for impressing on said members a high potential alternating current which is evenly distributed among the several said members.

7. Apparatus of the class described, comprising a lower and an upper conveyor consisting of metal belts having horizontal stretches one spaced above the other, means for driving said conveyors so that the opposed stretches travel in the same direction, means for feeding to the lower conveyor a layer of finely comminuted material to be classified, means for discharging sparks through said layer to deflocculate said material, an open screen between said opposed stretches, means for maintaining high positive and negative potentials on the upper conveyor and screen respectively, and a positively charged grid between said opposed stretches near the discharge end thereof.

8. Apparatus for deflocculating dry pulverized material, comprising a metal support for a layer of said material, and means for discharging disruptive electric sparks to said support and through said layer and thereby disrupting it into a cloud of discrete particles, said means including a pointed element in spark-discharging relation to said support, a source of high-voltage alternating potential, a condenser, and a point-to-plate spark gap connected in series with said condenser between said source of potential and said pointed element.

9. Apparatus for deflocculating dry pulverized material, comprising a metal support for a layer of said material, and means for discharging disruptive electric sparks to said support and through said layer and thereby disrupting it into a cloud of discrete particles, said means including a plurality of pointed elements in spark-discharging relation to said support, a point-to-plate spark gap connected to each said element, a condenser connected to each said spark gap, and means for impressing a high voltage alternating potential on said condensers.

10. Apparatus for deflocculating dry pulverized material, comprising a metal support for a layer of said material, and means for discharging disruptive electric sparks to said support and through said layer and thereby disrupting it into a cloud of discrete particles, said means including a plurality of pointed elements in spark-discharging relation to said support, a point-to-plate spark gap connected to each said element, a condenser connected to each said spark gap, a transformer having one end of its secondary connected to all of said condensers, and an extra condenser connected to said end of the transformer secondary and grounded.

11. In apparatus of the class described, means for deflocculating and dispersing in the atmosphere the particles to be classified and means for classifying them by electrostatic forces, said classifying means consisting of a grounded electro-conducting plate and a positively charged electro-conducting plate substantially parallel to each other and containing therebetween a thin negatively charged screen comprised of wires of small diameter.

12. In an apparatus for classifying finely divided dry particles of matter according to size comprising, in combination, a positively charged electro-conducting surface, a grounded electro-conducting surface, said surfaces being substantially parallel with each other, a thin negatively charged screen positioned between said surfaces and including wires of small diameter, and means for delivering deflocculated particles to be classified into the weaker electro-static field maintained in the space between said grounded surface and said screen, whereby particles of different sizes are precipitated on said respective surfaces.

13. In an apparatus for classifying finely divided dry particles of matter according to size comprising, in combination, a positively charged electro-conducting surface, a grounded electro-conducting surface, said surfaces being substantially parallel with each other, a thin negatively charged screen positioned between said surfaces and including wires of small diameter, means for delivering deflocculated particles to be classified into the weaker electro-static field maintained in the space between said grounded surface and said screen, whereby particles of different sizes are precipitated on said respective surfaces, means for moving said surfaces in their own planes and in the same general direction to transfer the particles so precipitated, apparatus for removing the precipitated materials separately from said sur-

faces, and a positively charged grid interposed between said grounded surface and said negatively charged screen in a region remote from that in which said particles are so delivered.

14. In an apparatus for classifying finely divided dry particles of matter according to size comprising the combination of two electro-conducting conveyors having parallel runs spaced apart and presenting relatively large opposed parallel surfaces, means for maintaining one of said conveyors positively charged electro-statically and the other grounded, a negatively charged screen interposed between said parallel runs and in a substantially parallel relationship to them, said screen including relatively small wires, means for conducting finely divided material to be classified into the space between said screen and said grounded conveyor where said particles will be acted upon by the electro-static field in said space, means for maintaining said particles in a deflocculated state, a positive grid interposed between said conveyors and parallel to them but located in a region spaced from the zone of delivery of said particles into said space, and means for removing the material collected on said conveyors.

RICHARD C. THOMPSON.