

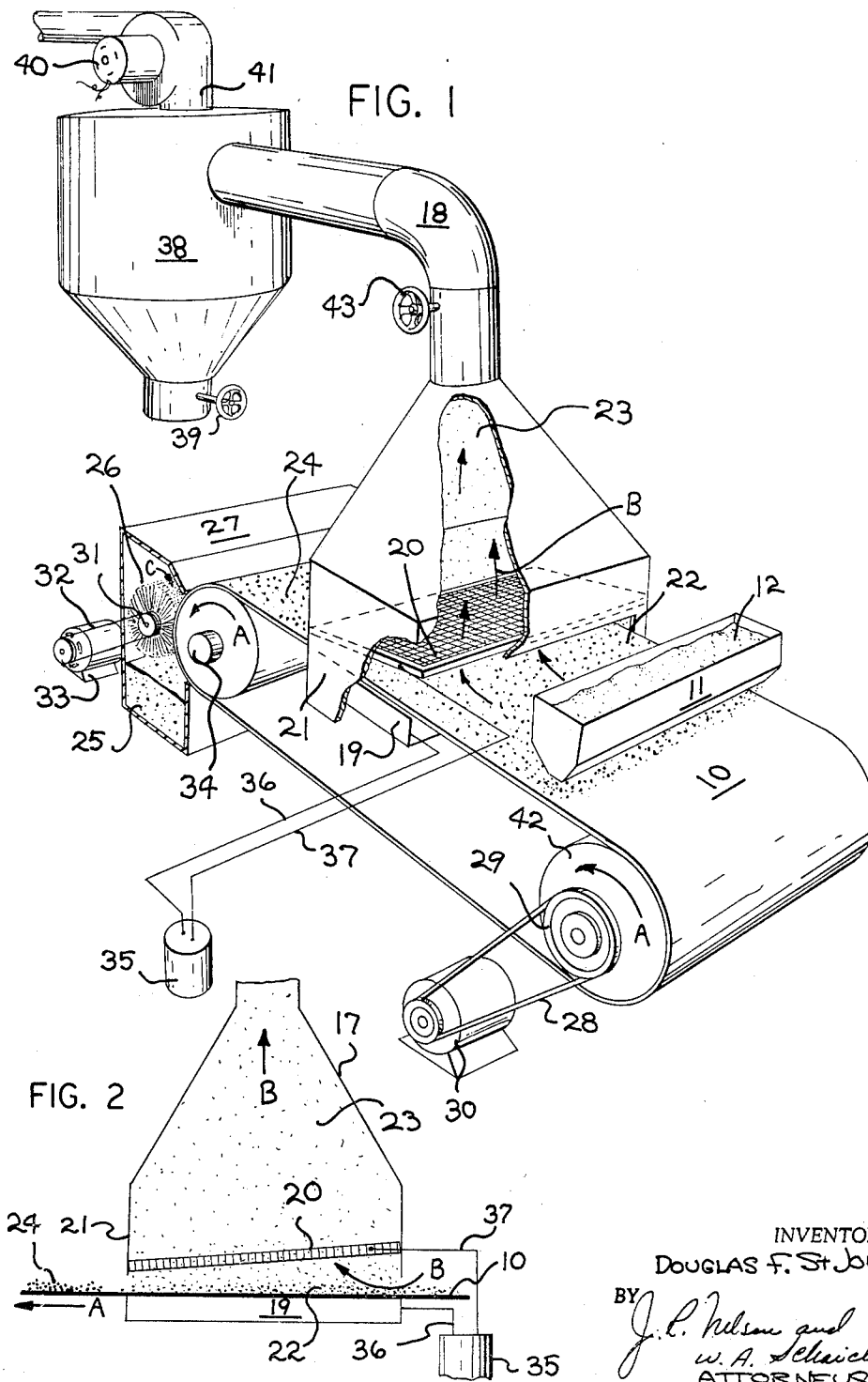
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PARTICULATE SEPARATOR AND SIZE CLASSIFIER

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PARTICULATE SEPARATOR AND SIZE CLASSIFIER

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ABSTRACT OF THE DISCLOSURE

A process for electrostatically separating a supply of particles into two fractions, one fraction of high bulk resistivity and the other of low bulk resistivity. The supply is fed into a classifying zone comprising an AC electric field established between two spacially separated, oppositely positioned, electrically isolated electrodes, one of which is of a foraminous construction. The frequency and voltage of the field are varied so as to separate the supply into the high and low bulk resistivity fractions. The low bulk resistivity fraction is propelled toward the foraminous electrode and those particles which traverse the apertures of the electrode are collected.

This invention relates to the separation and size classification of particulate matter; more particularly, it relates to methods and apparatus in which a screen is used to separate a supply of particles into desired and undesired fractions.

One of the oldest, and yet probably one of the most reliable methods of segregating a particulate mass according to particle size involves a process generally referred to in the arts as "screening" or "sieving." These screens, with which the particulate mass is brought into contact, essentially consist of a plurality of openings, or apertures, of predetermined dimensions. Particles having dimensions smaller than those of the screen openings pass through these apertures and are generally termed the fine fraction, those particles having larger dimensions are restrained from passage and comprise the coarse fraction.

Although some screens consist of slotted or perforated metal plates, or metal bars, those most commonly used comprise a woven wire cloth. The openings in these woven screens are designated, here in the United States, by either of two standardized series; these are the United States Sieve Series or the Tyler Standard Scale. Both standards represent the open area of these screens in mesh numbers, ranging from 2½ to 500, which have an inverse relationship to the size of the openings; for example, a 325 mesh screen will segregate particles into two fractions, one fraction having a minimum particle size of 44 microns and the other a maximum size of 44 microns, while a 500 mesh screen segregates sizes above and below 25 microns. Notwithstanding a slight variation in the actual size of the screen openings designated by the same mesh number, for all practical purposes the two standards may be used interchangeably.

While a vast spectrum of different mesh screens are available, those finer than 150 mesh are rarely used because their capacities, that is the feed rate of particulate matter per unit screen area per unit time, are too low for practical commercial operations. These decreased capacities of the higher mesh screens are caused by either an accumulation of powdery fines within the openings, or by the entrapment of oversize material within said openings; both of these possibilities, either jointly or

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severally, produce a damming or blinding of the open areas. Numerous endeavors have been made to minimize this blinding tendency by various design modifications of the screening process. Those skilled in the art readily appreciate the fact that the most widely accepted improvements, such as gyrating sifters and shaking or vibrating screens, have only resolved the capacity problem to a moderate degree. The reason for only a nominal increase in the capacity of higher mesh screens appears to be that the force imparted to the particles, resulting from either vibration or shaking, is insufficient in magnitude to rupture the adhesive bonding characteristics of the particles to the screen. Furthermore, these improvements generally provide for the approach of the particles, relative to the screen, at an oblique angle; this oblique approach in effect reduces the open area of the screen when compared to that actually available should the particles approach normal to the screen.

Another drawback to conventional sizing by screening is the fact that the screen classifies particulate matter exclusively on its particle size. Consequently, in the production of particles with a maximum allowable particle size and having a specified electrical conductivity, as for example, the coating of inherently resistive organic polymer particles with a conductive composition to produce a particulate mass of a certain particle size and having a conductive surface, the conductive product may include non-conductive contaminants because of a deficiency in the coating technique. If conventional screening is used to size the desired product there is no way of removing the undesirable, non-conductive contaminants which are of the same size as that of the desired product.

Accordingly, it is an object of this invention to provide for a novel screening method and apparatus for separating a supply of particles into a desired and undesired fraction.

It is another object of this invention to provide an improved screening method, and apparatus therefor, which minimizes the blinding of the higher mesh screens.

It is another object to provide a novel method and apparatus for screening particles which greatly increases the capacity of the screen.

Yet another object of this invention is to provide for a separating method and apparatus in which particles to be size separated are propelled and approach substantially normal to the size segregating member, thereby providing for the availability of the maximum open area of said member for the passage of the finer constituents of the particulate mass.

It is yet another object of the invention to provide for a separating method and apparatus in which the particles having a desired property are propelled through a separating member, and in which the particles which do not traverse said member are repelled therefrom.

It is still a further object to provide a method and apparatus for separating a fraction of powder, having preferential electrical properties and which is below a predetermined particle size, from a supply of powder having a much wider size distribution, wherein any particles in said supply which have electrical characteristics other than those deemed preferential are isolated from the desired size portion, notwithstanding an identity of particle size.

In the achievement of the foregoing, and other objects, the invention contemplates subjecting a supply of particles to an electric field established between two spaced, electrically isolated electrodes, one of which is a screen having a plurality of apertures, adjusting said electric

field to cause the particles existing in said supply with the desired properties to levitate and oscillate between the spaced electrodes, collecting those particles passing through the screening member and withdrawing from classifying zone those particles not traversing said screen. As used herein, the term screen is intended to be generic and to include perforated or slotted plates, woven wire screens and other conductive foraminous members.

The foregoing objects, and others, will become apparent by reference to the appended drawings of which:

FIGURE 1 is a perspective view, partially in schematic, of an apparatus capable of operating in accordance with the present invention.

FIGURE 2 is a schematic representation of the general mode of operation of the present invention.

Since the subject invention contemplates subjecting the particulate mass to an electric field, it is felt that an understanding of this invention will be facilitated if the nomenclature hereafter used to distinguish the electrical properties of different powders is set forth. Particulate matter having a bulk resistivity in excess of 10^8 - 10^9 ohm x cm. will be termed "resistive" or "non-conductive" while powders having values below said range will be termed "conductive." The method used to determine these bulk resistivities consists of: filling or packing said powder into an open ended insulating container of predetermined geometrical dimensions and placing conductive electrodes, possessing a substantially planar powder contact surface, onto the upper and lowermost ends of the container, being sure to have intimate contact between the respective electrode surfaces and the powder filling the container. Using a Keithley Model 610A Electrometer, the resistance of the bulk powder is measured and the resistivity calculated from the formula:

$$R = r \frac{L}{A}$$

where R is the measured resistance; r is the desired bulk resistivity; L is the axial length of the container or the distance between the innermost contact surfaces of the electrodes; and A is the radial, cross-sectional area of the bulk powder configuration. Specifically, the resistivity was measured using a cylindrical container of acrylic polymer composition, having an inside diameter of about 5 cm. and an axial length of approximately the same magnitude. The electrodes were of aluminum, having the geometrical shape of a disc whose outside diameter was substantially equivalent to the inside diameter of the cylindrical container, said electrodes being forced, much the same as a rubber stopper is forced into a test tube, into an internal relation to the cylinder.

In the drawings, which show a preferred embodiment of this invention, the particulate mass 12 containing particles having the desired and undesired properties is supplied to a conventional feeding hopper 11; this hopper distributes the particles unto a continuous belt 10 which is disposed beneath said hopper, thereby forming a layer of particles 22 on the belt. Said belt and particle layer, is continuously displaced (Arrow A) away from the hopper and toward the separating zone by means of a cylindrical driving roller 42; said roller is positioned to make contact with the internal surface of said belt, at one extremity thereof, and thereby also provides for the vertical support of the belt. This roller may be driven by any suitable power supplying members, such as a motor, V-belt and pulley arrangement, respectively numbers 30, 28 and 29. A suitable idler assembly 34 is internally positioned at the belt extremity opposite that of the driving roller 42 to provide for the additional vertical support of the belt.

As a result of the belt displacement, the powder layer 22 is continuously introduced into the separating zone or chamber 17. Internal to the chamber 17 is a spaced, electrode system comprised of a lower metallic member 19, and an upper metallic member 20 which is the separating screen; these electrodes are respectively connected

by means of electrical leads 36 and 37 to a suitable electrical power source 35 and are electrically isolated from each other, preferably by their being suitably fastened to the insulating sides 21 of the chamber 17. The belt 10 is preferably of an electroconductive or semi-conductive composition and the lower metallic electrode, which may for example be an aluminum plate, is horizontally disposed beneath and in substantial contact with the entire transverse dimension of said belt, thereby making said belt an approximate equipotential surface of the lower electrode 19. Spaced above the belt 10 and powder layer 22 is the upper screen electrode 20, which may, for example, comprise a brass woven wire screen. For reasons to be subsequently described, the upper and lower electrode members are preferably inclined to each other, the screen being spaced nearest the lower electrode at the exit of the separating chamber and furthest said lower electrode at the entrance.

Additionally, the separating chamber 17 is maintained under a negative pressure by means of an air blower 40, having its suction side connected by a duct 41 to a conventional bag collector 38. Said bag collector, which is equipped with a discharge valve 39 for removing the collected particles, in turn transmits the negative pressure to the chamber by means of a connecting duct 18. This negative pressure, which may be regulated by valve 43, maintains an air draft in the chamber 17 moving in the direction away from the electrodes (Arrow B) whereby the desired fraction of particles 23, upon traversing the apertures of the screen, are pneumatically removed and collected in bag collector 38.

The undesired fraction of particles does not pass through the screen and is removed from the separating chamber 17 by means of the continuous belt 10 as a residual layer 24; this layer is collected in a reclamation chamber 27. The reclamation chamber generally comprises a box positioned on the outlet side of the chamber, at the extremity of the belt 10, and is equipped with a cylindrical brushing member 26. Said cylindrical brush is positioned in contact with the entire transverse dimension of the belt 10 and is rotated in a clockwise direction by means of the motor, V-belt and pulley apparatus, respectively designated members 33, 32 and 31. Functionally, the brush dislodges the residual layer 24 from the belt whereby said layer is collected as a residual bulk 25 within the chamber 27.

The following explains in more detail what occurs within the separating chamber when the supply of particles is introduced thereto and the electric field is applied. This explanation includes a discussion of the observed phenomenon and what is thought to be the theoretical reasons therefor. It is felt that the latter discussion will help facilitate an understanding of this invention and is consequently included not by way of limitation but is intended to be merely exemplary.

When the layer of particles 22 are interposed between the spaced electrodes 19 and 20 and an electric potential is applied thereto by means of the power supply 35, the particles tend to become electrically charged. This charging mechanism may be likened to the charging of a parallel plate capacitor, which is commonly thought of in terms of an RC "time constant." Consequently, the time for particle charge transfer may be considered as being proportional to the product of its resistance and capacitance. Furthermore, since the capacitance of different materials of approximately the same size and shape will not vary to the degree that the resistance may vary, and considering the fact that the resistance of a material is proportional to its resistivity, the RC time constant may be approximated, for purposes of this discussion, by the resistivity of the particle. To further illustrate this charging mechanism, it may be well to consider the action of uncharged, electrically dissimilar particles, as for example a 50 micron conductive and non-conductive particle, when placed between plate-like electrodes of differ-

ent DC potential and in electrical contact with one of said electrodes. Both particles, by a mechanism of inductive charging, will tend to become charged to the polarity of the electrode with which they are in electrical contact; however, the more conductive particle will charge much more rapidly than will the nonconductive particle because the former has an inherently smaller time constant. If for example, the non-conductor has a resistivity of 10^{15} ohm x cm. and the conductor is 10^6 ohm x cm., it can be readily seen that the time constant of the former is substantially larger than the latter. Providing the electric field between the electrodes is of sufficient magnitude, the conductive particle will continue to charge until the force of attraction between the particle and the oppositely spaced electrode is sufficient to propel this particle to this oppositely spaced electrode; during this same time increment the resistive particle will remain electrically inert and stationary upon the lower electrode. Consequently, by adjusting the DC potential of the power supply 35 and the rate at which particles are supplied into the electric field, the conductive particles in the layer 22 can be propelled to the screen 20, while any non-conductive particles in said layer will remain electrically inert because of their high time constant. This method of propelling particles to a size discriminating screen provides for the maximum availability of the open areas of said screen because the force of the electrical field causes the charged conductive particles to approach substantially normal to the screen and not at a smaller, oblique angle.

Either of two possibilities, or a combination thereof, will occur when the particles which have been propelled to the screen, as described above, come into proximity with the screening member. First of all, those particles having a particle size smaller than that of the screen apertures pass through the screen and enter the negative pressure zone of chamber 17. The negative pressure and its resultant air draft will pneumatically convey these traversing particles 23 out of the chamber into the bag collector where they are collected as the desired fraction. Secondly, those particles which are too large to traverse the screen strike the metallic portions of said member and are arrested from passage. Upon striking the oppositely charged screen-electrode, the conductive powders will dissipate their original charge and recharge to the polarity of the electrode with which they are now in contact; the result will now be an electrical repulsion of these particles from the screen electrode toward the other electrode. Once these repelled particles electrically contact said other electrode they again dissipate their charge and recharge to the polarity of this electrode, whereby they are again propelled to the screen electrode. Thus, the particles in the layer 22 having conductive properties are caused to alternately contact the upper and lower electrode system while those particles which are resistive remain electrically inert because of their higher charging time. This oscillating movement provides the screening operation with several advantages. First of all, particles which have a desired size may not approach an open area of the screen but may be propelled against the wire mesh; thus, by causing numerous oscillations the probability of an undersize particle approaching the screen at an open area is greatly increased. Secondly, the blinding of the screen is greatly minimized because the particles which tend to dam the open screen areas undergo a force of electrical repulsion from said screen.

The same phenomena noted above with a DC potential may be accomplished by a variable frequency AC power supply, that is, by suitably adjusting the voltage and frequency, the conductive particles can be made to oscillate while the resistive particles, will remain inert. This oscillating movement of conductive particles between spaced, conductive electrodes under an applied AC potential may be the result of either of two possibilities. First of all, it would seem that the frequency can be so adjusted that the particle actually has time to discharge and recharge to the polarity of the electrode with which it is in contact

before said electrode reverses its polarity; that is, the oscillation results from a charge transferal, in much the same fashion as a conductive particle with a DC potential, notwithstanding the relative polarity reversal of the electrodes. Another possible explanation for the oscillation of a conductive powder in an AC field is that there may be no dissipation of electrical charge on the particle and the repulsion or attraction of the particle, as the case be, simply results from the change of relative polarities of the respective electrodes. Whatever may be the proper explanation, it has found that conductive particles can be made to oscillate between electrodes attached to an AC supply and, if non-conductive materials are present in a supply of powder they will remain inert relative to the more conductive materials.

In a preferred embodiment of this invention, the electric field established between the screen electrode and the lower electrode is a gradient or non-uniform electric field, that is, a field whose intensity varies and preferably increases along the electrodes in the direction of the belt displacement (Arrow A). This gradient field may, for example, be created as in FIGURE 2 by inclining the screen electrode 20 toward the lower electrode 19 such that said electrodes have a maximum spaced relation at the point where particles are introduced into the electric field, and a minimum spacing at the exit of the separating chamber. In addition to causing the successive oscillations of the particles, the gradient electric field imparts a horizontal displacement to said particles in the direction of increasing field intensity and consequently facilitates the removal of those oscillating particles from the field which do not traverse the open areas of the screen.

Because of the fact that the power requirements of the electrical supply, used in this invention to cause the oscillation of the particles having the preferential conductivity, are dependent on the nature of the particles, their feed rate and the size and spacing of the electrodes, it would be misleading to stipulate any exact power requirements for each supply. However, in order to facilitate the duplication of this invention, the following summary represents the general operation and conditions employed by the inventor. It should be noted that the conditions are exemplary and are not intended as any limitation upon the scope of this invention.

The powders used ranged in size from approximately 1 to 75 microns and the screens used for size classification ranged from 135 mesh to 500 mesh. Bulk resistivities of the conductive powder portions were below 10^8 – 10^9 ohm x cm. while the resistive powders had resistivities in excess of 10^{12} – 10^{13} ohm x cm. These powders were supplied to the electric field upon a continuous, $\frac{1}{8}$ inch thick, neoprene belt having a width of about 5 inches; the belt was displaced at the rate of 10 feet per minute and contained a layer of powder approximately $\frac{1}{16}$ to $\frac{1}{32}$ inch in height and 5 inches in width. The electrode system was comprised of an upper woven brass screen electrode and a lower aluminum plate electrode, both electrodes having a length of 4 inches and a width of 5 inches. These electrodes were spaced to provide for an air gap of $\frac{1}{8}$ to $\frac{3}{4}$ inch between the upper surface of the belt and screen. Additionally, the powders used required electric fields ranging from 10,000 volts/inch to 50,000 volts/inch in order to produce the propulsion and oscillatory motion previously described. Operating within the spectrum of exemplary conditions noted above, the inventor successfully utilized a DC power supply capable of 30,000 volts and 5 milliamperes, and a variable frequency AC supply, capable of 0–1000 cycles per second, nominally possessing the same capacity as the DC source.

I claim:

1. In a process for electrostatically separating a supply of particles into two fractions wherein the supply is fed to a classifying zone comprising two spacially separated, oppositely positioned, electrically isolated electrodes, one of which is a foraminous electrode having a plurality of

apertures, the improvement which comprises establishing an AC electric field between the electrodes and feeding a supply of particles to the electrode opposite the foraminous electrode so as to conductively charge the particles on the surface of said electrode, the electric field having sufficient frequency and voltage to differentiate between particles of different bulk resistivity such that the supply is separated into a fraction of low bulk resistivity particles and a fraction of high bulk resistivity particles, each relative to the other, said low bulk resistivity particles being propelled to the foraminous electrode and said high bulk resistivity particles being retained on the surface of the electrode opposite the foraminous electrode, and thereafter collecting those low bulk resistivity particles which traverse the apertures of the foraminous electrode and withdrawing the remaining particles from the classifying zone.

2. The process of claim 1 wherein the low bulk resistivity fraction has a bulk resistivity of less than about 10^8 - 10^9 ohm-centimeter.

3. The process of claim 2 wherein the magnitude of the electric field potential is about 10,000 to about 50,000 volts per inch.

4. The process of claim 3 wherein the particle size of the supply ranges from about 1 to about 75 microns.

5. The process of claim 1 wherein the frequency and

voltage of the field are maintained at a sufficient level to enable those particles not passing through the apertures to oscillate in the electric field.

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