Nov. 7, 1944. R. C. JOHNSON ET AL 2,361,946

ELECTROSTATIC SEPARATION OF PARTICLES

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Fig. 2

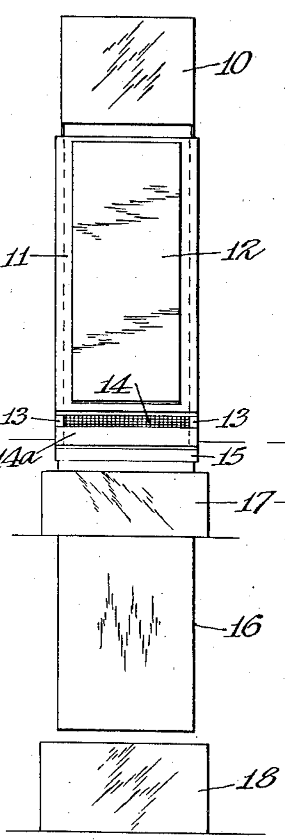

Fig. 1

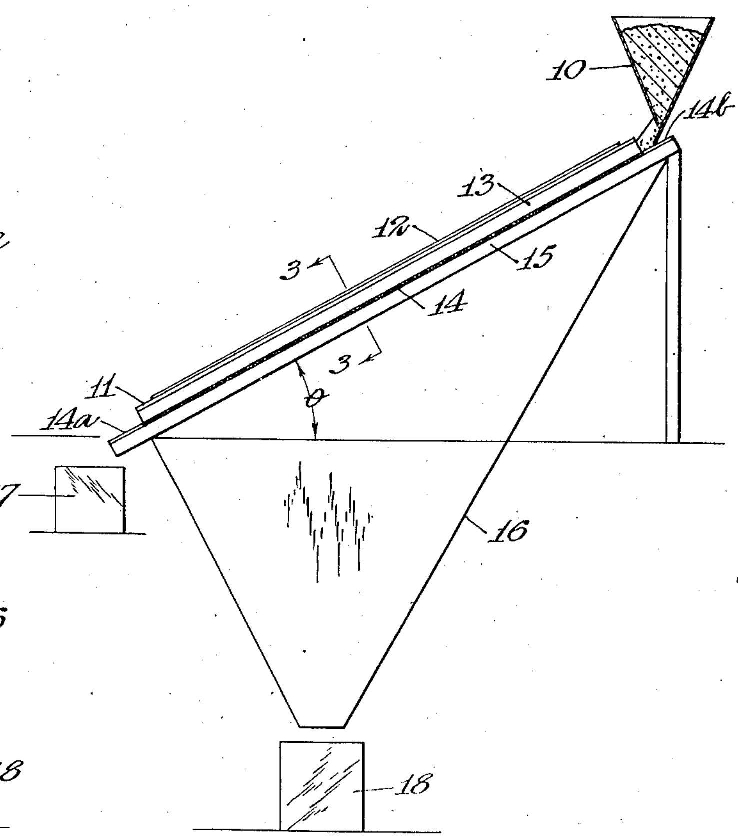

Fig. 3

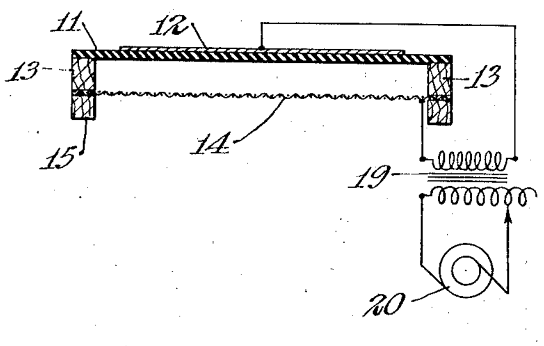

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Fig. 4

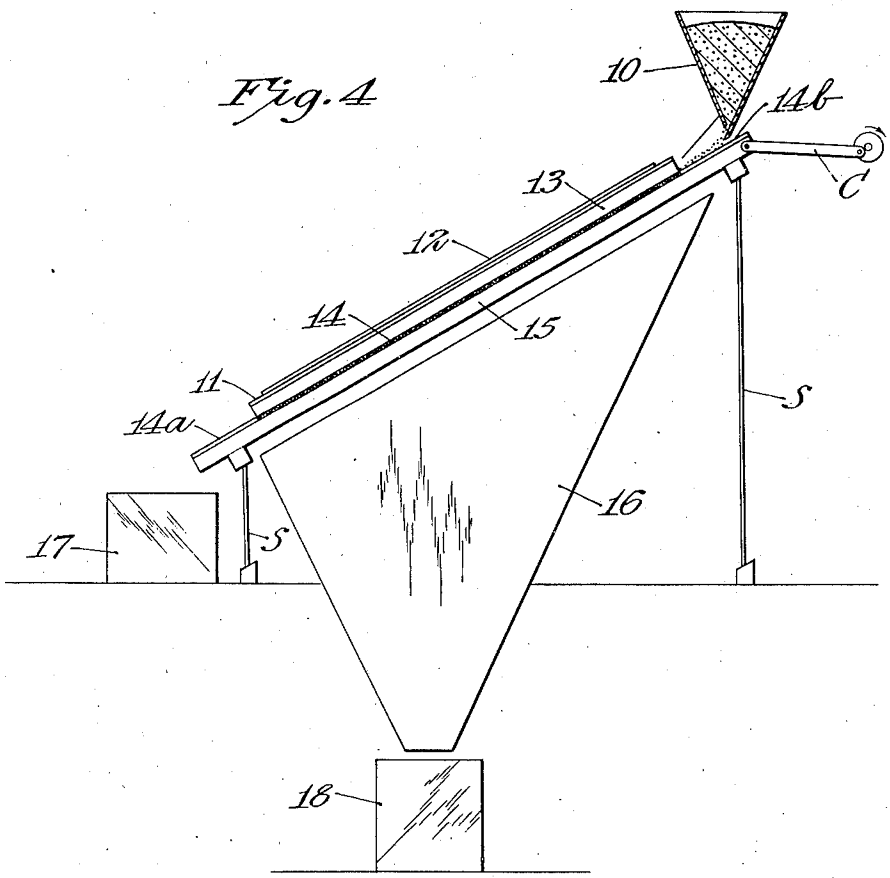
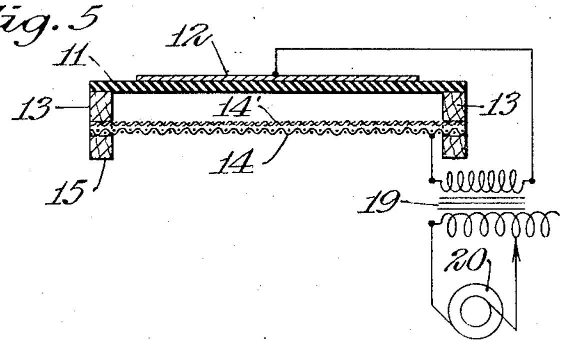


Fig. 5



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2,361,946

ELECTROSTATIC SEPARATION OF PARTICLES

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Application August 1, 1940, Serial No. 349,060

5 Claims. (Cl. 209—127)

This invention relates to separation and sorting of small particles of matter according to their size and shape by the use of an electrical field, e. g. an electrostatic field, or especially by the use of the latter in connection with a screen or sieve.

The prior art has used both electrostatic and magnetic fields to help separate one kind or type of material from another. Such separation has dependent on there being in the mixture of particles one kind that is more susceptible to propulsion by electrical fields than are any of the other kinds of material present so that such particues are electrically drawn away from, or propelled away from the locus of the remaining less susceptible particles, whereupon they may be collected in a container separate from the others.

In such cases the entire mixture of particles may sometimes be moved by the field, the more susceptible particles being removed from the locus of the others by reason of their faster travel, but such separation still depends on there being in the mixture two or more "kinds" of particles, electrically considered.

Before the present invention, however, there was no electrical screening method nor apparatus known to us whereby relatively small particles of matter could be separated and sorted according to size and shape from mixtures in which all particles were of the same or similar material and of approximately the same weight, their only chief difference being a difference in shape.

For example, in the manufacture of the sheeted abrasive articles commonly called "sandpaper," the crushed mineral particles or "sand" has some grains that are chunky, square or block-like, but there are usually mixed with them, when they come from the crusher, many long slender needle-like or splintery particles. For some purposes, sandpaper made from the block-like grains is desirable. For other purposes, only the splintery types are acceptable, for example, when manufacturing sandpaper in which the grits are oriented electrostatically with their longest axes perpendicular to or at some other predetermined angle to the working surface of the ultimate article, as disclosed in Smyser Patent No. 1,788,600, and other patents.

But in order to separate and sort the grains that emerge from the crusher according to both size and shape, no method has heretofore been available except that of mechanical sifting, and that method has been undesirable for many reasons including expense because of the repeated siftings that are necessary before all or nearly all the desired class of particles will sift out.

Therefore, an object of our invention is to provide a new and improved method and appatus for separating particles of matter:

Which will not only retain the simplicity of separation by sifting or screening, but will simplify to an even greater extent the mechanical operations now required for sifting and at the same time produce faster and cleaner grading, inexpensively;

Which will produce clean and complete grading of particles according to shape as well as size in substantially a single operation;

Which can utilize electrostatic fields and their capacity to move small particles of matter even though all the particles in a given mixture are of one kind and of the same approximate weight; and

Which is simpler, less expensive and more nearly productive of 100% accurate grading than are the mechanical methods heretofore known to us for the shape-grading of mixtures of particles that are of a generally uniform kind, size and weight.

Our invention, in accomplishing its objectives, utilizes electrical principles which, of themselves, are well known, but which, to our knowledge, have heretofore never been applied to the present problem, nor to the present art, nor in the particular manner hereinafter illustrated.

An electrostatic field is a condition of electrical stress existing between two bodies called electrodes between which there exists a difference of electrical potential, that is, they are charged to different values of potential. The stress is a relative proposition.

Perhaps the simplest electrical field is that existing between flat electrodes, having parallel surfaces and spaced a certain distance apart in a medium such as air. Such a field may be employed in the present invention.

One property of an electrostatic field is to produce motion of a body that is placed therein. When plate electrodes are used, the most efficient way of employing the field to move the body is by bringing the body in contact with one of the electrodes, whereupon the body, for example a mineral particle, will be charged up to the same polarity as the electrode which it touches, and since bodies carrying like charges repel each other, it will be propelled away from the first electrode towards the electrode of opposite polarity. Translation or movement of a particle may also take place even though the particle is not in contact with either electrode, especially if the particle is pointed at one or both ends, though in a lesser degree than when the particle contacts the electrode.

A second property of a field is dispersion. If a number of bodies brought within a field all receive a like charge they repel each other and thus tend to become evenly dispersed or spaced from each other throughout the field.

In visualizing the field and its effect upon particles of matter, the stress that exists between the plates may be thought of in terms of imaginary straight lines running between the plates perpendicular thereto and parallel to each other.

Different substances placed within a field exhibit different degrees of capacity for contending with these electrostatic lines of force, that is, some substances permit passage of the lines therethrough more easily than do others. For example the lines pass through most solid substances more easily than through air. Therefore, when a particle of matter, such as a mineral particle, is placed in that field, the lines of force tend to converge and go through that body, since that is the easier path, whereupon the particle, if it be elongate in shape, tends to turn or position itself in the field, with its longest axis parallel with the lines of force so that it will shorten the air gap, so as to give the maximum number of lines the minimum of resistance. This tendency of particles to align themselves with these force lines is known as orientation, which is a third property of a field.

In our invention these properties of a field are employed to sort particles according to their sizes and shapes by providing a metallic screen or sieve or equivalent whose perforations are of a size slightly greater than the maximum short diameter of the elongated or sliver-like particles and of a size to permit passage of all the particles that are to be sorted out. The screen is preferably positioned to form the lower electrode of an electrostatic field, a second electrode being placed above it, so that when the two are connected to a source of difference of electrical potential and particles are propelled along the top surface of the screen electrode, the entire layer or bed of particles is violently agitated by the field so as to bombard both electrodes, and all particles that are elongate in shape will turn with their longest axes perpendicular to the screen so that those whose short diameters permit them to pass through the screen may be passed or propelled therethrough in the manner hereinafter described.

One form of apparatus embodying the features of the invention is illustrated in the accompanying drawings in which:

Figures 1 and 2 are side and front elevations, respectively;

Figure 3 is a sectional view of the electrode structure taken on the lines 3—3 in Figure 1;

Figure 4 is a side elevation showing an alternative form of the invention in which the classifying screen is vibrated; and

Figure 5 is a sectional view of structure, comparable to though differing somewhat from Figure 3, and showing an alternative form of the invention which provides a classifying screen in addition to the screen electrode.

Referring more in detail to the drawings, in the different figures of which like reference characters denote similar parts, the hopper 10 contains the particles to be classified and may have a means, not shown, for feeding the particles at a definite rate into the area between the upper plate electrode 11 and the lower screen electrode 14. Upper electrode 11 consists of a sheet of dielectric material, such as "Herkolite" or phenol-fiber, having a sheet of metal 12 such as aluminum foil, cemented to its upper surface. The lower electrode 14 may be a metallic screen supported on a framework 15. The screen 14 may function both as the lower electrode and as the classifying screen, as shown in Fig. 3, in which case its openings are of a size to permit passage of the particles to be separated. An alternative form of the electrode 14 may be a screen of a larger mesh, for example as shown in Fig. 5, in which case it functions only as an electrode, the actual classifying being accomplished by means of a silk or other classifying screen 14' positioned between the electrodes, preferably parallel with and adjacent to the lower electrode 14. The electrodes 11 and 14 are held apart by insulating spacers 13 which may be of impregnated maple, "Herkolite" or any other good electrical insulating material. The spacers 13 serve both to separate the electrodes and to confine the mineral laterally to the electrode area.

The upper and lower extremities (14*a* and 14*b*) of the screen 14, that is, those portions which extend beyond the limits of the "thruage" hopper 16, may be of unperforated sheet material.

The electrodes 11 and 14 are supplied with potential from a transformer 20 which may, for example, be adjustable to supply from 30 to 50 kilovolts at 60 cycles from its secondary. The upper electrode is energized by connecting one of the transformer leads to the metallic plate 12. The adjustable primary of the transformer 20 may be supplied from any alternator or supply line at, for example, 115 volts, 60 cycles. The surfaces of the electrodes are preferably parallel and the combined electrode and screening structure is set at an angle θ (Figure 1) with the horizontal. The value of θ may be adjusted within wide limits to suit varying conditions. In one test, where the potential across the electrodes was 40 kilovolts at 60 cycles, the value of θ for best results was found to be 27.4 degrees.

Other frequencies than 60 cycles may be employed within limits determined by voltage, spacing of electrodes, size of particles, etc. For example, for agitating beds of larger particles agitation may be accomplished more successfully by the use of freqencies lower than 60 cycles. Also it is to be understood that the proper functioning of the apparatus does not depend on the use of a sinusoidal wave shape. For some types of particles it may be found more suitable to use an impulse type wave or in other instances a square wave. It is to be understood that the proper wave shape and frequency should be chosen best to produce agitation of the particular material to be treated.

Direct potentials may also be used with quite satisfactory results, in which case it would be necessary to replace the insulated upper electrode 11 with a bare metallic electrode.

The entire high voltage structure may be left ungrounded or either terminal may be grounded without disturbing the operation of the machine. However it is often desirable to ground the terminal that connects the lower electrode 14 in order that the supporting framework 15 and the hopper 10 may be kept at ground potential. This, however, is a structural consideration and is not fundamental to the operation of the equipment.

The collecting hopper 16 collects the particles that pass through the classifying screen 14 or 14' and feeds them to container 18. Such particles are termed the "thruage."

Container 17 collects particles which, by reason of their being too large to pass through the screen openings, pass down through the electrode structure and over the screen end. This fraction of the particles is termed the "overage."

In operation, particles that are fed from hopper 10 flow by gravity from the mouth of the hopper to a point just inside the active area of the electrostatic field.

At this point, when alternating potential is used, the particles are charged by contact with the lower electrode 14 and each individual particle is made to dance up and down from one to several times during each voltage pulsation. Since, for a 60 cycle voltage, there are 120 pulsations per second, it may readily be seen that each particle is presented with a very great number of chances to pass through the lower screen openings.

When direct potential is used, the particles also dance up and down, though at a frequency not so great. A particle, by reason of the charge received from the lower electrode, is propelled upwardly to the upper electrode, from which, by contact therewith, it receives the opposite charge and is propelled back downwardly to the lower electrode. Particles which do not touch the upper electrode are also naturally propelled downwardly by gravity in the illustrative embodiment of apparatus herein shown.

The particles also tend to disperse themselves evenly throughout the field.

In either alternating or direct fields, the elongated particles are oriented with their longest axes generally perpendicular to the lower screen electrode and during the course of repeated downward propulsions, each particle at some time strikes precisely into one of the openings in the lower screen or electrode, in which case the particle's momentum is sufficient to cause it to pass completely through the opening and out of the influence of the electrostatic field, whereupon it is collected by the hopper 16.

Under some conditions there may be a tendency for particles that are slightly over-size to become wedged in some of the screen openings temporarily so that the screen develops "blind spots."

This is a situation that occurs frequently in the mechanical screening of the prior art and there are many well-known means for counteracting it such as vibrating or rapping the classifying screen, any of which may be employed in connection with the present invention.

One example of such well known means is a motor driven crank C (Figure 4) connected so as to vibrate the framework 15 which holds the classifying screen and the attached electrode structure, it being of course understood that when such vibration or other movement is employed, the said framework must be movably supported as by, for example, flexible supports S in Figure 4, free from contact with the hoppers 10 or 16 or other stationary parts. It will also be understood from the previous description herein that vibration, etc., may be employed either when a single screen 14 is used (as shown in Figure 3) or when the screen 14 serves only as an electrode with a classifying screen 14' above it (as in Figure 5); and, conversely, either the single or the double form of screen may be used with or without vibration or periodic rapping.

Although the particles vibrate back and forth between the electrodes in paths that tend to be perpendicular thereto, the sloping position of the structure at an angle to horizontal permits the force of gravity to deflect each particle from its normal path slightly during each passage up and down so that all particles regardless of size and shape pursue a slightly zig-zag course downwardly toward the lower end of the structure.

During this passage, by reason of their orientation as above described, the elongate or slivery particles pass through the screen into the thruage hopper 16 while the larger blocky particles and the flat particles are held on top of the screen 14 or 14' and pass down into the overage bin or container 17. Thus it may be seen that classification of particles is accomplished according to both size and shape. This invention reduces to a low point and, in fact, substantially eliminates the passage of desired elongate abrasive particles into the overage bin 17, which would occur in substantial measure if mechanical screening only were employed.

Extremely small round or blocky particles called "fines" occur in some mixtures. These pass through with the long particles into the receptacle 18 and may be readily sifted out in a fine mesh vibrating sifter since the long particles lie flat in such an operation.

Mixtures containing no particles of elongate nature may be classified according to size alone by our invention.

Total time of transit of the large particles through the structure and into the overage collector 17 may vary considerably with conditions, typical times being from 3 to 10 seconds, but it will be understood that this is merely illustrative and in no way limitative, as the time of transit may vary widely.

Reference has been made to separation of mineral or abrasive particles such as are used in the manufacture of abrasive articles, but it is to be understood that our invention is not to be confined to such particles, but may be employed also in the separation of other particles of matter that are susceptible to the influence of an electrical field.

While we have described and illustrated our invention in various details, it will be understood that the same is exemplary and that all variations and modifications within the scope of this application, including the appended claims, are contemplated.

We claim:

1. An apparatus for the separation of particles of matter from a mixture, comprising a substantially flat screen electrode of large mesh with a classifying screen of smaller mesh superimposed upon and adjacent to said screen electrode, a substantially flat solid electrode positioned above, substantially parallel to and spaced from said screen electrode, and also spaced from said classifying screen, said electrodes being connected to a source of electrical difference of potential, the perforations of said classifying screen being of a size to permit passage of the particles that are to be separated out, the entire electrode structure being positioned in an inclined plane, means for holding a supply of the mixture to be classified, means for feeding and directing a supply thereof continuously from said holding means onto the said classifying screen between the elec-

trodes at the uppermost end of the sloping electrode structure, means below said screen electrode for collecting the thruage and means adjacent the lower open end of said electrode structure for collecting the overage.

2. An apparatus for the separation of particles of matter from a mixture comprising a substantially flat screen electrode of large mesh with a classifying screen of smaller mesh superimposed upon and adjacent to said screen electrode, a substantially flat solid electrode positioned above, substantially parallel to and spaced from said screen electrode, and also spaced from said classifying screen, said electrodes being connected to a source of electrical difference of potential, the perforations of said classifying screen being of a size to permit passage of the particles that are to be separated out, the entire electrode structure being positioned in an inclined plane, means for holding a supply of the mixture to be classified, means for feeding and directing a supply thereof continuously from said holding means onto the said classifying screen between the electrodes at the uppermost end of the sloping electrode structure, means for vibrating said classifying screen, means below said screen electrode for collecting the thruage and means adjacent the lower open end of said electrode structure for collecting the overage.

3. A screening process for separating and classifying according to size and shape and effecting a shape-grading of a mixture of dense, granular particles of a generally uniform kind and of the same order of size and weight in which some are chunky or block-like and some are relatively long, slender, needle-like or splintery in shape and in which the particles substantially all possess approximately the same electrical characteristics and are responsive to the dispersing, orienting and projecting influence of an alternating electric field, comprising conducting the mixture onto an inclined classifying screen and into an alternating electric field, which latter is positioned so that its lines of force are substantially perpendicular to the screen and which is of such strength in relation to the size and nature of the particles that the needle-like particles will be turned until their longer axes are approximately parallel with the electric field's lines of force to permit them to pass through the meshes of the screen when they are driven downwardly against the screen, and of such strength that substantially all of the particles of said mixture will be projected alternately upwardly from and downwardly toward the screen so as to bombard the screen with sufficient velocity to propel downwardly therethrough the particles that are of a size to pass through the meshes, whereby the particles are classified according to sizes and shapes and a shape-grading of said mixture is effected.

4. A screening process for separating and classifying according to size and shape and effecting a shape-grading of a mixture of dense granular particles of a generally uniform kind and of the same order of size and weight in which some are chunky or block-like and some are relatively long, slender, needle-like or splintery in shape and in which the particles substantially all possess approximately the same electrical characteristics and are sufficiently conductive to be responsive to the dispersing, orienting and projecting influence of a direct electric field, comprising conducting the mixture onto an inclined classifying screen and into a direct electric field, which latter is positioned so that its lines of force are substantially perpendicular to the screen and which is of such strength in relation to the size and nature of the particles and in relation to the distance between the screen and the field's upper limit that the needle-like particles will be turned until their longer axes are approximately parallel with the electric field's lines of force to permit them to pass through the meshes of the screen when they are driven downwardly against the screen, and of such strength that substantially all the particles of said mixture will be projected alternately upwardly and then downwardly to the screen so as to bombard the screen with sufficient velocity to propel downwardly therethrough the particles that are of a size to pass the meshes whereby the particles are classified according to sizes and shapes and a shape-grading of said mixture is effected.

5. A screening process for separating and classifying and effecting a size-grading of a mixture of dense granular particles of a generally uniform kind in which the particles substantially all possess approximately the same electrical characteristics and are responsive to the dispersing, orienting and projecting influence of an alternating electric field, comprising conducting the mixture onto an inclined classifying screen and into an alternating electric field which latter is positioned so that its lines of force are substantially perpendicular to the screen and which is of such strength in relation to the size and nature of the particles that substantially all of the particles of said mixture will be projected alternately upwardly from and downwardly toward the screen so as to bombard the screen with sufficient velocity to propel downwardly therethrough the particles that are of a size to pass through the meshes, whereby the particles are classified according to size and a size-grading of said mixture is effected.

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