

May 3, 1966

O. M. STUETZER ETAL

3,249,225

ELECTROSTATIC SEPARATION MEANS

Filed Feb. 9, 1962

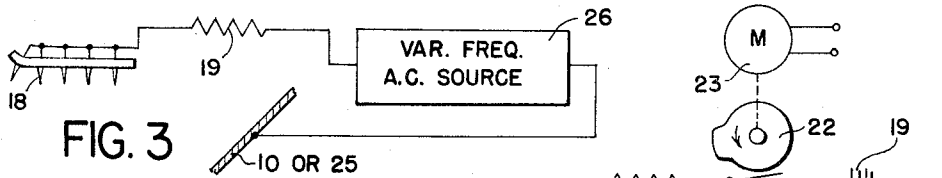


FIG. 3

FIG. 1

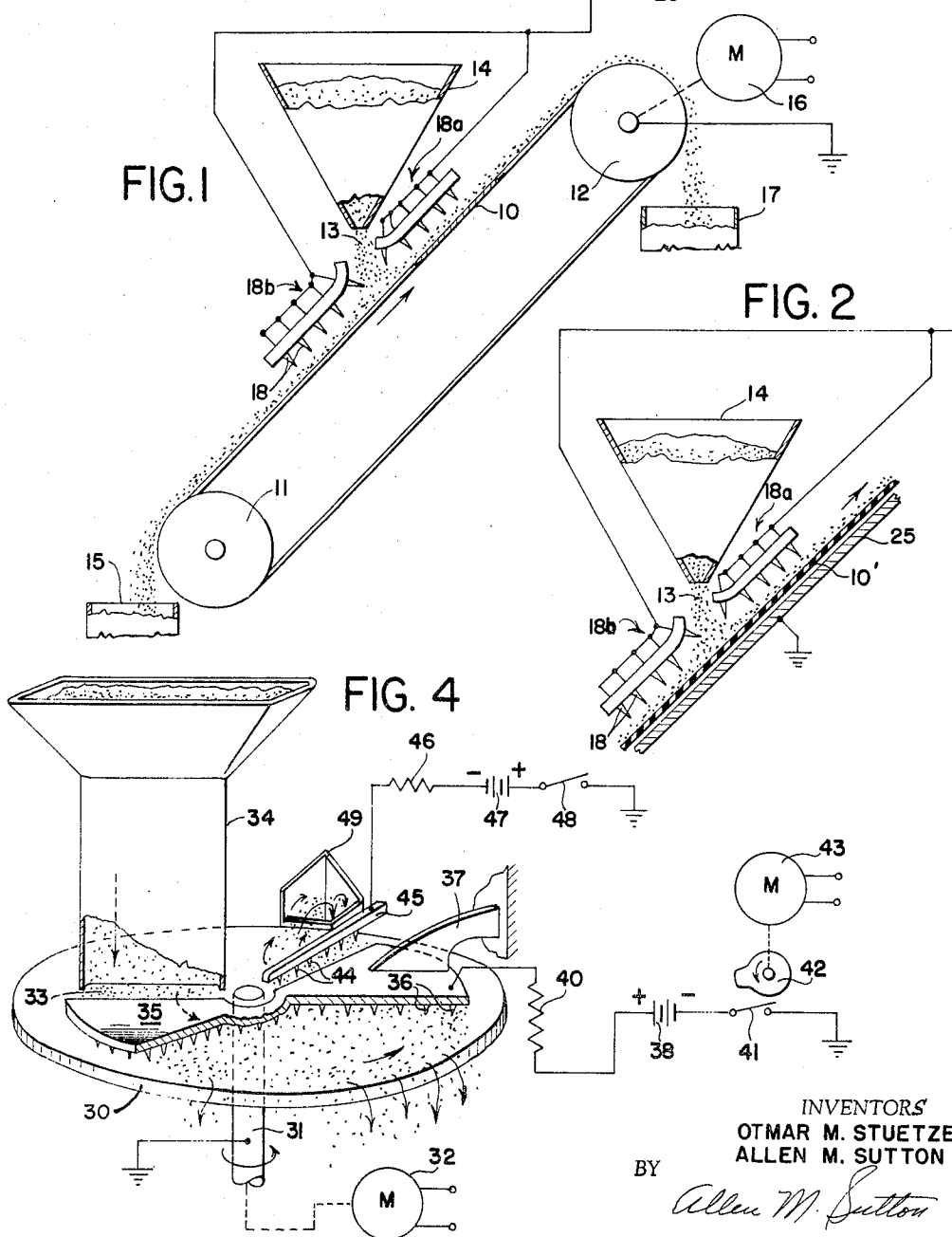
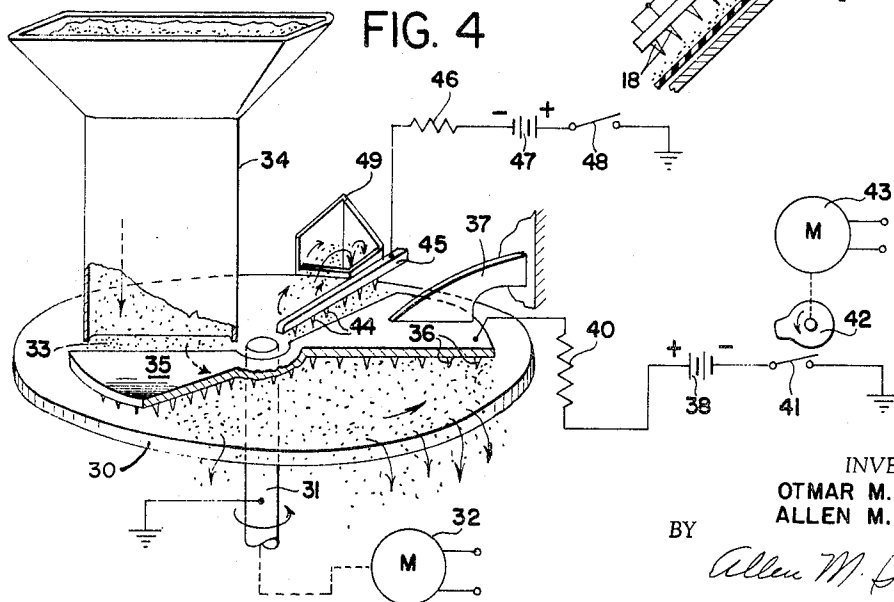


FIG. 2

FIG. 4



INVENTORS
OTMAR M. STUETZER
ALLEN M. SUTTON
BY *Allen M. Sutton*
ATTORNEY

1

3,249,225

ELECTROSTATIC SEPARATION MEANS

Otmar M. Stuetzer, Hopkins, and Allen M. Sutton, Edina, Minn., assignors, by mesne assignments, to Litton Systems, Inc., Beverly Hills, Calif., a corporation of Maryland

Filed Feb. 9, 1962, Ser. No. 172,283

12 Claims. (Cl. 209-129)

This invention relates to selective separation means and, more particularly, to means for selectively separating particulate materials having different electrical characteristics.

It is known that when an insulator is brought into contact with a conductor and a potential difference is provided between the two, a force results which attracts the two together. This effect, which is known as the Johnsen-Rahbek effect, is discussed by Zwicker in "Physical Properties of Solid Materials," Pergamon Press, 1955, page 258.

It is also known that various materials have different electrical characteristics such as resistivities and absolute dielectric constants. Resistivity is defined as the electrical resistance of one cubic centimeter of the material; the absolute dielectric ϵ of a medium is defined by the equation

$$\epsilon = \frac{QQ'}{F \cdot r^2}$$

where F is the force of attraction between two charges Q and Q' separated by a distance r in a uniform medium. Values of resistivities and absolute dielectric constants for various materials are easily obtainable from standard handbooks such as "Handbook of Chemistry and Physics," published by Chemical Rubber Publishing Company, Cleveland, Ohio.

The product of the resistivity and the absolute dielectric constant of any given material is a characteristic known as the time constant of the material. If it is desired to apply the aforementioned Johnsen-Rahbek effect to the separation of various materials, the time constants of the materials may be utilized to provide selective separation. Accordingly, it is an object of the invention to provide means for separating particulate materials according to the electrical time constants of the materials.

It is another object to provide apparatus for efficiently separating conductive and nonconductive particulate materials.

It is another object to provide apparatus for separating various nonconductive or poorly conductive particulate materials from each other.

It is a further object of the invention to provide apparatus which utilizes a natural force, such as gravitation, buoyancy, or centrifugal force, as a feature in the separation of particulate materials.

It is a still further object of the invention to provide apparatus in which the Johnsen-Rahbek effect is utilized to overcome a natural force to separate various particulate materials according to their electrical time constants.

In its broader aspects, the invention provides means for separating particulate materials having different electrical characteristics comprising means for depositing the particulate materials on a surface from which they tend to be removed by a natural force. Ionizing means is located adjacent the surface and the materials for establishing a charge on the materials and with it an electric field between the materials and the surface. Means is provided for repetitively energizing the ionizing means for a time interval which is less than the time constant of material to be removed from the surface and longer than the time constant of material to be retained on the surface.

2

Further objects and advantages and a better understanding of the invention will be obtained from the following description, taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagrammatic elevational view with parts broken away, of means for separating from each other nonconductive or poorly conductive particulate materials having various time constants, or for separating nonconductive or poorly conductive particulate material from conductive particulate material;

FIG. 2 is a fragmentary diagrammatic view similar to FIG. 1 showing a modification of the apparatus of FIG. 1;

FIG. 3 is a diagrammatic view of modified means for energizing the apparatus shown in FIGS. 1 and 2; and

FIG. 4 is a diagrammatic perspective view, with parts broken away, of another embodiment of the invention for separating particulate materials according to their time constants.

The embodiment of the invention shown in FIG. 1 is particularly adapted for the selective separation of insulating or poorly conducting particulate materials having different electrical time constants. As a natural consequence of its method of operation, it is also useful in separating conducting from nonconducting particulate material, but its principal advantage over other means known in the art lies in the former application. It is primarily adapted for the separation of nonconducting, or insulating, particulate materials because the medium on which separation occurs comprises an inclined conveyor belt 10 made of a conductive material.

The conveyor belt 10 is mounted between two pulleys 11 and 12 at such an angle that particulate material 13 to be separated, which is discharged from a hopper or bin 14 onto its upper surface, tends to roll or slide downwardly under force of gravity and be discharged into a receptacle 15 placed under the lower end of the conveyor. One of the pulleys, for example the pulley 12, may be rotated by a motor 16, to cause the surface of the conveyor belt 10 on which the particulate matter 13 is deposited to move upwardly. The motor 16 may be energized by conventional means (not shown) and preferably is capable of driving the conveyor belt 10 at various speeds.

When the selective separating means is unenergized, even though the conveyor belt 10 is being advanced, the conveyor belt is at such an angle that the particulate matter 13 falls or rolls down the belt under force of gravity. However, when the selective separating means is energized, that particulate material which it is desired to separate out from the remainder is caused to adhere to the surface of the moving conveyor belt 10 until it passes over the pulley 12, where it is discharged into a receptacle 17. In accordance with the invention, the means for separating the desired particulate material and causing it to adhere to the moving conveyor belt 10 comprises ionizing means located adjacent the upper surface of the belt 10 and the particulate material 13 being deposited thereon.

The ionizing means comprises a plurality of corona discharge points 18 located in two groups 18a, 18b, above and below the area where the particulate matter 13 falls onto the upper surface of the belt 10. It is preferable that the corona discharge points 18 be arranged as close as possible to the material 13 falling from the hopper 14.

The corona discharge points 18 are all electrically connected in parallel and to one side of a source of electrical potential 19 through a current-limiting resistor 20 and a switch 21. The electrical circuit is completed by grounding the other side of the potential source 19 and the conductive conveyor belt 10.

The switch 21 may be actuated by a cam 22 so that it may be periodically closed for predetermined intervals

of time. The cam 22 may be rotated by a motor 23, energized by conventional electrical means (not shown).

In operation, the ionizing means comprising the corona discharge points 18, when energized, ionizes the air or other protective noble gas surrounding the apparatus and sprays charges on the particulate matter being discharged onto the conveyor belt 10. Depending upon the length of time that the ionizing means is energized, certain of the particulate materials acquire an electrical charge and a high electric field is thereby created between those materials and the conveyor belt 10. This high electric field causes a force to be exerted between the particulate material and the conveyor belt 10, whereby the particulate material adheres to the conveyor belt and is advanced upwardly with the belt.

As was previously mentioned, various materials, and particularly those which may be classified as insulators, poor conductors, or dielectrics, have associated therewith various time constants. The significance of the time constant of a material is that it represents the time required for the material to acquire a substantial surface charge adjacent to the belt when it is sprayed with electric charges. Therefore, if a material is intermittently sprayed with electric charges, it may or may not acquire a substantial surface charge, depending on the length of the intervals during which it is being sprayed. Thus, if a particulate composition is composed of two materials having distinguishably different time constants, it is possible to spray electric charges on the composition for repetitive time intervals of such durations that the material having the longer time constant will not acquire a space charge, but the material having the shorter time constant will. The materials with the shorter time constants, having acquired a surface charge, will be subject to the high electric field existing between that material and a conductor and, hence, will be attracted to the conductor by a substantial force.

In the embodiment of the invention shown in FIG. 1, the means for repetitively energizing the ionizing means for a desired time interval comprises the switch 21, the cam 22 and the motor 23. By making the switch-closing projection on the cam 22 of the proper length and by rotating the cam 22 at the proper speed, the corona discharge points 18 may be energized for any desired length of time. Thus, they may be repetitively energized for a time interval which is longer than the time constant of materials to be advanced upwardly on the conveyor belt 10 and which is shorter than the time constant of materials to be removed at the lower end of the conveyor belt and deposited in the receptacle 15.

It is pointed out that the time constant of a material relates not only to the length of time required for the material to acquire a surface charge when it is sprayed with electric charges, but also relates to the length of time for which the material will hold the surface charge, once acquired, before the charge leaks off the material. Therefore, the speed of movement of the conveyor belt 10 must be so chosen that a point on the belt progresses from the upper end of the corona points 18 in the upper group 18a to approximately a vertical position over the pulley 12 in a time less than the time constant of the material being advanced by the conveyor belt. Of course, the corona points in the upper group 18a may be extended farther upwardly along the path of the conveyor belt 10 so that less distance must be traversed by the particulate material before its surface charge leaks off and the force-producing electric field collapses.

By adjusting the time interval of energization of the corona discharge points 18 so that the interval is longer than the time constants of any insulating particulate material in the material 13, any conductive material mixed therewith will be readily separated from the remainder. This occurs because any electric charges sprayed on the conductive material are immediately transferred to the conductive conveyor belt 10 and no charge or electric

field is built up between the conductive material and the conveyor belt. Therefore, the conductive material will fall down the inclined belt under the force of gravity and be deposited in the receptacle 15.

FIG. 2 illustrates a modification of the apparatus of FIG. 1, which is particularly useful in the separation of a small amount of conductive particulate material from a larger amount of nonconductive particulate material. In the description of the embodiment shown in FIG. 1, it was pointed out that conductive particulate material would not be advanced by the conveyor belt 10 because the belt was made of a conductive material. Thus, an electric field could not be established between the conductive particulate material and the conductive conveyor belt. In the embodiment illustrated in the fragmentary view of FIG. 2, a nonconductive or insulating conveyor belt 10' is utilized, along with a conductive plate or strip 25 which underlies the conveyor belt 10'. The remainder of the apparatus is as shown in FIG. 1, except that the plate 25 is grounded to complete the electrical circuit.

In the operation of the embodiment shown in FIG. 2, electric charges are sprayed by the corona discharge points 18 on the particulate matter 13 and on the insulating conveyor belt 10'. Because the particulate matter to be advanced by the conveyor belt 10' is a conductor, the charges are immediately distributed over the entire surface of each particle of the matter, but are not so distributed over the surface of the insulating conveyor belt 10'. Therefore, an electric field is established between the conducting particulate matter and the nonconducting conveyor belt that is of sufficient strength to cause the particulate matter to adhere to the conveyor belt and be advanced upwardly. The switch 21 need not be repetitively opened and closed in this mode of operation because nonconducting particulate matter on the nonconducting conveyor belt will be unaffected by the electric charges sprayed thereon. If, however, it is desired to separate two particulate materials, one of which is a good conductor, and the other of which is a poor conductor, the switch 21 may be repetitively closed by the cam 22 to separate the material having the shorter time constant from that having the longer time constant. That portion of the operation of the embodiment of FIG. 2 is substantially the same as that described with reference to FIG. 1; that is, the corona discharge points 18 are energized for a period of time that is longer than the time constants of the material to be advanced up the conveyor belt, but shorter than the time constant of the material which is to be deposited by force of gravity into the receptacle 15 at the lower end of the conveyor.

It is apparent that many variations and modifications may be made in the embodiments shown in FIGS. 1 and 2. For example, the number of corona discharge points 18 in each of the groups 18a and 18b may be varied, as dictated by a particular application. In addition, the locations of the groups 18a and 18b with respect to the material 18 being discharged onto the conveyor belt may be varied. It has been found in practice that the potential source 19 may comprise a source of either positive or negative voltage of the order of several thousand volts, delivered to the corona points through the current limiting resistor 20, having a value of approximately 10^8 ohms. Of course, these parameters may be varied as desired, but in any event only a few microamperes of current flow in the circuit. Each point may in certain cases be equipped with a current-limiting resistor of its own.

It is also apparent that the cam-operated switch 21 might be replaced with well-known electronic switching means. Such means, such as electronically operated relays, switching tubes and the like are well known in the art.

It has been found that the source of direct potential 19 and the cam-operated switch 21 may be replaced by a source of variable frequency alternating voltage. Such an arrangement is shown in FIG. 3, where a variable fre-

5

quency A.C. source 26 is connected between the corona discharge points 18 and the conductive belt 10 or conductive plate 25, through the current-limiting resistor 20. The variable frequency A.C. source 26 may be of conventional well-known design having a frequency range to be determined in accordance with the range of the time constants of the materials to be separated.

If it is desired to advance up the conveyor belt a material having a given time constant, it is necessary that the frequency of the A.C. source be such that the time duration of one-half cycle of the alternating voltage is longer than the time constant of the material. This may be expressed in another way by saying that two times the frequency of the alternating voltage should be less than the reciprocal of the time constant of the material to be advanced. It follows that if two materials having distinguishably different time constants are to be separated, the time duration of one-half cycle of the alternating voltage should be longer than the time constant of one of the materials, and shorter than the time constant of the other, to effect such separation.

The operation of the apparatus of the invention using an A.C. source is identical with that using a D.C. source in that positive and negative charges are alternately sprayed on the particulate material to be separated. The resultant electric fields between the material and the conveyor belt cause that material which bears a surface charge to adhere to the conveyor belt and be advanced thereby.

FIG. 4 illustrates another embodiment of the invention which operates on the same principle of selective separation according to electrical characteristics as those embodiments previously described, but which utilizes centrifugal force rather than gravitational force to remove a particulate material from the apparatus. The separation medium in that embodiment comprises a horizontal disc 30 mounted for rotation on a shaft 31 normal thereto, which may be driven by a motor 32. The disc 30 is made of a conductive material and may be electrically grounded through the shaft 31. The particulate material 33 to be separated (in this case, insulating or poorly conducting material) is contained in the hopper 34 mounted above the surface of the rotating disc 30 with the material being discharged from the lower end of the hopper onto the upper surface of the disc.

Mounted above and closely spaced from the rotating disc 30 is a segmental disc 35 which extends from just in front of the lower end of the hopper 34 and covers the major portion of the disc 30. A plurality of downwardly extending corona discharge points 36 are carried by the upper disc 35. The disc 35 may be conveniently mounted by means of a bracket 37 secured to an immovable portion of the apparatus.

As illustrated, the upper disc 35 is constructed of a conducting material and is electrically connected to the plurality of corona discharge points 36 so that all of the corona discharge points may be electrically energized by means of an electrical connection to the disc 35. Of course, alternative arrangements are possible, and in actual practice, it might be desirable to insulate the upper surface of the disc 35 for safety reasons.

The corona discharge points 36 are electrically energized from a potential source 38 to which one side of the disc 35 is connected through a current-limiting resistor 40. The electrical circuit is completed from the other side of the potential source 38 through a switch 41 to ground. As in the embodiment shown in FIG. 1, the switch 41 may be periodically opened and closed by means of a cam 42 rotated by a motor 43.

The embodiment of the invention shown in FIG. 4 operates in a manner very similar to that previously described with reference to the apparatus shown in FIG. 1. If the disc 30 is rotating, but the corona discharge points 36 are unenergized, particulate material discharged from the hopper 34 onto the upper surface of the disc 30 is discharged from the surface of the disc by centrifugal

6

force which throws it outwardly as the disc rotates. If, however, the ionizing means comprising the corona discharge points 36 is energized for an interval of time longer than the time constant of the material 33, the electric charges sprayed on the material 33 cause it to become electrically charged. The surface charge on the material causes a high electric field to be established between the particulate material and the disc 30, and the material adheres to the disc as it rotates. As in the embodiments previously discussed, the ionizing means may be repetitively energized for a time interval which is longer than the time constant of materials to be retained on the surface of the disc and shorter than the time constant of materials to be removed from the surface by centrifugal force. The intervals for which the ionizing means is energized may be varied by changing the cam 42 or by changing its speed of rotation.

The embodiment of the invention shown in FIG. 4 also includes means for positively discharging that material which remains on the surface of the disc 30 after it has passed out from under the corona discharge points 36. Normally, the surface charge on the particulate material would leak off in a time equal to the time constant of the material, the electric field between the material and the disc would collapse, and centrifugal force would tend to discharge the material from the disc. However, in order to insure its positive discharge and to permit higher speeds of rotation of the disc 30, means in the form of a plurality of corona discharge points 44 is provided, to neutralize any surface charge remaining on the particulate material. As illustrated, the corona discharge points 44 extend along a radius of the disc 30 at a position just beyond the end of the segment of the upper disc 35. The corona points 44 extend downwardly from a supporting bar 45, to which they are electrically connected, and it, in turn, is connected through a current-limiting resistor 46 to one side of a source 47 of electric potential. The electric circuit is completed by connecting the other side of the potential source 47 to ground through a switch 48. It is pointed out that if the corona discharge points 36 are energized by a positive voltage, the corona points 44 must be energized by a negative voltage to be effective, and vice versa.

In operation, when the switch 48 is closed, electric charges of opposite polarity to those already carried by the particulate material are sprayed on the material from the discharge points 44 and centrifugal force causes the material to move from the surface of the disc 30 into a receiving receptacle 49. Any material still remaining on the surface of the disc 30 will again pass under the hopper 34 and be mixed with new material 33 being added to the disc from the hopper.

Many variations may be made in the arrangement shown in FIG. 4. For example, the number and location of the various corona discharge points may be altered and the configuration of the segmental disc may be modified to suit the particular application. As in the case of the embodiments previously described, a positive or negative potential source 38 of the order of several thousand volts may be utilized, and the current-limiting resistors 40 and 46 may have values of the order of 10^8 ohms to limit the current flowing in the circuits to a few microamperes. The potential of the source 47 may be approximately that of the source 38, but of opposite polarity.

It is pointed out the positive discharge means comprising the corona points 44 and their energizing circuitry may also be used with the other embodiments of the invention. For example, in the apparatus shown in FIG. 1, they could advantageously be located vertically over the pulley 12.

It is apparent that many changes may be made in the embodiments of the invention illustrated and described without departing from the true scope and spirit of the invention.

What is claimed is:

1. Selective separation means for separating particulate materials having different electrical characteristics comprising means for depositing said materials on a surface from which said materials tend to be removed by a natural force, ionizing means located adjacent said surface and said materials for providing electric charges on said materials and thereby establishing an electric field between said materials and said surface, means for repetitively energizing and deenergizing said ionizing means so that said ionizing means is periodically energized for a time interval which is less than a first time constant of materials to be removed by said natural force from said surface and longer than a second time constant of materials to be retained on said surface and means for removing said materials retained on said surface prior to the termination of a period of time shorter than said second time constant.

2. The apparatus defined by claim 1 wherein said ionizing means comprises corona discharge means.

3. The apparatus defined by claim 2 wherein said repetitive energizing means comprises a potential source connected to said corona discharge means through an automatically operated switch.

4. The apparatus defined by claim 3 wherein said surface is part of an inclined conveyor from which said material tends to fall due to gravitational force.

5. The apparatus defined by claim 3 wherein said surface is rotatable about an axis substantially normal thereto and said material tends to be removed by centrifugal force.

6. The apparatus defined by claim 1 wherein said surface is part of an inclined conveyor from which said material tends to fall due to gravitational force.

7. The apparatus defined by claim 1 wherein said surface is horizontal and rotatable about an axis normal thereto, and said material tends to be removed by centrifugal force.

8. Selective separations means for separating insulating particulate materials having different electrical characteristics comprising means for depositing said insulating materials on a conductive surface from which said materials tend to be removed by a natural force, ionizing means located adjacent said materials for electrically charging said materials and establishing an electric field between said materials and said surface, means for re-

petitively energizing and deenergizing said ionizing means so that said ionizing means is periodically energized for a time interval which is less than a first time constant of materials to be removed by said natural force from said surface and longer than a second time constant of materials to be retained on said surface and means for removing said materials retained on said surface prior to the termination of a period of time shorter than said second time constant.

9. The apparatus defined by claim 8 wherein said ionizing means comprises corona discharge means.

10. The apparatus defined by claim 9 wherein means displaced from said corona discharge means are provided for electrically neutralizing the electrically charged materials.

11. The apparatus defined by claim 8 wherein means displaced from said ionizing means are provided for electrically neutralizing the electrically charged materials.

12. Apparatus for selectively separating a first material having a first time constant from a second material having a second time constant, which comprises, a carrier for moving material retained thereon from a first location to a second location; said carrier being effective to discharge material not retained thereon at a third location apart from said second locations; means for depositing a mixture of said first and second materials on said carrier at said first location; ionizing means for charging materials to retain said materials on said carrier; means for operating said ionizing means for a first period of time longer than said first time constant and shorter than said second time constant so that only said first material is retained on said carrier; means for operating said carrier so that said first material is moved to said second location within a period of time less than said first time constant; and means for discharging said first material from said second location to separate said first and second materials.

References Cited by the Examiner

UNITED STATES PATENTS

2,314,939	3/1943	Hewitt	209—127
3,012,668	12/1961	Frass	209—127

FRANK W. LUTTER, *Primary Examiner*.

HARRY B. THORNTON, ROBERT A. O'LEARY,
Examiners.