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COMPLETE SPECIFICATION

High Tension Separation of Materials

We, CARPCO RESEARCH & ENGINEERING INC., a Corporation organised and existing under the laws of the State of Florida, United States of America, of 4120 Hains Street, Jacksonville, Florida, Duval County, United States of America, do hereby declare the invention for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an improved method and apparatus for high tension separation and, more particularly, to an improved method and apparatus for the beneficiation of particulate materials containing a large percentage of fines, ranging in size from about 150 microns to about 5 microns.

High tension separation is an outgrowth of electrostatic separation but differs therefrom in many respects. The term "electrostatic" implies that no current is flowing. Basically, an electrostatic separation relies on the principles that if particles in an electrostatic or external electric field are differentially charged, particle trajectory will be so affected that the desired fractions separately can be collected. Requisite differential charging normally is effected in the various electrostatic separation processes by contact electrification or inductive conduction or by a combination of both these phenomena.

In high tension separation on the other hand, the entire particulate feed is sprayed with mobile ions, i.e., a corona discharge, while such particles are in contact with a grounded conductive surface such as a metal rotor. All of the particles are strongly charged by the mobile ions. The non-conductors and poor conductors lose their charge slowly, are pinned to the grounded conductive surface by their own image forces and are suitably removed from the grounded conductive surface outside the locus of mobile ion charging. The conductive particles lose their charges rapidly and, once removed from the influence of the mobile ion spray, are free to assume normal trajectories when discharged from the grounded conductive surfaces under normal gravitational or centrifugal forces. If, outside the locus of mobile ion charging, the conductive particles now are subjected to an external electrical field either on the grounded surface or in free fall, they again may be charged by inductive conduction in addition to contact electrification and their trajectories desirably altered to permit collection of various fractions of the now essentially conductive particles.

A more detailed discussion of the phenomena encountered in conventional electrostatic and high tension separations can be found in Perry, Chemical Engineers Handbook, 4th Edition, McGraw-Hill Pub. Co., (1963) Section 21, pages 67 through 70, and in Lawver, Fundamentals of Electrical Concentration of minerals, The Mines Magazine, January 1960.

High tension separation currently is employed commercially to beneficiate a number of ores. In all cases, however, where high tension separation has been of significant success the particulate materials treated have been characterized by a particle size of from −14 to +200 mesh and have not contained a substantial amount of particles of a size smaller than 200 mesh. Attempts by the art to employ high tension separation with materials which necessitate grinding to an extremely fine particle size in order to effect liberation, uiformly have been unsuccessful. Unfortunately some of the most commercially significant ores today, such as hematite or other iron ores require fine grinding to effect liberation. Some iron ores, when comminuted to liberation, contain over seventy-five per cent of particles at −325 mesh and contain a substantial amount of particles as small

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as five microns in diameter. The significance and economic advantages of an apparatus and method permitting the high tension separation of ores and other materials containing substantial quantities of dust-like particles ranging in size from about 250 microns down to about 5 microns, readily is apparent. Numerous commercially significant areas previously foreclosed to any type of dry beneficiation could then enjoy the advantages of this simple and economical system if such method were available.

Therefore it is the primary object of this invention to provide an improved method and apparatus for high tension separation for materials containing substantial portions of fines.

It is the further object of this invention to provide an improved method and apparatus for separating ores containing, when ground to liberation, substantial portions of fine material characterized by a particle size ranging from about 250 microns down to about 5 microns.

An additional object of this invention is to provide a method for beneficiation of ores wherein the particulate ore containing a substantial quantity of dust-like fines successively is subjected to a mobile ion discharge and an external electrical field, both of which are pulsating at a high frequency.

Other objects and advantages of the invention will become apparent from the general and specific description of this invention to follow.

The present invention is directed to a method and apparatus adapted to the beneficiation of particulate materials and especially to the separation of comminuted ores which are characterized by a sizable quantity of finely divided particles which pass a 200 mesh screen.

Generally described the method of this invention is a method for separation of particulate mixtures containing particles of varying conductivity which comprises subjecting the mixture while disposed on a grounded conductive surface to a spray of mobile ions produced by a corona discharge pulsed at the rate of between about 150 and 800 pulses per second, removing the mixture from the spray of mobile ions and separately collecting the particles pinned to the grounded conductive surface by the mobile ions and the particles not pinned to the grounded conductive surface by the mobile ions.

In terms of apparatus, the invention generally may be described as an apparatus for separating particulate materials containing particles of varying conductivity which comprises a grounded conductive surface adapted to convey the particulate mixture into a high tension charging zone, a high tension charging zone defined by the grounded conductive surface and a charging means positioned in spaced relation thereto for emitting a pulsed corona discharge into contact with the particles disposed on said surface at a pulse rate of between about 150 and 800 pulses per second, external electric field generating means disposed outside the high tension charging zone and in the direction of material flow through the apparatus for subjecting at least part of the particulate mixture to the action of an external electric field, collection means for separately collecting the particles pinned to the grounded conductive surface by the corona discharge and collection means for the particles discharged from said surface through said external electric field.

It is preferred to employ a corona voltage of between about 10 KV and about 100 KV and a corona current strength of between 0.1 milliamperes and 5.0 milliamperes per foot width of grounded conductive surface.

In accordance with the preferred embodiment of the invention, the grounded conductive surface will be a cylindrical rotor horizontally mounted to rotate about its longitudinal axis.

It is preferred that the corona discharge be unidirectional although it is not essential to obtaining the benefits of the invention that a unidirectional corona discharge be employed.

The present invention involves the concept that fine particulate materials having particle sizes of −200 mesh and as small as, say, 5 microns, may be separated or beneficiated in a high tension separation process where the corona discharge providing mobile ions for charging purposes is pulsed at a pulse rate of from about 150 to about 850 pulses per second. The use of an external electrical field in conjunction with high tension separation in accordance with this invention is preferred to further improve the separation of the conductive particles of the feed material which are not pinned to the grounded conductive surface by the mobile ion discharge. In the external electrical field, whether provided by a free-fall apparatus or rotor and electrode equipment the conductive particles recharge by inductive conduction and/or contact electrification and are deflected in accordance with this charge to permit more selective categorization. With some feed materials it is also preferred that the external electric field be unidirectional. Preferably a field gradient of between about 20 and about 100 KV/inch will be employed. A beamed electrode directed away from the rotor surface also may be employed in conjunction with an external electric field in order to still further affect the trajectory of the conductive particles.

The polarity of both the corona and the electrodes creating the external electric field

may be varied as dictated by the nature of the material to be separated.

In conjunction with high tension separation wherein the corona discharge is pulsed in accordance with the invention, it has been found additionally beneficial to employ rotor speeds faster than heretofore used by the art. In the combination of pulsed corona discharge higher rotor speeds and external electrical field has been found to give optimum results with those materials such as hematite ores which when comminuted to liberation contain as much as 75% by weight of particles which are —325 mesh.

Without being bound by any explanation of the surprising result of this invention, it is postulated that the success of the method and apparatus of this invention in the successful separation of particulate materials containing large proportions of dust-like materials may be explained by the following considerations.

The function of the corona discharge is to spray electrons or negative or positive ions on to the feed particles fed to the rotor or other grounded conductive surface. Charging, *per se*, of fine particles poses no problem. Indeed, owing to their relatively small surface area the smaller particles actually require less charge to generate an attraction value than do the larger particles. However, under the conditions created by the continuous wave or 60 cycle half or full wave rectified potentials heretofore used by the art in high tension separators, particles have all been strongly charged. Many of the large and small particles have thus arrived at the rotor at roughly the same time while substantial portions of the smaller particles, and particularly those of dust-like size, have arrived at a later time due to greater air resistance. As a result, the fine conductive particles have either been trapped to the rotor surface by overlying larger pinned particles of non conductors or else are last to arrive and lie over the pinned larger non-conductive particles and are unable to discharge.

It is believed that the process and apparatus of this invention obviates these conditions through two mechanisms. First the use of pulsed corona within the range of pulse rates disclosed enables the finer particles to be charged before the coarser particles become fully charged and thus reach the rotor or other grounded conductive surface employed before they can be blocked out by the larger pinned nonconductors. This is especially true where an increased rotor speed is employed in order that the finer particles are spread over a large surface of grounded conductor surface. In accordance with the invention, speeds of about 900 to about 1500 feet per minute have been found effective with rotors from 14 to 16 inches in diameter. As a consequence, the conductive fines are discharged quickly and are repelled for collection.

Secondly, the more conductive particles of the comminuted ores, such as iron ores, display polarizability. The resulting ionic motions thus create small particulate dipoles in the conductors. When these small particulate dipoles are placed on top of the nonconductors already pinned to the rotor the dipoles will oscillate about their centers of mass in the pulsed field of high frequency employed in the invention and cause the particles to shake loose from their bound condition and reach a metal spot on the rotor where if they are conductors they will discharge and be rejected for collection. This phenomenon has been observed in high speed motion pictures taken during operation of the apparatus of this invention.

Having now generally described the method and apparatus of the invention, a more specific description will be given with reference to the drawings in which:

Figure 1 is a schematic end elevation of the separator of this invention illustrating the flow pattern of minerals in this particular embodiment;

Figure 2 is a schematic end elevation of the separator of this invention illustrating a typical space relationship for the various parts of the separator; and

Figure 3 is a schematic perspective view of the separator of the invention.

Referring initially to Figure 1, a rotor 10, electrically connected to ground 36, is mounted for revolution at varying speeds in the direction indicated by the arrow by means not shown. A feed hopper section 12 is located above the rotor and terminates at a point above the upper face of the rotor. The first discharge electrode 14 is spaced from the rotor 10 with the electrode corona discharging wire portion 16 directed radially toward the rotor 10. A second electrode 20 is spaced from rotor 10 beneath the first electrode 14. As shown in the embodiment of Figure 1, electrode 20 is a dual purpose electrode which can be employed only to produce an external electric field or as in the embodiment shown additionally may be employed as a beam electrode. When the beam electrode is employed the electrode wire 22 for corona discharge is directed away from the rotor 10 for purposes hereinafter described in conjunction with the operation of the apparatus. A source of unidirectional pulsed voltage 18 is connected to both electrode 14 and electrode 20. Individual sources providing a different voltage for the two electrodes also may be employed.

A first splitter blade 26 is located beneath electrodes 14 and 20 and is spaced from the rotor 10. A second splitter blade 28 is located beneath rotor 10 and is spaced vertically therefrom. Three separate compartments 46,

48 and 50 are located beneath the splitter blades for separately collecting the various fractions of the separated ore. A wiper wire 30 connected to an alternating current source 32 is employed in the embodiment depicted and is positioned to the rear of and spaced from the surface of rotor 10. A brush 34 is located above wire 30 and in contact with the rotor 10.

In operation the mineral particles 38 are fed from the hopper 12 on to the revolving rotor 10, preferably moving at a rate of from about 900 to about 1500 feet per minute in the case of a rotor having a diameter of from 14 to 16 inches. The rotor carries the ore on its surface past the electrode 14 where the ore is charged by the pulsating corona discharge. The pulsed corona discharge causes the non-conductive particles to be firmly pinned to the surface of the rotor 10 while the conductive particles, including the fines, contact the rotor, lose their charges and are repelled.

As the particles continue past electrode 20, the particles are subjected to the effect of the external electric field produced by the electrode 20 which in the embodiment shown in Figure 1 is powered at the same frequency and voltage as electrode 14 by the power source 18. Conductive particles 40 under the influence of the external electric field, as well as centrifugal and gravitational forces, are removed from the surface of the rotor 10 and are displaced in the direction of electrode 20. In the embodiment shown in Figure 1 the corona discharge directed away from the rotor 10 by wire 22 causes the trajectory of the particles to be affected even further so that the majority of the conductive particles pass to the front of the first splitter blade 26 into compartment 50. As the rotor 10 continues its rotation the heavier conductive particles 44 with some of the gangue material fall by gravitational force between splitter blades 26 and 28 to form a middling fraction in compartment 48. As shown in Figure 1 essentially all of the pinned non-conductive particles are removed by the field generated by the electrode 30 and fall behind splitter blade 28 into compartment 46 as a tailing fraction. Any remaining, non-conductive material 42 not removed by the wiper electrode 30 is physically removed by the brush 34 and falls into compartment 46.

If desired, the middling material may be recirculated to exhaust in order to increase the recovery of valuable components of the ore.

For effective wiping, the AC wiper should operate at high frequency, but at one which is not a harmonic of the pinning pulse. Thus, 300 or 600 cycles has proved to be an effective wiping cycle to remove material pinned by 400 pulses per second.

Figure 2 illustrates one spacial relationship which has proved effective between the rotor 10 and electrodes 14 and 20. In Figure 2, the distance between the centre of the rotor 10 and the center of electrode 14 is indicated by the letter A, and the distance between the center of the rotor 10 and the center of electrode 20 is indicated by the letter B. The angle between the plane G—G passing through the horizontal axis of the rotor 10 and the radial center line passing between the center of rotor 10 and the center of electrode 14 is indicated by the letter J. Similarly, the angle between the plane G—G of the horizontal axis of rotor 10 and the radial center line passing between the center of rotor 10 and the center of electrode 20 is indicated by the letter K. The angle between the radial center line passing between the center of rotor 10 and the center of electrode 20 and the center line passing through the center of electrode 20 and the electrode wire portion 22 is indicated by the letter L.

The proper location of the discharging electrodes is dependent upon the decay time of the charges on the particles and upon the speed and size of the rotor. Particularly good results in the separation of iron ore fines have been obtained using a rotor about 14 inches in diameter, operating at from about 250 to about 400 RPMs. With these conditions dimension A should be about 10-1/2 inches; dimension B should about 8-1/2 inches; angle J should be about 45°; angle K should be about 16°; and angle L should be about 5°.

With dust-like particles it is preferable to feed the ore at a point forward of the vertical center of the rotor. This prevents overflow material from building up and sliding down the back of the roller and also prevents particles from receiving the pinning charge while still above the rotor surface. In Figure 2 the letter E represents the circumferential distance from the vertical center F—F of the rotor to the point where the hopper 12 terminates. Under the conditions specified in the preceding paragraph, the distance E should be about 1-1/4 inches.

The following example is intended to illustrate the present invention and is not intended to limit the invention beyond the limitations set forth in the claims.

Example

Iron ore essentially all having a particle size of −325 mesh was processed in accordance with the invention has herein described by feeding the particulate mixture to a 14" mild steel rotor revolving at 320 RPM. The two electrodes were operated at 400 pulses per second using negative unidirectional potential at 30 KV. The middling material was collected and recycled to exhaustion and various collections were assayed with the

results expressed in percentage of iron in each collection as follows:

Fraction	% Fe	% Iron Distribution
Concentrates from first pass	63.68	48.56
Tailings from first pass	6.44	2.94
Concentrates from middling pass	60.61	43.40
Tailings from middling pass	5.12	5.10
Percentage of iron recovered		91.96

It will be understood that the foregoing description, example and drawings are only illustrative of the present invention and it is not intended that the invention be limited thereto. Many modifications and variations of the present invention may be made without departing from the scope and spirit of this disclosure and only such limitations should be imposed as are indicated in the appended claims.

WHAT WE CLAIM IS:—

1. A method for separation of a particulate mixture containing particles of varying conductivity which comprises subjecting the mixture while disposed on a grounded conductive surface to a spray of mobile ions produced by a corona discharge pulsed at a rate of between about 150 and 800 pulses per second, removing the mixture from the spray of mobile ions, and separately collecting the particles pinned to the grounded conductive surface by the mobile ions and the particles not pinned to the grounded conductive surface by the mobile ions.

2. A method according to claim 1 in which the corona voltage is between about 10 and about 100 KV and the corona current is between about 0.1 milliamperes and about 5 milliamperes per foot width of grounded conductive surface.

3. A method according to claim 1 in which the grounded conductive surface is curved and is rotated to carry the particulate mixture into and out of the spray of mobile ions.

4. A method according to claim 1 in which the particles not pinned to the grounded conductive surface are collected after first being passed through an external electric field.

5. A method according to claim 1 in which the particulate mixture is a comminuted ore containing a substantial quantity of particles having a mesh size of −200.

6. A method according to claim 1 in which the particulate mixture is an iron ore comminuted to at least 75 percent through 325 mesh.

7. A method for separation of a particulate mixture containing particles of varying conductivity which comprises feeding such mixture to the surface of a rotatable grounded conductive roll, passing the mixture while in contact with the roll through a spray of mobile ions produced by a corona discharge pulsed at a rate between about 150 and 800 pulses per second, passing the particles not pinned to the roll by the mobile ions through an external electrical field, collecting in at least one fraction the particles not pinned to the roll and passed through the external electric field, and separately collecting the particles pinned to the roll by the mobile ions.

8. A method according to claim 7 in which the corona voltage is between about 10 and about 100 KV and the corona current is between about 0.1 milliamperes and about 5 milliamperes per foot width of grounded conductive surface.

9. A method according to claim 7 in which the external electrical field also is pulsed at a rate between about 150 and 800 pulses per second.

10. A method according to claim 7 in which the particles pinned to the roll are removed therefrom at least in part being subjected to a field generated by high frequency alternating current.

11. A method according to claim 7 in which the particulate mixture is a comminuted ore containing a substantial quantity of particles having a mesh size of −200.

12. A method according to claim 7 in which the particulate mixture is an iron ore comminuted to at least 75 percent through 325 mesh.

13. An apparatus for separating particulate mixtures containing particles of varying conductivity which comprises a grounded conductive surface adapted to convey the mixture into a high tension charging zone, a high tension charging zone defined by the grounded conductive surface and a charging means positioned in spaced relationship thereto for emitting a pulsed corona discharge into contact with the particles disposed on said surface at a pulse rate of between about 150 and about 800 pulses per second, external electric field generating means disposed outside the high tension charging zone and in the direction of material flow through the apparatus for subjecting at least part of the particulate mixture to the action of an external electric field, and collection means for separately collecting the particles pinned to the grounded conductive surface by the corona discharge and the particles discharged from said surface through said external electric field.

14. An apparatus for separating particulate

results expressed in percentage of iron in each collection as follows:

Fraction	% Fe	% Iron Distribution
Concentrates from first pass	63.68	48.56
Tailings from first pass	6.44	2.94
Concentrates from middling pass	60.61	43.40
Tailings from middling pass	5.12	5.10
Percentage of iron recovered		91.96

It will be understood that the foregoing description, example and drawings are only illustrative of the present invention and it is not intended that the invention be limited thereto. Many modifications and variations of the present invention may be made without departing from the scope and spirit of this disclosure and only such limitations should be imposed as are indicated in the appended claims.

WHAT WE CLAIM IS:—

1. A method for separation of a particulate mixture containing particles of varying conductivity which comprises subjecting the mixture while disposed on a grounded conductive surface to a spray of mobile ions produced by a corona discharge pulsed at a rate of between about 150 and 800 pulses per second, removing the mixture from the spray of mobile ions, and separately collecting the particles pinned to the grounded conductive surface by the mobile ions and the particles not pinned to the grounded conductive surface by the mobile ions.

2. A method according to claim 1 in which the corona voltage is between about 10 and about 100 KV and the corona current is between about 0.1 milliamperes and about 5 milliamperes per foot width of grounded conductive surface.

3. A method according to claim 1 in which the grounded conductive surface is curved and is rotated to carry the particulate mixture into and out of the spray of mobile ions.

4. A method according to claim 1 in which the particles not pinned to the grounded conductive surface are collected after first being passed through an external electric field.

5. A method according to claim 1 in which the particulate mixture is a comminuted ore containing a substantial quantity of particles having a mesh size of −200.

6. A method according to claim 1 in which the particulate mixture is an iron ore comminuted to at least 75 percent through 325 mesh.

7. A method for separation of a particulate mixture containing particles of varying conductivity which comprises feeding such mixture to the surface of a rotatable grounded conductive roll, passing the mixture while in contact with the roll through a spray of mobile ions produced by a corona discharge pulsed at a rate between about 150 and 800 pulses per second, passing the particles not pinned to the roll by the mobile ions through an external electrical field, collecting in at least one fraction the particles not pinned to the roll and passed through the external electric field, and separately collecting the particles pinned to the roll by the mobile ions.

8. A method according to claim 7 in which the corona voltage is between about 10 and about 100 KV and the corona current is between about 0.1 milliamperes and about 5 milliamperes per foot width of grounded conductive surface.

9. A method according to claim 7 in which the external electrical field also is pulsed at a rate between about 150 and 800 pulses per second.

10. A method according to claim 7 in which the particles pinned to the roll are removed therefrom at least in part being subjected to a field generated by high frequency alternating current.

11. A method according to claim 7 in which the particulate mixture is a comminuted ore containing a substantial quantity of particles having a mesh size of −200.

12. A method according to claim 7 in which the particulate mixture is an iron ore comminuted to at least 75 percent through 325 mesh.

13. An apparatus for separating particulate mixtures containing particles of varying conductivity which comprises a grounded conductive surface adapted to convey the mixture into a high tension charging zone, a high tension charging zone defined by the grounded conductive surface and a charging means positioned in spaced relationship thereto for emitting a pulsed corona discharge into contact with the particles disposed on said surface at a pulse rate of between about 150 and about 800 pulses per second, external electric field generating means disposed outside the high tension charging zone and in the direction of material flow through the apparatus for subjecting at least part of the particulate mixture to the action of an external electric field, and collection means for separately collecting the particles pinned to the grounded conductive surface by the corona discharge and the particles discharged from said surface through said external electric field.

14. An apparatus for separating particulate

mixtures containing particles of varying conductivity which comprises a grounded conductive rotor horizontally mounted to rotate abouts is longitudinal axis, means for driving said rotor at varying speeds, feed means positioned substantially above said rotor for feeding the particulate mixture on to the surface of the rotor, high tension charging means disposed adjacent the surafce of the rotor and in spaced relationship thereto for emitting a pulsed corona discharge, into contact with the particles disposed on the surface of said rotor, at a pulse rate of about 150 to 800 pulses per second, external electric field generating means disposed outside the high tension charging zone and in the direction of material flow through the apparatus for subjecting at least part of the particulate mixture to the action of an external electric field, collection means for separately collecting the particles pinned to the rotor surface by the corona discharge and collection means for the particles discharged from the rotor surface through said external electrical field.

15. Appparatus in accordance with claim 14 in which the collection means for collecting the particles pinned to the rotor by the corona includes means for applying to said particles on the rotor, outside of the high tension charging zone and external electric field, an electric field generated by a high frequency alternating current.

16. Apparatus in accordance with claim 14 in which the external electric field generating means is adapted to produce a pulsed field having a pulse rate of from about 150 to about 800 pulses per second.

17. A method for separation of a particulate mixture substantially as hereinbefore described with reference to the accompanying drawings.

18. An apparatus for separating particulate mixtures substantially as hereinbefore described with reference to the accompanying drawings.

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