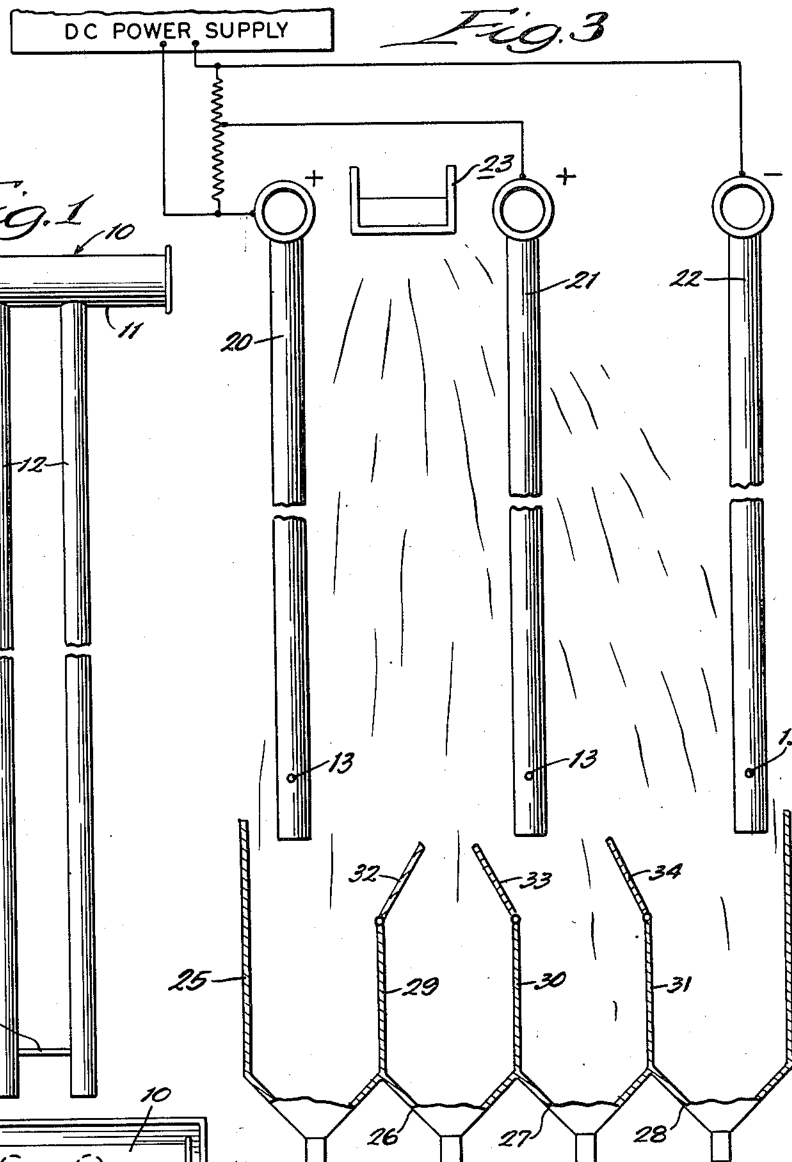
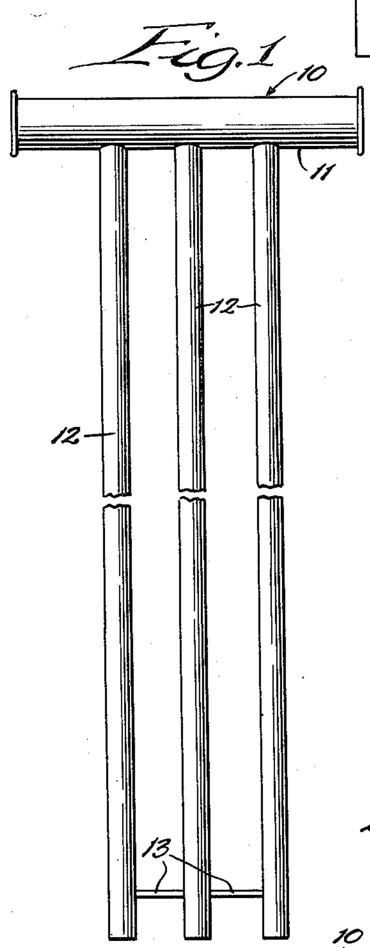
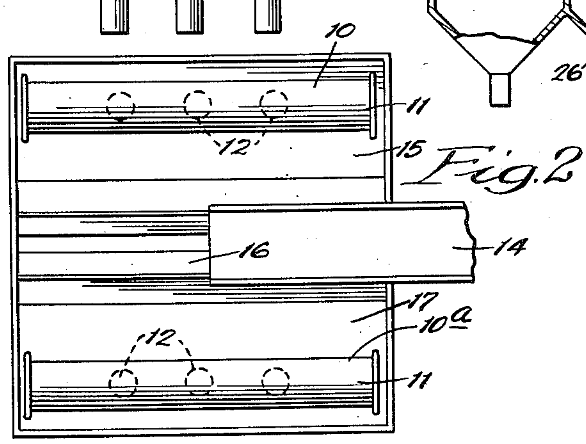
Feb. 26, 1957 C. C. COOK, JR., ET AL 2,782,923

METHOD AND APPARATUS FOR BENEFICIATING ORE

Filed March 30, 1951 3 Sheets-Sheet 1







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METHOD AND APPARATUS FOR BENEFICIATING ORE

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Fig. 4

Fig. 5

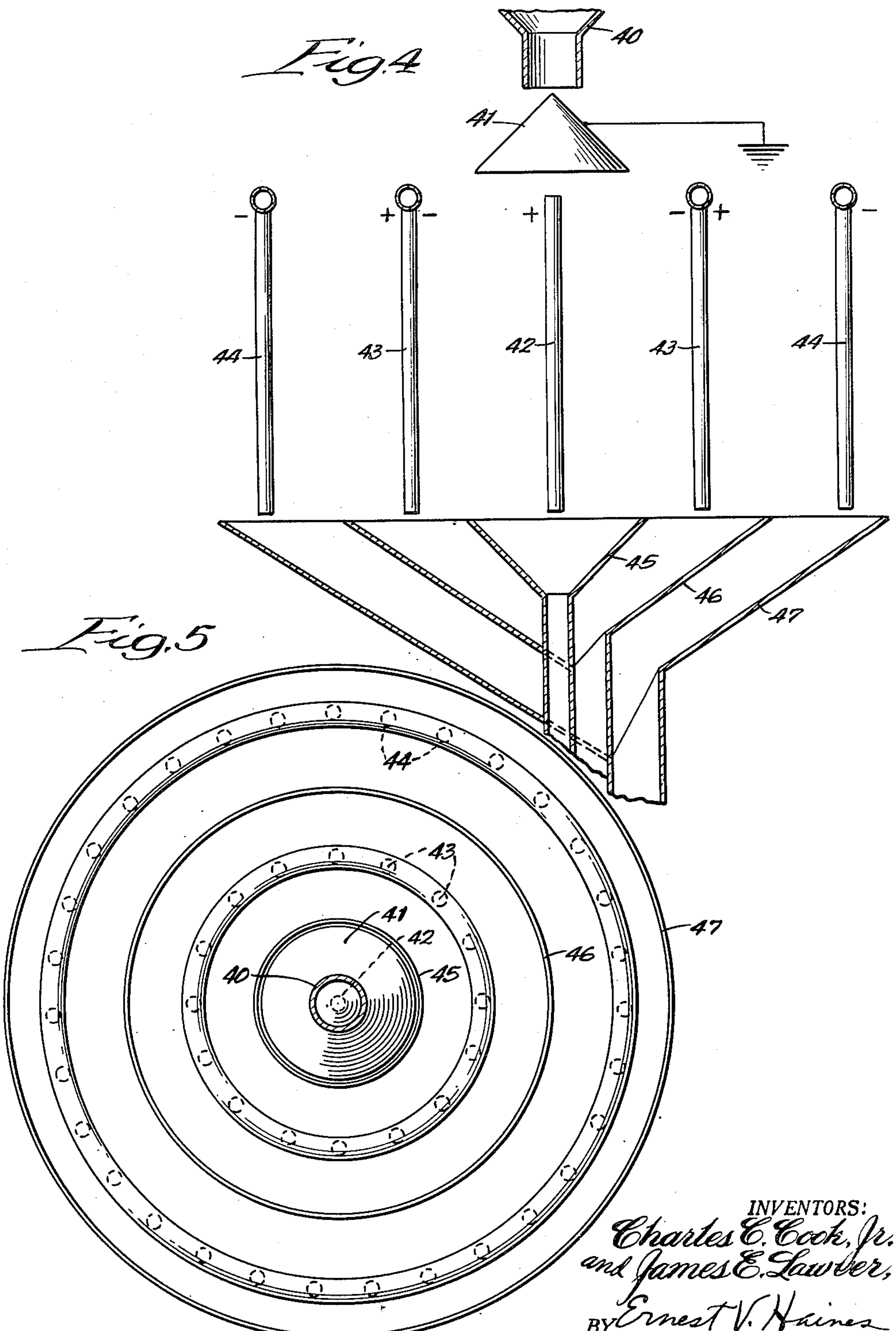

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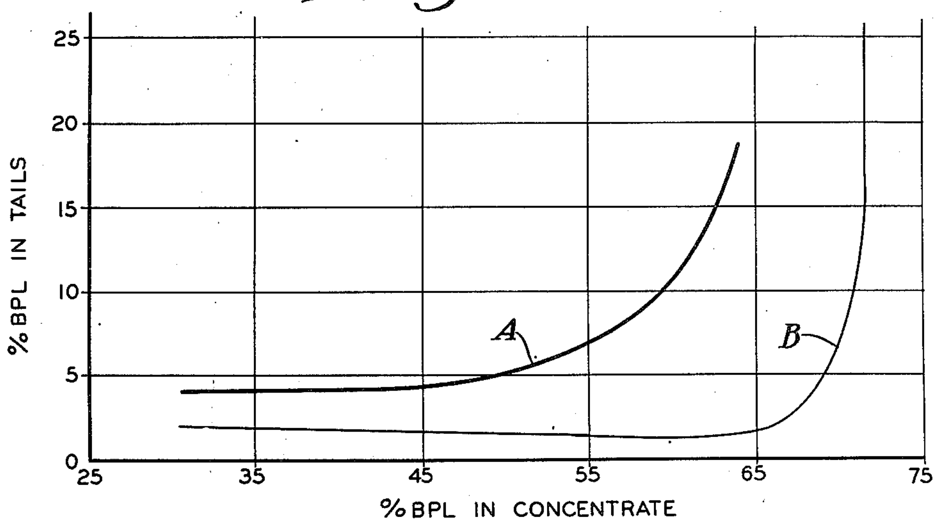
Fig. 6



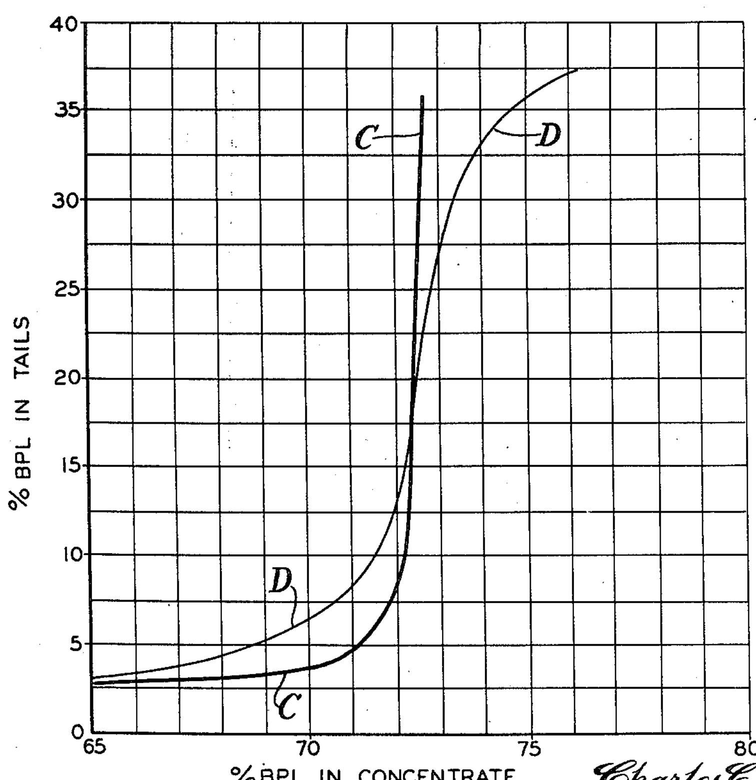


Fig. 7

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METHOD AND APPARATUS FOR BENEFICIATING ORE

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Application March 30, 1951, Serial No. 218,476

14 Claims. (Cl. 209—127)

This invention relates to the concentration of minerals. More particularly, it relates to electrostatic separation of material particles. Still more particularly, it relates to a novel process and apparatus for a separation of this type.

A number of methods have been devised for effecting electrostatic separation of conductor and nonconductor materials. A common system involves the delivery of material to the surface of a drum revolving at relatively slow speed, which drum is one of the charged electrodes. The principle involved is that charged particles which are conductors and bear a charge of opposite polarity from that of the drum are attracted to the drum and adhere thereto during movement of the drum. Particles bearing a charge of the same polarity as the drum are repelled from and are immediately thrown from the surface of the rotating drum if they should contact it.

Other electrostatic apparatus comprises essentially stationary, paired and oppositely charged electrodes. These electrodes have consisted of smooth, straight, or curved plates, between which previously charged material travels as free-falling bodies.

Plate electrodes and rolls, from the point of view of the instant invention, represent the same type of flat surface which has been a constant source of difficulty. The principal difficulty has been the tendency for particles, upon contact with the electrode surface, to take on a reverse charge upon contact with the electrode. When the charge of the particles is reversed, the particles are repelled and travel toward the oppositely charged electrode. Repelled particles of reversed charge thereupon mix with repelled particles originally of opposite charge reducing the effectiveness of the separation. The straight electrodes suffer additional disadvantages over the roll type in that they tend to build up material on the face of the electrode giving rise to interference with the electrostatic field. Additional straight electrodes must be divergent from parallel vertical planes in order to give the stream of falling particles room to spread out and still be in the electrostatic field. This divergence weakens the electrostatic field and thus the efficiency of separation effected between the lower portions of the electrodes falls off rapidly.

It is an object of the instant invention, therefore, to overcome the shortcomings and disadvantages of the processes and apparatus heretofore utilized.

It is a further object of the invention to provide a process in which a large portion of the separated particles are promptly and entirely removed from the influence of the electrostatic field, found directly between the electrodes, once they have migrated to the electrode or electrodes charged opposite to that charge originally possessed by said particles.

It is still a further object of the invention to provide a process in which particles whose polarity becomes reversed go out of the electrostatic field instead of moving toward the opposite electrode.

It is a further object of the invention to provide apparatus in which the electrodes may be equidistantly spaced over their entire length.

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It is a still further object of the invention to provide apparatus having interstitial free space opposite to the spaced areas of the electrostatic field of high intensity thereby permitting particles to escape from the area between the electrodes of opposite polarity.

It is a further object of the invention to provide apparatus which avoids interference at the edges of the electrodes.

It is a still further object of the invention to provide apparatus in which the electrodes need not be positioned in divergent planes to permit separation of falling material, thus avoiding any weakening of the electrostatic field at any point over the length of the electrode.

These and other objects will be apparent to those skilled in the art as the description proceeds.

The present invention has been predicated on the discovery that prompt removal from the electrostatic field maintained between the electrodes of a large portion of the finer particles, and other heavily charged particles which rapidly travel to the electrodes, materially improves the efficiency of separation. The process results in an improved concentration of products and markedly reduces the quantity of so-called middlings. It further eliminates a number of recycle steps to obtain the same degree of concentration, purity, and recovery, by passing the material through a series of electrostatic fields produced by solid flat-plate electrodes.

In one embodiment of the method, a field is not only built up between electrodes whose spaced, curved-face elements provide a large electrode surface, but a portion of the field of considerable strength is retained opposite the open areas between electrode elements of the same polarity, which open areas make the electrodes permeable to ore particles. That portion of the charged material which contacts electrode elements in general, tends to move to the rear of the electrode elements and falls off. That portion of the material which is given a movement by the field through the space between electrode elements of the same polarity upon passing between electrodes of like polarity is affected so as to arrest its flight. Since lateral flight of moving particles is arrested, the particles of like charge fall for collection just to the rear of the spaced electrode elements of like polarity.

In this method for beneficiating ore, material is subdivided until reduced to suitable liberated particle size. The dry comminuted multicomponent ore of relatively uniform particle size is first induced to accept an electrical charge. Charged material is subsequently introduced into an electrostatic field set up between electrodes of opposite polarity having interstitial free space through which the particles are free to move in escaping from the electrostatic field and is collected as concentrate fractions in the vicinity of the lower portions of said electrodes or conductors. In the operation of this method the feed material, generally a raw ore, is crushed sufficiently to unlock its constituents and screened by the usual procedures to produce a granular product having a particle size in the range of approximately −14 mesh and +200 mesh determined by standard screens. Particles in this size range are sufficiently comminuted or disintegrated to separate the ore into individual particles.

Comminuted ore is dried and then induced to accept an electrical charge. The material is preferably charged in the absence of an electric field by causing the particles to contact a conducting or donor surface as by having the donor surface grounded through an electrical conductor whereby electrons are exchanged between the grounded surface and the ore particles. One method of accomplishing this result is to contact warmed particles having a temperature in the range of approximately 85° F.

to approximately 500° F. with a feeder having a grounded contact chute surface of carbon, lead, zinc, aluminum, copper, tin, or the like. When the particles flow in a thin stream over the chute surface, which is connected by an electrical conductor to the earth, the individual particles either accept electrons or give up electrons, thus becoming charged either negative or positive according to the nature of the particular particle.

The charged particles are preferably fed as free-falling bodies in an electrostatic field between the electrodes of one or more electrostatic separating units, i. e., in a path normally not in contact with said electrodes. Free-falling particles are preferred because of the simplicity of the apparatus, but other methods of introducing particles may be utilized. In roll type units, some of the advantages of the pass-through electrode can be obtained by utilization of an electrode, either of straight or semicircular configuration of the hereinafter described type, or similarly acting electrodes, as a substitute for the electrode of opposite polarity from the roll.

The strength of the electrostatic field which will effectively alter the path of particle movement varies with the average particle size of the ore fed to the separator and its charge. This field gradient may vary from 3,000 volts per inch of distance between electrodes, for separating material of relatively fine particle size, to 15,000 volts per inch of distance separating electrodes for beneficiating coarser particles. In all such consideration of field strength it must be borne in mind that corona discharges are to be avoided by correct electrode design and effective corona rings. In general, it is preferred to operate with a total impressed difference in potential or voltage in the range of 50,000 volts to 250,000 volts. This voltage should be maintained at a high direct voltage potential substantially free of alternating current components, i. e., filtered D. C. current should be low in the so-called A. C. ripple. A steady supply of D. C. voltage may also be obtained without expensive filtering apparatus by the use of such equipment as rectified radio frequency power supplies. When several electrodes or conductors are used, the preferred impressed voltage for the primary pair of electrodes of opposite polarity, and adjacent the free-falling feed, is preferably in the range of approximately 50,000 volts to approximately 90,000 volts for the initial attack on the ore, although with a total impressed voltage of, say, 250,000 volts, a series of fields having varying electrostatic field gradients (contiguous to one another) may be set up.

In a further embodiment of the invention, the electrostatic field is elongated by being formed between three or more conductors arranged in a parallel alignment, preferably in a straight line, the pair of oppositely charged electrodes being face-to-face and electrodes of like polarity being in back-to-face arrangement. In such parallel alignment, at least the conductors adjacent the feed stream must be of the construction hereinbefore described, i. e., permeable to said ore particles. In this embodiment of the invention, the potential between a group of laterally displaced conductors of one polarity, and at least the conductor of opposite polarity nearest thereto, is progressively greater or increased as the distance between said conductors of one polarity and said conductor of opposite polarity is increased.

Although the over-all field gradient existing between electrodes is fixed by the impressed difference of potential and distance, the intermediate field gradients of a multiple field gradient electrostatic field may be varied at will by distribution of the potential difference existing between these points.

In elongating the electrostatic field, a potential of, for example, 70,000 volts, is impressed upon the pair of oppositely charged electrodes in close proximity. When a third electrode is used which, for example, gives two adjacent electrodes of the same polarity with reference to the third electrode, the outside electrode being at the highest difference of potential relative to the electrode farthest removed therefrom, the difference of potential between a charged electrode and the first or nearest oppositely charged electrode may be, for example, 70,000 volts, and the difference of potential between the outer electrodes of opposite polarity may be 90,000 volts. Further by way of example, if four electrodes are used, two negative electrodes and two positive electrodes, then the difference of potential between the inner pair may be 70,000 volts and the difference of potential between the outer pair of electrodes may be 110,000 volts. It will be apparent to those skilled in the art from the above description, relative to three and four electrode arrangements, that any number of electrodes may be used. The difference in effect between the odd number of electrodes of one polarity and an even number of electrodes of opposite polarity is to lengthen the potential lateral distance for movement of particles tending to move in the direction of the greater number of electrodes of like polarity, providing the odd number of electrodes are laterally displaced to provide a greater distance between first and last electrodes of like polarity. By pulling the particles a greater distance, opportunity is afforded for rejection of particles of polarity not moving in the direction normally dictated by the polarity of said particles, thus giving a dividing point between product and middling which is less critical while still obtaining efficient recoveries. This movement of particles a greater distance laterally accomplishes a result with Florida pebble phosphate ore or washer debris not heretofore accomplishable in electrostatic separations; namely, producing acceptable commercial-grade purity phosphate from washer debris feed with only a single pass through an electrostatic field.

In any determination of the relative strengths of electrostatic field segments, it must be borne in mind that the electrodes of like polarity must not be separated by such distance that the strength of the field intermediate two electrodes of the same polarity is substantially negligible, i. e., the innermost of the two electrodes is, in effect, the only operative electrode. Electrodes at high differences of potential may be separated by greater distances than electrodes of lower differences of potential and still maintain the same field gradient. When operating at voltages of about 70,000 volts between the primary electrodes, and maintaining higher differences of potential for each succeeding electrode of a group of like polarity, it is preferred that the electrodes be separated by not more than 24 inches and by not less than about 6 inches.

The above distances between electrodes of like polarity may or may not create field gradients between electrodes of like polarity less than the field gradient between the primary electrodes which are of opposite polarity. In general, it is preferred to operate with multiple electrodes so that a field gradient of 5,000 to 15,00 volts per inch is maintained between the primary electrodes and field gradients of between about 500 volts and 10,000 volts per inch are maintained between the secondary electrodes.

It will at once be recognized that symmetry of field gradients need not be maintained. A multiplicity of field segments, all of which have different field gradients, may be set up by variations of such factors as distance, ratio of the voltage drop across the voltage divider, and the like.

Additional factors in determining the distance required for separating products collected separately are the vertical distance between the point of introduction of the ore particles and the collection point and the rate at which particles are free to move in the vertical direction. If the ore, for example, is allowed to fall freely the vertical distance of twenty feet instead of ten feet, the ore will be subjected to lateral displacement by the electrostatic field for a considerably longer time. Consequently, particles of like character may be pulled laterally a greater distance giving rise to a greater purity of the products recoverable at the greatest distance laterally displaced from the point of introduction of the crude ore.

The process for separating ore into its individual components will be more fully understood from the following description as well as the drawings of apparatus incorporating the invention and suitable for carrying out the method.

Figure 1 is a front elevational view of an electrode.

Figure 2 is a top plan view of an electrostatic separator having two electrodes.

Figure 3 is a side elevational view of a diagrammatic electrostatic separator having three electrodes.

Figure 4 is a side elevational view of an electrostatic separator having the electrodes arranged as concentric circles.

Figure 5 is a top plan view of the electrode unit of Figure 4.

Figure 6 is a graph showing a comparison of the separation obtainable with feed material of the same character, in one pass, between standard plate electrodes and two electrodes designed in accordance with instant apparatus improvements.

Figure 7 is a graph showing a comparison of results between two permeable electrodes and a three electrode (permeable) arrangement.

Briefly, the electrostatic separation unit comprises a feed mechanism, a source of substantially unidirectional electromotive force and permeable electrodes of opposite polarity consisting of a plurality of spaced elements having a convex curvature in the direction of the electrode of opposite polarity.

In one embodiment of the invention, the electrodes consist of a crossbar or support member from which depend a multiplicity of spaced conductor members or elements. The spaced members are conductors and in the preferred form are tubular members of similar conducting material as the support member. Material of construction of the electrode elements is preferably one which can be given a relatively smooth finish, such as, for example, copper, iron, aluminum, aluminum alloys, and the like; metal-coated conductors and nonconductors, such as copper, zinc or tin clad elements, and the like.

The preferred shape of the electrode elements is circular or round, although other configurations such as ellipse, or semicircles having the convex curvature toward the preceding conductor of like polarity may be utilized.

In the second embodiment of the invention, the electrodes, except the electrode of either polarity furthest removed from the point of introduction of feed, must be permeable electrodes as hereinbefore described. The end electrodes may be either permeable or solid since this determines the point of collection of particles given the greatest throw or carry through the electrostatic field.

The invention will be best understood from the following description taken in conjunction with the drawings.

Referring to Figures 1 and 2, the numeral **10** indicates an electrode unit composed of a crossbar or support tube **11** and depending spaced tubes **12**. Adjacent the bottom of the spaced tubes are spacers **13**, preferably of conducting material. Comminuted ore to be separated is delivered to the space between electrode units by a vibratory grounded trough feeder **14** spaced intermediate the electrodes **10**, **10*a***, of opposite polarity and adjacent the top thereof. Below and extending beyond the space between the electrode units are a series of concentrate, middling and tailing collection hoppers **15**, **16**, and **17**. Walls on the hoppers may, if desired, be adapted with pivot arms positionable at any desired angle for altering the cut-point of material to be collected in the various hoppers.

In Figure 3 there is diagrammatically illustrated the apparatus when more than two electrode units are utilized. In this figure there is shown three electrode units indicated by the numerals **20**, **21**, and **22**, each of the construction shown in Figure 1 and connected to a source of D. C. power through a voltage divider establishing different impressed voltages upon the electrodes. Ore is delivered to the space between electrodes of opposite polarity by grounded feeder **23**. Below and extending beyond the space between electrodes are a series of concentrate, middlings, and tailing accumulator means; here shown as collection hoppers **25**, **26**, **27**, and **28**. Hoppers **25** and **26**, and hoppers **26** and **27**, and hoppers **27** and **28** are illustrated as having common walls **29**, **30**, and **31**, respectively, although such construction is not necessary. Walls **29**, **30**, and **31** are provided with pivot arms **32**, **33**, and **34**, respectively, adapted to be secured at any desired angle for altering the cut-point of material to be collected in the various hoppers.

Referring to Figures 4 and 5, the numeral **40** indicates a hopper feeder. Feeder **40** delivers granular feed to a cone distributor **41** which is a donor element grounded to the earth. Distributor **41** feeds material between concentric electrodes each respectively having a series of spaced elements **42** and **43** connected to the electrical circuit so as to have opposite polarity. Surrounding the electrode elements **43** and spaced therefrom is an outer concentric electrode having a series of spaced elements **44**. Below the electrodes are collection hoppers **45**, **46** and **47** for tails, middling, and concentrate, respectively.

The instant invention is clearly illustrated by the following examples.

Example I

Comminuted, dried, Florida pebble phosphate ore was separated into two components by passing between two 10 feet long, flat-plate electrodes. The separation effected is shown by curve A of Figure 6. The separation accomplished by the method and apparatus of the instant invention, also having 10 feet long electrodes arranged as in Figure 2, is shown by curve B. Phosphate ore utilized for these tests was deslimed Florida pebble rock washer debris, which was sized to a particle size in the range of −14 and +200 mesh. This material was dried in an electric oven. After drying, the warm particles were charged by passage over a zinc-coated surface of a trough whose zinc coating was grounded to the earth through a copper conductor. The charged ore particles then were fed to the respective separating units, each having a difference of potential of 90,000 volts impressed across the electrodes.

Comparison of curves A and B shows that the silica or tail fraction obtained with standard electrodes at low phosphate concentrations contains almost 100% more phosphate than that contained in the tails using the novel invention. Or expressed in another way, almost twice as much phosphate would be lost in the tail fraction unless such tail were subjected to additional processing. Further comparison shows that as the phosphate concentrate increases in bone phosphate of lime content (B. P. L.), the phosphate content of the tails obtained with standard electrodes rises sharply above any commercially practical phosphate concentration operation. On the other hand, the method of the instant invention (curve B) shows substantially no increase in the phosphate content of the throw-away tail fraction until the B. P. L. content of the concentrate exceeds 65%. A phosphate concentrate product of over 96% B. P. L. recovery was obtained using the novel method.

In Figure 7 there is shown a comparison of results obtained by use of two permeable electrodes of the type shown in Figure 2 and three permeable electrodes as shown in Figure 3.

For this test Florida phosphate rock was sized and a fraction having a particle size in the range of between −14 mesh and +200 mesh was divided into two portions. The portions were each dried in an electric oven for three hours and charged by passage over a grounded galvanized iron chute.

Curve C shows the separation effected when the two electrodes were spaced 9 inches apart and had a voltage of 90,000 volts impressed thereon. Curve D shows the separation of the second portion of the feed when the primary electrodes **20** and **21** (Figure 3) were separated by 8 inches with an impressed voltage of 80,000 volts, while the electrodes **21** and **22** (Figure 3) were separated by 13 inches and had a difference of potential of 10,000 volts.

Comparison of curves C and D shows that for phosphate ore having a B. P. L. content of approximately 38.4%, the maximum attainable B. P. L. content in one pass through two 10 feet long permeable electrodes is about 72.7%. On the other hand, the multiple field gradient arrangement concentrates of 76.2% B. P. L. content are obtainable with the same B. P. L. content of tails as is obtainable with the two electrode arrangement.

Example II

Sylvinite ore from the Carlsbad section of New Mexico was crushed in a jaw crusher and screened to produce a fraction having particles in the size range of −28 to +65 mesh. This material was dried in an electric oven at 360° F. The dry material was electrostatically separated in a unit arranged as in Figure 3 having 20 feet long electrodes, the individual segments being 3 inches in diameter. Dry material was fed at a rate of one ton per hour per foot of electrode length.

Data obtained on one pass operation was as follows when the primary electrodes were spaced 7 inches apart and had 20,000 volts impressed thereon (field gradient of approximately 3,000 volts per inch). The secondary electrode was spaced 17 inches from the primary electrode and had an impressed voltage differential between electrodes of 60,000 volts (field gradient of approximately 3,500 volts per inch).

	Wt. percent of feed	Percent K_2O (wt.)
Feed	100	15.68
Tail	15.3	9.9
Middling	43.3	13.6
Concentrate	41.4	20.1

Having thus fully described and illustrated the character of the invention, what is desired to be secured and claimed by Letters Patent is:

1. A method of beneficiating phosphate ore which comprises inducing the dry ore of relatively uniform particle size to selectively accept an electrical charge, subjecting the charged phosphate ore as free-falling bodies to the attractive and repulsive forces of a multiple field gradient electrostatic field produced by at least three electrodes in parallel alignment, at least the electrodes adjacent the feed stream being permeable to said phosphate ore particles, the field gradient of field segments outside the primary electrodes varying from less than to more than the field gradient between the primary electrodes, and collecting at least a concentrate rich in phosphate values and a tail low in phosphate values in the vicinity of the lower portions of the electrodes.

2. A method of beneficiating phosphate ore which comprises contacting the granular ore of a particle size in the range between about 14 mesh and about 200 mesh and at a temperature in the range of about 150° F. to about 350° F. with a galvanized iron plate grounded to the earth by an electrical conductor, subjecting the selectively charged ore particles as free-falling bodies to a multiple field gradient electrostatic field bounded by electrodes, at least the electrodes adjacent the feed stream being permeable to said phosphate ore particles, the electrostatic field having a total impressed difference of potential of about 90,000 volts, the primary pair of electrodes adjacent the feed stream being at an impressed difference of potential of about 70,000 volts, and collecting at least a concentrate rich in phosphate values and a tail low in phosphate values in the vicinity of the lower portion of the electrodes.

3. A method of beneficiating sylvinite ore which comprises inducing the dry granular ore of a particle size in the range of about −28 mesh and about +65 mesh and at a temperature in the range of about 150° F. to about 350° F. with a galvanized iron plate grounded to the earth by an electrical conductor whereby the particles are charged by exchange of electrons, subjecting the selectively charged particles as free-falling bodies to a multiple field gradient electrostatic field bounded by three electrodes, at least the electrodes adjacent the feed stream being permeable to said ore particles, the field gradient between the electrodes adjacent the feed being approximately 8,000 volts per inch of distance separating the electrodes and the field gradient between the secondary electrode spaced from said primary electrode being approximately 3,500 volts per inch of distance separating these electrodes, and collecting at least a concentrate rich in sylvite and a tail low in sylvite in the vicinity of the lower portion of said electrodes.

4. A method for beneficiating ore which comprises inducing dry multicomponent ore to selectively accept an electrical charge, introducing the charged ore into an electrostatic field having a multiplicity of laterally disposed field gradient segments whereby particles passing from the initial field segment into which the particles are introduced may move into adjacent field segments whose effective horizontal force is in the same direction of that of the initial field segment, the field gradient of field segments outside the initial field segment into which the particles are introduced varying from less than to more than the field gradient in the initial field segment, and collecting the material concentrated after passage through the electrostatic field in the vicinity of the lower portions of said field gradient segments.

5. A method of beneficiating ore which comprises inducing dry multicomponent ore of relatively uniform particle size to selectively accept an electrical charge, subjecting the charged particles as freely falling bodies to the attractive and repulsive forces of an electrostatic field having two laterally disposed field gradient segments whereby particles of one polarity passing from the initial field segment into which the particles are introduced may pass to the second field segment whose horizontal force is in the same direction as that of the initial field segment, the field gradient of the field segment outside that into which the particles are introduced varying from less than to more than the field gradient in the initial field segment, and collecting the material concentrated after passage through the electrostatic field in the vicinity of the lower portions of the field gradient segments.

6. A method of beneficiating ore which comprises contacting dry multicomponent ore of relatively uniform particle size in the range between about 14 mesh and about 200 mesh and at a temperature in the range between about 150° F. and about 350° F. with a zinc plate grounded to the earth by an electrical conductor, subjecting the selectively charged ore particles as freely falling bodies to an electrostatic field having three laterally disposed contiguous field gradient segments whereby particles passing from the initial field segment into which the particles are introduced may pass into adjacent field segments whose effective horizontal force is in the same direction as to the particles of identical polarity as that of the initial field segment, the electrostatic field having a total impressed difference of potential of between about 50,000 volts and about 250,000 volts, the initial field segment being at an impressed difference of potential in the range of approximately 20,000 volts and of approximately 90,000 volts, and collecting the material concentrated after passage through the electrostatic field in the vicinity of the lower portions of said field gradient segments.

7. An electrostatic separation machine comprising a source of substantially unidirectional electromotive force, at least three vertically suspended electrodes mounted in parallel alignment and connected to said source of electromotive force by means insuring that adjacent field gradients are different in strength although the effective horizontal force as regards particles of a single polarity is always in the same direction, a feed mechanism having a low work function surface which is capable of exchange of electrons with the ore to be treated for contacting the particles delivered, said surface being connected to the earth by an electrical conductor and adapted to introduce the particles into the area intermediate the electrodes, said electrodes comprising a plurality of vertically suspended spaced elements having a convex surface in the direction of an electrode of opposite polarity and collection hoppers for separated material.

8. An electrostatic separation machine comprising a source of substantially unidirectional electromotive forces delivered at a voltage of approximately 250,000 volts, four vertically suspended electrodes mounted in parallel alignment and connected to said source of electromotive force insuring that field gradients are different in strength although the effective horizontal force as regards particles of a single polarity is always in the same direction, a feed mechanism having a zinc coated delivery chute connected to the earth by an electrical conductor and positioned adjacent the top of the inner pair of electrodes, said delivery chute being adapted to drop charged ore particles intermediate said inner pair of electrodes, said electrodes consisting of a plurality of spaced vertically disposed elements having convex curvature in the direction of the electrode of opposite polarity, and collection hoppers for separated materials.

9. An electrostatic separation machine comprising a source of substantially unidirectional electromotive force, at least three vertically suspended electrodes connected to said source of electromotive force by means insuring that adjacent field gradients are different in strength although the effective horizontal force as regards particles of a single polarity is always in the same direction, a feed mechanism wherein material to be separated contacts a surface which is capable of exchange of electrons with the feed material and which is adapted to introduce the feed material into the space intermediate electrodes of opposite polarity, said electrodes being arranged with a central core electrode and said electrodes outside the core electrode being arranged concentric therewith and the individual electrodes comprising a horizontal conductor having a plurality of circular vertically disposed elements equilaterally spaced to form a circular unit, and collection hoppers for separated material.

10. An electrostatic separation mechanism comprising means for feeding pulverulent material, parallel electrodes spaced beneath and upon opposite sides of the feed means, auxiliary electrode means horizontally spaced from at least one of the first electrodes and positioned parallel to said parallel electrodes, and means beneath the electrodes to collect pulverulent material passing therebetween.

11. An electrostatic separation machine comprising a solid particle feed mechanism, a source of substantially unidirectional electricity, at least three electrodes connected to said source of electricity, said electrodes having the electrode headers horizontally spaced and parallel and the depending portions of the electrodes substantially vertically suspended in parallel alignment, at least the two electrodes between which the feed mechanism delivers

feed being of opposite polarity, the depending portions of said electrodes consisting of a plurality of spaced elements having convex curvature in the direction of the oppositely charged electrode.

12. An electrostatic separation machine comprising a solid particle feed mechanism, a source of substantially unidirectional electricity, at least three electrodes connected to said source of electricity, said electrodes having the electrode headers horizontally spaced and parallel and the depending portions of the electrodes substantially vertically suspended in parallel alignment, at least the two electrodes between which the feed mechanism delivers feed being of opposite polarity, the depending portions of said electrodes consisting of a plurality of spaced elements having convex curvature in the direction of the oppositely charged electrode and collection hoppers for separated particles.

13. An electrostatic separation machine comprising a solid particle feed mechanism having a low work function surface which will exchange electrons with the ore to be treated for contacting the particles delivered, said surface being connected to the earth by an electrical conductor, a source of substantially unidirectional electricity, at least three electrodes connected to said source of electricity, said electrodes having the electrode headers horizontally spaced and parallel and the depending portions of the electrodes substantially vertically suspended in parallel alignment, at least the two electrodes between which the feed mechanism delivers feed being of opposite polarity, the depending portions of said electrodes comprising a multiplicity of spaced depending conductor elements, and accumulator means for separated particles.

14. A method of beneficiating ore which comprises inducing dry multi-component ore to selectively accept an electrical charge, forming at least two electrostatic fields disposed in contiguous side-by-side relationship and having a permeable boundary between said fields, the contiguous secondary field having a polarity such that the force causing particle deviation from the free-fall path in the first field is continuous in one direction into the second field, introducing the charged ore into less than all of the fields, causing the ore to fall freely while subjecting the particle to said field and particles of at least one polarity being subjected to the forces of both the primary and secondary fields, and collecting the material concentrated after passage through the electrostatic field in the vicinity of the lower portions of the electrodes.

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