Aug. 11, 1959 I. M. LE BARON 2,899,055

ELECTROSTATIC METHOD AND APPARATUS FOR BENEFICIATING MINERALS

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FIG. 1

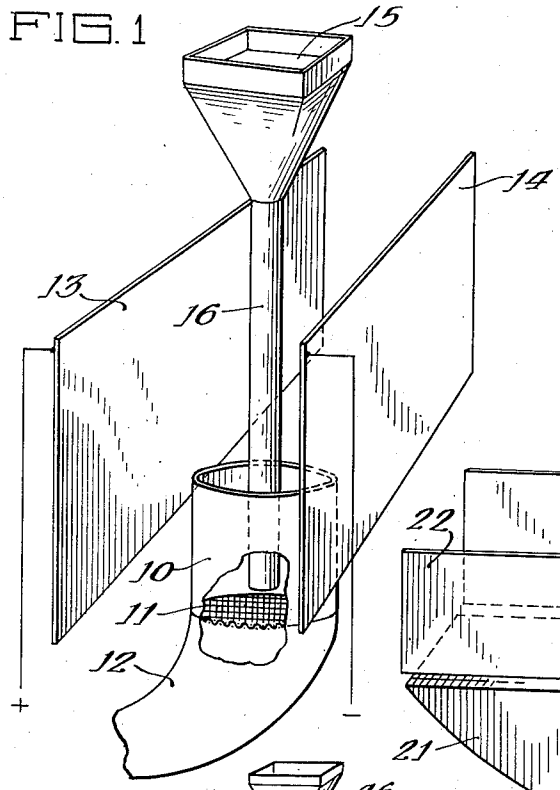
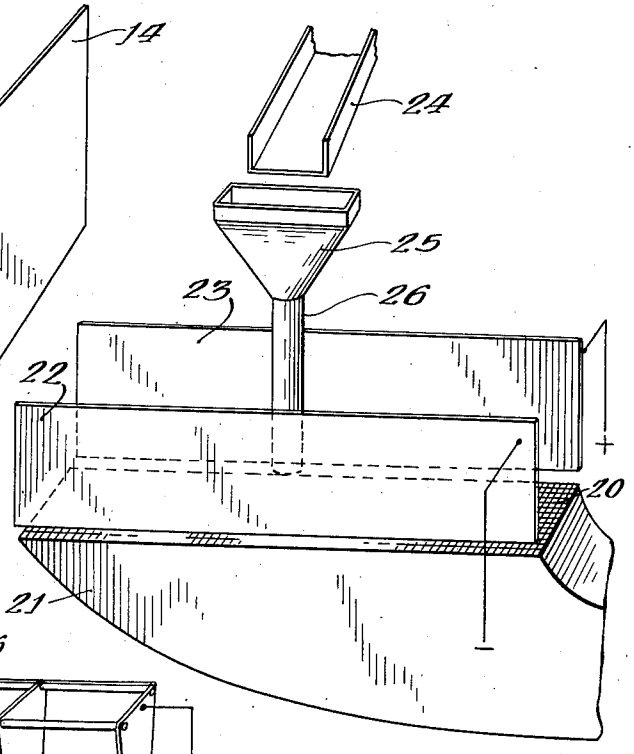


FIG. 2



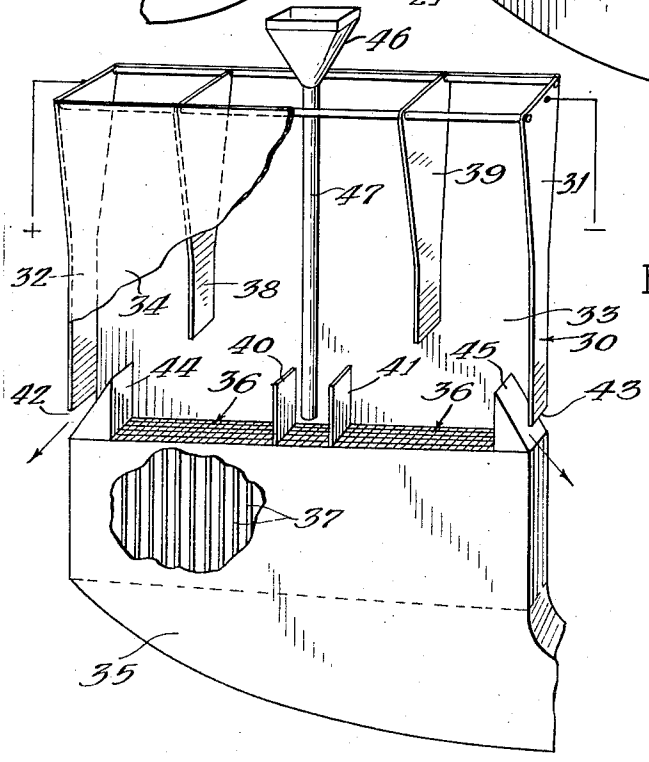


FIG. 3

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ELECTROSTATIC METHOD AND APPARATUS FOR BENEFICIATING MINERALS

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This invention relates to a method and apparatus for beneficiating minerals. More particularly, it relates to a method and apparatus for electrostatically separating relatively nonconductive materials. Still more particularly, it relates to a method and apparatus for electrostatically separating phosphate values from the silica with which the phosphate is found associated in nature.

A number of methods have been devised for effecting electrostatic separation of nonconductor materials. A commonly applied system involves the passage of selectively charged ore particles as free-falling bodies through at least one electrostatic field, the particles falling in a path normally not in contact with the electrodes at the extremities of the field or fields.

This method has a number of disadvantages. A primary disadvantage is that in travelling as free-falling bodies, the particles travel rapidly through the electrostatic field, the period during which the lateral displacement force can act being extremely short. Secondly, the gravitational component of force acting on the particles is sufficiently large to reduce the effectiveness of the lateral forces of the electrostatic field.

Another disadvantage of the commonly applied systems is the sensitivity of electrostatic separations to small changes in moisture content of the ore feed. For effective separations in electrostatic fields, the granular feed material must be dry at least on the surface and maintaining a dry surface under varying humidity conditions often is difficult.

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

It is a further object to provide a method wherein particles are suspended in an electrostatic field instead of falling freely in response to gravitational pull.

It is a still further object to provide a method wherein weakly charged particles are exposed to an electrostatic field in a medium permitting free movement until the particle is committed to lateral movement toward one or the other of the oppositely charged electrodes.

It is another object of the invention to provide a method wherein the granular material to be electrostatically separated is suspended in a medium whose moisture content can be controlled so as to maintain the granular material at least dry on the surface.

It is a further object to provide apparatus for carrying out an electrostatic separation method of the type above indicated.

It is a further object to provide apparatus for suspending mineral particles in a dispersed form which give substantially vertical movement so that lateral movement of particles is solely due to the electrostatic field.

These and other objects of the instant invention will be apparent to those skilled in the art.

It has been discovered that multicomponent ore particles can be maintained in suspension in a flowing gaseous stream within the effective zone of an electrostatic field, which suspension is such that the forces of the electrostatic field are given freedom to exercise maximum effectiveness on charged particles and cause particles of like electrical charge to be accumulated adjacent one or the other of the electrodes bounding the electrostatic field while the lateral movement force of the electrostatic field is given freedom to exercise maximum effectiveness.

It has further been discovered that multicomponent ore particles of relatively uniform particle size may be effectively dried in an aerated or fluidized state and the gas velocity so regulated that the particles when dry will be suspended or entrained in air while in the effective zone of an electrostatic field. Air-borne particles if dry and preferably hot, are readily separated when the particles come under the influence of electrostatic field forces.

In this novel method, granular ore is introduced into a directionalized gas stream flowing at a rate sufficient to fluidize the bed, and electrostatic separation effected while the particles are in an aerated state. More particularly, ore of a relatively uniform particle size is introduced into a gas stream flowing in a constricted space at a rate sufficient to fluidize the bed and to move the particles to a position where they are free to migrate in response to an electrostatic field, following which the particles free to migrate are subjected to the attractive and repulsive forces of an electrostatic field. When the air flow is from a constricted zone to an expanded zone such transitions must be accomplished in a manner minimizing turbulence, since turbulence must be kept to a minimum at all times when electrostatically separating solids while suspended in a gas stream. In carrying out a drying and separating method, ore having a moisture content excessive for effective electrostatic separations is introduced into a directionalized warm gas stream at a rate sufficient to fluidize the ore, following which the gas and entrained particles are preferably directed through an area of cross section larger than the fluidizing ore whereby gas velocity is reduced and entrained particles are held in a rough unstable suspension, at which stage particles are subjected to electrostatic separation. When operating in accordance with the preferred form of this invention, multicomponent ore particles are suspended in a gas stream which may comprise inert gases alone, mixtures thereof or mixtures thereof with other gases; for example, nitrogen, carbon dioxide, helium, as well as such mixtures as air, and the like. These gases, in which the ore is either fluidized or suspended, or both, preferably have a temperature in the range of about 90° F. to about 500° F. when separating materials such as phosphate and silica but temperatures outside this range may be used for other ores such as sylvinite ore; for example, 850° F. A gas stream generally will be maintained at temperatures sufficient to hold the solid particles at a temperature above about 200° F.

Various types of minerals may be beneficiated by the method of the instant invention; for example, to recover phosphate from silica in beneficiating phosphate ores, sylvite from potash ores, such as sylvinite, feldspar from quartz of various sands, barite from fluorite and numerous other nonconductor and conductor minerals. When an ore is sufficiently dry to be effectively separated, and is suspended in a position free to move without appreciable mutual hindrance, the particles are subjected to the attractive and repulsive forces of an electrostatic field. The over-all difference of potential impressed upon the electrodes bounding this field is generally in the range of 50,000 to about 250,000 volts, the field gradient or gradients within the field generally being in the range of about 1,000 volts per inch to about 15,000 volts per inch of distance separating the electrodes.

Particles responding to the pull of an electrostatic field must have an electrical charge. Particles may acquire this charge in a number of different ways. The development of polarity of the particles may arise from tribo-

electrification, as in agitated contact between multicomponent ore particles with or without the aid of an electrostatic field or from X-ray radiation, electromagnetic irradiation associated with sodium vapor light and the like. The particles also exhibit charges after having been dried in a fluidized or suspended state. The particles exhibit a considerably higher selectivity in charging and acquire charges of relatively greater magnitude if the charging is accomplished while particles are heated. In general, it is preferred to heat, for example, phosphate particles to a temperature in the range of about 90° F. to about 350° F. It must be borne in mind however, that all the particles need not be selectively charged in order to make separations in an electrostatic field. So long as all particles of like chemical nature are similarly charged, separation can be made from uncharged or oppositely charged particles.

In beneficiating ore, material for electrostatic separation is prepared having due regard to the density of the particles and to the gas velocity to be utilized. The more uniform the particle size the smaller the zone in which particles will remain suspended. The means for preparing the feed is determined by the nature of the ore. Florida phosphate pebble, for example, can be prepared in particle sizes in the range between about 14 mesh and about 200 mesh merely by washing and sizing. In the Florida operations, only +14 mesh size pebbles are subjected to grinding. On the other hand, phosphate rock from other sources, such as Tennessee, and many other minerals, must be ground to economic liberation to effect the unlocking of components.

When beneficiating phosphate pebble ore, granular material of an over-all particle size in the range between 14 mesh and 200 mesh may be utilized, although materials having a smaller range, for example, 14 mesh to about 65 mesh, or 50 mesh to about 150 mesh, are preferably utilized. Material of this particle size and density may be fluidized and suspended in gases having practical velocities in the range of about 300 feet per minute to about 700 feet per minute. Naturally, minerals of different density but of the same relative particle size may be suspended by gas velocities outside of this range. In order to accomplish most effective separations, the ore particles are held in suspension in substantially vertical streams so that the path followed by the particle is normally not in contact with the electrodes establishing the electrostatic field. The particles thus suspended derive their lateral movement substantially from the pull exerted upon them by the electrostatic field.

The strength of the electrostatic field which will effectively alter the path of ore particles varies with the average particle size and the type of material. The field gradient or strength may vary from 1,000 to about 5,000 volts per inch of distance between electrodes in separating materials of relatively fine particle size and of a comparable density to phosphate ore and from 3,000 to 15,000 volts per inch for beneficiating of coarser particles. In all such discussion of field strength it must be borne in mind that corona discharges which ionize air are to be avoided. In general, it is preferred to operate with a total impressed difference of potential in the range of about 30,000 volts to about 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 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 high frequency power supply.

Separations of the type above discussed may be made on comminuted raw ore or upon fractions recovered from a previous separation. In general, the beneficiation procedure is to make a first or so-called rougher separation and to subject the tail and concentrate products obtained in the rougher separation to one or more additional separations known as scavenger and cleaner separations respectively. Intermediate value products obtained in these latter separations generally are combined with feeds to separation and stages which the product approaches in chemical assay.

The method of separating ore into its components will be more fully understood from the following description as well as the drawings of apparatus suitable for carrying out the method in which:

Figure 1 is a perspective schematic view of an apparatus provided with a circular suspension area.

Figure 2 is a perspective schematic view of an apparatus provided with a rectilinear suspension area.

Figure 3 is a perspective view of the side elevation of an apparatus having a rectilinear fluidizing area and a baffled and enlarged cross sectional suspension area.

Briefly, the electrostatic separation unit comprises gas channeling means for providing substantially straight air flow at least initially, a conduit through which the air flows, a source of unidirectional electricity, electrodes connected to said electricity source and of opposite polarity positioned on opposite sides of said conduit, and means for introducing granular feed material into said conduit.

In one embodiment of the invention, the conduit, in which ore is suspended, comprises a uniform dimensional feed pick-up area of rectangular cross section which at one end is provided with two oppositely positioned diverging walls. Particles suspended within this area of enlarged cross section are in suspension within the effective zone of an electrostatic field whose forces operate to move the particles laterally beyond the effective range of the upwardly flowing gas medium. Particles thus moved into the vicinity of one or the other of the electrodes falls to an outlet for passage to collection means adjacent the bottom of the electrodes.

Referring to Figure 1, the numeral **10** indicates a circular tube of a relatively poor conductor material. At the bottom of tube **10** is positioned a porous medium **11** adapted to hold material of particle size being fed to the tube. Below medium **11**, the tube is provided with air inlet means **12** adapted to give substantially vertical gas flow. On opposite sides of tube **10** are positioned plate electrodes **13** and **14**. Plates **13** and **14** have a height depending upon the interrelated factors of particle size, density, and velocity. Feed material enters tubular member **10** from a hopper **15** through conduit **16** which is adapted to deliver the feed in close proximity to the screen.

Referring to Figure 2, the numeral **20** indicates a rectangular screen of a mesh capable of retaining on its surface the smallest particles of the ore being delivered thereto. Below screen **20** is a gas inlet conduit **21** adapted to deliver substantially vertical gas streams through the screen. Along the longest sides of the rectangular screen **20** there are positioned vertical electrodes **22** and **23**. Electrodes **22** and **23** are sufficiently removed from the edges of screen **20** to enable material coming to an electrode face to drop into a quiet collection area and not be caught in upwardly moving gas streams. Material travelling to levels slightly higher than the electrodes generally are pulled laterally and pass over the top of the electrode falling to the rear thereof for collection. Feed material is delivered to screen **20** through a vibratory feeder **24**, hopper **25**, and conduit **26**.

Referring to Figure 3, numeral **30** indicates a rectangular cross section tubular chamber having four walls **31**, **32**, **33** and **34**. Tubular chamber **30** is provided on its lower end with gas inlet conduit **35**. Intermediate the ends of tubular member **30** there is positioned a screen **36**. Below screen **36** are positioned a multiplicity of closely set baffles **37** between which gas must pass before reaching screen **36**. At the upper ends walls **33** and **34** diverge to form a chamber of enlarged cross sectional area. End walls **31** and **32** are electrode elements or have secured thereto, conductor material which forms elec-

trodes; for example, copper, iron, aluminum, aluminum alloys, as well as zinc-surfaced elements, and the like. The interior of unit **30** is baffled to reduce the effects of stray air currents. Generally, the baffling consists of two baffles such as baffles **38** and **39** in the suspended powder zone and baffles such as baffles **40** and **41** isolating the feed section of the fluidizing zone. End walls **31** and **32** are provided with apertures **42** and **43** inwardly from which are wedge-shaped units **44** and **45** which serve to direct particles brought into the vicinity of the electrodes and falling out of contact with suspended air streams to collection means outside chamber **30**. Feed is introduced between baffles **40** and **41** by means of a hopper **46** and a conduit **47**.

The following examples illustrate results accomplished by the method and apparatus of the invention.

Example I

Florida phosphate ore was water washed and was sized to produce a fraction having a particle size 100% of which was in the range between about 35 mesh and about 325 mesh. The granular ore was heated to a temperature of about 300° F. Warm ore was fed directly into tubular member **10** of apparatus shown in Figure 1 having a polystyrene plate at the bottom perforated with about 100 holes of 0.004 mesh diameter per 40 square inches of area. The air pressure was adjusted until the bed became fluid. With a slight increase in air pressure, the granular material moved upwardly outside the fluidizing area where the particles were free to migrate in response to the electrostatic field. The field gradient between electrodes was fixed at approximately 3,500 volts per inch. The material had a B.P.L. content of approximately 36%. Two products were collected. The phosphate concentrate fraction had a 65.3% B.P.L. content with approximately 13.9% insoluble material. The silica product or tail fraction had approximately 3.8% B.P.L. content.

Example II

Sylvinite ore from the Carlsbad area of New Mexico was ground and sized to produce a granular ore having a particle size in the range of about 28 mesh to about 150 mesh. This ore analyzed approximately 17.5% K_2O. The sized ore was dried in an electric oven for six hours at a temperature of about 350° F. The dry ore was delivered to the apparatus of Figure 3. A warm air stream of sufficient strength was used to move the granular ore up out of the feed section between baffles **40** and **41**. The electrodes were galvanized iron sheets having a field gradient between the electrodes of about 1500 volts per inch of distance separating the electrodes. Two products were collected: a potassium chloride concentrate and a sodium chloride tail. The potassium chloride concentrate (sylvite) from one pass between the electrodes analyzed approximately 47.5% K_2O while the sodium chloride tail analyzed approximately 11.2% K_2O.

An examintion of the results in Examples I and II show that in each instance marked beneficiation was accomplished in one pass through the suspension apparatus.

Having thus fully described my invention, what I claim is:

1. A method of separating relatively non-conductive materials which comprises introducing relatively uniform particle size material having excess moisture for effective electrostatic separation into a warm gas stream flowing vertically upward at a rate sufficient to fluidize said particles, directing the gas stream flowing from the fluidized particles vertically upward through a zone of larger cross sectional area between spaced electrodes of opposite charge in a path normally out of contact with said electrodes, whereby the gas velocity is reduced and dry entrained particles are held in a relatively rough unstable suspension, and particles of like electrical charge are caused to accumulate adjacent the electrode of opposite charge, and separately collecting the particles accumulating adjacent each of said electrodes.

2. A method or separating relatively non-conductive materials which comprises introducing relatively uniform particle size material having excess moisture for effective electrostatic separation into a substantially vertically directed warm gas stream flowing upward at a rate sufficient to fluidize said particles, directing the gas flowing from the fluidized particles vertically upward through a zone of progressively expanding cross sectional area between spaced electrodes of opposite charge in a path normally out of contact with said electrodes, whereby the gas velocity is reduced and dry entrained particles are held in a relatively rough unstable suspension, and particles of like electrical charge are caused to accumulate adjacent the electrode of opposite charge, and separately collecting the particles accumulating adjacent each of said electrodes.

3. A method of separating relatively non-conductive materials which comprises continuously introducing relatively uniform particle size material having excess moisture for effective electrostatic separation into a gas stream flowing vertically upward at a rate sufficient to fluidize said particles, heating the gas stream to a temperature in the range of about 90° F. to about 500° F., whereby upon passage through said fluid bed the particles are dried, directing the gas flowing from the fluidized particles vertically upward through a zone of larger cross sectional area between spaced electrodes of opposite charge in a path normally out of contact with said electrodes, whereby the gas velocity is reduced and dried particles are suspended in the gas stream, and particles of like electrical charge are caused to accumulate adjacent the electrode of opposite charge, and separately collecting the particles accumulating adjacent each of said electrodes.

4. In a method of separating particulate solid materials, which method comprises passing selectively charged particles of said materials between spaced electrodes of opposite charge in a path normally out of contact with said electrodes, whereby said particles are subjected to the attractive and repulsive forces of an electrostatic field and whereby particles of like electrical charge are caused to accumulate adjacent the electrode of opposite charge, and separately collecting the particles accumulating adjacent each of said electrodes, the improvement which comprises suspending said particles in a gaseous stream flowing substantially vertically upward between said electrodes, whereby the lateral forces of said electrostatic field are permitted to exercise maximum effectiveness.

5. A process as in claim 4 wherein said material in finely divided form is introduced into a gaseous stream flowing upward at a rate sufficient to fluidize the body of material and to elevate particles of the material to a zone of reduced particle concentration, in which zone said particles are subjected to contact with said electrostatic field.

6. In a method of beneficiating a multicomponent ore, which method comprises passing selectively charged particles of said ore between spaced electrodes of opposite charge in a path normally out of contact with said electrodes, whereby said particles are subjected to the attractive and repulsive forces of an electrostatic field having a field gradient between about 1,000 and about 15,000 volts per inch of distance separating the electrodes, and whereby particles of like electrical charge are caused to accumulate adjacent the electrode of opposite charge, and separately collecting the particles accumulating adjacent each of said electrodes, the improvement which comprises suspending said particles of said ore in a hot gaseous stream flowing substantially vertically upward between said electrodes, whereby the lateral forces of said electrostatic field are permitted to exercise maximum effectiveness.

7. A method as in claim 6 wherein a phosphate ore of a particle size in the range between about 14 and about 200 mesh is subjected to beneficiation in an electrostatic field having a field gradient in the range between about 3,000 and about 10,000 volts per inch.

8. A method as in claim 6 wherein a sylvinite ore of a particle size in the range between about 28 and about 150 mesh is separated into fractions comprising a sylvite-rich fraction and a halite-rich fraction by suspension in a gaseous stream maintained at a temperature sufficiently high to hold the particles at a temperature above about 200° F. and contact with an electrostatic field having a field gradient of about 1,500 volts per inch.

9. Electrostatic separation apparatus comprising a vertically disposed conduit, gas inlet means in the lower portion thereof, gas channeling means in the lower portion of said conduit for permitting the upward passage of gases while substantially preventing the downward passage of finely divided solids, inlet means for introducing finely divided solids into said conduit above said gas channeling means, an upward extension of said conduit having a larger cross sectional area than said conduit, and electrodes at opposite sides of said extension, connectable to a source of unidirectional electricity.

10. Apparatus as in claim 9 wherein said conduit is of substantially uniform cross sectional area.

11. Apparatus as in claim 9 wherein said extension of said conduit progressively increases in cross sectional area in the upward direction.

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