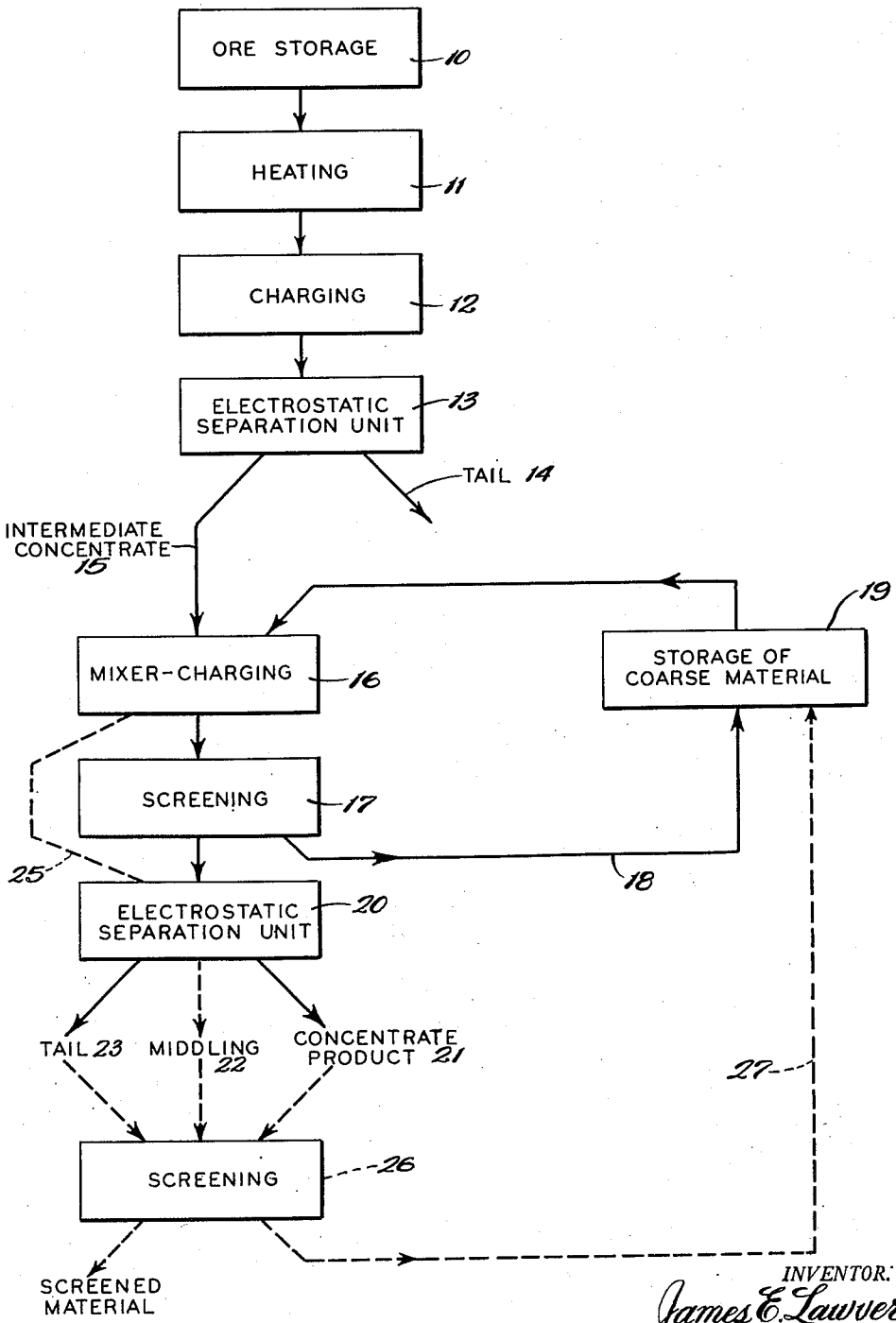
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METHOD OF BENEFICIATING MULTICOMPONENT ORE

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INVENTOR.
James E. Lawver,
BY
Ernest V. Haines
ATTORNEY.

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METHOD OF BENEFICIATING MULTICOMPONENT ORE

James E. Lawver, Lakewood, Colo., assignor to International Minerals & Chemical Corporation, a corporation of New York

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This invention relates to an electrostatic method of beneficiating ore materials. More particularly, it relates to the concentration of multicomponent ore materials reducible to an unlocked granular form. Still more particularly it relates to the recovery by electrostatic separation of relatively pure components of nonmetallic materials such as phosphate, silica, sylvite, feldspar, fluorspar, and the like.

Electrostatic beneficiation of minerals has been practiced in a number of forms. It has been commonly utilized to separate conductors from nonconductors. Apparatus utilizing corona discharge, or using a rotating roll, which is one of a pair of electrodes, are examples of equipment for this type of operation. A second system utilizable for separation of conductors from conductors and nonconductors from nonconductors has been the selective reagentizing of materials so that they may be processed as though the separation were one of removing conductors from nonconductors. Electrostatic separation has been applied in still a third form to separate nonconductors. In the latter system, the nonconductors are selectively induced to accept a positive or a negative charge and then are separated as freely-falling bodies drawn in the direction of one or the other of the electrodes being maintained at a high impressed difference of potential.

When separating nonconductors by the last outlined system, many mineral ores, after concentration to a greater or lesser degree, exhibit weak or incomplete charging as proven by the reaching of a stage wherein the ore particles, or some components thereof, show little or no tendency for movement in response to an electrostatic field. Treatment of such ore concentrates in the manner initially utilized to induce charging, such as by contacting a grounded donor plate, or introducing thermal energy and the like, as well as combinations thereof, have failed to render the concentrates sufficiently responsive to an electrostatic field to effect recovery of concentrates of the desired higher component content.

It is a primary object of the instant invention to provide a process for the recovery of concentrates of a high degree of purity.

It is a further object of the instant invention to provide a process wherein the use of reagents such as are commonly employed in flotation processes is eliminated.

It is still a further object to provide a method whereby electrically inactive ore concentrates are again rendered responsive to an electrostatic field.

It is a further object of the instant invention to provide a simplified separation method for nonmetallic ore material.

It is a still further object to provide a process wherein charged coarse grains of a material capable of exchanging electrons through contact potential means with the components of a concentrate is recirculated to improve the charging of ore particles, and is then removed by methods other than electrostatic separation.

These and other objects of the novel method will be more fully understood from the following description.

The method of the instant invention is based upon the discovery that ore concentrates which exhibit poor charging characteristics and, therefore, are not subject to any appreciable upgrading by subsequent passes through electrostatic fields may be caused to charge to an extent restoring response to electrostatic fields by tribo-electrification in the presence of a mechanically removable material of work function different from the ore component exhibiting the insufficient charging for electrostatic field response.

By the terminology "work function different from the ore component" is meant the characteristic of exchanging electrons with the ore component whereby the ore component exhibits a definite charge. Materials which receive electrons are generally referred to as having a higher work function than the doner material. Applicant does not wish to be bound by theory, but includes equivalent applications by which ore components exhibiting insufficient charge for effecting separation are, by contact with a removable material, caused to show a response to electrostatic fields warranting additional passes for further ore concentration.

In carrying out this novel method, the nonconductor material of work function different from the ore component to be concentrated and separable from the ore by means of differences of shape, differences in size, specific gravity, or other utilizable distinguishing characteristics, is mixed with said ore concentrate which initially or subsequently shows substantially no response to electrostatic separation. The mixture of ore and coarse nonconductor material is agitated either in the presence of or in the absence of an electrostatic field and the further concentration thereof effected before or after separation of the added coarse granular material.

As applied to the electrostatic beneficiation of phosphate ores, the process involves mixing into either a phosphate concentrate, a silica tail concentrate or other fraction a predetermined quantity of the minor component of the fraction having a size appreciably larger than the largest particles of the material being subjected to electrostatic beneficiation. In the case of phosphate concentrates, granular silica is added to an electrostatically prepared phosphate concentrate and the mixture agitated thoroughly in a dry state to induce the particles selectively to be electrically charged by tribo-electrification. In the case of electrostatically prepared middling fractions from an electrostatic phosphate concentration operation; the addition agent may be either phosphate pebbles or hard rock phosphate of a proper size. When electrostatically treating potash ore such as sylvinite, coarse granular halite crystals would be mixed with sylvite concentrates.

In the preferred embodiment, the phosphate ore concentrate and coarse silica are agitated in a mixer whose material of construction has a work function different from either the phosphate or the silica. The charged mixture is screened to effect separation of silica upon a particle size basis. The phosphate ore concentrate is then passed through additional electrostatic separations to obtain a phosphate product of high purity.

When the process is placed on a continuous basis, the method of beneficiating phosphatic ore comprises mixing dry concentrate with a predetermined amount of a recycle stream of coarse silica of an average particle size larger than the largest particles of concentrate, electrostatically separating the mixture, recovering at least a concentrate portion and a tailing portion, and screening the coarse silica from appropriate fractions for recycle

to the system, if such screening is not made before the electrostatic separation.

In the preliminary treatment of ores prior to any passage through electrostatic fields, the ore is treated so as to have a reasonable uniform particle size. In the case of Florida phosphate pebble ore, the operation is purely one of washing to free the phosphate pebbles of matrix and then sizing to produce a fraction in the range of about 14 mesh to about 200 mesh. Only Florida phosphate pebbles of +14 mesh size are subjected to any grinding operation in the preparation of feeds which are to be subjected to benefication treatments. On the other hand, phosphate ores from other regions, and other non-conductor mineral ores, require grinding to the economic liberation stage for freeing or unlocking the undesired ore components. Different types of material being fed to an electrostatic field will have different particle sizes, but in general the particle size will fall in a range between about 14 mesh and about 325 mesh. Some of the different types of materials having a somewhat shorter range of particle size as, for example, washer debris, phosphate, or fines, have a particle size in the range between about 14 mesh and about 150 mesh whereas, the fines from low-grade pebble grinding operations often have a particle size in the range of about 150 mesh to about 325 mesh.

The multicomponent material, freed as individual particles, is next dried. This may be accomplished either by direct or indirect heating; for example, by contacting a bed of granular material with hot gases, as in a rotary kiln, tunnel dryer, electric oven, or the like. In the dryer the solids are raised to an elevated temperature, the temperature for such ores as sylvinite being in excess of about 675° F. the temperature being that which conditions the ore for charging and separation, while ores such as phosphate need only be raised to a temperature in excess of the optimum for separation. After heating, the ore is induced selectively to accept an electrical charge, either during the cooling down period or after cooling to the optimum temperature for separation, by such contact potential methods as strong agitation under particle to particle contact conditions or so-called tribo-electrification or by particle to donor element contact with or without the donor being grounded to the earth.

Charged material is fed as freely-falling bodies between electrodes held at a high difference of potential. After one or more electrostatic separations, the ore concentrates begin to exhibit an appreciable reduction in response to the forces acting in an electrostatic field even though they still are maintained at an elevated temperature and are subjected to donor element contact. When this stage of concentration is reached, the particles are treated in accordance with this invention in order to make them again approach their initial activity. Phosphate concentrates, for example, which have become inactive, are then mixed with coarse silica having a particle size in the range between about 4 mesh and about 10 mesh, the preferred silica material being relatively uniform in size. The recharging of the ore concentrate-added component of different work function mixture may then be accomplished by intimately contacting one another in a suitable mixer. By intimate contact, the particles exchange electrons and thereby materials of different nature acquire either a positive or a negative charge. Recharging is preferably carried out in a suitable mixer, such as a rotating cylinder, a paddle mixer, or the like, partially or wholly of metal construction, such as iron, steel, copper, copper alloys, and the like.

Mixtures of materials respond differently depending upon the relative work functions of the materials of the concentrate and the added component of different work function, and therefore, generalizations applicable in all situations are difficult to set forth. A material may be of such nature as to impart to phosphate a charge of greater or lesser magnitude than silica. It is believed sufficient to state, therefore, that combinations of ingredients or ingredients plus material of the mixer where the mixer may act as a donor element should result in the charging of the concentrate material whereby particles of one kind are given a charge and particles of another type acquire a charge of different character or different magnitude such that they may be effectively separated by passage through an electrostatic separating unit.

In the preferred embodiment, after intimate contacting, the added material is segregated by screening. The now charged concentrate is next subjected to one or more passes through electrostatic fields as freely-falling bodies, i. e., in a path normally not in contact with the electrodes. In both the initial stages of separation and the final stages of separation, the strength of the electrostatic field which will effectively alter the path of particle movement varies with the average particle size of the feed to the separator unit. The field gradient in such operations may vary from 3,000 volts per inch of distance between electrodes in separating material of relatively fine particle size to 15,000 volts per inch of distance separating electrodes for beneficiation 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 at a total impressed difference of potential in the range of about 50,000 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 the so-called A. C. ripple. A steady and relatively inexpensive supply of D. C. voltage may also be obtained by the use of such equipment as radio frequency power supply.

The invention will be more fully understood from the following description taken in conjunction with the attached flow sheet, it being understood that the foregoing flow sheet illustrates but one method of taking advantage of the invention, i. e., processing of phosphate concentrate, and that other equivalent methods will be obvious, i. e., processing of desired component fractions, such as tail fractions, middling fractions, etc.

Referring to the flow sheet for phosphate beneficiation, ore of a mesh size in the range between about 14 mesh and about 200 mesh passes from storage bin **10** to a heating station **11** where the ore material is raised to a temperature in the range between about 200° F. and about 350° F. or even up to about 500° F. Preferably while still hot, the dried material is conveyed to a charging station **12** where the particles are induced to take on an electrical charge, as by passage over a grounded contact surface of graphite, lead, zinc, aluminum, copper, tin, and the like. The charged feed is next delivered to an electrostatic separation unit **13** which may consist of one or more stages of electrostatic separation. At separation unit **13** there is produced a throw-away tail fraction **14** and an intermediate concentrate **15**. The intermediate concentrate **15** is commingled with coarse material, such as silica, of a particle size appreciably larger than that of the largest particle of the concentrate at the mixer-electron recharging station **16**. The mixed and charged material issuing from station **16** in the preferred embodiment of the invention is conveyed to screening station **17** where the coarse material, such as silica, is removed. The said coarse material is returned by conveyor **18** to coarse material storage **19** pending recycling to the mixer-recharging station **16**. The charged concentrate is then passed with or without reheating to an electrostatic separation unit **20**. Upon passage through one or more stages of electrostatic separation, at least two products, and usually three products, are collected; namely, a final concentrate fraction **21**, a middling fraction **22**, which generally is recycled to recover a component therefrom, and a tail fraction **23**.

In an alternative mode of operation, the intermediate concentrate 15 is commingled with coarse material, such as silica, of a particle size appreciably larger than that of the concentrate at the mixer-charging station **16**. The mixed and charged material issuing from station **16** is moved by conveyor **25** to electrostatic separation unit **20**. Upon passage through one or more stages of electrostatic separation, at least two products, and usually three products are collected; namely, a predominantly concentrate fraction **21**, a middling fraction **22**, and a predominantly tail component fraction **23**. Each of these fractions, or only some, may be conveyed to a screening station **26**, depending upon the nature of the coarse material where the coarse material may be separated, if desired. If the coarse material is to be recycled, it is returned to storage station **19** by conveyor **27**. Materials which may be either concentrate or tail, or both, collected individually, are segregated for storage or for further processing.

The following examples are given to illustrate an application of the instant novel process to Florida phosphate rock and to sylvinite ore and are not to be construed as limiting the invention thereto.

Example I

Florida phosphate ore was washed to produce a low-grade Florida phosphate pebble ore having a B. P. L. content of approximately 30%. The pebble material had a particle size in the range of about 14 and about 200 mesh. This material was dried at a temperature of approximately 225° F. The pebble material was passed while hot through four stages of electrostatic separation at which time a concentrate was produced constituting approximately 20% by weight of the feed and having approximately 73.5% B. P. L. content and approximately 8% of insoluble material. These separations were each effected by passage of feed material at a rate of approximately one ton per hour per linear foot of electrode between 10 feet long electrodes spaced approximately 9 inches apart and having a difference of potential impressed thereon such that the field gradient was approximately 10,000 volts per inch of distance separating the electrodes.

The intermediate concentrate was segregated into two portions for comparative tests. Upon passage of the first portion through a fifth stage of electrostatic separation under identical electrostatic conditions as was maintained previously, a concentrate and tail was produced of substantially identical analyses showing that no effective separation was being accomplished.

The second portion of the intermediate concentrate was mixed with 20% by weight of coarse silica of a particle size of about +10 mesh. The mixture was then agitated in an iron paddle mixer allowing the mixture a retention period of about twenty minutes. The coarse silica was recovered by seiving the mixture on a 10 mesh Tyler standard screen. The concentrate passing through the screen was delivered at a rate of approximately one ton per hour per linear foot of electrode through a fifth stage of electrostatic separation. The concentrate recovered had approximately 78% B. P. L. content and approximately 2.5% of insoluble material. This concentrate constituted a recovery of approximately 70% of the original phosphate content as premium grade pebble material. The middling phosphte stream which was to be recycled accounted for approximately 17% of the phosphate content of the original phosphate pebble material. A comparison of the results is as follows:

	Concentrate		Tail, Percent B. P. L.
	Percent B. P. L. Feed	Percent B. P. L.	
Untreated Material	73	73	73.0
Mixer Recharged Material	73	78	70.0

As can be seen from the above comparison, the separation effected in the fifth stage produces a premium grade phosphate and, by a recycling system for the high B. P. L. content tail, an approximately 85% recovery of the phosphate can be effected as this high-grade product.

Example II

Slime-bearing sylvinite ore from the Carlsbad section of New Mexico was crushed and then comminuted in a hammer mill. The comminuted ore was screened to produce a fraction containing particles in the range between about 14 mesh and about 200 mesh size. This granular sylvinite feed was heated to approximately 800° F. Heating when the solids attained this temperature, was continued for about five minutes. The material was then removed from the heating unit and cooled to approximately 375° F. The particles were delivered to a feed hopper and cascaded downwardly through a vibratory cast-iron trough. The granular material differentially charged, halite charged positively, and sylvite charged negatively, cooled to about 225° F. during delivery and was allowed to drop between vertical electrodes at a rate of approximately 2000 pounds per hour per foot of horizontal electrode breadth. The electrodes had a difference of potential of approximately 100,000 volts impressed thereon giving a field gradient of approximately 10,000 volts per inch of distance between oppositely charged electrodes. In the first pass through the electrodes, a concentrate was recovered. This concentrate was split into two portions. The first portion was reheated for one hour in an oven held at approximately 800° F. This reheated portion was screened to remove +28 mesh size material and then was passed through an electrostatic unit identical to that used for the first or rougher separation.

The second portion of this sylvite concentrate was mixed with halite crystalline material of a particle size of about 14 mesh. This mixture containing a 2 to 1 ratio by weight of second portion of the concentrate and added halite was heated to 800° F. in the same manner as the first portion of the concentrate. The reheated mixture during cooling was agitated in a stirring mixer. The agitated mixture was then screened to remove the added material and then was passed through the same electrostatic unit as was used for separation of the first portion of the concentrate.

The assay of the various concentrates shows that addition of coarse halite to the sylvinite rougher concentrate improves the separation. These assays are as follows:

	Feed, Percent K_2O	Concentrate, Percent K_2O	Tail, Percent K_2O
Untreated sylvinite rougher concentrate	35	51	15
Mixer recharged concentrate	35	53	13

In each case the recovery of KCl in the final concentrate was 55% of the weight of sylvite in the rougher concentrate used as feed material to the last separation.

This application is a continuation-in-part of application Serial No. 222,690, filed April 24, 1951, now abandoned.

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 ore which comprises subjecting a multicomponent mineral ore feed to at least one electrostatic separation, mixing with the desired component fraction produced by said separations a predetermined quantity of solid particles of material of work function different from the mineral component being concentrated, agitating the mixture whereby the material in the fraction is induced selectively to accept an electrical charge, and subjecting the charged ore fraction to additional electrostatic separation.

2. A method of beneficiating ore which comprises subjecting a nonconductor multicomponent mineral ore feed

to at least one electrostatic separation, mixing with the concentrate produced by said separations a predetermined quantity of solid particles of material of work function different from the mineral component being concentrated and agitating the mixture whereby the concentrate is induced selectively to accept an electrical charge, and subjecting the charged ore concentrate material to additional electrostatic separation.

3. A method of beneficiating ore which comprises subjecting a multicomponent nonconductor mineral ore feed to at least one electrostatic separation, adding to the concentrate produced a predetermined quantity of solid particles of material of work function different from the mineral component being concentrated, agitating the mixture under conditions to effect tribo-electrification, and subjecting the charged ore concentrate material to electrostatic separation.

4. A method of beneficiating ore which comprises subjecting a nonconductor mineral ore feed to at least one electrostatic separation, mixing with the concentrate produced a predetermined quantity of solid particles of material of work function different from the mineral component being concentrated and agitating the mixture whereby the concentrate is induced selectively to accept an electrical charge, separating the added material from the ore concentrate, and subjecting the charged ore concentrate material to additional electrostatic separation.

5. A method of beneficiating ore which comprises subjecting a nonconductor mineral ore feed to at least one electrostatic separation, mixing with the concentrate produced a predetermined quantity of solid particles of material of work functions different from the mineral component being concentrated whereby the concentrate is induced selectively to accept an electrical charge, segregating the added material by mechanical means, and subjecting the charged concentrate to the attractive and repulsive forces of one or more electrostatic fields.

6. A method of beneficiating ore which comprises subjecting a nonconductor mineral ore feed having a particle size range between about 14 mesh and about 325 mesh to at least one electrostatic separation, mixing with the concentrate produced by said separations a predetermined quantity of solid particles of material of work function different from the mineral component being concentrated having a particle size larger than the largest particle of the ore feed and agitating the mixture whereby the concentrate is induced selectively to accept an electrical charge, and subjecting the charged ore concentrate material to additional electrostatic separation.

7. A method of beneficiating ore which comprises subjecting a nonconductor mineral ore feed having a particle size range of between about 14 mesh and about 200 mesh to at least one electrostatic separation, mixing with the concentrate produced a predetermined quantity of solid particles of material of work function different from the mineral component being concentrated and having a particle size range between about 4 mesh and about 10 mesh, and subjecting the charged ore concentrate material to further electrostatic separation.

8. A method of beneficiating ore which comprises subjecting a nonconductor mineral ore feed having a particle size range between about 14 mesh and about 200 mesh to at least one electrostatic separation, mixing with the concentrate produced a predetermined quantity of solid particles of material having a particle size range between about 4 mesh and about 10 mesh and of work function different from the mineral component being conentrated, screening the mixture to recover the material having a particle size range betwen about 4 mesh and about 10 mesh, and subjecting the charged ore concentrate material to further electrostatic separation.

9. A method of beneficiating ore which comprises subjecting a nonconductor mineral ore feed having a particle size in the range between about 14 mesh and about 200 mesh to at least one electrostatic separation, mixing with the concentrate produced a predetermined quantity of soild particles of material of work function different from the mineral component being concentrated and having a particle size in the range between about 4 mesh and about 10 mesh, screening the mixture to recover the material having a particle size between about 4 mesh and about 10 mesh, subjecting the charged ore concentrate material to electrostatic separations as freely-falling bodies, and collecting at least a concentrate fraction and a tail fraction in the vicinity of the lower portions of the electrodes bounding said electrostatic field.

10. A process as in claim 9 wherein the concentrate fraction is screened to recover the beneficiated ore fraction.

11. A method of beneficiating ore which comprises subjecting a relatively uniform particle size nonconductor mineral ore feed to at least one electrostatic separation in an electrostatic field having a field gradient in the range between about 3,000 volts per inch and about 15,000 volts per inch of distance separating electrodes, mixing with the concentrate produced by said separations a predetermined quantity of solid particles of material of different physical characteristics and of work function different from the mineral component being concentrated whereby the concentrate is induced selectively to accept an electrical charge, and subjecting the charged ore concentrate material to additional electrostatic separation.

12. A method of beneficiating phosphate ore which comprises subjecting a raw phosphate feed having a particle size range between about 14 mesh and about 200 mesh to at least one electrostatic separation, adding to the concentrate produced silica having a particle size range between about 4 and about 10 mesh, agitating the mixture under conditions to effect tribo-electrification, screening the coarse silica from the agitated mixture, and subjecting the charged phosphate material to further electrostatic separation.

13. A method of beneficiating potash ore which comprises subjecting potash ore having a particle size range between about 14 mesh and about 200 mesh to at least one electrostatic separation, adding to the concentrate produced halite material having a particle size larger than about 14 mesh, agitating the mixture under conditions to effect tribo-electrification, screening the coarse halite material from the agitated mixture, and subjecting the charged potash concentrate to further electrostatic separation.

14. A method of beneficiating electrostatically prepared ore concentrates which exhibit substantially no response to an electrostatic field due to loss of charge during electrostatic separation which comprises mixing with said concentrate a predetermined quantity of solid particles of material of work function different from the mineral component being conecntrated whereby the concentrate is induced selectively to accept an electrical charge, and subjecting the charged ore concentrate material to additional electrostatic separation.

15. A method of beneficiating electrostatically prepared ore concentrates which exhibit substantially no response to an electrostatic field due to loss of charge during electrostatic separation which comprises adding to the concentrate a predetermined quantity of solid particles of material of work function different from the mineral component being concentrated, agitating the mixture under conditions to effect tribo-electrification, and subjecting the charged ore concentrate material to electrostatic separation.

16. A method of beneficiating electrostatically prepared ore concentrates which exhibit substantially no response to an electrostatic field due to loss of charge during electrostatic separation which comprises mixing with the concentrate a predetermined quantity of solid particles of material of work function different from the mineral component being concentrated whereby the concentrate is induced selectively to accept an electrical charge, segregating the added material by mechanical

means, and subjecting the charged concentrate to the attractive and repulsive forces of one or more electrostatic fields.

17. A method of beneficiating electrostatically prepared ore concentrates having a particle size range of between about 14 mesh and about 200 mesh which exhibit substantially no response to an electrostatic field due to loss of charges during electrostatic separations which comprises mixing with the concentrate a predetermined quantity of solid particles of material of work function different from the mineral component being concentrated and having a particle size range between about 4 mesh and about 10 mesh, and subjecting the charged ore concentrate material to further electrostatic separation.

18. A method of beneficiating electrostatically prepared ore concentrates which exhibit substantially no response to an electrostatic field due to loss of charges during electrostatic separation which comprises mixing with the concentrate a predetermined quantity of solid particles of material of work function different from the mineral component being concentrated and agitating the mixture whereby the concentrate is induced selectively to accept an electrical charge, and subjecting the charged ore concentrate material to additional electrostatic separation in an electrostatic field having a field gradient in the range between about 3,000 volts per inch and about 15,000 volts per inch of distance separating electrodes.

19. A method of beneficiating electrostatically prepared ore concentrates having a particle size in the range between about 14 mesh and about 200 mesh and which exhibit substantially no response to an electrostatic field due to loss of charges during electrostatic separation which comprises mixing with the concentrate a predetermined quantity of solid particles of material

of work function different from the mineral component being concentrated, screening the mixture to recover the nonconductor material having a particle size range between about 4 mesh and about 10 mesh, and subjecting the charged ore concentrate material to at least one electrostatic separation as freely-falling bodies, and collecting at least a concentrate fraction and a tail fraction in the vicinity of the lower portions of the electrodes bounding said electrostatic field.

20. A method of beneficiating electrostatically prepared Florida phosphate ore concentrates having a particle size range between about 14 mesh and about 200 mesh and which exhibit substantially no response to an electrostatic field due to loss of charges during electrostatic separation which comprises adding to the concentrate silica having a particle size range between about 4 mesh and about 10 mesh, agitating the mixture under conditions to effect tribo-electrification screening the coarse silica from the agitated mixture, and subjecting the charged ore concentrate material to further electrostatic separation.

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